CHAPTER THREE

FLUORIDATION SYSTEMS

3.1 General

3.1.1 Methods of Feeding Fluorides

Fluoride must be fed into the water supply system in liquid form or as a solution. This is true for both dry chemical feeders and solution feeders.
Fluorides can be fed into a water supply in the following ways:

1. Dry Chemicals Feed
The amount of dry chemical compound (usually sodium Nuorosilicate) can be measured with a machine, then added to a mixing tank (solution tank) where it is thoroughly mixed and then delivered to the main flow of water, either by gravity or using a solution pump.
2. Acid Feed
A small pump can be used to add solutions of fluorosilicic acid directly to the water supply system. This method can utilize the acid as delivered.
3. Saturated Solution Feed
Saturated solutions of sodium fluoride in constant strengths of four percent cart be produced in a saturator tank at almost any temperature of water encountered in the usual water plant.
This saturated solution can be pumped with a small solution feeder directly into the main flow of water of a water supply system. The use of these devices eliminates the need for weighing sodium fluoride and stirring to ensure dissolving.

4. Unsaturated Solution Feed

Unsaturated solutions of sodium fluorosilicate or sodium fluoride may be prepared by weighing amounts of the compounds, measuring quantities of water, and thoroughly mixing them together. **This method of feeding fluorides is not very desirable and should be avoided.**

3.1 .2 Types of Equipment

Devices for feeding fluorides accurately have generally been adapted from those machines originally designed for feeding a variety of liquid or solid chemicals in water treatment and industrial plants. In many cases, the equipment is the same.

Fluoride chemicals are always added to a water supply as liquids, but they may be measured in either liquid or solid form. The solid form of fluorides must be dissolved into a solution before entering the water supply system. Chemical feeders can therefore be broadly divided into two types: (l) Metering pumps, which are essentially small pumps used to feed a measured quantity of liquid fluoride solution during a specific time; and (2) dry feeders, which deliver a predetermined quantity of the solid material during a given time interval. The term "metering pump" is used in this manual for the terms "solution pump," "feed pump." and "solution feeder."

The choice of a feeder depends on the fluoride chemical used and the amount to be fed. The rate of feed will depend on the desired fluoride content of the treated water the amount of water to be treated after passing a given point, and the fluoride content of the untreated water. In general, metering pumps (with acid or with saturators) are used for smaller water supply systems and dry feeders for larger systems. There is a wide range within which either type would be equally successful.

3.2 Metering Pumps

3.2.1 Introduction

All pumps may be classified as steam, electrical, water power, wind power, etc., in accordance with the kind of power used to actuate them. They also may be classified as well pumps, low-service pumps, high-service pumps, or metering pumps, in accordance with the kind of service to which they are to be put; or they may be classified as positive displacement, centrifugal, impulse, or bucket pumps, in accordance with the mechanical principles of their operation. For feeding fluoride solutions, as with most other water treatment chemicals, electrically powered pumps (pumps with an electrical motor) are generally used. They are classified as metering pumps, and, regarding the mechanical classification, the fluoride feed pumps almost always are of the positive displacement type. Only transfer pumps are not classified as positive displacement pumps they are usually centrifugal pumps.

In general, a metering pump is nothing more than a small pump, of which there are almost unlimited varieties. For feeding fluoride solutions, almost any type of metering pump that is used for feeding other water treatment chemicals can be used with, at most, only minor modification in construction details. If there is, indeed, any requirement for a fluoride metering pump that distinguishes it from metering pumps for other purposes, it is the accuracy and constancy of delivery. The optimal fluoride level has been prescribed between very narrow limits and thus requires that fluoride be added in precise proportion to the quantity of water being treated. This requirement favors the positive displacement type of metering pump.

A positive displacement pump, as used in the waterworks industry, is a device that draws in and expels liquid as a result of the alternate tilling and emptying of a closed chamber. It delivers a specific volume of liquid for each stroke of a piston or diaphragm. Very few metering pumps deliver replicate volume under all conditions, for such factors as pressure and viscosity can affect the volume displaced by the driving member of the pump. However, by using fluoride solutions of fixed strength, by feeding against a fixed pressure, and by pumping into a constant flow of water, the positive displacement metering pump has shown sufficient reliability. The positive displacement pump has a problem that if the line becomes plugged for any reason, the pump continues to operate until something breaks. (The one major exception to this is the electronic metering pump.)

Ordinarily, such solution feeding devices as centrifugal pumps, bucket pumps, gravity feed pumps, pot feeders, or head tanks and orifice, are not used for fluoridation because of their relative inaccuracy. Several types of rotary pumps qualify as positive displacement feeders. These include gear, swinging-vane, sliding-vane, oscillating screw, eccentric and cam pumps, and various modifications of these pumps. They generally are not used in fluoridation either.

The criteria used in selecting a metering pump are capacity, corrosion resistance, pressure capability, accuracy, and durability. A point to consider is that most pumps perform most accurately near mid-range of both stroke length and stroking frequency and should be selected accordingly.

Most metering pumps come equipped with plastic heads and resilient check valves, which are generally satisfactory for discharge pressures up to l50psi. For higher pressures corrosion-resistant alloys such as 316 stainless steel or Carpenter 20 alloy are required for metering pump head construction. The type of plastic the metering pump heads should be made of depends upon the fluoride chemical used. Acrylic, polypropylene, and PVC heads can be used for fluorosilicic acid as well as for sodium fluoride and sodium fluorosilicate. In addition, Kynar, Ryton, and Tril heads can also be used with sodium fluoride and sodium fluorosilicate. Metering pump heads of stainless steel (SS) 316, as well as the 20 series SS alloys, can be used with all three fluoride chemicals.

The check valves can be made of ceramic, Teflon, or 31 6 stainless steel. If fluorosilicic acid is used, then the check balls and spring must be coated with Teflon or its equivalent.

Note, do not use ceramic check balls, if fluorosilicic acid is used! The acrylic head is one of the most popular heads on metering pumps used in water fluoridation.

The volume of solution pumped by most metering pumps is adjusted by both stroke length, which determines the volume of liquid delivered per stroke, and stroke frequency, usually expressed in strokes-per-minute (SPM). 80th factors should be considered in selecting the size of the pump for a particular application.

In all types of metering pumps, a pulsating flow of chemical solution into the water line will occur because of the reciprocating nature of the operating mechanism. Ordinarily, this is not objectionable if variations in fluoride levels cannot be detected in the distribution system. However, if the closest consumer to the water plant has drinking water with fluoride level varying more than 0.1ppm, then a method to suppress this variation should be provided. This can be done in four ways: (l) A mixing basin or detention tank can be inserted in the line after the point of application of the fluoride solution, or an in-line static mixer can be added', (2) the frequency of metering pump stroking can be increased-this will also require a proportional reduction in the amount of solution delivered per stroke; (3) dual metering pumps can be used so that the feeding stroke of one will occur during the intake stroke of the other-this plan may require a dilution of the fluoride solution; (4) or flow pacing of fluoride solution may be required. The third method of using dual metering pumps is usually not considered very desirable.

Many manufacturing companies recommend that their metering pumps operate with a "flooded suction." This means the pump should be located below the level of the storage vessel. However, in fluoridation, it is important that the pumps never operate below the level of the storage vessel because *of* the danger *of* back-siphonage and overfeeding of the fluoride chemical.

There are three types of positive displacement metering pumps, which are commonly used in water fluoridation: the piston pump, the peristaltic pump, and the diaphragm metering pump. As the diaphragm pump is the most common type of metering pump used in fluoridation, it will be the only one discussed in detail.

3.2.2 Diaphragm Metering Pumps

3.2.2. 1 Introduction

As stated before, the diaphragm pump is by far the most common type of metering pump used in fluoridation. A flexible diaphragm is driven to alternately force solution out of a chamber, and on the return stroke, the diaphragm refills the chamber by pulling solution from a reservoir. In a typical diaphragm pump there is no chemical packing that would result in leaking through a packing gland. Typically a diaphragm is made of hypalon, tenon, polyurethane, or viton.

Diaphragm pumps are ideally suited for medium-pressure service-up to about 150 (pounds per square inch [psi]). They should not be used against pressures less than about 15psi and never against a vacuum, such as that obtained in the suction side of a well pump. A constant positive pressure on the discharge is a guarantee of their continued accuracy. Some metering pumps are equipped with spring-or rubber-loaded discharge valves that assure the maintenance of such positive pressures. Negative suction heads should not exceed 4 feet. In other words, the metering pumps should be no more than 4 feet above the solution container.

Diaphragm pumps are driven by almost any source of power such as: electric motors of various speeds, hydraulic pressure, solenoid, etc. The principal characteristic of such sources of power is that they are operated at a constant speed proportional to the quantity of water to be treated.

Three common types of diaphragm metering pumps are used in fluoridation: Mechanically driven, hydraulically actuators and electronic. Other types are available, such as water-powered pneumatic-drive, etc. but they are rarely used in water fluoridation.

3.2.2.2 ***Mechanical Diaphragm Metering Pumps***

In the mechanical-driven diaphragm metering pump, the eccentric-push rod assembly is the heart of the system. An eccentric mechanism converts rotary motor input to a reciprocating push-rod motion. The motor drives an input shaft via pulleys. A worm on this shaft engages a worm gear on an eccentric shaft to rotate the eccentric. A ring, driven by the eccentric, drives the diaphragm push rod. Forward motion produces the discharge stroke. A heavy spring returns the push rod for the suction stroke. An adjustable return-stroke stop varies the stroke length.

As with all diaphragm pumps, the alternating motion forces solution out of a chamber. and, on the return stroke, refills the chamber by pulling solution from a reservoir. Again, as is typical of all other diaphragm pumps, the back pressure (main water line pressure) which these pumps operate will range from 15psi to 125psi. Some brands of mechanical diaphragm pumps can operate with a back pressure up to 150psi. SCR variable feed drives, or automatic stroke control, are available to add on the most pumps.

Some companies produce a mechanical-driven metering pump with two diaphragms and a fluid generally silicone oil, between them. This is done to provide a measure of safety for the drive mechanism. A break in the main diaphragm will allow only the silicone oil to be contaminated. Buts this type pump is still a mechanical-driven pump, not a hydraulic metering pump; it is commonly confused with the hydraulic pump.

3.2.2.3 Hydraulic Diaphragm Metering Pumps

In a hydraulically-actuated diaphragm metering pump, a plunger, reciprocating at a fixed stroke, displaces hydraulic fluid, which creates the pumping action. The capacity of the pump is regulated by controlling the volume of hydraulic fluid that passes through a valve. A diaphragm separates the oil from the fluoride solution. The diaphragm is free to move in exact response to the volume displaced by the piston, but the diaphragm does not do any actual work-it act: only as a separator. Consequently, the displacement of the oil is translated into an equal amount of fluoride solution displacement.
The reciprocating action of the piston causes the product to enter through the suction check valve as the piston travels to the rear of its chamber. A like quantity of product is discharged through the discharge check valve on the forward stroke of the piston.

Generally, adjustments in pumping rates are made manually but can be done automatically by instrument signal. While most diaphragm pumps require only a minimum discharge pressure (back pressure) of 15psi, some hydraulic metering pumps will require at least 50psi pressure. As with most diaphragm pumps, they will discharge into water with pressures up to approximately 150psi, although the more expensive hydraulic metering pumps can discharge into pressures up to 2,000psi.

3.2.2.4 Electronic Diaphragm Metering Pumps

The electronic diaphragm metering pump is the newest and most popular fluoride metering pump in the field today. The pump has gained rapidly in acceptance because it is ideal for smaller flow rates-thus, it predominates in small fluoridated water systems and in school fluoridation systems.

The electronic metering pump is a special version of a diaphragm pump. (See Figure 3-1 below.) Most diaphragm pumps used for fluoridation. as explained in the previous sections, have a flexible diaphragm driven by a mechanical linkage. In the electronic metering pump, a solenoid armature that is periodically energized moves the flexible diaphragm. It has solid state electronics, circuit breakers, and built-in potentionmeters. The stroke is extremely short with a maximum stroke length of 1.25 mm. Thus, the diaphragm has a low amount of wear even during continuous prolonged operation-but must be replaced periodically.

TYPICAL ELECTRONIC METERING PUMP

FIGURE 3-1
TYPICAL ELECTRONIC METERING PUMP

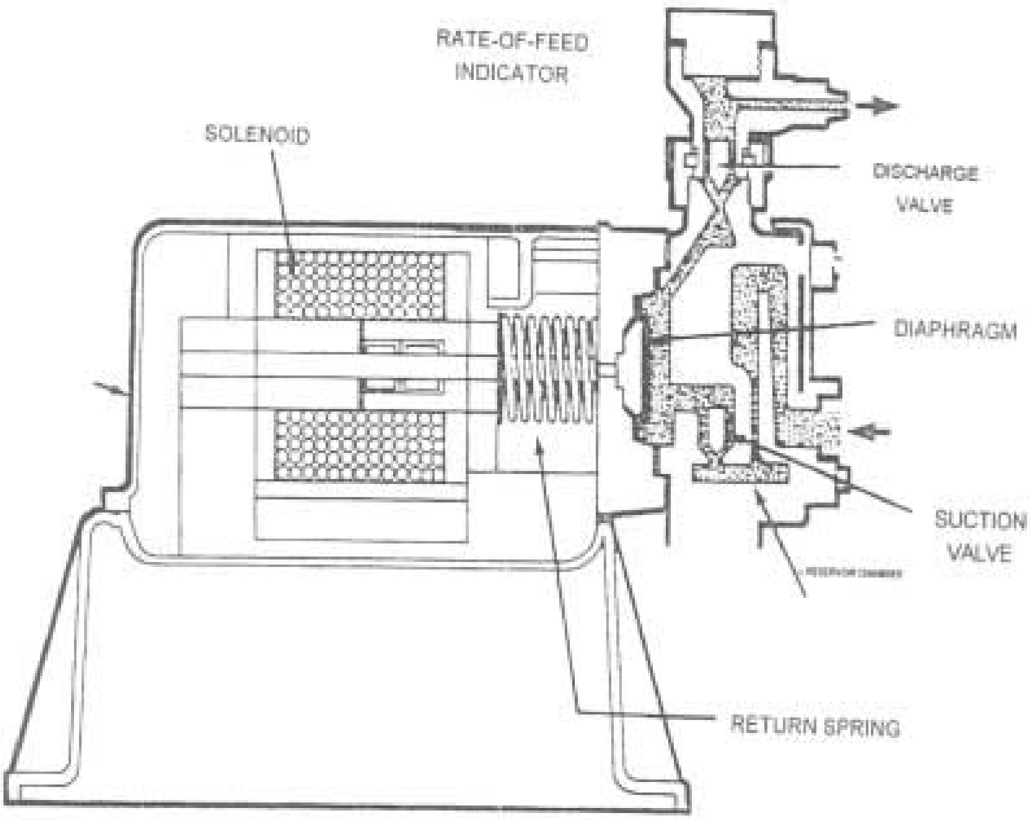
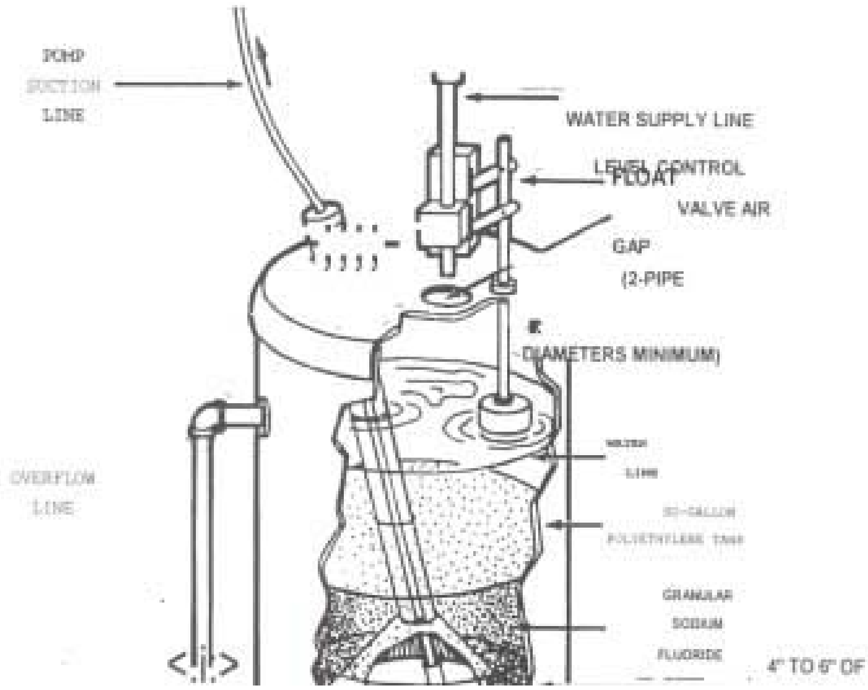


FIGURE 3-2
TYPICAL DOWNFLOW SATURATOR



Another characteristic of the electronic pump is the fact that a blocked or plugged line during operation will not break or burn up the pump because there is no mechanical linkage. When the back pressure in the line exceeds the strength of the magnetic force developed by the power coil, the pump simply stops stroking, and no damage will occur to the pump. Yet, the electronic diaphragm pump is still considered a positive displacement pump.

There are several other advantages to the electronic metering pump over other diaphragm pumps: There is only one moving part-the armature-diaphragm assembly, which can be easily adapted to automatic controls, and the actual speed of each discharge stroke remains the same, no matter how low the stroke frequency is set. Also, both the stroke length and stroke frequency are adjustable and have a multiplying effect. A practical adjustability range of 200 to 1 is common. The electronic pumps generally do not require lubrication. And finally, electronic pumps use power only during the discharge portion of the stroke, thus causing minimum electrical consumption and low heat generation.

3.2.3 Calibration of Metering Pumps

Metering pumps usually have name plates or a chart showing their pump capacity. lf this unfortunately, is not available, then the pump must be calibrated by adjusting the pump to various settings and measuring the amount of solution pumped during the measured time intervals. This should also be done periodically to verify the delivery rate of a metering pump or to make adjustments when the feed rate is too high or too low.

Simply measuring the output from the discharge outlet of the metering pump is unsatisfactory, since even the output of so-called positive displacement pumps varies with pressure. One acceptable way is to measure the volume of the liquid being pumped, preferably in a graduated cylinder (without losing prime or spilling any solution). Feed for a timed interval, withdraw the suction tube and note the volume of solution remaining. The difference will represent the volume fed during the measured interval. By adjusting the feeder to various scale settings, a calibration chart or curve can be developed that will be representative of the pumping conditions and the chemical pumped at the time.

Another way to calibrate a metering pump that is superior to the above method, especially with acid solutions, is to equip the solution tank with a calibrated sight glass. (However, the sight "glass" is not to be made of glass, but clear polyethylene or vinyl tubing.) By closing the valve between the sight glass and tank (the sight glass is outside the tank, parallel to the side) while the metering pump is operating normally, solution will be withdrawn from the sight glass only, and the volume over a timed interval can be calculated. This system has the advantage of freedom from interruption of the fluoride addition as well as avoiding direct contact with the chemical being fed. After the measurement, opening the valve will be all that is necessary to resume normal feed.

The rate of feed in milliliters per minute can be calculated from the feed rate in pounds per day. Once the feed rate has been calculated in pounds per day, it is a simple matter to determine the metering pump feed rate in mi/min. Please see the fluoridation calculation section (Section 4.2) for the step-by-step calculations.

3.3 Saturators

3.3.1 Introduction

The saturator is a type of chemical feed equipment unique to fluoridation. The principle of a saturator is that a saturated fluoride solution will result if water is allowed to trickle through a bed containing a large amount of sodium fluoride. A small pump then delivers the solution of sodium fluoride into the water supply system. Saturated solutions of sodium fluoride can be manually prepared and is sometimes preferred.

There are two kinds of saturators: upflow and downflow. The downflow saturator was developed in the late 1940's by Proportioneers Incorporated and engineers in the U.S. Public Health Service. It did not receive wide application until the late 1950's and early 1960's. In the mid-1970's, the upflow saturater was developed, and by the late 1970's, was becoming more popular than the downier. After 1980, the downflow saturator was no lodger being manufactured and has been replaced in most states by the upflow saturator.

3.3.2 Downflow Saturators

In a downflow saturator, a bed of granular sodium fluoride is placed on layers of sand and gravel to prevent particles of undissolved sodium fluoride from infiltrating the solution area under the cone or within the pipe manifold. The metering pump draws the solution from within the cone or manifold at the bottom of the plastic drum.

(See Figure 3-2. on page 32)

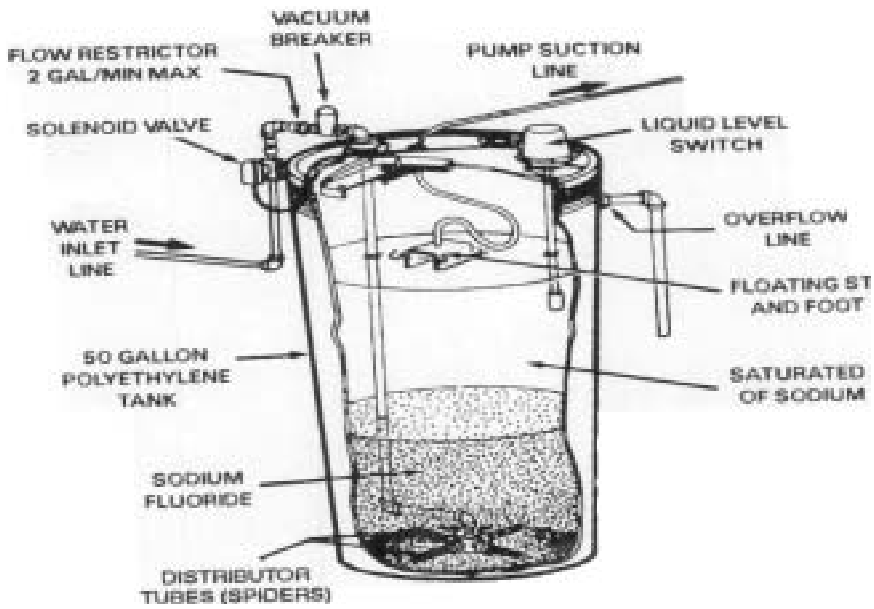
When a downflow saturator is in operation, water is admitted at the top of the saturator tank (an air gap avoids the possibility of a cross-connection) and the level is regulated with a float-operated controller. The water then trickles down through the bed of sodium fluoride, the solution is clarified in the sand and gravel filter bed, and ends up as a clear, saturated solution at the bottom of the tank where it is withdrawn by the metering pump. The operator is required to ensure that an adequate quantity of sodium fluoride is kept in the saturator and that the saturator is kept in a reason- ably clean condition. This can involve considerable maintenance if the saturator is heavily used.

The downflow saturator is not as popular as the upflow and in time it may be phased completely out.

3.3.3 Upflow Saturators

In an upflow saturator, the layer of sand and gravel is eliminated and the bed of undissolved sodium fluoride is placed on the bottom of the tank. (**See Figure 3-3 below**.) A spider type water distributor located at the bottom of the tank contains hundreds of very small slits. Water, forced under pressure through these slits, flows upward through the sodium fluoride bed at a controlled rate to assure the desired 4 percent solution. The metering pump intake line floats on top of the solution in order to avoid withdrawal of undissolved sodium fluoride. The water pressure requirements are 20psi minimum to 125 psi maximum, and the upward flow must not exceed 2gpm. Since introduction of water to the bottom of the saturator constitutes a definite cross-connection a mechanical syphon-breaker must be incorporated into the water line. Also, a minimum of 12 inches of sodium fluoride must be kept in the bottom of the tank.

FIGURE 3-3
TYPICAL UPFLOW SATURATOR



3.3.4 Liquid Level Switches

Liquid level switches or controllers, are used to automatically maintain preset (fluoride) liquid levels in sodium fluoride saturators. In rare instances they are used with fluorosilicic day tanks when these are filled from a bulk storage tank or used with dry feeder solution tanks. The switches keep the tanks from going dry or overflowing, and may also be used to prevent a metering pump from running dry. The switch may be of the manual (lower cost) or electrical (higher cost) type. (**See Figure 3-4 page 38)**

Several different types of switches are on the market today and work on different principles: mercury, air pressure, electrode, conductivity, and encapsulated reed. Most newer models today are electrical (12or115 volt) and are wired to control a solenoid valve (electrically operated open- close valve), on a water line to a saturator. The manual type requires no electricity and uses water pressure or a float valve to activate a type of ball cock, similar to the common boat valve in a water closet. Liquid level switches are adjustable and the high and low levels may be changed as necessary', however, the high liquid level must be set below the overflow pipe.

3.3.5 Softeners

When a fluoridation system uses a sodium fluoride solution (primarily a saturator), remember that while sodium fluoride is quite soluble, the fluorides of calcium and magnesium are not. Thus, the fluoride ions in solution will combine with calcium and magnesium ions in the make-up water and form a precipitate, which can clog the metering pump, the injection point the metering pump suction line, the saturator bed, etc. For this reason, water used for sodium fluoride saturators should be softened whenever the total hardness exceeds 50ppm or even less if the amount of labor involved in clearing stoppages or removing scale is objectionable. Remember-the entire water supply need not be softened-only the water used for solution preparation (the make-up water).

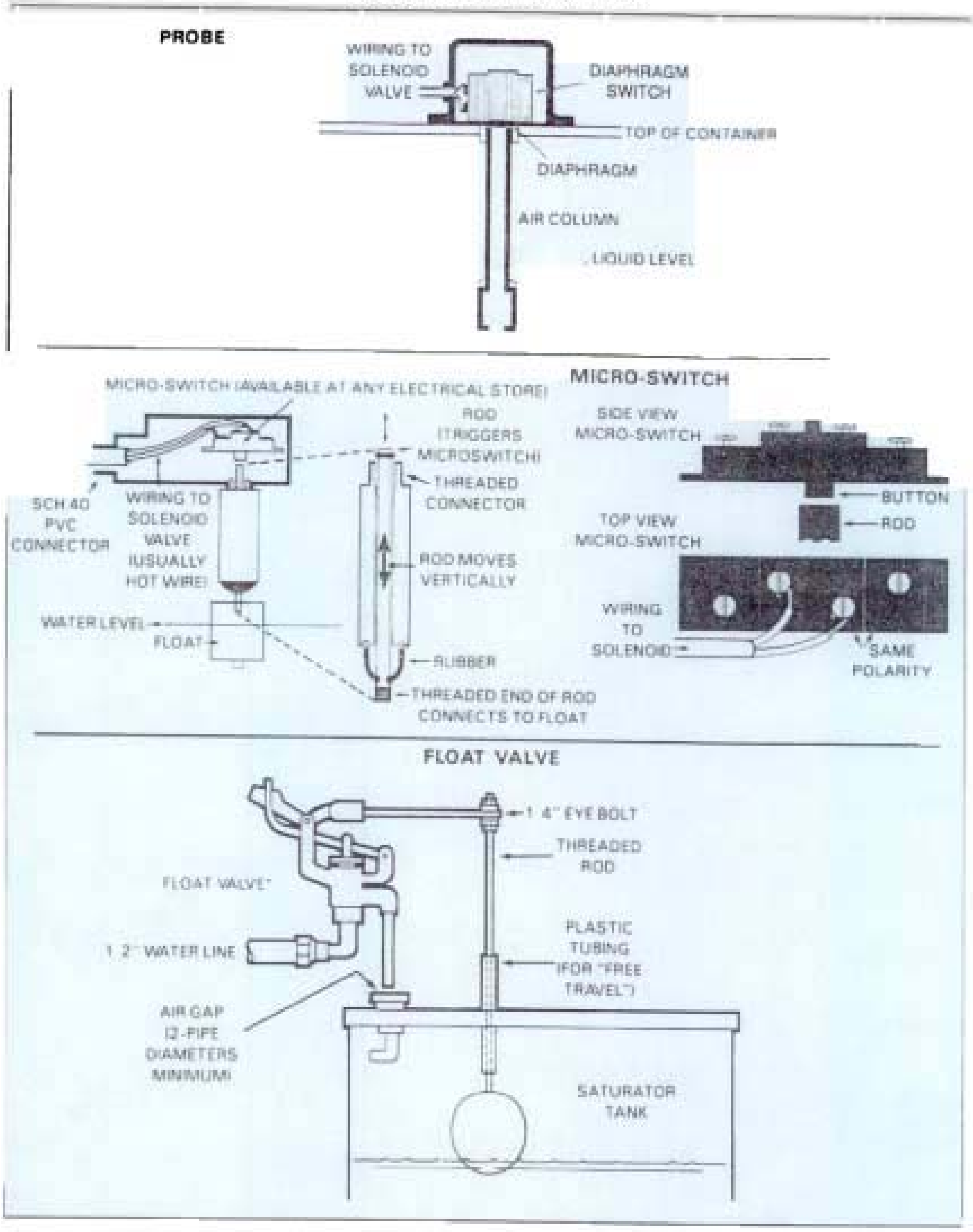
Two types of softening treatment are available: ion exchange and the use of polyphosphates (calgon, microbes, etc.), The ion exchange method removes all hardness. Polyphosphates are used for sequestering (keeping in solution) calcium and magnesium and other hardness elements. The amount required usually ranges from 5 to 12mg/L, although new more efficient types of poly-phosphates are now available. They are fed at a rate of 1-1/2 mg/L to 2mg/L. The polyphosphate may be added directly into the solution tank or, in some cases, a metering pump will be required.

The ion exchange method removes all hardness by using a zeolite medium or synthetic resins. Since the volume of water to be softened is usually quite small, a household type of zeolite softener is usually more than adequate. This type of softener can be installed directly in the pipeline used for solution make-up water. When the softening capacity is exhausted, the zeolite (or synthetic resin) can be regenerated with brine made from common salt. (**See Figure 3-5 page 39**)

When the softener is in service. it is strongly recommended that a complete recharge program be performed before the softener runs out of capacity. This is important in order to protect the conditioning media from injury and to maintain its capacity. For example, waters containing corrosive hydrogen sulfide can strip and permanently damage the media if the capacity of the filters is allowed to exhaust. Iron bearing waters, too, can cause an exhausted media bed to become impacted and fouled with chunks of rust. If these conditions are allowed to develop there will be poor performance and a noticeable reduction in capacity.

The pH of the water supply is an important consideration and should be checked closely before the equipment is installed. Water having a pH value below 6.5, for example can be corrosive to the conditioning media.

FIGURE 3-4
LIQUID LEVEL CONTROLLERS



*Courtesy of North Carolina Department of Human Services, Dental Health Section.

FIGURE 3-5
ZEOLITE WATER SOFTENER

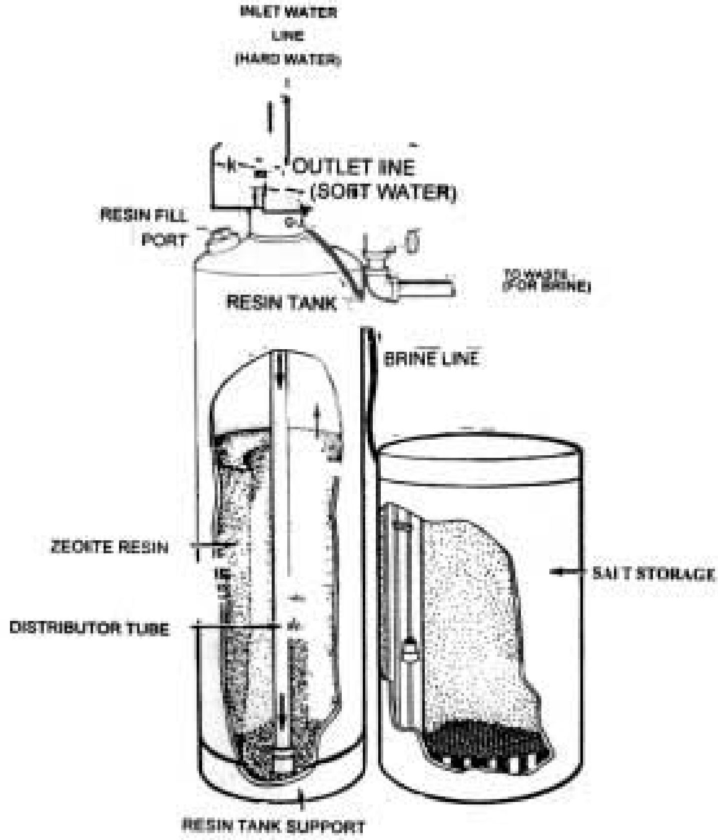
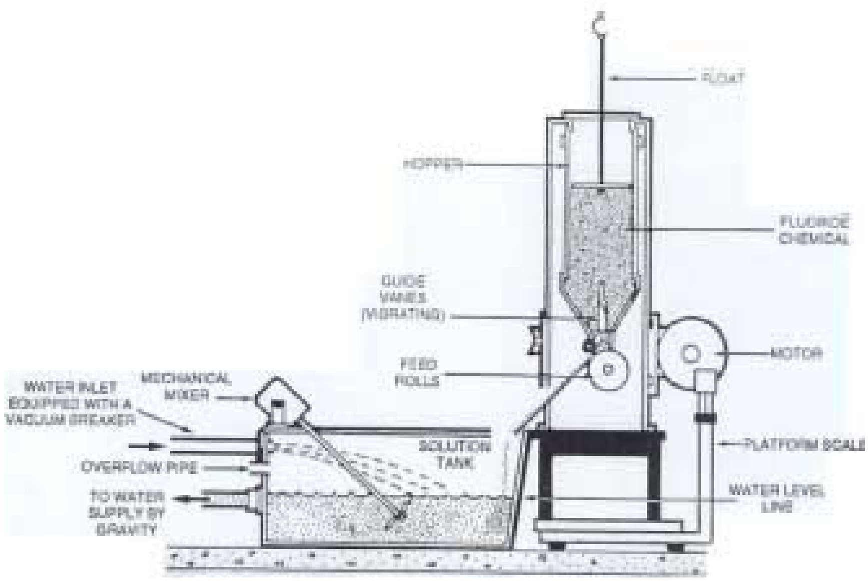


FIGURE 3-6
VOLUMETRIC FEEDER, ROLL- TYPE



A bypass system is a necessary part of the installation and is used to divert the flow of water around the conditioner during recharge and/or service. A drain line is also essential. It is used during recharge to direct the now of regeneration water to a suitable waste outlet. Sodium chloride (table salt) is used as the regeneration material.

The water pressure to the softener should be checked. Most manufactures recommend operation between 20psi and 100psi.

3.4 Dry Feeders

3.4.1 Introduction

Dry chemical feeders deliver a predetermined quantity of fluoride chemical in a given time interval. The two types of dry feeders are volumetric and gravimetric. 'The volumetric dry feeder delivers a measured volume of dry fluoride chemical per unit of time and the gravimetric dry feeders deliver a measured weight of chemical per unit of time.

Many water treatment plants that treat surface water (rivers, lakes, reservoirs, etc.) will utilize dry feeders to add other chemicals to the water. Thus, many surface water plants will consider using dry feeders in order for fluorides to be consistent with their other equipment. In fluoridation, dry feeders are used to feed sodium fluorosilicate almost exclusively. Very few water supply systems use sodium fluoride in dry feeders because the high cost of this chemical usually dictates the use of sodium fluorosilicate.

3.4.2 Volumetric Feeders

Volumetric feeders essentially consist of a combination of a driving mechanism for delivering a constant volume of dry compound. a hopper for holding the compound, and a chamber for dissolving the compound before discharge into the water supply.

The chemical delivery mechanism distinguishes one type of volumetric feeder from another. Almost every manufacturer has a different design for feeding chemicals volumetrically and can be classified according to several types rotating disk, oscillating pan, vibratory pan, rotating screw, rotating roller, star wheel, and combinations of these types.

Brief descriptions of the various types are given here merely to indicate the broad principles of operation. More complete details are readily obtainable from the manufacturers.

The roll-type feeder with a feed slide adjustment was one of the most widely used feeders, particularly in smaller plants. (**See Figure 3-6 page 39**) They are not as popular today as the screw- type feeders. In the roll-type feeder, the fluoride chemical is placed in the hopper through a top opening. From the hopper, it flows by gravity to the feed rolls.