CHAPTER 3

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 fluorosilicate) 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 can 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: (1) 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 filling 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. For greatest accuracy, metering pumps should be sized to feed fluoride nar the midpoint of their range. Pumps should always operate between 30%-70% of capacity.

Metering pumps that do not meet design specifications should not be installed. Oversized metering pumps should not be used because serious overfeeds (i.e. in excess of 4mg of fluoride/l) can occur if they are not set too high. Conversely, undersized metering pumps can cause erratic fluoride levels.

Most metering pumps come equipped with plastic heads and resilient check valves, which are generally satisfactory for discharge pressures up to 1 000 kPa. For higher pressures, corrosionresistant 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 316 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). Both 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 0.1 ppm, then a method to suppress this variation should be provided. This can be done in four ways: (1) 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, teflon, polyurethane, or viton.

Diaphragm pumps are ideally suited for medium-pressure service up to about 1 000 kPa. They should not be used against pressures less than about 100 kPa 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 1,2 meter. In other words, the metering pumps should be no more than 1,2 meter above the lowest normal level of liquid in the 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 actuated, 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 100 kPa to 860 kPa. Some brands of mechanical diaphragm pumps can operate with a back pressure up to 1 000 kPa. 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. But, 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 acts 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 100 kPa, some hydraulic metering pumps will require at least pressure. As with most diaphragm pumps, they will discharge into water with pressures up to approximately 1 000 kPa, although the more expensive hydraulic metering pumps can discharge into pressures up to 13 790 kPa.

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.

FIGURE 3-1

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. If 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.

3.3 SATURATORS

3.3.1 Introduction

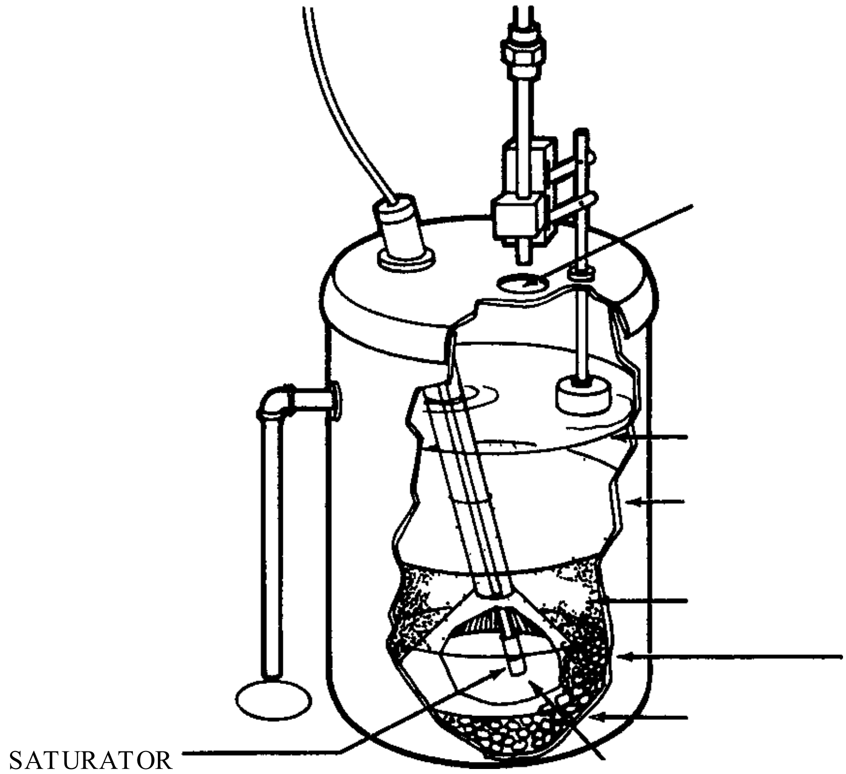
The saturator is a type of chemical feed equipment unique to fluoridation. The principle of a saturator is that a saturated fluoride solution will result if water is allowed to trickle through a bed containing a large amount of sodium fluoride. A small pump then delivers the solution of sodium fluoride 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 saturator was developed, and by the late 1970's, was becoming more popular than the downflow. After 1980, the downflow saturator was no longer 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 fluonde is placed on layers of sand and gravel to prevent particles of undissolved sodium fluonde 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 below.)

FIGURE 3-2



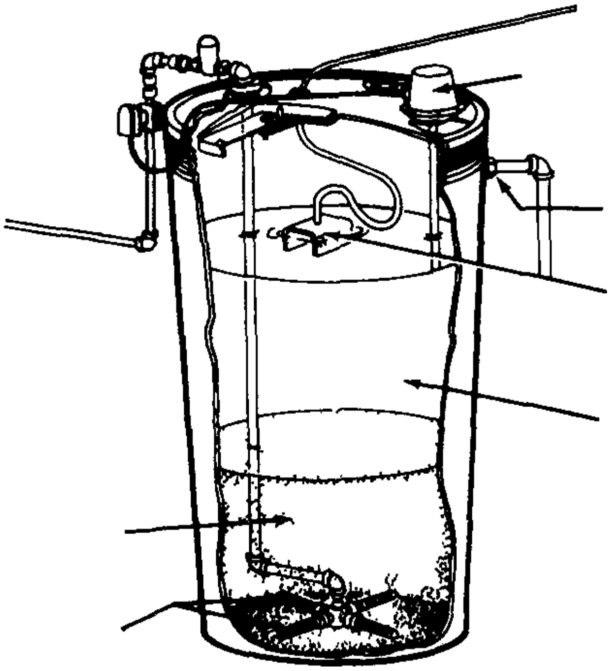
When a downflow saturator is in operation, water is admitted at the top of the saturator tank (an air gap avoids the possibility of a cross-connection) and the level is regulated with a float-operated controller. The water then trickles down through the bed of sodium fluoride, the solution is clarified 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 reasonably 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 140 kPa minimum to 860 kPa maximum, and the upward flow must not exceed 9 liter per minute. Since introduction of water to the bottom of the saturator constitutes a definite cross-connection, a mechanical syphon-breaker must be incorporated into the waterline. Also, a minimum of 300 mm of sodium fluoride must be kept in the bottom of the tank.

FIGURE 3-3



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 on page 3.10)

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 and are wired to control a solenoid valve (electrically operated openclose 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 float 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 50 ppm, 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 in exchange and the use of polyphosphates (calgon, micromet, 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 12 mg/L, although new more efficient types of polyphosphates are now available. They are fed at a rate of 1-1/2 mg/L to 2 mg/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 on page 3.11)

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.

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 flow 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 140 kPa and 690 kPa.

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.

FIGURE 3-4

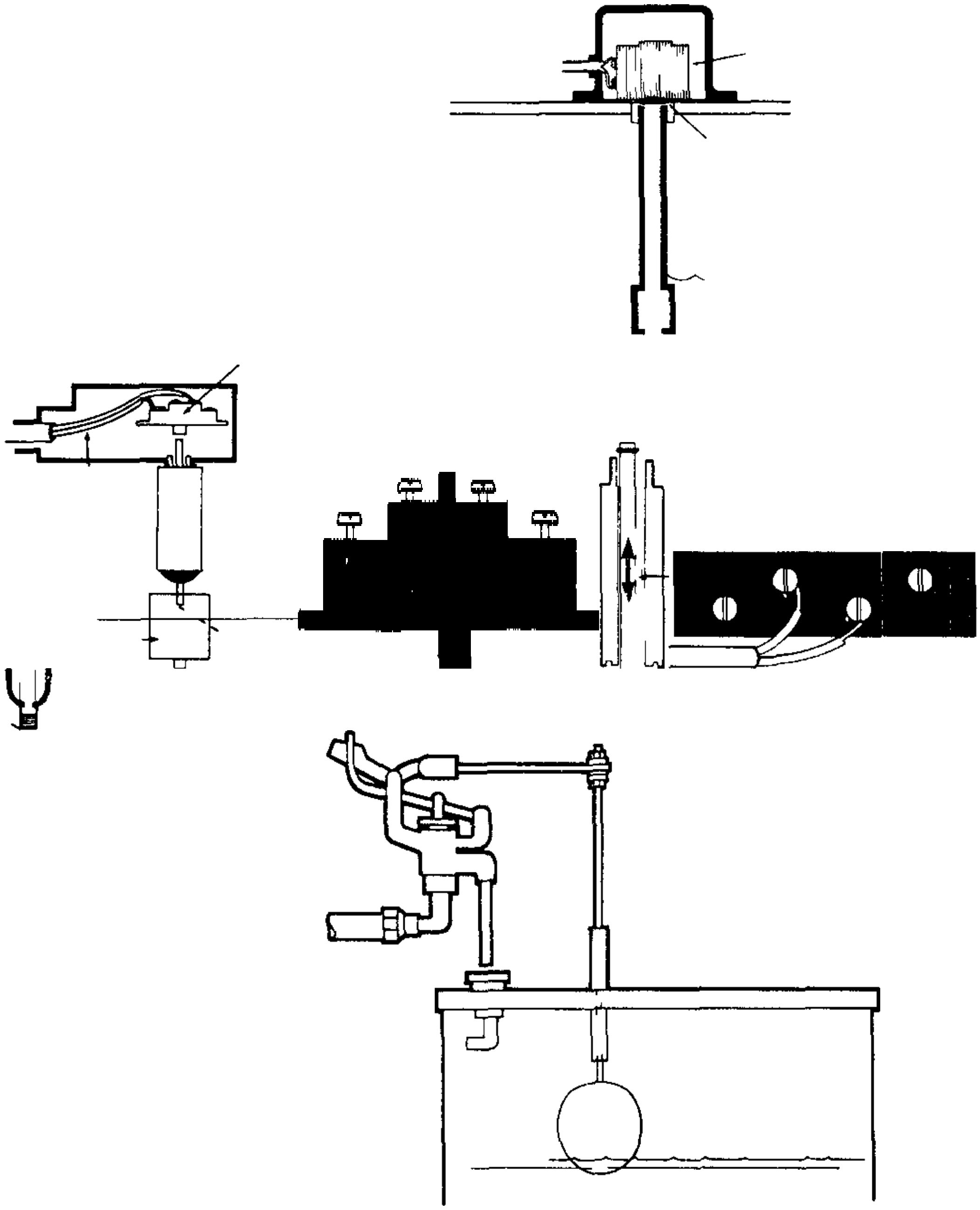
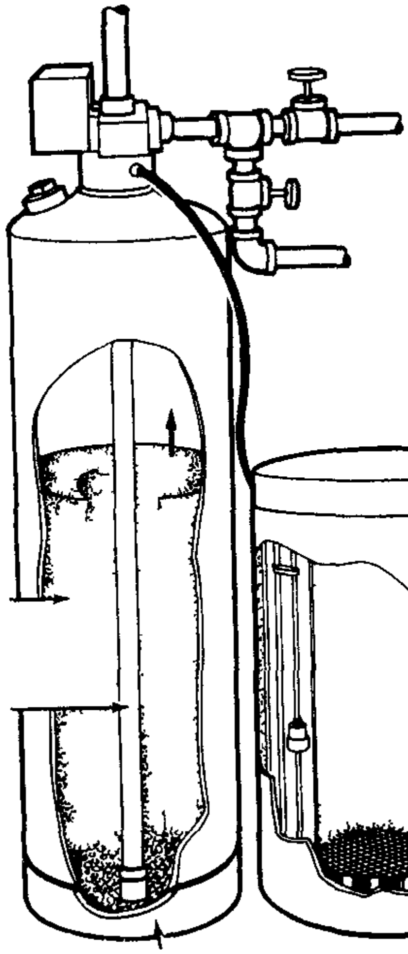


FIGURE 3-5



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.) They are not as popular today as the screwtype 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.

Stainless steel feed rollers, which are driven in opposite directions form the material into a smooth ribbon of uniform thickness. The feed rate is adjusted externally on a graduated feed slide by varying the width of this ribbon. If the feeder is equipped with a variable speed drive, it has no feed slide. The feed rate is then adjusted by changing input rpm to the three-speed gearbox. Material leaves the rolls at a uniform rate, falls into a solution tank, and is discharged to the main water system.

The roll-type volumetric feeder feeds powdery or granular dry, free-flowing materials at rates from 2,7 kg/hr to 950 kg/hr, although the very fine powder will tend to run freely through the rollers.

The oscillating-pan type of feeder consists essentially of a flat, narrow pan or trough into which the fluoride compound falls from a hopper above. Either the pan or the lower part of the hopper slowly oscillates along the axis of the pan, forcing the removal along the two open edges of the pan of a portion of the chemical in the pan. Delivery rates are controlled by both the speed of oscillation and the length of the stroke or the thickness of the chemical on the pan.

The vibratory-pan dry feeder is a device for discharging a volume of chemical from a pan, chute, or trough made to vibrate electrically. A magnet is energized by means of a pulsating current (either ordinary alternating current or rectified, pulsating direct current). The trough is mounted on springs and connected directly to the magnet. The action of the tray is downward and backward on the power stroke, and upward and forward on the next stroke through the action of the springs. The material on the tray moves forward slightly on each stroke and appears to flow like water because of the high stroking frequence (3,600 strokes per minute on 60-cycle current). The rate of delivery is controlled by a rheostat, which determines the voltage and consequently, the degree of movement of the trough.

The most popular type of volumetric feeder is the rotating screw feeder. (See Figure 3-7.) The fluoride chemical is placed in the hopper through the top. It settles to the bottom by gravity. An arrangement with vibrating plates in the hopper walls provides constant agitation. The agitation extends to the feed screw (hopper bottom) and is designed to prevent arching and packing. It also helps maintain uniform delivery to the feed screw. An eccentric on the feed screw shaft drives a rocker arm connected to vibrating plates in the hopper walls. The feed screw gives single-ended delivery of fluoride to the solution tank at a uniform rate via the discharge line There is a range of feed rates between 0.01 and 2 270 kg per hour.

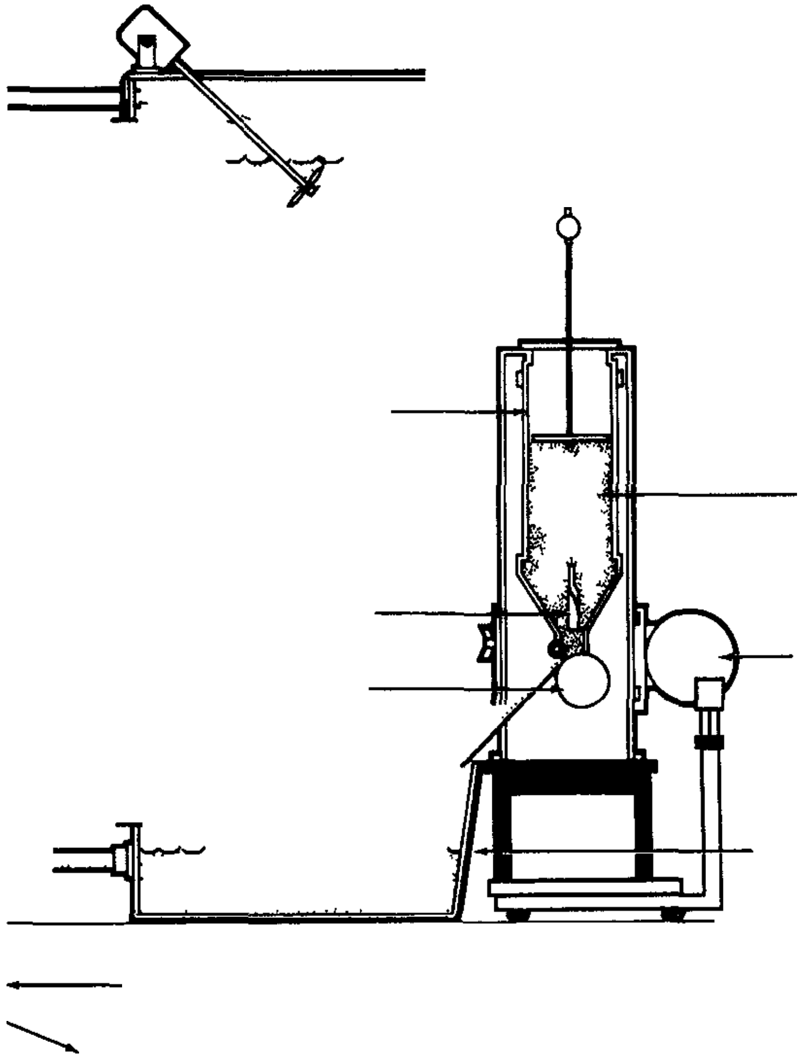
3.4.3 Gravimetric Feeders

Gravimetric feeders discharge chemicals at a constant weight rather than at a constant volume during a given period of time. There are two general types of gravimetric dry feeders those based on loss-in-weight of the feeder and those which are based on the weight of material on a section of a moving belt. Many gravimetric dry feeders also incorporate some of the features of volumetric feeders, in that they have rotary feed mechanism between the hopper and the weighing section, or use a mechanical vibrator to move chemicals out of the hopper. Since, ultimately, it is the weight of material per unit of time that is measured and regulated, such variables as material density or consistency have no effect on feed rate. This accounts for the extreme accuracy of which these feeders are capable.

The first type (loss in weight) consists of a hopper suspended from a scale system, an electrical-mechanical system for moving the poise on the scale beam, a mechanical means for moving the compound from the hopper in an amount depending on the position of the scale beam, and a solution tank. The lead screw drive (a synchronous motor) moves the poise along the beam at a pre-set rate of speed. If more material is fed momentarily than indicated by the position of the poise, then the beam will lower. This action moves the control wedge (near the oscillator) downward, permitting a decrease in the amplitude of the stroke driving the star wheel or vibrating feeder mechanism. Less material will then be delivered until the weight of the compound remaining in the hopper is again balanced by the weight of the scale beam. The margin of error in feeding for this type of feeder is generally less than 1 percent. The minimum delivery is 700 gram per hour with range of feed in the order of 100 to 1, while some models can deliver more than 2 tons per hour.

The other type of gravimetric feeder is one in which a section of a loaded, moving belt is continuously weighed. (See Figure 3-8.) The weight of the belt is balanced by a scale beam. The position of the beam controls delivery of the compound onto the belt. Any deviation from this weight on the belt causes the vertical gate to go up or down, thus causing more or less material to fall onto the belt. Vibrations imparted to a diaphragm on the hopper

FIGURE 3-6



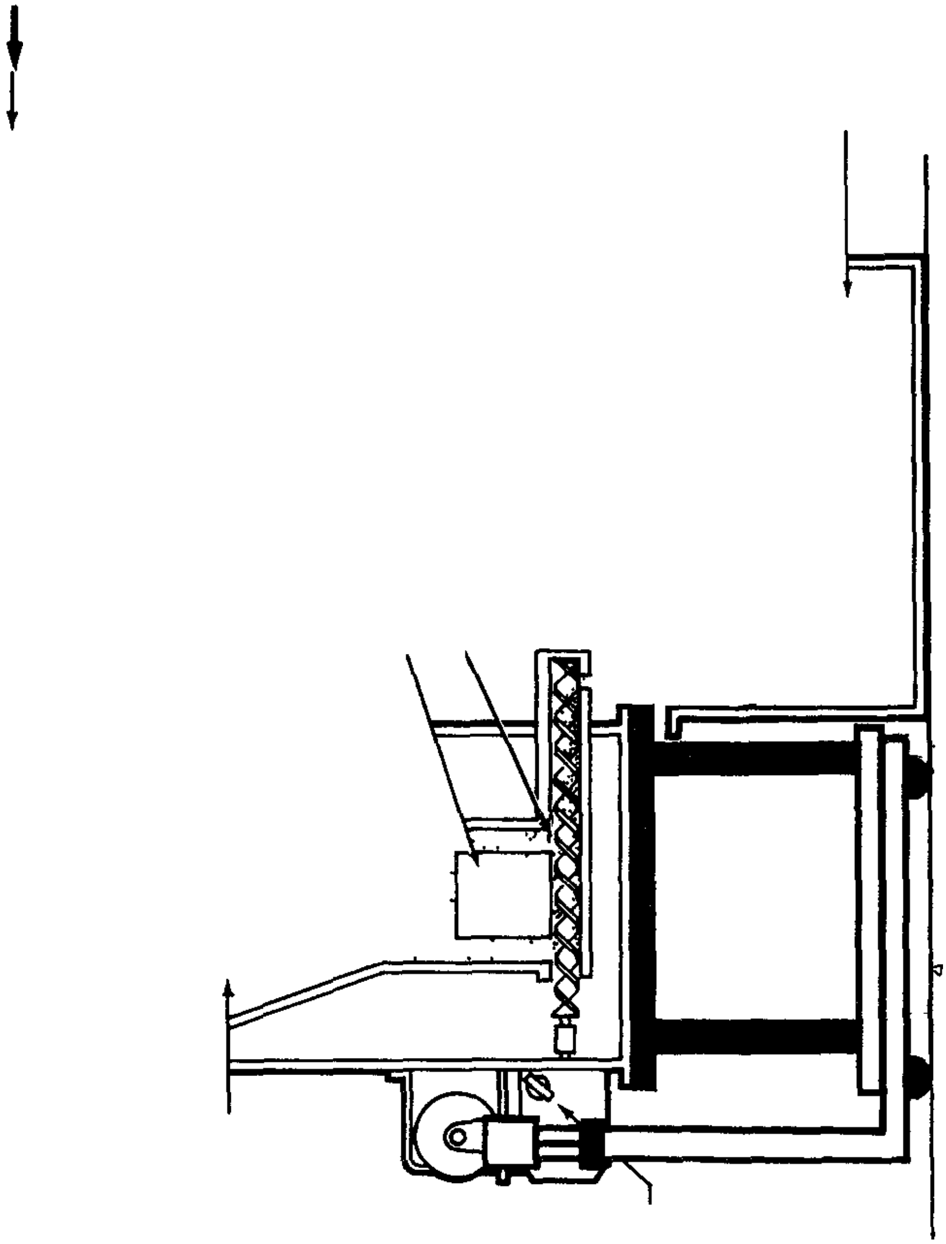
are generated by an eccentric and transmitted through a wedge that varies the amplitude of the vibrations, depending on the position of the scale beam. Accuracy in these feeders is in the order of 99 percent or more. Range of feed is as much as 100 to 1, and adjustments are readily made merely by moving the poise on the scale beam.

3.4.4 Solution Tanks

The materials discharged from a dry feeder are continuously dissolved in a chamber beneath the feeder. From this chamber the clear solution falls or is pumped into the water to be treated. This chamber has been referred to as the solution tank, dissolver tank, solution pot, or dissolving chamber. While some chemicals can be fed directly into flumes or basins without using a solution tank, fluorides are not among them. The necessity for accurate feed rates will not permit the possibility of slurry feed, which may form build-ups of undissolved dry material.

Solution tanks come in sizes from 22,5 liters on up, with the size often being determined by the size of the feeder under which they are mounted. If there is a choice, the largest size available should be used for fluoride compounds. Mixing of the chemical with water may be accomplished by a system of baffles, and agitation can be provided by a paddle driven by jets of water, but it is strongly recommended by CDC that a mechanical mixer be used. (Please refer to Section 3.5.7.) Experience has shown that the jet mixer is not nearly as dependable

FIGURE 3-7



as a good mechanical mixer, even under ideal conditions. Solution tanks should be covered, if possible, and the lid should be lined with fiberglass. The solution tank should be made of stainless steel or fiberglass. Because of the corrosive nature of sodium fluorosilicate, painted metal solution tanks are not recommended.

The failure to produce a clear, homogeneous solution discharge from the solution tank of a dry feeder indicates that: (1) The solution tank is too small; (2) the detention time is too short; (3) too little solution water is being provided; (4) agitation is insufficient, and/or (5) dry chemical is shortcircuiting and is not being adequately mixed with the water.

It has been determined experimentally that detention time (the length of time the fluoride compound remains in the solution tank) needs to be a minimum of 5 minutes to provide a concentration which is one-fourth the maximum solubility, provided the water temperature is above 15 degrees C and the chemical is in the form of a fine powder. If the chemical is in the form of crystals or the water temperature is below 15 degrees C, the dissolving time should be doubled; if both, the time should be tripled (i.e., 15 minutes).

Short-circuiting (which is the flow of water directly from the inlet to the outlet without any mixing) is essentially a problem in the solution tank design, and is more likely to occur in the smaller tanks. If short-circuiting does occur, the remedy is to add baffles to the tank so that the path of the chemical to the outlet of the chamber is sufficiently deflected to provide the necessary mixing for solution.

Since the usual arrangement for a solution tank is to have the water inlet below the outlet, there is a cross-connection that requires adequate safety measures. If a break occurs in the water line, fluoride solution from the solution tank could be drawn back into the water line. If the solution tank is not already equipped with a correctly placed vacuum-breaker, one should be installed on the water inlet as near as possible to the entry and be elevated above the lip of the tank. If there is a solenoid or manually operated valve on the water inlet line, the vacuum breaker must be installed between the valve and the tank for adequate cross-connection protection. (See Section 3.5.4.)

3.4.5 Dry Feeder Accessories

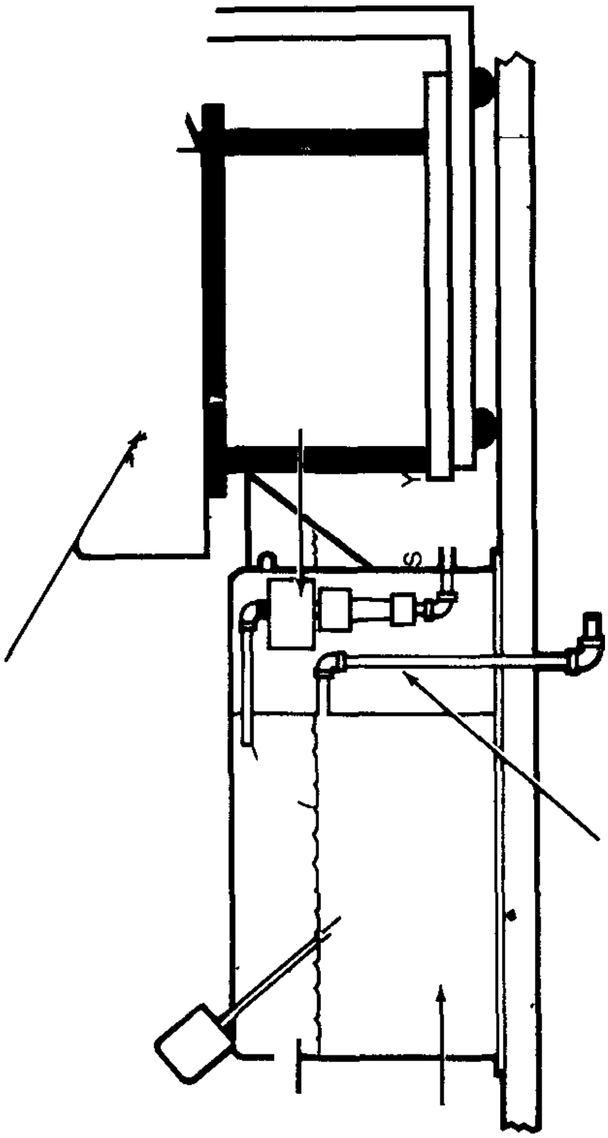
For holding the fluoride chemical, many dry feeders will be purchased with a small hopper. In large installations, an additional extension is provided above the main hopper for additional chemical storage. Access to the extension hopper is usually located one floor above the dry feeder. The sodium fluorosilicate, if stored on the second floor, can then be conveniently loaded into the hopper.

In small plants, the chemical hopper should be large enough to hold slightly more than the entire bag or drum of chemical. The hopper does not have to be completely emptied before a new bag or drum can be added. By loading an entire container this way, handling of chemicals, dust, and spillage is minimized.

When the hopper is installed directly above the feeder, the operator must lift the bag of chemical a considerable height to fill the hopper. A bag loader is essential in this situation. A bag loader is a hopper extension large enough to hold a single 45 kg bag of chemical. The front of the loader is hinged so that it will swing down to a more accessible height. The bag is fastened by running an attached rod through the bottom of the bag. The bag is then opened and the loader is swung back into position. This device makes emptying the bag easier and minimizes dust.

Handling powdered dry chemicals always generates dust. For this reason, an operator should wear a respirator. When small quantities of fluoride are being handled, ordinary care will minimize dust, and good housekeeping plus an exhaust fan, will keep the storage and loading area relatively
dust-free. However, when larger quantities (more than one bag at a time) are handled, dust prevention and collection facilities should be provided.

FIGURE 3-8



A dust canopy that completely encloses the hopper-filling area and is equipped with an exhaust fan, prevents dust from spreading throughout the loading area. To prevent dust from escaping into the atmosphere and into the area surrounding the water plant, dust filters should be incorporated into the exhaust system. Dust collectors and exhaust fans are sometimes incorporated into the hoppers of larger dry feeders.

A float in the hopper lid indicates the level of material in the hopper. The sides of the hopper and the built-in guide vanes flex with an oscillating motion to provide constant agitation. This prevents arching, caking, or packing and assures uniform feeding to the feed rollers.

It is strongly recommended that a beam scale be used to weigh the dry chemicals or solutions that are added. A recorder can be attached to keep a record of the weight of the chemical fed. Many volumetric dry feeders have recorders available as an accessory.

3.4.6 Calibration of Dry Feeders

The rate of feed of a dry chemical feeder can be varied by adjusting the controls according to a scale. The numbers on this scale have no particular units and cannot be converted to ppm or mg/L until a calibration chart or curve has been prepared. A separate calibration chart is required for each machine and for each chemical fed by the machine. If it is possible to operate your water plant at more than one rate, then you must also have different calibration charts for each plant rate.

To calibrate a dry feeder, fill the hopper to the normal depth with the chemical to be fed. Be sure the chemical is dry, free-flowing, and contains no lumps.

Set the machine adjustment on a low number--certainly lower than the normal operation. Allow the machine to run for few minutes so that it is feeding uniformly. Use a pan or cardboard box (which has been weighed empty), to catch the total discharge of chemical from the feeder for several minutes (say 5 minutes). Weigh the chemical on the laboratory balance (in grams) and record on a chart.

Repeat the same operation for other scale settings on the machine--usually four or five different settings. Be sure to cover the full range at which the feeder will be operated. Post the calibration curves near the machine (be sure to label each curve for the right machine) so that they can be used without mistakes or loss of time.

The feed rate of a given machine, when operating at a given setting, will vary, depending on machine wear, humidity, variation in texture of the chemical being fed, etc.; therefore, a calibration curve should not be used over an extended period without verifying the accuracy of the curve.

3.5 AUXILIARY EQUIPMENT

3.5.1 Introduction

Most water systems that add fluoride do need additional equipment beyond the bare minimum equipment required. The following sections will explain each type of auxiliary equipment commonly used and where each item belongs in a fluoridation system. As the size and complexity of the fluoridation system grows, the amount and complexity of auxiliary equipment required also increases.

3.5.2 Water Meters

Meters are used for two primary purposes in water plants in connection with fluoridation. One use is to register total flow (water flow) to determine the amount of fluoride chemicals based on water usage. The other important use is as a pacing meter for variable flow conditions. The pacing meter will vary the frequency of a metering pump to maintain a desired fluoridation dosage at any flow rate.

The water meter, often absent in the smallest water plants, is one of the primary requisites for accurate fluoride feedings. A water meter measures the flow of water in a water line (volume). Usually, the unit of measurement is gallons or cubic feet. This type of meter in the water line at home is read once a month and the difference between two months' figures is the amount of water used that month. But note, that with a water meter there is no way to know the rate of flow or when the water was used.

One other use of small totalizing water meters is to record the make-up water for a sodium fluoride saturator. The amount of make-up water is directly related to the amount of sodium fluoride injected, since a saturator provides a constant 4 percent solution. By relating make-up water to total water being treated over an equal time span, fluoride dosage can be monitored and adjusted. This requires the smallest type of positive displacement totalizing water meter available (usually 16 mm) that will record low flows since saturator make-up flows are very low. Many times the term "water meter" is used to describe water meters, flow meters, pacing meters, compound meters, etc. While this is incorrect, it is a common practice in the waterworks field.

3.5.3 Pacing Meters

A flow meter, in contrast to an ordinary water meter, measures **rate of flow** rather than **volume of flow.** It registers units of liters per minute, liters per hour, cubic metor per minute, etc. and is installed in-line where the flow is to be measured. Some types of flow meters, in addition to measuring the rate of flow, can also produce signals relative to the rate of flow. These flow meters are called pacing meters.

Many water systems, because of their design, will have varying flows. Varying flows can be the result of: (1) gravity flow; (2) systems that have two or more water pumps that feed into a common line and are not always all operating simultaneously; and (3) a variable output from pumps because of a changing head. It can be more economical to use one fluoridation system paced by a meter on a common main than to have a system for each pump. The paced system is generally **more accurate** than a chemical metering pump timed to turn on with a water pump.

Pacing meters provide a signal that is proportional to rate of flow. Some meters also provide totalizing as a secondary function, which is useful but not necessary. This signal that is proportional to rate of flow controls the fluoride injection pump output, which is also directly proportional to the water flow in the line being treated, so as to maintain the desired dosage ratio at all flow rates possible.

Two types of signals are generally used for pacing chemical metering pumps. They are the standard analog 4 to 20 mA DC instrument signal and a digital signal whose frequency is proportional to flow rate and digitally proportional to volume.

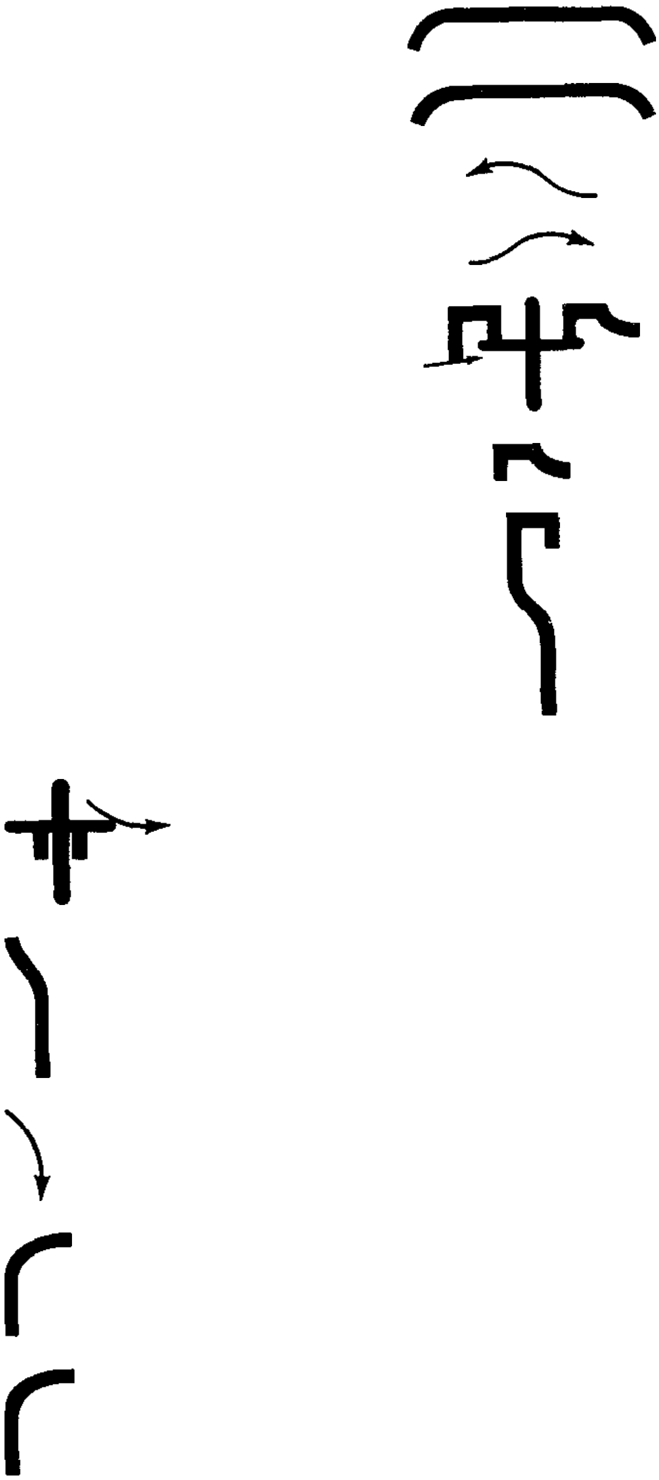
A **pacing** meter is a complicated piece of equipment and should only be used in fluoridation systems when it is necessary. In a typical water plant, when there is only one well pump operating at a fixed rate, the fluoride feeder can be tied electrically to the pump operation and a pacing system is not required. When the well is in operation, the water flow is constant, and the fluoride metering pump can feed at a constant rate. Generally, a meter paced system is necessary when the rate of flow past the point of injection varies by more than +15-20 percent of the average flow.

3.5.4 Vacuum Breakers

The simplest method for preventing a potential back-siphonage situation is to provide an air-gap in the line. Since an air-gap is sometimes impossible or impractical, a device known as a vacuum breaker is installed.

Many states require a vacuum breaker (non-pressure type) on the potable make-up water lines to upflow type saturators, dry feeder solution tanks, and hose bibs located in the fluoride area. The most common use in fluoridation is on the make-up water lines to the saturators. (See Figure 3-9 below.) The vacuum breaker is different from a metering pump anti-siphon (backpressure) valve, and the two must not be confused.

FIGURE 3-9



When in operation, and water is normally flowing through, the disc in the vacuum breaker is kept closed by water pressure. Whenever the water stops flowing through, tlle valve disc drops, thus opening the atmospheric vent and allowing air to be drawn in rather than pulling the fluoride solution back into the line.

Most vacuum breakers are of the atmospheric or non-pressure type. The vacuum breaker must, therefore, be installed after the last shut-off valve or solenoid valve (downstream) and be elevated 150 mm above the top of the saturator liquid level.

Always install the vacuum breaker where it will be accessible for observation and cleaning. Do not install it where it will be under water, subject to freezing, out of sight, or where emergency water spillage will create problems.

If the vacuum breaker is functioning correctly, air bubbles will be momentarily visible from the bottom of the upflow type saturator during each fill cycle. Failure to see air bubbles means the vacuum breaker needs immediate service or replacement.

The vacuum breaker is important for adequate cross-connection protection and must not be removed. Keep a spare vacuum breaker on hand, inspect the disc for wear annually, and replace as directed by the manufacturer.

3.5.5 Anti-siphon Valves

It is sometimes require that an anti-siphon valve or spring be located on the discharge side of the fluoride metering pump wherever a fluoride solution is added to any pipeline, channel, or clearwell. Of all the auxiliary equipment used, the anti-siphon valve is probably the most important from a safety viewpoint. (See Figures 3-10 and 3-11 below.) The lack of an anti-siphon valve has resulted in several overfeeds that could have been prevented. The anti-siphon valve is different from an atmospheric or non-pressure type vacuum breaker, which was discussed previously.

FIGURE 3-10

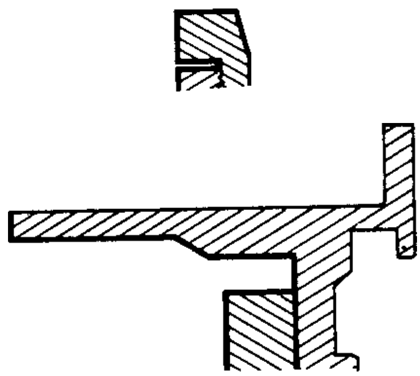
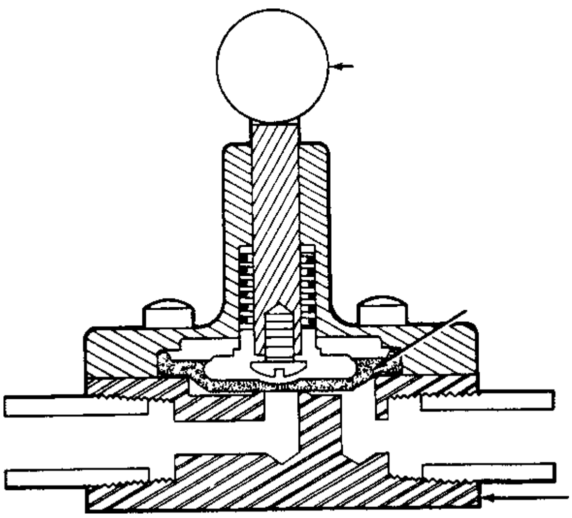


FIGURE 3-11



The purpose of the anti-siphon valve is to prevent a potential overfeed of fluoride, which could occur when the metering pump is not pumping or is unplugged. It prevents dynamic siphoning ("free wheeling") and flow-through when suction pressure exceeds discharge pressure. Always install an anti-siphon valve on the discharge (pressure) side of the metering pump head when it is accessible for observation and cleaning. Also install an anti-siphon valve at the fluoride injection point, if this point is under pressure. Do not install it where it will be underwater or out of sight.

The anti-siphon valve operates by a spring being compressed when the pump diaphragm strokes. Usually the spring is protected by a hypalon or teflon diaphragm. If fluorosilicic acid is used, the spring must be protected by a diaphragm or be coated. The diaphragm type anti-siphon valve is better than the coated valve because the spring itself is protected from the fluoride solution. Some anti-siphon valves can be adjusted by turning a screw and some are pre-set at the factory. Most are set in the range of 100 - 140 kPa. Some anti-siphon valves are built into the pump head, but most are considered additional and must be purchased separately. Always check with the pump manufacturer or distributor to determine if it is included with the pump assembly.

The anti-siphon valve spring should be inspected for wear annually and replaced as directed by the manufacturer. A spare should be kept on hand.

3.5.6 Day Tanks

A day tank is just what the name implies a tank that holds a day's supply of a particular water treatment chemical. It is a convenient and often necessary means for isolating the supply of fluoride solution that will be fed during I day or shift at the water plant. Sometimes these tanks are called 30-hour tanks. Also, there are times the day tank will hold enough solution to last for a week, but this is not recommended.

The day tank is a necessity when feeding large amounts of fluorosilicic acid, particularly if the acid is received and stored in a large tank (bulk storage). In order to provide a record of the weight of acid fed, a small quantity of the acid is pumped or siphoned into a small tank mounted on a platform scale, and it is from this day tank that the fluorosilicic acid is fed into the water system.

The types of construction materials used in day tanks are determined by the chemical being used but generally are of three types: rubber-lined steel tanks, fiberglass, and polyethylene. Strong sunlight will cause the plastics to "age" and eventually crack. Black coloring reduces the effects of sunlight, but most plastic day tanks are made of the white translucent polyethylene.

Day tanks are made in all kinds of shapes, but the best for fluoridation is the cylindrical tank with a flat bottom and seamless construction. The lid should have a lip gasket and be airtight, and the day tank should be mounted on a scale. The tank can be provided with graduations or a gauge so that approximate volume measurements can be used.

For systems using fluorosilicic acid and bulk storage, the day tank should be sealed and vented to the outside. The day tank lid should be sealed around the edges or lip, and the three openings where the vent line, fill line entrance, and the pump suction line exits must also be sealed. These line openings are frequently left unsealed. These is no need for an overflow line if the day tank is properly vented.

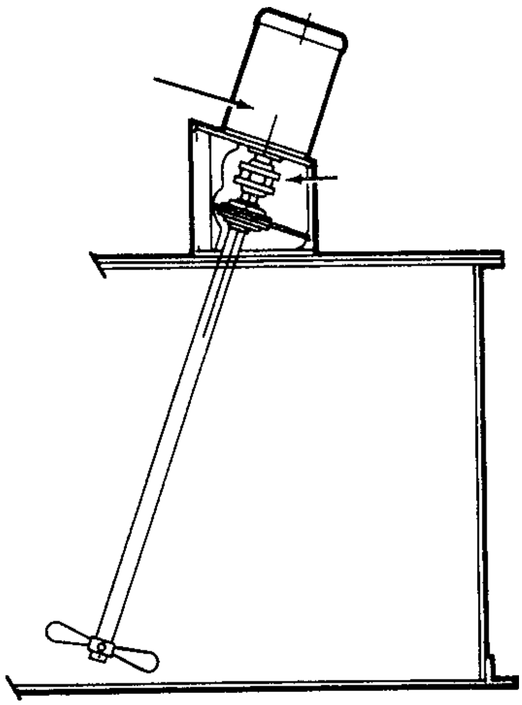
3.5.7 Mixers

Whenever solutions are prepared, whether manual preparation of sodium fluoride solutions, dilution of fluorosilicic acid, or the output of a dry feeder, it is particularly important that the solution be homogeneous. Slurries must not be tolerated in the feeding of fluorides, since undissolved fluoride compounds can go into solution, subsequently causing a higher-than-optimal concentration. If the fluoride compound remains undissolved, a lower-than-optimal concentration will result. Undissolved material can also cause clogging of equipment and other devices having small openings, and if allowed to accumulate, resultsin considerable waste.

Two kinds of mixers are commonly used in fluoridation the in-line and small mechanical high speed. The in-line mixer is used in the main water line to ensure proper mixing of the fluoride solution prior to the potable water being consumed. The mechanical mixer is used in the solution tanks of dry feeders and in the manual preparation of fluoride solutions.

The dissolving of sodium fluorosilicate in the solution tank of a dry feeder can be accomplished by a jet mixer, but, again, a mechanical mixer is strongly recommended. (See Figure 3-12 below.) Because of the low solubility of sodium fluorosilicate, particularly in cold water, and the limited detention time available for dissolving, violent agitation is essential to prevent the discharge of a slurry. Preferred construction materials are 316 stainless-steel or PVC-coated steel. One note of caution: if the mixing is too vigorous, water may splash up into the feed mechanism and cause plugging problems.

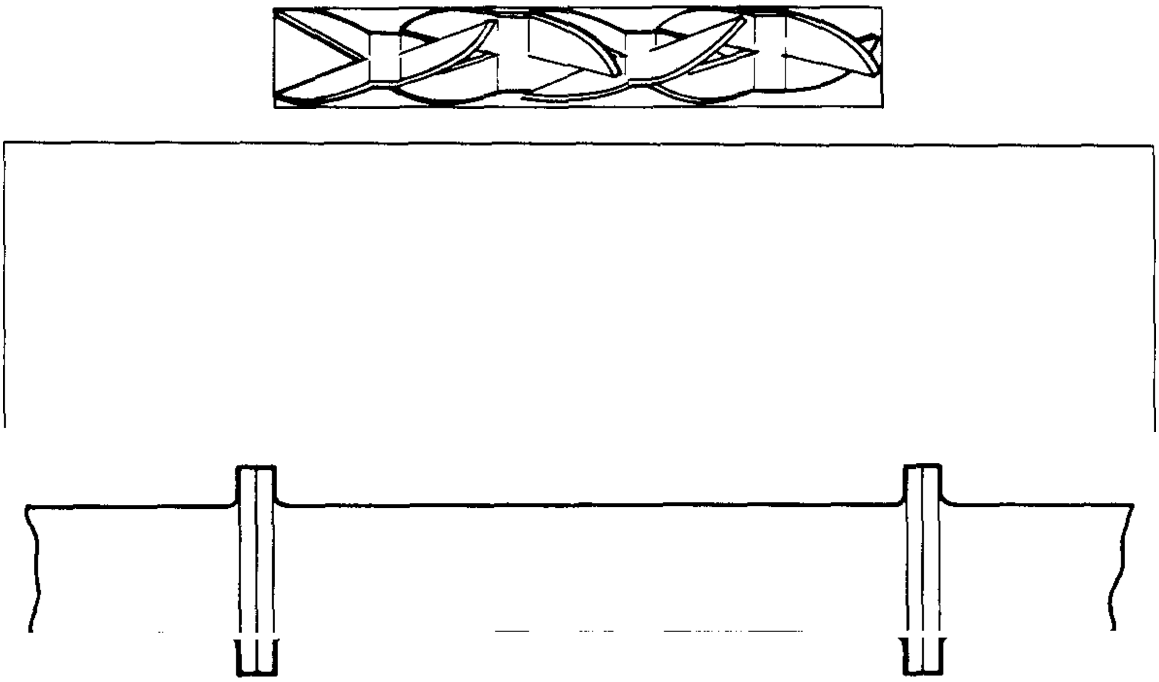
FIGURE 3-12



An in-line mixer (see Figure 3-13 below) should be a simple motionless mixer made of a fixed arrangement of geometrically designed elements enclosed in a tube or pipe. The flowing water provides the energy needed for mixing. (There are no moving parts in an in-line mixer.) Surprisingly, most in-line mixers are very efficient, with very little head loss. Mixers are available in sizes from 19 mm to 1 830 mm in diameter. Construction materials include stainless steel, carbon steel, fiberglass, and PVC. For fluoridation, 316 stainless steel is generally recommended.

An in-line mixer requires very little, if any, maintenance, thus it can be installed underground or in other inaccessible locations. Any location that requires proper mixing of the fluoride chemical but is close to the point of injection is a place that may require an in-line mixer. CDC recommends an in-line mixer if the first customer is 30 meters or less from the fluoride injection point and there is no storage tank located before the customer, and the fluoride content of the treated water varies by more than 0.1 mg/L. This is a minimum distance, assuming normal valves and bends in the line.

FIGURE 3-13



3.5.8 Scales

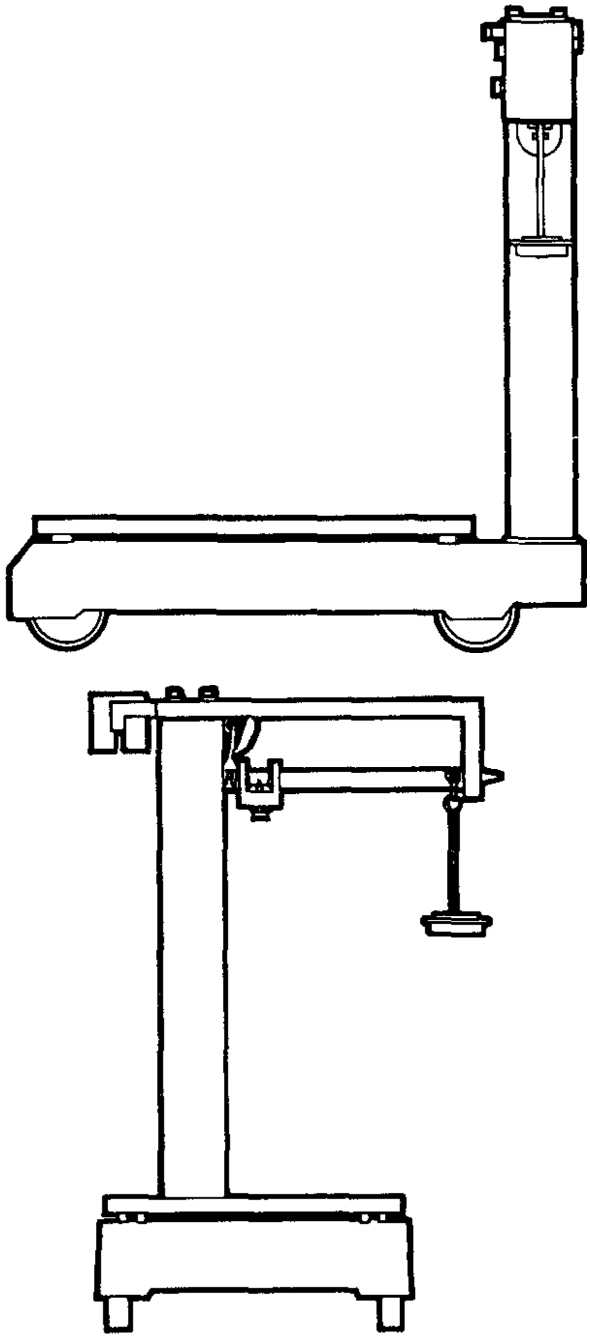
In any fluoridation installation, except for one based on a sodium fluoride saturator, scales are a necessity for weighing the quantity of solution fed, or weighing the quantity of dry fluoride compound or fluorosilicic acid delivered by the appropriate feeder.

The type of scale can vary from a small household-type used for weighing a kilogram or two of sodium fluoride for solution preparation to a complex type with a built-in mechanism. The general types are beam scales, dial scales, and digital read-out scales. The most generally applicable is the beam-type scale with a platform. It is frequently erroneously called a platform scale. (See Figure 3-14.)

A solution tank, a carboy of acid, or an entire volumetric dry feeder can be placed on the platform of the beam scales. Although the scales may be designed for a specific application, as are those supplied by manufacturers of volumetric dry feeders, in many cases an ordinary hardware-store type of scale will be perfectly acceptable. Some minor modifications, such as removing the wheels or rotating the beam, may be necessary, but as long as the scales have sufficient capacity and sensitivity, there is no reason why they cannot be used. Capacity and sensitivity are the only serious considerations. The scales must be capable of weighing the tank and its contents when full, or the volumetric feeder and its hopper when full. Measurement to the nearest 500 gram or better is adequate for dry feeders. Fluorosilicic acid should be weighed to the nearest 200 gram. For small scales used for measuring sodium fluoride in manual solution preparation, sensitivity to the nearest ounce should be sufficient. Generally, a 500 kg minimum scale should be specified, as it is better constructed. The life of a good beam scale is approximately 15 years.

No particular problems should be encountered when mounting equipment on beam scales, except when there is a connection to a vent, suction line, water line, or discharge line. All such connections must be flexible enough to permit the scale tc operate properly. This flexible connection should be horizontal for best results.

FIGURE 3-14



3.5.9 Other Appurtenances

Unions

Unions are a type of plumbing fitting used for joining pipes or tubing that may be disconnected at a later date for maintenance or repair purposes. Unions save time and money when removing or disconnecting any fixtures for repair or replacement.

Unions may be constructed of many materials, such as bronze or PVC, and should be compatible with the fluoride chemical in the pipe. Unions are especially recommended on a saturator system, because equipment must be removed, drained, and cleaned more often than other fluoridation systems. The cleaning process requires disassembly of: the overflow pipe; the submerged make-up water line to the upflow saturator; and the make-up water line inlet to the saturator. All of the above connections should have unions.

Other places to consider using unions are at connections to softeners, small water meters, and at reduced pressure backflow preventers. If plastic pipes are used on a saturator make-up line, unions should be included.

Strainers

Pump check valves, reduced pressure blackflow preventers, and other parts of the equipment are highly susceptible to dirt and other contaminants in the water. To prevent accumulation of dirt or sediment, which can cause a malfunction, Y-strainers are recommended for most water plumbing lines. The Y-strainer must be installed in the direction of flow. It is easy to install them backwards by mistake. One hundred mesh size screen (0.25 mm) is commonly used in the strainers used in fluoridation systems. A spare mesh screen should be kept on hand.

Timers

An interval timer as used in fluoridation is basically a clock mechanism, usually electric, which will operate an electric pump upon receipt of a signal. Timers are frequently used in conjunction with water meter contactors to operate electric-motor operated feeders. Thus, the timer serves to extend the impulse received from the contactor.

Another application of a timer is in those installations where the minimum reliable feeder setting is still too high for the water flow. In these cases, the timer can be set to provide a proportion of the full-time feed rate. For example, by setting the timer to operate the feeder at 75 percent of each 10-minute period, the feed rate will only be 75 percent of that obtained without the use of the timer.

A word of caution: Using a proportional timer at low percentages, particularly for long interval settings, can result in cyclic fluoride levels. If there is insufficient detention time in clearwells or pipelines before the water reaches the consumers, the on-off action of the feeder will result in alternately too high and too low fluoride readings. The remedy, other than using a smaller metering pump, is to make the proportioned time interval as short as possible. If possible, it is best not to use timers in water fluoridation.

Alarms

To prevent underfeeding or even loss of feed, alarm systems can be included in either solution or dry feed systems. The alarm alerts the operator when the solution level in the day tank is low or when a new bag of dry chemical should be put into the hopper. An alarm can also signal that the water supply to a saturator or dissolving tank has either stopped or diminished. The alarms are rigged by level switches, flow switches, or pressure switches.

Flow Switches

In fluoridation installations it is important that the fluoride metering pump operate only when the water is flowing. This is especially true in school fluoridation systems. CDC recommends that an additional safety device, the flow switch, be electrically interconnected with the well pump and the fluoride metering pump.

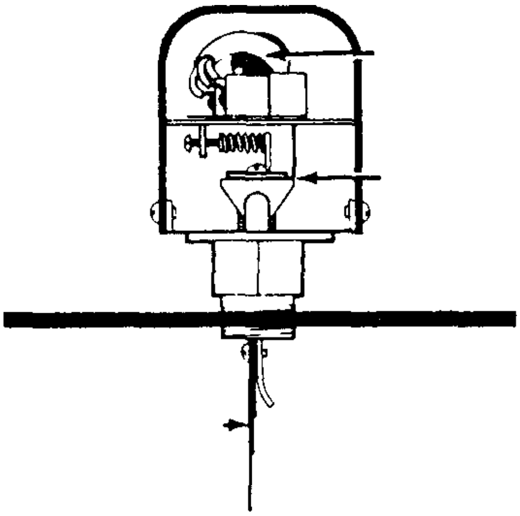
A flow switch is a device installed in a water main that will trip an electrical switch whenever there is flow in the water line. When there is no flow, the electrical switch will remain open. The two general types of flow switches used in water fluoridation are the mechanical and the thermally actuated. Both are used in the United States in fluoridated school systems.

The mechanical flow switch has a paddle or wheel inserted into the water line, see Figure 3-15 on page 3.25. When there is flow, the paddle (wheel) will close an electrical contact. This type of flow switch can fit into a water line as small as 19 mm or as large as 400 mm. This is a high maintenance item and needs to be provided with regular care. The most common problem is with corrosion or breakage of the paddle.

The thermally actuated flow switch is a temperature differential flow sensor. It detects variations in flow velocity by sensing changes in the heat transfer properties of the flowing water. The sensing head consists of three stainless steel thermowells, (two matched pairs of resistive temperature sensors [one active and one reference] and a low-powered heating element in the third thermowell). The heating element is located so as to heat the active temperature sensor. This creates a temperature differential between the active and the reference temperature sensors. Changes in the flow rate cause changes in the temperature differential. This temperature differential is electronically converted to a signal that is inversely related to actual flow.

The thermally actuated flow switch is much more expensive than the mechanical flow switch but requires less maintenance. The response time is very fast (2 -50 seconds, depending on the switch point adjustment). It can operate at almost any water pressure (up to 14 000 kPa) and can

FIGURE 3-15



detect flow velocities as low as 3 mm/sec.

Pressure Switches

The pressure switch is a simple device that is installed to detect changes in pressure. In a water line, the change in water pressure will cause a diaphragm to flex and thus open or close on electrical contact. This, in turn, will activate or deactivate an electrical circuit.

Pressure switches are commonly used in individual well systems such as those found in rural school systems. The pressure switch will regulate the operation of the well pump, and should be electrically interlocked with the fluoride metering pump. Also, as an additional safety measure, it is recommended that the pressure switch be installed in-line and electrically in series with a flow switch (or switches). This would be an additional safe guard against a fluoride overfeed. CDC believes that this additional protection is unnecessary.

Hauling Equipment

The weight of 67,5 liter drums of fluorosilicic acid is approximately 70 kg. This is obviously to heavy for an ordinary man to lift. Thus, a drum truck, or something similar must be used. (See Figure 3-16.) Even carboys of acid should be moved by a "truck."

FIGURE 3-16