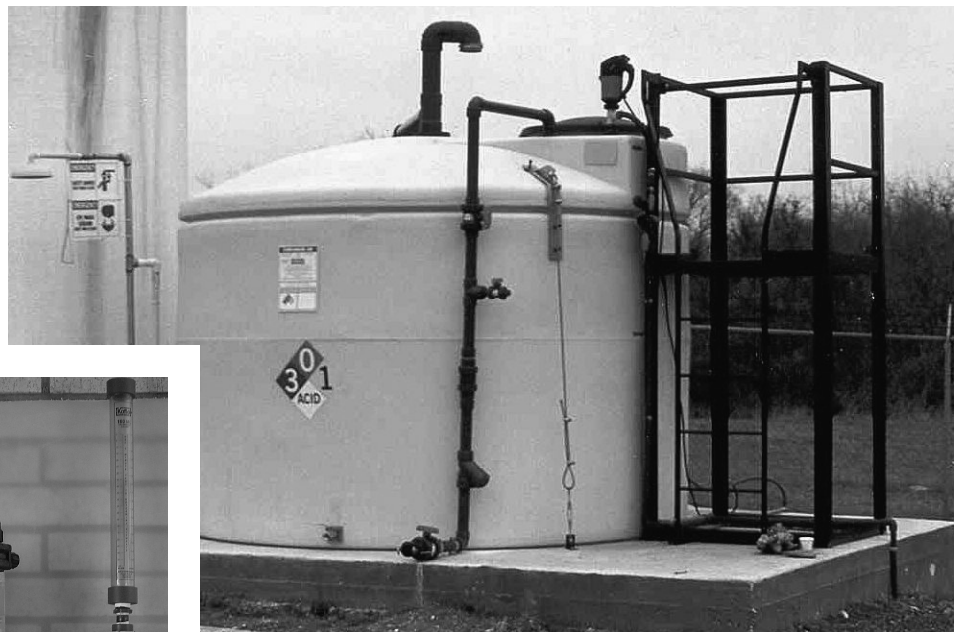
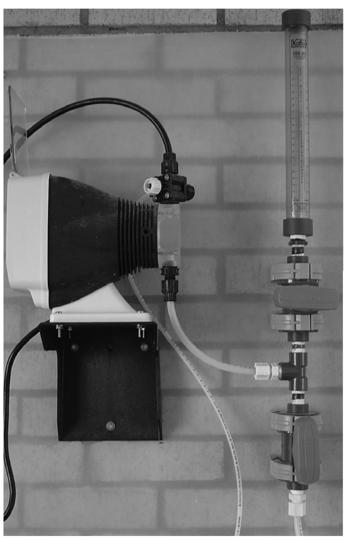
Texas Fluoridation Program

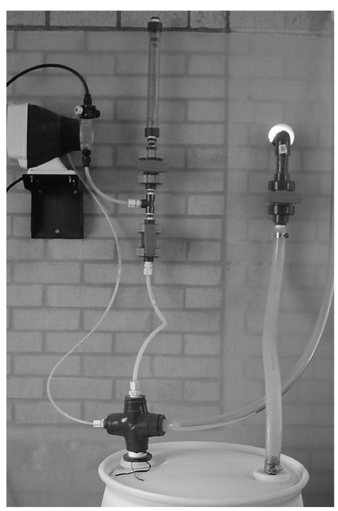
Operator Manual on Fluoridation Procedures

TEXAS
Department of
State Health Services

Fluoridation Procedures







A Course Manual for Water-Utility Operators

TEXAS FLUORIDATION PROGRAM

TEXAS DEPARTMENT OF STATE HEALTH SERVICES
Revised October 2015
www.dshs.state.tx.us/epitox/fluoride.shtm

Foreword

Efforts have intensified to make Texans' teeth healthier by adding fluoride to the water supplied to all the state's citizens. For that reason, the state faces a rapidly growing need for operators of water utilities who are competent and skilled. The responsibility for safety and success in bringing about healthier teeth through controlled fluoridation rests upon their shoulders.

This course and manual aim to assist water-utility operators in the proper procedures for maintaining optimal levels of fluoride in drinking water. By maintaining constant optimal levels, a water-utility operator can actually do more for the prevention of dental disease than any dentist alone can do.

Please use this manual as a workbook. It has ample room for your notes and comments. It is revised regularly according to your suggestions about the book and the school, so your suggestions are appreciated. Remember this is your school — you are the expert in water production.

Thanks for attending! What you learn today will help you improve the dental health of your customers!

Acknowledgments

Materials for this manual were provided in part and previously published by the following sources:

American Water Works Association

BIF, a unit of General Signal

American Public Health Association

Water Pollution Control Federation

United States Environmental Protection Agency, Water Hygiene Division

Texas State Technical Institute, Waco, Texas

The U.S. Department of Health and Human Services

The U.S. Public Health Service

The Centers for Disease Control and Prevention

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Fluoridation — Its Significance To Public Health

History of Fluoridation

Nature has been fluoridating water since the earth was formed. But only during the 20th century did it become clear that fluoride is an essential element used by the human body to prevent tooth decay. Nature, however, has not distributed fluoride equally throughout the waters of the planet. Water in some areas contains an excess of fluoride, which results in discolored tooth enamel but very high resistance to tooth decay. Water in other areas contains too little fluoride, which results in low resistance to tooth decay and poor dental health.

Extensive studies on fluoride began in 1902 when a Colorado dentist, Dr. Frederick S. McKay, observed patients with little or no tooth decay but with dark stains on their teeth, which he called "mottled enamel." These studies continued until 1945, when the initial controlled studies were begun.

Some of the earliest studies in water fluoridation were conducted in Texas. In 1945, Marshall, Texas, became one of the first three cities in the United States to fluoridate their public water supplies.

Since that time, thousands of communities have begun controlled fluoridation, and approximately 74.6 percent of U.S. population on public water systems, and 79.6 percent of Texans, benefit from having the proper amount of fluoride in their drinking water.

Fluoridation is not new by any means, and certainly not new in Texas.

Why Is It Needed?

Tooth decay is one of the most common diseases in our society, and it affects a vast majority of the population. Adjustment of the fluoride level of the water supply can easily prevent this disease, which is a major public-health problem. No other disease can be controlled so effortlessly and so economically. Fluoridation is safe, economical, and practical.

How It Works

Fluoride occurs naturally in all water supplies, but often not at levels that are high enough to prevent tooth decay. Fluoride is a mineral nutrient that is essential for optimal health.

In April 2015, the US Health and Human Services Commission issued the final Public Health Service recommendation for the adjustment of fluoride in the drinking water. The new optimal recommendation for adjusting fluoride in the water is 0.7 mg/l. Due to increased access to fluoridated products, i.e., toothpaste, mouth rinses and products prepared from fluoridated water, the operational level was reduced.

Teeth begin forming before birth and continue to form and grow until the teen years. Persons consuming water containing adequate fluoride during this period have stronger tooth enamel, which is resistant to tooth decay. The benefits from ingesting fluoride are known as *systemic* benefits.

Topical benefits of fluoride occur when water is consumed. The continuous flow of water coating the teeth can halt the progress of existing decay. Older people who consume fluoridated water may have fewer gum-line cavities because the fluoride protects newly exposed tooth surfaces as their gums recede.

Health Benefits

The fluoridation of water at the optimum level:

- reduces tooth decay by up to 40 percent when children drink it from birth to 16 years of age;
- continues to reduce decay throughout a lifetime;
- increases the number of persons reaching adulthood with no cavities;
- gives better appearance of teeth;
- gives continued dental benefits throughout life, including the loss of fewer teeth, and less need for dentures; and
- reduces the pain and suffering associated with poor dental health.

Cost of Fluoridation

The cost to the individual for community water fluoridation is less than a dollar per year — far less than the cost of even one filling. The cost varies in each community, depending upon the size of the community and the number and complexity of water sources that must be fluoridated. In Texas it costs most systems about 50 cents per person per year to adjust fluoride up to the optimal level.

Fluoridation saves hundreds of dollars for every family, prevents needless extractions that require costly replacements, and prevents expenditures for treatment of related ills caused by tooth decay.

Few public-health measures offer so much at such little cost. The cost of dental care has been drastically reduced in communities that adjust the fluoride level of the drinking water they produce.

Even more important than the money saved by fluoridating community water systems is the reduction in the pain and suffering from tooth decay and related ills. This is especially true for children. A cavity prevented in childhood can prevent root canals, tooth extraction, and dentures in later life.

Safety of Fluoridation

The safety of fluoridation is attested to by the large number of people who have been drinking fluoridated water all of their lives in many places, including large areas of Texas. For generations, millions of people in the U.S. have been drinking water containing enough natural fluorides for tooth protection — without harm. Since 1945, an additional 5,999 water systems supplying approximately 211 million people in the U.S. have adjusted the fluoride level of their water — without harm.

There has never been a clinically substantiated case of harm to anyone from drinking optimally fluoridated water.

Opposition to Fluoridation

The charges against fluoridation come from a small but growing percentage of the people.

This small group in opposition is very vocal, however, and misleads the general public by distorting facts and making allegations that include interference with individual rights, adverse side effects, and unknown or unsubstantiated harm. The charges are based on supposition, personal opinion, or misinterpretation of scientific studies. Many valid studies have refuted repeatedly the opposition's claims.

Over 70 years of water fluoridation involving scores of human epidemiological studies both in the United States and in other countries, there has not been any evidence that shows a relationship between fluoridation and cancer or other diseases in humans.

Once individuals are given the correct facts by a credible source, they usually will support fluoridation.

Endorsers of Fluoridation

Nearly every major health organization in the world has endorsed fluoridation. A representative, but only partial, list follows:

National And International

World Health Organization

U.S. Public Health Service

American Medical Association

American Dental Association

AFL-CIO

American Heart Association

American Public Health Association

American Pharmaceutical Association

American Water Works Association

National Health Council

American Academy of Allergy

State

Texas Medical Association

Texas Dental Association

Texas Department of State Health Services

Texas Public Health Association

Equipment Operation

The operation of fluoridation equipment must include consideration for public safety and operator safety through consistent regulation of small dosages. The equipment must be maintained properly for a smooth operation.

Operations should include:

- Daily practices to reduce operator exposure and contact with chemicals;
- Adjusting optimal fluoride level to provide the highest benefit to the customers while reducing risk;
- Preventive maintenance practices to reduce process down time;
- Barriers to chemical overfeed; and
- Emergency planning to prepare for responses to problems before they occur.

Each operator is responsible for his or her own safety. It is crucial that personal protective gear (PPG) be worn during any operation that may result in contact with fluorosilicic acid. Goggles, face shield, gloves and apron are the minimum PPG required in order to prevent eye injuries and skin contact. Rinse equipment before removing it for storage. Test safety showers and eyewashes weekly to insure the equipment is operating correctly and that the water is clean.

Acid Feed

Daily injection site visits are recommended to check the general operation of the equipment, the acid level in the day tank, and the chemical level in the bulk tank or supply carboy drum.

Each system should establish a day tank operating level that is the maximum amount of chemical allowed in the day tank.

The operating level of the day tank should be set to limit the day tank contents to 3 days of chemical, leaving approximately 1/3 of the tank empty.

Overfilling the day tank will lead to spillage, exposure to acid and fumes, and possible damage to equipment, not to mention a cleanup. Each transfer line/pump will behave differently depending on the relative elevations of the components. Stop the transfer pump to the day tank before reaching the desired level/weight and close the fill line valve, chemical will often continue to flow to the day tank. Use a scale and the weight of chemical in the day tank to set the day tank operating level. Record the chemical weight before and after filling the day tank. Was the amount of chemical used about the same as the amount used the day before?
If not, find out why.

If daily site visits are not possible, visits should be scheduled frequently to insure that the acid in the day tank is within the operating range; and that the metering pump does not break suction, becoming air bound.

Test water sample and record the results. Make necessary adjustments to the metering pump in small increments.

Examining the daily fluoride test results as they are recorded in the monthly report will prevent trends to feed above or below 0.7 mg/l. Adjust metering pump when necessary. Consistent fluoride testing provides the basis for smooth optimum fluoride adjustment. Most water strata produce water with consistent fluoride levels, but the natural fluoride variation from some rivers and impoundments can be significant.

Compare monthly split sample results with system test results to verify that you are using consistent accurate measurements to regulate the fluoridation process. Alum and phosphate chemicals used in water treatment can interfere with fluoride measurements made using the SPADNS method. Alum will lower the test results while phosphates will cause a higher fluoride measurement. Refer to Chapter 6.

Spacing injection points to allow ample mixing will minimize interferences caused by reactions with other chemicals.

Check the purity of each shipment of chemical when delivered. Make sure your receipt is certified for the load and has a current date before allowing the load to be transferred to a bulk tank. Fluoride chemicals used in water treatment must be American National Standards Institute/National Sanitation Foundation (ANSI/NSF) Standard 60.

Equipment Maintenance

Barriers to Chemical Overfeed

Once a year the operator should inspect the system carefully to insure that all barriers to chemical overfeed are functioning as designed.

The following is a list of barriers that must be included in the Fluoridation system design:

- Day tanks
- Scales
- Properly sized metering pumps
- Electrical interlocked metering pumps
- Anti–siphon protection
- Injection point prior to storage
- Daily testing
- Records

Metering Pumps

Follow the manufacturer's recommendations for equipment maintenance. Your supplier can prepare a list of spare parts, which you should keep on hand in the event of equipment failure. Consistent, uninterrupted service is required of the equipment. Proper preventive maintenance will minimize downtime and reduce chemical exposure. Cleanliness is important to the life expectancy of equipment. Poor ventilation or exposure to previous chemical leaks will reduce the effective life span of the equipment.

Pumps used to deliver fluorosilicic acid and solutions of sodium fluoride should be maintained like any other chemical pump. Change the lubricant in gearboxes for mechanical

pumps in accordance with the manufacturers' recommendations. Diaphragms in mechanical and electronic pumps should be changed in accordance with the manufacturers' recommendations, or once each year. Fittings should be hand tightened to prevent leaks. The corrosive nature of fluorides requires polyethylene, PVC, or polypropylene containers and piping. Replacement parts should be kept on hand at all times.

Open valves before the pumps are placed in service. Accidents occur when valves are not opened prior to starting the system.

Dry Feeders

Chemicals for dry feed systems must be stored in a dry area off the floor. Wooden pallets work well. To assure consistent feed rates, select the crystalline form in the particle size appropriate for the type of feeder used. Since solids produce dust, dust collectors should be installed and maintained to minimize operator exposure. The equipment used to feed fluoride compounds is the same equipment used to feed other water treatment chemicals such as polyelectrolyte's and lime. The difference between fluoride and the other chemicals is that fluoride is always fed at less than one milligram per liter.

Solid chemicals fed must be completely dissolved before leaving the solution tank. An inspection of delivery troughs in gravity feed systems may reveal deposits of undissolved chemical which could explain erratic fluoride levels. Always check the discharge line at the injection point for flow, fouling by encrustation, or corrosion of sidewalls by splattering. Make certain air gaps are maintained and siphoning is prevented.

The use of under-saturated solutions of sodium silicofluoride or sodium fluoride should be avoided due to the difficulty of mixing constant concentration solutions. Solution preparation presents the greatest source for error. This is not a problem with saturators or direct liquid feed systems. Where sodium fluoride solution is manually prepared, an error in concentration of solution can be made if the operator does not follow solution preparation directions. If a day tank is used, carefully measure the water added to the tank. The measured amount of solid sodium fluoride is then added to the water. The solution should be mixed vigorously to insure a proper solution (See Figure 8). Permanent markings on the day tank at various levels allows for the accurate addition of water. The use of cleaned and maintained scales will provide the accuracy needed to properly weigh the sodium fluoride.

The largest single factor in proper operation of fluoridation equipment is the pride of the operator.

Every man, woman, and child in your service area is dependent on your pride and skills in maintaining the optimum level of fluoride for their dental health. Your daily records and monthly reports will reflect the pride you take in your work. No other chemical is added as precisely and consistently and can be analyzed as accurately as fluorides. The fluoride content of your treated water is a direct measure of your abilities and attitudes. Be right all the time.

Fluoridation Systems

Types of Systems

While the operator is not responsible for selecting the design of the fluoridation system, the design engineer should always confer with the operator and owner before designing such a system.

The type of system (liquid or solid feed), choice of chemicals, cost of equipment and chemicals, equipment operating and maintenance procedures, and ease with which the optimum level of fluorides can be maintained should all be considered in the design.

A review of the factors affecting the system design will help the operator understand the system — including its operation and maintenance.

Feeders

The feeders used in fluoride addition are similar to liquid and solid feeders for other chemicals commonly used in water-treatment plants. The feeders may be broken down into three types.

A. Liquid Feed

This type of system — easy to install and operate — is the most common type found in Texas. Other types of feed systems are being replaced with liquid systems as older equipment reaches the end of its service life.

This system pumps fluorosilicic acid from a small storage container (day tank) directly into the water at a point that will permit rapid and complete mixing.

The typical direct liquid-feed system (*Figures 1, 2, 3, 4* and *5*) consists of the following components:

1. A storage container for the fluoride chemical — usually the container in which the chemical was delivered, or, in the case of large water systems, a bulk storage tank. Shipping containers are usually polyethylene carboys available in 15 to 55 gallon capacities. Bulk storage facilities are economically feasible for most systems that have an average daily flow greater than 2 million gallons per day. Bulk storage facilities must have, at minimum, storage capacity for a tank truckload (4400 gallons) of chemical. Having sufficient capacity allows the system to purchase chemicals at a reduced unit cost.

2. A day tank with a capacity of one to three days' chemical supply should have sufficient free space to prevent overfilling and spills. A day tank physically limits the amount of acid that can be siphoned or injected into the water system in the event of a malfunction. For the typical system, the day tank should be translucent, which allows the operator to observe the amount of chemical in the tank and be set on a scale to measure the amount of chemical in the tank (*Figure 5*).

3. The metering pump is usually of the electronic type (*Figure 6*). It should have a maximum capacity of approximately twice the average daily chemical use at normal operating pressures. This capacity allows the pump to operate within its most accurate operational range during periods of both minimum and maximum daily flow demand.

4. The chemical feed line from the pump to the injector must contain an anti-siphon valve; a bypass valve, which allows the pump to be primed; and a shutoff valve. A check valve with a standard PVC injector that extends through a corporation stop should be used when injecting into a water pipe. A simple drip system in lieu of an injector can be used at most surface water treatment plants.

5. Containment must be provided for day tanks, acid drums and bulk storage tanks in accordance with §290.42, Texas Commission on Environmental Quality, Drinking Water Rules and Regulations. Different types of containment include double wall tank, a tank inside an open top tank, acid resistant coated concrete containment and containment pallet.

All components of this system that come in contact with the chemical must be acid resistant.

Fluorosilicic acid must never be diluted. A properly sized chemical feed pump can accurately regulate the feed rate of the chemical as delivered. Any attempt to dilute the chemical will only decrease the accuracy of chemical feed (due to errors in measuring both the acid and the dilution water), increase the potential for spills, and increase the potential for operator contact with the chemical.

Figure 1. Bulk Tank Flow Drawing, Drum Pump

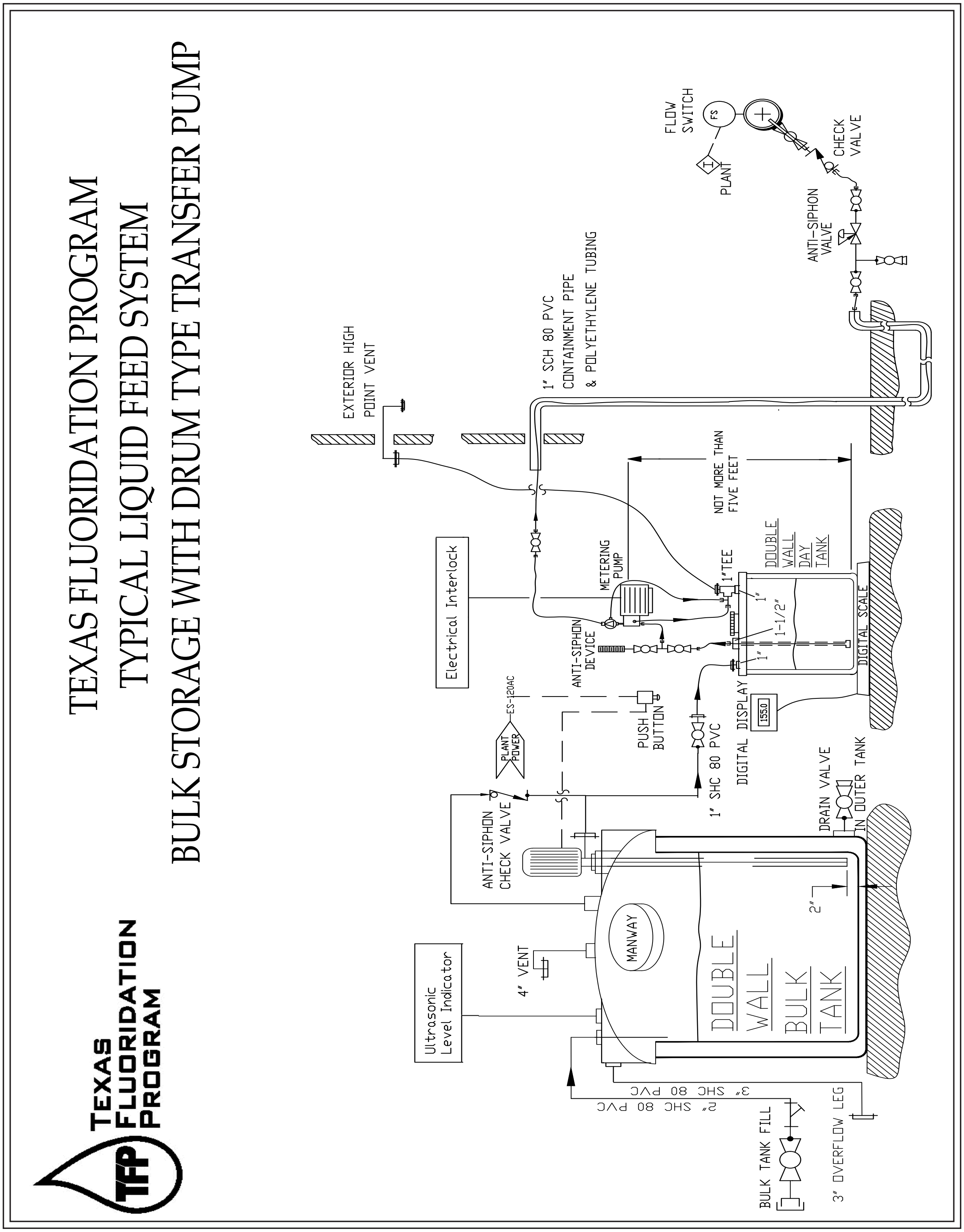


Figure 2. Bulk Tank Flow Drawing, Peristaltic Pump

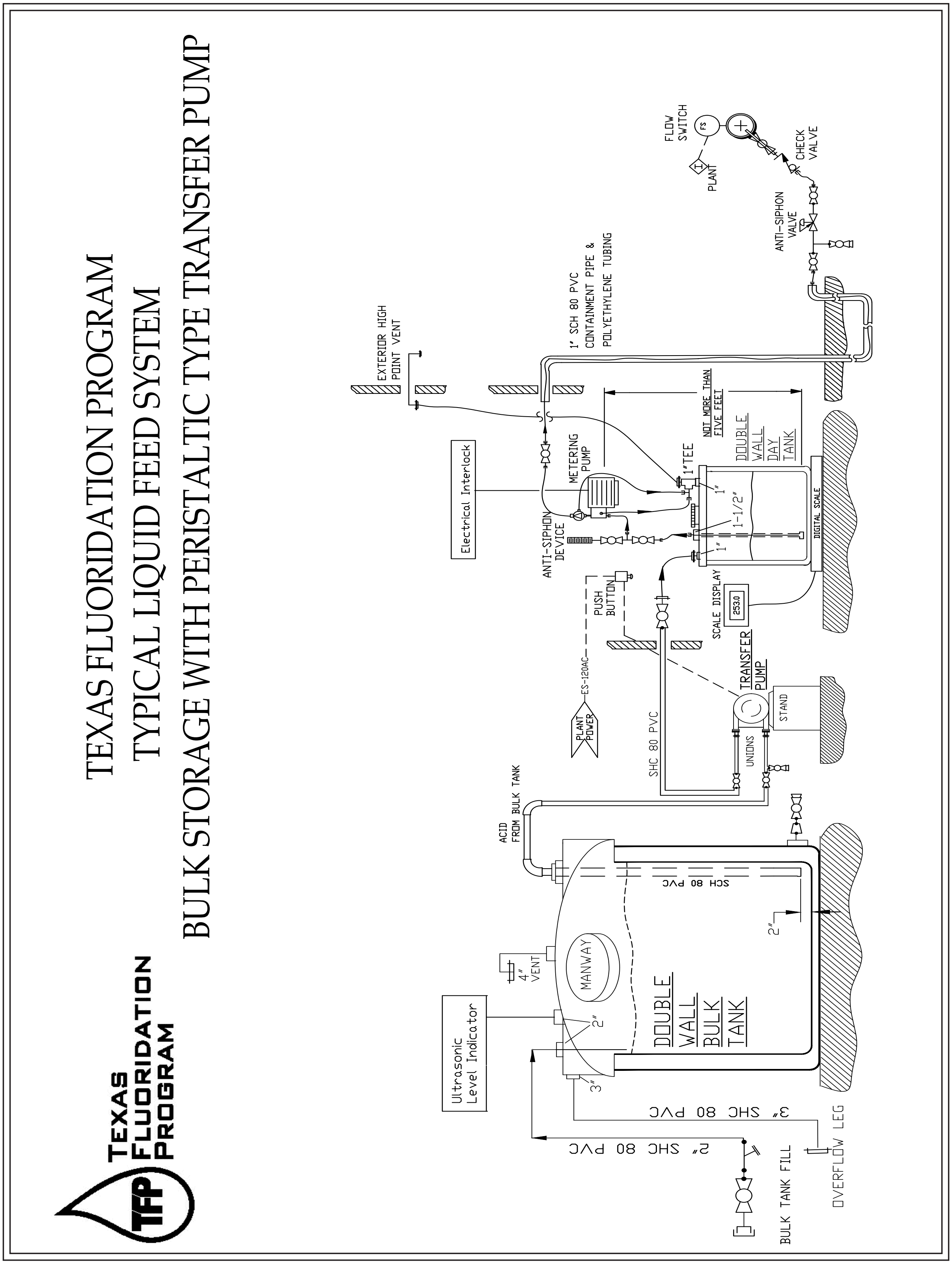


Figure 3. Small Bulk Tank Flow Drawing

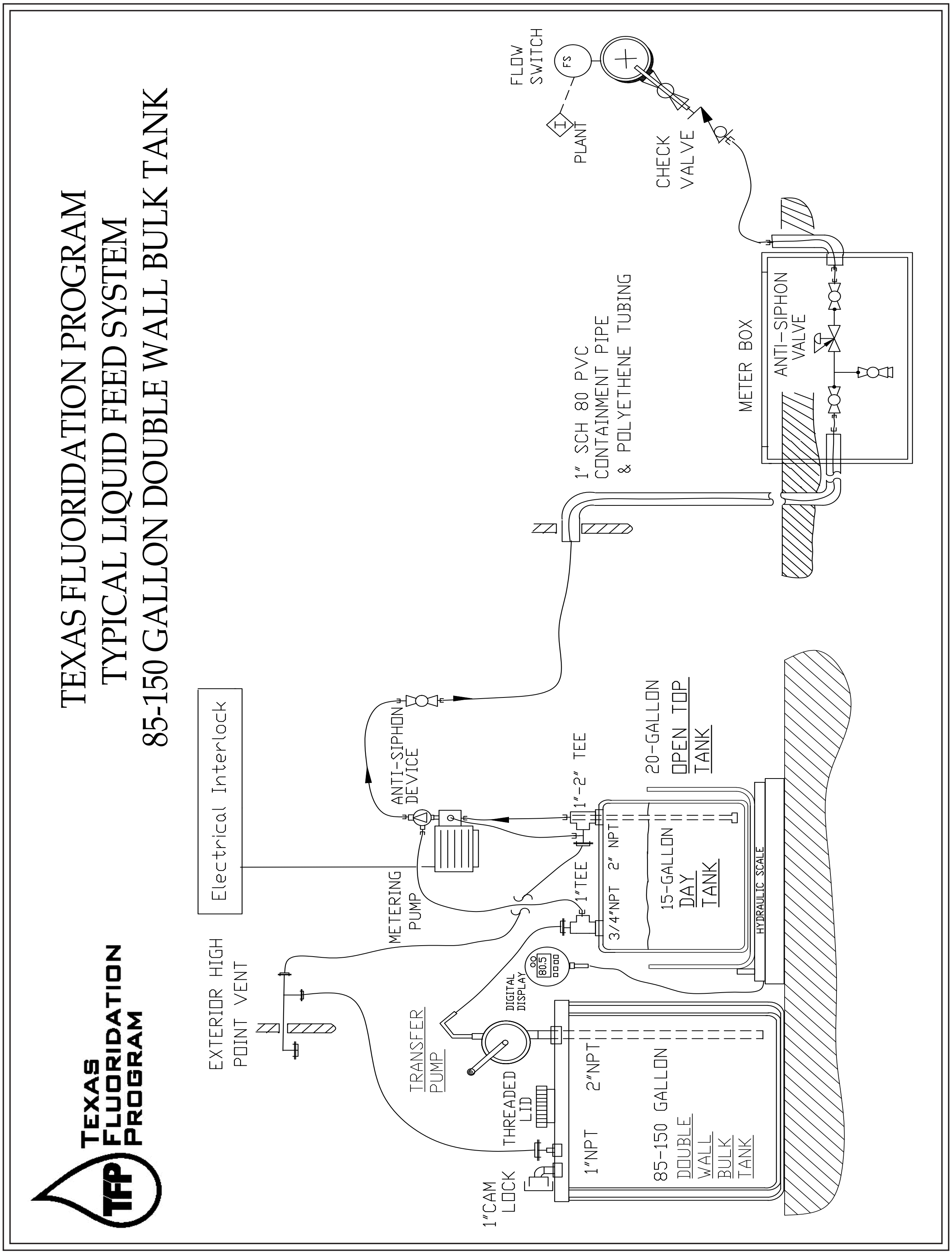


Figure 4. Carboy Supply Flow Drawing

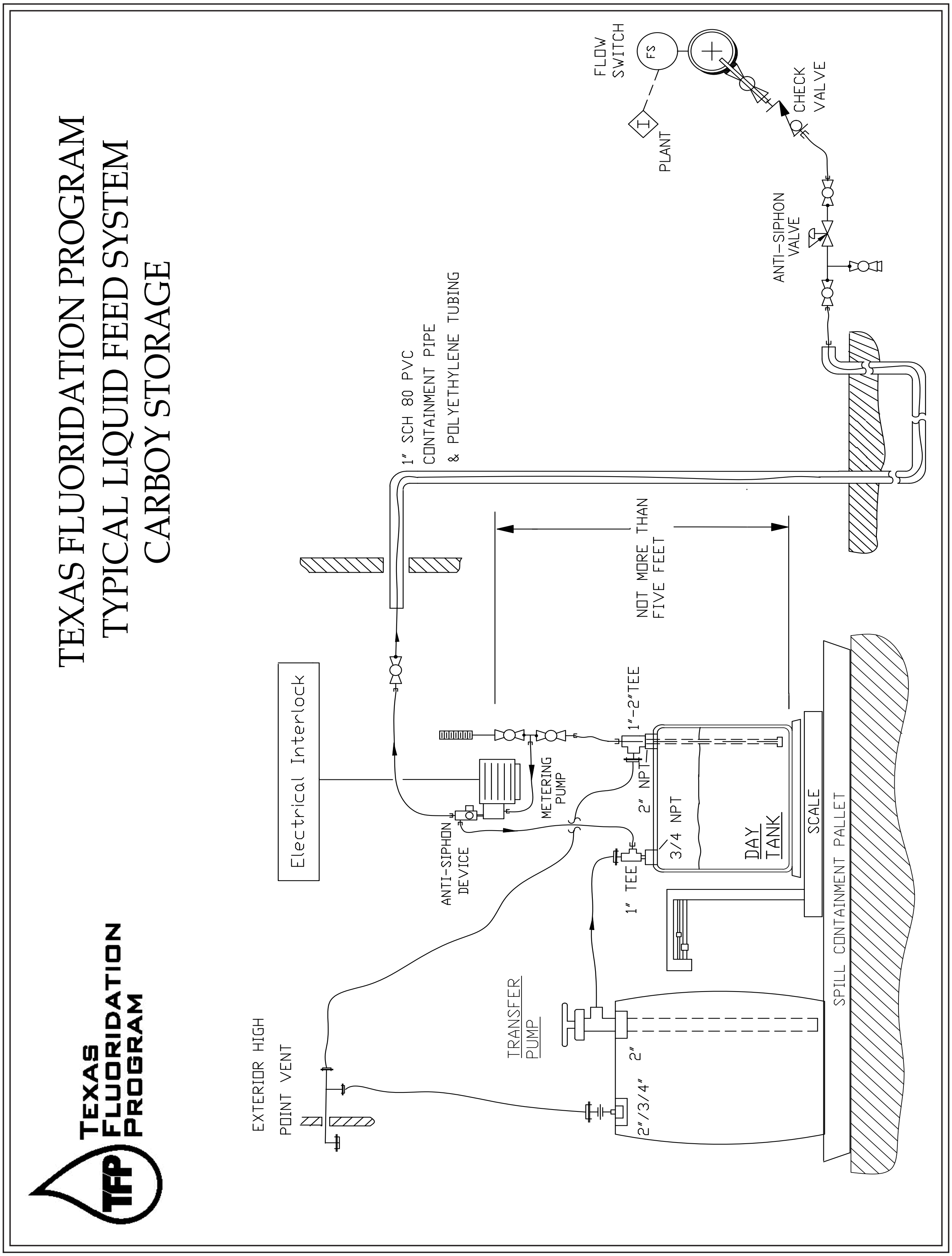
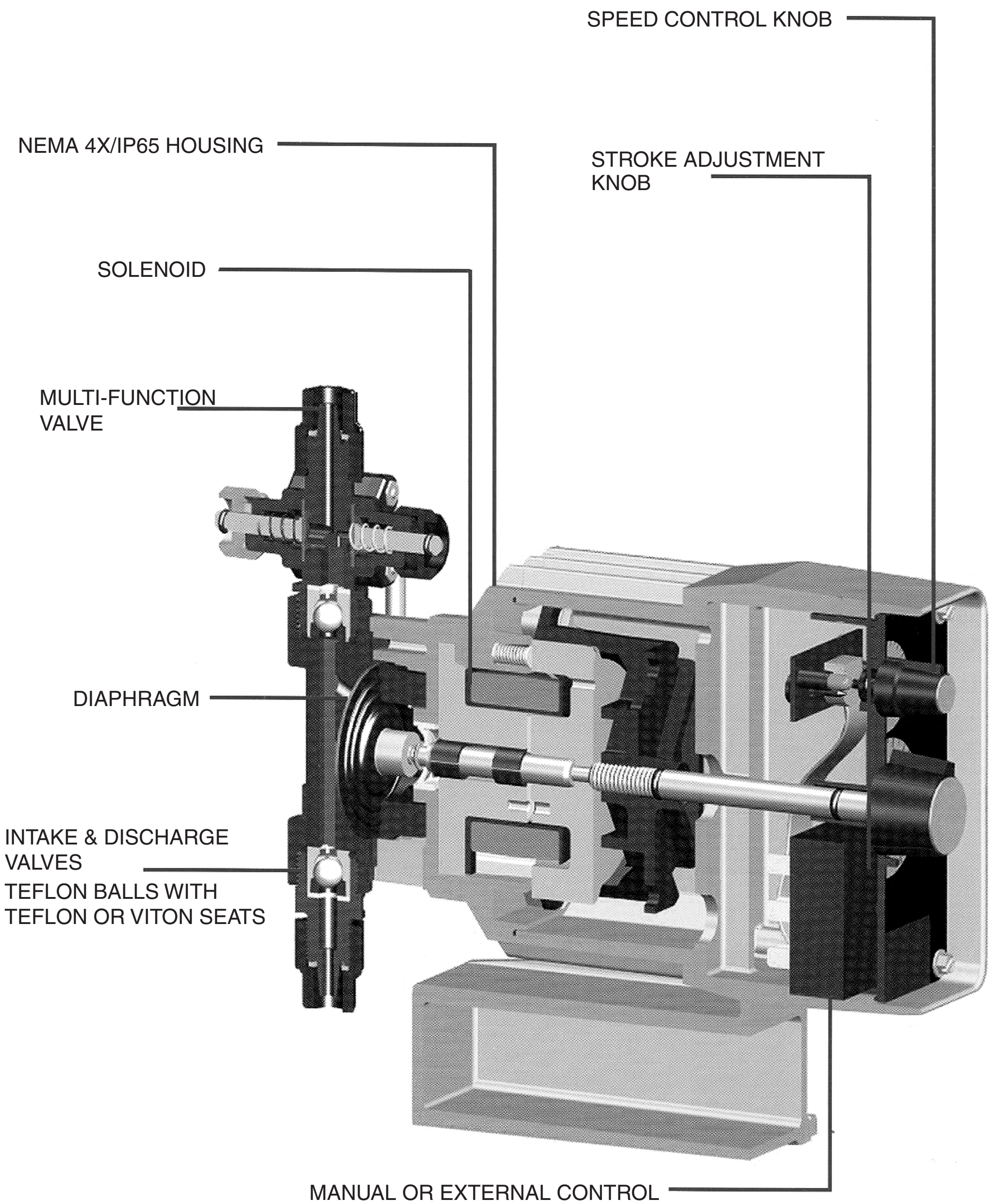


Figure 5. Typical Day Tank with Scale

Figure 6. Typical Electronic Metering Pump



B. Solution Feed

A solution-feed system is nothing more than a chemical pump for drawing a known concentration of fluoride solution from a container and discharging the solution into the water. The fluoride solution is prepared from dissolved sodium fluoride. The solution can be fed directly into the water being produced at the plant or injected prior to ground storage.

The need for constant, optimal fluoride addition requires a pump that operates with very small variations in output. Therefore, an electronic metering pump (*Figure 6*) similar to that used for the liquid-feed system must be used.

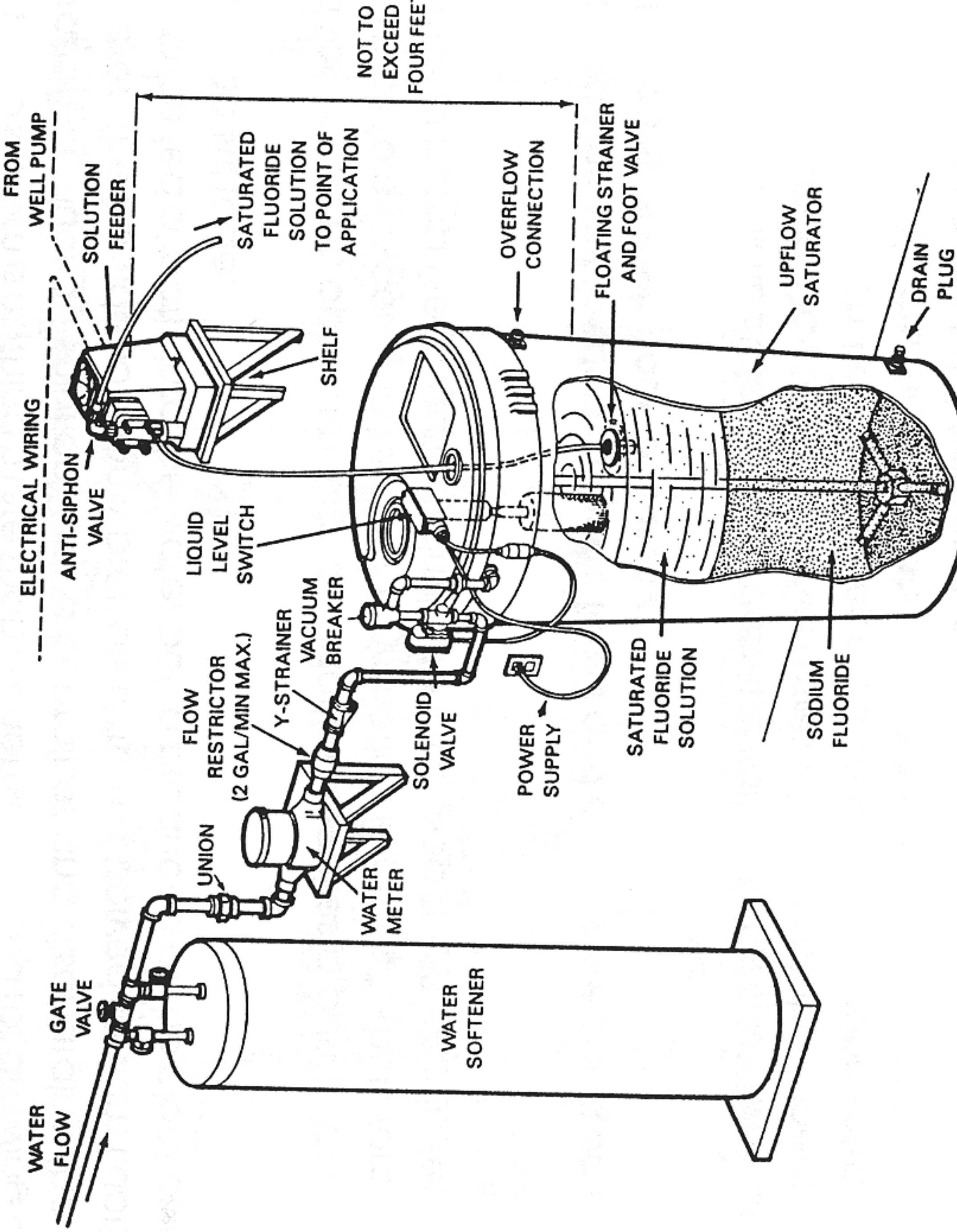
Centrifugal pumps, pot feeders, or head tanks and orifices are not used in fluoride addition because of their poor accuracy.

The feed rate of all fluoride solutions depends on feeding a known concentration of fluoride solution. Day tanks are often used which contain a one-day supply of fluoride solution, which has been prepared to a known concentration. Only sodium fluoride is fed in this manner.

> Note: Where water supplies contain 75 mg/l or more total hardness, solution feed water must be processed through a water softener to prevent precipitation of calcium and magnesium fluoride.

Sodium fluoride saturators (*Figure 7*) have an advantage over the manual solution preparation and day tank method of adding sodium fluoride. The advantage is that a solution of sodium fluoride can be made without measuring the water or the sodium fluoride. When water passes through a bed of sodium fluoride it becomes saturated with sodium fluoride. This saturated solution of sodium fluoride contains 18,000 mg/l of fluoride ion. Saturators are maintained with an excess amount of solid sodium fluoride in them at all times.

Figure 7. Sodium Fluoride Installation, Upflow Saturator



Sodium fluoride is normally used in plants producing water at a rate less than 100 gallons per minute. Sodium fluoride saturators can be used for water systems with flows of up to 2,000 gallons per minute.

C. Dry Feed

Equipment for dry-feeding sodium fluorosilicate is virtually the same as that used for feeding soda ash or lime.

The two types of dry feeders shown are volumetric and gravimetric (*Figures 8* and *9*). Volumetric feeders are used for systems with flows of more than 140,000 gallons per day, and gravimetric feeders for flows of more than 2 million gallons per day. The accuracy of volumetric feeders is usually within 3 percent, while the more accurate gravimetric feeders should control within 1 percent. Both feeders measure powdered fluoride from a hopper into a dissolving chamber, from which the fluoride is gravity-fed or injected into the treated water prior to ground storage.

Important: The operator should take care to ensure that all solid fluorides have dissolved before adding the solution to the treated water. If undissolved particles enter the water, fluoride content will show unacceptable variations.

Figure 8. Volumetric Feeder, Screw Type

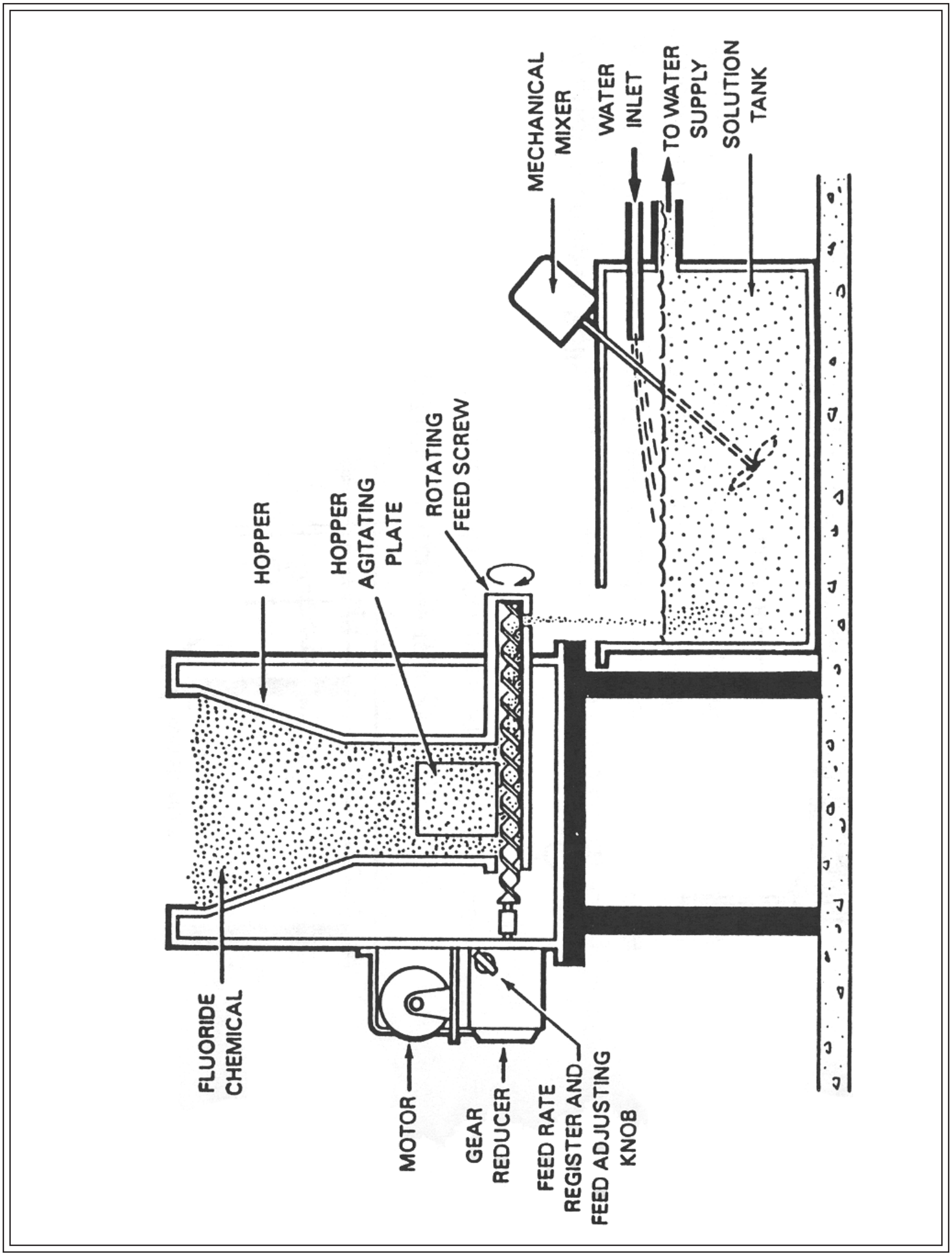
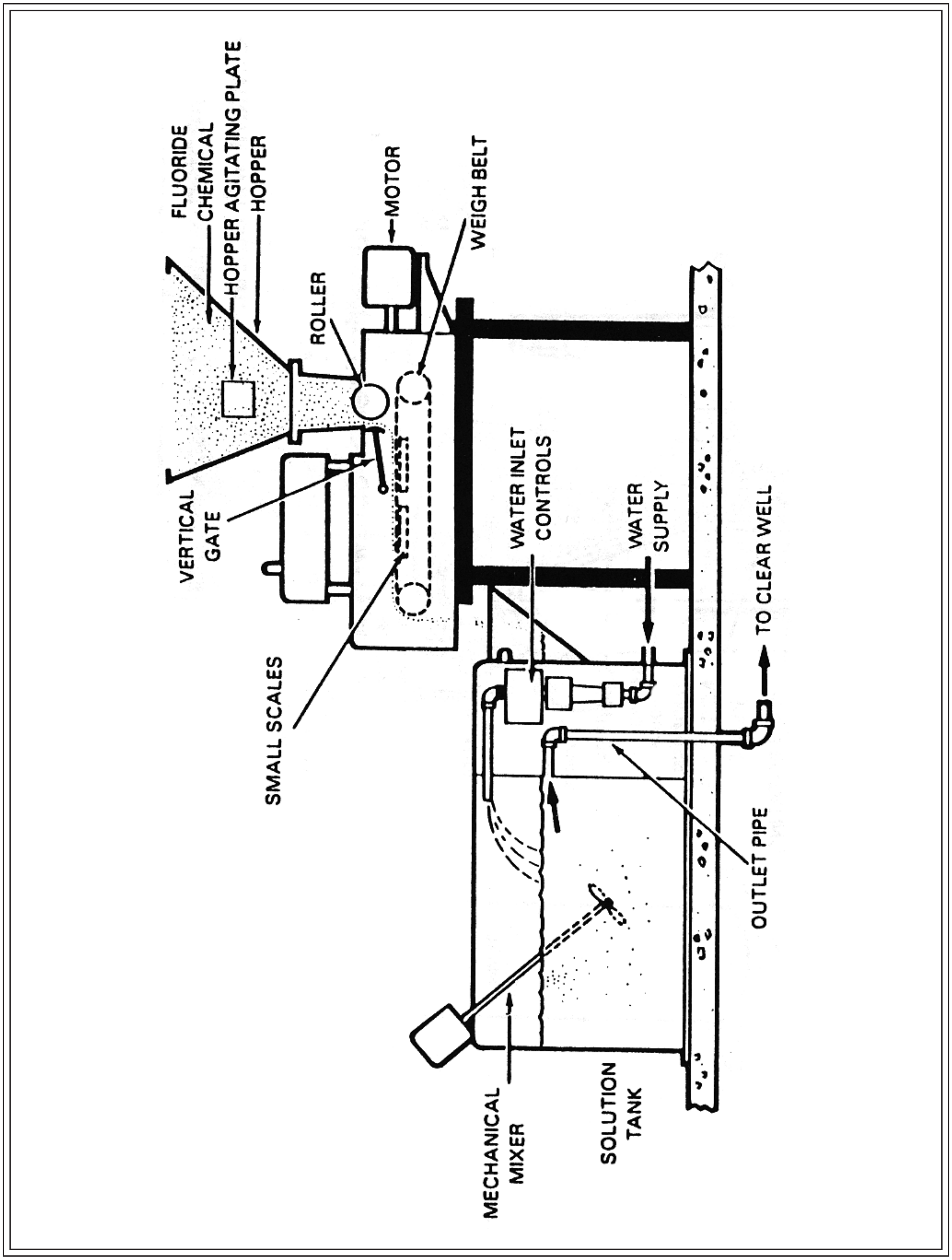


Figure 9. Gravimetric Feeder



Point of Fluoride Addition

It is generally recommended that the addition point be after the filters or into the clear well of surface water treatment plants. The injection point for groundwater treatment plants can be at any convenient location between any wells and the storage facilities. This is thought to eliminate the possibility of fluoride loss during water treatment. However, studies at water plants in Austin, Texas have shown no detectable loss when fluorosilicic acid is added to the flocculation basin effluent in one case and the center-mix compartment of a down-flow clarifier in another. Purification processes used at surface-water treatment plants will not reduce the fluoride level of the treated water produced, so long as the fluoride chemical is thoroughly mixed with the raw water prior to the addition of other chemicals.

The chemical should be added to water treatment plants at a location which allows for good mixing with the total plant production. Care must be taken to prevent back siphoning of the fluoride chemicals into the potable water. Cross-connections are possible at the discharge of both solution tanks and the atmospheric discharges of chemical feed lines if the chemical feed line terminates below the water level of the receiving trough. An air gap can be established by terminating the feed line above the highest possible water level in the receiving trough. When chemicals are fed under pressure, a diaphragm type anti-siphon device should be installed at the discharge end of the chemical feed line to protect the system from overfeeding.

Fluoridation Chemicals

Fluorosilicic acid, Sodium Fluoride and Sodium Fluosilicate are the chemicals used to adjust fluoride. The choice of chemical is based on availability, cost, ease of additon, and hazard involved in handling. Fluorosilicic acid is the most commonly used chemical in Texas.

A. Fluorosilicic acid (H_2SiF_6) is a 23–25% aqueous solution having a 79.2% concentration of fluoride ion. It is a straw-colored, transparent, corrosive liquid having a pungent odor, and is irritating to the skin. Fluorosilicic acid has a low pH and, at a concentration of 1 ppm, can slightly depress the pH of poorly buffered potable waters. It must be handled with great care because it will cause a delayed burn on skin tissue and can permanently damage eye tissue if not treated immediately. A more thorough discussion of handling precautions is presented in the following sections.

The average density of 23% acid is 10 lbs/gal. Fluorosilicic acid will freeze at approximately 4° F or −15.5° C. It takes approximately 14 pounds (1.4 gallons) of 23% fluorosilicic acid to adjust the fluoride level of one million gallons of water from 0.4 ppm to 0.7 ppm (the optimum level for Texas).

Fluorosilicic acid is shipped in 15- and in 55-gallon drums, in bulk tank trucks, and by rail. The cost of the acid varies greatly according to transportation costs and the quantity purchased. In 2013, the price of acid in Texas ranged from $0.30 to $0.68 per pound, depending on the quantity and the distance from its source.

How much fluorosilicic acid to add may be calculated as follows:

$$\text{Pounds of acid required} = \frac{\text{Flow Rate} \times 8.34 \times \text{Fluoride Increase}}{(\text{\% acid concentration}/100) \times 0.792}$$

Notes:

a. Flow Rate expressed in millions of gallons per day (MGD).

b. 8.34 is the weight (in pounds) of one gallon of water — a constant.

c. Fluoride Increase is the difference between the optimum level of fluoride and the natural level of the raw water expressed in parts per million or mg/l. The optimum level for water systems in Texas is 0.7 ppm.

d. % acid concentration / 100 is the acid concentration expressed as a decimal. An acid having a 23% concentration would be expressed as 0.23.

e. 0.792 the available fluoride ion present in the acid expressed as a decimal — constant.

f. The results can be converted from pounds of acid to gallons of acid by dividing by the weight of one gallon of acid, approximately 10 pounds.

The basic formula can be used for numerous calculations.

The amount of acid to be used in one year, month, day, hour, or minute can be determined by using the flow, in millions of gallons, for the time period.

Example:

A water plant produces water at a rate of 5.38 millions of gallons per day or MGD.
To convert from gallons per minute to millions of gallons per day, multiply gpm by 1440 minutes per day and divide by 1,000,000 to MGD. The natural level of fluoride in the raw water is 0.2 ppm. The operator wants to know how much 23% acid he should be using per day and how to set the metering pump.

The fluoride level increase is 0.5 ppm (0.7 ppm – 0.2 ppm).

To determine acid used per day use **total plant production rate.**

Acid used per day (lbs/day) = $\frac{5.38 \text{ MGD} \times 8.34 \times 0.5}{0.23 \text{ X } 0.792}$

123.16 lbs/day, or

Acid used per min (ml/min) = $\frac{\text{lbs/day} \times 3785 \text{ ml/gal}}{10 \text{ lbs/gal} \times 1440 \text{ min/day}}$

$\frac{123.16 \text{ lbs/day} \times 3785 \text{ ml/gal}}{14400}$

32.37 ml/min

Setting metering pump =

Metering pump output 32.37 ml/min
Metering pump max output 1 gal/hr or 63 mil/min

Output % = pump output ÷ pump max output

$\frac{32 \text{ ml/min}}{63 \text{ ml/min}}$

0.51 or 51%

Output % = stroke length % × stroke speed %

.51 = .75 × stroke speed %

$\frac{.51}{.75}$ = stroke speed %

.68 = stroke speed %

B. Sodium fluoride (NaF) is an odorless, white (sometimes dyed blue) powder or crystal. Its solubility in water is nearly constant at 4% over a very wide range of temperatures. The purity of sodium fluoride ranges from 90 to 98 percent. The crystalline form is preferred because of dust problems encountered with the powder. Coarse grade crystals are used in the saturators, while fine grade crystals are used for manual solution preparation and for dry feeders. Sodium fluoride does not alter the pH of treated water. The concentration of fluoride ion is 45.25% of the sodium fluoride.

Sodium fluoride is shipped in 50-pound bags. The cost in 2006 was $0.81 to $1.00 per pound.

How much sodium fluoride to add using a dry feeder may be calculated as follows:

$$\text{Pounds of chemical required} = \frac{\text{Flow Rate} \times 8.34 \times \text{Fluoride Increase}}{(\%\ \text{NaF}/100) \times 0.4525}$$

Example:

A water plant produces water at 2000 GPM and has an average daily flow of 1.1 MGD. The natural level of fluoride in the raw water is 0.2 mg/l. The operator wants to know the feed-rate setting for his feeder and the daily chemical use of 98% sodium fluoride.

The plant production rate is:
(2000 GPM × 1440 min/day) / 1,000,000 = 2.88 MGD

The fluoride level increase is:
0.7 mg/l – 0.2 mg/l = 0.5 mg/l

The feeder setting is:
(2.88 MGD × 8.34 × 0.5 mg/l) / (0.98 × 0.4525) = 27.1 lbs/day

Daily chemical use is:
(1.1 MGD × 8.34 × 0.5 mg/l) / (0.98 × 0.4525) = 10.34 lbs/day

Saturators feed a constraint solution of 4% sodium fluoride, which equals 18,000 mg/l of fluoride ion. Therefore, the calculation for the amount of sodium fluoride to be added using a saturator is as follows:

$$\text{Gallons of solution per day} = \frac{\text{Flow Rate} \times \text{Fluoride Increase}}{18{,}000}$$

Example:

A water plant produces 1.5 million gallons per day. The natural level of fluoride in the raw water is less than 0.1 mg/l. The operator wants to know the gallons of solution required per day if a saturator is used.

The fluoride level increase is:

0.7 mg/l – 0.0 mg/l = 0.7 mg/l

The solution requirement is:

(1,500,000 × 0.7 mg/l) / 18,000 = 58.33 gallons per day

C. Sodium fluorosilicate (Na_2SiF_6) is a white, odorless crystalline powder. It lowers the pH of the finished water only slightly. It is fed as a dry feed and is the least expensive fluoride. The concentration of fluoride ion is 60.7% of the sodium fluorosilicate content. In 2013, 99% material cost $1.52 per pound. It is shipped in 50-pound bags. The calculation for amount of sodium fluorosilicate required is as follows:

$$\text{Pounds of chemical per day} = \frac{\text{Flow Rate} \times 8.34 \times \text{Fluoride Increase}}{(\%\ Na_2SiF_6/100) \times 0.607}$$

Example:

A treatment plant using 98.5% sodium fluorosilicate has a flow of 3 MGD. The level of fluoride in the raw water is 0.2 mg/l. The operator wants to know the amount of chemical required per day.

The fluoride level increase is:

0.7 mg/l – 0.2 mg/l = 0.5 mg/l

Daily chemical use is:

(3.0 MGD × 8.34 × 0.5 mg/l) / (0.985 × 0.607) = 20.9 lbs/day

WORKSHEET

Clayton W.C.I.D. is installing a liquid-injection system at its water-treatment plant to adjust the fluoride level. The district and plant have the following pertinent characteristics:

Production rate	900 gallons per minute
Existing fluoride level	0.3 parts per million
Yearly average production rate	364,000 gallons per day
Peak production day	678,961 gallons
Number of connections	1203
Water storage capacity	480,000 gallons

Mr. Tex Ritter, district general manager, is to appear at a meeting of the board of directors tonight. He instructs Dusty Rhodes, plant operator, to provide the total yearly chemical cost, and the chemical cost per connection, if 23% liquid is used at a cost of $415 per 55-gallon drum. To prepare for possible board questions, Mr. Ritter wants Mr. Rhodes to provide the following additional information:

1. What size of chemical feed pump should be purchased?
2. What is the feed rate for the pump?
3. What size of day tank should be purchased?
4. How much chemical should be purchased with each order?
5. What is the risk to district customers if the pump controls fail and the entire contents of the day tank are injected into the distribution system?

The calculations that Mr. Rhodes must perform are —

A. Yearly chemical cost:

B. Chemical cost per connection:

C. Pump size (considering metering pumps should have a capacity of about twice the required feed rate):

D. Day tank size:

E. Recommended amount of each chemical order:

F. Risk if day tank is emptied into system:

Worksheet Answers: Page 43

Personal Protective Gear and First Aid

Safety

Solid fluorides, when admitted into the body in large enough quantities, are health hazards. Fluorosilicic acid is both corrosive and a health hazard if admitted into the body. Therefore, concentrated fluorides, like other chemicals used in the water treatment process, should not be breathed or consumed. When properly handled with adequate safety equipment, the operator should experience no adverse effects from fluorides.

The accident rate among water-utility personnel is one of the highest of any industry. Yet, after 60 years of adding fluoride to the potable waters of the United States, no water-plant operator has ever been seriously injured by fluoride, according to the Centers for Disease Control and Prevention. Neither has there ever been a workers' compensation case in Texas for any injury related to fluoride.

Personal Protective Gear (PPG)

The recommended PPG equipment for handling fluorides depends on both the type of fluoride chemical and the maintenance activity. Anytime work is to be performed near pumps or acid storage, goggles, face shield, rubber gloves and an apron are the absolute minimum. If acid transfers are to be made, a PVC raincoat should also be worn. Always rinse gloves before storing them to prevent exposure to acid.

All safety equipment must be readily available and must be stored outside the fluoride-feed area. Safety equipment that has been contaminated by a spill or leak is of no use to the operator. An eyewash station, safety shower, or a wash-down hose with a vacuum breaker on the water source (or some combination) should be readily accessible near the fluoride area. Safety showers and eyewash facilities must be accessible within 10 seconds, free of obstructions, and must be within a travel distance no greater than 50 feet from the hazard.

Full safety gear should be worn when transferring bulk shipments of acid from tanker trucks to a bulk storage tank. Fluorosilicic acid is transferred from the tank truck to the storage tank using air pressure provided by the chemical supplier. Most tank trucks have pressure regulators to prevent a safety hazard from excessive air pressure.

Dust masks, respirators, exhaust fans, and dust collectors should be in use in dry-fluoride work and storage areas. Sacks of dry fluoride should be handled carefully. The sacks should not be dropped, should be opened evenly at the top rather than by tearing down the side, and the contents should be poured gently into hoppers, to minimize dust. Good ventilation is necessary when handling any fluoride. Masks should be worn when working around fluorides, even if no dust is visible.

Never eat or store food in fluoride storage or feed areas. Always wash your hands when leaving any fluoride area, and wash thoroughly to remove accumulated dust when leaving a dry-feed area.

Overexposure

While potable water with fluoride levels at the recommended concentration of 1.0 ppm has been exhaustively studied and firmly established as safe beyond question, the fluoride levels to which the water plant operator can be exposed are potentially much higher. To prevent overexposure, the best safety measure is the proper handling of fluoride chemicals. Proper handling implies adequate knowledge of the material, correct procedure, and the use of indicated safety equipment.

The greatest chance for overexposure to fluoride chemicals comes from the inhalation of dust generated when the feeder hoppers or saturators are being filled.

Fluorosilicic acid is a fuming acid. The fumes are lighter than air and have a pungent odor. Since the fumes do not collect (unlike chlorine fumes) and are easily detected by the human nose, it is unlikely that an operator of a properly designed and ventilated system will inhale large doses of fluoride from this source. Systems should be sealed and ventilated to prevent operator exposure to acid fumes.

If fluorosilicic acid is swallowed, the stomach's contents will empty, including the acid. Burning of the mouth and esophagus is possible.

If acid contacts the skin, a delayed burning sensation occurs; if it is splashed in the eyes, severe irritation is expected.

Treatment for exposure to a concentrated fluoride chemical consists of immediate, rapid, and thorough rinsing of the affected area with large quantities of water, which not only will wash the chemical away from the affected area, but will also neutralize it, making it no longer harmful.

It is important to recognize symptoms of fluoride overexposure. In acute poisoning, the first symptoms to appear are vomiting, stomach cramps, and diarrhea. If large amounts have been ingested, what is vomited may be white or blue, depending on the color of the chemical ingested. The patient usually becomes weak, has difficulty in speaking, is thirsty, and has disturbed color vision.

When the poisoning is by inhalation of dust or acid vapors, sharp biting pains occur in the nose, followed by nosebleed or nasal discharge.

First Aid

The importance of rapid treatment cannot be overemphasized. Once it is determined that poisoning is by fluoride, the treatment is as follows:

Acid Splash

1. Wash away the chemical with large amounts of water as quickly as possible. Remove the victim's clothing from the affected areas and continue washing for at least 15 minutes.
2. Where skin damage has occurred, cover the burn with a dressing bandage and seek medical attention.
3. If the eye is involved, immediately begin to wash the eye, eyelid, and face. Hold the eyelid open and wash the eye for at least 15 minutes.
4. After a thorough washing, cover the eye with a clean, dry, protective dressing and hold it in place, then transport the victim to a doctor.
5. All instances of eye injury require medical attention. Even seemingly minor eye injuries can leave the eye vulnerable to infections, which can lead to blindness.

The fluoride ion seeks to bond with the hydrogen ion in water. It is very important to flush the exposed area with water to allow the ions to mix with each other and to prevent any burning of the skin.

Ingestion

Less than 5.0 mg/kg* (226 mg /100 lbs)

1. Give calcium (milk) orally to relieve gastrointestinal symptoms. Observe for a few hours. (Note: A can of evaporated milk can be kept on hand for a long period of time.)

2. It is not necessary to induce vomiting.

Over 5.0 mg/kg

1. Move the victim away from any contact with fluoride and keep him warm.

2. If a victim is conscious, induce vomiting by rubbing the back of the throat with a spoon or your finger; or use syrup of ipecac. While vomiting, the patient should be placed face down with the head lower than the body to prevent inhalation of the stomach contents. [For patients with depressed gag reflex caused by age (6 months of age or younger), Down's syndrome, or severe mental retardation, vomiting should not be induced and endotracheal intubation should be performed before gastric lavage.]

3. Give the victim a glass of milk or any source of soluble calcium (5% calcium gluconate, or calcium lactate solution).

4. Take the victim to the hospital as quickly as possible.

Inhalation (Nosebleed)

1. Move the victim away from the exposed area.

2. Keep the victim quiet.

3. Place the victim in a sitting position, leaning forward, if possible; if that is not possible, place the victim in a reclining position with the head and shoulders raised.

4. Apply pressure directly by pressing the bleeding nostril toward the midline.

5. Apply cold compresses to the victim's nose and face.

6. If bleeding cannot be controlled by the preceding measures, insert a small, clean pad of gauze (not absorbent cotton) into one or both nostrils and apply pressure externally with the thumb and index finger. A free end of the pad must extend outside the nostrils so that the pad can be removed later.

7. If bleeding continues, obtain medical assistance.

**Average weight for ages 1–2 years = 15kg; 4–5 years = 20kg; 6–8 years = 23kg.*

Inspections, Records, And Reporting

Inspections

After the fluoridation equipment has been installed and started, its proper operation and maintenance becomes the operator's responsibility. The best designed system is only as good as its maintenance. Since the purpose of adding fluoride is to optimize its benefits, the operator must realize the importance of ensuring proper operation of the equipment.

Personnel from the Texas Fluoridation Program will periodically inspect the equipment and operating procedures.

Records and Reporting

All water systems must keep good records. Not only is this requirement good operational procedure, it is mandatory for all public water-supply systems. Optimizing fluoride concentration requires an accurate analysis of treated water and a record of daily measurements of fluoride.

A quick check of the accuracy of the fluoride addition process can be made from recorded information, which includes the weight of fluoride added and the total water produced. For example, if a plant added 16 pounds of 23% fluorosilicic acid to 500,000 gallons of water that contained 0.2 mg/l of fluoride, the final analysis should reveal 0.9 mg/l of fluoride. If the analysis actually revealed 0.6 mg/l, the operator would know that there was a problem: his scales are incorrect; he is losing fluoride in the process due to injection point location, precipitation as calcium (generally on filter media), or poor mixing of the fluoride with the water; or his chemical is not as concentrated as reported. Water does not have a fluoride demand such as is exhibited with chlorine. The fluoride added plus the natural fluoride in the raw water equals the total fluoride and should be equal to the fluoride in the treated water.

Split Monthly Sample Reporting

The Texas Fluoridation Program requests all water treatment plants in Texas that adjust the fluoride level of the water they produce to send the Department of State Health Services laboratory two samples of the finished water each month. The plant operator makes a fluoride analysis of a portion of each sample, indicates the results on the form provided, and mails the remaining portion (4 ounces minimum) of each sample and the forms to the laboratory. The department provides the forms, bottles, labels, and shipping boxes. The laboratory will analyze each of the two samples.

The water operator may take the samples from any point in the treatment plant or distribution system that is downstream from the point that fluoride is added. The operator may take the samples on any two days of the month.

A monthly report is mailed out to each system with the results of the water system and the state laboratory. If there is a problem with the fluoride level, or a discrepancy between the department's analysis and the operator's analysis, a technician will contact the operator. The program will determine if there is a problem and, if so, assist the operator or laboratory personnel in solving it.

Remember: The project's purpose is not to regulate, but to assist. Do not hesitate to contact the fluoridation engineer or technician about any problem, operational or administrative.

TEXAS Department of State Health Services Specimen Acquisition: (512) 458-7598	**G-22** **Specimen Submission Form** **(Jan 2011)** NELAC#45D0660644 Laboratory Services Section, MC-1947 P. O. Box 149347, Austin, Texas 78714-9347 Courier: 1100 W. 49th Street, Austin, Texas 78756 (888) 963-7111 x7318 or (512) 458-7318 http://www.dshs.state.tx.us/lab	***Place DSHS Bar Code Label Here***

THE SUBMITTER WILL BE BILLED FOR ALL TESTING DSHS is not responsible for 3rd party payment arrangements

Section 1. SUBMITTER/BILLING INFORMATION – (REQUIRED)**

Sample Identifier	Submitter Number	Establishment or Location

Date of Collection ** (REQUIRED)	Time of Collection **	☐ AM** ☐ PM**	Collected By/Contact **

Agency / Submitter Name

Address

City	State	Zip Code

Laboratory Identification Number	Phone #	Fax #

Section 2. SAMPLE INFORMATION -- (REQUIRED)**

Sample Type/Description:

Section 3. TESTING INFORMATION

***** To Ensure Proper Collection Please Refer to Manual of Reference Services @ www.dshs.state.tx.us/lab for Container, Sample Size, and Requirements Specific to the Test Requested*****

MICROBIOLOGY

☐ Reagent Water Suitability Test

☐ Food Microbiology:

List the Test(s) Requested ____

☐ Other:

ENVIRONMENTAL

☐ Reagent Water Suitability Test

☐ Other:

Section 4. Reporting Information

Indicate where & how you would like the results sent

Name

Address

City	State	Zip Code

Preferred Reporting Method	Fax Number or email:
☐ Mail ☐ Fax ☐ Email	

Section 5. PROGRAM INFORMATION when applicable

Program Name

Program Identification Number	Program Sample Identifier

Section 6. SPLIT SAMPLE FLUORIDE

System ID #:	Date Collected

Name of Water System

Collected By:

Phone #

Sample Location / Comments:

Water System Test Results	DSHS Lab Test Results(Do Not Write Below)
Fluoride ___________mg/L	Fluoride ____________mg/L

Place Pre-Printed Label Here

FOR LABORATORY USE ONLY Specimen Received: ☐ Room Temp. ☐ Cold ____________ ˚C

Date Received	Date Reported	

NOTES:

Reflex/Reference testing will be performed when necessary and the appropriate party will be billed.

Details of test and specimen requirements can be found in the Laboratory Services Section's Manual of Reference Services. Visit our web site at http://www.dshs.state.tx.us/lab/.

Laboratory Procedures For Fluoride Analysis

Selection of Method

Several approved methods are available for analysis of fluorides in water. These include the electrode method and the SPADNS colorimetric method. In addition to their standard laboratory methods, test kits based on these methods are available for field analysis. Each of the methods has advantages and disadvantages, and which method to choose should be based on the availability of laboratory equipment, trained operators, and funds available for purchase of the needed equipment.

Electrode Method *(Figure 10)*

The most accurate method of fluoride analysis is the electrode method, which uses an expanded-scale pH meter capable of reading in millivolts and an electrode which is specific for fluorides.
The electrode method is capable of measuring fluoride concentrations from 0.10 to 10.00 mg/l, while the SPADNS method is limited to 0.1 to 2.0 mg/l. Just as a pH electrode only measures hydrogen ions, a fluoride electrode only measures fluoride ions. This specifically enables the operator to analyze fluoride in water without having to neutralize residual chlorine or to distill a sample to remove turbidity and interfering substances. Certain chemicals in water could interfere; however, a special solution, total ionic strength adjustment buffer, is added to the sample to reduce interference.

Table 1 lists chemical interferences that will result in false readings using the SPADNS method.

Table 1

If you have	The fluoride test results will read
0.1 mg/l of Alum	0.1 mg/l lower
10 mg/l of Iron	0.1 mg/l lower
16 mg/l of Phosphate	0.1 mg/l higher
1.0 mg/l of Hexametaphospate	0.1 mg/l higher

Electrode preparation, care, and operation

Fluoride electrodes have a crystal doped with fluoride ions at its tip. The crystal acts as an ionic conductor so that, when the fluoride concentration outside of the electrode is higher than that inside, ions move toward the inside, setting up a voltage potential proportional to the difference in fluoride concentration. Conversely, when the fluoride concentration on the outside is lower than that on the inside, a proportional potential of opposite sign is set up. In most fluoride electrodes, the concentration of the internal solution below 19 ppm results in positive voltage readings. Some electrodes contain no internal solution, but the principle of operation is similar. Two types of electrodes are available. One uses a filling solution; the other a gel cartridge. To prepare an electrode for use, the chamber must be filled with the solution supplied with the electrode. Follow the manufacturer's recommendations.

Electrodes should never be stored with filling solution or gel in the chamber for extended period of time; the solution or gel will crystallize in the electrode, making it useless. Electrodes should be drained and thoroughly rinsed with deionized water before storage. If the electrode is to be stored for a short time, the crystal should be immersed in a liquid (standards will work) having the highest fluoride concentration available. This will prevent fluoride loss from the crystal to the storage liquid.

Calibration and testing procedure vary depending on the manufacturer and model of pH meter used. Procedures using multiple standards for calibration are more accurate than procedures using a single standard.

Advantages and Disadvantages

The advantages of the electrode method are the ability to use an existing pH meter, its accuracy, the lack of sample preparation, and an absence of interferences when the proper buffers are utilized. The lack of interferences make this method the best choice for most surface-water treatment processes.

The disadvantages include the necessity of a special fluoride electrode and multiple standards, its cost, the time required for calibration, and its lack of portability.

Figure 10. Equipment Setup for Electrode Method

SPADNS Method *(Figure 11)*

The colorimetric method, or SPADNS photometric method, is based on a reaction in which a dye lake (a deep color) is formed with zirconium and SPADNS dye. Any fluoride present in the water sample removes zirconium from the solution, which decreases the intensity of color. The color of the reaction mixture (water sample plus reagent) varies from very deep red in the absence of fluoride to light red when the concentration of fluoride is high.

The colors produced by different concentration of fluoride ions are all shades of red, and it is almost impossible to detect the difference in shades by eye. It is necessary to use a photometer to detect the color differences and therefore determine the concentration of fluoride in a water supply. A photometer is an instrument for detecting differences in color, consisting of a light source, a filter for producing monochromatic light, and a photocell for measuring the intensity of the light transmitted through the sample.

The manufacturer's recommended procedure should be followed. The general procedure for using the photometer for analysis of the fluoride concentration in a sample of water consists of adding a measured volume of reagent (SPADNS) to a measured volume of the water sample, placing a portion of the mixture in a cell or curvette, placing the cell in the instrument, and determining the fluoride concentration in parts per million from the instrument scale. As mentioned above, premeasured, vacuum-packaged SPADNS reagent is available and eliminates the measurement of sample or reagent, making the procedure simple and accurate.

The fluoride analysis of water is a comparatively delicate operation, as the quantities involved are minute, and the greatest possible accuracy is desirable. For these reasons, the following special precautions should be taken with any of the SPADNS procedures:

- Ensure that the temperature of the standard sample and the water sample is the same, preferably around 20° C. If the temperatures of the standard and the sample are different, the colorimeter will not give a correct reading of the fluoride content.
- Ensure that beakers are clean.
- Do not wash plastic beakers with detergent. All detergents contain phosphates, which are absorbed by the plastic and interfere with the test. The beakers should be periodically checked for scratches or chips. The readings can be affected by any obstructions in the glassware.
- Measure the reagent accurately with proper pipettes, or use premeasured vacuum-packed reagents.
- If chlorine is present, make sure the reagent contains arsenite solution.
- To calibrate the test equipment, you must use deionized water. Deionized water has a fluoride content of 0.0 mg/l. Carefully snap the tip by placing pressure against the beaker filled with deionized water. Allow ampule to fill (vacuum) completely up. If ampule breaks suction, discard and retry with a new ampule. Let the sample sit for one minute. Insert the ampule into the unit and cover with the lid. Press the ZERO button. The colorimeter is now ready for testing.

- Perhaps the most important source of error is the presence of interfering ions in the water sample. None of the colorimetric methods are entirely specific for fluoride, and to varying degrees many of the other ions found in water affect the fluoride analysis. The reagents are designed to eliminate the effects of these interfering ions or to minimize the effects as much as possible. However, if a water supply contains a large quantity of interfering ions, the reagent may not be able to minimize the effects of the interfering ions enough to get an accurate determination of the quantity of fluoride in the water. If the interferences become a problem, the ion-electrode method should be considered.

Advantages and Disadvantages

The SPADNS colorimetric method is based on the ability of fluorides to react with the chemicals in the SPADNS reagent (sodium 2-parasulfophenylazo-1,8-dihydroxy-3,6-naphtalene disulfonate) to reduce or change the color of the reagent. The color of the SPADNS reagent grows lighter with a greater fluoride concentration. The amount of light absorbed by the color of the sample allows measurement of the fluoride ion.

The advantages of the SPADNS method are the speed of analysis, the low cost of equipment, and its portability. Premeasured SPADNS reagent packaged in vacuum vials eliminates the need for measuring. This makes both calibration and testing quick and extremely easy. Some of the newer colorimeters are calibrated using only deionized water as a zero standard. Test kits for the SPADNS methods read directly in fluoride concentration and are portable.

The disadvantages of the SPADNS method include interferences, as shown in *Table 1*, and the necessity of distilling samples containing these interfering substances. The SPADNS method is generally utilized for groundwater treatment plants.

These two methods will be used in the laboratory session for this course. Results from the SPADNS and electrode methods are satisfactory for the monthly operating report as long as split sampling is performed with the Department of State Health Services laboratory.

Figure 11. Equipment and Setup for SPADNS Method

WORKSHEET ANSWERS

Clayton W.C.I.D. is installing a liquid-injection system at its water-treatment plant to adjust the fluoride level. The district and plant have the following pertinent characteristics:

Production rate	900 gallons per minute
Existing fluoride level	0.3 parts per million
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Peak production day	678,961 gallons
Number of connections	1203
Water-storage capacity	480,000 gallons

Mr. Tex Ritter, district general manager, is to appear at a meeting of the board of directors tonight. He instructs Dusty Rhodes, plant operator, to provide the total yearly chemical cost, and the chemical cost per connection if 23% liquid is used at a cost of $415 per 55-gallon drum. To prepare for possible board questions, Mr. Ritter wants Mr. Rhodes to provide the following additional information:

1. What size of chemical-feed pump should be purchased?
2. What is the feed rate for the pump?
3. What size of day tank should be purchased?
4. How much chemical should be purchased with each order?
5. What is the risk to district customers if the pump controls fail and the entire contents of the day tank are injected into the distribution system?

The calculations that Mr. Rhodes must perform are —

A. Yearly chemical cost:

Unit chemical cost = 55 gal × 10 lbs/gal =550 lbs
= $415 / 550 lbs = $0.75/lb

Average daily usage in lbs = $\frac{.364 \text{ MGD} \times 8.34 \text{ lbs/gal} \times 0.4 \text{ ppm}}{0.23 \times 0.792}$
= 6.67 lbs / 10= 0.66 gal

Yearly chemical cost = average daily usage × 365 × unit chemical cost
= 6.67 lbs × 365 × $0.75/lb
= $1825.91/year

B. Chemical cost per connection:

Yearly chemical cost / connection = \$1825.91 / 1203 connections = \$1.52

C. Pump size (considering metering pumps should have a capacity of about twice the required feed rate):

$$\text{Feed rate} = \frac{(900 \text{ gal/min} \times 1440 \text{ min/day} / 1{,}000{,}000) \times 8.34 \times 0.4}{0.23 \times 0.792}$$

= 23.73 lbs/day / 10 lbs/gal

= 2.37 gal/day

To get gallons per hour divide by 24 (hours in a day):
2.37/24 = **0.10 gal/hr**

pump feed rate = feed rate × 2

= 2.37 × 2
= 4.74 gal/day

Therefore, a pump with a capacity of approximately **5 gal/day** should be purchased.

D. Day tank size:

The day tank must be adequate for peak production days.
Therefore, peak daily chemical use is:

$$= \left(\frac{0.68 \text{ MGD} \times 8.34 \times 0.4}{0.23 \times 0.792}\right) / 10$$

= 1.25 gallons

Since day tanks are only available in full-gallon increments, a day tank of approximately **2 gallons** should be purchased.

E. Recommended amount of each chemical order:

The average daily chemical use is 0.66 gallons (see A above). Therefore, a 55-gallon carboy will last 83 days (55/0.66) and only one 55-gallon carboy should be purchased.

F. Risk if day tank is emptied into system:

If the worst case happens (the day tank is full and the water storage tank is completely empty) the fluoride level of the water produced will be:

$$\frac{\text{2 gallons (day tank) x 24 hr/day}}{\text{5 gal/day (maximum pump capacity)}} = \mathbf{9.6\ hours}$$

9.6 hours = time it will take pump to empty a full day tank

9.6 hours x 60 min/hr x 900 gal/min = **518,400 gallons**

518,400 gallons = water produced while pump empties day tank

2.0 gal x 0.23 (concentration) x 0.792 (available F ion) = **0.36 gal**

0.36 gallons = amount of fluoride ion in 2 gallon day tank

Therefore, fluoride level = $\frac{\text{0.36 gallons}}{\text{0.5184 MGD}}$ + 0.4 ppm (existing fluoride level)

= 0.7 ppm + 0.4 ppm = **1.1 ppm**

1.1 ppm = fluoride level of drinking water if day tank is emptied

Even if someone carried the day tank to the top of the storage tank and emptied a full day tank into a half-full storage tank, the resulting fluoride level would only be 0.36/0.24 MG + 0.4 or 1.9 ppm — a level still below the EPA primary notification limit.

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Feed Rate Calculation Form

Constants

Optimal fluoride level in Texas	0.7 mg/l
Weight of one gallon of water	8.34 lbs/gal
Weight of one gallon of acid	10 lbs/gal
Acid concentration	23% or 0.23
Available fluoride ion (AFI)	0.792
Milliliters per gallon	3785 ml

WTP Information

1. Natural Fluoride level = __________ mg/l

Fluoride level increase mg/l = Optimal 0.7 mg/l – Natural fluoride level mg/l

__________ mg/l = 0.7 mg/l – __________ mg/l

Fluoride level increase mg/l = __________ mg/l

2. Flow rate = __________ MGD

Pounds of Acid Used Per Day

3. Acid used per day (lbs/day) = $\frac{\text{MGD x 8.34 lbs/gal x mg/l Increase}}{\text{Acid Concentration x AFI}}$

Acid used per day (lbs/day) = $\frac{\text{\_\_\_\_\_\_\_\_\_ MGD x 8.34 lbs/gal x \_\_\_\_\_\_\_\_\_ mg/l Increase}}{0.23 \times 0.792}$

Acid used per day = __________ lbs/day

Conversion from lbs/day to ml/min

4. Metering pump output (ml/min) = $\frac{\text{lbs/day x 3785 ml/gal}}{\text{10 lb/gal x 1440 min/day}}$

Metering pump output (ml/min) = $\frac{\text{\_\_\_\_\_\_\_\_\_ lbs/day x 3785 ml/gal}}{\text{10 lb/gal x 1440 min/day}}$

Metering pump output = _________ ml/min = _________ gal/hr gal/hr= $\frac{\text{(ml/min)(6}}{3785}$

(This is the number used when calibrating with a calibration cylinder.)

Metering Pump Settings ml/min

Metering pump output	________	ml/min
Maximum pump output	________	ml/min

Solving for Metering Pump Output Percentage

1. Pump Output % = $\frac{\text{Pump output ml/min}}{\text{Pump max output ml/min}}$

Pump Output % = $\frac{\text{\_\_\_\_\_\_\_\_ ml/min}}{\text{\_\_\_\_\_\_\_\_ ml/min}}$

Pump Output % = ________

Choosing the Pump Stroke Length

2. Pump Output % = Stroke Length % x Stroke Speed %

________ = Stroke Length % x Stroke Speed %

Pick a Stroke Length ________ %   (divide by 100 to convert to decimal)

Each term is expressed as a decimal fraction.

Stroke Length = .________

Solving for Pump Stroke Speed

3. Stroke Length x Stroke Speed = Pump Output

.________ x Stroke Speed = .________

Stroke Speed = $\frac{\text{.\_\_\_\_\_\_\_\_ Pump Output}}{\text{.\_\_\_\_\_\_\_\_ Stroke Length}}$

Stroke Speed = .________

Multiply by 100 to convert to percentage.

4. Set the knobs on the metering pump to:

Stroke Speed % = ________

Stroke Length % = ________

Metering Pump Settings gal/hr

Metering pump output	________	gal/hr
Maximum pump output	________	gal/hr

Solving for Metering Pump Output Percentage

1. Pump Output % = $\frac{\text{Pump output gal/hr}}{\text{Pump max output gal/hr}}$

   Pump Output % = $\frac{\text{\_\_\_\_\_\_ gal/hr}}{\text{\_\_\_\_\_\_ gal/hr}}$

   Pump Output % = ________

Choosing the Pump Stroke Length

2. Pump Output % = Stroke Length % x Stroke Speed %

   ________ = Stroke Length % x Stroke Speed %

Pick a Stroke Length ________ % (divide by 100 to convert to decimal)

Each term is expressed as a decimal fraction.

Stroke Length = .________

Solving for Pump Stroke Speed

3. Stroke Length x Stroke Speed = Pump Output

   .________ x Stroke Speed = .________

   Stroke Speed = $\frac{\text{.\_\_\_\_\_\_ Pump Output}}{\text{.\_\_\_\_\_\_ Stroke Length}}$

   Stroke Speed = .________

Multiply by 100 to convert to percentage.

4. Set the knobs on the metering pump to:

   Stroke Speed % = ________

   Stroke Length % = ________

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