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ABSTRACT This document is an instructional module package prepared in objective form for use by an instructor familiar with fluoridation and fluoride feeding equipment. Enclosed are objectives, an instructor guide, student handouts and transparency masters. The module considers the principles and purposes of fluoridation, methods of feeding fluoride, operation and maintenance of feeding equipment, feed rates and defluoridation in general. (Author/RH)

***********************************************************************
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***********************************************************************
FLUORIDATION AND DEFLUORIDATION
Training Module 2.230.2.77

Prepared for the
Iowa Department of Environmental Quality
Wallace State Office Building
Des Moines, Iowa 50319

by

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September, 1977
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II. TRANSPARENCIES

Transparency #1 - History of Fluoridation
Transparency #2 - Fluoride Concentration vs Dental Caries
Transparency #3 - EPA Drinking Water Fluoride Standard
Transparency #4 - Sodium Fluoride
Transparency #5 - Fluosilicic Acid
Transparency #6 - Sodium Silicofluoride
Transparency #7 - Summary of Fluoride Compounds
Transparency #8 - Summary of Chemical Use
Transparency #9 - Typical Solution Feeder
Transparency #10 - Typical Dilute Acid Feeder
Transparency #11 - Positive Displacement Solution Feeders
Transparency #12 - Example Problem on Feeder Selection
Transparency #13 -
Transparency #16 - Dry Feeders
Transparency #17 - Example of proper safety labeling
Transparency #18 - Auxiliary Equipment
Transparency #19 - Design of Fluoridation System
Transparency #20 - Fluoridation Check List
Transparency #21 - Monitoring Requirements
Transparency #22 - Laboratory Control
Transparency #23 - Basic Defluoridation System

III. CLASS HANDOUT

IV. EXAMINATION
INSTRUCTOR GUIDE

for

Training Module for II2WWS
Module No.: II2WWS

Module Title: Fluoridation and Defluoridation

Submodule Title:

Approx. Time: 16 hours

Topic: Summary

Objectives: Upon completion of this module, the participant will be able to:
1. Evaluate the fluoridation needs for a water supply.
2. Design the optimal fluoridation system for a water supply.
3. Evaluate the analytical requirement for a water supply.
4. Determine if a defluoridation system is required for a water supply.

Instructional Aids:
1. Handout
2. Transparencies #1-#23

Instructional Approach:
Discussion and class problems

References:
2. Manual of Instruction for Water Treatment Plant Operators, HES
3. Standard Methods for Examination of Water and Wastewater, 14th Ed.

Class Assignments:
Read Handout & Work Problems #1-#2
<table>
<thead>
<tr>
<th>Instructor Notes</th>
<th>Instructor Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Distribute Handout</td>
<td>1. Discuss the need, design, laboratory control and safety requirements for a fluoridation system.</td>
</tr>
</tbody>
</table>
Module No:  
Module Title: Fluoridation and Defluoridation
Submodule Title:

Approx. Time: 1 hour

Topic: Introduction

Objectives: Upon completion of this topic, the participants will be able to:
1. Describe what fluoridation is.
2. Describe the need for fluoride in drinking water.
3. Analyze a given water supply and determine the optimal fluoride concentration.
4. Analyze a given water supply and determine the concentration of fluoride above which defluoridation would be required.

Instructional Aids:
1. Handout - Introduction
2. Transparency #1 - History of fluoridation
3. Transparency #2 - Fluoride concentration vs dental caries
4. Transparency #3 - EPA Drinking Water Fluoride Standard

Instructional Approach:
Discussion and problem solving

References:
2. Manual of Instruction for Water Treatment Plant Operators, Health Education Service

Class Assignments:
1. The participant will read Handout - Introduction.
2. The participant will work a class problem #1 to determine maximum allowable and optimal fluoride concentration for a given water supply.
### Module No: II2WWS
### Topic: Introduction

#### Instructor Notes:

1. Present Transparency #1.
2. Present Transparency #2.
3. Present Transparency #3.
4. Present Class Problem #1. Work problem with class participation.

#### Instructor Outline:

1. Discuss the history of fluoridation and the total population affected.
2. Discuss the benefits of fluoridation and the age groups mostly affected.
3. Discuss the limits for fluoride in the EPA Drinking Water Standards. Discuss why air temperature is used. Discuss the optimum concentration.
4. a) Defluoridation
   b) 9 mg/l
   c) 1.4 mg/l
   d) .7 mg/l
Module No: II2WWS
Module Title: Fluoridation and Defluoridation
Submodule Title: 

Approx. Time: 1 1/2 hours
Topic: Principles of Fluoridation

Objectives: Upon completion of this topic, the participant will be able to:
1. Describe the role of fluoride in prevention of dental caries.
2. List compounds commonly used in controlled fluoridation.
3. List an advantage and one disadvantage for each compound used in controlled fluoridation.

Instructional Aids:
1. Handout-Principles of Fluoridation
2. Transparency #4-Sodium Fluoride
3. Transparency #5-Fluosilicic Acid
4. Transparency #6-Sodium Silicofluoride
5. Transparency #7-Summary of Fluoride Compounds
6. Transparency #8-Summary of Chemical Use

Instructional Approach:
Discussion

References:
2. Manual of Instruction for Water Treatment Plant Operators, Health Education Service

Class Assignments:
1. The participant will read Handout - Principles of Fluoridation
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Present Transparency #4</td>
<td>1. Discuss advantages and disadvantages of using sodium fluoride for controlled fluoridation.</td>
</tr>
<tr>
<td></td>
<td>a. Chemical Costs</td>
</tr>
<tr>
<td></td>
<td>b. Capital Costs</td>
</tr>
<tr>
<td></td>
<td>c. Safety</td>
</tr>
<tr>
<td></td>
<td>d. Operation</td>
</tr>
<tr>
<td>2. Present Transparency #5</td>
<td>2. Discuss advantages and disadvantages of using fluorosilicic acid for controlled fluoridation.</td>
</tr>
<tr>
<td></td>
<td>a. Chemical Costs</td>
</tr>
<tr>
<td></td>
<td>b. Capital Costs</td>
</tr>
<tr>
<td></td>
<td>c. Safety</td>
</tr>
<tr>
<td></td>
<td>d. Operation</td>
</tr>
<tr>
<td>3. Present Transparency #6</td>
<td>3. Discuss advantages and disadvantages of using sodium silicofluoride for controlled fluoridation.</td>
</tr>
<tr>
<td></td>
<td>a. Chemical Costs</td>
</tr>
<tr>
<td></td>
<td>b. Capital Costs</td>
</tr>
<tr>
<td></td>
<td>c. Safety</td>
</tr>
<tr>
<td></td>
<td>d. Operation</td>
</tr>
<tr>
<td>4. Present Transparency #7</td>
<td>4. Compare the various compounds and their uses for different applications.</td>
</tr>
<tr>
<td></td>
<td>a. Review material from previous transparencies</td>
</tr>
<tr>
<td></td>
<td>1) Chemical Costs</td>
</tr>
<tr>
<td></td>
<td>2) Capital Costs</td>
</tr>
<tr>
<td></td>
<td>3) Safety</td>
</tr>
<tr>
<td></td>
<td>4) Operation</td>
</tr>
<tr>
<td>5. Present Transparency #8</td>
<td>5. Compare the various compounds and general types of installation.</td>
</tr>
<tr>
<td></td>
<td>a. Types of installations for different sizes of communities</td>
</tr>
</tbody>
</table>
Module No: II2WWS

Module Title: Fluoridation and Defluoridation

Submodule Title:

Approx. Time: 3 hours

Topic: Solution Feeders Used for Adding Fluorides

Objectives: Upon completion of this topic, the participant will be able to:
1. List chemicals that are commonly fed by solution feeders.
2. List types, advantages and disadvantages of solution feeders.
3. Describe required maintenance for solution feeders.
4. Describe safety and hazards in handling chemicals.
5. Compute desired solution feed rate for a given water supply.
6. Select a solution feeder system for a given application.

Instructional Aids:
1. Handout - Solution Feeders
2. Transparency #9 - Typical Solution Feeder
3. Transparency #10 - Typical Dilute Acid Feeder
4. Transparency #11 - Positive Displacement Solution Feeders
5. Transparency #12 - Example problem on feeder selection

Instructional Approach:
Discussion and problem solving

References:
2. Manual of Instruction for Water Treatment Plant Operators, Health Education Service

Class Assignments:
1. The participant will read Handout - Solution Feeders
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Present Transparency #9</strong></td>
<td>1. <strong>Discuss the typical solution feeder installation.</strong> Discuss which chemicals are commonly used with system. <strong>Discuss operational problems,</strong> necessary safety practices, and maintenance for systems.</td>
</tr>
<tr>
<td></td>
<td>a. Softener &amp; meter</td>
</tr>
<tr>
<td></td>
<td>b. Float valve</td>
</tr>
<tr>
<td></td>
<td>c. Distributor tubes</td>
</tr>
<tr>
<td></td>
<td>d. Pumps</td>
</tr>
<tr>
<td><strong>2. Present Transparency #10</strong></td>
<td>2. <strong>Discuss the typical dilute acid feeder installation.</strong> Discuss which chemicals are commonly used with system. <strong>Discuss operational problems,</strong> necessary safety practices and maintenance for systems.</td>
</tr>
<tr>
<td></td>
<td>a. Transfer pump</td>
</tr>
<tr>
<td></td>
<td>b. Mixer</td>
</tr>
<tr>
<td></td>
<td>c. Air Gap</td>
</tr>
<tr>
<td></td>
<td>d. Pumps</td>
</tr>
<tr>
<td><strong>3. Present Transparency #11</strong></td>
<td>3. <strong>Discuss the positive displacement solution feeds available.</strong> Discuss advantages and disadvantages of each.</td>
</tr>
<tr>
<td></td>
<td>a. Resistance to corrosion</td>
</tr>
<tr>
<td></td>
<td>b. Resistance to abrasive materials (scale)</td>
</tr>
<tr>
<td></td>
<td>c. Type of flow produced</td>
</tr>
<tr>
<td></td>
<td>d. Repair record</td>
</tr>
</tbody>
</table>
Module No: II2WWS
Module Title: Fluoridation and Defluoridation
Submodule Title:
Approx. Time: 3 hours
Topic: Dry Feeders used for Adding Fluoride.

Objectives: Upon completion of this topic, the participant will be able to:
1. List chemicals that are commonly fed by dry feeders.
2. List types, advantages and disadvantages of dry feeders.
3. Describe required maintenance for dry feeders.
4. Describe safety and hazards in handling chemicals.
5. Compute desired chemical feed rate for a given water supply.
6. Select a chemical feeder system for a given application.

Instructional Aids:
1. Handout - Dry Feeders
2. Transparency #13-#16 - Dry Feeders
3. Transparency #17 - Example of proper safety labeling

Instructional Approach:
Discussion and problem solving

References:
2. Manual of Instruction for Water Treatment Plant Operators, Health Education Service

Class Assignments:
1. The participant will read Handout - Dry Feeders
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Present Transparencies #13-#16</td>
<td>1. Discuss each type of dry feeder. Include operation, maintenance, advantages and disadvantages compared to other dry feeders. Also include accuracy and safety with each feeder.</td>
</tr>
<tr>
<td>2. Present Transparency #17</td>
<td>a. Screw-type Feeder 1) Varying characteristics of chemical 2) Scaling in solution tank 3) Control 4) Capital costs</td>
</tr>
<tr>
<td></td>
<td>b. Roll-type Feeder 1) Varying characteristics of chemical 2) Scaling in solution tank 3) Control 4) Capital costs</td>
</tr>
<tr>
<td></td>
<td>c. Belt-type Feeder 1) Varying characteristics of chemical 2) Scaling in solution tank 3) Control 4) Maintenance of belt &amp; yoke 5) Capital costs</td>
</tr>
<tr>
<td></td>
<td>d. &quot;LOSS-IN-WEIGHT&quot; Feeder 1) Varying characteristics of chemical 2) Scaling in solution tank 3) Control 4) Maintenance of screw drive &amp; scale beam 5) Capital costs</td>
</tr>
</tbody>
</table>
Module No: 112WWS
Module Title: Fluoridation and Defluoridation
Submodule Title:
Approx. Time: 3 hours
Topic: Selection of Optimal Fluoridation System

Objectives: Upon completion of this topic, the participant will be able to:
1. Select the necessary auxiliary equipment for a fluoridation system.
2. Design the optimal fluoridation system for a given water system.

Instructional Aids:
1. Handout - Optimal Fluoridation System
2. Transparency #18 - Auxiliary Equipment
3. Transparency #19 - Design of Fluoridation System
4. Transparency #20 - Fluoridation Check List

Instructional Approach:
Discussion and problem solving

References:
2. Manual of Instruction for Water Treatment Plant Operators, Health Education Service

Class Assignments:
1. The participant will read Handout - Optimal Fluoridation System
2. The participant will work problem #2 on design of a fluoridation system for a given water supply.
Module No: II2WWS

Topic: Selection of Optimal Fluoridation System

Instructor Notes:

1. Present Transparency #18
2. Present Transparency #19
3. Present Transparency #20
4. Present Class Problem #2. Work problem with class participation.

Instructor Outline:

1. Discuss the necessary auxiliary equipment needed for a fluoridation system. Discuss in detail the reason and points of application for each item.
2. Discuss the Ten States Standards for fluoridation systems.
3. Discuss the fluoridation check-list and how it can be used to evaluate a system design.
4. a) .8 mg/l
   b) Fluorosilicic Acid Diluted
      $250 and up
   c) (.3)(.15)(8.34) = .38 lbs/day
      use 50¢/lb
      (.38)(.5) = $.19/day
<table>
<thead>
<tr>
<th>Module No:</th>
<th>Module Title:</th>
</tr>
</thead>
<tbody>
<tr>
<td>I12WWS</td>
<td>Fluoridation and Defluoridation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Submodule Title:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Approx. Time:</th>
<th>Topic:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 hours</td>
<td>Analytical Control</td>
</tr>
</tbody>
</table>

**Objectives:** Upon completion of this topic, the participant will be able to:

1. Define the monitoring requirements for a given water supply set forth by the USEPA.
2. Define the monitoring requirements for a given water supply set forth by the Iowa D.E.Q.
3. List the approved methods of analysis.
4. Interpret laboratory data for plant control.

**Instructional Aids:**

1. Handout - Laboratory Control
2. Transparency #21 - Monitoring requirements
3. Transparency #22 - Laboratory Control

**Instructional Approach:**

Discussion

**References:**

1. Standard Methods for Examination of Water and Wastewater, 14th Ed.
2. Methods for Chemical Analysis of Water and Waste EPA

**Class Assignments:**

1. The participant will read Handout - Analytical Control
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Present Transparency #21 1. Discuss the necessary monitoring requirements for fluoridation systems.</td>
<td></td>
</tr>
<tr>
<td>2. Present Transparency #22 2. Discuss in detail the various methods for fluoridation testing. Include type of equipment needed and relative cost.</td>
<td></td>
</tr>
<tr>
<td>Module No:</td>
<td>Module Title:</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------</td>
</tr>
<tr>
<td>II2WWS</td>
<td>Fluoridation and Defluoridation</td>
</tr>
</tbody>
</table>

**Approx. Time:** 1 hour

**Topic:** Defluoridation

**Objectives:** Upon completion of this topic, the participant will be able to:

1. Describe a basic defluoridation system.

**Instructional Aids:**

1. Handout - Defluoridation
2. Transparency #23 - Basic Defluoridation System

**Instructional Approach:** Discussion

**References:**

2. Manual of Instruction for Water Treatment Plant Operators, Health Education Service

**Class Assignments:**

1. The participant will read Handout - Defluoridation
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Present Transparency #23</td>
<td>1. Discuss the various defluoridation systems. Include costs and how they operate. State the chemistry involved for removal.</td>
</tr>
<tr>
<td>Module No.</td>
<td>Module Title</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------</td>
</tr>
<tr>
<td>II2WWS</td>
<td>Fluoridation and Defluoridation</td>
</tr>
</tbody>
</table>

**Submodule Title:**

**Approx. Time:**

1 hour

**Evaluation Objectives:**

The participant should be able to answer correctly 25 of the 30 questions asked.

**Instructional Aids:**

None

**Instructional Approach:**

Examination

**References:**

None

**Class Assignments:**

None
<table>
<thead>
<tr>
<th>Module No:</th>
<th>Topic:</th>
</tr>
</thead>
<tbody>
<tr>
<td>112WWS</td>
<td>Evaluation</td>
</tr>
</tbody>
</table>

**Instructor Notes:**

1. Distribute exam. Each participant is to complete the exam independently and with no books or notes. Collect after 1 hour.
TRANSPARENCIES
for
Training Module II2WWS
HISTORY OF FLUORIDATION

![Graph showing the history of fluoridation of water]

- **Millions of Persons Served by Controlled Fluoridation of Water**
- **Percent of Population Served**

Timeline:
- 1950
- 1955
- 1960
- 1965
- 1970
- 1975

Graph indicates an increase in the number of persons served by controlled fluoridation over time, with a significant rise towards 1975.
FLUORIDATION’S EFFECT ON DENTAL CARIES

Graph showing the relationship between fluoride concentration (F, mg/l) and the number of missing, decayed, and filled teeth. The graph indicates a decrease in the number of missing, decayed, and filled teeth as the fluoride concentration increases.
### Recommended Fluoride Concentrations

<table>
<thead>
<tr>
<th>Annual Average of Maximum Daily Air Temperatures Based on Temperature Data Obtained for a Minimum of 5 Years (°F)</th>
<th>Fluoride-Ion Concentrations (mg/l)</th>
<th>Recommended Limits</th>
<th>Approval Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Optimum</td>
<td>Upper</td>
</tr>
<tr>
<td>50.0–53.7</td>
<td>0.9</td>
<td>1.2</td>
<td>1.7</td>
</tr>
<tr>
<td>53.8–58.3</td>
<td>0.8</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td>58.4–63.8</td>
<td>0.8</td>
<td>1.0</td>
<td>1.3</td>
</tr>
<tr>
<td>63.9–70.6</td>
<td>0.7</td>
<td>0.9</td>
<td>1.2</td>
</tr>
<tr>
<td>70.7–79.2</td>
<td>0.7</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>79.3–90.5</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
</tr>
</tbody>
</table>

## SODIUM FLUORIDE

<table>
<thead>
<tr>
<th>Item</th>
<th>Sodium Fluoride NaF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Form</strong></td>
<td>Powder or crystal</td>
</tr>
<tr>
<td><strong>Molecular weight</strong></td>
<td>42.00</td>
</tr>
<tr>
<td><strong>Commercial purity—per cent</strong></td>
<td>90 - 98</td>
</tr>
<tr>
<td><strong>Fluoride ion—per cent</strong></td>
<td>42.25</td>
</tr>
<tr>
<td>(100 per cent pure material)</td>
<td></td>
</tr>
<tr>
<td><strong>Pounds required per mg for 1.0 ppm F at indicated purity</strong></td>
<td>18.8 (98 per cent)</td>
</tr>
<tr>
<td><strong>pH of saturated solution</strong></td>
<td>7.6</td>
</tr>
<tr>
<td><strong>Sodium ion contributed at 1.0 ppm F—ppm</strong></td>
<td>1.17</td>
</tr>
<tr>
<td><strong>F ion storage space—cu.ft/100lb</strong></td>
<td>22 - 34</td>
</tr>
<tr>
<td><strong>Solubility—at 25C</strong></td>
<td>4.05</td>
</tr>
<tr>
<td><strong>g/100g water</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Weight—lb/cu.ft</strong></td>
<td>65 - 90</td>
</tr>
<tr>
<td><strong>Cost:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Cents/lb</strong></td>
<td>18 - 25</td>
</tr>
<tr>
<td><strong>Cents/lb available F</strong></td>
<td>41 - 57</td>
</tr>
<tr>
<td><strong>Shipping containers</strong></td>
<td></td>
</tr>
<tr>
<td>100-lb bags</td>
<td></td>
</tr>
<tr>
<td>125—400-lb fiber drums, bulk</td>
<td></td>
</tr>
</tbody>
</table>
# FLUOSILICIC ACID

<table>
<thead>
<tr>
<th>Item</th>
<th>Fluosilic Acid $H_2SiF_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form</td>
<td>Liquid</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>144.08</td>
</tr>
<tr>
<td>Commercial purity—per cent</td>
<td>22 - 30</td>
</tr>
<tr>
<td>Fluoride ion—per cent (100 per cent pure material)</td>
<td>79.2</td>
</tr>
<tr>
<td>Pounds required per mg for 1.0 ppm F at indicated purity (30 per cent)</td>
<td>35.2</td>
</tr>
<tr>
<td>pH of saturated solution (1 per cent solution)</td>
<td>1.2</td>
</tr>
<tr>
<td>Sodium ion contributed at 1.0 ppm F—ppm</td>
<td>0.00</td>
</tr>
<tr>
<td>F ion storage space—cu ft/100 lb</td>
<td>54 - 73</td>
</tr>
<tr>
<td>Solubility—at 25C g/100 g water</td>
<td>Infinite</td>
</tr>
<tr>
<td>Weight—lb/cu ft</td>
<td>10.5 lb/gal (30 per cent)</td>
</tr>
<tr>
<td>Cost: Cents/lb</td>
<td>2 1/4 - 15'</td>
</tr>
<tr>
<td>Cents/lb available F</td>
<td>14 - 63</td>
</tr>
<tr>
<td>Shipping containers</td>
<td>13-gal carboys 55-gal drums, bulk</td>
</tr>
</tbody>
</table>
**SODIUM SILICOFLUORIDE**

<table>
<thead>
<tr>
<th>Item</th>
<th>Sodium Silico-fluoride (Na₂SiF₆)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form</td>
<td>Powder or very fine crystal</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>188.05</td>
</tr>
<tr>
<td>Commercial purity—per cent</td>
<td>98-99</td>
</tr>
<tr>
<td>Fluoride ion—per cent (100 per cent pure material)</td>
<td>60.7</td>
</tr>
<tr>
<td>Pounds required per mg for 1.0 ppm F at indicated purity (98.5 per cent)</td>
<td>14.0</td>
</tr>
<tr>
<td>pH of saturated solution</td>
<td>3.5</td>
</tr>
<tr>
<td>Sodium ion contributed at 1.0 ppm F—ppm</td>
<td>0.40</td>
</tr>
<tr>
<td>F ion storage space—cu ft/100 lb</td>
<td>23-30</td>
</tr>
<tr>
<td>Solubility—at 25°C g/100 g water</td>
<td>0.762</td>
</tr>
<tr>
<td>Weight—lb/cu ft</td>
<td>55-72</td>
</tr>
<tr>
<td>Cost:</td>
<td></td>
</tr>
<tr>
<td>Cents/lb</td>
<td>8-10</td>
</tr>
<tr>
<td>Cents/lb available F</td>
<td>13-17</td>
</tr>
<tr>
<td>Shipping containers</td>
<td>100-lb bags, 125-400-lb fiber drums, bulk</td>
</tr>
</tbody>
</table>
### Summary of Fluoride Compounds

<table>
<thead>
<tr>
<th>Item</th>
<th>Sodium Fluoride NaF</th>
<th>Sodium Silico-fluoride Na$_2$SiF$_6$</th>
<th>Fluosilicic Acid H$_2$SiF$_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Form</strong></td>
<td>Powder or crystal</td>
<td>Powder or very fine crystal</td>
<td>Liquid</td>
</tr>
<tr>
<td><strong>Molecular weight</strong></td>
<td>42.00</td>
<td>188.05</td>
<td>144.08</td>
</tr>
<tr>
<td><strong>Commercial purity—per cent</strong></td>
<td>90 - 98</td>
<td>98 - 99</td>
<td>22 - 30</td>
</tr>
<tr>
<td><strong>Fluoride ion—per cent</strong></td>
<td>42.25</td>
<td>60.7</td>
<td>79.2</td>
</tr>
<tr>
<td><strong>(100 per cent pure material)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pounds required per mg for 1.0 ppm F</strong> at indicated purity</td>
<td>18.8 (98 per cent)</td>
<td>14.0 (98.5 per cent)</td>
<td>35.2 (30 per cent)</td>
</tr>
<tr>
<td><strong>pH of saturated solution</strong></td>
<td>7.6</td>
<td>3.5</td>
<td>1.2 (1 per cent solution)</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>a-h</td>
<td>c, d, h</td>
<td>d-f, h, i, j</td>
</tr>
<tr>
<td><strong>F ion storage space—cu ft/100 lb</strong></td>
<td>22 - 34</td>
<td>23 - 30</td>
<td>54 - 73</td>
</tr>
<tr>
<td><strong>Solubility—at 25°C</strong></td>
<td>4.05</td>
<td>0.762</td>
<td>Infinite x</td>
</tr>
<tr>
<td><strong>Weight—lb/cu ft</strong></td>
<td>65 - 90</td>
<td>55 - 72</td>
<td>10.5 lb/gal (30 per cent)</td>
</tr>
<tr>
<td><strong>Cost:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cents/lb</strong></td>
<td>18 - 25</td>
<td>8 - 10</td>
<td>2½ - 15</td>
</tr>
<tr>
<td><strong>Cents/lb available F</strong></td>
<td>41 - 57</td>
<td>13 - 17</td>
<td>14 - 63</td>
</tr>
<tr>
<td><strong>Shipping containers</strong></td>
<td>100-lb bags</td>
<td>100-lb bags</td>
<td>13-gal carboys</td>
</tr>
<tr>
<td></td>
<td>125 - 400-lb</td>
<td>125 -400-lb</td>
<td>55-gal drums, bulk</td>
</tr>
<tr>
<td></td>
<td>fiber drums, bulk</td>
<td>fiber drums, bulk</td>
<td></td>
</tr>
</tbody>
</table>

* Ceramic crocks or other corrosion-resistant containers.
* Conditioning make-up water to minimize clogging by sludge.
* Respirator (dust mask).
* Rubber gloves.
* Residual.
* Weighting scales.
* Polyphosphate feed to stabilize solution and minimize incrustation.
* Automatic stop-start controls.
* Acidproof aprons.
* Industrial goggles for protection against acid.
<table>
<thead>
<tr>
<th>Population Size of Water Supply Systems</th>
<th>Number of Systems</th>
<th>Sodium Fluoride Fluoridating Dry Solution</th>
<th>Sodium Silicofluoride Dry Solution</th>
<th>Sodium Fluorsilicic Acid Solution</th>
<th>Ammonium Fluosilicate Dry Solution</th>
<th>Calcium Fluoride Solution</th>
<th>Other, Adjusted Natural Fluoride, And Not Specified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totals</td>
<td>1,785</td>
<td>147</td>
<td>412</td>
<td>710</td>
<td>67</td>
<td>383</td>
<td>1 6 1- 58</td>
</tr>
<tr>
<td>1,000,000 and OVER</td>
<td>5</td>
<td></td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td>58</td>
</tr>
<tr>
<td>500,000 thru 999,999</td>
<td>13</td>
<td></td>
<td>11</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250,000 thru 499,999</td>
<td>16</td>
<td>4</td>
<td>9</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100,000 thru 249,999</td>
<td>47</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50,000 thru 99,999</td>
<td>60</td>
<td>2</td>
<td>1</td>
<td>47</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24,000 thru 49,999</td>
<td>140</td>
<td>19</td>
<td>8</td>
<td>80</td>
<td>10</td>
<td>19</td>
<td>1- 1- 2</td>
</tr>
<tr>
<td>10,000 thru 24,999</td>
<td>335</td>
<td>37</td>
<td>33</td>
<td>192</td>
<td>8</td>
<td>56</td>
<td>2</td>
</tr>
<tr>
<td>5,000 thru 9,999</td>
<td>344</td>
<td>41</td>
<td>57</td>
<td>167</td>
<td>12</td>
<td>61</td>
<td>4</td>
</tr>
<tr>
<td>2,500 thru 4,999</td>
<td>303</td>
<td>21</td>
<td>86</td>
<td>115</td>
<td>10</td>
<td>66</td>
<td>3</td>
</tr>
<tr>
<td>1,000 thru 2,499</td>
<td>342</td>
<td>17</td>
<td>137</td>
<td>58</td>
<td>17</td>
<td>105</td>
<td>7</td>
</tr>
<tr>
<td>UNDER 1,000</td>
<td>144</td>
<td>89</td>
<td>2</td>
<td>5</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOT SPECIFIED</td>
<td>36</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TYPICAL SOLUTION FEEDER

FLOW CONTROL

125 PSI MAX.

SYMPHON BREAKER

WALL OUTLET

115 VAC

60 Hz

ANTI-SIPHON VALVE

PCPC, 5000 SERIES

FLOW CONTROL

40 GAL. POLYETHYLENE TANK

SATURATED SOLUTION

SOFTENER OF 4% FLUORIDE

DISTRIBUTOR TUBES

PCPC LIQUID LEVEL SWITCH

SODIUM FLUORIDE

PVC BALL VALVE (OPTIONAL)

3/4" NPT DRAIN

1 1/4" NPT DRAIN

3/4" NPT OVERFLOW

PCPC 5000 SERIES FLUORIDE PUMP

3/4" NPT OVERFLOW

WATER SOFTENER

SODIUM FLUORIDE

50 GAL. POLYETHYLENE TANK

WATER SOFTENER

SATURATED SOLUTION

OF 4% FLUORIDE

TO POINT OF APPLICATION

WATER METER

FLOW CONTROL

MOLDED FIBERGLASS COVER

PVC UNION

PVC BOLT

PVC BLOCK

FLOAT VALVE ASSEMBLY

PVC BALL VALVE (OPTIONAL)

DISTRIBUTOR TUBES
TYPICAL DILUTE ACID FEEDER

ACID TANK

TRANSFER PUMP

WATER SUPPLY

ANTI-SIPHON VALVE

MIST PUMP

AIR GAP

OVERFLOW

MIXER

DAY TANK

PLACE ON PLATFORM SCALE

30% ACID
POSITIVE DISPLACEMENT FEEDERS

POSITIVE-DISPLACEMENT-PLUNGER PUMP

CAM AND PISTON

STROKE-POSITION-CONNECTING ROD ECCENTRIC

POSITIVE-DISPLACEMENT DIAPHRAGM PUMP

INLET

DIAPHRAGM

OUTLET

GEAR

VANE SLIDING

VANE SWINGING
Problem: Select a solution feeder for the following application:
Water flow—200 gpm at 75 psi
Fluoride source — saturator (produces a 4 per cent sodium fluoride solution, 18,000 ppm as F)
Desired fluoride level — 1.0 ppm
Calculated solution feed rate: \( R_1 \times C_1 = R_2 \times C_2 \)
where
\( R_1 = \) water rate, in gallons per minute
\( C_1 = \) fluoride level, in parts per million
\( R_2 = \) solution feed rate, in gallons per minute (the unknown quantity, in this case)
\( C_2 = \) solution strength in parts per million
then
\[
200 \text{ gal/min} \times 1.0 \text{ ppm} = x \times 18,000 \text{ ppm}
\]
\[
x = \frac{200 \text{ gal/min} \times 1.0 \text{ ppm}}{18,000 \text{ ppm}} = 0.011 \text{ gal/min}
\]
\[
\frac{0.011 \text{ gal}}{\min} \times \frac{60 \text{ min}}{\text{hr}} = 0.67 \text{ gal/hr}
\]
Feeders available:
Manufacturer A, Model 1203, three-step pulley drive.
Delivery rate:
at 13 spm, 0.02 - 0.3 gpm at 100 psi
at 26 spm, 0.04 - 0.6 gph
at 46 spm, 0.06 - 1.06 gph
Manufacturer B, Model 5701-111, single speed (37.5 spm)
Delivery rate: 0.05 - 5 gph maximum
Manufacturer C, Model 12000, electronic stroking control (3 - 72 spm)
Delivery rate: 0.01 - 1.6 gph
Selection: The required delivery rate falls within the range of all three feeders, so all are possibly acceptable. However, the delivery rate would require the highest stroke frequency of the feeder from Manufacturer A, a situation which, while not unacceptable, is not preferred. Similarly, the delivery rate is too close to the minimum of the feeder from Manufacturer B to be completely satisfactory. The feeder from Manufacturer C appears to be the best choice, since the delivery rate is approximately in the middle of its range. Further investigation into the feeder characteristics should be made in order to ascertain the combination of output per stroke and stroke frequency that would be required, and to verify that neither is near the extremes of the feeder capability.
SCREW-TYPE DRY FEEDER

HOPPER

MOTOR

GEAR REDUCER

FEED RATE REGISTER AND FEED ADJUSTING KNOB

SOLUTION CHAMBER

ROTATING AND RECIPROCATING FEED SCREW

VACUUM BREAKER

WATER INLET

JET MIXER
ROLL-TYPE DRY FEEDER

FLOAT

HOPPER

GUIDE VANES

FEED SLIDE

FEED ROLLS

MOTOR-DRIVEN AGITATOR

TO DISSOLVING CHAMBER

MOTOR
"LOSS-IN-WEIGHT" TYPE DRY FEEDER

- CONTROL PANEL
- RATE SETTER
- SCALE BEAM
- TRANSITION HOPPER
- HELIX TYPE FEEDER MECH
- VARIABLE RATE SPEED SET FROM PHOTOCELL
- VARIABLE SPEED FEEDER MOTOR
DRY FEEDER OPERATIONS PROBLEM

To determine the accuracy and reliability of a dry feeder, a small balance or scales and a stopwatch, or a watch with a sweep second hand, are required. Insert a shallow pan or sheet of cardboard between the measuring mechanism and dissolving chamber of the feeder while the feeder is operating, making sure that all the chemical that feeds through will be collected. Collect the chemical that is fed in several short periods; for example, 5 periods of 5 min each. Weigh each of the amounts collected and the total. Provided the weighings and timings are accurate, the individual samples will indicate the uniformity of feed, and the total will indicate the accuracy of feed rate.

Example: Weights of sodium silicofluoride in grams collected in 5-min periods

<table>
<thead>
<tr>
<th>Amounts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>

Total: 175
Average: 35 g/min

Uniformity: \( \frac{35 \pm 1}{5} \text{ g in 5 min} \) (about 3 percent variation)

Feed rate: \( \frac{35 \text{ g}}{5 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ hr}} = 420 \text{ g/hr or 0.925 lb/hr} \)

The uniformity of feed in this case would be acceptable. If fluoride levels are to be maintained within 10 percent, the feeder delivery rate should be maintained at the highest accuracy possible. Repeating a test with longer sampling periods would tend to show a smaller percentage of variations if the feeder is in proper working condition.
**FLUORIDATION AUXILIARY EQUIPMENT**

1. Meters
2. Scales
3. Softeners
4. Mixers
5. Dissolving Tanks
6. Flow Meters
7. Day Tanks
8. Bag Loaders
9. Dust Collectors and Wet Scrubbers
10. Alarms
11. Vacuum Breakers
12. Hoppers
13. Height Recorders
14. Controllers
15. Eductors
16. Pumps
17. Timers
18. Hopper Agitators
19. Flow-Splutters
4.7.1 Fluoride compound storage

Compounds shall be stored in covered or unopened shipping containers and should be stored inside a building. Unsealed storage units for hydrofluosilicic acid should be vented to the atmosphere at a point outside any building.

4.7.2 Chemical feed equipment and methods

In addition to the requirements in Part 5, fluoride feed equipment shall meet the following requirements:

a. scales or loss-of-weight recorders shall be provided for dry chemical feeds,
b. feeders shall be accurate to within five percent of any desired feed rate,
c. to avoid precipitation of fluoride, the fluoride compound should not be added before lime-soda softening and shall not be added before ion exchange softening,
d. the point of application of hydrofluosilicic acid, if into a horizontal pipe, shall be in the lower half of the pipe,
e. a fluoride solution shall be applied by a positive displacement pump having a stroke rate, not less than 20 strokes per minute,
f. adequate anti-siphon devices shall be provided for all fluoride feed lines.

4.7.3 Protective equipment

At least one pair of rubber gloves, a respirator of a type certified by the National Institute for Occupational Safety and Health for toxic dusts or acid gas (as necessary), an apron, or other protective clothing, and goggles or face masks shall be provided for each operator. Other protective equipment must be provided as necessary.

4.7.4 Dust control

a. Provision must be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers in such a way as to minimize the quantity of fluoride dust which may enter the room in which the equipment is installed. The enclosure shall be provided with an exhaust fan and dust filter which place the hopper under a negative pressure. Air exhausted from fluoride handling equipment shall discharge through a dust filter to the outside atmosphere of the building.

b. Provision shall be made for disposing of empty bags, drums or barrels in a manner which will minimize exposure to fluoride dusts. A floor drain should be provided to facilitate the hosing of floors.
## Fluoridation Check List

<table>
<thead>
<tr>
<th>Chemical And System</th>
<th>Sodium Fluoride Manual Solution Preparation</th>
<th>Sodium Fluoride Automatic Solution Preparation</th>
<th>Fluosilicic Acid Diluted</th>
<th>Fluosilicic Acid 23 - 30%</th>
<th>Sodium Silicofluoride Or Sodium Fluoride, Dry Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Flow Rate</strong></td>
<td>Less Than 50 gpm</td>
<td>Less Than 2000 gpm</td>
<td>Less Than 50 gpm</td>
<td>More Than 50 gpm</td>
<td>More Than 100 gpm</td>
</tr>
<tr>
<td><strong>Population Served By System Or Each Well Of Multiple-Well System</strong></td>
<td>Less Than 5000</td>
<td>Less Than 10,000</td>
<td>Less Than 10,000</td>
<td>More Than 10,000</td>
<td>More Than 10,000</td>
</tr>
<tr>
<td><strong>Chemical Cost, FOB Manufacturer</strong></td>
<td>22 - 25¢/lb</td>
<td>20 - 22¢/lb</td>
<td>8 - 15¢/lb (30% Basis)</td>
<td>$51 - $58/ton (23% Basis)</td>
<td>9 - 10¢/lb</td>
</tr>
<tr>
<td><strong>Chemical Cost/lb</strong></td>
<td>50 - 57¢</td>
<td>46 - 50¢</td>
<td>33 - 63¢</td>
<td>14 - 16¢</td>
<td>15 - 17¢</td>
</tr>
<tr>
<td><strong>Equipment Cost/Unit</strong></td>
<td>$100 - $500</td>
<td>$500 - $1000</td>
<td>$250 And Up</td>
<td>$500 And Up</td>
<td>$1,000 And Up</td>
</tr>
<tr>
<td><strong>Equipment Required</strong></td>
<td>Solution Feeder, Mixing Tank, Scales, Mixer</td>
<td>Solution Feeder, Saturator, Water Meter</td>
<td>Solution Feeder, Scales, Measuring Container, Mixing Tank, Mixer</td>
<td>Solution Feeder, Day Tank, Scales, Transfer Pump</td>
<td>Volumetric Dry Feeder, Scales, Hoppers, Dissolving Chamber</td>
</tr>
<tr>
<td><strong>Feed Accuracy</strong></td>
<td>Depends On Solution Preparation And Feeder</td>
<td>Depends On Feeder</td>
<td>Depends On Solution Preparation And Feeder</td>
<td>Depends On Feeder</td>
<td>Usually Within 3%</td>
</tr>
<tr>
<td><strong>Chemical Specifications And Availability</strong></td>
<td>Crystalline NaF, Dust-Free, In Bags Or Drums, Generally Available.</td>
<td>Low-Silica Or Fortified Acid In Drums Or Carboys, Generally Available.</td>
<td>Bulk Acid In Tank Casks Or Trucks, Available On Contract</td>
<td>Powder In Bags, Drums Or Bulk, Generally Available.</td>
<td></td>
</tr>
<tr>
<td><strong>Handling Requirements</strong></td>
<td>Weighing, Mixing, Measuring</td>
<td>Dumping Whole Bags Only</td>
<td>Pouring Or Siphoning, Measuring, Mixing, Weighing</td>
<td>All Handling By Pump</td>
<td>Bag Loaders Or Bulk Handling Equipment Required</td>
</tr>
<tr>
<td><strong>Feeding Point</strong></td>
<td>Injection Into Filter Effluent Line Or Main</td>
<td>Injection Into Filter Effluent Line Or Main</td>
<td>Injection Into Filter Effluent Line Or Main</td>
<td>Gravity Feed From Dissolving Chamber Into Open Flume Or Clear-Well, Pressure Feed Into Filter Effluent Line Or Main</td>
<td></td>
</tr>
<tr>
<td><strong>Other Requirements</strong></td>
<td>Solution Water May Require Softening</td>
<td>Solution Water May Require Softening</td>
<td>Acid-Proof Storage Tank, Piping, Etc.</td>
<td>Dry Storage Area, Dust Collectors, Dissolving-Chamber Mixers, Hopper Agitators, Eductors, Etc.</td>
<td></td>
</tr>
<tr>
<td><strong>Hazards</strong></td>
<td>Dust, Spillage, Solution Preparation Error</td>
<td>Dust, Spillage</td>
<td>Corrosion, Fumes, Spillage, Solution Preparation Error</td>
<td>Dust, Spillage, Arching And Flooding In Feeder And Hopper</td>
<td></td>
</tr>
</tbody>
</table>

### Additional Information
- **Chemical Cost, FOB Manufacturer**
  - Sodium Silicofluoride: 9 - 10¢/lb
  - Sodium Fluoride: 8 - 9¢/lb
- **Equipment Cost/Unit**
  - Solution Feeder: $100 - $500
  - Mixing Tank, Scales, Mixer: $500 - $1000
- **Feed Accuracy**
  - Depends On Solution Preparation And Feeder
  - Usually Within 3%
- **Chemical Specifications And Availability**
  - Crystalline NaF, Dust-Free, In Bags Or Drums, Generally Available.
  - Low-Silica Or Fortified Acid In Drums Or Carboys, Generally Available.
  - Bulk Acid In Tank Casks Or Trucks, Available On Contract
- **Handling Requirements**
  - Weighing, Mixing, Measuring
  - Dumping Whole Bags Only
  - Pouring Or Siphoning, Measuring, Mixing, Weighing
- **Feeding Point**
  - Injection Into Filter Effluent Line Or Main
  - Gravity Feed From Dissolving Chamber Into Open Flume Or Clear-Well, Pressure Feed Into Filter Effluent Line Or Main
- **Other Requirements**
  - Solution Water May Require Softening
  - Dry Storage Area, Dust Collectors, Dissolving-Chamber Mixers, Hopper Agitators, Eductors, Etc.
- **Hazards**
  - Dust, Spillage, Arching And Flooding In Feeder And Hopper
MONITORING REQUIREMENTS

A. ENVIRONMENTAL PROTECTION AGENCY
   1. DRINKING WATER STANDARDS
      A) SURFACE WATER SUPPLIES
         ONE SAMPLE PER YEAR
      B) GROUND WATER SUPPLIES
         ONE SAMPLE PER TWO YEARS
   2. FLUORIDATION PROGRAM
      A) ONE SAMPLE PER DAY AT PLANT AND AT SOME POINT IN THE DISTRIBUTION SYSTEM.

B. IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY
   1. DAILY SAMPLING AT THE PLANT
   2. MONTHLY REFEREE SAMPLES FROM THE STATE HYGENICS LABORATORY
LABORATORY CONTROL

A. Alizarin method
B. SPADIS method
C. Electrode method
DEFLUORIDATION

A. Activated Alumina
   Regenerated with 1% Solution of Caustic Soda

B. Bone Char
   Regenerated with 1% Solution of Caustic Soda

C. Ion Exchange
CLASS PROBLEMS
for
Training Module II2WWS
CLASS PROBLEM #1

1. If a water supply serves an area with an annual maximum daily air temperature of 70°F and has a natural fluoride concentration of 7.0 mg/l:
   a) What fluoridation system should be used?
   b) What will be the optimal concentration?
   c) What will be the maximum allowable concentration?
   d) What will be the recommended minimum concentration?
CLASS PROBLEM #2

1. A community of 2,000 people is considering a new fluoridation system. The current water supply is a well water having a natural background fluoride concentration of 0.5 mg/l.

   a. If the average maximum air temperature is 75°F, what should the fluoride concentration be adjusted to?

   b. What fluoridation feeding system would be the most economical? Approximately what would the cost be?

   c. If the community uses 150,000 gallons per day, what will be the chemical cost?
CLASS HANDOUT

for

Training Module II2WWS.
Handout for II2WWS - Fluoridation and Defluoridation

I. Introduction
A. History of fluoridation
B. Benefits of fluoridation
C. Drinking water standards

| Annual Average of Maximum Daily Air Temperatures Based on Temperature Data Obtained for a Minimum of 5 Years (°F) | Fluoride-Ion Concentrations (mg/l) |
|---|---|---|---|---|
| | Lower | Optimum | Upper | Approval Limit |
| 50.0-53.7 | 0.9 | 1.2 | 1.7 | 1.8 |
| 53.8-58.3 | 0.8 | 1.1 | 1.5 | 1.7 |
| 58.4-63.8 | 0.8 | 1.0 | 1.3 | 1.5 |
| 63.9-70.6 | 0.7 | 0.9 | 1.2 | 1.4 |
| 70.7-79.2 | 0.7 | 0.8 | 1.0 | 1.2 |
| 79.3-90.5 | 0.6 | 0.7 | 0.8 | 1.1 |


II. Principles of Fluoridation
A. Sodium fluoride
B. Fluosilicic Acid
C. Sodium Silicofluoride
D. Summary of fluoride compounds
<table>
<thead>
<tr>
<th>Item</th>
<th>Sodium Fluoride NaF</th>
<th>Sodium Silico-fluoride Na$_2$SiF$_6$</th>
<th>Fluosilicic Acid H$_2$SiF$_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Form</strong></td>
<td>Powder or crystal</td>
<td>Powder or very fine crystal</td>
<td>Liquid</td>
</tr>
<tr>
<td><strong>Molecular weight</strong></td>
<td>42.00</td>
<td>188.05</td>
<td>144.08</td>
</tr>
<tr>
<td><strong>Commercial purity—per cent</strong></td>
<td>90-98</td>
<td>98-99</td>
<td>22-30</td>
</tr>
<tr>
<td><strong>Fluoride ion—per cent</strong></td>
<td>42.25</td>
<td>60.7</td>
<td>79.2</td>
</tr>
<tr>
<td>(100 per cent pure material)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pounds required per mg for 1.0 ppm F at indicated purity</strong></td>
<td>18.8</td>
<td>14.0</td>
<td>35.2</td>
</tr>
<tr>
<td>(98 per cent)</td>
<td>(98.5 per cent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>pH of saturated solution</strong></td>
<td>7.6</td>
<td>7.5</td>
<td>1.2 (1 per cent solution)</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td>α-δ</td>
<td>d, δ, h</td>
<td>d-f, h, i, j</td>
</tr>
<tr>
<td><strong>F ion storage space— cuF/100lb</strong></td>
<td>22-34</td>
<td>23-30</td>
<td>54-73</td>
</tr>
<tr>
<td><strong>Solubility—at 25°C</strong></td>
<td>4.05</td>
<td>0.262</td>
<td>Infinite</td>
</tr>
<tr>
<td>g/100 g water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weight—lb/cu ft</strong></td>
<td>65-90</td>
<td>55-72</td>
<td>10.5 lb/gal (30 per cent)</td>
</tr>
<tr>
<td><strong>Cost:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cents/lb</td>
<td>18.25</td>
<td>8-10</td>
<td>22-15</td>
</tr>
<tr>
<td>Cents/lb available F</td>
<td>41-57</td>
<td>13-17</td>
<td>14-63</td>
</tr>
<tr>
<td><strong>Shipping containers</strong></td>
<td>100-lb bags</td>
<td>100-lb bags</td>
<td>13-gal carboys</td>
</tr>
<tr>
<td></td>
<td>125-400-lb</td>
<td>125-400-lb</td>
<td>55-gal drums, bulk</td>
</tr>
</tbody>
</table>

- Ceramic crocks or other corrosion-resistant containers.
- Conditioning make-up water to minimize clogging by sludge.
- Respirator (dust mask).
- Rubber gloves.
- Residual.
- Weighing scales.
- Polyphosphate feed to stabilize solution and minimize incrustation.
- Automatic stop-start controls.
- Acidproof aprons.
- Industrial goggles for protection against acid.
III. Solution Feeders Used for Adding Fluoride
   A. Typical solution feeders
   B. Typical dilute acid feeder
   C. Positive displacement solution feeders

IV. Dry Feeders Used for Adding Fluoride
   A. Screw-Type
   B. Roll-Type
   C. Belt-Type
   D. "Loss-In-Weight" Type

V. Selection of Optimal Fluoridation System
   A. Auxiliary Equipment
   B. Ten States Standards

4.7 FLUORIDATION

Commercial sodium fluoride, sodium silicofluoride and hydrofluosilicic acid shall conform to the applicable AWWA standards. Other fluoride compounds which may be available must be approved by the reviewing authority. The proposed method of fluoride feed must be approved by the reviewing authority prior to preparation of final plans and specifications.

4.7.1 Fluoride compound storage

Compounds shall be stored in covered or unopened shipping containers and should be stored inside a building. Unsealed storage units for hydrofluosilicic acid should be vented to the atmosphere at a point outside any building.

4.7.2 Chemical feed equipment and methods

In addition to the requirements in Part 5, fluoride feed equipment shall meet the following requirements:

a. scales or loss-of-weight recorders shall be provided for dry chemical feeds,

b. feeders shall be accurate to within five percent of any desired feed rate,

c. to avoid precipitation of fluoride, the fluoride compound should not be added before lime-soda softening and shall not be added before ion exchange softening,

d. the point of application of hydrofluosilicic acid, if into a horizontal pipe, shall be in the lower half of the pipe,

e. a fluoride solution shall be applied by a positive displacement pump having a stroke rate not less than 20 strokes per minute,

f. adequate anti-siphon devices shall be provided for all fluoride feed lines.
4.7.3 Protective equipment

At least one pair of rubber gloves, a respirator of a type certified by the National Institute for Occupational Safety and Health for toxic dusts or acid gas (as necessary), an apron, or other protective clothing, and goggles or face masks shall be provided for each operator. Other protective equipment must be provided as necessary.

4.7.4 Dust control

a. Provision must be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers in such a way as to minimize the quantity of fluoride dust which may enter the room in which the equipment is installed. The enclosure shall be provided with an exhaust fan and dust filter which place the hopper under a negative pressure. Air exhausted from fluoride handling equipment shall discharge through a dust filter to the outside atmosphere of the building.

b. Provision shall be made for disposing of empty bags, drums or barrels in a manner which will minimize exposure to fluoride dusts. A floor drain should be provided to facilitate the hosing of floors.

4.7.5 Testing equipment

Equipment shall be provided for measuring the quantity of fluoride in the water. Such equipment shall be subject to the approval of the reviewing authority.

C. Fluoridation Check List

(See Figure #1)

VI. Analytical Control

A. Monitoring requirements
   1. Environmental Protection Agency
      a. Drinking Water Standards
         1) Surface water supplies
            one sample per year
         2) Ground water supplies
            one sample per two years
      b. Fluoridation Program
         1) One sample per day at plant and at some point in the distribution system
   2. Iowa Department of Environmental Quality
      a. Daily sampling at the plant
      b. Monthly referee samples from the State Hygienics Laboratory

B. Laboratory Control
   1. Alizarin Method
   2. SPADNS Method
   3. Electrode Method
VII. Defluoridation
A. Activated Alumina
B. Bone Char
C. Ion Exchange
<table>
<thead>
<tr>
<th>Chemical And System</th>
<th>Sodium Fluoride Manual Solution Preparation</th>
<th>Sodium Fluoride Automatic Solution Preparation</th>
<th>Fluosilicic Acid Diluted</th>
<th>Fluosilicic Acid 23 - 30%</th>
<th>Sodium Silicofluoride Or Sodium Fluoride Dry Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Flow Rate</td>
<td>Less Than 500 gpm</td>
<td>Less Than 2000 gpm</td>
<td>Less Than 500 gpm</td>
<td>More Than 500 gpm</td>
<td>More Than 100 gpm</td>
</tr>
<tr>
<td>Population Served By System Or Each Well Of Multiple-Well System</td>
<td>Less Than 5000</td>
<td>Less Than 10,000</td>
<td>Less Than 10,000</td>
<td>More Than 10,000</td>
<td>More Than 10,000</td>
</tr>
<tr>
<td>Chemical Cost, FOB Manufacturer</td>
<td>22 - 25¢/lb</td>
<td>20 - 22¢/lb</td>
<td>8 - 15¢/lb (30% Basis)</td>
<td>$51 - $58/ton (23% Basis)</td>
<td>$9 - 10¢/lb</td>
</tr>
<tr>
<td>Chemical Cost/lb Fluoride Ion</td>
<td>50 - 57¢</td>
<td>46 - 50¢</td>
<td>33¢ - 63¢</td>
<td>$14 - $16¢</td>
<td>$15 - $17¢</td>
</tr>
<tr>
<td>Equipment Cost/Unit</td>
<td>$100 - $500</td>
<td>$500 - $1000</td>
<td>$250 And Up</td>
<td>$500 And-Up</td>
<td>$1,000 And-Up</td>
</tr>
<tr>
<td>Equipment Required</td>
<td>Solution Feeder, Mixing Tank, Scales, Mixer</td>
<td>Solution Feeder, Saturator, Water Meter</td>
<td>Solution Feeder, Saturator, Water Meter</td>
<td>Solution Feeder, Day Tank, Scales, Transfer Pump</td>
<td>Volumetric Dry Feeder, Scales, Hopper, Dissolving Chamber</td>
</tr>
<tr>
<td>Feed Accuracy</td>
<td>Depends On Solution Preparation And Feeder</td>
<td>Depends On Feeder</td>
<td>Depends On Solution Preparation And Feeder</td>
<td>Depends On Feeder</td>
<td>Usually Within 3%</td>
</tr>
<tr>
<td>Chemical Specifications And Availability</td>
<td>Crystalline NaF, Dust-Free, In-Bags Or Drums, Generally Available.</td>
<td>Downflow - Coarse Crystalline NaF In Bags Or Drums May Be Scarce. Upflow - Fine Crystalline NaF</td>
<td>Low-Silica Or Fortified Acid In Drums Or Carboys Generally Available.</td>
<td>Bulk Acid In Tank Cars Or Trucks, Available On Contract</td>
<td></td>
</tr>
<tr>
<td>Handling Requirements</td>
<td>Weighing, Mixing, Measuring</td>
<td>Dumping Whole Bags Only</td>
<td>Pouring Or Siphoning, Measuring, Mixing, Weighing</td>
<td>All Handling By Pump</td>
<td>Bag Loaders Or Bulk Handling Equipment Required</td>
</tr>
<tr>
<td>Feeding Point</td>
<td>Injection Into Filter Effluent Line Or Main</td>
<td>Injection Into Filter Effluent Line Or Main</td>
<td>Injection Into Filter Effluent Line Or Main</td>
<td>Injection Into Filter Effluent Line Or Main</td>
<td>Gravity Feed From Dissolving Chamber Into Open Flume Or Clear-Well Pressure Feed Into Filter Effluent Line Or Main</td>
</tr>
<tr>
<td>Other Requirements</td>
<td>Solution Water May Require Softening</td>
<td>Solution Water May Require Softening</td>
<td>Dilution Water May Require Softening</td>
<td>Acid-Proof Storage, Tank, Piping, Etc.</td>
<td>Dry Storage Area, Dust Collectors, Dissolving-Chamber Mixers, Hopper Agitators, Eductors, Etc.</td>
</tr>
<tr>
<td>Hazards</td>
<td>Dust, Spillage, Solution Preparation Error</td>
<td>Dust, Spillage</td>
<td>Corrosion, Fumes, Spillage, Solution Preparation Error</td>
<td>Corrosion, Fumes, Leakage</td>
<td>Dust, Spillage, Arching And Flooding In Feeder And Hopper</td>
</tr>
</tbody>
</table>

**Figure II2-MS-71**
EXAMINATION
for
Training Module II2WWS
Examination for II2WWS - Fluoridation and Defluoridation

1. Fluoridation is a common water treatment process for the prevention of __________.

2. Maximum fluoride levels in drinking water have been set by __________.

3. The maximum fluoride level in drinking water depends on __________.

4. List three common chemicals used in fluoridation.
   a. __________
   b. __________
   c. __________

5. List four dry fluoride feeds.
   a. __________
   b. __________
   c. __________
   d. __________

6. List three laboratory tests used to control fluoridation.
   a. __________
   b. __________
   c. __________

7. Defluoridation is generally accomplished using __________ or __________.

8. Monitoring requirements state that samples are to be collected daily at __________
   and __________.

9. If a water plant adds .6 mg/l of fluoride to 1 mgd, how many pounds of fluoride will be needed per day? __________. If the fluoride is added by use of a 20% solution, how many gallons of fluoride solution will be pumped per day? __________.

TRUE OR FALSE. CIRCLE THE CORRECT ANSWER.

T or F 10. Fluoride solutions are very soluble in high calcium waters.
T or F 11. Fluoride benefits increase with increased concentration.
T or F 12. Fluosilicic Acid is usually shipped as a powder.
T or F 13. Solution feeders are normally less expensive and easier to operate than dry feeders.
T or F 14. Dry feeders are normally more economical for large water supplies.
T or F 15. A respirator and eye protection should always be used when handling dry fluoride chemicals.

T or F 16. Softeners or polyphosphates are normally required for solution feeders.

T or F 17. DEQ requires referee samples be tested by plant operators and the State Hygienic Laboratory.

T or F 18. The electrode method for fluoride determination is the only one method approved by EPA.

T or F 19. Defluoridation systems are normally regenerated with caustic soda.