This document is an instructional module package prepared in objective form for use by an instructor familiar with ion exchange softening. It includes objectives, an instructor guide, student handouts, and transparency masters. This is the first level of a three-module series. The module considers the principles, components, operation, maintenance, laboratory control and safety for ion exchange softening units. It is designed for individuals with little or no operating experiences. (Author/RH)
BASIC ION EXCHANGE SOFTENING

Training Module 2.210.2.77

Prepared for the
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Des Moines, Iowa  50319

by

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September, 1977
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## II. TRANSPARENCIES

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<td>Basic Components of a Softener</td>
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<tr>
<td>Preventative Maintenance</td>
<td>#18</td>
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<td>Safety</td>
<td>#19</td>
</tr>
<tr>
<td>Laboratory Control</td>
<td>#20</td>
</tr>
<tr>
<td>Soap Test</td>
<td></td>
</tr>
</tbody>
</table>

## III. CLASS PROBLEMS

| Problem #1                                                            |      |
| Part A                                                                |      |
| Part B                                                                |      |
| Problem #2                                                            |      |
| Problem #3                                                            |      |
| Problem #4                                                            |      |

## IV. CLASS HANDOUT

|                                      |      |

## V. EXAMINATION

|                                      | 3    |
INSTRUCTOR GUIDE

for

Training Module I12SWS
Module No: II2SWS
Module Title: Basic Ion Exchange Softening
Submodule Title:
Approx. Time: 10 hours.

<table>
<thead>
<tr>
<th>Topic:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary</td>
</tr>
</tbody>
</table>

Objectives: Upon completion of this module, the participant will be able to:
1. Describe the operation of a basic ion exchange softener.
2. Describe the maintenance of a basic ion exchange softener.
3. Describe the laboratory control necessary for ion exchange.
4. Describe the safety requirements for ion exchange softening.

Instructional Aids:
1. Handout
2. Transparencies #1-#20

Instructional Approach:
Discussion and Class Problems

References:
1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service
3. Elements of Ion Exchange, Kunin
4. Standard Methods for the Examination of Water and Wastewater, 14th Ed.
5. Methods for Chemical Analysis of Water and Waste, EPA

Class Assignments:
- The participant will
  1. Read Handout
  2. Complete Problems #1-#4
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Discuss and identify the purpose, operation, maintenance, laboratory control and safety requirements for ion exchange softening.</td>
</tr>
<tr>
<td></td>
<td>2. Give evaluation of 30 questions.</td>
</tr>
<tr>
<td>1. Distribute Handout</td>
<td></td>
</tr>
<tr>
<td>2. Present Transparencies</td>
<td></td>
</tr>
</tbody>
</table>
Module No: 112SWS
Module Title: Basic Ion Exchange Softening
Submodule Title: 
Approx. Time: 1/2 hour
Topic: Introduction

Objectives: Upon completion of this topic, the participant will be able to:
1. Describe what hardness is.
2. Describe what ion exchange softening is.
3. State advantages of ion exchange softening.
4. State disadvantages of ion exchange softening.

Instructional Aids:
1. Handout - Introduction
2. Transparency #1 - What is Hardness.
3. Transparency #2 - What is Softening.
4. Transparency #3 - Advantages of ion exchange.
5. Transparency #4 - Disadvantages of ion exchange.

Instructional Approach:
Discussion

References:
1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service
3. Elements of Ion Exchange, Kunin

Class Assignments:
The participant will
1. Read Handout - Introduction
**Module No:** II2SWS  
**Topic:** Introduction

<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
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</thead>
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<tr>
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</tr>
</tbody>
</table>

1. Present Transparency #1

1. Discuss What Hardness Is.
   a. Chemical Components of Hardness
   b. Types of Hardness
      1) Carbonate
      2) Non carbonate
   c. Typical Hardnesses in the U.S.
   d. Typical Hardnesses in Iowa.

2. Present Transparency #2

2. Discuss What Softening Is.
   a. Removal of Hardness
   b. Types of Softening
      1) Chemical
      2) Ion exchange

3. Present Transparency #3 and #4

3. Why Soften
   a. Advantages
      1. Consume less soap and detergent.
      2. Increase the life of clothing and other articles being cleaned.
      3. Increase the life of pipes and fixtures, heating systems, and boiler shells and tubes for depositing water.
      4. Certain industrial processes require it.
      5. Some indications that hard water may be the cause of certain cardiovascular diseases.
      6. Remove radioactive nuclides.
   b. Disadvantages
      1. With improper control, softened water may be more corrosive or sealing than the raw water.
      2. If ion exchange softening is used, the sodium content of the water is greatly increased with a potential cardiovascular health hazard to certain people.
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
</table>
| 4. Present Transparency #5 Ask the class to provide the instructor with the correct definition for each term and write it on the transparency. | b. Disadvantages (continued)  
3. If ion exchange softening is used, the total dissolved solids of the product water is increased.  
4. With both processes, a waste sludge or waste brine has to be disposed of.  
4. 1. Hardness—The concentration of Calcium, Magnesium and other divalent cations found in water.  
2. Carbonate Hardness—That portion of hardness that is in combination with bicarbonate.  
3. Non Carbonate Hardness—That portion of hardness that is in combination with sulfates, chlorides, nitrates and other anions.  
4. Softening—The removal of hardness ions from the water.  
5. Chemical Softening—The removal of hardness ions by precipitation with lime and soda ash.  
6. Ion Exchange Softening—The removal of hardness ions by exchanging them with sodium ions. |
<table>
<thead>
<tr>
<th>Module No.: II2SW5</th>
<th>Module Title: Basic Ion Exchange Softening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx. Time: 1 hour</td>
<td>Topic: Principles of Ion Exchange Softening</td>
</tr>
</tbody>
</table>

Objectives: Upon completion of this topic, the participant will be able to:
1. Write the chemical reactions for ion exchange softening
2. Write the regeneration reactions for ion exchange softening

Instructional Aids:
- Handout - Principles of Ion Exchange Softening
- Transparency #6 - Softening reactions
- Transparency #7 - Softening reactions in the resin
- Transparency #8 - Regeneration reactions

Instructional Approach:
Discussion and Class problem

References:
1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service
3. Elements of Ion Exchange, Kunin

Class Assignments:
The participant will
1. Read Handout - Principles of Ion Exchange Softening
2. The participant will complete Problem #1 on chemical reactions.
### Instructor Outline:

<table>
<thead>
<tr>
<th>Instructor Notes</th>
<th></th>
<th>Instructor Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Present Transparency #6</td>
<td><strong>1. Discuss the softening reactions.</strong></td>
<td></td>
</tr>
<tr>
<td>2. Present Transparency #7</td>
<td>( { \text{Ca}} \left( \begin{array}{c} \text{HCO}_3 \text{Mg} \ \text{SO}_4 \text{Cl}_2 \end{array} \right) + \text{Na}_2 \text{R} \rightarrow )</td>
<td></td>
</tr>
<tr>
<td>3. Present Transparency #8</td>
<td>( \text{Na}_2 \left( \begin{array}{c} \text{HCO}_3 \ \text{SO}_4 \text{Cl}_2 \end{array} \right) + { \text{Ca}} \text{R} \rightarrow )</td>
<td></td>
</tr>
<tr>
<td>4. Repeat Transparency #7</td>
<td><strong>2. Discuss the reactions taking place inside the resin.</strong></td>
<td></td>
</tr>
<tr>
<td>5. Present class Problem #1</td>
<td><strong>3. Discuss the regeneration reactions.</strong></td>
<td></td>
</tr>
<tr>
<td>Work part A. with class participation. Have class work part B. on their own and help those with problems.</td>
<td>( { \text{Ca}} \text{R} + 2 \text{Na Cl} \rightarrow )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \text{Na}_2 \text{R} + { \text{Ca}} \text{Cl}_2 \rightarrow )</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>4. Discuss the reaction taking place inside the resin.</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Part A</td>
<td></td>
</tr>
<tr>
<td>1. 2 moles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. ( \frac{250 \text{ mg/l}}{162 \text{ mg/m mole}} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2 moles) ( \frac{23 \text{ mg/m mole}}{\text{m mole}} ) = 71 mg/l Na increase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. ( \frac{250 \text{ mg/l}}{162 \text{ mg/m mole}} ) ( \frac{40 \text{ mg/m mole}}{\text{m mole}} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>= 62 mg/l Ca originally</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>solids increase = 71-62 = 9 mg/l</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Instructor Notes:

Instructor Outline:

5. Part B
   1. 2
   2. \(\frac{250 \text{ mg/l}}{120 \text{ mg/m mole}} \times 2 \text{ moles} = \frac{23 \text{ mg/m mole}}{250 \text{ mg/l}} \times 120 \text{ mg/m mole} = 95 \text{ mg/l}\) Na increase for Mg
      \[\text{total increase} = 71 + 95 = 106 \text{ mg/l}\] Na increase
   3. \(\frac{250 \text{ mg/l}}{120 \text{ mg/m mole}} \times 25 \text{ mg/m mole} = 50 \text{ mg/l}\) Mg originally
      \[\text{solids increase for Mg would be:}\]
      \[95 - 50 = 45 \text{ mg/l}\]
      \[\text{and total increase would be:}\]
      \[9 + 45 = 54 \text{ mg/l}\]
<table>
<thead>
<tr>
<th>Module No:</th>
<th>Module Title:</th>
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<tr>
<td>II2SWS</td>
<td>Basic Ion Exchange Softening</td>
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<th>Approx. Time:</th>
<th>Topic:</th>
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<tbody>
<tr>
<td>1 hour</td>
<td>Components of Ion Exchange Softener</td>
</tr>
</tbody>
</table>

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

1. Identify the basic components of an Ion Exchange Softener.

Instructional Aids:

1. Handout - Components of Ion Exchange Softener
2. Transparency #9 - Basic Components of an Ion Exchange Softener
3. Transparency #10 - Basic Components of a brine tank

Instructional Approach:

Discussion

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service
3. Elements of Ion Exchange, Kunin

Class Assignments:

The participant will

1. Read Handout - Components of Ion Exchange Softener
2. Complete Problem #2 identifying components of a softener.
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
</table>
| 1. Present Transparency #9 | 1. Discuss the Components of the Softener.  
| 2. Present Transparency #10 |   a. Identify each  
| 3. Present Class Problem #2 |   b. Purpose of each  
|   Have class match name of component with number on their own. Then work the problem with class participation. | 2. Discuss the components of the Brine Tank  
| |   a. Identify each  
| |   b. Purpose of each  
| | 3. Review the components and purpose in working the problem. |
Module No: II2SWS
Module Title: Basic Ion Exchange Softening
Submodule Title:
Approx. Time: 2 hour
Topic: Basic Operation of Ion Exchange Softener

Objectives: Upon completion of this topic, the participant will be able to:
1. State the steps necessary to regenerate a softener.
2. State the reason for each step of regeneration.
3. Compute when a softener should be regenerated.

Instructional Aids:
1. Handout - Basic Operation of Ion Exchange Softening
2. Transparency #11 - Softener regeneration
3. Transparency #12 - Calculations for regeneration
4. Transparency #13 - Typical data sheet

Instructional Approach:
Discussion and class problem

References:
1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service
3. Elements of Ion Exchange, Kunin

Class Assignments:
1. The participant will read Handout - Basic Operation of Ion Exchange Softening
2. The participant will complete Problem #3 calculating when a softener should be regenerated and how much salt should be added to the softener.
## Instructor Notes:

1. Present Transparency #11
2. Present Transparency #12
3. Present Transparency #13
4. Present Class Problem #3
   Have class work problem on their own. Then work the problem with class participation.

## Instructor Outline:

1. Discuss the Regeneration of a softener.
   a. Identify which valves are to be opened and closed.
   b. Discuss the reason for each step.
2. Discuss the pounds of salt required to regenerate a softener.
3. Discuss the items on the data sheet and their importance.
4. Review the salt dosage for regeneration in working the problem.
   a. \((174) (11,500) = 1,000,000\) grains capacity water contains \(170/17 = 10\) grains hardness:
      for full exhaustion capacity is \(1,000,000/10 = 100,000\) gallons of water
   b. \((100,000) (2/3) = 66,667\) gallons of water
   c. \((.5) (1000) = 500\) lbs of salt
   d. \((.3) (667) = 200\) lbs of salt
<table>
<thead>
<tr>
<th>Module No:</th>
<th>Module Title:</th>
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<tbody>
<tr>
<td>II2SWS</td>
<td>Basic Ion Exchange Softening</td>
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<table>
<thead>
<tr>
<th>Submodule Title:</th>
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<thead>
<tr>
<th>Approx. Time:</th>
<th>Topic:</th>
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<tbody>
<tr>
<td>2 hours</td>
<td>Water Stabilization</td>
</tr>
</tbody>
</table>

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

1. Determine the proper water composition for the water distribution system.
2. Determine the proper chemical feeds to obtain the necessary water stabilization.

**Instructional Aids:**

1. Handout - Water Stabilization
2. Transparency #14 - Factors affecting water stabilization
3. Transparency #15 - Ryznar Index
4. Transparency #16 - Saturation pH

**Instructional Approach:**

Discussion and class problem

**References:**

1. Manual of Instruction for Water Treatment Plant Operators, HEALTH EDUCATION SERVICE
3. Elements of Ion Exchange, Kunin

**Class Assignments:**

1. The participant will read Handout-Water Stabilization
2. The participant will complete Problem #4-Water Stabilization
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
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</thead>
<tbody>
<tr>
<td>1. Present Transparency #14</td>
<td>1. Discuss the factors and their importance in water stabilization. Discuss by passing water to achieve a 80 mg/l finished water.</td>
</tr>
<tr>
<td>2. Present Transparency #15</td>
<td>2. Discuss the Reizener curve and equation. Point out the index is only a guide and not absolute. For cold water a S.I. of 6.0 is a good starting point.</td>
</tr>
<tr>
<td>3. Present Transparency #16</td>
<td>3. Discuss the use of the diagram for use in calculating pHs. Work problem at bottom of diagram.</td>
</tr>
<tr>
<td>4. Present Class Problem #4 Have class work problem on their own. Then work the problem with class participation.</td>
<td>4. Review the idea of bypassing to obtain the desired water. Then calculate the proper finished water pH.</td>
</tr>
</tbody>
</table>

\[ \text{a) } \frac{80}{360} \times 100 = 27\% \]

\[ \text{b) Hardness } = 360 \times 0.27 \% = 80 \, \text{mg/l as CaCO}_3 \]
\[ \text{Calcium } = 180 \times 0.27 \% = 49 \, \text{mg/l as CaCO}_3 \]
\[ \text{Alkalinity } = 300 \, \text{mg/l as CaCO}_3 \]
\[ \text{Temperature } = 60^\circ \text{F} \]
\[ \text{pH} = 7.3 \]
\[ \text{Total Dissolved Solids } = 1000 \, \text{mg/l} \]

Note: TDS has little effect on pH's; therefore, assume a value slightly higher than natural water.

\[ \text{c) pHs } = 9.30 + \frac{0.2}{1} + 2.07 - 1.31 - 2.49 = 7.77 \]
\[ \text{pH } = 2(7.77) - 6.0 = 9.5 \]
Module No: II2SWS
Module Title: Basic Ion Exchange Softening
Submodule Title:
Approx. Time: 1/2 hour
Topic: Preventative Maintenance

Objectives: Upon completion of this topic, the participant will be able to:
1. State those items necessary for a basic preventive maintenance program.

Instructional Aids:
1. Handout - Preventative Maintenance
2. Transparency 17 - Preventative Maintenance

Instructional Approach:
Discussion

References:
1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service
3. Elements of Ion Exchange, Kunin

Class Assignments:
1. The participant will read Handout - Preventative Maintenance
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
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</thead>
<tbody>
<tr>
<td>1. Present Transparency #17</td>
<td>1. Discuss Preventative Maintenance for a zeolite softener.</td>
</tr>
<tr>
<td>Module No: II2SWS</td>
<td>Module Title: Basic Ion Exchange Softening</td>
</tr>
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</tr>
<tr>
<td>Approx. Time: 1/2-hour</td>
<td>Submodule Title: Safety</td>
</tr>
</tbody>
</table>

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

1. State the potential hazards in operating a ion exchange softener.
2. State the proper corrective measures to minimize safety hazards.
3. State the proper actions required after an accident.

Instructional Aids:
1. Handout - Safety
2. Transparency #18 - Safety

Instructional Approach:
Discussion

References:
3. *Elements of Ion-Exchange*, Kunin

Class Assignments:
1. The participant will read Handout - Safety
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Present Transparency #18</td>
<td>1. Discuss safety in operating a zeolite softener.</td>
</tr>
<tr>
<td>Module No: II2SWS</td>
<td>Module Title: Basic Ion Exchange Softening</td>
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<tr>
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</tr>
<tr>
<td></td>
<td>Submodule Title:</td>
</tr>
<tr>
<td>Approx. Time: 1½ hour</td>
<td>Topic: Laboratory Control</td>
</tr>
</tbody>
</table>

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

1. Select the proper analytical tests for operational control.
2. Explain the necessary analytical tests for operational control.
3. Interpret the results of analytical tests used in operational control.

**Instructional Aids:**

1. Handout - Laboratory Control
2. Transparency #19 - Laboratory Control
3. Transparency #20 - Soup Test

**Instructional Approach:**

Discussion and class problem

**References:**

1. Standard Methods for the 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 - Laboratory Control
Module No: II2SWS  
Topic: Laboratory Control

<table>
<thead>
<tr>
<th>Instructor Notes:</th>
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<tbody>
<tr>
<td>1. Present Transparence #19</td>
</tr>
<tr>
<td>2. Present Transparency #20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructor Outline:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Discuss the various laboratory analysis and the need for each.</td>
</tr>
<tr>
<td>2. Discuss the soap test.</td>
</tr>
<tr>
<td>Module No:</td>
</tr>
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<tr>
<td>I12SWS</td>
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</tbody>
</table>

**Objectives:**
The participant should be able to answer correctly 30 of the 36 questions asked.

**Instructional Aids:**
None

**Instructional Approach:**
Examination

**References:**
None

**Class Assignments:**
None
<table>
<thead>
<tr>
<th>Instructor Notes:</th>
<th>Instructor Outline:</th>
</tr>
</thead>
</table>
| 1. Distribute exam. Each participant is to complete the exam independently and with no books or notes. Collect after 1 hour. | }
TRANSPARENCIES #1 - #20

for

Training Module II2SWS
WHAT IS HARDNESS?

1. CHEMICAL COMPONENTS
   A) Ca++
   B) Mg++
   C) OTHER

2. TYPES OF HARDNESS
   A) CARBONATE
      Ca(HCO₃)₂ or Mg(HCO₃)₂
   B) NON CARBONATE
      CASO₄ or Mg(Cl)₂
WHAT IS SOFTENING?

1. REMOVAL OF HARDNESS

2. TYPES
   A) CHEMICAL PRECIPITATION
   B) ION EXCHANGE
WY SOFTER?

1. ADVANTAGES
   A) CONSUME LESS SOAP AND DETERGENT
   B) INCREASE THE LIFE OF CLOTHING AND OTHER ARTICLES BEING CLEANED.
   C) INCREASE THE LIFE OF PIPES AND FIXTURES, HEATING SYSTEMS, AND BOILER SHELLS AND TUBES IN DEPOSITING WATER.
   D) CERTAIN INDUSTRIAL PROCESSES REQUIRE IT.
   E) SOME INDICATIONS THAT HARD WATER MAY BE THE CAUSE OF CERTAIN CARDIOVASCULAR DISEASES.
   F) REMOVE RADIOACTIVE NUCLIDES.
2. DISADVANTAGES.
   A) WITH IMPROPER CONTROL, SOFTENED WATER MAY BE MORE CORROSIVE OR SCALING THAN THE RAW WATER.
   B) IF ION EXCHANGE SOFTENING IS USED, THE SODIUM CONTENT OF THE WATER IS GREATLY INCREASED WITH A POTENTIAL CARDIOVASCULAR HEALTH HAZARD TO CERTAIN PEOPLE.
   C) IF ION EXCHANGE SOFTENING IS USED, THE TOTAL DISSOLVED SOLIDS OF THE PRODUCT WATER IS INCREASED.
   D) WITH BOTH PROCESSES, A WASTE-SLUDGE OR WASTE BRINE HAS TO BE DISPOSED OF.
REVIEW OF TERMINOLOGY

1. Hardness

2. Carbonate Hardness

3. Noncarbonate Hardness

4. Softening

5. Chemical Softening

6. Ion Exchange Softening
SOFTENING REACTIONS

Hard Water  \rightarrow\hspace{1cm} \text{Sodium Exchange Resin}  \rightarrow\hspace{1cm} \text{Soft Water}  \rightarrow\hspace{1cm} \text{Exhausted Exchange Bed}

\[
\left\{ \begin{array}{l} \text{Ca} \\ \text{Mg} \end{array} \right\} + \left\{ \begin{array}{l} \text{(HCO}_3\text{)}_2 \\ \text{SO}_4 \\ \text{Cl}_2 \end{array} \right\} + \text{Na}_2 \cdot \text{R} \rightarrow \text{Na}_2 \cdot \left\{ \begin{array}{l} \text{(HCO}_3\text{)}_2 \\ \text{SO}_4 \\ \text{Cl}_2 \end{array} \right\} + \left\{ \begin{array}{l} \text{Ca} \\ \text{Mg} \end{array} \right\} \cdot \text{R}
\]
**REGENERATION REACTIONS**

Exhausted Exchange Bed + Sodium Chloride (Salt) Solution → Sodium Exchange Bed + Waste Brine.

\[
\{C_{A}\} \text{R} + 2\text{NaCl} \rightarrow \text{Na}_2\text{R} + \{C_{A}\} \text{Cl}_2
\]
BASIC COMPONENTS OF A SOFTENER

1. Inlet valve
2. Backwash control valve
3. Outlet valve
4. Backwash outlet valve
5. Brine to waste valve
6. Brine control valve
7. Bottom manifold
8. Top manifold

SOFTENER EXTERNAL VIEW

SOFTENER INTERNAL VIEW

BOTTOM VIEW

TOP VIEW
BASIC COMPONENTS OF A BRINE TANK

- RATE SET VALVE
- RAW WATER SUPPLY
- EJECTOR
- GATE VALVE
- OVERFLOW
- RATE SET VALVE
- BRINE COLLECTOR
- SUPPORTS BY OTHERS
SALT DOSAGE FOR REGENERATION

1. FULL EXHAUSTION - .5 LBS/1000 GRAINS REMOVED
2. 2/3 EXHAUSTION - .3 LBS/1000 GRAINS REMOVED

EXAMPLE:

Softener contains resin having a total capacity of 200,000 grains. For full exhaustion, the salt dosage would be:

\[
\text{salt dosage} = (0.5 \text{ LBS/1000 GRAINS}) \times (200,000 \text{ GRAINS}) \times (1 \text{ GRAIN/1000 GRAINS}) = 100 \text{ LBS OF SALT}
\]

For 2/3 exhaustion, the salt dosage would be:

\[
\text{salt dosage} = (0.3 \text{ LBS/1000 GRAINS}) \times (200,000 \text{ GRAINS}) \times (1 \text{ GRAIN/1000 GRAINS}) \times \frac{2}{3} = 40 \text{ LBS OF SALT}
\]
IV. BASIC OPERATION OF ION EXCHANGE SOFTENER

A. REGENERATION

1. BACKWASH SOFTENER FOR FIVE MINUTES OR UNTIL WASHWATER IS CLEAR, WHICH EVER ONE IS LONGER.

2. ADD THE REQUIRED AMOUNT OF BRINE TO THE SOFTENER FROM THE BRINE SATURATOR.

3. CONTINUE ADDING WATER AT A SLOW RATE UNTIL A SALT TASTE IS NOTICED AT THE WASTE.

4. DISCONTINUE WATER ADDITION AND ALLOW BRINE TO REMAIN IN SOFTENER FOR 15-30 MINUTES.

5. START SLOW RINSE UNTIL ALL SALT TASTE IS GONE.

6. START FAST RINSE FOR 10-15 MINUTES.

7. PLACE UNIT INTO SERVICE.
<table>
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<tr>
<th>Day</th>
<th>Location</th>
<th>Week of</th>
<th>Meter Readings</th>
<th>Raw Hardness</th>
<th>lbs. salt added to tank</th>
<th>Operator</th>
<th>Remarks</th>
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Etc.
FACTORS AFFECTING WATER STABILIZATION

1. Temperature
2. Calcium
3. Total Dissolved Solids
4. Alkalinity
5. pH
S.I. = 2 pHs - pH
TRANSPARENCY 16 "SATURATION PH" REMOVED PRIOR TO BEING SHIPPED TO EDRS FOR FILMING DUE TO COPYRIGHT RESTRICTIONS.
PREVENTATIVE MAINTENANCE

A. ACCURATE RECORD OF PERFORMANCE
   1. PERIODIC CAPACITY CHECKS
   2. PERIODIC BRINE FLOW CHECKS

B. KEEP ALL PARTS WELL PAINTED TO PREVENT CORROSION

C. PROPERLY TREAT UNITS WHEN THEY ARE LAID UP
   1. FOR ABOVE FREEZING TEMPERATURES
      A) BACKWASH AND REGENERATE
      B) LEAVE A VALVE OPEN TO RELEASE ANY PRESSURE BUILDUP
   2. FOR BELOW FREEZING TEMPERATURES
      A) BACKWASH
      B) FILL TANK WITH STRONG BRINE
      C) LEAVE A VALVE OPEN TO RELEASE ANY PRESSURE BUILDUP
SAFETY

A. ELECTRICAL SAFETY
   1. Always use grounded or double insulated electrical tools when working on softeners.
   2. If softener has automatic controls always connect to an appropriately grounded outlet. Replace any worn or frayed power cords.

B. LIFTING HEAVY SALT BAGS
   1. Always lift from the knees to prevent personal injury.

C. EYE PROTECTION
   1. Always wear eye protection when handling salt or working around the brine tank.
   2. If salt gets into your eye, flush with a large quantity of fresh water.
LABORATORY CONTROL

A. PHYSICAL
1. TEMPERATURE - FINAL
2. PRESSURE LOSS THROUGH SOFTENER

B. CHEMICAL
1. ALKALINITY - FINAL
2. TOTAL AND CALCIUM HARDNESS - RAW AND FINAL
3. TOTAL DISSOLVED SOLIDS - FINAL
4. pH - FINAL
5. SOAP TEST - FINAL
SOAP TEST

1. Rinse the testing bottle thoroughly, then fill it to the mark with finished water when softener is in service.

2. Hold the dropper at a 45-degree angle and add three (3) full drops of standard soap solution. Hold the testing bottle in one hand with thumb closing the end of the bottle and shake it vigorously. With soft water ("zero-soft") a suds will be formed that will stand for several minutes.

3. When a suds forms that will stand for several minutes the sample "tests soft".

4. If, on the other hand, a suds is not obtained or it will not stand for several minutes, the sample "tests hard".
CLASS PROBLEMS.
for
Training, Module II2SWS
CLASS PROBLEM #1

PART A.

1. For a water containing calcium bicarbonate \((\text{Ca(HCO}_3)_2\)) , how many moles of sodium will be released for each mole of calcium?

2. If a water contained 250 mg/l of calcium bicarbonate, how much will the sodium concentration increase?

3. How much will the total dissolved solids increase?
PART B.

1. For a water containing magnesium sulfate (Mg SO₄), how many moles of sodium will be released for each mole of magnesium?

2. If a water contained 250 mg/l of calcium bicarbonate and 250 mg/l of Magnesium Sulfate, how much will the sodium concentration increase?

3. How much will the total dissolved solids increase?
1. Match each number with the correct component:

- Top Manifold
- Outlet Valve
- Backwash outlet valve
- Brine to waste valve
- Bottom manifold
- Backwash control valve
- Inlet valve
- Brine control valve
CLASS PROBLEM #3

1. A softener contains 174 cu. ft. of synthetic zeolite resin having a capacity of 11,500 grains per cu. ft.
   
a. If raw water contains 170 mg/l as CaCO₃ of hardness, how many gallons of water will total exhaust the softener?
   
b. How many gallons of water will exhaust 2/3 the capacity of the softener?
   
c. How many pounds of salt will be required to regenerate a totally exhausted softener?
   
d. How many pounds of salt will be required to regenerate a 2/3 exhausted softener?
CLASS PROBLEM #4

1. A water to be zeolite softened has the following chemical and physical characteristics:

- Hardness = 360 mg/l as CaCO₃
- Alkalinity = 300 mg/l as CaCO₃
- Calcium = 180 mg/l as CaCO₃
- Total Dissolved Solids = 800 mg/l
- pH = 7.3
- Temperature = 60°F

a. What percentage of water will have to be bypassed to achieve stable water?

b. What will be the chemical and physical characteristics of the blended water?

c. What pH should the blended water be adjusted to achieve a stable water?
CLASS HANDOUT
for
Training Module 112SWS
I. Introduction
A. What is Hardness
1. Chemical Components
   a) Ca
   b) Mg
   c) Other
2. Types
   a) Carbonate
   b) Noncarbonate
3. Typical Hardness in U.S.
4. Typical Hardness in Iowa
B. What is Softening
   1. Removal of Hardness
   2. Types of Softening
      a) Chemical precipitation
      b) Ion exchange
C. Why Soften
   1. Advantages
      a) Conserve less soap and detergent.
      b) Increase the life of clothing and other articles being cleaned.
      c) Increase the life of pipes and fixtures, heating systems, and boiler shells and tubes for depositing water.
      d) Certain industrial processes require it.
      e) Some indications that hard water may be the cause of certain cardiovascular diseases.
      f) Remove radioactive nuclides.
   2. Disadvantages
      a) With improper control, softened water may be more corrosive or scaling than the raw water.
      b) If ion exchange softening is used, the sodium content of the water is greatly increased with a potential cardiovascular health hazard to certain people.
      c) If ion exchange softening is used, the total dissolved solids of the product water is increased.
      d) With both processes, a waste sludge or waste brine has to be disposed of.
II. Principles of Ion Exchange Softening
A. Softening Reactions
\[
\begin{align*}
\{\text{Ca}^{++}\} + \{\text{HCO}_3^-\} + \{\text{SO}_4^{2-}\} & \rightarrow \{\text{Na}^+\} + \{\text{Ca}^{++}\} + \{\text{Mg}^{++}\} + \{\text{Cl}^-\} \\
\{\text{Mg}^{++}\} + \{\text{SO}_4^{2-}\} + \{\text{Cl}^-\} & \rightarrow \{\text{Na}^+\} + \{\text{Ca}^{++}\} + \{\text{Mg}^{++}\} + \{\text{Cl}^-\}
\end{align*}
\]
B. Regeneration Reactions

\[
\left\{ \text{Ca}^{++} \right\} + 2\text{NaCl} \rightarrow \left\{ \text{Mg}^{++} \right\} + \text{Na}_2\text{R} \rightarrow \left\{ \text{Ca}^{++} \right\} + \text{Mg}^{++} \text{Cl}_2
\]

III. Components of Ion Exchange Softener

A. Softener
(See Figure 1)

B. Brine Tank
(See Figure 2)

IV. Basic Operation of Ion Exchange Softener

A. Regeneration
1. Backwash softener for five minutes or until washwater is clear, which ever one is longer.
2. Add the required amount of brine to the softener from the brine saturator.
3. Continue adding water at a slow rate until a salt taste is noticed at the waste.
4. Discontinue water addition and allow brine to remain in softener for 15-30 minutes.
5. Start slow rinse until all salt taste is gone.
7. Place unit into service.

B. Salt Dosage
1. Full exhaustion - .5 lbs/1000 grains removed
2. 2/3 exhaustion - .3 lbs/1000 grains removed

V. Water Stabilization

A. Factors affecting water stabilization
1. Temperature
2. Calcium
3. Total Dissolved Solids
4. Alkalinity
5. pH

B. Reizener Index
S.I. = 2 pHs - pH

C. Saturation pH
(See Figure 3)

VI. Preventative Maintenance

A. Accurate record of performance
1. Periodic capacity checks
2. Periodic brine flow checks

B. Keep all parts well painted to prevent corrosion.

C. Properly treat units when they are laid up
1. For above freezing temperatures
   a) Backwash and regenerate
   b) Leave a valve open to release any pressure buildup
2. For below freezing temperatures
   a) Backwash
   b) Fill tank with strong brine
   c) Leave a valve open to release any pressure build up
VII. Safety
A. Electrical Safety
   1. Always use grounded or double insulated electrical tools when working on softeners.
   2. If softener has automatic controls always connect to a appropriately grounded outlet. Replace any worn or frayed power cords.
B. Lifting heavy salt bags
   1. Always lift from the knees to prevent personal injury.
C. Eye protection
   1. Always wear eye protection when handling salt or working around the brine tank.
   2. If salt gets into your eye, flush with a large quantity of fresh water.

VIII. Laboratory Control
A. Physical
   1. Temperature - Final
   2. Pressure loss through softener
B. Chemical
   1. Alkalinity - Final
   2. Total and Calcium Hardness - Raw and Final
   3. Total Dissolved Solids - Final
   4. pH - Final
   5. Soap Test - Final
1. **Inlet valve**
2. **Backwash control valve**
3. **Outlet valve**
4. **Backwash outlet valve**
5. **Brine to waste valve**
6. **Brine control valve**
7. **Bottom manifold**
8. **Top manifold**
EXAMINATION

for

Training Module II2SWS
Examination for II2WS - Basic Ion Exchange Softening

1. Hardness in most waters is caused by ___________ and ___________ divalent cation ions.

2. Hardness ions that are matched with bicarbonate anions is called ___________ hardness.

3. Softening is defined as ___________.

4. List three advantages of softening:
   a. ___________
   b. ___________
   c. ___________

5. List three disadvantages of ion exchange softening:
   a. ___________
   b. ___________
   c. ___________

6. In ion exchange softening, hardness ions are removed and replaced with ___________ ions.

7. When a softener is fully exhausted, it requires ____ lbs of salt per 1000 grains of hardness removed.

8. When a softener is 2/3 exhausted, it requires ____ lbs of salt per 1000 grains of hardness removed.

9. List the five factors affecting water stabilization.
   a. ___________
   b. ___________
   c. ___________
   d. ___________
   e. ___________
10. Match each number with the correct component.

- Top Manifold
- Outlet Valve
- Backwash outlet valve
- Brine to waste valve
- Bottom manifold
- Backwash control valve
- Inlet valve
- Brine control valve

SOFTENER EXTERNAL VIEW

SOFTENER INTERNAL VIEW
TRUE OR FALSE - CIRCLE THE CORRECT ANSWER

11. When a softener is regenerated, the brine should never be allowed to sit in contact with the resin for any length of time.

12. A properly stabilized water always has a pH of 7.0.

13. When a softener is laid up in freezing temperatures it should always be left with brine in the tank.

14. The soap test can give a quick determination for headloss across the softener.

15. When water contains CaSO₄ it is considered noncarbonate.

16. Radioactive particles are removed by ion exchange softening.

17. Total dissolved solids always decrease with ion exchange softening.

18. The majority of ion exchange reactions occur inside the resin particles.

19. It is cheaper to operate a softener at full exhaustion than at 2/3 exhaustion.

20. Zero soft water is always stable and never needs any chemical adjustment.