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ABSTRACT

This document is an instructional module package prepared in objective form for use by an instructor familiar with the operation and maintenance of a chemical precipitation softening system. Included are objectives, instructor guides, student handouts and transparency masters. This is the second level of a three module series. The module considers chemical dosages, economical operation, troubleshooting process problems, and evaluation of softener design. (Author/RH)

INTERMEDIATE CHEMICAL PRECIPITATION SOFTENING

Training Module 2.216.3.77

Prepared for the

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by

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September, 1977

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INSTRUCTOR GUIDE

for

Training Module II3ABWS

Module No:	Module Title:
II3ABWS	Intermediate Chemical Precipitation Softening
	Submodule Title:
Approx. Time: 11 hours	Topic: Summary

Objectives: Upon completion of this module, the participant will be able to:
1. Describe the operation of a chemical precipitation softener.
2. Calculate chemical feeds for a given water.
3. Identify process problems.
4. Design a chemical precipitation softener.

Instructional Aids:
1. Handout
2. Transparencies #1-#27

Instructional Approach:

Discussion and Class Problems

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operations, Texas Water Utility Association.
3. Water Supply & Treatment, National Lime Association
4. Recommended Standards for Water Works, Health Education Services.

Class Assignments:

The participant will:
1. Read Handout
2. Complete Problems #1-#2.

Module No: II3ABWS	Topic: Summary
Instructor Notes:	**Instructor Outline:**
1. Distribute Handout 2. Present Transparencies	1. Discuss the operation, chemical feeds and design of chemical precipitation softener. 2. Give evaluation of 30 questions.

Module No:	Module Title:
II3ABWS	Intermediate Chemical Precipitation Softening
	Submodule Title:
Approx. Time: 1 hour	Topic: Introduction

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

1. Describe the chemistry of chemical precipitation softening.
2. Describe the operation of chemical precipitation softening.
3. Describe the laboratory control necessary for chemical precipitation softening.
4. Describe the safety requirements for chemical precipitation softening.

Instructional Aids:

1. Handout-Introduction
2. Transparency #1-#2-Softening reactions
3. Transparency #3-Recarbonation reactions
4. Transparency #4-#5-Operating a two stage softening plant
5. Transparency #6-#7-Operating a split treatment softening plant
6. Transparency #8-#9-Operating a single stage softening plant
7. Transparency #10-Laboratory control
8. Transparency #11-Safety

Instructional Approach:

Discussion

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operations, Texas Water Utility Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Introduction

Module No: IJ3ABWS	Topic: Introduction

Instructor Notes:	Instructor Outline:
1. Present Transparency #1-#2	1. Review the softening reactions. Review the amount of lime for each reaction.
2. Present Transparency #3	2. Review the recarbonation reactions. Review the amount of carbon dioxide for each type of excess hydroxide.
3. Present Transparency #4-#5	3. Review the operation of a two stage softening plant. Include how each type of softener is affected and what reactions are taking place.
4. Present Transparency #6-#7	4. Review the operation of a split treatment softening plant. Include how each type of softener is affected and what reactions are taking place.
5. Present Transparency #8-#9	5. Review the operation of a single stage softening plant. Include how each type of softener is affected and what reactions are taking place.
6. Present Transparency #10	6. Review the laboratory control needed for operating a chemical softening plant.
7. Present Transparency #11	7. Review safety in operating a chemical precipitation softening plant.

Module No: II3ABWS	Module Title: Intermediate Chemical Precipitation Softening
	Submodule Title:
Approx. Time: 3 hours	Topic: Chemical Feeds

Objectives: Upon completion of this topic, the participant will be able to:
1. Determine which chemicals are necessary to soften a given water.
2. Calculate the approximate feed rate for chemicals used in water softening.

Instructional Aids:

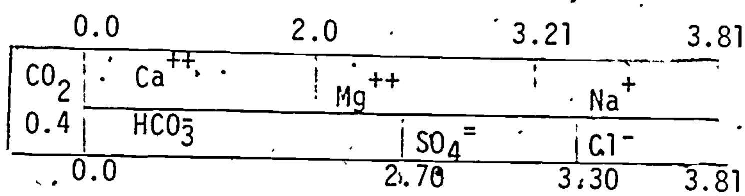
1. Handout - Chemical feeds
2. Transparency #14 - Lime feed
3. Transparency #15 - Soda Ash feed
4. Transparency #16 - Carbon Dioxide
5. Transparency #17 - Caldwell-Lawrence Diagram

Instructional Approach:

Discussion and Class Problem

References:
1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operations, Texas Water Utility Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:
The participant will:
1. Read Handout-Chemical Feed
2. Complete Problem #1-Chemical feed rates

Module No: II3ABWS	Topic: Chemical Feeds
Instructor Notes:	**Instructor Outline:**
1. Present Transparency #12	1. Discuss the construction of the water quality bar diagram. Also show the usefullness of knowing the chemical composition.
2. Present Transparency #13	2. Discuss the use of the nomograph for converting mg/l to me/l.
3. Present Part 1 of class problem #1. Work the problem with class participation.	3. 
4. Present Transparency #14	4. Discuss lime dosage calculations in relation to equations and water quality bar diagram.
5. Present Part 2 of class problem #1. Work the problem with class participation.	5. Lime dosage = (2.7 + 1.21 + .4 + 1) x 28 = 148 $\approx$ 150 mg/l CaO
6. Present Transparency #15	6. Discuss soda ash calculations in relation to equations and water quality bar diagram.
7. Present part 3 of class problem #1. Work the problem with class participation.	7. Soda ash = (3.21-2.70) 53 = 27 mg/l 27 mg/l Na_2CO_3
8. Present Transparency #16	8. Discuss carbon dioxide calculations in relation to equations and water quality bar diagram.
9. Present part 4 of class problem #1. Work the problem with class participation.	9. CO_2 = (.2 + .4) x 44 = 26 mg/l
10. Present Transparency #17	10. Discuss the use of the Caldwell-Lawrence diagram in calculating chemical dosages.

Module No: II3ABWS

Topic: Chemical Feeds

Instructor Notes:

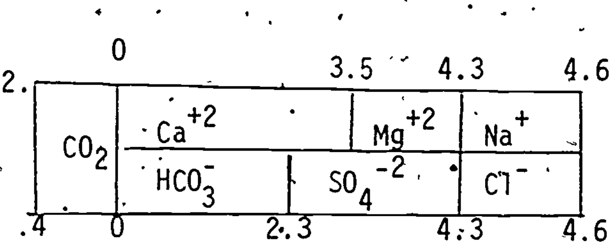
11. Work class problem #1 parts 1-3 using Caldwell Lawrence diagram.

12. Present part #5 of class problem #1. Have class work problem on their own. Then work problem with class participation.

Instructor Outline:

11. Lime dose = 225 mg/l as $CaCO_3$ or 131 mg/l as CaO
    Soda Ash = 10 mg/l as $CaCO_3$ or ≈ 10 mg/l as Na_2CO_3

    Explain difference between two methods.

12. 

Lime = (2.3 + .8 + .4 + 1) x 28 = 126 mg/l
Soda Ash = (2.0) x 53 = 106 mg/l
CO_2 = (.2 + .4) x 44 = 26 mg/l

CALDWELL-LAWRENCE DIAGRAM
Lime = 106 mg/l $CaCO_3$
Soda Ash = 90 mg/l Na_2CO_3

Module No:	Module Title: Intermediate Chemical Precipitation Softening
II3ABWS	Submodule Title:
Approx. Time: 3 hours	Topic: Design Evaluation

Objectives: Upon completion of this topic, the participant will be able to:
1. Evaluate the design of an existing chemical precipitation softener.
2. Calculate approximate chemical costs for chemical precipitation softener

Instructional Aids:

1. Handout-Design #18-#22-TEN STATES STANDARDS FOR SOFTENER
2. Transparency #23-Chemical Costs Calculations

Instructional Approach:

Discussion and Class Problem

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operations, Texas Water Utility Association.
3. Water Supply & Treatment, National Lime Association.
4. Recommended Standards for Water Works, Health Education Service.

Class Assignments:

1. The participant will read Handout-Design
2. The participant will complete Problem #2-Design Evaluation and costs of operation

Module No:	Topic:
II3ABWS	Design Evaluation

Instructor Notes:

1. Present Transparencies #18-#22
2. Present Transparency #23
3. Present class problem #2. Complete problem with class participation.

Instructor Outline:

1. Discuss the various standards and their relationship to softener operations. Stress the difference between coagulation design and softener design and the reasons for the different values.
2. Discuss the calculations for chemical costs.
3. 1. Check Flocc Zone time:

   $$\frac{(2260)(7.5)(60)(24)}{2,000,000} = 12.0 \text{ min}$$

   ∴ low, says 30 min.

   Check Total Detention:

   $$\frac{(35 \times 35 \times 15)(7.5)(60)(24)}{2,000,000} = 99 \text{ min}$$

   ∴ low, says 4 hours

   Check weir loading:

   $$\frac{(2,000,000)}{(60)(24)(192)} = 7.2 \text{ gpm/ft}$$

   ∴ ok, says 20 gpm/ft

   Check upflow rates:

   $$\frac{(2,000,000)}{(50 \times 24)(35 \times 35)} = 1.1 \text{ gpm/ft}^2$$

   ∴ ok, says 1.75 gpm/ft^2

   2. <u>Chemical Cost</u>

   Lime cost
   (150)(2.0)(8.34)(.017) = $42.53/day

   Soda ash
   (27)(2.0)(8.34)(.0325) = $14.09/day

   $79.14/day

   or $.04/1000 gals

Module No: II3ABWS	Module Title: Intermediate Chemical Precipitation Softening
	Submodule Title:
Approx. Time: 1 hour	Topic: Advanced Operation of Chemical Precipitation Softening

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

1. Diagnose and describe solution to solids concentration operational problems in upflow solids contact units.
2. Describe operational alternatives for chemical softening plants during periods of low hardness.

Instructional Aids:

1. Handout-Advanced Operation
2. Transparency #24 - Advanced Operation

Instructional Approach:

Discussion

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operations, Texas Water Utility Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Advanced Operation

Module No:	Topic:
II3ABWS	Advanced Operation of Chemical Precipitation Softening

Instructor Notes:	Instructor Outline:
1. Present Transparency #24	1. Discuss the role of the lime sludge slurry in the operation of a softening unit. Then discuss the operational controls available for each type of softener. a. Role of slurry 1) Hardness removal 2) Turbidity removal b. Control of slurry 1) Turbine or flocculator speed 2) Recycle solids 2. Discuss the general operational problems when treating low hardness waters such as encountered when treating surface water during runoff events. Then discuss in detail the operation of each type of unit during these periods. a. Problems 1) Reduction of solids formation and sludge age 2) Higher turbidity carry-over b. Operation 1) Discontinue softening 2) Recycle more solids 3) Add excess lime

Module No: II3ABWS	Module Title: Intermediate Chemical Precipitation Softening
	Submodule Title:
Approx. Time: 2 hour	Topic: Maintenance

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

1. Describe the necessary maintenance for a chemical precipitation softening plant.

Instructional Aids:

1. Handout-Maintenance.
2. Transparency #25-Upflow Solids Contact Unit.
3. Transparency #26-Straight Lime Softening Unit.
4. Transparency #27-Spiractor Softening Unit.

Instructional Approach:

Discussion

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operations, Texas Water Utility Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Maintenance.

Module No:	Topic:
II3ABWS	Maintenance

Instructor Notes:	Instructor Outline:
1. Present Transparency #25	1. Discuss the maintenance for upflow solids contact unit. Includes a) General 1) Cleaning weirs and chemical feed lines 2) Cleaning turbine 3) Cleaning rake b) Turbine 1) Adjustments 2) Lubrication c) Rake 1) Adjustment 2) Lubrication
2. Present Transparency #26	2. Discuss the maintenance for straight line softener. Include: a) General 1) Cleaning weirs and chemical feed lines 2) Cleaning sludge collector b) Flocculators 1) Adjustments 2) Lubrication c) Sludge collector 1) Adjustment 2) Lubrication
3. Present Transparency #27	3. Discuss the maintenance for "Spiractor" softener, include: a) General 1) Cleaning weirs and chemical feed lines b) Catalyst feeder 1) Cleaning and adjustment

Module No: II3ABWS	Module Title: Intermediate Chemical Precipitation Softening
Approx. Time:	Submodule Title:
	Topic: 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

Module No: IIЗABWS	Topic: Evaluation

Instructor Notes:	Instructor Outline:
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 II3ABWS

SOFTENING REACTIONS

1. FREE CARBON DIOXIDE

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + H_2O$$

CARBON DIOXIDE — LIME — CALCIUM CARBONATE — WATER

2. CALCIUM CARBONATE HARDNESS

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2\,CaCO_3\downarrow + 2\,H_2O$$

CALCIUM CARBONATE — LIME — CALCIUM CARBONATE — WATER

3. MAGNESIUM CARBONATE HARDNESS

$$Mg(HCO_3)_2 + 2\,Ca(OH)_2 \longrightarrow CaCO_3\downarrow + Mg(OH)_2\downarrow\ 2\,H_2O$$

SOFTENING REACTIONS

4. CALCIUM NONCARBONATE HARDNESS

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + Na_2SO_4$$

CALCIUM SULFATE	SODA ASH	CALCIUM CARBONATE	SODIUM SULFATE

5. MAGNESIUM NONCARBONATE HARDNESS

$$MgSO_4 + Na_2CO_3 + Ca(OH)_2 \longrightarrow CaCO_3 \downarrow + Mg(OH)_2 \downarrow + Na_2SO_4$$

MAGNESIUM SULFATE	SODA ASH	LIME	CALCIUM CARBONATE	MAGNESIUM HYDROXIDE	SODIUM SULFATE

TRANSPARENCY [illegible]

RECARBONATION REACTIONS

1. EXCESS HYDROXIDE

$$2\ OH^- + H_2CO_3 \longrightarrow CO_3^= + 2\ H_2O$$

HYDROXIDE ION	CARBONIC ACID	CARBONATE ION	WATER

2. CALCIUM CARBONATE

$$2\ CaCO_3 + H_2CO_3 \longrightarrow 2\ Ca(HCO_3)_2$$

CALCIUM CARBONATE	CARBONIC ACID	CALCIUM BICARBONATE

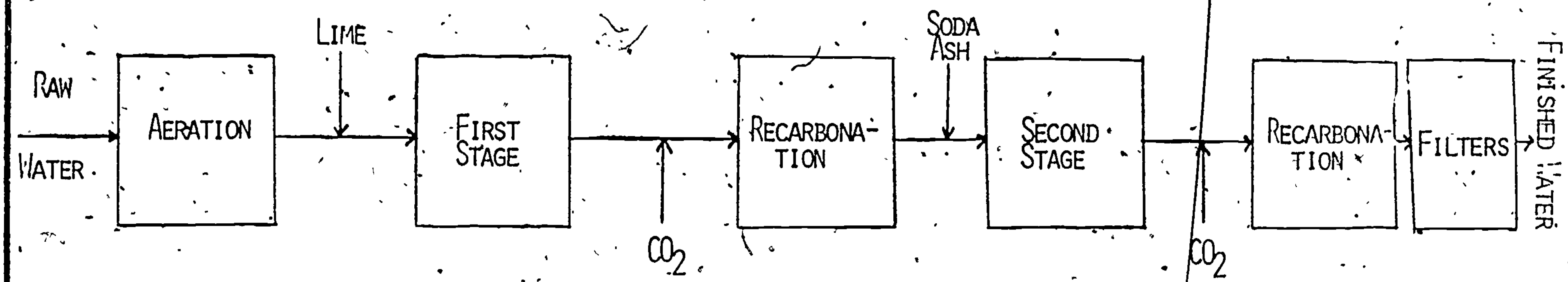
3. MAGNESIUM HYDROXIDE

$$Mg(OH)_2 + 2\ H_2CO_3 \longrightarrow Mg(HCO_3)_2 + 2\ H_2O$$

MAGNESIUM HYDROXIDE	CARBONIC ACID	MAGNESIUM BICARBONATE	WATER

TRANSPARENCY [illegible]

TWO STAGE SOFTENING



TRANSPARENCY [illegible]

TWO STAGE SOFTENING

1. FIRST STAGE

   A) PH SHOULD BE ADJUSTED TO ABOVE 11.0 WITH LIME TO OBTAIN MAGNESIUM REMOVAL. THIS PH CAN BE REDUCED SOMEWHAT IF NOT TOTAL MAGNESIUM REMOVAL IS REQUIRED.

2. SECOND STAGE

   A) PH OF THE SECOND STAGE SHOULD BE APPROXIMATELY 10 TO OBTAIN OPTIMUM CALCIUM REMOVAL.

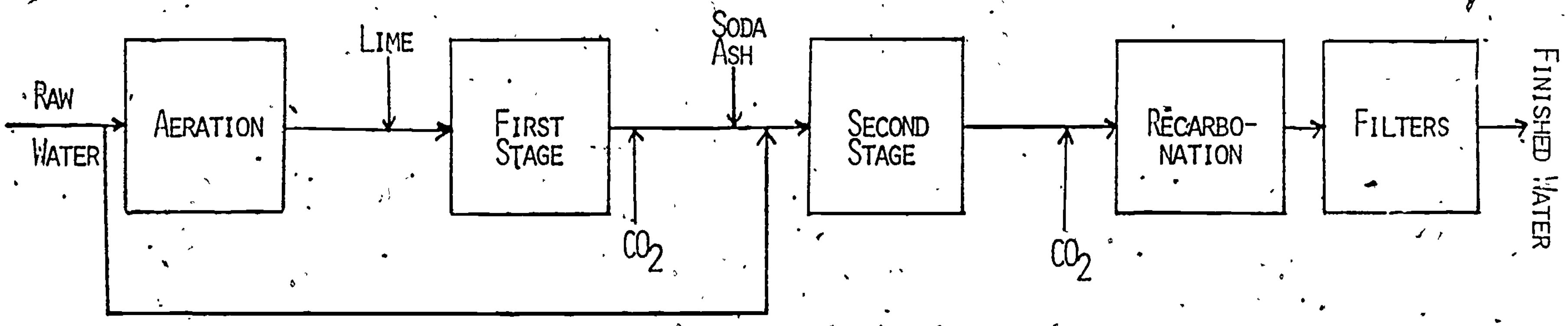
   B) IF SODA ASH IS USED IT SHOULD BE ADDED JUST PRIOR TO THE SECOND STAGE TO HELP REDUCE THE PH.

   C) RECARBONATION WITH CARBON DIOXIDE IS USUALLY REQUIRED TO LOWER THE PH TO THE OPTIMUM LEVEL.

   D) RECARBONATION OF THE FINISHED WATER TO APPROXIMATELY 9.5 IS USUALLY REQUIRED TO PREVENT SCALE BUILDUP ON THE FILTERS. THIS FINAL PH IS DEPENDENT ON THE WATER, CHEMICAL AND PHYSICAL CHARACTERISTICS AND THEREFORE REQUIRES A CALCULATION OF THE FINAL PH FOR EACH PLANT TO ENSURE PROPERLY STABILIZED WATER.

TRANSPARENCY II3ADWS - #5

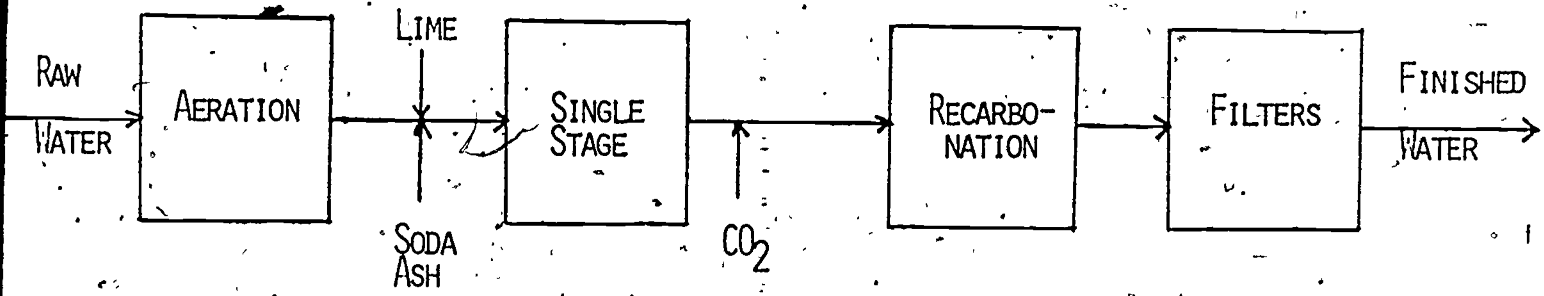
SPLIT TREATMENT SOFTENING



SPLIT TREATMENT SOFTENING

1. FIRST STAGE
   - A) PH SHOULD BE ADJUSTED TO ABOVE 11.0 WITH LIME TO OBTAIN MAGNESIUM REMOVAL. THIS PH CAN BE REDUCED SOMEWHAT TO OBTAIN THE DESIRED TOTAL MAGNESIUM REMOVAL.
2. SECOND STAGE
   - A) PH OF THE SECOND STAGE SHOULD BE APPROXIMATELY 10 TO OBTAIN OPTIMUM CALCIUM REMOVAL.
   - B) IF SODA ASH IS USED IT SHOULD BE ADDED JUST PRIOR TO THE SECOND STAGE TO HELP REDUCE THE PH.
   - C) GENERALLY THE CARBON DIOXIDE AND BICARBONATE IN THE SPLIT FLOW IS ADEQUATE TO LOWER THE PH IN THE SECOND STAGE TO OBTAIN OPTIMUM CALCIUM REMOVAL.
   - D) IF PH DROPS BELOW 10.0 ADD ADDITIONAL LIME TO SEOND STAGE TO OBTAIN THE DESIRED CALCIUM REDUCTION.
   - E) RECARBONATION OF THE FINISHED WATER TO APPROXIMATELY 9.5 IS USUALLY REQUIRED TO PREVENT SCALE BUILDUP ON THE FILTERS. THIS FINAL PH IS DEPENDENT ON THE WATER CHEMICAL AND PHYSICAL CHARACTERISTICS AND THEREFORE REQUIRES A CALCULATION OF THE FINAL PH FOR EACH PLANT TO ENSURE PROPERLY STABILIZED WATER.

SINGLE STAGE SOFTENING



SINGLE STAGE SOFTENING

1. Single Stage

   A) pH should be above 10 to obtain acceptable performance of the softener. If magnesium removal is desired, the pH should be above 11.0. The optimum operation, that operation resulting in the least hardness, will be different for each plant, resulting in some experimentation to determine what pH is optimal.

   B) All chemical feeds are added just at the head of the unit.

   C) Recarbonation of the finished water to approximately 9.5 is usually required to prevent scale buildup on the filters. This final pH is dependent on the water, chemical and physical characteristics and therefore requires a calculation of the final pH for each plant to ensure properly stabilized water.

Transparency 113APWS - #9

LABORATORY CONTROL

A. PHYSICAL
   1. TEMPERATURE
   2. TURBIDITY

B. CHEMICAL
   1. ALKALINITY
   2. TOTAL AND CALCIUM HARDNESS
   3. TOTAL DISSOLVED SOLIDS
   4. pH
   5. SOLIDS CONCENTRATION (UPFLOW UNITS ONLY)
   6. "CATALYST" ANALYSIS ("SPIRACTOR" ONLY)

SAFETY

A. ELECTRICAL SAFETY

1. ALWAYS USE GROUNDED OR DOUBLE INSULATED ELECTRICAL TOOLS WHEN WORKING ON SOFTENERS OR CHEMICAL FEEDERS.
2. MAKE SURE ALL MOTORS AND ELECTRICAL CONTROLS ON SOFTENERS AND CHEMICAL FEEDERS ARE PROPERLY GROUNDED.

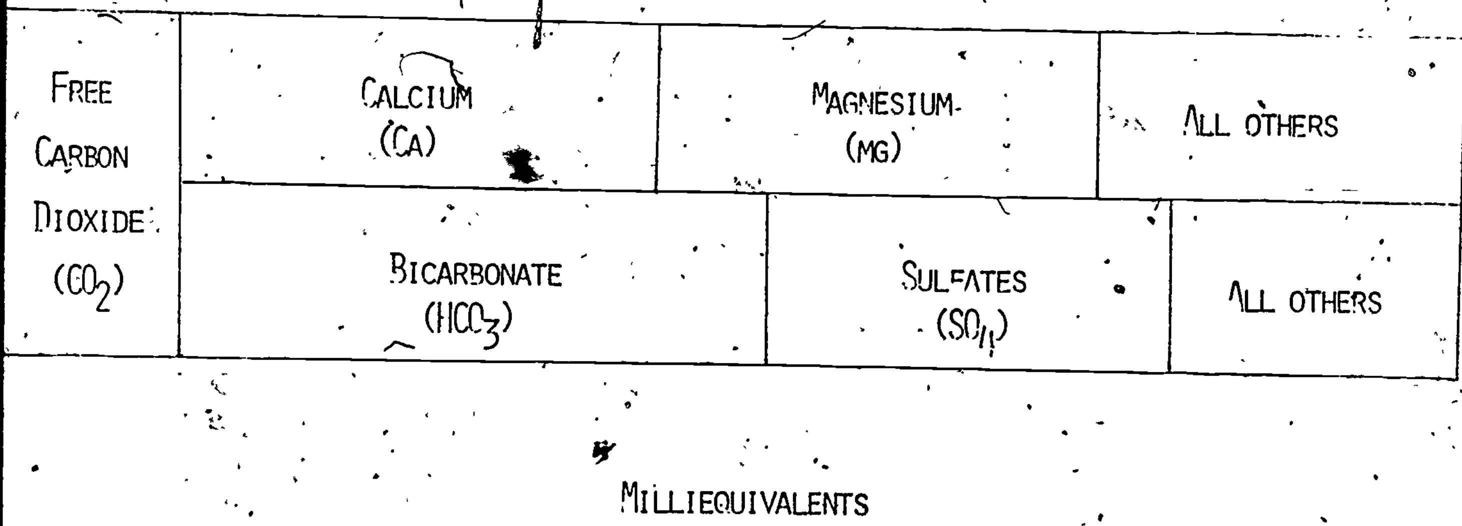
B. LIFTING CHEMICAL LIME AND SODA ASH BAGS

1. ALWAYS LIFE FROM THE KNEES TO PREVENT PERSONAL INJURY.

C. EYE PROTECTION

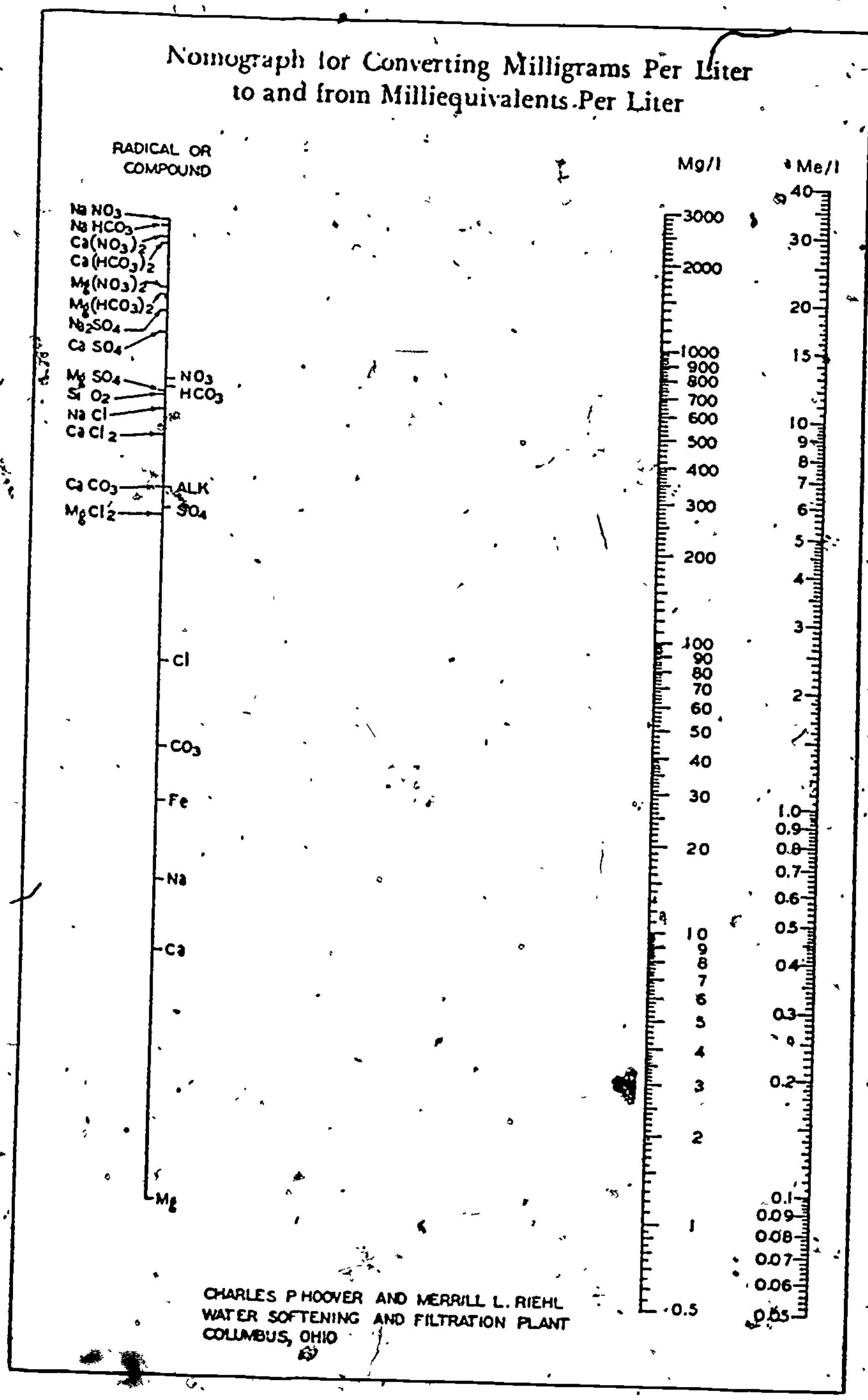
1. ALWAYS WEAR EYE PROTECTION WHEN HANDLING OR WORKING AROUND LIME OR SODA ASH FEEDERS.
2. ALWAYS WEAR PROTECTIVE COVERINGS ON HANDS AND ARMS WHEN HANDLING LIME AND SODA ASH.
3. IF LIME OR SODA ASH SHOULD COME IN CONTACT WITH EYE OR SKIN, FLUSH WITH A LARGE QUANTITY OF FRESH WATER AND CONTACT A PHYSICIAN IMMEDIATELY.

WATER QUALITY BAR DIAGRAM



NOMOGRAPH FOR CONVERTING

MG/L TO ME/L



TRANSPARENCY IIB.M.S. - #13

LIME DOSAGE

LIME DOSAGE (MG/L) = (Alk(ME/L) + Mg(ME/L) + CO_2(ME/L) + 1 (ME/L)) X 28
(CaO)

36

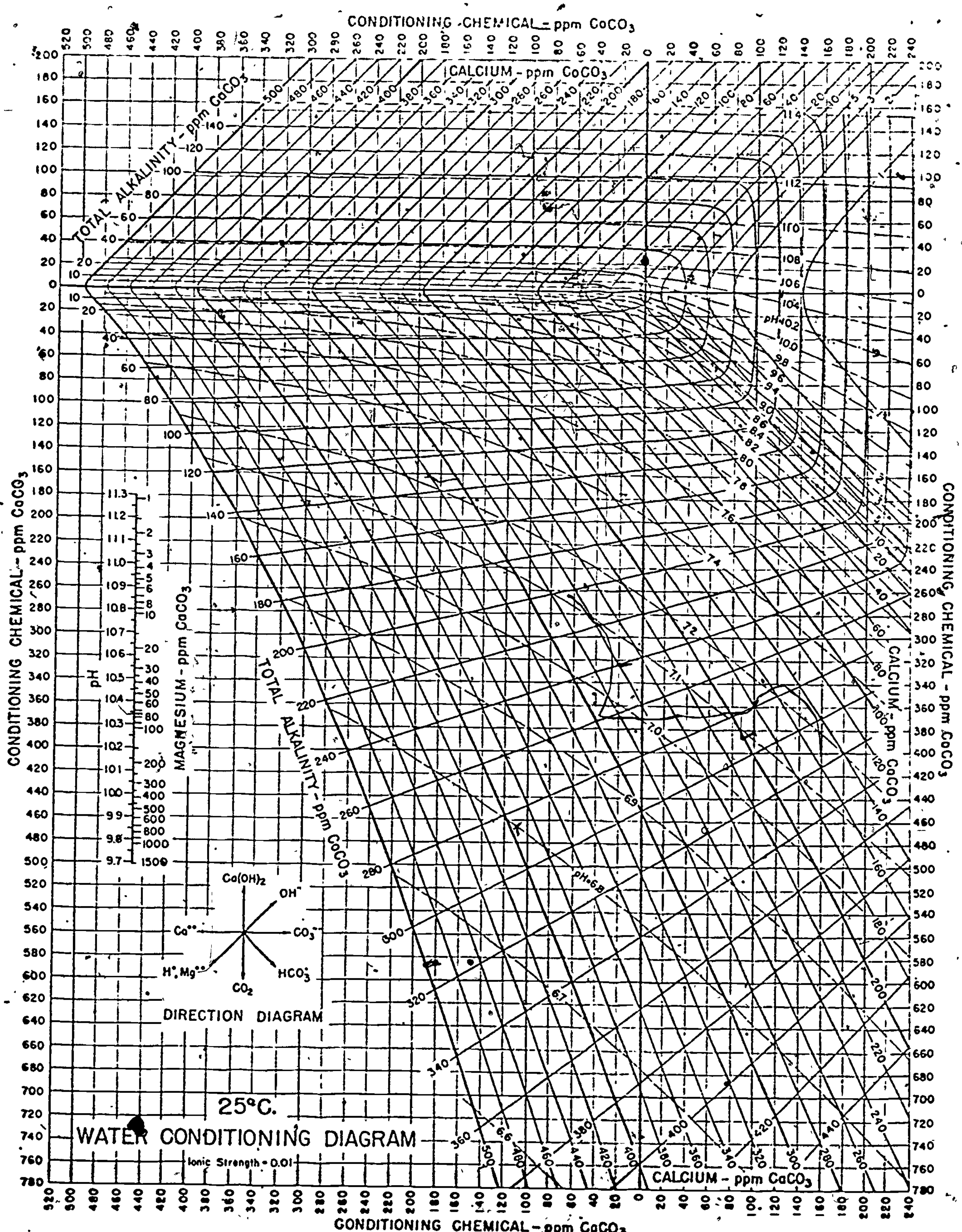
SODA ASH DOSAGE

SODA ASH DOSAGE (MG/L) = (NONCARBONATE HARDNESS (ME/L)) X 53
(Na_2CO_3)

CARBON DIOXIDE DOSAGE

Carbon Dioxide Dosage (mg/L) = (Excess Hydroxide (me/L) + Carbonate (me/L)) x 44
(CO_2)

CALDWELL-LAWRENCE DIAGRAM



TRANSPARENCY II3ABMS - #7

4.1.2 Rapid mix

Rapid mix shall mean the rapid dispersion of chemicals throughout the water to be treated, usually by violent agitation.

a. Equipment - Basins should be equipped with mechanical mixing devices.

b. Mixing - The detention period should be not more than thirty seconds.

c. Location - The rapid mix and flocculation basins shall be as close together as possible.

4.1.3 Flocculation

Flocculation shall mean the agitation of water at low velocities for long periods of time.

a. Basin design - Inlet and outlet design shall prevent short-circuiting and destruction of floc. A drain or pumps shall be provided to handle dewatering and sludge removal.

b. Detention - The flow-through velocity shall not be less than 0.5 nor greater than 1.5 feet per minute with a detention time for floc formation of at least 30 minutes.

c. Equipment - Agitators shall be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 to 2.0 feet per second.

d. Piping - Flocculation and sedimentation basins shall be as close together as possible. The velocity of flocculated water through pipes or conduits to settling basins shall not be less than 0.5 nor greater than 1.5 feet per second. Allowances must be made to minimize turbulence at bends and changes in direction.

e. Other designs - Baffling may be used to provide for flocculation in small plants only after consultation with the reviewing authority. The design should be such that the velocities and flows noted above will be maintained.

f. Superstructure - A superstructure over the flocculation basins may be required.

4.1.4 Sedimentation

Sedimentation shall follow flocculation. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The following criteria apply to conventional sedimentation units:

a. Detention time - Detention shall provide a minimum of four hours of settling time. This may be reduced to two hours for lime-soda softening facilities treating only groundwater.

b. Inlet devices - Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are required. A baffle should be constructed across the basin close to the inlet end and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows accross the basin.

c. Outlet devices - Outlet devices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in flow.

d. Overflow rate - The rate of flow over the outlet weir shall not exceed 20,000 gallons per day per foot of weir length. Where submerged orifices are used as an alternate for over-flow weirs, they should not be lower than three feet below the flow line with flow rates equivalent to weir loadings.

e. Velocity - The velocity through settling basins shall not exceed 0.5 feet per minute. The basins must be designed to minimize short-circuiting. Baffles must be provided as necessary.

f. Overflow - An overflow weir (or pipe) should be installed which will establish the maximum water level desired on top of the filters. It shall discharge with a free fall at a location where the discharge will be noted.

g. Superstructure - A superstructure over the sedimentation basins may be required. If there is no mechanical equipment in the basins and if provisions are included for adequate monitoring under all expected weather conditions, a cover may be provided in lieu of a superstructure.

h. Sludge collection - Mechanical sludge collection equipment should be provided.

i. Drainage - Basins must be provided with a means for dewatering. Basin bottoms should slope toward the drain not less than one foot in twelve feet where mechanical sludge collection equipment is not required.

j. Flushing lines - Flushing lines or hydrants shall be provided and must be equipped with backflow prevention devices acceptable to the reviewing authority.

k. Safety - Permanent ladders or handholds should be provided on the inside walls of basins above the water level. Guard rails should be included.

l. Sludge disposal - Facilities are required by the reviewing authority for disposal of sludge. (see Section 4.11). Provisions shall be made for the operator to observe or sample sludge being withdrawn from the unit.

4.1.5 Solids contact unit

Units are acceptable for combined softening and clarification where water characteristics are not variable and flow rates are uniform. Before such units are considered as clarifiers without softening, specific approval of the reviewing authority shall be obtained. Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flow which are less than the design rate and for changes in water characteristics. A minimum of two units are required for surface water treatment.

TEN STATES STANDARDS

(CONTINUED)

4.1.5.1 Installation of equipment

Supervision by a representative of the manufacturer shall be provided with regard to all mechanical equipment at the time of

a. installation, and

b. initial operation.

4.1.5.2 Operating equipment

The following shall be provided for plant operation:

a. a complete outfit of tools and accessories,

b. necessary laboratory equipment,

c. adequate piping with suitable sampling taps so located as to permit the collection of samples of water from critical portions of the units.

4.1.5.3 Chemical feed

Chemicals shall be applied at such points and by such means as to insure satisfactory mixing of the chemicals with the water.

4.1.5.4 Mixing

A rapid mix device or chamber ahead of the solids contact units may be required by the reviewing authority to assure proper mixing of the chemicals applied. Mixing devices employed shall be so constructed as to

a. provide good mixing of the raw water with previously formed sludge particles, and

b. prevent deposition of solids in the mixing zone.

4.1.5.5 Flocculation

Flocculation equipment

a. shall be adjustable (speed and/or pitch),

b. must provide for coagulation in a separate chamber or baffled zone within the unit,

c. should provide the flocculation and mixing period to be not less than 30 minutes.

4.1.5.6 Sludge concentrators

The equipment should provide either internal or external concentrators in order to obtain a concentrated sludge with a minimum of waste water.

4.1.5.7 Sludge removal

Sludge removal design shall provide that

a. sludge pipes shall not be less than three inches in diameter and so arranged as to facilitate cleaning,

b. the entrance to sludge withdrawal piping shall prevent clogging,

c. valves shall be located outside the tank for accessibility,

d. the operator may observe and sample sludge being withdrawn from the unit.

4.1.5.8 Cross-connections

a. Blow-off outlets and drains must terminate and discharge at places satisfactory to the reviewing authority.

b. Cross-connection control must be included for the potable water lines used to backflush sludge lines.

4.1.5.9 Detention period

The detention time shall be established on the basis of the raw water characteristics and other local conditions that affect the operation of the unit. Based on design flow rates, the detention time should be

a. four hours for suspended solids contact clarifiers and softeners treating surface water, and

b. one hour for the suspended solids contact softeners treating only groundwater.

The reviewing authority may alter detention time requirements.

4.1.5.10 Suspended slurry concentrate

Softening units should be designed so that continuous slurry concentrates of one per cent or more, by weight, can be satisfactorily maintained.

4.1.5.11 Water losses

a. Units shall be provided with suitable controls for sludge withdrawal.

b. Total water losses should not exceed

1. five per cent for clarifiers,

2. three per cent for softening units.

c. Solids concentration of sludge bled to waste should be

1. three per cent by weight for clarifiers,

2. five per cent by weight for softeners.

4.1.5.12 Weirs or orifices

The units should be equipped with either overflow weirs or orifices constructed so that water at the surface of the unit does not travel over 10 feet horizontally to the collection trough.

a. Weirs shall be adjustable, and at least equivalent in length to the perimeter of the tank.

b. Weir loading shall not exceed

1. 10 gallons per minute per foot of weir length for units used for clarifiers,

2. 20 gallons per minute per foot of weir length for units used for softeners.

c. Where orifices are used the loading per foot of launder should be equivalent to weir loadings. Either shall produce uniform rising rates over the entire area of the tank.

4.1.5.13 Upflow rates

Unless supporting data is submitted to the reviewing authority to justify rates exceeding the following, rates shall not exceed

a. 1.0 gallon per minute per square foot of area at the sludge separation line for units used for clarifiers,

b. 1.75 gallons per minute per square foot of area at the slurry separation line, for units used for softeners.

4.1.6 Tube settlers

Although recognized as an alternate method of clarification, sufficient experience is not yet available to establish design standards. Therefore, proposals for tube settler clarification must include pilot plant and/or full scale demonstration satisfactory to the reviewing authority prior to the preparation of final plans and specifications for approval.

CHEMICAL COSTS CALCULATIONS

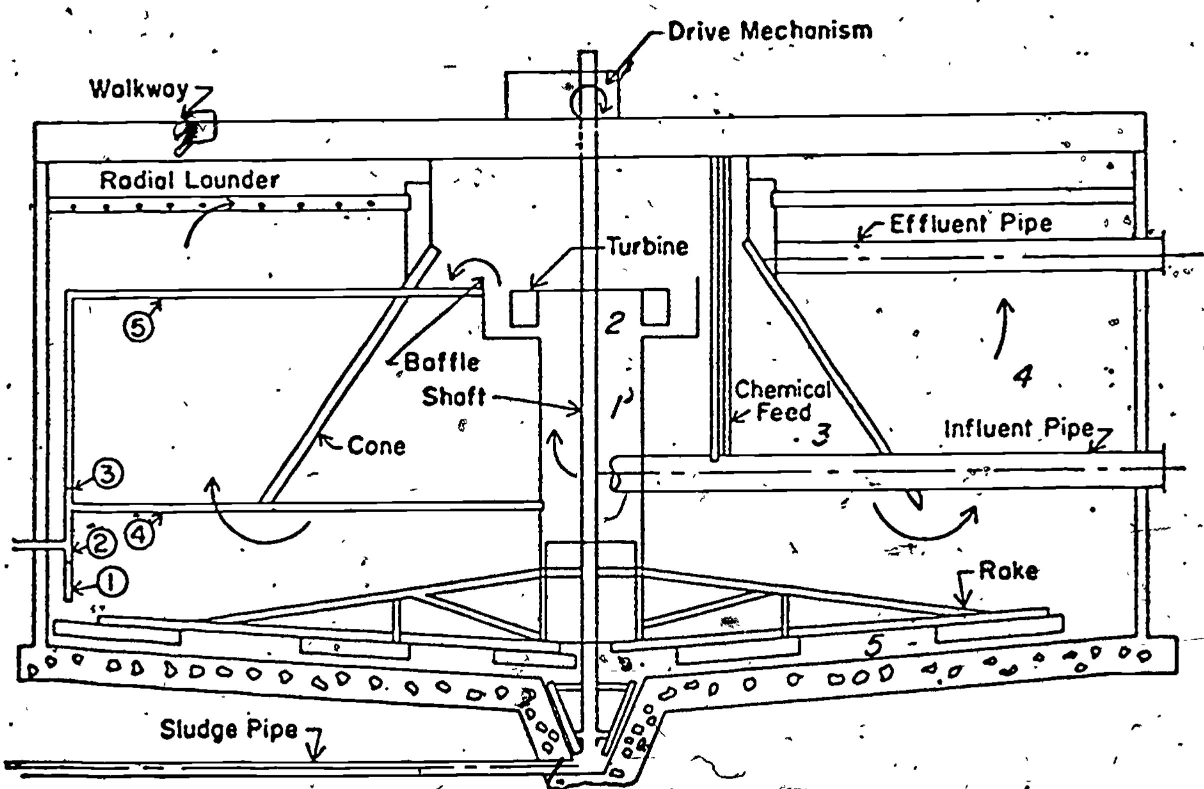
COSTS = (DOSAGE IN MG/L) X (MILLION GALLONS TREATED) X (8.34) X (CHEMICAL COST PER POUND)

ADVANCED OPERATION

A. SOFTENING SLUDGE SLURRY
   1. STRAIGHT LIME
   2. "SPIRACTOR"
   3. UPFLOW SOLIDS CONTACT UNIT

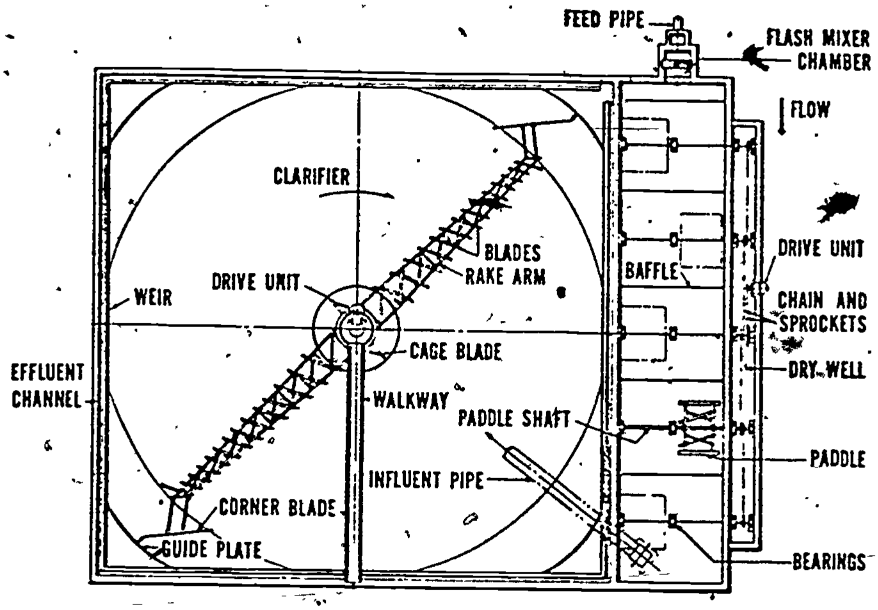
B. LOW HARDNESS
   1. STRAIGHT LIME
   2. "SPIRACTOR"
   3. UPFLOW SOLIDS CONTACT UNIT

UPFLOW SOLIDS CONTACT SOFTENER

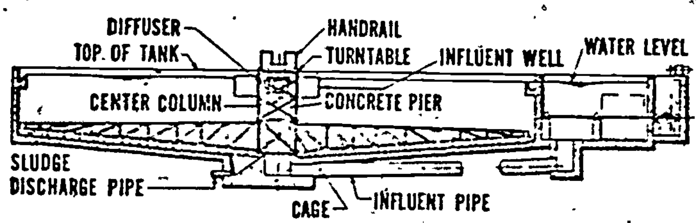


1 Riser Zone
2 Primary Reaction Zone
3 Secondary Reaction Zone
4 Clarification Zone
5 Sludge Blanket and Thickening Zone

STRAIGHT LINE SOFTENER

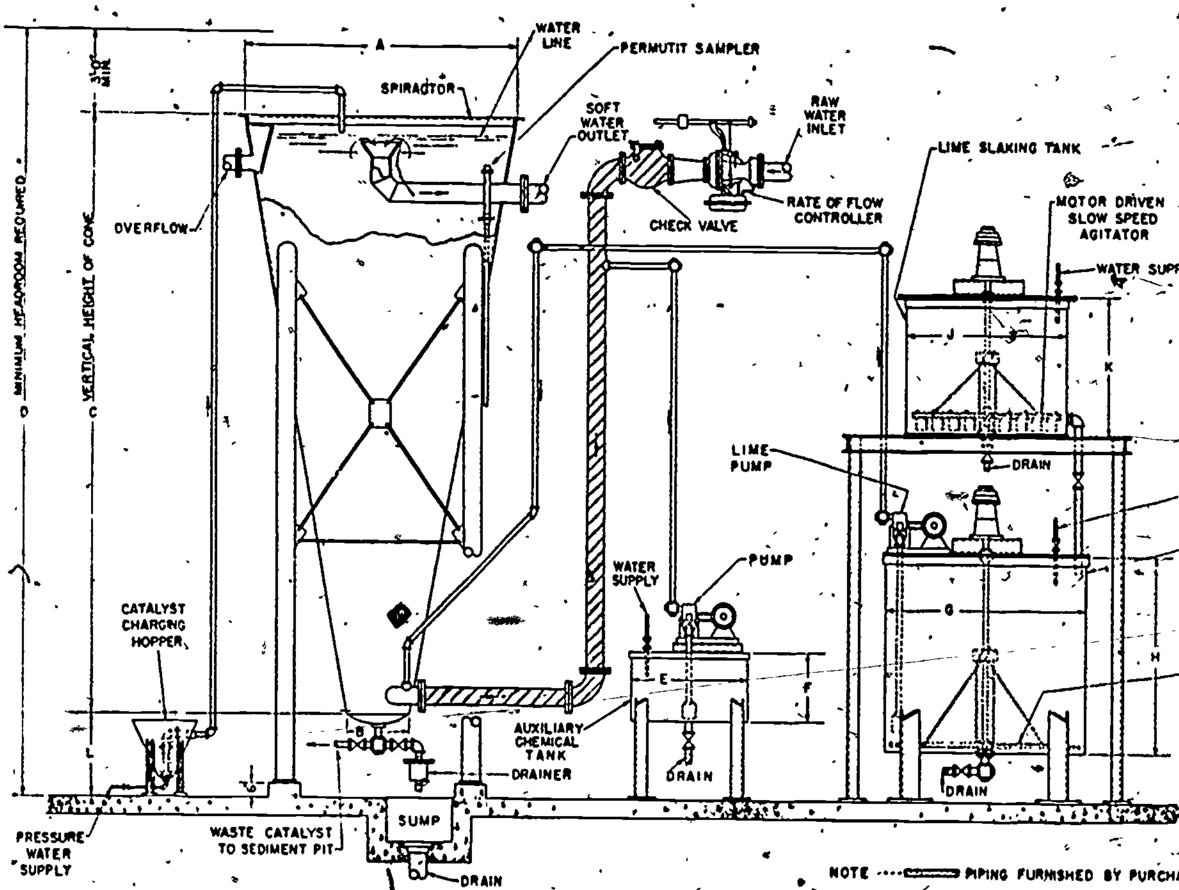


PLAN



SECTIONAL ELEVATION

"SPIRACTOR" SOFTENER



TRANSPARENCY II3ABWS - #27

CLASS PROBLEMS

for

Training Module II3ABWS

CLASS PROBLEM #1

For the following water quality:

CO_2 = 8.8 mg/l	Alk (HCO_3) = 135 mg/l as $CaCO_3$
Ca^{++} = 40.0 mg/l	$SO_4^{=}$ = 29.0 mg/l
Mg^{++} = 14.7 mg/l	Cl^- = 17.8 mg/l
Na^+	pH = 7.4

1. Sketch a me/l water quality bar graph.

2. Calculate the lime requirements for softening.

3. Calculate the soda ash requirements for softening.

4. Calculate the carbon dioxide requirements. Assume carbonate is 40 mg/l as $CaCO_3$ and OH is 10 mg/l as $CaCO_3$.

5. Determine the lime, soda ash, and carbon dioxide requirements to soften the following water.

CO_2 = 8.8 mg/l	Alk = 115 mg/l as $CaCO_3$
Ca^{+2} = 70 mg/l	SO_4^{+2} = 96 mg/l
Mg^{+2} = 9.7 mg/l	Cl^- = 10.6 mg/l
Na^+ = 6.9 mg/l	pH = 7.4

CLASS PROBLEM #2

1. A chemical precipitation upflow softener has been experiencing operational problems. It is thought that it is possibly currently overloaded. Evaluate the design.

Upflow Solids Contact Unit

1. Size - 35' x 35' x 15' deep
2. Total weir length - 192'
3. Flocc Zone - 2260 ft^3
4. Flow - 2 mgd

2. What will the chemical cost be for the plant in question 1 if the water quality is the same as part 1 of class problem #1. Chemical costs are

Lime = $34.00/ton
Soda Ash = $5.00/100 lb.
Carbon Dioxide = $3.25/lb

CLASS HANDOUT

for

Training Module II3ABWS

Handout for II3ABWS - Intermediate Chemical Precipitation Softening

I. Introduction
   A. Softening Reactions
   B. Recarbonation Reactions
   C. Operation of a Two Stage Softening Plant
   D. Operation of a Split Treatment Plant
   E. Operation of a Single Stage Treatment Plant
   F. Laboratory Control for Chemical Softening Plant
   G. Safety in a Chemical Softening Plant

II. Chemical Feeds
   A. Water Quality Bar Diagram
      1. General

Cations	Ca	Mg	Na^+	CO_2
Anions	HCO_3	SO_4	Cl^+	

milliequivalents

      2. Nomograph for Converting mg/l to me/l

         (See Figure 1)

   B. Lime Requirements

      Lime Dosage (mg/l) = (Alk(me/l)+ Mg(me/l) = 1(me/l)) x 28

   C. Soda Ash Requirements

      Soda Ash Dosage (mg/l) = (Non Carbonate Hardness (me/l) x 53
      (NO_2CO_3)

   D. Carbon Dioxide Requirements

      Carbon Dioxide Dosage (mg/l) = (Excess Hydroxide (me/l) + Carbonate (me /l)) x 44

   E. CALDWELL-LAWRENCE Diagram (See Figure 2)

4.1 CLARIFICATION

Plants designed for processing surface water shall

a. provide a minimum of two units each for rapid mix, flocculation and sedimentation,

b. permit operation of the units either in series or parallel,

c. be constructed to permit units to be taken out of service without disrupting operation, and with drains or pumps sized to allow dewatering in a reasonable period of time,

d. provide multiple-stage treatment facilities when required by the reviewing authority,

e. be started manually following shutdown.

4.1.1 Presedimentation

Waters containing high turbidity may require pretreatment, usually sedimentation, either with or without the addition of coagulation chemicals.

a. Basin design - Presedimentation basins should have hopper bottoms or be equipped with continuous mechanical sludge removal apparatus, and provide arrangements for dewatering.

b. Inlet - Incoming water shall be dispersed across the full width of the line of travel as quickly as possible; short-circuiting must be prevented.

c. Bypass - Provisions for bypassing presedimentation basins shall be included.

d. Detention time - Three hours detention is the minimum period recommended; greater detention may be required.

4.1.2 Rapid mix

Rapid mix shall mean the rapid dispersion of chemicals throughout the water to be treated, usually by violent agitation.

a. Equipment - Basins should be equipped with mechanical mixing devices.

b. Mixing - The detention period should be not more than thirty seconds.

c. Location - The rapid mix and flocculation basins shall be as close together as possible.

4.1.3 Flocculation

Flocculation shall mean the agitation of water at low velocities for long periods of time.

a. Basin design - Inlet and outlet design shall prevent short-circuiting and destruction of floc. A drain or pumps shall be provided to handle dewatering and sludge removal.

b. Detention - The flow-through velocity shall not be less than 0.5 nor greater than 1.5 feet per minute with a detention time for floc formation of at least 30 minutes.

c. Equipment - Agitators shall be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 to 2.0 feet per second.

d. Piping - Flocculation and sedimentation basins shall be as close together as possible. The velocity of flocculated water through pipes or conduits to settling basins shall not be less than 0.5 nor greater than 1.5 feet per second. Allowances must be made to minimize turbulence at bends and changes in direction.

e. Other designs - Baffling may be used to provide for flocculation in small plants only after consultation with the reviewing authority. The design should be such that the velocities and flows noted above will be maintained.

f. Superstructure - A superstructure over the flocculation basins may be required.

4.1.4 Sedimentation

Sedimentation shall follow flocculation. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The following criteria apply to conventional sedimentation units:

a. Detention time - Detention shall provide a minimum of four hours of settling time. This may be reduced to two hours for lime-soda softening facilities treating only groundwater.

b. Inlet devices - Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are required. A baffle should be constructed across the basin close to the inlet end and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows accross the basin.

c. Outlet devices - Outlet devices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in flow.

d. Overflow rate - The rate of flow over the outlet weir shall not exceed 20,000 gallons per day per foot of weir length. Where submerged orifices are used as an alternate for over-flow weirs, they should not be lower than three feet below the flow line with flow rates equivalent to weir loadings.

e. Velocity - The velocity through settling basins shall not exceed 0.5 feet per minute. The basins must be designed to minimize short-circuiting. Baffles must be provided as necessary.

f. Overflow - An overflow weir (or pipe) should be installed which will establish the maximum water level desired on top of the filters. It shall discharge with a free fall at a location where the discharge will be noted.

g. Superstructure - A superstructure over the sedimentation basins may be required. If there is no mechanical equipment in the basins and if provisions are included for adequate monitoring under all expected weather conditions, a cover may be provided in lieu of a superstructure.

h. Sludge collection - Mechanical sludge collection equipment should be provided.

i. Drainage - Basins must be provided with a means for dewatering. Basin bottoms should slope toward the drain not less than one foot in twelve feet where mechanical sludge collection equipment is not required.

j. Flushing lines - Flushing lines or hydrants shall be provided and must be equipped with backflow prevention devices acceptable to the reviewing authority.

k. Safety - Permanent ladders or handholds should be provided on the inside walls of basins above the water level. Guard rails should be included.

l. Sludge disposal - Facilities are required by the reviewing authority for disposal of sludge. (see Section 4.11). Provisions shall be made for the operator to observe or sample sludge being withdrawn from the unit.

4.1.5 Solids contact unit

Units are acceptable for combined softening and clarification where water characteristics are not variable and flow rates are uniform. Before such units are considered as clarifiers without softening, specific approval of the reviewing authority shall be obtained. Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flow which are less than the design rate and for changes in water characteristics. A minimum of two units are required for surface water treatment.

4.1.5.1 Installation of equipment

Supervision by a representative of the manufacturer shall be provided with regard to all mechanical equipment at the time of

a. installation, and

b. initial operation.

4.1.5.2 Operating equipment

The following shall be provided for plant operation:

a. a complete outfit of tools and accessories,

b. necessary laboratory equipment,

c. adequate piping with suitable sampling taps so located as to permit the collection of samples of water from critical portions of the units.

4.1.5.3 Chemical feed

Chemicals shall be applied at such points and by such means as to insure satisfactory mixing of the chemicals with the water.

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A rapid mix device or chamber ahead of the solids contact units may be required by the reviewing authority to assure proper mixing of the chemicals applied. Mixing devices employed shall be so constructed as to

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Flocculation equipment

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c. should provide the flocculation and mixing period to be not less than 30 minutes.

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The equipment should provide either internal or external concentrators in order to obtain a concentrated sludge with a minimum of waste water.

4.1.5.7 Sludge removal

Sludge removal design shall provide that

a. sludge pipes shall not be less than three inches in diameter and so arranged as to facilitate cleaning,

b. the entrance to sludge withdrawal piping shall prevent clogging,

c. valves shall be located outside the tank for accessibility,

d. the operator may observe and sample sludge being withdrawn from the unit.

4.1.5.8 Cross-connections

a. Blow-off outlets and drains must terminate and discharge at places satisfactory to the reviewing authority.

b. Cross-connection control must be included for the potable water lines used to backflush sludge lines.

4.1.5.9 Detention period

The detention time shall be established on the basis of the raw water characteristics and other local conditions that affect the operation of the unit. Based on design flow rates, the detention time should be

a. four hours for suspended solids contact clarifiers and softeners treating surface water, and

b. one hour for the suspended solids contact softeners treating only groundwater.

The reviewing authority may alter detention time requirements.

4.1.5.10 Suspended slurry concentrate

Softening units should be designed so that continuous slurry concentrates of one per cent or more, by weight, can be satisfactorily maintained.

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The units should be equipped with either overflow weirs or orifices constructed so that water at the surface of the unit does not travel over 10 feet horizontally to the collection trough.

a. Weirs shall be adjustable, and at least equivalent in length to the perimeter of the tank.

b. Weir loading shall not exceed

1. 10 gallons per minute per foot of weir length for units used for clarifiers,

2. 20 gallons per minute per foot of weir length for units used for softeners.

c. Where orifices are used the loading per foot of launder should be equivalent to weir loadings. Either shall produce uniform rising rates over the entire area of the tank.

4.1.5.13 Upflow rates

Unless supporting data is submitted to the reviewing authority to justify rates exceeding the following, rates shall not exceed

a. 1.0 gallon per minute per square foot of area at the sludge separation line for units used for clarifiers,

b. 1.75 gallons per minute per square foot of area at the slurry separation line, for units used for softeners.

4.1.6 Tube settlers

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IV. Advanced Operation
    A. Softening Sludge Slurry
        1. Straight Line
        2. "Spiractor"
        3. Upflow Solids Contact Unit
    B. Low Hardness
        1. Straight Line
        2. "Spiractor"
        3. Upflow Solids Contact Unit

V. Maintenance
    A. Upflow Solids Contact Unit
        1. General
        2. Turbine
        3. Rake
    B. Straight Line
        1. General
        2. Flocculators
        3. Sludge Collector
    C. "Spiractor"
        1. General
        2. Catalyst Feeder

SOFTENING REACTIONS

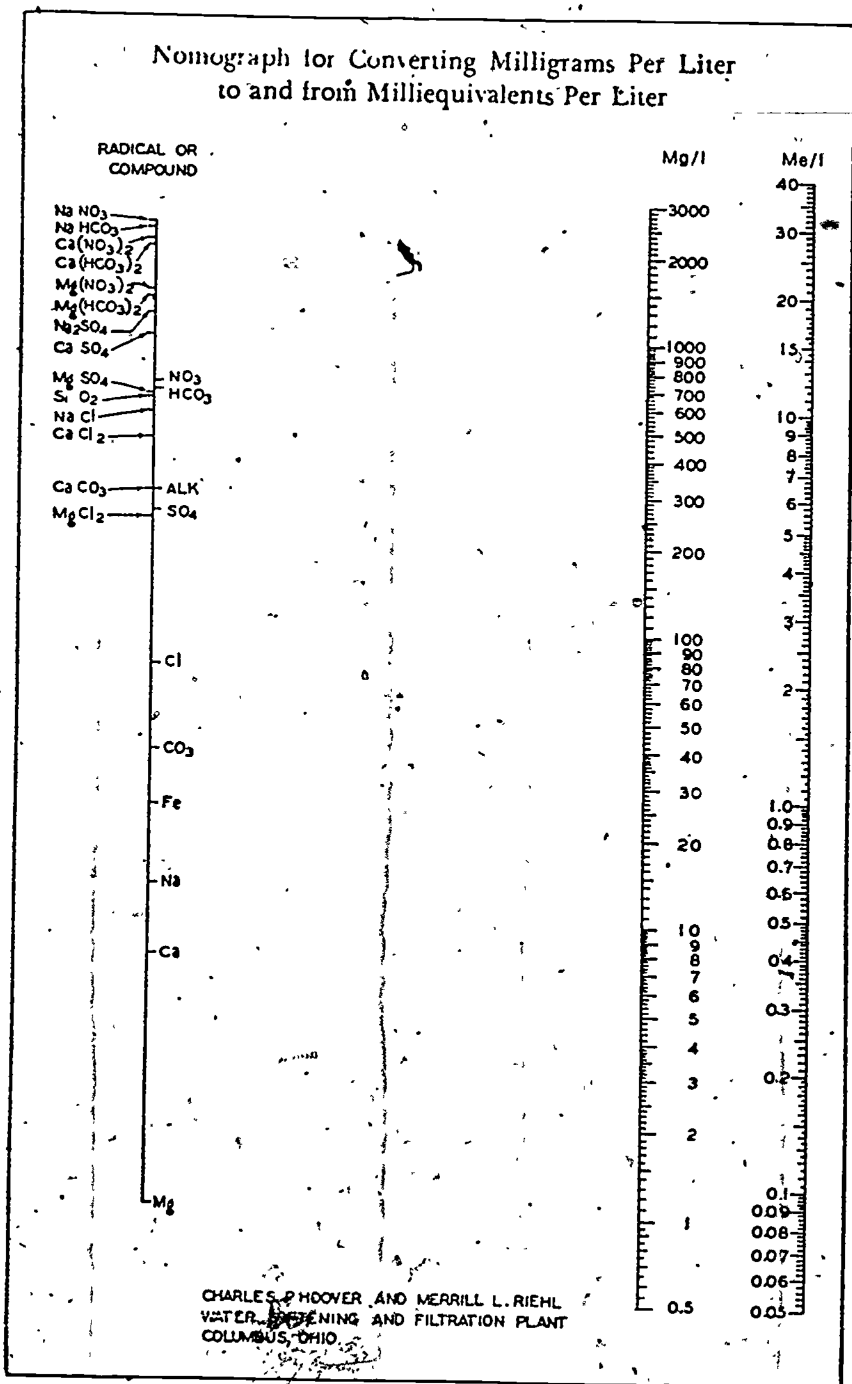

FIGURE III3ABWS - #1

SOFTENING REACTIONS

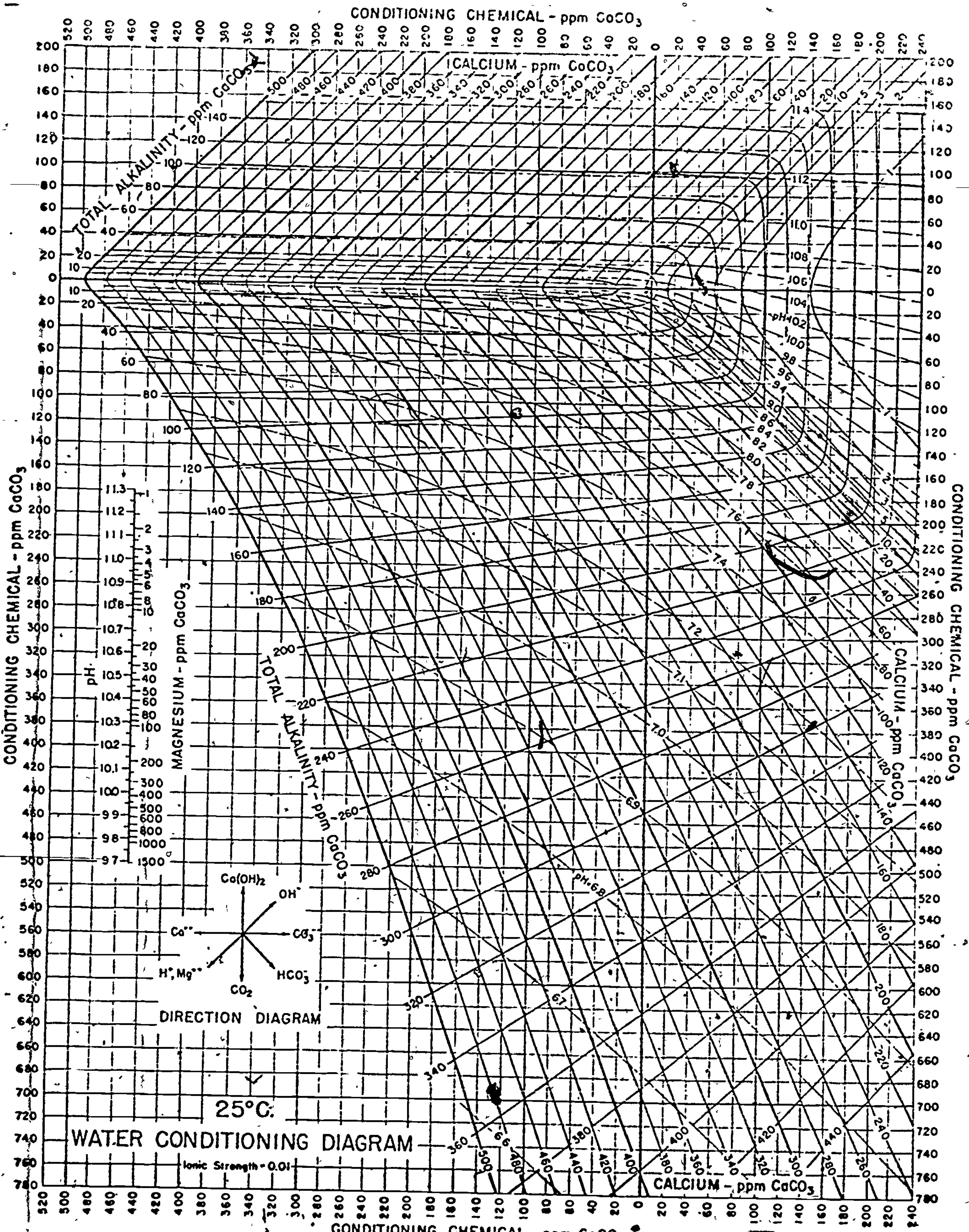

FIGURE II3ADMS - 42

EXAMINATION

for

Training Module II3ABWS

Examination for II3ABWS - Intermediate Chemical Precipitation Softening

1. In chemical precipitation softening, magnesium ions are always removed as ________________.

2. Lime only is required for removal of ________________ hardness.

3. List the five factors affecting water stabilization
   a.
   b.
   c.
   d.
   e.

4. Calcium is removed by adding ________ moles of lime for each mole of calcium.

5. For the following water, what will be the lime and soda dosages to soften the water.

   CO_2 = 20 mg/l   Alk = 120 mg/l

   Ca^{++} = 30 mg/l   pH = 7.2

   Mg^{++} = 40 mg/l

6. What will be the general carbon dioxide requirements for the water in problem 5.

7. If lime costs $34.00/ton, soda ash $5.00/100/lb. and carbon dioxide $3.25/lb. what will be the cost to treat 1 million gallons of water in problem #5 &#6.

TRUE OR FALSE. CIRCLE THE CORRECT ANSWER

T or F 8. Carbon dioxide recarbonation is usually required to properly stabilize water after chemical softening.

T or F 9. A pH of 9.5 is adequate to precipitate calcium in chemical softening.

T or F 10. Softeners in Iowa are designed under "~~Ten States~~ Standards".

T or F 11. Caldwell-Lawrence Diagram will generally give a higher chemical feed than the simplier water quality bar method.

T or F 12. Soda Ash is always needed for removal of magnesium hardness.

T or F 13. Upflow solids contact units can be operated at a higher hydraulic loading when used for softening than when used for coagulation.

T or F 14. In determining the final water quality, it is best to leave calcium carbonate and remove all of the magnesium.

T or F 15. The advantage of the "Spiractor" is that it results in a sludge that dewaters very rapidly.

T or F 16. Split treatment saves in chemical costs by using the naturally occurring carbon dioxide in the raw water.

T or F 17. A properly stabilized lime-soda softened water will always have a neutral pH of 7.0.