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ABSTRACT

This document is an instructional module package prepared in objective form for use by an instructor familiar with water stabilization and deposition and corrosion control in a water supply system. Included are objectives, an instructor guide, student handouts and transparency masters. The module considers water stability, water chemistry, deposition, deposition control, corrosion and corrosion control. This is the first level of a twc module series. (Author/RH)

BASIC STABILIZATION

Training Module 2.225.2.77

Prepared for the

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by

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September, 1977

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ABSTRACT

Basic Stabilization is a training module for water treatment plant operators. It is prepared in objective form and is intended as a guide for an instructor familiar with stabilization and corrosion control. Upon completion of this module the participant will have a better understanding of the analysis of these problems and be able to identify and recommend control measures. Participants should have some background in water chemistry and analysis and knowledge of water treatment and distribution systems. Total contact time will be 10.0 hours. The instructor should have a blackboard, overhead projector and a 2 x 2 slide projector.

INSTRUCTOR GUIDE

for

Training Module II2XWS

Basic Stabilization

Module No:	Module Title:
II2XWS	Basic Stabilization
	Submodule Title:
Approx. Time: 10 hours	Topic: Summary

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

1. Describe the stability analysis of a water and deposition control.
2. Describe the common mechanisms of corrosion.
3. Describe methods of corrosion detection and evaluation.
4. Describe methods of corrosion control.
5. Identify special areas of concern regarding deposition and corrosion control in water treatment.

Instructional Aids:

Handouts
Transparencies
Slides
Pipe samples

Instructional Approach:
Class Presentation and Discussion

References:

1. New York Health Department, Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. American Water Works Association, Basic Water Treatment Operator's Manual, AWWA No. M18, 1971.
3. Standard Methods for the Examination of Water & Wastewater, 14th Edition

Class Assignments:

Reading handout materials.
Read assigned material in references 1 and 2.

Module No:	Module Title:
II2XWS	Basic Stabilization
Approx. Time:	Submodule Title:
1.0 hour	Topic: Introduction

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

1. Describe stabilization and state the reasons for deposition concern.
2. Describe corrosion and cite typical concerns.
3. Identify problem areas in treatment plants, wells and distribution systems.

Instructional Aids:

Handout-Introduction
Pipe samples
Slides
Transparencies-Typical Problems

Instructional Approach:

Discussion

References:

1. New York Health Department, Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. American Water Works Association, Basic Water Treatment Operator's Manual, AWWA No. M18, 1971.

Class Assignments:

Read handouts and reference assigned readings.

Module No: II2XWS	Topic: Introduction

Instructor Notes:	Instructor Outline:
TRANS - BS1 Stability - Deposition	1. Discuss stability of a water a. Really is $CaCO_3$ equilibria b. Used to help analyze waters regarding deposition and corrosive tendency 2. Discuss examples of deposition problems and note the reasons for concern with each example. e.g. How does the deposition interfere with a water supply operation 3. Ask participants to relate typical deposition problems from their experience
TRANS - BS2 Corrosion	4. Discuss corrosion a. Chemical interaction - water & metal or chemical & metal b. Cite and discuss examples of corrosion 5. Ask participants to relate typical corrosion problems from their experience
Note: If possible, the instructor should check with water utilities and DEQ staff to obtain any examples of pipe that demonstrate corrosion or deposition for use in the class and return	

Module No: II2XWS	Module Title: Basic Stabilization
	Submodule Title:
Approx. Time: 2.0 hours	Topic: Water Chemistry and Water Softening

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

1. List and describe significant water quality parameters including hardness, alkalinity, iron, chlorine, fluorides, etc.
2. Describe stability indices* and typical analytical approaches.
3. Identify chemical interactions of concern in scale formation and corrosion.
4. Describe lime-soda and ion exchange softening and the resultant water quality.

*Langelier and Ryznar

Instructional Aids:

Handout-Water Chemistry; Stability Indices
Transparencies
Nalco Aquagraph

Instructional Approach:

Discussion

References:

1. New York Health Department, Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. American Water Works Association, Basic Water Treatment Operator's Manual, AWWA No. M18, 1971.
3. Standard Methods for the Examination of Water & Wastewater, 14th Edition

Class Assignments:

Read handouts and assigned readings.
Use Nalco Aquagraph.

Module No.: II2XWS	Topic: Water Chemistry and Water Softening

Instructor Notes:	Instructor Outline:
TRANS BS-3 Water Quality Parameters	1. Present, define and discuss the primary water quality parameters associated with stability and corrosion. a. Comment on the formation of precipitates and solubility b. Distinguish between the carbonate and and non-carbonate systems in hardness reduction c. The emphasis should be on their meaning, significance and units not on analytical procedures.
TRANS BS-4 Water Softening Reactions	2. Describe the typical water softening reactions. a. Stress the nature of the treated effluent quality from the processes. b: Comment on the pH ranges, and excess lime precipitation process c. Discuss the qualitative aspects of ion exchange effluent and include comments on blending to achieve a finished water quality
TRANS BS-5 Saturation pH TRANS BS-6 Saturation pH (Larson-Buswell Diagram)	3. Define and discuss saturation pH a. $CaCO_3$ equilibrium aspect b. Factors affecting pHs c. Explain the ways in which it can be calculated (Nalco aquagraph, Larson-Buswell & Std. Methods)
TRANS BS-7 Stability Indices	4. Discuss stability indices a. Note that the saturation index denotes tendencies

Module No: II2XWS	Topic: Water Chemistry and Water Softening

Instructor Notes:	Instructor Outline:
TRANS BS-8 Ryznar Index Experiences	b. The Ryznar Index is an attempt to quantitatively indicate scaling and corrosion c. The Ryznar Index is an emperical development. Note experiences with it in TRANS BS-8 d. These indices are guides not absolute indicators. Use laboratory tests and system samples to evaluate what is happening
Sample Problems 1. Via Nalco Aquagraph: pHs @ 50°F - 7.1 pHs @ 160°F - 6.2 Water is depositing by Ryznar and Langelier analysis at 160°F. 2. Ans. — 798 lbs using 8.33 lbs/gal	5. Solve sample problems a. Stability index analysis for heated water commercial user. b. Chemical requirements to feed a corrosion inhibitor. c. Analyze data provided by student participants for their plants.

Module No: II2XWS	Module Title: Basic Stabilization
	Submodule Title:
Approx. Time: 1.5 hours	Topic: Deposition Control

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

1. Describe the factors affecting $CaCO_3$ deposition.
2. Describe the process of recarbonation for deposition control.
3. Identify the problems associated with deposition.
4. Describe the use of chelating chemicals in deposition control.
5. Identify special cases of deposition, e.g. silicates.

Instructional Aids:

Handouts-Recarbonation; Chelating Chemicals
Transparencies

Instructional Approach:

Discussion

References:

1. New York Health Department, Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. American Water Works Association, Basic Water Treatment Operator's Manual, AWWA No. M18, 1971.

Class Assignments:

Read handouts and assigned readings.

Module No: II2XWS	Topic: Deposition Control

Instructor Notes:	Instructor Outline:
	1. Discuss factors affecting $CaCO_3$ deposition including calcium concentration, temperature, pH, alkalinity and loss of CO_2.
TRANS BS-9 Recarbonation	2. Discuss the purposes of recarbonation and the transformations that take place. a. React with hydroxides b. pH Adjustment c. Minimize $CaCO_3$ deposition on filter media d. Comment on pH goals
	3. Discuss the problems associated with deposition a. Clogging of plant feedlines and piping b. Increase in resistance to flow and decreased flow coefficient, C. c. Irregular deposition may set up corrosion opportunities d. Heat transfer problems in private and commercial water heating systems. Energy & failures.
See reference article Ralston, P.H. "Inhibiting Water Formed Deposits with Threshold Compositions", Materials Protection and Performance, p 39-44 June 1972	4. Discuss the use of chelating chemicals. a. Polyphosphates will tie up or hold Calcium ions and minimize the deposition of Ca CO_3. Comment on temperature instability. b. Industrial water practice uses phosphonates.
See N.Y. Manual p.215 See M18 p.73	5. Comment on special cases of deposition a. Silicates in fluosilicic acid feeding

Module No:	Topic:
112XWS	Deposition Control

Instructor Notes:	Instructor Outline:
See M18 p.61	b. Calcium or magnesium fluorides c. Iron deposits due to oxidation of iron and/or combination with hydroxide d. Manganese deposits e. Calcium carbonate, iron oxides in well screens and use of acids e.g. muriatic acid. Chlorination for iron bacteria.

Module No:	Module Title:
II2XWS	Basic Stabilization
	Submodule Title:
Approx. Time:	Topic:
2.0 Hours	Corrosion

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

1. Describe the common mechanisms of corrosion including differential aeration, galvanic and stray currents.
2. Identify special cases of corrosion, e.g. CO_2, fluoride and chlorine systems.
3. Describe factors affecting corrosion.
4. Identify methods of corrosion detection including material checks and water analysis.

Instructional Aids:

Handouts-Corrosion Mechanisms; Detection Techniques
Transparencies

Instructional Approach:

Discussion

References:

1. New York Health Department, Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. American Water Works Association, Basic Water Treatment Operator's Manual, AWWA No. M18, 1971.

Class Assignments:

Read handouts and reference assigned readings.

Module No: II2XWS	Topic: Corrosion

Instructor Notes:	Instructor Outline:
TRANS BS-10 Types of Corrosion Cells TRANS BS-11 Corrosion Cell Note: Go lightly on the detailed chemistry. This is covered in the advanced course.	1. Discuss the types of corrosion cells. Indicate examples of each of the types in water supply practice a. Galvanic b. Differential Aeration c. Concentration Cells d. Differential Stress e. Impressed Current
TRANS BS-12 Galvanic Series	Note: Ask participants to cite personal examples of the corrosion cells in their experience.
	2. Briefly comment on special cases of corrosion.
p.57 M18	a. Handling of corrosive chemicals regarding storage & piping e.g. acids, hypochlorite solutions
p.197 N.Y. Manual	b. Copper corrosion from soft waters containing CO_2 c. Formation of aluminum oxide deposits
p.215 N.Y. Manual	d. Corrosion of feed lines with fluoride salts
	3. Discuss factors that affect corrosion. a. Type of metal & dissimilar aspects b. pH - type of corrosion product and relationship to stability c. Oxygen - access to points on metal surface d. Flow velocity - oxygen availability, movement of corrosion products and

Module No: II2XWS	Topic: Corrosion

Instructor Notes:	Instructor Outline:
	coatings e. Temperature - reaction rates, solubility 4. Discuss methods of corrosion detection a. Observations and reports of staining and "red water" b. Analyze the water supply at various locations for iron concentrations
TRANS BS-13 Corrosion Coupons	c. Remove pipe sections, valves and fittings for observation d. Use of coupons - a device for monitoring corrosion or deposition rates

Module No:	Module Title:
II2XWS	Basic Stabilization
	Submodule Title:
Approx. Time: 2.0 hours	Topic: Corrosion Control

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

1. List various approaches of corrosion control.
2. Describe techniques of corrosion control including water chemistry change, use of inhibitors, coatings, material selection, and cathodic protection.

Instructional Aids:

Handouts-Control Methods
Case Studies
Transparencies

Instructional Approach:

Discussion

References:

1. New York Health Department, Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. American Water Works Association, Basic Water Treatment Operator's Manual, AWWA No. M18, 1971.

Class Assignments:

Read handouts and assigned reference readings.
Case studies

Module No: II2XWS	Topic: Corrosion Control

Instructor Notes:	Instructor Outline:
TRANS BS-16 Approaches to Corrosion Control	1. Review the various approaches to corrosion control 2. Describe and discuss alternative techniques of corrosion control a. Use of corrosion resistant materials e.g. stainless steel, aluminum, nickel, brass, asbestos cement, concrete, PVC-plastic, fiberglass tanks & piping b. Use of coatings and linings e.g. galvanizing, cement linings, coal tar enamels, resins and paints, zinc silicate paints
	c. Deposition of $CaCO_3$; pH adjustment e.g. use of lime, soda ash or caustic soda raise S.I. to: +0.8 to 1.2
p.68 M18; p.206 N.Y. Man. See Mullen & Ritter, "Potable Water Corrosion Control", p.473-79 JAWWA, Aug. 1974	d. Use of protective chemical coatings e.g. cathodic inhibitors, phosphates especially zinc-phosphate e. Cathodic protection. e.g. use of sacrificial anodes in water tanks and treatment units

Module No: II2XWS	Module Title: Basic Stabilization
	Submodule Title:
Approx. Time: 1.0 hour	Topic: Miscellaneous Topics and Summary

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

1. Identify some special related areas of concern including main flushing, iron bacteria, sulfate breakdown, storage and handling of corrosive and depositing chemicals.
2. Recognize the interrelationships of stabilization-deposition and corrosion control and various water treatment systems.

Instructional Aids:

Handout
Transparencies

Instructional Approach:
Discussion

References:

1. New York Health Department, Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. American Water Works Association, Basic Water Treatment Operator's Manual, AWWA No. M18, 1971.

Class Assignments:

Read handouts and assigned reference readings.

Module No: II2XWS	Topic: Miscellaneous Topics and Summary

Instructor Notes:	Instructor Outline:
	1. Discuss some areas of related concern a. Incidence of iron bacteria - source, filamentous nature, deposits, problems and possible treatment measures e.g. chlorine and copper sulfate b. Sulfate breakdown in low flow areas - release of H_2S c. Water main flushing - does not solve problems. Dislodging deposits. Purposes. d. Storage & handling of chemicals fluorides, chlorine re-corrosion & deposition 2. Summarize the chemical interrelationships of $CaCO_3$ deposition and its role in corrosion prevention in chemical softening and ion exchange treatment plants.

Module No's: II2XWS & II3ADWS	Topic: Reference Materials Utilized in Developing The Modules
Instructor Notes:	**Instructor Outline:**
Chlorine Feeding, p.45-58 Iron & Manganese Control, p. 59-62 Scaling & Corrosion Control, p.63-68 Fluoride feeding, p.72-73	AWWA, Basic Water Treatment Operator's Manual, AWWA No.M18, 1971
Softening, p.171-78 Corrosion & corrosion control, p.197-207 Fluoride deposition, p.214-15 Operation & Maintenance of Distribution Systems, 219-20 Plant Structures, p.234 Marble Test, p.281-83	N.Y. ~~Dept.~~ of Health, Manual of Instruction for Water Treatment Plant Operators, Health Educ. Service, N.Y.
Filters in Softening Plants, p.277-78 Corrosion Phenomena - Causes and Cures, p.295-312 Chemistry of the Lime-Soda Process, p.313-39 Iron and Manganese, p.378-396 Hydrofluosilicic Acid, 419-20 Nuisance organisms, p.494	AWWA, Inc. Water Quality and Treatment, 3rd Edit. McGraw-Hill, 1971
Wells, p.60-67, 73-77 Metallic Corrosion, p.274-88 Recarbonation, p.514-88 Misc. methods of treat., p. 572-77	Babbitt, H.E., Doland, J.J., Cleasby, J.L. Water Supply Engineering, 1962

Module No's: II2XWS & II3ADWS	Topic: Reference Materials Utilized in Developing The Modules
Instructor Notes:	**Instructor Outline:**
Calcium Carbonate Saturation, p. 61-63 Iron & Sulfur Bacteria, 993-999	Amer. Public Health Assoc., Standard Methods For the Examination of Water and Wastewater, 14th Edition, 1976
Chemical equilibria, p.31-38, p.59 Alkalinity, p.327-39 Hardness, p.347-355 Water Softening, p.356-62 Iron & Manganese, p.446-52	Sawyer, C.N. & McCarty, P.L., Chemistry for Sanitary Engineers, 2nd Edit. 1967
Chemical Precipitation, Stabilization and Ion Exchange, p.29-1 to 29-34 Corrosion, 30-15 to 30-26	Fair, G.M., Geyer, J.C. & Okun, D.A., Water and Wastewater Engineering, Vol. 2. 1968
	Kleber, John P. "The Effect of Water Quality on the Corrosion of Pipe Lines", p264-290 Proceedings of the Second Annual Underground Corrosion Short Course, Late 1950's
	Larson, T.E. "Corrosion by Domestic Waters" Illinois State Water Survey Study, 48 pages, mid 1970's
	Ralston, P.H., "Inhibiting Water Formed Deposits with Threshold Compositions", p.39-44, V.11 No6 Materials Protection and Performance, June 1972
	Mullen E.D. & Ritter, J.A. "Potable Water Corrosion Control" p.473-79, JAWWA, Aug 1974
	Corrosion Article Series - Aug 1974, JAWWA
	Weers, W.A. & Middlebrooks, E.J., "A Review of the Theory and Control of Corrosion", R18-R28, Water and Sewage Works, Ref. No. 1967.

TRANSPARENCIES

for

TRAINING MODULE II2XWS

Basic Stabilization

STABILITY - DEPOSITION

STABILITY - $CaCO_3$ EQUILIBRIUM. A CHARACTERISTIC OF A WATER RELATED TO ITS TENDENCY TO DEPOSIT $CaCO_3$ OR BE CORROSIVE TO METAL SURFACES

DEPOSITION CONCERNS

DEPOSITION IN TREATMENT PROCESS EQUIPMENT AND PIPING - eg. $CaCO_3$, Iron oxides, CaF - Interference with flow and operations

DEPOSITION ON FILTER MEDIA - Media change, backwashing

DEPOSITION OF $CaCO_3$ IN DISTRIBUTION SYSTEM - Resistance to flow, Inc. head loss

DEPOSITION IN HEATED WATER SYSTEMS - Heat transfer, failure

IRON DEPOSITS FROM CORROSION OR NATURAL SOURCES - Iron bacteria, Tuberculation, Staining, Water flow

MANGANESE DEPOSITS FROM NATURAL Mn SOURCES - Staining

WELL SCREEN INCRUSTATION AND WELL EQUIPMENT DEPOSITS - Restrict flow

TRANS BS-1

CORROSION

CORROSION - THE DESTRUCTION OF A METAL BY CHEMICAL OR ELECTROCHEMICAL REACTION WITH ITS ENVIRONMENT

CORROSION CONCERNS

LOSS OF METAL FROM PIPING DUE TO WATER-METAL SURFACE ACTION - Pitting

INCREASE IN IRON CONTENT OF WATER SUPPLY - Staining

DEVELOPMENT OF IRON DEPOSITS - Tuberculation, staining, water flow

DETERIORATION OF PROCESS EQUIPMENT IN CHEMICAL FEED AREAS - eg. Hypochlorite, H_2SiF_6

EXTERNAL CORROSION OF METAL SURFACES IN PROCESS AREAS, PIPE GALLERIES - Interference, Appearance

EXTERNAL CORROSION OF BURIED PIPE

COPPER CORROSION WITH SOFT WATER - Staining

WELL SCREENS, CASINGS, SHAFTS

TRANS BS-2

WATER QUALITY PARAMETERS

pH - $\log \frac{1}{[H^+]}$ less than 7 - Acid
greater than 7 - Alkaline

ALKALINITY - Hydroxide (OH^-)
Carbonate ($CO_3^=$)
Bicarbonate (HCO_3^-)

HARDNESS - Calcium (Ca^{++}); Magnesium (Mg^{++})
Carbonate ($\approx$ Alkalinity e.g. HCO_3^-)
Non-carbonate ($\sim SO_4^=$)

IRON - Ferrous (Fe^{++}); Ferric (Fe^{+++})

PHOSPHORUS - Polyphosphate e.g. $Na_3(PO_4)_6$
Orthophosphate e.g. Na_3PO_4
Polyphosphates hydrolyze in aqueous solution to the ortho form - rate of reversion increases with temperature increases.

WATER SOFTENING REACTIONS

Chemical Precipitation

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2\ \underline{CaCO_3} + 2\ H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 = CaCO_3 + MgCO_3 + 2\ H_2O$$

$$MgCO_3 + Ca(OH)_2 = \underline{CaCO_3} + \underline{Mg(OH)_2}$$

$$MgSO_4 + Ca(OH)_2 = CaSO_4 + \underline{Mg(OH)_2}$$

$$CaSO_4 + Na_2CO_3 = \underline{CaCO_3} + Na_2SO_4$$

$$CO_2 + Ca(OH)_2 = CaCO_3 + H_2O$$

Ion Exchange

$$\left.\begin{matrix}Ca\\Mg\end{matrix}\right\}(HCO_3) = Na_2R = \left.\begin{matrix}Ca\\Mg\end{matrix}\right\}R + 2\ NaHCO_3$$

$$\left.\begin{matrix}Ca\\Mg\end{matrix}\right\}SO_4 + Na_2R = \left.\begin{matrix}Ca\\Mg\end{matrix}\right\}R + Na_2SO_4$$

SATURATION pH

THE pH AT WHICH WATER WOULD NEITHER DEPOSIT NOR DISSOLVE CALCIUM CARBONATE

FACTORS AFFECTING pHs ARE: Calcium
Alkalinity
Temperature
Total Dissolved Solids

CALCULATION:

1. USE NALCO AQUAGRAPH
2. USE LARSON-BUSWELL DIAGRAM
3. USE <u>STANDARD METHODS</u> TABLES, (p. 62)

PAGE 25 "SATURATION PH LARSON-BUSWELL DIAGRAM" REMOVED PRIOR TO BEING SHIPPED TO EDRS FOR FILMING DUE TO COPYRIGHT RESTRICTIONS.

STABILITY INDICES

LANGELIER'S SATURATION INDEX (S.I.)

S.I. = pH Actual - pHs

Where pHs is the pH of saturation

A plus value indicates:
A lack of excess CO_2
$CaCO_3$ scale-forming qualities

A minus value indicates:
An excess of CO_2
Scale dissolving properties

Note: The S.I. is not quantitative but shows directional tendency

RYZNAR INDEX (R.I.)

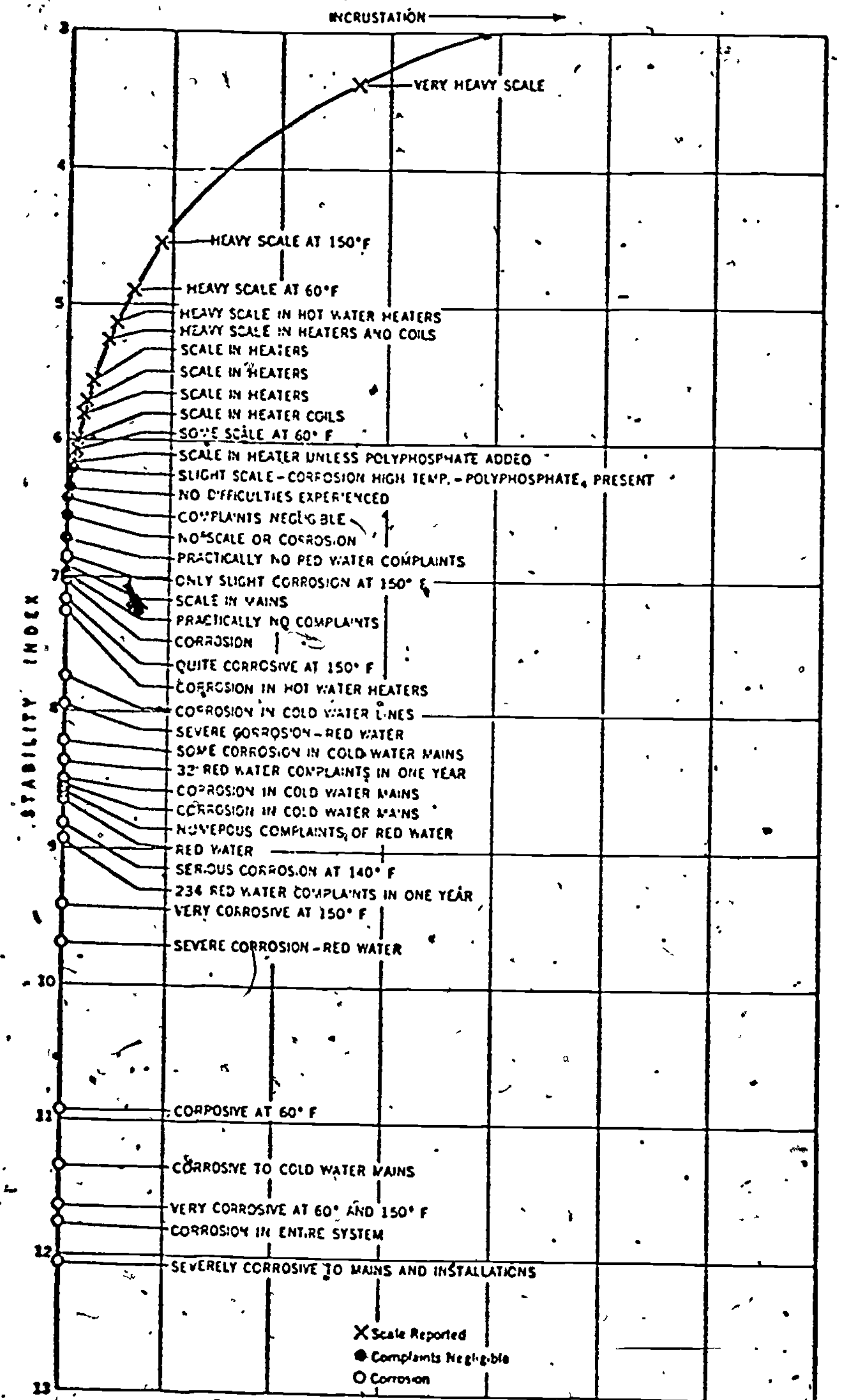
R.I. = 2 pHs — pH

Values greater than 7.0 indicate a corrosive water

Values less than 7.0 indicate a scale-forming water.

Note: The Nalco Aquagraph uses 6.0 as a breakpoint. Also, see figure.

RYZNAR INDEX



RECARBONATION

EXCESS LIME (Hydroxide)

$$Ca^{++} + 2\ OH^{-} + CO_2 \longrightarrow CaCO_3 + H_2O$$

SUPERSATURATION WITH $CaCO_3$

$$CO_2 + CO_3^{=} + H_2O \longrightarrow 2\ HCO_3^{-}$$

MAGNESIUM HYDROXIDE

$$Mg^{++} + 2\ OH^{-} + CO_2 \longrightarrow Mg^{++} + CO_3^{=} + H_2O$$

TYPES OF CORROSION CELLS

CORROSION CELL — AN ELECTROLYTIC CELL IN WHICH METAL IS REMOVED FROM THE ANODIC (Negative) AREA DURING THE PASSAGE OF DIRECT CURRENT BETWEEN THE CATHODIC (Positive) AREA AND THE ANODIC AREA.

TYPES OF CELLS

GALVANIC — DISSIMILAR METALS e.g. CAST IRON and COPPER

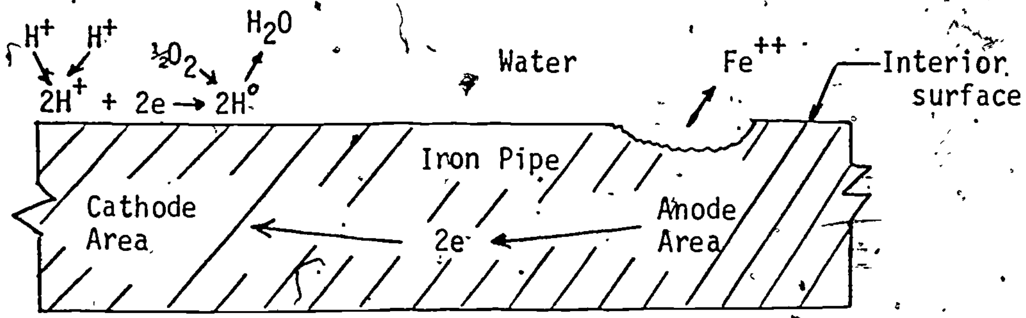
DIFFERENTIAL AERATION — TWO PORTIONS OF THE METAL RECEIVE OXYGEN AT DIFFERENT RATES

CONCENTRATION CELLS — THE VARIATION IN CONCENTRATION OF DIFFERENT SUBSTANCES IN SOILS CAN CAUSE A CORROSION CELL TO BE FORMED

DIFFERENTIAL STRESS — STRESSES e.g. WELDING CHANGE THE PHYSICAL CHARACTERISTICS OF A METAL - CAN AFFECT ITS ELECTRO-POTENTIAL

IMPRESSED-CURRENT — WHERE "GROUNDING" IS PRACTICED. THE LOCATION WHERE THE CURRENT LEAVES (Anodic Area) MAY SHOW INCREASED CORROSION.

CORROSION CELL



COMMENT: AREAS OF ACTIVITY

-- THE AREA TO WHICH OXYGEN HAS EASIEST ACCESS TENDS TO BECOME THE CATHODIC AREA.

-- THE AREA TO WHICH OXYGEN HAS ACCESS WITH DIFFICULTY BECOMES THE ANODIC AREA.

EXAMPLES OF ANODIC AREAS OR AREAS SHELTERED AGAINST OXYGEN ARE:

-- PITS OR DEPRESSIONS IN THE METAL

-- AREAS UNDERLYING MILL SCALE OR PRODUCTS OF CORROSION

-- AREAS BELOW BIOLOGICAL GROWTHS

Galvanic Series of Metals and Alloys

Corroded end (Anodic or least noble)	Magnesium
	Zinc
	Aluminum (commercial pure)
	Steel or iron
	Cast iron
	Lead
	Tin
	Brasses
	Copper
	Bronzes
	Chromium - iron (passive)
	Silver
Protected end (Cathodic or most noble)	Graphite
	Gold
	Platinum

COUPON EVALUATION in DISTRIBUTION

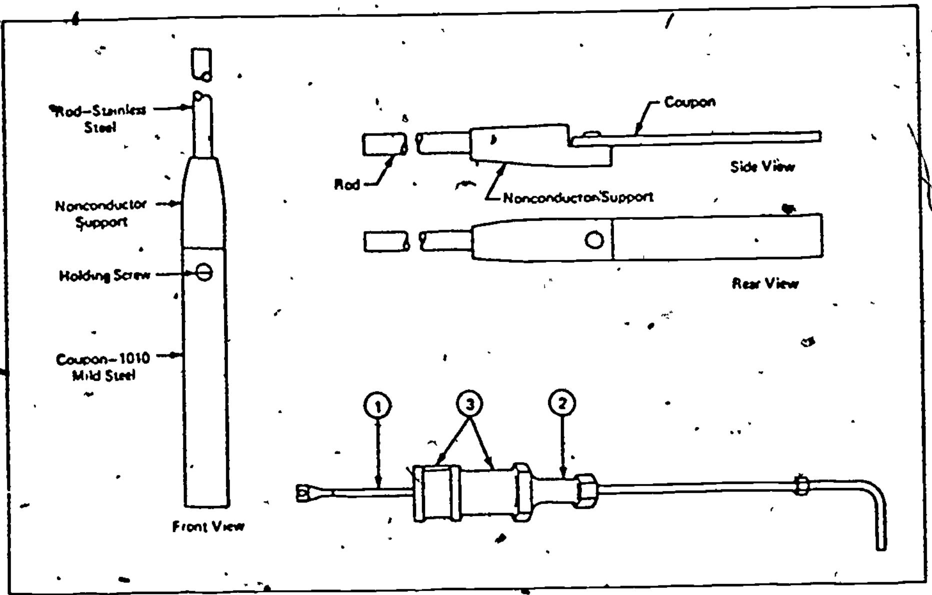


Fig. 5. Distribution-System Coupon-Holder Assembly

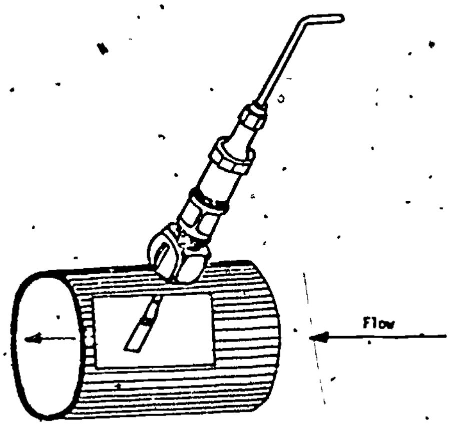


Fig. 6. Corrosion Coupon Assembly

Ref: Mullen & Ritter, "Potable Water Corrosion Control", p.473-79, J-AWWA, Aug. 1974.

AWWA WATER QUALITY GOAL: 90 day tests

Incrustation on stainless steel not to exceed 0.05 mg/sq.cm.

Loss by corrosion of galvanized iron not to exceed 5.0 mg/sq.cm.

Ref: p.62 AWWA Journal September 1973

APPROACHES TO CORROSION CONTROL

USE CORROSION RESISTANT MATERIALS

USE COATINGS AND LININGS

DEPOSITION OF $CaCO_3$ AND pH ADJUSTMENT

PROTECTIVE CHEMICAL COATINGS

CATHODIC PROTECTION

TRANS BS-14

STUDENT-PARTICIPANT GUIDE

for

TRAINING MODULE II2XWS

Basic Stabilization

PARTICIPANT INSTRUCTIONAL MATERIALS

I. Each participant will receive an outline of the module topics with supplemental comments as appropriate. This outline is to assist the participant in preparing for class discussions and guiding the students in their study of reference materials and transparencies.

II. Students will receive a xerox copy of each transparency. If desired, NALCO aquagraphs can be obtained from the NALCO Chemical Co., Chicago, Illinois.

III. The New York Manual and the AWWA M18 Manual should probably be required for the modules. They should be owned by the participants as they are of value for other modules and as general references.

If the participants do not own these references then permission should be obtained to provide them with xerox copies of the primary subject material.

IV. Some of the examination questions could be used as class study questions or a means for evaluation of the instruction. They could also be supplemented based on the instructor's treatment of the topics.

IIZXWS BASIC STABILIZATION MODULE

STUDENT OUTLINE

Note: Participants will receive a copy of each transparency used in the presentations. Participants will receive appropriate reference material from the New York Health Dept. Manual of Instruction for Water Treatment Plant Operators and from the AWWA M18, Basic Water Treatment Operator's Manual.

Participants are encouraged to bring documented examples of corrosion and deposition problems and solutions to the class for group discussion and analysis. Pipe or fitting samples and/or photographs are especially of interest.

I. Introduction

A. Stability of Water (Trans BS-1)
1. Relates to $CaCO_3$ equilibria - is a water depositing or not regarding $CaCO_3$.
2. It is used to help analyze water supply tendencies to be depositing or corrosive.

B. Examples of deposition. (Trans BS-1)
1. Note the types of deposition problems
2. Observe the nature of the interference with a water supply function
3. Describe examples of deposition problems in your water supply and treatment system

C. Corrosion (Trans BS-2)
1. Note the definition and chemical nature of corrosion
2. Observe the types of corrosion and note the water supply problem associated with each type
3. Describe examples of corrosion problems in your water supply and treatment system

II. Water Chemistry and Water Softening

A. Review and discuss typical water quality parameters (Trans BS-3)
1. pH - alkalinity - precipitation relationships
2. Note types of hardness and how they relate to each other
3. Note the forms of iron and the more insoluble ferric state and the more insoluble ferric state and its precipitates
4. Compare polyphosphates - $Na_3(PO_3)_6$ and orthophosphates - Na_3PO_4

B. Water softening reactions (Trans BS-4)
1. Review the typical chemical reactions
2. Note the higher pH requirements for magnesium removal. The unreacted lime and high OH^- concentrations lead to the need for recarbonation. Lime softened waters tend to be depositing.

3. In ion exchange note that there is no decrease in alkalinity. Ion exchange waters need blending for optimum water quality and stability. They tend to be corrosive waters.

C. Saturation pH (Trans BS-5 & BS-6)
1. Note that the saturation pH refers to the $CaCO_3$ equilibrium
2. Note the factors affecting pHs. Observe changes in pHs as you change the water quality factors. (Use Larson-Boswell Diagram or Nalco Aquagraph)

D. Stability indices (Trans BS-7 & BS-8)
1. Note that the Langelier (S.I.) Index indicates tendencies and the numerical values do not denote quantities.
2. The Ryznar Index was developed with the intent to quantitatively predict scaling or corrosion. Trans BS-8 illustrates some experiences with various R.I. values.
3. These indices are guides not absolute indicators. Laboratory tests and field water system samples should be used to further evaluate the response of any water system.

III. Deposition Control

A. Review the factors that affect $CaCO_3$ deposition including calcium concentration, temperature, pH, alkalinity, TDS and loss of CO_2.

B. Note the recarbonation reactions in chemical softening (Trans BS-9)
1. The functions of the CO_2 addition include reaction with hydroxide, pH adjustment and decreased $CaCO_3$ deposition
2. The purposes of recarbonation relate to the stability of the treated water in the water plant e.g. minimize deposition of $CaCO_3$ on filter media and in the distribution system.

C. What are the problems associated with deposition
1. Plant piping and fittings may become clogged with deposits and not function properly.
2. Piping systems may develop an increased resistance to flow. This could result in increased head (pressure) loss and affect flow rates and pumping energy requirements.
3. Irregular deposition in piping could lead to the development of differential aeration corrosion cells.
4. Deposits on heating surfaces result in increased energy requirements in heated water systems. Severe deposition could result in failure of the system.

D. Deposition rates can be affected by the use of chelating (sequestering) chemicals
1. Polyphosphates can be used to tie-up or hold calcium ions in solution and control or minimize their deposition as $CaCO_3$.
2. Polyphosphates are used ahead of rapid sand filters and in distribution systems.
3. Some polyphosphates revert back to ortho phosphate form and lose their chelating ability. This change increases with temperature e.g. in a 140° F hot water system.
4. Polyphosphates can also tie-up or hold soluble iron (ferrous) in solution.

5. Industrial water operations have successfully used phosphates as chelates.

E. There are many special cases of deposition in water systems. Some examples include the following
   1. Silicates in fluosilicic acid feeding
   2. Calcium and/or magnesium fluorides
   3. Iron deposits - oxides and hydroxides
   4. Manganese deposits
   5. $CaCO_3$, iron oxides etc. in well screens

IV. Corrosion

A. Note the various types of corrosion cells (Trans BS-10)
   1. Note the features of a typical differential aeration cell (Trans BS-11)
   2. The galvanic series (Trans BS-12) can be used to help predict potential for galvanic corrosion due to dissimilar metals

B. There are several additional types of corrosion occurrences. They include
   1. Handling of corrosive chemicals e.g. acids, hypochlorite solutions
   2. Copper corrosion due to soft waters containing CO_2 and other anions e.g. chlorides
   3. Aluminum oxides
   4. Feed line corrosion with fluoride salts

C. Several physical and chemical factors affect corrosion and corrosion rates
   1. The nature of connecting metal surfaces in the galvanic series can result in a corrosion incident
   2. High pH values (>9.5) tend to decrease corrosion rates due to deposition of $CaCO_3$ and corrosion products
   3. Differential access of dissolved oxygen to metal surfaces can lead to the development and continuation of corrosion cells
   4. Increases in flow velocities can increase oxygen availability, increase the removal of corrosion products and extend the distribution of corrosion products and coatings.
   5. Increases in temperature tend to increase corrosion rates and also affect the solubility of compounds e.g. $CaCO_3$.

D. Corrosion detection
   1. The existence of corrosion of iron piping can be noted by observing "red water" conditions, staining and tuberculation of the interior surfaces of piping.
   2. Increases in iron concentration in the water supply distribution system are indications of corrosion in the system
   3. Pipe sections, valves or fittings can be removed for inspection
   4. Coupons (Trans BS-13) can be inserted in piping systems to monitor corrosion and deposition

V. Corrosion control

A. Review the approaches to corrosion control (Trans BS-14)

B. Many laternate techniques can be used alone or in combination to achieve corrosion control

1. Corrosion resistant materials e.g. stainless steel, aluminum, nickel, brass, asbestos cement, concrete, PVC plastic and others can be used. Fiberglass and rubber-lined tanks for chemicals are used
2. Metals can be galvanized and cement linings are commonly used. Various paints and chemical coatings can be applied e.g. coal tar enamels, epoxy resins and paints, zinc silicate paints, etc.
3. The pH of the finished water may be adjusted by alkali feed (lime, soda ash, caustic soda) to raise the Langelier Index to a positive value say 0.8 to 1.2. This procedure is an attempt to have a $CaCO_3$ depositing water.
4. Protective chemical coatings may be created by adding cathodic inhibitors. Phosphate only feeds must be quite high and there is a probable EPA water quality limitation on phosphate levels. Success with a zinc-ortho phosphate compound has been reported.
5. The concept of cathodic protection can be practiced. A sacrificial metal (anode), one that will corrode based on the galvanic series, can be utilized e.g. magnesium in water heaters. This type of control has been successful for water storage tanks and water treatment units.

VI. Miscellaneous Topics and Summary

A. There are several areas of concern in water supply, treatment and distribution that relate to corrosion and deposition problems. Some example include

1. Iron bacteria are associated with iron problems in wells and distribution systems. They can cause staining, iron deposits and interference with flow. Copper sulfate and chlorine have been used as treatment measures
2. In water distribution systems with low flow regions and high sulfate levels, sulfate can break down bacterially to release H_2S. The H_2S can react further to form acid solutions and/or sulfide deposits.
3. Flushing of water mains is practiced to remove build-ups of deposits. It is also used to temporarily minimize "red water" problems in local areas. Flushing is a temporary solution and can also cause problems with deposit movement.
4. Many chemicals must be stored and handled with concern for deposition and/or corrosion conditions e.g. fluorides, chlorine solutions

B. Note the inter-relationships of $CaCO_3$ deposition as a problem, if in excess, and as a solution to corrosion control. Note the different approaches to chemically softened waters and ion exchange softened waters.

SAMPLE PROBLEMS

1. Your municipality is supplying water of the following quality to a commercial user. They are heating the water to 160°F for use in a laundry operation. They are losing their water heaters within 2 years and they have a 5 year warranty. By analyzing the water stability indicate what you think may be the problem. The water receives no treatment prior to the heaters.

Calcium Hardness	250 mg/l	Total dissolved solids	400 mg/l
Alkalinity	300	Temperature	50°F
pH	7.0		

2. A water treatment plant has decided to add 1.5 mg/l of a corrosion inhibitor to its finished water. If the average flow is 710,000 gpd, how many pounds of chemical would be needed for a 90 day supply?

EXAMINATION QUESTIONS

<u>Note</u>: The sequence of questions generally follows the pattern of topics and objectives presented in the module.

1. When a water is considered to be stable

   a. It will cause iron to go into solution readily
   b. It will deposit $CaCO_3$
   c. Phosphates should be added to oxidize the iron
   d. It will not deposit $CaCO_3$

2. T or F

   Tuberculation refers to a water borne bacterial disease.

3. The deposition of $CaCO_3$ in piping systems

   a. Is associated with lime softening plants
   b. Will increase the resistance to flow
   c. Can limit the carrying capacity (flow)
   d. All of the above

4. Deposits of $CaCO_3$ can be extended further into the distribution system by using

   a. Carbon dioxide
   b. Polyphosphates
   c. Soda ash
   d. Potassium permanganate

5. Two causes of well screen blockage or deposits are

   a. ______________________________
   b. ______________________________

6. T or F

   One of the primary factors that affect external corrosion of pipe is the soil chemistry.

7. Two specific examples of deposition in a water treatment plant are

   a. ______________________________
   b. ______________________________

8. T or F

   Hard waters can result in deposition problems with some fluoride feeders.

9. T or F

   Soft waters are especially corrosive to copper piping systems.

10. T or F

Cation exchange softened waters tend to be corrosive waters.

11. A positive Langelier Index indicates that a water

a. Contains too much manganese
b. Tends to be a depositing water ($CaCO_3$)
c. Tends to be corrosive to iron
d. Has excess magnesium

12. The alkalinity of most ground water supplies is primarily due to

a. Bicarbonates (HCO_3^-)
b. Hydroxide (OH)
c. Carbonate (CO_3)
d. Iron oxides (Fe_2O_3)

13. T or F

In lime softening the alkalinity of the water supply is decreased, the pH increased and the iron content decreased.

14. T or F

The calcium hardness of a water is normally equal to the total hardness minus the magnesium hardness.

15. T or F

Ion exchange reduces the carbonate and non-carbonate hardness equally whereas lime softening only reduces the carbonate hardness.

16. T or F

Iron is most insoluble in the ferric (Fe^{+++}) state.

17. The four water quality characteristics that are used to calculate the pHs (saturation pH) are total dissolved solids, ____________ ____________ and ______________.

18. The Langelier or Saturation Index is equal to the pH-pHs.

19. The Ryznar Index is equal to two times the pHs minus the actual pH.

20. A laboratory test that can be utilized to analyze for calcium carbonate deposition tendencies is

a. Oxidation-reduction
b. Marble
c. Crenothrix
d. The hydroxide/carbonate ratio

21. T or F

Iron can precipitate as iron oxides and iron hydroxides.

22. T or F

A water with high pH, high alkalinity and high calcium content would likely be a depositing water.

23. T or F

The process of recarbonation results in a decrease in the pH of the water.

24. Recarbonation of a water to protect filters

a. Reacts with excess OH^- ions
b. Reacts with $CaCO_3$
c. Increases the HCO_3^- concentration
d. All of the above

25. Recarbonation of water refers to the addition of

a. Soda ash, Na_2CO_3
b. Carbon dioxide, CO_2
c. Activated carbon
d. Ammonium bicarbonate, NH_4HCO_3

26. T or F

The flow resistance of piping increases, that is the C value decreases, with increases in deposition.

27. Phosphates will tie up or chelate ferric (Fe^{+++}) iron because it is the most soluble form.

28. Phosphate added after recarbonation and prior to filtration in a water plant

a. Ties up (chelates) calcium and minimizes $CaCO_3$ deposition
b. Provides a nutrient for the bacteria to aid the filter
c. Flocculates any bacteria or algae present
d. Causes iron to precipitate

29. T or F

Higher temperatures in home and commercial water systems will increase deposition rates of $CaCO_3$.

30. Corrosion of iron in piping can

a. Result in increases in the iron content of the water
b. Result in the development of tuberculation
c. Provide a source of iron for iron bacteria
d. All of the above

31. T or F

Galvanic corrosion can result from the contact of dissimilar metals.

32. If a electrochemical corrosion cell is established with copper and cast iron which metal will corrode (anodic)

a. Copper
b. Cast iron

33. Blue-green staining of enamel fixtures could result from

a. Manganese
b. Copper corrosion
c. Tuberculation

34. What is pitting corrosion and how does it develope?

35. Two ways to analyze a cast iron distribution system for corrosion are

a.____

b.____

36. For each of the factors listed indicate how it affects corrosion

a. Alkalinity
b. Carbon dioxide
c. Dissolved Oxygen
d. Flow velocity

37. Cite an example of corrosion concern in a

a. Fluoridation system________________________

b. Chlorination system________________________

38. List two chemical approaches to corrosion control in a distribution system.

a.____

b.____

39. Which of the following is an example of a corrosion inhibitor

a. Sodium aluminate
b. HOCl
c. Zn-Phosphate
d. NH_4HCO_3

40. Which of the following could be used to protect against steel or cast iron corrosion via cathodic protection

a. Chromium
b. Tin
c. Magnesium

41. T or F

Feeding of alkali chemicals is done to yield a water that is depositing or non-corrosive.

42. List three examples of the use of alternate materials for corrosion control.

a. ____________________
b. ____________________
c. ____________________

43. T or F

Main flushing will permanently correct corrosion problems.

44. Main flushing could actually cause increased staining problems because

a. It adds oxygen
b. It would dislodge deposits
c. It increases iron bacteria growth

45. What are two materials that can be used with corrosive chemicals to prevent corrosion

a. ____________________
b. ____________________

46. T or F

Hydrogen sulfide formation in a high sulfate water will most likely occur in high flow distribution areas near the water plant.

47. T or F

Iron bacteria can develope deposits in piping systems.

48. List one control or treatment technique for iron bacteria in a water system.

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