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OPERATION OF WASTEWATER TREATMENT PLANTS

Volume IV

TREATMENT OF WASTEWATER FROM ELECTROPLATING, METAL FINISHING AND PRINTED CIRCUIT BOARD MANUFACTURING

Field Study Training Program

• CALIFORNIA STATE UNIVERSITY, SACRAMENTO •
• OFFICE OF WATER PROGRAMS •

REVIEW NOTICE

This training manual has been reviewed by the persons listed as reviewers in the preface. Approval does not signify that the contents necessarily reflect the views and policies of the reviewers. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the reviewers or California State University, Sacramento.

OPERATION OF WASTEWATER TREATMENT PLANTS

First Edition

Volume IV

TREATMENT OF WASTEWATER FROM ELECTROPLATING, METAL FINISHING AND PRINTED CIRCUIT BOARD MANUFACTURING

Prepared by

California State University, Sacramento
Department of Civil Engineering
Office of Water Programs

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OPERATOR TRAINING MANUALS IN THIS SERIES are available from Ken Kerri, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819-2694, phone (916) 278-6142.

1. *WATER SUPPLY SYSTEM OPERATION* - 1 Volume,
2. *WATER TREATMENT PLANT OPERATION* - 2 Volumes,
3. *OPERATION OF WASTEWATER TREATMENT PLANTS* - 4 Volumes, and
4. *OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS,* 1 Volume.

NOTICE

This manual is revised and updated before each printing based on comments from persons using this manual.

FIRST EDITION

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PREFACE TO VOLUME IV

This *MANUAL* on the Treatment of Wastewater from Electroplating, Metal Finishing and Printed Circuit Board Manufacturing was prepared in response to requests from the operators of these wastewater treatment facilities. The operators identified a need for training materials similar to the training manuals prepared by California State University, Sacramento, for the operators of both municipal and industrial wastewater treatment plants titled, *OPERATION OF WASTEWATER TREATMENT PLANTS,* Volumes I, II and III. Volume III deals mainly with the operation and maintenance of advanced wastewater treatment plants and industrial wastewater treatment facilities.

Material covered in this *MANUAL* emphasizes how to operate and maintain facilities which neutralize acidic and basic waters, treat wastes containing metals, destroy cyanide and also treat complexed metal wastes. Volume III of *OPERATION OF WASTEWATER TREATMENT PLANTS* contains considerable information on neutralization and also the removal and disposal of solids from treated wastewaters. Although the authors of this *MANUAL,* Volume IV, have made every effort to present accurate and complete explanations of the topics discussed, you may find it helpful to refer also to Volume III of *OPERATION OF WASTEWATER TREATMENT PLANTS* for additional information. Relevant portions of Volume III will be referred to as appropriate in this *MANUAL,* Volume IV. In the future when more copies of Volume III are printed, the current material will be revised and expanded and the Third Edition will be published as two volumes. One volume will deal with the treatment of industrial wastewaters and the other volume will emphasize advanced waste treatment processes. This *MANUAL* may be incorporated in the industrial wastewater treatment manual.

Portions of the material contained in this *MANUAL* were taken from *GUIDANCE MANUAL FOR ELECTROPLATING AND METAL FINISHING PRETREATMENT STANDARDS,* U.S. Environmental Protection Agency, Effluent Guidelines Division and Permits Division, Washington, D.C., February 1984. All of the material in this Manual was reviewed by Bill Strangio who wrote Section 7, *OPERATION, MAINTENANCE AND TROUBLESHOOTING.* Joe Shockcor wrote major portions of Section 5, *METHODS OF TREATMENT,* and provided the excellent flow diagrams on the treatment processes. The special contributions by Strangio and Shockor are greatly appreciated. Larry Hannah reviewed all of the material and served as education consultant. The drawings and illustrations were prepared by Martin Garrity. The manuscript was prepared and all details were taken care of by Gay Kornweibel. The people listed below reviewed the drafts of this volume and provided many helpful suggestions.

Josephine W. Boyd
HACH Company, CO

A. F. Crane
Hughes Aircraft-EDSG, CA

Patrick Kwok
Private Consultant, CA

Tom Korpalski
Hewlett Packard, ID

Jay Kremer
County Sanitation Districts
of Los Angeles County, CA

Robert McAnespie
Massachusettes Water
Pollution Control
Division, MA

Steve Medbery
San Francisco Department
of Public Works, CA

Albin D. Pagorski
Sanitary District of Elgin, IL

Donald Pottle
University of Lowell, Lowell, MA

Joe Shockcor
Consulting Engineer, VT

Bill Strangio
Lee, Strangio & Associates, CA

Elaine Tait
Signet Scientific, CA

Bruce E. Warner, President
New England Plating Co, Inc., MA

Whenever California State University, Sacramento, reprints one of the operator training manuals, the material is updated in accordance with the comments and suggestions received from the operators enrolling in courses which use the manual. While you are reading the material in this Manual, Volume IV, please make notes of questions and areas where you would improve the material. By sending your comments and suggestions to me, operators who use the manual in the future will benefit from your experience, knowledge and contributions.

Kenneth D. Kerri
Program Director
Office of Water Programs
CSU, Sacramento
6000 J Street
Sacramento, CA 95819-~~2694~~ 6025
Phone: (916) 278-6142

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OBJECTIVES

Following completion of this Manual, you should be able to:

1. Define terms used in the Manual,
2. Explain the need to treat metal wastestreams,
3. Identify the sources of metal wastestreams,
4. Obtain information on how to safely store and handle chemicals from a Material Safety Data Sheet (MSDS),
5. Determine what information employers must provide to operators regarding the handling of and exposure to hazardous materials in the workplace (employee Right-To-Know legislation),
6. Operate and maintain neutralization, metal precipitation, cyanide destruction and complexed metal treatment facilities,
7. Collect, treat and dispose of sludges generated by these treatment processes,
8. Troubleshoot treatment facilities described in this Manual, and
9. Safely perform the duties of an operator of these facilities.

USES OF THIS MANUAL

This *MANUAL* was developed to serve the needs of operators in several different situations. The format was developed to serve as a *home-study or self-paced instruction course* for operators in remote areas or persons unable to attend formal classes either due to shift work, personal reasons or the unavailability of suitable classes. This home-study training program uses the concept of self-paced instruction where you are your own instructor and work at your own speed. In order to certify that a person has successfully completed this program, an objective test is included at the end of each lesson.

Also, *this manual can serve effectively as a textbook in the classroom.* Many colleges and universities have used similar manuals as texts in formal classes (often taught by operators). In areas where colleges are not available or are unable to offer classes in the treatment of wastewater from electroplating, metal finishing and printed circuit board manufacturing, industries can join together to offer their own courses using this manual.

Industries can use the manual in several types of on-the-job training programs. In one type of program, a manual is purchased for each operator. A senior operator or a group of operators are designated as instructors. These operators *help answer questions when the persons in the training* program have questions or need assistance. The instructors grade the objective tests at the end of each chapter, record scores and notify California State University, Sacramento, of the scores when a person successfully completes this program. This approach eliminates any waiting while papers are being graded and returned by CSUS. This *MANUAL* was prepared to help operators operate and maintain their wastewater treatment facilities. Please feel free to use the manual in the manner which best fits your training needs and the needs of other operators. *We will be happy to assist you* in developing your training program. Please feel free to contact

Ken Kerri, Program Director
Office of Water Programs
California State University, Sacramento
6000 J Street
Sacramento, California 95819-2694
Phone: (916) 278-6142

INSTRUCTIONS TO PARTICIPANTS IN HOME-STUDY COURSE

Procedures for reading the lessons and answering the questions are contained in this section.

To progress steadily through this program, you should establish a regular study schedule. For example, many operators in the past have set aside two hours during two evenings a week for study.

The study material is contained in three lessons. Some lessons are longer and more difficult than others. For this reason, many of the lessons are divided into two or more chapters. The time required to complete a lesson will depend on your background and experience. Some people might require 8 hours to complete a lesson and some might require 20 hours; but that is perfectly all right. *THE IMPORTANT THING IS THAT YOU UNDERSTAND THE MATERIAL IN THE LESSON!*

Each lesson is arranged for you to read a short section, write the answers to the questions at the end of each section, check your answers against suggested answers; and then *YOU* decide if you understand the material sufficiently to continue or whether you should read the section again. You will find that this procedure is slower than reading a normal textbook, but you will remember much more when you have finished the lesson.

Some discussion and review questions are provided following each lesson. These questions review the important points you have covered in the lesson. Write the answers to these questions in your notebook before continuing with the Objective Test.

You will find an "Objective Test" following the discussion and review questions at the end of each lesson. The objective test consists of multiple-choice questions. The purposes of this test are to review the lesson and to provide experience in taking this type of exam. Mark your answers on the special answer sheet provided for each lesson. When you finish taking the objective test, mail *ONLY* your answer sheet to the Program Director. Remember, you *MUST* use the answer sheets provided by the Director for these objective tests.

After you have completed the last objective test, you will find a final examination. This exam is provided for you to review how well you remember the material. You may wish to review the entire manual before you take the final exam. Some of the questions are essay-type questions which are used by some states for higher level certification examinations. After you have completed the final examination, grade your own paper and determine the areas in which you might need additional review before your next certification or civil service examination.

You are your own teacher in this program. You could merely look up the suggested answers from the answer sheet or copy them from someone else, but you would not understand the material. Consequently, you would not be able to apply the material to the operation of your plant nor recall it during an examination for certification or a civil service position.

YOU WILL GET OUT OF THIS PROGRAM WHAT YOU PUT INTO IT.

SUMMARY OF PROCEDURE

A. OPERATOR (YOU)

1. Read what you are expected to learn (the objectives).
2. Read sections in the lesson.
3. Write your answers to questions at the end of each section in your notebook. You should write the answers to the questions just as you would if these were questions on a test.
4. Check your answers with the suggested answers which begin on page 85.
5. Decide whether to reread the section or to continue with the next section.
6. Write your answers to the discussion and review questions at the end of each lesson in your notebook.
7. Mark your answers to the objective test on the answer sheet provided by the Program Director or by your instructor.
8. Mail material to the Program Director. (Send ONLY your completed answer sheet.)

Ken Kerri, Program Director
Office of Water Programs
California State University, Sacramento
6000 J Street
Sacramento, California 95819-2694

B. PROGRAM DIRECTOR

1. Mails answer sheet for each lesson to operator.
2. Corrects tests, answers any questions, and returns results to operators.

C. ORDER OF WORKING LESSONS

To complete this program you will have to work all of the lessons. You may proceed in numerical order, or you may wish to work some lessons sooner.

DEFINITIONS OF WORDS

ACID | ACID

(1) A substance that tends to lose a proton. (2) A substance that dissolves in water with the formation of hydrogen ions. (3) A substance containing hydrogen which may be replaced by metals to form salts.

ACUTE HEALTH EFFECTS | ACUTE HEALTH EFFECTS

Health effects which are evident immediately or shortly after, and as a result of, an exposure to a hazardous substance. (Definition from California General Industry Safety Orders, Section 5194.)

ANION (AN-EYE-en) | ANION

A negatively charged ion in an electrolyte solution, attracted to the anode under the influence of a difference in electrical potential. Chloride ion (Cl^-) is an anion.

ANODE (an-O-d) | ANODE

The positive pole or electrode of an electrolytic system, such as a battery. The anode attracts negatively charged particles or ions (anions).

AQUEOUS (A-kwee-us) | AQUEOUS

Something made up of, similar to, or containing water; watery.

BASE | BASE

(1) A substance which takes up or accepts protons. (2) A substance which dissociates (separates) in aqueous solution to yield hydroxyl ions (OH^-). (3) A substance containing hydroxyl ions which reacts with an acid to form a salt or which may react with metals to form precipitates.

BASIS METAL | BASIS METAL

A metal used to make workpieces and that receives the electroplate and the treatments in preparation for plating.

BATCH PROCESS | BATCH PROCESS

A treatment process in which a tank or reactor is filled, the water is treated, and the tank is emptied. The tank may then be filled and the process repeated.

BENCH SCALE ANALYSIS | BENCH SCALE ANALYSIS

A method of studying different ways of treating wastewater and solids on a small scale in a laboratory.

CAPTIVE SHOPS | CAPTIVE SHOPS

Those electroplating and metal finishing facilities which in a calendar year own more than 50 percent (on an area basis) of the materials undergoing metal finishing. (Definition from "Guidance Manual for Electroplating and Metal Finishing Pretreatment Standards," Effluent Guidelines Division and Permits Division, U.S. EPA, Washington, D.C., February 1984.) Also see JOB SHOPS.

CAS NUMBER (pronounce as separate letters) | CAS NUMBER

The unique identification number assigned by the Chemical Abstracts Service (American Chemical Society) to specific chemical substances. (Definition from California Labor Code, Division 5, Chapter 2.5.)

CATHODE (KA-thow-d) | CATHODE

The negative pole or electrode of an electrolytic cell or system. The cathode attracts positively charged particles or ions (cations).

CATION (CAT-EYE-en) | CATION

A positively charged ion in an electrolyte solution, attracted to the cathode under the influence of a difference in electrical potential. Sodium ion (Na^+) is a cation.

CAVITATION (CAV-uh-TAY-shun) | CAVITATION

The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.

CHROME PLATE | CHROME PLATE

Chrome plate is one of the most common surface coatings for auto bumpers and cutting tools. Also see *CHROMIUM.*

CHROMIUM — CHROMIUM

A hard, brittle metallic element often used in metal alloys and as a corrosion resistant surface coating for metal parts. Chromium is an especially toxic metal, with hexavalent chromium being appreciably more toxic than trivalent chromium. Inadequate or improper handling and disposal of chromium may create serious environmental hazards. Also see *CHROME PLATE, HEXAVALENT CHROMIUM* and *TRIVALENT CHROMIUM*.

CHRONIC HEALTH EFFECTS — CHRONIC HEALTH EFFECTS

Health effects which develop over a long period of time after, and as a result of, a single or repeated exposure to a hazardous substance. (Definition from California General Industry Safety Orders, Section 5194.)

COMMON METALS — COMMON METALS

Aluminum, cadmium, chromium, copper, iron, lead, nickel, tin, zinc or any combination of these elements are considered common metals.

COMPLEXED METALS — COMPLEXED METALS

Metals with a tendency to remain in solution rather than form precipitates and settle out. These metals have reacted with or are tied up with chemical complexing agents such as ammonia or citrates, tartrates, quadrol and EDTA.

COMPOSITE (come-PAH-zit) (PROPORTIONAL) SAMPLES — COMPOSITE (PROPORTIONAL) SAMPLES

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the rate of flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

CONTINUOUS PROCESS — CONTINUOUS PROCESS

A treatment process in which water is treated continuously in a tank or reactor. The water being treated continuously flows into the tank at one end, is treated as it flows through the tank, and flows out the opposite end as treated water.

COUNTERCURRENT RINSING — COUNTERCURRENT RINSING

A rinsing procedure in which rinse water flows from tank to tank in a direction that is opposite to movement of parts being rinsed from tank to tank.

CYANIDE — CYANIDE

The cyanide ion (CN^-) consists of carbon (C) and nitrogen (N). Cyanide is commonly found in metal plating wastewaters because most metal cyanides are soluble and plating occurs readily from cyanide solutions. The cyanide ion is extremely toxic and must be removed from metal wastes before discharge to the environment. Treatment of wastes containing cyanide under acidic conditions may produce extremely toxic gases which must never come in contact with people or animals.

DPD METHOD — DPD METHOD

A method of measuring the chlorine residual in water. The residual may be determined by either titrating or comparing a developed color with standards. DPD stands for N, N-diethyl-p-phenylene-diamine.

ELECTROLYTE (ee-LECK-tro-LIGHT) — ELECTROLYTE

A substance which dissociates (separates) into two or more ions when it is dissolved in water.

ELECTROWINNING — ELECTROWINNING

A reverse electroplating process which uses a carbon electrode (insoluble anode). An advantage of this process is that no sludge is produced.

ELEMENT — ELEMENT

A substance which cannot be separated into its constituent parts and still retain its chemical identity. For example, sodium (Na) is an element.

EMPLOYEE EXPOSURE RECORD — EMPLOYEE EXPOSURE RECORD

A record containing any of the following kinds of information concerning operator exposure to toxic substances or harmful physical agents:

1. Environmental (workplace) monitoring or measuring, including personal, area, grab, wipe, or other form of sampling, as well as related collection and analytical methodologies, calculations, and other background data relevant to interpretation of the results obtained;
2. Biological monitoring results which directly assess the absorption of a substance or agent by body systems (such as the level of chemical in the blood, urine, breath, hair or fingernails) but not including results which assess the biological effect of a substance or agent;
3. Material safety data sheets; or

4. In the absence of the above, any other record which reveals the identity (such as chemical, common, or trade name) of a toxic substance or harmful physical agent.

(Definition from California General Industry Safety Orders, Section 3204).

EMPLOYEE MEDICAL RECORD EMPLOYEE MEDICAL RECORD

A record concerning the health status of an employee which is made or maintained by a physician, nurse, or other health care personnel or technician.

(A) Employee medical record includes the following:

1. Medical and employment questionnaire or histories (including job description and occupational exposures);
2. The results of medical examinations (pre-employment, pre-assignment, periodic, or episodic) and laboratory tests (including X-ray examinations and all biological monitoring);
3. Medical opinions, diagnoses, progress notes, and recommendations;
4. Descriptions of treatments and prescriptions; and
5. Employee medical complaints.

(B) Employee medical record does not include the following:

1. Physical specimens (e.g., blood or urine samples) which are routinely discarded as a part of normal medical practice and are not required to be maintained by other legal requirements;
2. Records concerning health insurance claims if maintained separately from the employer's medical program and its records, and not accessible to the employer by employee name or other direct personal identifier (such as social security number or payroll number); or
3. Records concerning voluntary employee assistance programs (alcohol, drug abuse, or personal counseling programs) if maintained separately from the employer's medical program and its records.

(Definition from California General Industry Safety Orders, Section 3204.)

EXPOSE or EXPOSURE EXPOSE or EXPOSURE

Any situation arising from work operation where an employee may ingest, inhale, absorb through the skin or eyes, or otherwise come into contact with a hazardous substance; provided that such contact shall not be deemed to constitute exposure if the hazardous substance present is in a physical state, volume, or concentration for which it has been determined that there is no valid and substantial evidence that any adverse effect, acute or chronic, on human health may occur from such contact. (Definition from California General Industry Safety Orders, Section 5194.)

GRAB SAMPLE GRAB SAMPLE

A single sample collected at a particular time and place which represents the composition of the wastestream only at that time and place.

HARMFUL PHYSICAL AGENT or TOXIC SUBSTANCE HARMFUL PHYSICAL AGENT or TOXIC SUBSTANCE

Any chemical substance, biological agent (bacteria, virus or fungus), or physical stress (noise, heat, cold, vibration, repetitive motion, ionizing and non-ionizing radiation, hypo- or hyperbaric pressure) which

(A) Is regulated by any California or Federal law or rule due to a hazard to health;

(B) Is listed in the latest printed edition of the National Institute for Occupation Safety and Health (NIOSH) Registry of Toxic Effects of Chemical Substances (RTECS);

(C) Has yielded positive evidence of an acute or chronic health hazard in human, animal, or other biological testing conducted by, or known to, the employer; or

(D) Is described by a material safety data sheet available to the employer which indicates that the material may pose a hazard to human health.

(Definition from California General Industry Safety Orders, Section 3204.)

HAZARDOUS WASTE HAZARDOUS WASTE

(Abbreviated EPA definition for identification by testing)

A waste that possesses any one of the following four characteristics:

1. Ignitability, which identifies wastes that pose a fire hazard during routine management. Fires not only present immediate dangers of heat and smoke, but also can spread harmful particles over wide areas. A liquid that has a flash point of less than 140°F (60°C).
2. Corrosivity, which identifies wastes requiring special containers because of their ability to corrode standard materials, or requiring segregation from other wastes because of their ability to dissolve toxic contaminants. An aqueous solution with a pH less than or equal to 2 or a pH greater than or equal to 12.5.
3. Reactivity (or explosiveness), which identifies wastes that, during routine management, tend to react spontaneously, to react vigorously with air or water, to be unstable to shock or heat, to generate toxic gases or to explode. A cyanide or sulfide bearing waste which, when exposed to a pH of between 2 and 12.5, can generate toxic gases, vapors or fumes in a quantity sufficient to present a danger to public health, safety, or welfare, or to the environment.
4. Toxicity, which identifies wastes that, when improperly managed, may release toxicants in sufficient quantities to pose a substantial present or potential hazard to human health or the environment.

NOTE: The actual definition is a detailed three-page document.

HAZARDOUS WASTE (RCRA definition) — HAZARDOUS WASTE

A waste, or combination of wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may:

1. Cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or
2. Pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of or otherwise managed.

HEXAVALENT CHROMIUM — HEXAVALENT CHROMIUM

Hexavalent chromium (Cr^{6+}) bearing wastewaters are produced in chromium electroplating, chromium conversion coatings, etching with chromic acid, and in metal finishing operations carried out on chromium as a basis metal. Hexavalent chromium must be reduced to trivalent chromium (Cr^{3+}) before chromium can be removed from metal wastestreams by hydroxide precipitation. Hexavalent chromium is highly toxic in comparison with trivalent chromium. Also see *CHROME PLATE, CHROMIUM,* and *TRIVALENT CHROMIUM.*

HYDROXIDE PRECIPITATION — HYDROXIDE PRECIPITATION

A method of removing common metals from wastestreams by the precipitation process. The pH of the metal waste is increased to an optimum level for hydroxide metal precipitates to form for the wastes being treated. The metal precipitates are settled out of the wastestream in clarifiers and are removed from the bottom of the clarifiers as metal sludges.

HYGROSCOPIC (HI-grow-SKOP-ick) — HYGROSCOPIC

Absorbing or attracting moisture from the air.

IMPURITY — IMPURITY

A hazardous substance which is unintentionally present with another substance or mixture. (Definition from California Labor Code, Division 5, Chapter 2.5.)

INHIBITION — INHIBITION

The introduction of pollutants into publicly owned treatment works (POTW) which could *INTERFERE* with the operation of the wastewater treatment processes. Also see *INTERFERENCE.*

INTEGRATED PLANT — INTEGRATED PLANT

A captive electroplating and metal finishing facility which, prior to treatment, combines electroplating wastestreams with significant process wastestreams not covered by the electroplating category. (Definition from "Guidance Manual.")

INTERFERENCE — INTERFERENCE

The introduction of pollutants into publicly owned treatment works (POTW) which could *INTERFERE* with the operation of the wastewater treatment processes. Also see *INHIBITION.*

IPCBM (pronounced as separate letters) — IPCBM

Independent Printed Circuit Board Manufacturers.

JOB SHOPS — JOB SHOPS

Those electroplating and metal finishing facilities which in a calendar year do not own more than 50 percent (on an area basis) of the materials undergoing metal finishing. (Definition from "Guidance Manual.") Also see *CAPTIVE SHOPS.*

MATERIAL SAFETY DATA SHEET (MSDS) — MATERIAL SAFETY DATA SHEET (MSDS)

A document which provides pertinent information and a profile of a particular hazardous substance or mixture. An MSDS is normally developed by the manufacturer or formulator of the hazardous substance or mixture. The MSDS is required to be made available to employers and operators whenever there is the likelihood of the hazardous substance or mixture being introduced into a workplace.

METAL — METAL

An element yielding positively charged ions in aqueous solutions of its salts.

MIXTURE — MIXTURE

Any solution or intimate admixture of two or more substances, at least one of which is present as a hazardous substance, which do not react chemically with each other. (Definition from California Labor Code, Division 5, Chapter 2.5.)

"MOTHER" CIRCUIT BOARD — "MOTHER" CIRCUIT BOARD

The base circuit board or the main circuit board.

MSDS — MSDS

A document which supplies information about a particular hazardous substance or mixture. See *MATERIAL SAFETY DATA SHEET.* (Definition from California General Industry Safety Orders, Section 5194.)

NON-INTEGRATED PLANT NON-INTEGRATED PLANT

A captive electroplating and metal finishing facility which has significant wastewater discharges only from operations addressed by the electroplating category. (Definition from "Guidance Manual.") Also see *CAPTIVE SHOPS, JOB SHOPS* and *INTEGRATED PLANT.*

OXIDATION (ox-uh-DAY-shun) OXIDATION

Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In the environment, organic matter is oxidized to more stable substances. The opposite of *REDUCTION.*

OXIDATION-REDUCTION POTENTIAL (ORP) OXIDATION-REDUCTION POTENTIAL (ORP)

The electrical potential required to transfer electrons from one compound or element (the oxidant) to another compound or element (the reductant); used as a qualitative measure of the state of oxidation in wastewater treatment systems.

OXIDIZING AGENT OXIDIZING AGENT

Any substance, such as oxygen (O_2) or chlorine (Cl_2) that will readily add (take on) electrons. The opposite is a *REDUCING AGENT.*

PASS THROUGH PASS THROUGH

The passage of untreated pollutants through a publicly owned treatment works (POTW) which could violate applicable water quality standards or National Pollutant Discharge Elimination System (NPDES) effluent limitations.

pH (pronounced as separate letters) pH

pH is an expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion activity.

$$pH = \text{Log}\,\frac{1}{(H^+)}$$

The pH may range from 0 to 14 where 0 is most acid, 14 most basic, and 7 neutral.

PILOT SCALE STUDY PILOT SCALE STUDY

A method of studying different ways of treating wastewater and solids or to obtain design criteria on a small scale in the field.

POLYELECTROLYTE (POLLY-ee-LECK-tro-lite) POLYELECTROLYTE

A high-molecular-weight (relatively heavy) substance having points of positive or negative electrical charges that is formed by either natural or man-made processes. Natural polyelectrolytes may be of biological origin or derived from starch products and cellulose derivatives. Man-made polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water. Often called a *POLYMER.*

POLYMER POLYMER

A chemical formed by the union of many monomers (a molecule of low molecular weight). Polymers are used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water. All polyelectrolytes are polymers, but not all polymers are polyelectrolytes.

POTTING COMPOUNDS POTTING COMPOUNDS

Sealing and holding compounds used in electrode probes.

PRECIOUS METALS PRECIOUS METALS

Metals that are very valuable, such as gold or silver.

PRECIPITATE PRECIPITATE

(1) An isoluble, finely divided substance which is a product of a chemical reaction within a liquid. (2) The separation from solution of an insoluble substance.

RCRA RCRA

Public Law (PL) 94-580. The Resource Conservation and Recovery Act (10/21/78).

REDOX (ree-DOCKS) REDOX

Reduction-oxidation reactions in which the oxidation state of at least one reactant is raised while that of another is lowered.

REDUCING AGENT REDUCING AGENT

Any substance, such as base metal (iron) or the sulfide ion (S^{2-}), that will readily donate (give up) electrons. The opposite is an *OXIDIZING AGENT.*

REDUCTION (re-DUCK-shun) REDUCTION

Reduction is the addition of hydrogen, removal of oxygen, or the addition of electrons to an element or compound. Under anaerobic conditions (no dissolved oxygen present), sulfur compounds are reduced to odor-producing hydrogen sulfide (H_2S) and other compounds. In the treatment of metal finishing wastewaters, hexavalent chromium (Cr^{6+}) is reduced to the trivalent form (Cr^{3+}). The opposite of *OXIDATION.*

REPRESENTATIVE SAMPLE REPRESENTATIVE SAMPLE

A portion of material or wastestream that is as nearly identical in content and consistency as possible to that in the larger body of material or wastestream being sampled.

SALT SALT

A compound which upon dissociation yields cations (positively charged) of a metal, and anions (negatively charged) of an acid radical.

SEGREGATE SEGREGATE

To keep separate or prevent mixing (of two or more wastestreams.) Wastes from various in-plant sources are easier to treat before they become mixed together.

SPECIFIC GRAVITY SPECIFIC GRAVITY

Weight of a particle, substance or chemical solution in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (39°F).

TOXIC (TOX-ick) TOXIC

A substance which is poisonous to an organism. Toxic substances may be classified in terms of their physiological action, such as irritants, asphyxiants, systemic poisons, and anesthetics and narcotics. Irritants are corrosive substances which attack the mucous membrane surfaces of the body. Asphyxiants interfere with the oxidation processes in the body. Systemic poisons are hazardous substances which injure or destroy internal organs of the body. The anesthetics and narcotics are hazardous substances which depress the central nervous system and lead to unconsciousness.

TOXIC ORGANICS TOXIC ORGANICS

Organic compounds which can be classified according to the following categories:

CATEGORY	*EXAMPLES*
1. Base/Neutral Extractibles	Benziline, Hexachloroethane, Naphthalene, Fluorene, Pyrene
2. Acid Extractibles	P-Chloro-M-Cresol, 2-Chlorophenol, 4-Nitrophenol, Pentachlorophenol
3. Volatile Organics	Benzene, Carbon Tetrachloride, Chloroform, Toluene, Vinyl Chloride
4. Pesticides	Aldrin, Chlordane, Dieldrin, Endrin, Toxaphene, PCB

TOXIC SUBSTANCE or HARMFUL PHYSICAL AGENT TOXIC SUBSTANCE or HARMFUL PHYSICAL AGENT

Any chemical substance, biological agent (bacteria, virus or fungus), or physical stress (noise, heat, cold, vibration, repetitive motion, ionizing and non-ionizing radiation, hypo- or hyperbaric pressure) which:

(A) Is regulated by any California or Federal law or rule due to a hazard to health;
(B) Is listed in the latest printed edition of the National Institute for Occupation Safety and Health (NIOSH) Registry of Toxic Effects of Chemical Substances (RTECS);
(C) Has yielded positive evidence of an acute or chronic health hazard in human, animal, or other biological testing conducted by, or known to, the employer; or
(D) Is described by a material safety data sheet available to the employer which indicates that the material may pose a hazard to human health.

(Definition from California General Industry Safety Orders, Section 3204.)

TOXICITY (tox-IS-it-tee) TOXICITY

The relative degree of being poisonous or toxic. A condition which may exist in wastes and will inhibit or destroy the growth or function of certain organisms.

TRIVALENT CHROMIUM TRIVALENT CHROMIUM

Trivalent chromium (Cr^{3+})is the reduced state of hexavalent chromium (Cr^{6+}). Trivalent chromium is significantly less toxic than hexavalent chromium and can be removed from metal wastestreams by hydroxide precipitation.

WATER HAMMER WATER HAMMER

The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the the system.

TREATMENT OF WASTEWATER FROM ELECTROPLATING, METAL FINISHING AND PRINTED CIRCUIT BOARD MANUFACTURING

(Lesson 1 of 3 Lessons)

1 NEED FOR TREATMENT

Treatment of wastewater generated by industrial electroplating, metal finishing and printed circuit board manufacturing processes is essential prior to discharge of these wastewaters to wastewater collection systems or to the environment. Adequate treatment or pretreatment before discharge to wastewater collection systems is important to prevent toxic, corrosive, flammable or explosive wastes from damaging the collection system, the treatment plant, the operators of these facilities, and the public which lives, works or plays near these facilities. Toxic pollutants from industrial facilities must be controlled to prevent the:

1. Introduction of pollutants into publicly owned treatment works (POTW) which could interfere with its operation (often called interference or inhibition),

2. Passage of untreated pollutants through a publicly owned treatment works which could violate applicable water quality standards or National Pollutant Discharge Elimination System (NPDES) effluent limitations (pass through), and
3. Contamination of POTW sludge which would limit the selected sludge uses or disposal practices (sludge contamination).

Municipalities or wastewater collection system utility agencies have adopted sewer-use or industrial waste ordinances which provide the necessary authority to require industrial pretreatment in order to control the discharge of industrial wastes into sewers. These ordinances serve as a mechanism for inspections, the gathering of data base information and equitable sewer service charges. Sewer-use ordinances outline the procedures which industries must follow in order to obtain a permit to discharge into a municipality's wastewater collection system.

There are situations where industry may find the most economical and practical solution to the disposal of industrial wastewaters is treatment at the industrial site and then discharge to the environment directly. Under these circumstances the industry would be issued an NPDES permit by a state regulatory agency or the U.S. Environmental Protection Agency. The permit would specify discharge limitations necessary to protect the environment from the disposal of any harmful substances in the wastewater. The environment must be protected for the sake of people, plants, birds, animals and aquatic life.

Most industries that discharge their treated wastewater to either the collection system or the environment try to minimize the use of water and maximize the recovery and recycling of both water and raw or waste materials to reduce waste treatment and disposal costs to the lowest possible level. Industries have successfully lowered waste treatment and disposal costs by using conductivity meters to control rinse flows, installing spray rinses, and proper racking to reduce metal drag out. The use of non-hazardous materials such as aqueous cleaners instead of organic solvents and the elimination of cyanide plating baths also have been helpful in reducing costs.

QUESTIONS

Write the answers to these questions in a notebook and then compare your answers with the suggested answers on page 85. By writing down the answers to these questions you will be helping yourself to remember important information in this manual.

1.0A Why is adequate treatment or pretreatment of industrial wastewater important before discharge to wastewater collection systems?

1.0B List three problems that can be avoided by the control of toxic pollutants from entering publicly owned treatment works (POTW).

1.0C What is a sewer-use ordinance?

1.0D What is an NPDES permit?

2 SOURCES OF WASTEWATER

Wastewaters come from several different sources at industrial facilities such as cleaning, preparation, production and rinsing processes, as well as the washing of equipment and production facilities. These processes produce various types of industrial wastes such as toxic organic solvents used as degreasing and cleansing agents; highly acidic or basic solutions used for cleaning, plating and pH adjustment; cyanide from plating processes; and toxic metals from the basic plating solutions.

The metal wastestreams from electroplating, metal finishing and printed circuit board manufacturing originate mainly from six types of electroplating operations.

1. *ELECTROPLATING* is the production of a thin surface coating of one metal upon another by electrodeposition. In electroplating, metal ions supplied by the dissolution of metal from anodes or other pieces, are reduced on the workpieces (cathodes) while in either acid, alkaline, or neutral solutions. The electroplating baths contain metal salts, alkalies, and other bath control compounds in addition to plating metals such as copper, nickel, silver or lead. Many plating solutions contain metallic, metallo-organic, and organic additives to induce grain refining, leveling of the plating surface, and deposit brightening.

2. *ELECTROLESS PLATING* is the chemical deposition of a metal coating on a workpiece by immersion in an appropriate plating solution. Copper and nickel electroless plating for printed circuit boards are the most common operations. In electroless nickel plating the source of nickel is a salt, and a reducer is used to reduce the nickel to its base state. A complexing agent is used to hold the metal ion in solution. Immersion plating produces a metal deposit by chemical displacement; however, it is not an autocatalytic process but is promoted by one of the products of the reaction. Immersion plating baths are usually formulations of metal salts, alkalies and complexing agents (typically cyanide or ammonia).

3. *ANODIZING* is an electrochemical process which converts the metal surface to a coating of an insoluble oxide. The formation of the oxide occurs when the parts are made anodic in dilute sulfuric or chromic acid solutions. The oxide layer begins formation at the extreme outer surface, and as the reaction proceeds, the oxide grows into the metal. Chromic acid anodic coatings are more protective than sulfuric acid coatings and are used if a complete rinsing of the part cannot be achieved. Anodizing wastewater typically contains the *BASIS METAL*[1] and either chromic or sulfuric acid. When dyeing of anodized coatings occurs, the wastewaters will contain chromium or other metals from the dye. Other potential pollutants include nickel acetate (used to seal anodic coatings) or other complexes and metals from dyes and sealers.

4. *COATINGS* include chromating, phosphating, metal coloring and passivating. Pollutants associated with these processes enter the wastestream through rinsing and batch dumping of process baths. The process baths usually contain metal salts, acids, bases, and dissolved basis materials. In chromating, a portion of the base metal is converted to a component of the protective film formed by the coating solutions containing hexavalent chromium and active organic or inorganic compounds. Phosphate coatings are formed by the immersion of steel, iron, or zinc plated steel in a dilute solution of phosphoric acid plus other reagents to condition the surfaces for cold forming operations, prolong the life of organic coatings, provide good paint bonding and improve corrosion resistance. Metal coloring involves the chemical method of converting the metal surface into an oxide or similar metallic compound to produce a decorative finish. A variety of solutions utilizing many metals may contribute to the wastestream. Passivating is the process of forming a protective film on metals by immersion in an acid solution, usually nitric acid or nitric acid with sodium dichromate.

5. *ETCHING AND CHEMICAL MILLING* are processes used to produce specific design configurations or surface appearances on parts by controlled dissolution with chemical reagents or etchants. Chemical etching is the same process as chemical milling except the rates and depths of metal removal are usually much greater in chemical milling. The major wastestream constituents are the dissolved basis material and etching solutions.

6. *PRINTED CIRCUIT BOARD MANUFACTURING* involves the formation of a circuit pattern of conductive metal (usually copper) on nonconductive board materials such as plastic or glass. There are five basic steps involved in the manufacturing of printed circuit boards: cleaning and surface preparation, catalyst and electroless plating, pattern printing and masking, electroplating, and etching.

Wastewater is produced in the manufacturing of printed circuit boards from the following processes:

1. *SURFACE PREPARATION.* The rinses following scrubbing, alkaline cleaning, acid cleaning, etchback, catalyst application, and activation.
2. *ELECTROLESS PLATING.* Rinses following the electroless plating step.
3. *PATTERN PLATING.* Rinses following acid cleaning, alkaline cleaning, copper plating, and solder plating.
4. *ETCHING.* Rinses following etching and solder brightening.
5. *TAB PLATING.* Rinses following solder stripping, scrubbing, acid cleaning, and nickel, gold, or other plating operations.
6. *IMMERSION PLATING.* Rinses following acid cleaning and immersion tin plating.

Additionally, water may be used for subsidiary purposes such as rinsing away spills, air scrubbing water, equipment washing, and dumping spent process solutions. The principal constituents of the wastestreams from the printed circuit board industry are suspended solids, copper, fluoride, phosphorus, tin, palladium, and chelating agents. Low pH values are characteristic of the wastes because of the necessary acid cleaning and surface pretreatment.

Regardless of the type of industry or the sources of wastewaters, the ideal situation is to have the ability to treat each wastestream individually rather than as a combined industrial wastestream. Individual wastestreams are highly concentrated, there are fewer (if any) interfering chemicals and the flows are lower, thus allowing for greater treatment efficiencies than when attempting to treat larger flows of diluted wastes with interfering chemicals. Wastestream segregation also allows for the opportunity to recover precious metals.

If the different wastestreams are kept separate, each individual pollutant can be treated by a specific process. Once the wastestreams become mixed, the pollutants may react together and become even more difficult to treat. Industrial wastewater treatment facility operators can do an outstanding job if acidic and basic wastestreams are kept separate. Wastestreams containing cyanide must never be allowed to mix with acidic wastestreams due to the generation of toxic hydrogen cyanide gas. Organic solvents should be kept separate from other wastestreams. They should be treated and disposed of separately. There is an optimum pH for the precipitation of various metal hydroxides. Thus, two-stage precipitation processes may be necessary to precipitate different metals at different pH levels. Hexavalent chromium must be reduced to trivalent chromium before chromium can be removed by hydroxide precipitation. Cyanide must be destroyed (oxidized) before metals can be precipitated. Complexed metals may be precipitated at very high pH levels. For these reasons you will often achieve the minimum cost and highest efficiency for pollutant removal by the treatment of individual industrial wastestreams for specific pollutants. Lesson 2, Section 5, "Methods of Treatment," outlines procedures for treating individual wastestreams from separate sources. The remainder of this lesson emphasizes how to do your job as an operator safely. Material safety data sheets (MSDS) contain valuable information on safely storing and handling chemicals. Employee Right-To-Know laws have been passed which require em-

[1] *Basis Metal. The metal used to make workpieces and that receives the electroplate and the treatments in preparation for plating.*

ployers to inform operators of any hazards associated with jobs and how to perform required tasks safely.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 85.

2.0A List the possible sources of wastewaters at industrial facilities.

2.0B What is the ideal situation for treating industrial wastewaters?

3 MATERIAL SAFETY DATA SHEETS (MSDS)

3.0 EXPLANATION OF FORM

A Material Safety Data Sheet (MSDS) is a document which provides pertinent information and a profile or description of a particular hazardous substance or mixture. An MSDS is usually developed by the manufacturer or formulator of the hazardous substance or mixture. The MSDS is required to be made available to employers and operators whenever there is the likelihood of the hazardous substances or mixture being introduced into a workplace. Table 1 lists the required information for a *MATERIAL SAFETY DATA SHEET* (MSDS) and Figure 1 is a typical *MATERIAL SAFETY DATA SHEET.* The remainder of the section is an explanation and discussion of the terms and information normally contained in a Material Safety Data Sheet based on the OSHA Form 20.

SECTION I

MANUFACTURER'S NAME AND ADDRESS. Self-explanatory; however, if the data is provided by a source other than the manufacturer of the substance or mixture, the actual source of the data should also be listed.

TABLE 1. REQUIRED INFORMATION ON MATERIAL SAFETY DATA SHEETS

A. The Chemical Name
B. Any Common Names
C. The CAS[a] Number of the "Hazardous Substance"
D. The Potential for Fire
E. The Potential for Explosion
F. The Potential for Reactivity
G. Acute and Chronic Health Effects
H. Potential Routes of Exposure
I. Symptoms of Overexposure
J. Proper Precautions
K. Handling Practices
L. Necessary Personal Protective Equipment
M. Other Safety Precautions in the Use of or Exposure to the "Hazardous Substance"
N. Emergency Procedures for Spills
O. Emergency Procedures for Fires
P. Disposal Procedures
Q. First Aid Procedures
R. A Description in Lay Terms of the Specific Potential Health Risks Posed by the "Hazardous Substance"
S. The Month and Year the Information Was Compiled
T. Name and Address of the Manufacturers Responsible for Preparing the Information

[a] *The unique identification number assigned by the Chemical Abstract Service (American Chemical Society) to specific chemical substances.*

EMERGENCY TELEPHONE NUMBERS. Entries here include telephone numbers which can be used in the event of an emergency to obtain further information about the hazardous substance or mixture.

CHEMICAL NAME AND SYNONYMS. Generally includes the name that the product is sold by.

CHEMICAL FAMILY. Listed will be the general class of compounds to which the hazardous substance or mixture belongs, i.e., ethers, acids, ketones, etc.

FORMULA. Entries here will usually include the chemical formula for single elements and compounds, not the formulation of a mixture; examples of chemical formulas are Sulfur Dioxide (SO_2), Sulfuric Acid (H_2SO_4), Formaldehyde (HCHO), etc.

SECTION II HAZARDOUS INGREDIENTS

HAZARDOUS INGREDIENTS. By definition, a hazardous ingredient is a substance or form of a substance in a mixture, in sufficient concentration to produce a flammable vapor or gas, or to produce acute or chronic adverse effects in persons exposed to the product either in normal use or predictable misuse of it.

PAINTS, PRESERVATIVES AND SOLVENTS. The six categories under this heading are self-explanatory.

NOTE: TLV stands for threshold level value, a term used to express the highest airborne concentration of a substance to which nearly all persons (adults) can be repeatedly exposed, day after day, without experiencing adverse effects. TLVs may be expressed in parts of material per million parts (PPM) of air by volume for gases and vapors, or as milligrams of material per cubic meter (mg/cu m) of air for dust and mist, as well as gases and vapors.

The % (percent) column is intended to show the approximate percentage by weight or volume that each hazardous substance represents when compared to the total weight or volume of the product. Normally, percentages will be listed to the nearest whole number.

Sometimes a substance that is normally considered to be hazardous exists in its pure form as part of a solution or mixture. When such a substance makes up less than 1 percent of the mixture or exists as an impurity in a mixture at levels less than 2 percent, the substance will be so listed.

ALLOYS AND METALLIC COATINGS. Entries under this general heading include coatings such as plating, cladding and metalizing. Filler metal is any metal added in making a brazed, soldered or welded joint. Filler metals will be considered with the ingredient of rod coatings and core fluxes as a single mixture.

TLV was covered above.

PERCENTAGE was covered above. In mixtures such as filler metals and their coatings, and core fluxes, the hazardous substance usually constitutes a very small proportion of the mixture, so the hazardous substance should be stated to the nearest 0.5 percent. Any ingredient constituting less than 0.5 percent should be indicated as such.

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS OR GASES. Entries here will include such hazards as abrasive blasting materials and items not covered elsewhere in Section II.

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Form Approved
OMB No. 44-R1387

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME	EMERGENCY TELEPHONE NO.
ADDRESS *(Number, Street, City, State, and ZIP Code)*	
CHEMICAL NAME AND SYNONYMS	TRADE NAME AND SYNONYMS
CHEMICAL FAMILY	FORMULA

SECTION II - HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)		SPECIFIC GRAVITY (H_2O=1)	
VAPOR PRESSURE (mm Hg.)		PERCENT, VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)		EVAPORATION RATE (________ =1)	
SOLUBILITY IN WATER			
APPEARANCE AND ODOR			

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Lel	Uel
EXTINGUISHING MEDIA			
SPECIAL FIRE FIGHTING PROCEDURES			
UNUSUAL FIRE AND EXPLOSION HAZARDS			

SECTION V - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE

EFFECTS OF OVEREXPOSURE

EMERGENCY AND FIRST AID PROCEDURES

SECTION VI - REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE		
INCOMPATABILITY *(Materials to avoid)*			
HAZARDOUS DECOMPOSITION PRODUCTS			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR		

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

WASTE DISPOSAL METHOD

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION *(Specify type)*		
VENTILATION	LOCAL EXHAUST	SPECIAL
	MECHANICAL *(General)*	OTHER
PROTECTIVE GLOVES	EYE PROTECTION	
OTHER PROTECTIVE EQUIPMENT		

SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

OTHER PRECAUTIONS

Form OSHA-20
Rev. May 72

Fig. 1 MSDS from CA GISO, Section 5194

SECTION III PHYSICAL DATA

BOILING POINT. The temperature at which a liquid changes to a vapor state, at a given pressure; usually stated in degrees Fahrenheit (°F) at sea level pressure of 760 millimeters (mm) of mercury (Hg). For mixtures, the initial boiling point or the boiling range may be given.

VAPOR PRESSURE. The pressure exerted by a saturated vapor above its own liquid in a closed container, usually stated in millimeters (mm) of mercury (Hg) at 68 degrees Fahrenheit (°F) or 20 degrees Celsius (°C).

SPECIFIC GRAVITY. The ratio of the weight of a volume of material to the weight of an equal volume of water at 39.2 degrees Fahrenheit (°F).

PERCENTAGE VOLATILE BY VOLUME. The percentage of a liquid or solid (by volume) that will evaporate at an ambient temperature of 70 degrees Fahrenheit (°F).

EVAPORATION RATE. The rate at which a particular material will vaporize (evaporate) when compared to the rate of vaporization of a known material, usually butyl acetate. If another known material is used for comparison, that information should be provided.

APPEARANCE AND ODOR. A brief description of the material at normal room temperature and atmospheric conditions, such as viscous, colorless liquid with an aromatic hydrocarbon odor.

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT AND METHOD USED. The lowest temperature, in degrees Fahrenheit (°F), at which a liquid will give off enough flammable vapor to ignite. Since flash points vary according to how they are obtained, the method used must be listed. The methods used most extensively include: Tag Closed Cup (TCC); Pensky-Martens Closed Cup (PMCC); and Setaflash (SETA).

FLAMMABLE OR EXPLOSIVE LIMITS. The range of concentrations over which a flammable vapor mixed with proper proportions of air will flash or explode if an ignition source is present.

The range extends between two points designated lower explosive limit (LEL) and the upper explosive limit (UEL) and are expressed in percent of volume of vapor in air.

EXTINGUISHING MEDIA. The firefighting substances that are suitable for use on the specific material that is burning. The firefighting substance should be indicated by its generic name such as water, fog, foam, alcohol foam, carbon dioxide (CO_2) or dry chemical.

SPECIAL FIREFIGHTING PROCEDURES (AND PRECAUTIONS). If certain firefighting substances are unsuitable or unsafe when used to control a specific type of burning material, they should be listed here. Special handling procedures and personal protective equipment should also be listed.

UNUSUAL FIRE AND EXPLOSIVE HAZARDS. Under this heading should be listed hazards which might occur as the result of overheating or burning of the specific material, including any chemical reactions or change in chemical form or composition. This Section should also include any special hazards which may need to be considered while extinguishing a fire with one of the available types of extinguishing substances.

SECTION V HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE. The highest airborne concentration of a material to which nearly all persons can be exposed, day after day, without experiencing adverse effects. Threshold Limit Values (TLV) may be expressed in three ways: (1) Time Weighted Average (TWA), based on an allowable concentration exposure averaged over a normal 8-hour workday or a 40-hour workweek; (2) Short-Term Exposure Limit (STEL) or maximum concentration for a continuous 15-minute exposure period (not to exceed 4 such exposures per day); and (3) the Ceiling (C) Exposure Limit, an exposure concentration not to be exceeded under any circumstances. The American Conference of Governmental Industrial Hygienists (ACGIH) periodically publishes these TLV values for various hazardous chemicals. Chemical manufacturers should provide the most current TLVs in their Material Safety Data Sheets.

EFFECTS OF OVEREXPOSURE. A list of the most common sensations or symptoms a person could expect to experience from overexposure to a specific material or its components.

EMERGENCY AND FIRST AID PROCEDURES. The instructions for treatment of a victim of acute inhalation, ingestion and skin or eye contact with a specific hazardous substance or its components. The listed items should be for emergency procedures only as the victim should be examined by a doctor as soon after exposure as possible.

SECTION VI REACTIVITY DATA

STABILITY. The checked box will indicate whether the subject material is stable or unstable under any reasonably foreseeable conditions of storage, handling, use or misuse. If checked unstable, the conditions which could result in a dangerous reaction or decomposition should be listed, including temperatures above 150°F (65°C).

INCOMPATIBILITY. A list (if any) of common materials or contaminants with which this specific material could reasonably be expected to come in contact. Such contact could be expected to produce a reaction or decomposition which would release large amounts of energy, flammable vapor or gas, or to produce toxic vapor or gas. Conditions to avoid (if any) should also be listed, i.e., extreme temperature, jarring, or inappropriate storage. If no common incompatible materials, contamination or conditions are applicable, the boxes should indicate "None."

HAZARDOUS DECOMPOSITION PRODUCTS. A list (if any) of the hazardous materials that may be produced in dangerous amounts if the subject material is exposed to burning, oxidation or heating, or is allowed to react with other chemicals.

HAZARDOUS POLYMERIZATION. Polymerization is a chemical reaction in which two or more molecules of a substance combine to form repeating structural units of the original molecule and produce an energy level change. A hazardous polymerization is a reaction with an extremely high or uncontrolled release of energy. The box should indicate whether or not a hazardous polymerization can occur and, if so, the reasonable foreseeable conditions which could start the polymerization should be listed. The list should also include the expected time period in which the polymerization inhibitors in the product may be used up.

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE THE MATERIAL IS RELEASED OR SPILLED. List should include the methods to be used to control and clean up spills and leaks and should include applicable precautions such as: avoid breathing gases or vapors; avoid contact with specific liquids and solids; and remove sources of ignition. The list should also include any special equipment needed for cleanup, such as glass or plastic scoops.

WASTE DISPOSAL METHODS. Should describe the acceptable as well as the prohibited methods for disposing of spilled solids or liquids, such as flushing with water, returning to container, or burning. Should also alert the user to any potential danger to the environment such as effects on general population, crops, or water supplies.

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION. Whenever respiratory protective devices may be needed during routine or unusual conditions to protect persons from over exposure to a specific substance, the class of device acceptable for use should be listed along with any special conditions of use or limitation.

VENTILATION. Whenever ventilation is needed to capture or contain contaminants at their source as a means of controlling personal exposure to a specific substance or to prevent the build up of an explosive atmosphere, the appropriate types of ventilation systems should be listed along with any applicable conditions of use or limitations.

PROTECTIVE GLOVES. Many solvents can easily penetrate through rubber or neoprene. Whenever gloves are necessary to prevent skin exposure while handling a specific substance or material, special glove design, construction and material requirements should be listed, if appropriate.

EYE PROTECTION. There are many types of eye and face protective devices on the market and a suitable type is available for almost any type of hazard you might encounter. When handling or exposure to a specific substance or mixture requires more eye or face protection than general use industrial safety glasses provide, suitable protective devices should be listed here. The listing should include conditions of use and limitations of device (if any).

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING OR STORAGE. Any additional or special precautions not addressed elsewhere in the MSDS should be listed here. List may include such items as handling or storing to avoid reaction hazards, safe storage life of the product in relation to reactivity, special packaging requirements, and temperature control.

OTHER PRECAUTIONS. A catch-all category for any other precautions not covered elsewhere in the MSDS.

NOTE: Although the Federal OSHA Form 20 does not provide a box for indicating the date the Material Data Safety Sheet was developed, California Law requires that each Material Safety Data Sheet include the month and year the information was compiled.

Information in this section was obtained from *MATERIAL SAFETY DATA SHEETS,* a reprint of General Industry Safety Orders, Title 8, California Administrative Code, Section 5194, plus an explanation of the terms and entries used in material safety data sheets (Form OSHA 20).

3.1 EMERGENCIES

If your shop has not developed procedures for handling potential emergencies, do it NOW. Emergency procedures must be established for operators to follow when emergencies are caused by the release of chlorine, hazardous or toxic chemicals, power outages or broken transmission lines. These procedures should include a list of emergency phone numbers located near a telephone that is unlikely to be affected by the emergency.

1. Police
2. Fire
3. Hospital and/or Physician
4. Poison Control Center
5. Responsible Plant Officials
6. Local Emergency Disaster Office
7. *CHEMTREC* (800) 424-9300
8. Emergency Team (if your plant has one)
9. Regulatory Agencies

The *CHEMTREC* toll-free number may be called at any time. Personnel at this number will give information on how to handle emergencies created by hazardous materials and will notify appropriate emergency personnel.

An emergency team for your shop may be trained and assigned the task of responding to *SPECIFIC EMERGENCIES* such as chlorine leaks. This emergency team must meet the following specifications at all times.

1. Team personnel must be physically and mentally qualified.
2. Proper equipment must be available at all times, including:
   a. Protective equipment, including self-contained breathing apparatus,
   b. Repair kits, and
   c. Repair tools.
3. Proper training must take place on a regular basis and include instruction about:
   a. Properties and detection of hazardous chemicals,
   b. Safe procedures for handling and storage of chemicals,
   c. Types of containers, safe procedures for shipping containers, and container safety devices, and
   d. Installation of repair devices.
4. Team members must be exposed regularly to simulated field emergencies or practice drills. Team response must be carefully evaluated and any errors or weaknesses corrected.
5. Emergency team performance must be reviewed annually on a specified date. Review must include:
   a. Training program,
   b. Response to actual emergencies, and
   c. Team physical and mental examinations.

WARNING. One person should never be permitted to attempt an emergency repair alone. Always wait for trained assistance. Valuable time could be lost rescuing a foolish individual rather than repairing or correcting a serious emergency.

3.2 TYPICAL MSDS

The remainder of this section contains a Material Safety Data Sheet (MSDS) provided Hughes Aircraft by McKesson Chemical Company for caustic soda, liquid. This MSDS is indicative of the information available on an MSDS regarding a specific chemical.

MATERIAL SAFETY DATA SHEET

CAUSTIC SODA, LIQUID

REVISION OF: 11/18/85

HUGHES AIRCRAFT
BUILDING E 4
2000 E. EL SEGUNDO E-4
EL SEGUNDO, CA 90245

ORDER NO: 560W04715

McKESSON CHEMICAL COMPANY ONE POST STREET SAN FRANCISCO, CA 94104

EMERGENCY ASSISTANCE

FOR EMERGENCY ASSISTANCE INVOLVING CHEMICALS CALL CHEMTREC (800) 424-9300.

FOR PRODUCT AND SALES INFORMATION

CONTACT YOUR LOCAL McKESSON CHEMICAL COMPANY SERVICE CENTER

PRODUCT IDENTIFICATION

PRODUCT NAME: CAUSTIC SODA LIQUID
COMMON NAMES/SYNONYMS: SODIUM HYDROXIDE SOLUTION; LYE SOLUTION; SODA LYE

CAS NO: 1310-73-2
McKESSON CODE:T1377

FORMULA: NA O H
HAZARD RATING (NFPA 704)
- HEALTH: 3
- FIRE: 0
- REACTIVITY: 1
- SPECIAL: NONE

DATE ISSUED: 09/85
SUPERCEDES: NONE
HAZARD RATING SCALE:
0 = MINIMAL 3 = SERIOUS
1 = SLIGHT 4 = SEVERE
2 = MODERATE

HAZARDOUS INGREDIENTS

		EXPOSURE LIMITS, MG/M3			
		OSHA	ACGIH	OTHER	
COMPONENT	%	PEL	TLV	LIMIT	HAZARD
SODIUM HYDROXIDE	10-50	2	2	NONE	CORROSIVE; TOXIC
WATER	BALANCE	NONE	NONE	NONE	NONE

PHYSICAL PROPERTIES

BOILING POINT, DEG F: SEE BELOW
MELTING POINT, DEG F: SEE BELOW
SPECIFIC GRAVITY (WATER = 1): SEE BELOW
APPEARANCE AND ODOR:
WATER-WHITE TO SLIGHTLY TURBID SOLUTION, NO ODOR

VAPOR PRESSURE, MM HG/20 DEG C:1
VAPOR DENSITY (AIR = 1):N/A
WATER SOLUBILITY, %:100
EVAPORATION RATE (BUTYL ACETATE = 1):N/A

	SODIUM HYDROXIDE, %						
	10	18	20	25	30	33	50
BOILING POINT, DEG F	218	224	226	232	240	246	288
FREEZING POINT, DEG F	10	-20	-16	-2	32	42	50
SPECIFIC GRAVITY (WATER = 1)	1.11	1.20	1.22	1.27	1.33	1.36	1.53

FIRST AID MEASURES

IF INHALED: REMOVE TO FRESH AIR. GIVE ARTIFICIAL RESPIRATION IF NOT BREATHING BUT NEVER TO AN UNCONSCIOUS OR CONVULSING PERSON. GET IMMEDIATE MEDICAL ATTENTION.

IN CASE OF EYE CONTACT: IMMEDIATELY FLUSH EYES WITH LOTS OF RUNNING WATER FOR 30 MINUTES, LIFTING THE UPPER AND LOWER EYELIDS OCCASIONALLY. GET IMMEDIATE MEDICAL ATTENTION.

IN CASE OF SKIN CONTACT: IMMEDIATELY FLUSH SKIN WITH LOTS OF RUNNING WATER FOR 30 MINUTES. REMOVE CONTAMINATED CLOTHING AND SHOES; WASH BEFORE REUSE. GET IMMEDIATE MEDICAL ATTENTION.

IF SWALLOWED: DO NOT INDUCE VOMITING. IF CONSCIOUS, GIVE LOTS OF WATER OR MILK. GET IMMEDIATE MEDICAL ATTENTION. DO NOT GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS OR CONVULSING PERSON.

---HEALTH HAZARD INFORMATION---

PRIMARY ROUTES OF EXPOSURE: SKIN OR EYE CONTACT

SIGNS AND SYMPTOMS OF EXPOSURE

INHALATION: VAPORS AND MISTS ARE EXTREMELY CORROSIVE TO THE NOSE, THROAT, AND MUCOUS MEMBRANES. BRONCHITIS, PULMONARY EDEMA, AND CHEMICAL PNEUMONITIS MAY OCCUR. IRRITATION, COUGHING, CHEST PAIN, AND DIFFICULTY IN BREATHING MAY OCCUR WITH BRIEF EXPOSURE WHILE PROLONGED EXPOSURE MAY RESULT IN MORE SEVERE IRRITATION AND TISSUE DAMAGE. BREATHING HIGH CONCENTRATIONS MAY RESULT IN DEATH.

EYE CONTACT: VAPORS, LIQUID, AND MISTS ARE EXTREMELY CORROSIVE TO THE EYES. BRIEF CONTACT OF THE VAPORS WILL BE SEVERELY IRRITATING. BRIEF CONTACT OF THE LIQUID OR MISTS WILL SEVERELY DAMAGE THE EYES AND PROLONGED CONTACT MAY CAUSE PERMANENT EYE INJURY WHICH MAY BE FOLLOWED BY BLINDNESS.

SKIN CONTACT: VAPORS, MISTS, AND LIQUID ARE EXTREMELY CORROSIVE TO THE SKIN. VAPORS WILL SEVERELY IRRITATE THE SKIN AND LIQUID AND MISTS WILL SEVERELY BURN THE SKIN. PROLONGED LIQUID CONTACT WILL BURN OR DESTROY SURROUNDING TISSUE AND DEATH MAY ACCOMPANY BURNS WHICH EXTEND OVER LARGE PORTIONS OF THE BODY.

SWALLOWED: VAPORS, MISTS, AND LIQUID ARE EXTREMELY CORROSIVE TO THE MOUTH AND THROAT. SWALLOWING THE LIQUID BURNS THE TISSUES, CAUSES SEVERE ABDOMINAL PAIN, NAUSEA, VOMITING, AND COLLAPSE. SWALLOWING LARGE QUANTITIES CAN CAUSE DEATH.

CHRONIC EFFECTS OF EXPOSURE: MAY RESULT IN AREAS OF DESTRUCTION OF SKIN TISSUE OR PRIMARY IRRITANT DERMATITIS. SIMILARLY, INHALATION OF DUSTS, VAPORS, OR MISTS MAY CAUSE VARYING DEGREES OF DAMAGE TO THE AFFECTED TISSUES AND ALSO INCREASING SUSCEPTIBILITY TO RESPIRATORY ILLNESS.

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE: NONE KNOWN.

---TOXICITY DATA---

ORAL: RAT LD50 = 140-340 MG/KG

DERMAL: RABBIT LD50 = 1350 MG/KG

INHALATION: NO DATA FOUND

CARCINOGENICITY: THIS MATERIAL IS NOT CONSIDERED TO BE A CARCINOGEN BY THE NATIONAL TOXICOLOGY PROGRAM, THE INTERNATIONAL AGENCY FOR RESEARCH ON CANCER, OR THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION.

OTHER DATA: NONE.

---PERSONAL PROTECTION---

VENTILATION: LOCAL MECHANICAL EXHAUST VENTILATION CAPABLE OF MAINTAINING EMISSIONS AT THE POINT OF USE BELOW THE PEL.

RESPIRATORY PROTECTION: NIOSH-APPROVED CANNISTER RESPIRATOR IN THE ABSENCE OF ADEQUATE ENVIRONMENTAL CONTROLS AT THE POINT OF USE.

EYE PROTECTION: CHEMICAL GOGGLES AND FULL FACE SHIELD.

PROTECTIVE CLOTHING: ALKALI-RESISTANT SLICKER SUIT WITH RUBBER APRON, RUBBER BOOTS WITH PANTS OUTSIDE, AND RUBBER GLOVES WITH GAUNTLETS.

OTHER PROTECTIVE MEASURES: AN EYEWASH AND SAFETY SHOWER SHOULD BE NEARBY AND READY FOR USE.

---FIRE AND EXPLOSIVE INFORMATION---

FLASH POINT, DEG F: NONE
METHOD USED, N/A

FLAMMABLE LIMITS IN AIR, %
LOWER: N/A UPPER: N/A

EXTINGUISHING MEDIA: THIS MATERIAL IS NOT COMBUSTIBLE.

SPECIAL FIRE FIGHTING PROCEDURES: FIRE FIGHTERS SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS. USE WATER SPRAY TO COOL NEARBY CONTAINERS AND STRUCTURES EXPOSED TO FIRE.

UNUSUAL FIRE AND EXPLOSION HAZARDS: EXTINGUISH ALL NEARBY SOURCES OF IGNITION SINCE FLAMMABLE HYDROGEN GAS WILL BE LIBERATED FROM CONTACT WITH SOME METALS.

HAZARDOUS REACTIVITY

STABILITY: STABLE
POLYMERIZATION: WILL NOT OCCUR
CONDITIONS TO AVOID: NONE

MATERIALS TO AVOID: ACIDS, COMBUSTIBLE MATERIALS, AND METALS SUCH AS ALUMINUM, TIN, GALVANIZED ZINC, BRASS, AND BRONZE.

HAZARDOUS DECOMPOSIION PRODUCTS: GENERATED HAZARDOUS MIST AT BOILING POINT, 218-288 DEG F. FLAMMABLE HYDROGEN GAS WILL BE LIBERATED UPON CONTACT WITH METALS SUCH AS ALUMINUM, TIN, OR ZINC.

SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS OR LEAKS: WEAR ALKALI-RESISTANT SLICKER SUIT AND COMPLETE PROTECTIVE EQUIPMENT INCLUDING RUBBER GLOVES AND RUBBER BOOTS AND CHEMICAL GOGGLES AND FACESHIELD. FOR SMALL SPILLS OR DRIPS, MOP OR WIPE UP AND DISPOSE OF IN DOT (DEPARTMENT OF TRANSPORTATION)-APPROVED WASTE CONTAINERS. FOR LARGE SPILLS, CONTAIN BY DIKING WITH SOIL OR OTHER ABSORBENT MATERIAL AND CAREFULLY NEUTRALIZE WITH DILUTE HYDROCHLORIC ACID. KEEP NON-NEUTRALIZED MATERIAL OUT OF SEWERS, STORM DRAINS, SURFACE WATERS, AND SOIL.
COMPLY WITH ALL APPLICABLE GOVERNMENTAL REGULATIONS ON SPILL REPORTING, AND HANDLING AND DISPOSAL OF WASTE.

DISPOSAL METHODS: DISPOSE OF CONTAMINATED PRODUCT AND MATERIALS USED IN CLEANING UP SPILLS OR LEAKS IN A MANNER APPROVED FOR THIS MATERIAL. CONSULT APPROPRIATE FEDERAL, STATE AND LOCAL REGULATORY AGENCIES TO ASCERTAIN PROPER DISPOSAL PROCEDURES.
NOTE: EMPTY CONTAINERS CAN HAVE RESIDUES, GASES AND MISTS AND ARE SUBJECT TO PROPER WASTE DISPOSAL. AS ABOVE.

SPECIAL PRECAUTIONS

STORAGE AND HANDLING PRECAUTIONS: STORE IN A WARM, DRY PLACE. VENT CONTAINER CAREFULLY, AS NEEDED, TO RELIEVE PRESSURE. KEEP CONTAINER TIGHTLY CLOSED WHEN NOT IN USE. DO NOT USE PRESSURE TO EMPTY CONTAINER. WASH THOROUGHLY AFTER HANDLING. DO NOT GET IN EYES, ON SKIN, OR ON CLOTHNG. STORE AT TEMPERATURES ABOVE THE SOLUTION FREEZING POINT TO REMAIN LIQUID. REFER TO TABLE IN INGREDIENTS SECTION FOR APPROPRIATE FREEZING POINTS.

REPAIR AND MAINTENANCE PRECAUTIONS: DO NOT CUT, GRIND, WELD, OR DRILL ON OR NEAR THIS CONTAINER. HAZARDOUS CARBON MONOXIDE GAS CAN FORM UPON CONTACT WITH FOOD AND BEVERAGE PRODUCTS IN ENCLOSED SPACES AND CAN CAUSE DEATH. DO NOT ENTER TANKS WHERE SUCH CONTACT IS SUSPECTED UNLESS THE ABSENCE OF CARBON MONOXIDE HAS BEEN CONFIRMED BY TESTS.

OTHER PRECAUTIONS: CONTAINERS, EVEN THOSE THAT HAVE BEEN EMPTIED, WILL RETAIN PRODUCT RESIDUE AND VAPORS. ALWAYS OBEY HAZARD WARNINGS AND HANDLE EMPTY CONTAINERS AS IF THEY WERE FULL. WHEN MIXING CAUSTIC SODA WITH WATER ALWAYS ADD CAUSTIC SLOWLY TO WATER AND STIR CONTINUOUSLY TO DISSIPATE THE HEAT OF DILUTION THAT IS FORMED. NEVER ADD WATER TO CAUSTIC SODA.

FOR ADDITIONAL INFORMATION

CONTACT DOUGLAS EISNER, TECHNICAL DIRECTOR, McKESSON CHEMICAL COMPANY DURING BUSINESS HOURS, PACIFIC TIME (415) 983-9214

NOTICE

ALL INFORMATION, RECOMMENDATIONS, AND SUGGESTIONS APPEARING HEREIN CONCERNING THIS PRODUCT ARE BASED UPON DATA OBTAINED FROM THE MANUFACTURER AND/OR RECOGNIZED TECHNICAL SOURCES; HOWEVER, McKESSON CHEMICAL COMPANY ("MCC") MAKES NO WARRANTY, REPRESENTATION OR GUARANTY AS TO THE ACCURACY. SUFFICIENCY OR COMPLETENESS OF THE MATERIAL SET FORTH HEREIN. IT IS THE USER'S RESPONSIBILITY TO DETERMINE THE SAFETY, TOXICITY AND SUITABILITY OF HIS OWN USE, HANDLING AND DISPOSAL OF THE PRODUCT. ADDITIONAL PRODUCT LITERATURE MAY BE AVAILABLE UPON REQUEST. SINCE ACTUAL USE BY OTHERS IS BEYOND OUR CONTROL, NO WARRANTY, EXPRESS OR IMPLIED, IS MADE BY MCC AS TO THE EFFECTS OF SUCH USE, THE RESULTS TO BE OBTAINED OR THE SAFETY AND TOXICITY OF THE PRODUCT, NOR DOES MCC ASSUME ANY LIABILITY ARISING OUT OF USE BY OTHERS OF THE PRODUCT REFERRED TO HEREIN. THE DATA IN THIS MSDS RELATE ONLY TO THE SPECIFIC MATERIAL DESIGNATED HEREIN AND DO NOT RELATE TO USE ON COMBINATION WITH ANY OTHER MATERIAL OR IN ANY PROCESS.

END OF MSDS

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 85.

3.0A What is a Material Safety Data Sheet (MSDS)?

3.0B What information regarding a hazardous substance can an operator obtain from a Material Safety Data Sheet?

3.0C What is a hazardous ingredient?

3.0D What is meant by "flammable or explosive limits" for a flammable vapor?

3.0E What types of information should be listed under "Spill or Leak Procedures" on an MSDS?

4 EMPLOYEE RIGHT-TO-KNOW LAWS[2]

4.0 NEED

Employee "Right-To-Know" legislation has been implemented to require employers to inform employees (operators) of the possible health effects resulting from contact with hazardous substances. At locations where this legislation is in force, employers must meet certain requirements. Employers must provide operators with information regarding any hazardous substances which the operators might be exposed to under either normal work conditions or reasonably foreseeable emergency conditions resulting from workplace conditions. Information regarding hazardous substances is available from manufacturers in the form of Material Safety Data Sheets (MSDS) for hazardous substances. Employers must provide operators with a copy of MSDSs upon request and also must train operators to work safely with the hazardous substances that are encountered in the workplace.

As an operator you have the right to ask your employer if you are working with any hazardous substances. If you work with any hazardous substances, your employer must provide you with information on the health implications resulting from contact with the substances, the Material Safety Data Sheets, and training for working safely with the hazardous substances.

4.1 NOTIFICATION

Operators must be notified of any hazardous substances in their workplace if there is any potential for their exposure to the substance. Notification of operators may be accomplished by:

1. Prominently posting a list of the hazardous substances present in the workplace, plus information indicating the location and manner in which the Material Safety Data Sheets are available to the operators. If lists of hazardous substances are posted in several locations, each *MAY* refer to all the hazardous substances in the workplace but any particular list *MUST AT LEAST* refer to the hazardous substances in the immediate area.
2. Prominentaly displaying binders containing Material Safety Data Sheets for hazardous substances in the area. There must be enough binders in enough different locations to provide all affected operators with reasonable notice of the hazardous substances in the workplace.
3. Any other appropriate method involving written notice which lists the hazardous substances used in the work area, the availability and location of the Material Safety Data Sheets on the hazardous substances, and the establishment of a procedure which will provide operators with reasonable and timely access to the Material Safety Data Sheets at the worksite.

4.2 TRAINING

An operator information and training program must be developed and implemented so that operators will have the knowledge necessary to perform their work safely with or around any materials or substances that could be potentially hazardous.

Operators must be informed of their right to personally receive information regarding hazardous substances to which they may be exposed, including copies of Material Safety Data Sheets. Also, your personal physician has the right to receive information regarding hazardous substances to which you may be exposed. You cannot be discharged (fired) or subjected to any discrimination due to the exercising of your rights to be informed of potential exposure to hazardous substances in the workplace.

Hazardous substance information and training must be provided to each operator prior to assignment to any work area in which the operator has not received previous information or training. Operators must be given an explanation of what a Material Safety Data Sheet is, either in written form or through training programs.

Operators who may be exposed to a hazardous substance must be furnished with information on the contents of the Material Safety Data Sheets for that hazardous substance, or equivalent information, either in written form or through training programs. This information must include as a minimum:

1. Any health hazards known to be associated with exposure to the hazardous substances;
2. Proper instructions for handling, necessary personal protective equipment or other safety precautions necessary to prevent or minimize exposure to the hazardous substances; and
3. Emergency procedures to be followed for spills, fire, disposal and first aid.

Whenever an employer receives a new or revised Material Safety Data Sheet, this information should be provided to the operators as soon as possible (within 30 days).

4.3 ACCESS TO RECORDS

4.30 EXPOSURE AND MEDICAL RECORDS

Your employer must allow you and also your designated representative access to (1) your exposure records and (2) your medical records.

OPERATOR EXPOSURE RECORDS. Operator exposure records relevant to your work activity consist of:

1. Records of your past or present exposure to toxic substances or harmful physical agents;
2. Exposure records of other operators with past or present job duties or working conditions related to or similar to yours;
3. Records containing exposure information concerning

[2] *OSHA's "Hazard Communication Standard" (Title 29 CFR Part 1910.1200) is the federal regulation and state statues are called "Right-To-Know Laws." As of January 1985, 21 states had adopted "Right-To-Know Laws."*

your workplace or working conditions; and

4. Exposure records pertaining to workplaces or working conditions to which you are being assigned or transferred.

OPERATOR MEDICAL RECORDS. Operator medical records relevant to your work activity consist of a record concerning your health status which is made or maintained by a physician, nurse, or other health care personnel or technician.

(A) Your medical record should include the following:

1. Medical and employment questionnaires or histories (including job description and occupational exposures);
2. The results of medical examinations (pre-employment, pre-assignment, periodic, or episodic) and laboratory tests (including X-ray examinations and all biological monitoring);
3. Medical opinions, diagnoses, progress notes, and recommendations;
4. Descriptions of treatments and presciptions; and
5. Your medical complaints.

(B) Your medical record does not need to include the following:

1. Physical specimens (e.g., blood or urine samples) which are routinely discarded as a part of normal medical practice and are not required to be maintained by other legal requirements;
2. Records concerning health insurance claims if maintained separately from the employer's medical program and its records, and not accessible to the employer by employee name or other direct personal identifier (such as social security number or payroll number); or
3. Records concerning voluntary employee assistance programs (alcohol, drug abuse, or personal counseling programs) if maintained separately from the employer's medical program and its records.[3]

4.31 ACCESS LIMITATIONS

1. Your employer shall, upon request from you, assure you access to your medical records.
2. Your employer shall, upon specific written request from you, assure your designated representative access to your medical records.
3. Whenever you request access to your medical records, a physician representing your employer may recommend that you or your designated representative consult with the employer's physician for the purpose of reviewing and discussing the records requested; accept a summary of material facts and opinions in lieu of the records requested; or accept release of the requested records only to a physician or other designated representative.
4. Whenever you request access to your employee medical records and a physician representing your employer believes that allowing you direct access to information contained in the records regarding a specific diagnosis of a terminal illness or a psychiatric condition could be detrimental to your health, your employer may deny your request for direct access to this information only, and your employer shall inform you that access will only be provided to a designated representative of yours having specific written consent.
5. Where your designated representative with specific written consent requests access to information withheld from you, your employer should assure the access of your designated representative to this information even when it is known that your designated representative will give you the information.

4.4 REFUSAL TO WORK

An operator may have the right to refuse to work with a hazardous substance if your employer fails to produce a Material Safety Data Sheet (MSDS) or evidence that your employer has tried to obtain the requested MSDS.

4.5 LIABILITY

The providing of information in Material Safety Data Sheets to operators does not affect any other liability of your employer with regard to safeguarding the health and safety of operators or any other persons exposed to a toxic or hazardous substance. Also, providing this information will not affect any other duty or responsibility of a manufacturer, producer, or other maker to warn ultimate users of a hazardous substance.

4.6 NOTICE

Information in this section is typical of what an operator might expect to find in an area where "Employee Right-To-Know Legislation" has been enacted and is enforced. However, these regulations may differ from one area to another and you should become familiar with the laws and regulations that pertain to you and your workplace.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 85.

4.0A Why was employee "Right-To-Know" legislation enacted?

4.0B What information must be included in an operator training program in order to comply with "Right-To-Know" legislation?

4.0C Under what conditions may an operator refuse to work with a hazardous substance?

4.7 ARITHMETIC ASSIGNMENT

A good way to learn how to solve arithmetic problems is to work on them a little bit at a time. In this operator training manual we are going to make an arithmetic assignment at the end of every lesson. If you will work this assignment at the end of every lession, you can learn how to solve arithmetic problems.

Turn to Appendix III, "How to Solve Arithmetic Problems," and read the following sections:

A. How to Study This Appendix,

B. Steps in Solving Problems,

C. Basic Conversion Factors,

D. Basic Formulas,

E. Flow Conservation and Equalization, and

F. Sampling and Analysis.

Solve example problems 1 through 8 on an electronic pocket calculator. You should be able to get the same answers.

[3] *Definition from California General Industry Safety Orders, Section 3204.*

DISCUSSION AND REVIEW QUESTIONS

(Lesson 1 of 3 Lessons)

DO NOT USE SPECIAL ANSWER SHEET. Please write your answers in your notebook before working the Objective Test that is located after these questions. The purpose of these questions is to indicate to you how well you understand the material in this lesson. If you have the opportunity you might wish to discuss some of these questions with other operators to find out how they operate and maintain their facilities, what kinds of problems they encounter and how they respond to these problems.

1. Why must metal wastes be treated before discharge to sewers or the environment?
2. The ideal situation for operators is to have the ability to treat each wastestream individually rather than as a combined wastestream. Why is this so?
3. How can the costs and complexity of metal waste treatment facilities be reduced?
4. What are the main types of electroplating operations which produce metal wastestreams?
5. Why are Material Safety Data Sheets (MSDS) important to operators?
6. Who must develop an MSDS?
7. What is a hazardous ingredient?
8. How would you determine if you had been overexposed to a hazardous material?
9. Why is adequate ventilation around hazardous chemicals important?
10. What is the purpose of employee "Right-To-Know" legislation?

DIRECTIONS FOR WORKING OBJECTIVE TEST

1. You have been provided with a special answer sheet for each lesson. Be sure you follow the special directions provided with the answer sheets. If you lose an answer sheet or have any problems, please notify the Program Director.
2. Mark your answers on the answer sheet with a dark lead pencil. Do not use ink. For example, if Question 2 had three correct answers (1, 2 and 3), you should place a mark under Columns 1, 2 and 3 on the answer sheet. Please mark your answers in your workbook for your record because answer sheets will not be returned to you.
3. Mail answer sheet to the Program Director immediately after you have completed the test.
4. Answer sheets may be folded (but not into more than 3 equal parts) and mailed in a 4 x 9-1/2 standard white envelope to:

   Ken Kerri, Program Director
   Office of Water Programs
   California State University, Sacramento
   6000 J Street
   Sacramento, CA 95819-2694

OPERATION OF WASTEWATER TREATMENT PLANTS

IMPORTANT

PLEASE READ INSTRUCTIONS ON REVERSE SIDE BEFORE COMPLETING THIS FORM.

OFFICE USE ONLY
DO NOT MARK

Name: ______________________________
Last First MI

Address: ______________________________

____
City State Zip Code

Mail to: Professor Kenneth Kerri
California State University, Sacramento
6000 J Street
Sacramento, California 95819

SOCIAL SECURITY NUMBER	CHAPTER NUMBER
0–9 (nine columns)	0–3, 0–9

FOLD

Sample

Do not use

IMPORTANT DIRECTIONS FOR MARKING ANSWERS

Use black lead pencil only (# 2 or softer).
Make heavy black marks that fill the circle completely.
Erase clearly any answer you wish to change.
Make no stray marks on this answer sheet.

1. MULTIPLE CHOICE QUESTIONS: Fill in the correct answers. If 2 and 3 are correct for question 1, mark:

1 2 3 4 5
1 Ⓣ ● ● ○ ○

2. TRUE—FALSE QUESTIONS: If true, fill in the circle in column 1; if false, fill in column 2. If question 3 is true, mark:

1 2 3 4 5
3 ● Ⓕ ○ ○ ○

EXAMPLE

SOCIAL SECURITY NUMBER	CHAPTER NUMBER
1 2 3 4 5 6 7 8 9	0 1

A2803

NCS Trans-Optic 05-16451-3

FOLD

1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
1 Ⓣ Ⓕ ○ ○ ○	11 Ⓣ Ⓕ ○ ○ ○	21 Ⓣ Ⓕ ○ ○ ○	31 Ⓣ Ⓕ ○ ○ ○	41 Ⓣ Ⓕ ○ ○ ○	51 Ⓣ Ⓕ ○ ○ ○
2 Ⓣ Ⓕ ○ ○ ○	12 Ⓣ Ⓕ ○ ○ ○	22 Ⓣ Ⓕ ○ ○ ○	32 Ⓣ Ⓕ ○ ○ ○	42 Ⓣ Ⓕ ○ ○ ○	52 Ⓣ Ⓕ ○ ○ ○
3 Ⓣ Ⓕ ○ ○ ○	13 Ⓣ Ⓕ ○ ○ ○	23 Ⓣ Ⓕ ○ ○ ○	33 Ⓣ Ⓕ ○ ○ ○	43 Ⓣ Ⓕ ○ ○ ○	53 Ⓣ Ⓕ ○ ○ ○
4 Ⓣ Ⓕ ○ ○ ○	14 Ⓣ Ⓕ ○ ○ ○	24 Ⓣ Ⓕ ○ ○ ○	34 Ⓣ Ⓕ ○ ○ ○	44 Ⓣ Ⓕ ○ ○ ○	54 Ⓣ Ⓕ ○ ○ ○
5 Ⓣ Ⓕ ○ ○ ○	15 Ⓣ Ⓕ ○ ○ ○	25 Ⓣ Ⓕ ○ ○ ○	35 Ⓣ Ⓕ ○ ○ ○	45 Ⓣ Ⓕ ○ ○ ○	55 Ⓣ Ⓕ ○ ○ ○
6 Ⓣ Ⓕ ○ ○ ○	16 Ⓣ Ⓕ ○ ○ ○	26 Ⓣ Ⓕ ○ ○ ○	36 Ⓣ Ⓕ ○ ○ ○	46 Ⓣ Ⓕ ○ ○ ○	56 Ⓣ Ⓕ ○ ○ ○
7 Ⓣ Ⓕ ○ ○ ○	17 Ⓣ Ⓕ ○ ○ ○	27 Ⓣ Ⓕ ○ ○ ○	37 Ⓣ Ⓕ ○ ○ ○	47 Ⓣ Ⓕ ○ ○ ○	57 Ⓣ Ⓕ ○ ○ ○
8 Ⓣ Ⓕ ○ ○ ○	18 Ⓣ Ⓕ ○ ○ ○	28 Ⓣ Ⓕ ○ ○ ○	38 Ⓣ Ⓕ ○ ○ ○	48 Ⓣ Ⓕ ○ ○ ○	58 Ⓣ Ⓕ ○ ○ ○
9 Ⓣ Ⓕ ○ ○ ○	19 Ⓣ Ⓕ ○ ○ ○	29 Ⓣ Ⓕ ○ ○ ○	39 Ⓣ Ⓕ ○ ○ ○	49 Ⓣ Ⓕ ○ ○ ○	59 Ⓣ Ⓕ ○ ○ ○
10 Ⓣ Ⓕ ○ ○ ○	20 Ⓣ Ⓕ ○ ○ ○	30 Ⓣ Ⓕ ○ ○ ○	40 Ⓣ Ⓕ ○ ○ ○	50 Ⓣ Ⓕ ○ ○ ○	60 Ⓣ Ⓕ ○ ○ ○

OBJECTIVE TEST

(Lesson 1 of 3 Lessons)

Please mark the correct answers on a special answer sheet as directed. There may be more than one correct answer for the multiple-choice questions.

PLEASE MARK CHAPTER 31 ON YOUR ANSWER SHEET

1. Toxic pollutants from industrial facilities must be controlled to prevent
    1. Allowance of untreated pollutants to pass through a POTW.
    2. Contamination of POTW sludge.
    3. Inhibition of biological treatment processes in a POTW.
    4. Interference with the operation of a POTW.
    5. Stimulation of biological growths in a POTW.
2. Municipalities have adopted sewer-use ordinances to serve as a mechanism to
    1. Control use of raw materials.
    2. Equitably allocate sewer service charges.
    3. Gather data base information.
    4. Inspect industrial facilities.
    5. Regulate capacity of industiral production.
3. Sources of wastewaters from industrial metal finishing and plating facilities include
    1. Anaerobic sludge digesters.
    2. Production processes.
    3. Rinsing processes.
    4. Washing of equipment.
    5. Waste activated sludge.
4. Information required on Material Safety Data Sheets includes
    1. Disposal procedures.
    2. Emergency procedures for spills.
    3. Improper precautions.
    4. Potential routes of exposure.
    5. Symptoms of underexposure.
5. The letters CAS stand for
    1. Chemical Abstract Service.
    2. Chemical Analysis and Support.
    3. Chemical Alternatives and Safety.
    4. Chemical Analytical Service.
    5. Chemical Analytical Supplies.
6. Physical data required on an MSDS include
    1. Boiling point.
    2. Chemical formula.
    3. Evaporation rate.
    4. Odor.
    5. Vapor pressure.
7. Fire and explosion hazard data that must be included on an MSDS include
    1. Evaporation rate.
    2. Extinguishing media.
    3. Firefighting procedures.
    4. Flash point.
    5. Percent volatile.
8. Health hazard data that must be listed on an MSDS include
    1. Effects of overexposure.
    2. Explosive hazard.
    3. First aid procedures.
    4. Odor level.
    5. Threshold Limit Value (TLV).
9. Reactivity data that must be listed on an MSDS include
    1. Hazardous decomposition products.
    2. Hazardous polymerization.
    3. Incompatibility.
    4. Specific gravity.
    5. Stability.
10. Information that should be listed on an MSDS under spill or leak procedures include
    1. Applicable precautions.
    2. Firefighting procedures.
    3. First aid procedures.
    4. Need for special equipment.
    5. Waste disposal methods.
11. Information that should be listed under special protection information on an MSDS includes
    1. Eye protection.
    2. Fire protection.
    3. Protective gloves.
    4. Respiratory protection.
    5. Ventilation.
12. Employee "Right-To-Know" legislation requires employers to provide operators
    1. Additional sick and vacation leave to recover from overexposure of hazardous substances.
    2. Copy of MSDSs upon request.
    3. Insurance policy covering injuries resulting from hazardous substances.
    4. Relief operators when certain threshold level exposures have been exceeded.
    5. Training to work safely with hazardous substances that are encountered.
13. Operators have the right to
    1. Ask employer if they are working with a hazardous substance.
    2. Be provided with information on health implications resulting from contact with hazardous substances.
    3. Obtain MSDSs.
    4. Receive training for working safely with hazardous substances.
    5. Refuse to work with a potentially hazardous substance if employer fails to produce an MSDS.
14. Calculate the percent reduction in flows achieved by an industrial water conservation program if wastewater flows are reduced from 400 GPM to 280 GPM.
    1. 16%
    2. 24%
    3. 27%
    4. 30%
    5. 43%
15. Determine the flow capacity of a pump in GPM if the pump lowers the wastewater in a 5 foot by 4 foot rectangular sump one foot in 4 minutes.
    1. 3 GPM
    2. 5 GPM
    3. 17 GPM
    4. 30 GPM
    5. 37 GPM

END OF OBJECTIVE TEST

TREATMENT OF WASTEWATER FROM ELECTROPLATING, METAL FINISHING AND PRINTED CIRCUIT BOARD MANUFACTURING

(Lesson 2 of 3 Lessons)

5 METHODS OF TREATMENT

Electroplating, metal finishing and circuit board manufacturing wastewaters are usually treated by chemical processes because the contaminants are generally not only resistant to biological treatment, but are frequently highly toxic to organisms. Some of the specific waste treatment processes include neutralization for highly acidic or basic wastes, hydroxide and sulfide precipitation of toxic heavy metals, oxidation for cyanide destruction, reduction and neutralization for chromium wastes and ion exchange, evaporation, or *ELECTROWINNING*[4] for recovery of valuable metals.

Experienced operators know that their job is much easier if they can treat certain wastestreams before they become mixed with other wastestreams. If wastestreams are *SEGREGATED*[5] then the operator's job is fairly easy when the task is to recover precious metals (such as gold), reduce hexavalent chromium, destroy cyanide, and remove and recover oils prior to the removal of common metals. Treatment costs can be reduced by wastestream segregation. Water conservation, good housekeeping and prevention of spills, process control and other practices will reduce the flow of wastewater which will also result in lower treatment costs.

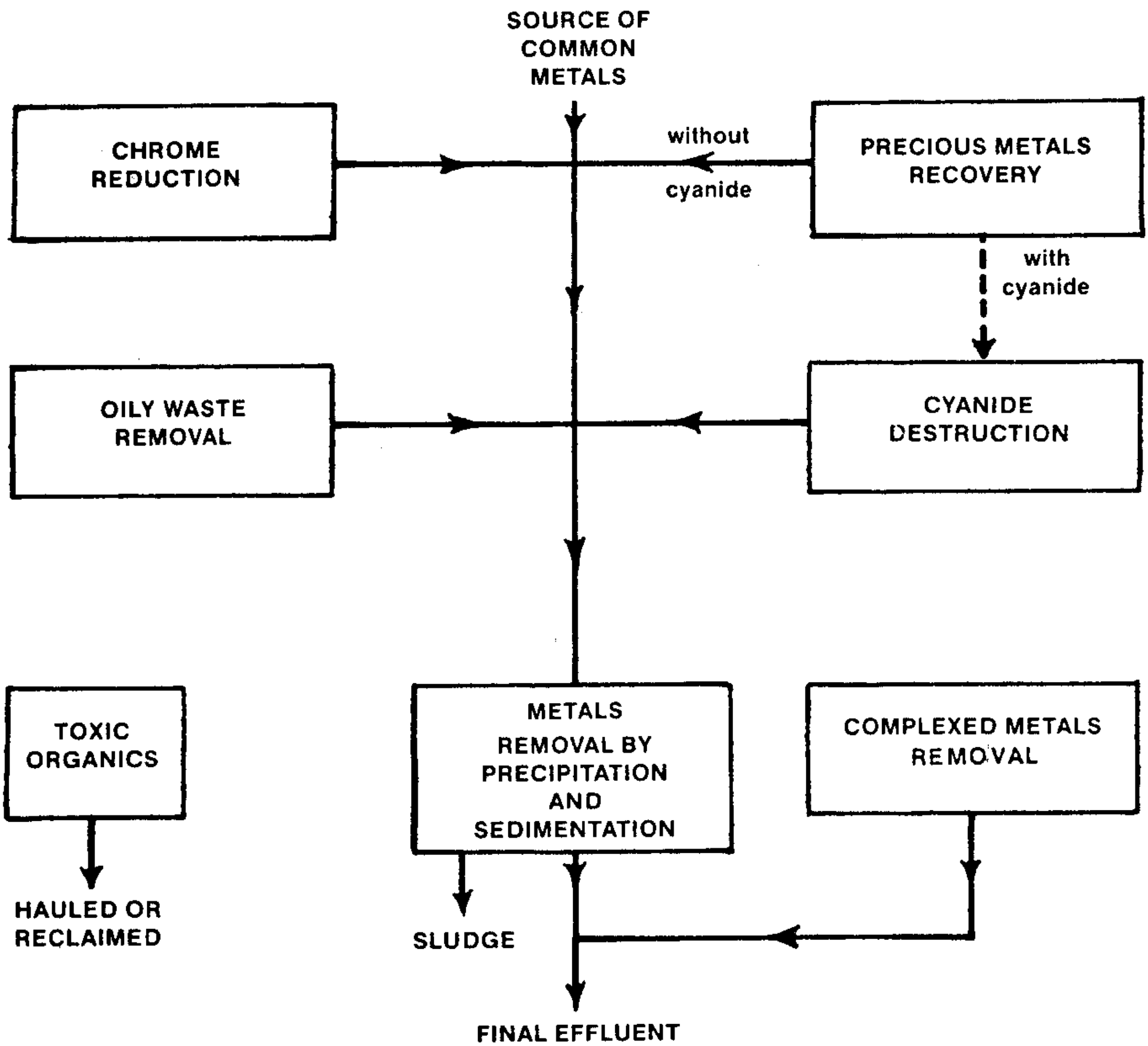
Figure 2 illustrates one method of treating segregated wastestreams prior to the removal of common metals. All sources of metal wastes must be identified. If a metal wastestream contains chrome, cyanide, oily wastes or precious metals to be recovered, these wastestreams must be kept segregated and treated separately before they are combined with source wastestreams of common metals. *HEXAVALENT CHROMIUM AND CYANIDE WASTEWATERS MUST BE PRETREATED INDIVIDUALLY BEFORE THEY ARE SENT TO THE METALS REMOVAL PROCESS.* Wastestreams containing hexavalent chromium must be chemically treated (usually with gaseous sulfur dioxide or sodium bisulfite) to reduce the hexavalent chromium to trivalent chromium. Once chrome reduction has been achieved, the trivalent chromium can be treated with the other metals by alkaline precipitation. Precious or valuable metals are removed prior to the remaining metals being removed by precipitation. If the metal wastes contain cyanide, the cyanide must be destroyed by oxidation (usually alkaline chlorination) before the metals can be removed by precipitation. *ANY WASTES CONTAINING OILS SHOULD BE TREATED SEPARATELY BY SOME TYPE OF SEPARATION PROCESS.* Oils in wastestreams can prevent the proper operation of treatment monitoring probes. *COMPLEXED METAL*[6] *WASTES PREVENT METAL PRECIPITATES FROM FORMING AND SETTLING OUT.* Therefore, complexed metal wastes must be segregated and treated individually.

The final effluent can be discharged to a sewer if the effluent meets the pretreatment requirements (Table 1) plus any more stringent local regulations. If a shop intends to consistently comply with the limits in Table 2, the long-term concentration average (Table 3) should be used as the basis for design and operation. The limitations in Table 2 were found to be attainable by the technology the US Environmental Protection Agency evaluated when the limitations were developed. Table 4 is a summary of conventional chemical treatment methods.

[4] *Electrowinning (ELECTRO-winning). A reverse electroplating process which uses a carbon electrode (insoluble anode). An advantage of this process is that no sludge is produced.*

[5] *Segregate. To keep separate or prevent mixing (of two or more wastestreams). Wastes from various in-plant sources are easier to treat before they become mixed together.*

[6] *Complexed Metal. A metal with a tendency to remain in solution rather than form a precipitate and settle out. This metal has reacted with or is tied up with chemical complexing agents such as ammonia or citrates, tartrates, quadrol and EDTA.*



NOTE: Cadmium, chromium, copper, lead, nickel and zinc are common metals found in wastestreams.

Fig. 2 Treatment of segregated metal finishing wastestreams

TABLE 2 PRETREATMENT STANDARDS FOR THE METAL FINISHING CATEGORY[a]
40 CFR PART 433

PRETREATMENT STANDARDS FOR EXISTING SOURCES (PSES)

Pollutant	Daily Maximum (mg/*L*)	Maximum Monthly Average (mg/*L*)
Cadmium (T)	0.69	0.26
Chromium (T)	2.77	1.71
Copper (T)	3.38	2.07
Lead (T)	0.69	0.43
Nickel (T)	3.98	2.38
Silver (T)	0.43	0.24
Zinc (T)	2.61	1.48
Cyanide, total	1.20	0.65
Total Toxic Organics (interim)	4.57	—
Total Toxic Organics (final)	2.13	—
Alternative to total cyanide: Cyanide, amenable to chlorination	0.86	0.32

PRETREATMENT STANDARDS FOR NEW SOURCES (PSNS)

Pollutant	Daily Maximum (mg/*L*)	Maximum Monthly Average (mg/*L*)
Cadmium (T)	0.11	0.07
Chromium (T)	2.77	1.71
Copper (T)	3.38	2.07
Lead (T)	0.69	0.43
Nickel (T)	3.98	2.38
Silver (T)	0.43	0.24
Zinc (T)	2.61	1.48
Cyanide, total	1.20	0.65
Total Toxic Organics	2.13	—
Alternative to total cyanide: Cyanide, amenable to chlorination	0.86	0.32

NOTE: No maximum monthly average TTO concentration regulated.
(T) = total

[a] *GUIDANCE MANUAL FOR ELECTROPLATING AND METAL FINISHING PRETREATMENT STANDARDS, US Environmental Protection Agency, Effluent Guidelines Division and Permits Division, Washington, DC 20460, February 1984.*

TABLE 3 LONG-TERM CONCENTRATION AVERAGES[a]

Pollutant or Pollutant Property	Long Term Concentration Average Milligrams Per Liter (mg/*L*)
Cadmium (T)[b]	0.13
Chromium (T)	0.572
Copper (T)	0.815
Lead (T)	0.20
Nickel (T)	0.942
Silver (T)	0.096
Zinc (T)	0.549
Cyanide (T)	0.18
Cyanide, A	0.06
TTO (raw water)	1.08
TTO (effluent)	0.434

[a] *GUIDANCE MANUAL FOR ELECTROPLATING AND METAL FINISHING PRETREATMENT STANDARDS, US Environmental Protection Agency, Effluent Guidelines Division and Permits Division, Washington, D.C. 20460, February 1984.*
[b] *Cadmium (T) for new sources is 0.058 mg/L.*

TABLE 4 SUMMARY OF CONVENTIONAL CHEMICAL TREATMENT METHODS[a]

Treatment Method	Treatment Chemical	Usage Ratio	Optimum pH	Minimum Reaction Time (min)	*Comments*
I. Hexavalent chromium reduction					
Acid method	Sodium metabisulfite	1.5:1	pH = 3.0-3.5	5	Reaction time dependent on pH.
	Sulfur dioxide	1:1	pH = 3.0-3.5	5	Reaction time dependent on pH.
	Ferrous sulfate	8:1	pH = 3.0-3.5	5	Reaction time dependent on pH.
II. Cyanide Oxidation					
A. Cyanide to cyanate	Chlorine gas	3.5:1	pH > 11.0	10	pH > 11.0 critical to prevent toxic gas.
	15% sodium hypochlorite		pH > 11.0	10	pH > 11.0 critical to prevent toxic gas.
	Calcium hypochlorite		pH > 11.0	10	pH > 11.0 critical to prevent toxic gas.
B. Cyanate to CO_2 and N_2	Chlorine gas	5:1	pH = 8.5	20	Reaction time dependent on pH.
	15% sodium hypochlorite		pH = 8.5	20	Reaction time dependent on pH.
	Calcium hypochlorite		pH = 8.5	20	Reaction time dependent on pH.
III. Metals precipitation					
A. Hydroxide	Hydrated lime	Variable	pH = 7.0-10.0	20	Optimum pH varies depending on metal to be removed.
	Caustic soda	Variable	pH = 7.0-10.0	20	Optimum pH varies depending on metal to be removed.
B. Sulfide	Ferrous sulfide/ sodium sulfide	5:1	pH = 8.0-9.0	15	Polishing after hydroxide precipitation when complexing agents present
C. Carbonate	Sodium bicarbonate	Variable	Variable	15	Advantageous for lead, cadmium, nickel removal.
D. Insoluble starch xanthate	Cross linked starches	5-10:1	pH > 7.0	Instantaneous	Polishing after hydroxide precipitation when complexing agents present.
IV. Oily waste demulsification					
Acidification/hydrolysis/ adsorption	Sulfuric acid	Variable	pH < 3.0	10-20	Removal efficiencies related to type of emulsifying agent used and nature of oil (i.e., mineral based or synthetic type). Addition of heat may also be needed for certain applications.
	Polyelectrolyte	Variable	pH = 3.0-5.0	10-20	
	Alum	Variable	pH < 3.0	10-20	
	Calcium chloride	Variable	pH < 3.0	10-20	

[a] *Reproduced by permission of TMSI Contractors from METAL FINISHING PLATING BUYERS GUIDE.*

5.0 BATCH AND CONTINOUS PROCESSES

Many of the treatment methods may be of either the *BATCH*[7] or *CONTINUOUS*[8] type of treatment process. Usually wastewaters are treated by the batch process when dealing with small wastewater flows because storage requirements for wastewaters prior to treatment are minimal. Batch processes are easier to control and the water being treated is not discharged to sewers or the environment until after a satisfactory level of treatment is achieved.

Many operators consider the batch treatment process the simplest and most dependable. A typical hydroxide precipitation metals removal process can accomplish pH adjustment, mixing, flocculation and clarification successively in a single tank (Figure 3). Usually two or more batch tanks are necessary for efficient operation. Metal wastes can flow into one batch tank while the other tank is treating a full tank of wastes. If only cyanide or hexavalent chromium is present in separate wastestreams, these wastes can be pretreated on a separate batch basis also (Figure 4). Batch treatment is cost effective when the operation and waste flows are relatively small. Most industries do not use batch treatment processes, however, because of high wastewater flows and the space required for batch treatment facilities. In shops using continuous processing, batch treatment is very beneficial to handle acid dumps, spent plating solutions, alkaline cleaners and other concentrated solutions which would overwhelm the continuous process systems.

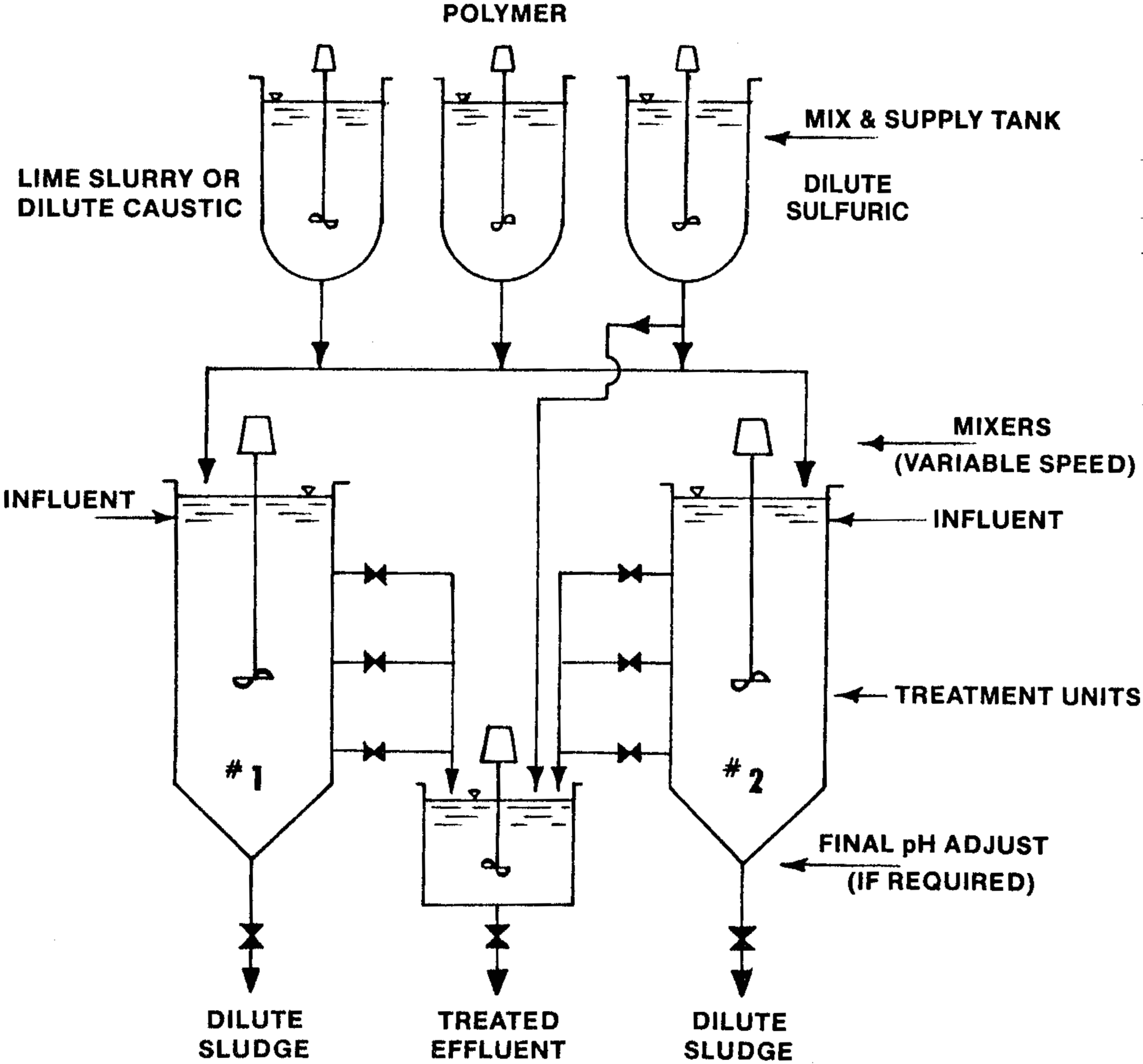
Most total treatment systems segregate wastewaters that result from periodic dumping of process solutions that have reached the end of their useful life from wastewaters resulting from the flowing rinses. The batch dumps are low in volume and high in contamination. Two major factors govern this segregation for treatment.

Closer control is obtainable when the contamination level of the raw waste does not fluctuate widely. If a spent process solution (a pickle, for example) is dumped directly into rinse water, the contamination level can increase 10,000 times for a short duration of time. The control system for rinse water treatment cannot respond to this surge without losing the close control required for normal discharge of effluent.

The other governing factor concerns the handling of suspended solids from waste treatment practices. The sludges resulting from batch treatment vary somewhat in

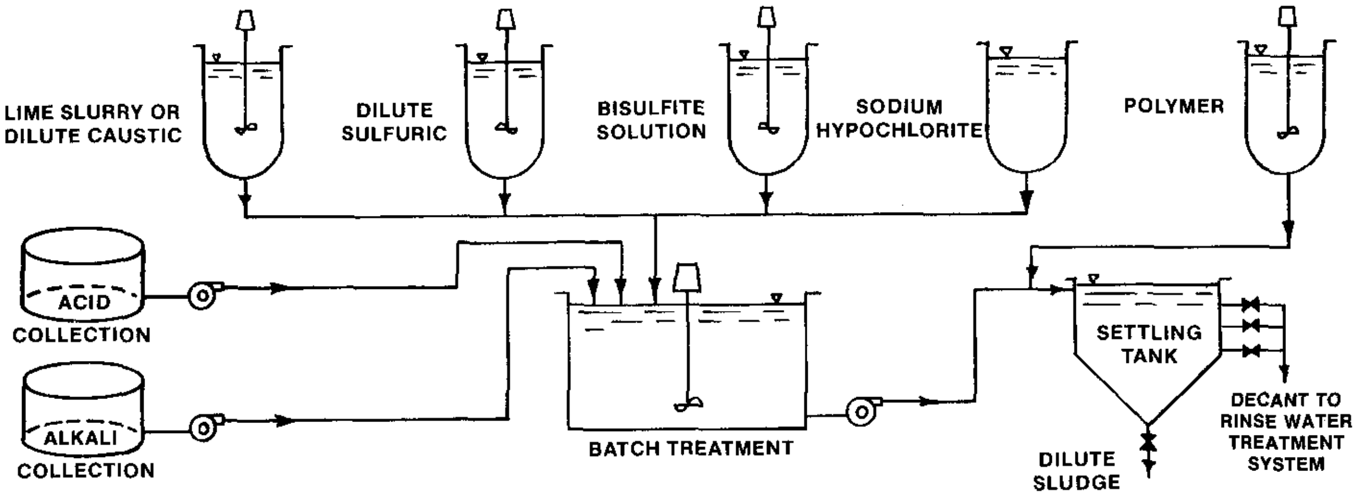
[7] *Batch Process. A treatment process in which a tank or reactor is filled, the water is treated, and the tank is emptied. The tank may then be filled and the process repeated.*

[8] *Continuous Process. A treatment process in which water is treated continuously in a tank or reactor. The water being treated continuously flows into the tank at one end, is treated as it flows through the tank, and flows out the opposite end as treated water.*



1. Tank #1 fills while Tank #2 is being treated.
2. Lime or caustic, and/or acid, is added to adjust pH for metal hydroxide precipitation.
3. Rapid mix (3-10 min. depending on size) to mix chemicals added for pH adjustment.
4. Polymer is added to improve flocculation.
5. Slow mixing for 20-30 min. to promote floc formation.
6. No mixing for 1-3 hours to allow floc to settle.
7. Decant clarified water to second pH adjustment tank.
8. After decanting, remove settled solids as dilute sludge.
9. If required, add sulfuric to correct pH, mix for 10 min., then discharge treated effluent.

Fig. 3 Batch treatment units for common metal removal by hydroxide precipitation and sedimentation by Joe Shockcor



BATCH TREATMENT PROCESS FOR CONCENTRATED BATCH WASTE

Acid Collection may contain hexavalent chromium. Alkaline Collection may contain cyanide.

Sequence A - CN^- Present
1. Transfer alkali waste to Batch Treatment Tank. Start mixer.
2. Batch alkaline chlorination, using caustic to up pH to 10.5 to 11.5 & hypochlorite until all cyanide is oxidized.
3. Adjust pH to 8.5 to 9.5 and add hypochlorite for cyanate oxidation.
4. Transfer to Settling Tank, adding polymer.
5. After 1-3 hr settling, decant treated effluent.
6. Remove dilute sludge.

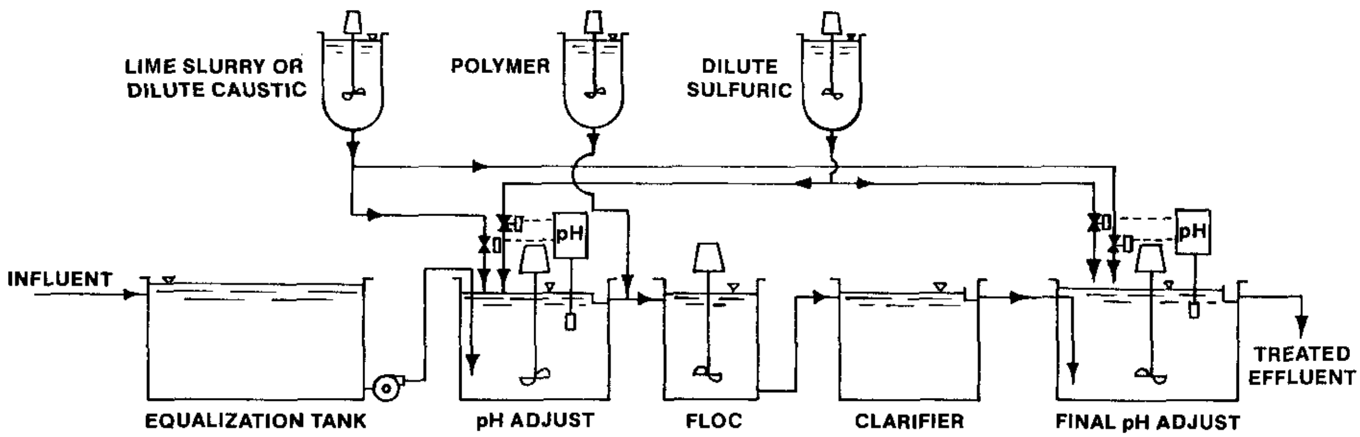
Sequence B – Cr^{6+} Present
1. Transfer acid waste to Batch Treatment Tank. Start mixer.
2. Batch reduction of Cr^{6+}, using sulfuric acid to adjust pH to 2.0 or lower and adding bisulfite.
3. Add alkali to increase pH to 8.0 to 8.5 or higher for hydroxide precipitation.
4. Transfer to Settling Tank, adding polymer.
5. After 1-3 hr settling, decant treated effluent.
6. Remove dilute sludge.

Sequence C – No CN^- or Cr^{6+}
1. Transfer either acid or alkali waste to Batch Treatment Tank.
2. Start mixer.
3. Transfer either alkali or acid waste to Treatment Tank to adjust pH to 8.5 to 9.5. Final trim adjust with caustic and sulfuric.
4. Transfer to Settling Tank, adding polymer.
5. After 1-3 hr settling, decant treated effluent.
6. Remove dilute sludge.

Fig. 4 Batch treatment units for common metal removal by hydroxide precipitation and sedimentation for concentrated wastes by Joe Shockcor solids content, depending upon what is being treated. As an average, the resulting sludge solids concentration from a batch treatment process is in the range of 5 to 10 percent (50,000 to 100,000 mg/*L*) solids. Suspended solids in rinse waters are usually around 100 to 200 mg/*L*. After these suspended solids have been removed from the rinse waters, they produce a sludge in the range of 0.5 to 1.0 percent solids. Therefore, it is much easier for an operator to deal with a small volume of 5 to 10 percent solids than a large volume of 0.5 to 1.0 percent solids if the batch process was not used and the wastes were bled into the rinse waters for treatment.

Continuous flow treatment facilities are used to treat relatively high flows of metal wastes (Figure 5). In the continuous flow treatment process several tanks or treatment units are used. If the wastewater flow rate and/or metal concentrations fluctuate, a flow equalization tank will be needed before the treatment processes. The sequences of processes would then consist of a rapid chemical mixing and precipitation process, flocculation and final clarification. Metal precipitates are removed from the clarifier as sludge and are then usually dewatered and containerized for disposal.

Costs and complexity of metal waste treatment facilities can be reduced by a source control program. Plating processes can be changed or altered to reduce the volumes of process wastewaters and to control amounts of wastes that must be treated. In the metal plating industry, volumes of wastewater to be treated can be reduced by countercurrent rinsing processes (Figure 6). Rinse flows can be controlled and reduced by using conductivity meters, spray rinses, and proper racking to reduce drag out. Some companies install static rinse tanks which have no running flow. These tanks are used for rinsing gross contamination. The temperature of static rinse tanks is frequently kept at an elevated level to encourage evaporation. The contents of these tanks are sometimes disposed of by transferring the water to plating tanks as make-up water. Good housekeeping practices, prevention of accidental spills, and control of leaks and drag out are procedures used to reduce the amount of waste that must be treated. Table 5 summarizes procedures for reducing waste treatment costs.



CONTINUOUS TREATMENT PROCESS FOR RINSE WATER

1. Equalization of flows and concentrations of influent in first step.
2. Pump transfers equalized raw waste to subsequent treatment at uniform rate.
3. Adjust pH by adding alkali or acid to precipitate heavy metals using rapid mixing for 5 to 7 minutes.
4. During gravity transfer to Floc Tank, polymer is added to improve flocculation.
5. Slow mixing in Floc Tank to promote growth of large settleable floc for 5 to 7 minutes.
6. Gravity settling of suspended solids in Clarifier during 1 to 3 hr retention period. (Dilute sludge is periodically removed from bottom of tank).
7. Final pH adjustment (if required) by controlled addition of acid and/or alkali for 5 to 7 minutes, prior to discharge of treated effluent.

Fig. 5 Continuous treatment units for common metal removal by hydroxide precipitation and sedimentation for rinse water by Joe Shockcor.

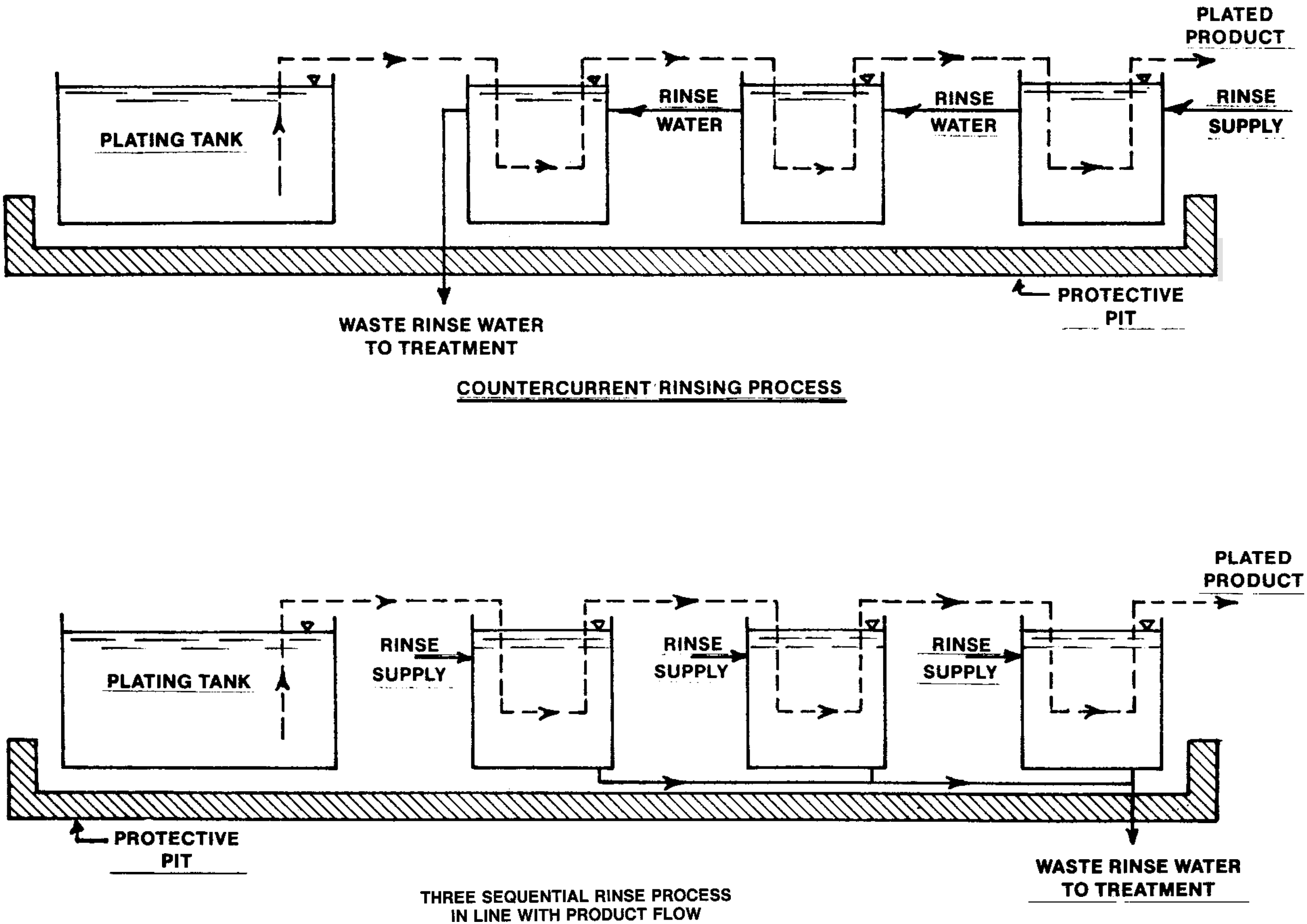


Fig. 6   Countercurrent rinsing and three sequential rinse process line with product flow

TABLE 5 PROCEDURES FOR REDUCING WASTE TREATMENT COSTS[a]

1. Reduction of flow volumes
2. Segregation of different wastestreams
3. Recycling of water
4. Changing production processes to decrease generation of wastes
5. Effective rinsing techniques
6. Elimination of batch dumps of process wastes
7. Controlling wastes at source
8. Good housekeeping and control of accidental spills
9. Good solvent management plan

[a] *Provided by Patrick Kwok*

5.1 NEUTRALIZATION

Neutralization of wastewaters is required for highly acidic (low pH) or highly basic (high pH) waters before these waters are discharged to a sewer or the environment. Highly acidic or basic waters may originate at cleaning, manufacturing or waste treatment processes.

Wastewaters with high pH levels are neutralized by the addition of acids such as sulfuric acid (H_2SO_4) and hydrochloric acid (HCl). Carbon dioxide (CO_2) and sulfur dioxide (SO_2) can be applied in the gaseous form to lower the pH of liquids. Some industries use flue gases (high in carbon dioxide or sulfuric acid fumes) to lower the pH of waters when the gas is available and this is an economical solution.

Low pH wastewaters are neutralized by calcium oxide or lime (CaO), magnesium oxide (MgO), calcium hydroxide ($Ca(OH)_2$), a hydrated form of lime), magnesium hydroxide ($Mg(OH)_2$), sodium hydroxide (NaOH, caustic soda) or soda ash (Na_2CO_3).

Neutralization may be accomplished by either batch or continuous processes, depending on the amount of wastewater to be treated. In many industrial situations, acidic wastewaters may be generated from one source and basic wastewater produced by another source. Under these conditions the wastewaters are frequently stored in separate containers and mixed together at appropriate times to neutralize each other (provided the wastes are compatible). Both acidic and basic chemicals are needed to treat the wastewater if the flow from one source becomes excessive or is drastically reduced. When precise control of pH is essential, weak acids and bases may be used to adjust or "fine tune" the pH.

When mixed with water, acids and bases produce solutions made up wholly or partially of ions. Solutes that exist almost completely as ions in solution are termed strong *ELECTROLYTES*.[9] Those that react incompletely with the water so that both neutral molecules and ions formed from them are present are called weak electrolytes. The degree of ionization may be determined by measuring the electrical conductivity.

Chemical equilibrium exists when the reactants are forming as rapidly as the products, so that the composition of the mixture remains constant and does not change with time. At any one temperature, the equilibrium constant K has a fixed numerical value characteristic of the particular chemical equation. However, in industrial wastewater treatment, the stream being treated is made up of water plus many contaminants which provide competing equilibria. Furthermore, reaction rate, temperature and mixing conditions vary as does the waste loading. Therefore, the pure chemistry involved is not directly used by the operator in day-to-day activities.

As the graphic representation of pH versus added titrant, the titration curve provides a means to characterize the substance to be pH adjusted or neutralized and the amount of adjusting agent required. Titration curves for process optimization commonly are based on chemicals likely to be used in the process in a manner designed to indicate process variables such as contact time, temperature, nature and amount of solids, and handling characteristics in relation to the system pH.

The following titration curves illustrate terminology, characteristics, and changes with respect to a few commonly encountered adjustments. Figure 7 illustrates titration of a strong base (NaOH) with a strong acid (H_2SO_4). Initial additions of the titrant have a minor effect upon pH because NaOH plus product Na_2SO_4 has little buffer capacity. The curve is almost flat for each addition of titrant prior to the inflection. The inflection indicates an approach to the equivalence point. The equivalence point is graphically located half way along the straight line on the graph between the upper and lower inflections. Strong acid and base equivalence points commonly occur near pH 7.0. The product of volume and concentration of added titrant at the equivalence point is an estimate of sample basicity.

Figure 8 shows the effect of adding 4 percent or 1 N NaOH to a sample of industrial wastewater made up primarily of contact cooling water, machining rinse waters and miscellaneous combined process discharges. From the curve, the operator can readily determine the amount of caustic needed to adjust the pH to whatever value best suits the process used.

Figure 8 also shows the effect of adding 4.9 percent or 1 N H_2SO_4 to the same sample of industrial wastewater. The curves in Figures 7 and 8 differ significantly but provide the same basic information. Five gallons of 4 percent NaOH in 1,000 gallons of wastewater will result in a pH of 11.65, and 5 gallons of 4.9 percent H_2SO_4 in the same 1,000 gallons of wastewater will result in a pH of 3.0.

Similar curves can and should be developed by the operator as a means of understanding any waste that must be neutralized. They are of further use in monitoring processes and calibrating automatic instrumentation. The steepness of the curves near the equivalence points is a good indication of the difficulty of pH control, especially when mixing times are short, tankage is too small, titrant concentrations are too high and feed equipment including pumps as well as instrumentation are marginally sized.

Operators must be very careful whenever highly acidic and basic solutions are mixed because of the potential for splattering, the generation of heat and the production of toxic gases. Highly acidic or basic solutions are very harmful to your skin, can cause loss of eyesight, and the fumes are extremely irritating to your lungs and the mucous membranes in your body.

[9] *Electrolyte (ELECT-tro-LIGHT). A substance which dissociates (separates) into two or more ions when it is dissolved in water.*

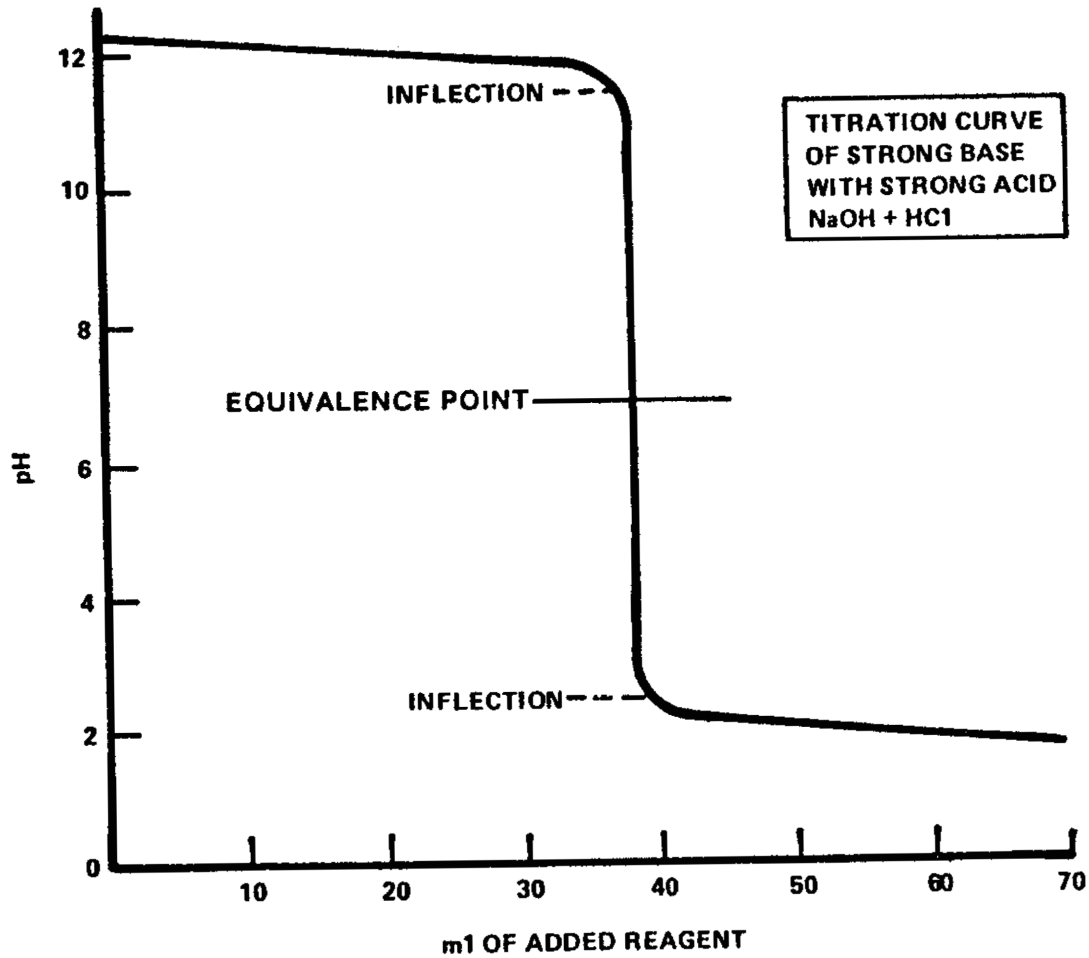


Fig. 7 Titration curve

(From *PHYSICAL CHEMICAL TREATMENT TECHNOLOGY*, U.S. Environmental Protection Agency, Washington, D.C., 1972)

PH OF 1,000,000 GALLONS OF WATER WITH
A STARTING pH OF 8.0

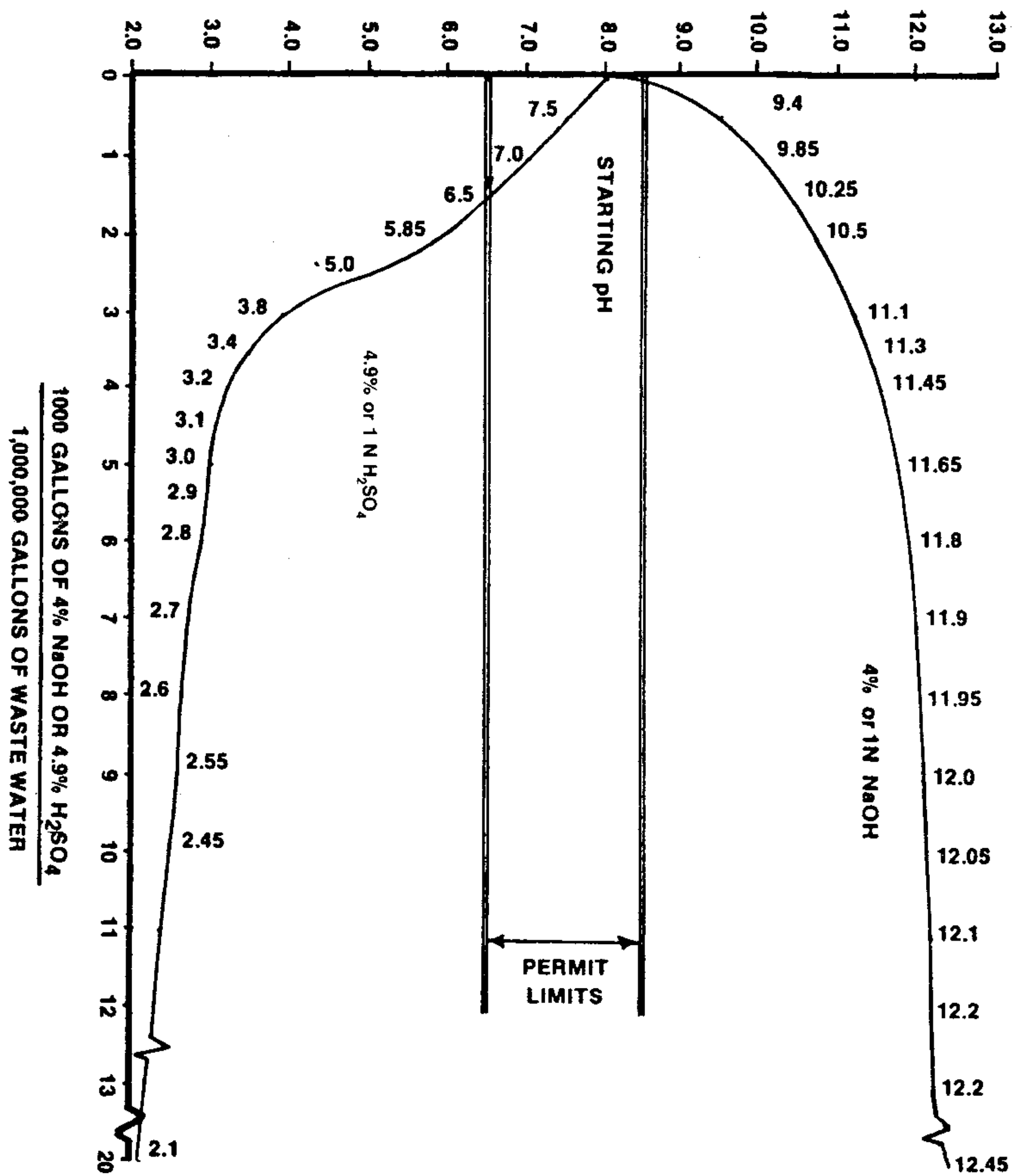


Fig. 8 Example titration of an industrial wastewater

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 85.

5.0A What type of wastewater flow is treated by the batch process?

5.1A How are wastewaters with high pH levels neutralized?

5.1B How are wastewaters with low pH levels neutralized?

5.1C What safety precautions must an operator take when working with highly acid and highly basic solutions?

WARNING: NEVER STORE ACIDS AND BASES TOGETHER.

5.2 COMMON METALS[10] REMOVAL

Common metals can be removed from wastestreams by either hydroxide precipitation or sulfide precipitation. As shown on Figure 2, hexavalent chromium and cyanide wastes must be treated before attempting to remove the other common metals. Hexavalent chromium is not removed by hydroxide precipitation and cyanide will interfere with the precipitation processes' ability to remove the dissolved metals.

The first step in hydroxide precipitation of common metals is to determine the optimum pH for precipitating each type of metal you wish to remove. Figure 9 contains "idealized"[11] curves of metal concentrations versus pH for the common metals. Assume your wastestream contains trivalent chromium and zinc. Looking at the idealized curves in Figure 9, you will see that the optimum pH for trivalent chromium removal would be around 7.5 and the trivalent chromium concentration remaining in the treated water would be about 0.2 mg/*L*. Optimum pH for zinc removal would be around 10.5 and the remaining zinc concentration would be 0.2 mg/*L*.

When treating wastestreams containing two or more common metals with significantly different optimum pH levels, a two-stage operation is commonly used. First, the wastewaters are adjusted to the lowest desired pH level (7.5 for trivalent chromium) and the common metals are allowed to form precipitates and settle out by precipitation. Then the remaining wastewater is transferred to another tank and the pH is readjusted (to 10.5 for zinc removal) and the remaining common metals are allowed to form precipitates and to settle out. Usually the pH is increased to optimum levels by the addition of a lime slurry or sodium hydroxide (caustic soda).

From a practical standpoint, in many situations it may be necessary and possible to remove the common metals present in a wastestream at a single pH level due to the "mix" of chemicals in the metal wastes being treated. The optimum pH level can be determined by a series of jar tests or bench tests on the wastestream. The pH is changed in increments of 0.5 pH units in each jar. The jar that requires the minimum pH adjustment and meets pretreatment standards (Table 2) indicates the optimum pH.

When a lime slurry or caustic soda is added to a wastestream containing common metals, these chemicals need to be mixed with the wastestream by some type of mixing device. Since metal hydroxide precipitates are often a colloidal type of suspended solid, a coagulating chemical or polymer is added to encourage coagulation, flocculation and sedimentation.[12] Final pH adjustment may be required after the precipitated solids have been removed to reduce the high pH created by the basic treatment chemicals. Hydroxide precipitation produces large quantities of sludge containing toxic metals which must be collected, treated, dewatered and disposed of. Filter presses are commonly used to dewater metal sludges. Metal hydroxide sludges are considered hazardous wastes and must be handled accordingly.

---

[10] *Common Metals. The metals usually treated in electroplating and metal finishing wastestreams are cadmium, chromium, copper, lead, nickel and zinc.*

[11] *NOTE: Each of the curves in Figure 9 was drawn assuming pure compounds and deionized water. There were no "common ion" effects or chelates considered when the data were developed for plotting the curves.*

[12] *See Section 28.4, "Coagulation and Precipitation," pages 612-634 in OPERATION OF WASTEWATER TREATMENT PLANTS, Volume III.*

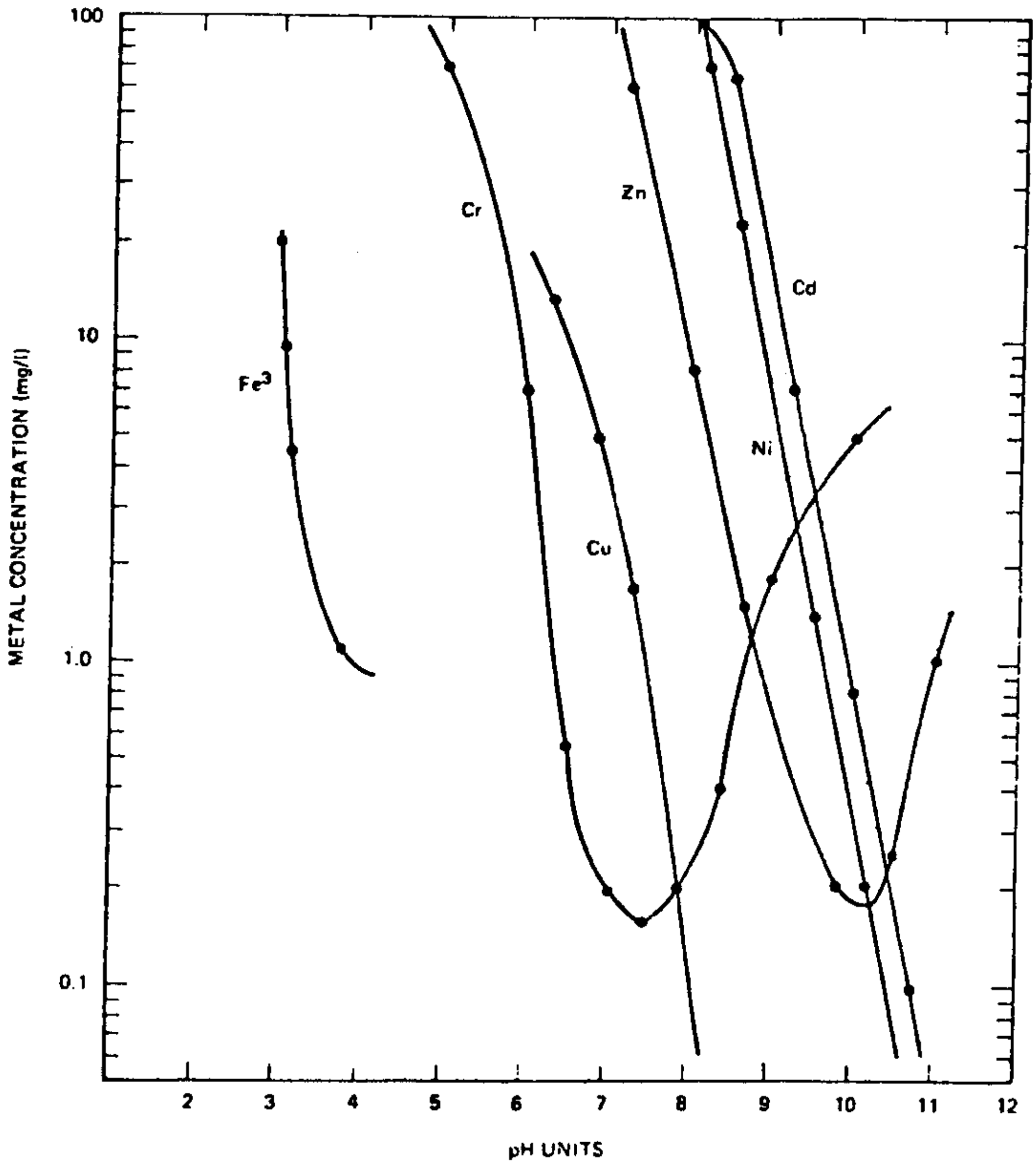


Fig. 9 Precipitation of metal salts versus pH
(From *METAL FINISHING WASTES*, EPA Technology/Transfer, U.S. Environmental Protection Agency, Washington, D.C.)

To further reduce the suspended metal hydroxide precipitates in the effluent from a clarifier, filtration procedures such as microscreening, ultrafiltration and sand filtration may be used. Figure 10 shows a suspended solids removal process using a lemella settler (Figure 11) and a sand filter (Figure 12).

Limitations of the hydroxide precipitation process include:

1. The presence of complexing ions (chelating agents) such as EDTA, phosphate, and ammonia, commonly found in plating formulations may adversely affect metal removal efficiencies.

Due to the extremely low solubilities of most metal sulfide compounds, very high metal removal efficiencies can be achieved. The sulfide precipitation process can remove hexavalent chromium with preliminary reduction of hexavalent chromium to trivalent chromium. Also most complexed metals can be precipitated by the sulfide process.

Unfortunately the sulfide precipitation process has several severe limitations. If the pH drops below 8, toxic hydrogen sulfide gas can be produced and released to the atmosphere. However, if the source of sulfide is ferrous sulfide, the problem of hydrogen sulfide gas production can be minimized.

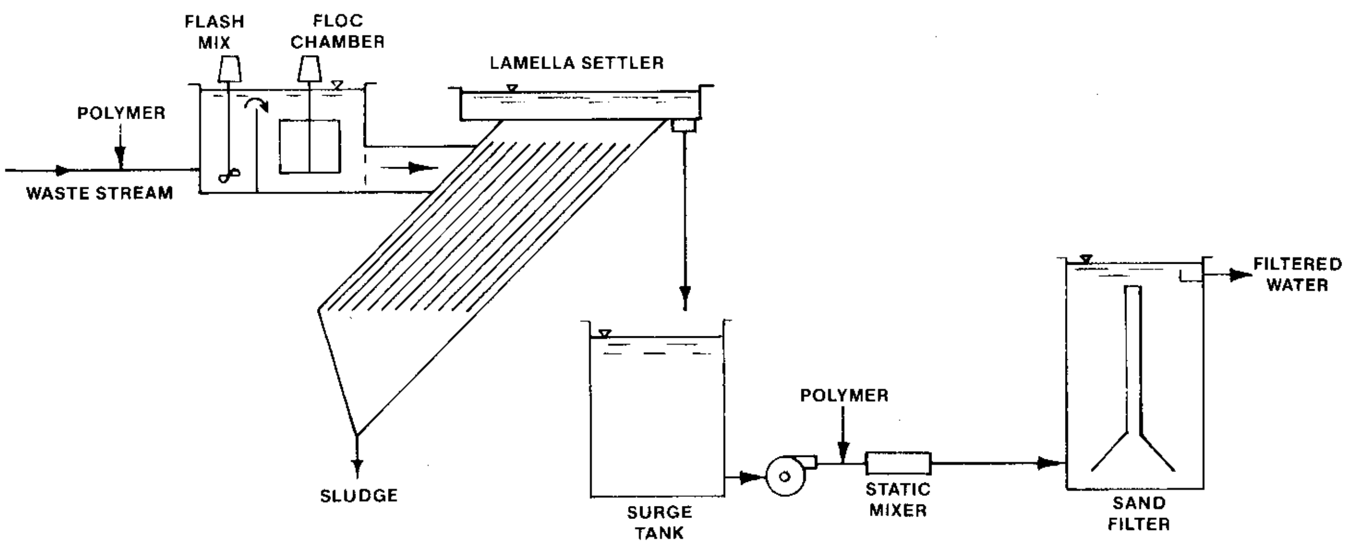


Fig. 10 Suspended solids removal using lamella settler and sand filter.

2. Hydroxide precipitates tend to resolubilize (go back into solution) if the solution pH is either increased or decreased from the minimum solubility point of the metal, thereby reducing the removal efficiency (pH must be carefully controlled); and

3. Different metals have different theoretical minimum solubilities at different pHs.

An effective alternative method for removing many heavy metal compounds is the addition of hydrogen sulfide or soluble sulfide salts such as sodium sulfide to cause precipitation of the metals as sulfide compounds. This procedure is capable of achieving greater heavy metal removal than hydroxide precipitation because most metal sulfides are less soluble than metal hydroxides at high pH levels. The solubilities of metal sulfide compounds depend on the pH, just like the metal hydroxide compounds; however heavy metal sulfides are insoluble over a much wider pH range.

SULFIDE IS TOXIC. THE PROCESS EFFLUENT MUST NOT CONTAIN ANY SULFIDE. The use of sulfide for heavy metal precipitation may require add-on effluent oxidation steps involving the addition of chlorine or peroxide to oxidize any residual sulfide. The costs of sulfide precipitating chemicals are high in comparison with hydroxide precipitation chemicals. Another major concern when using the sulfide precipitation process is the disposal of toxic metal sulfide sludges. The cost of placing the sludges in suitable containers, transporting them to an acceptable disposal site and the long-term risks associated with the ultimate disposal of toxic waste must be weighed against the high quality effluent achieved by sulfide precipitation. On the positive side, however, heavy metal sulfide sludges are much less soluble over a broad pH range than hydroxide precipitated sludges. When disposed of in a landfill, the sulfide sludges are less likely to leach out and contaminate groundwater supplies or adjacent soil than hydroxide sludges. Table 6 is a comparison of the hydroxide and sulfide metal precipitation processes.

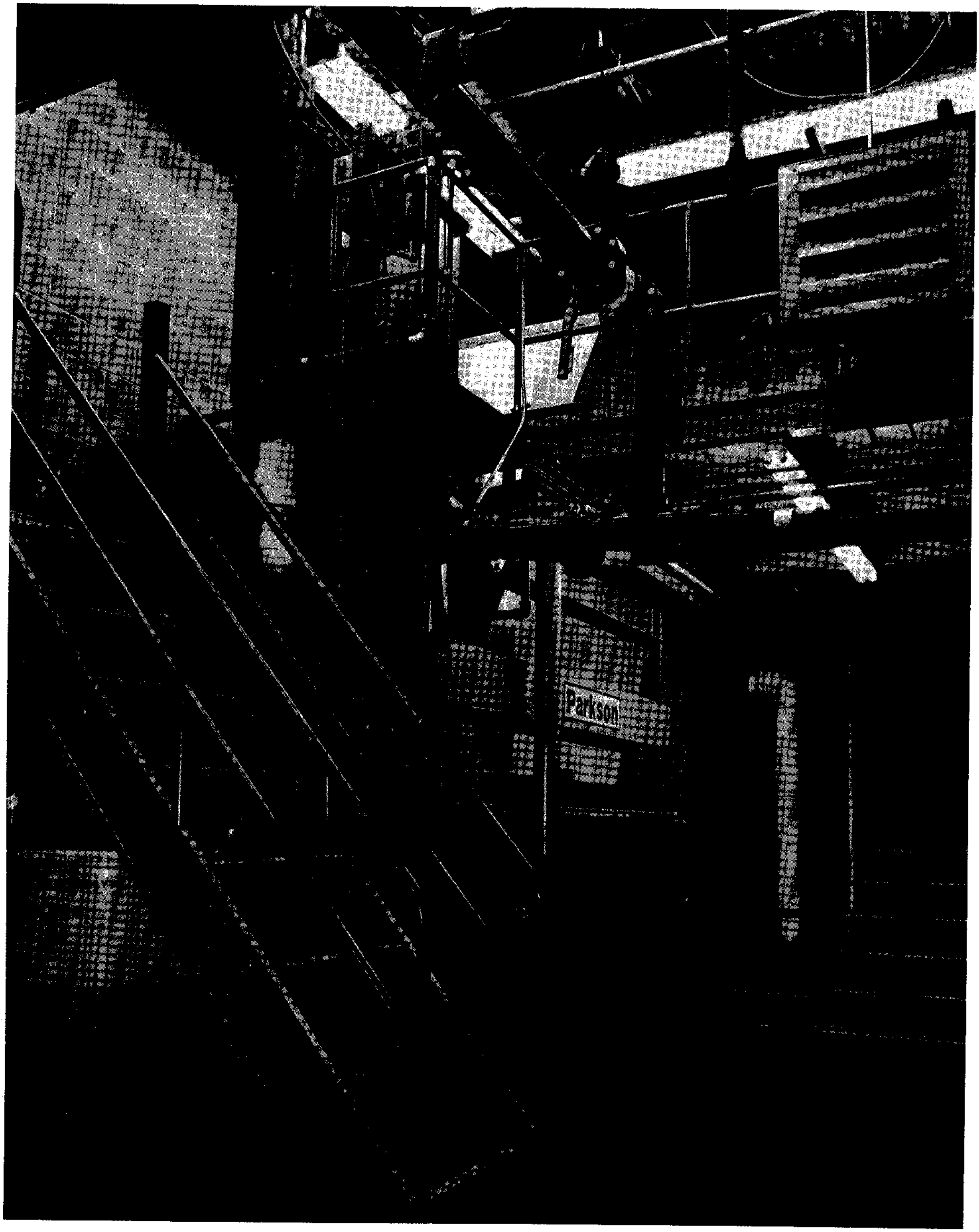


Fig. 11 Lamella settler (behind Parkson sign)
(Permission of New England Plating Co., Inc.)

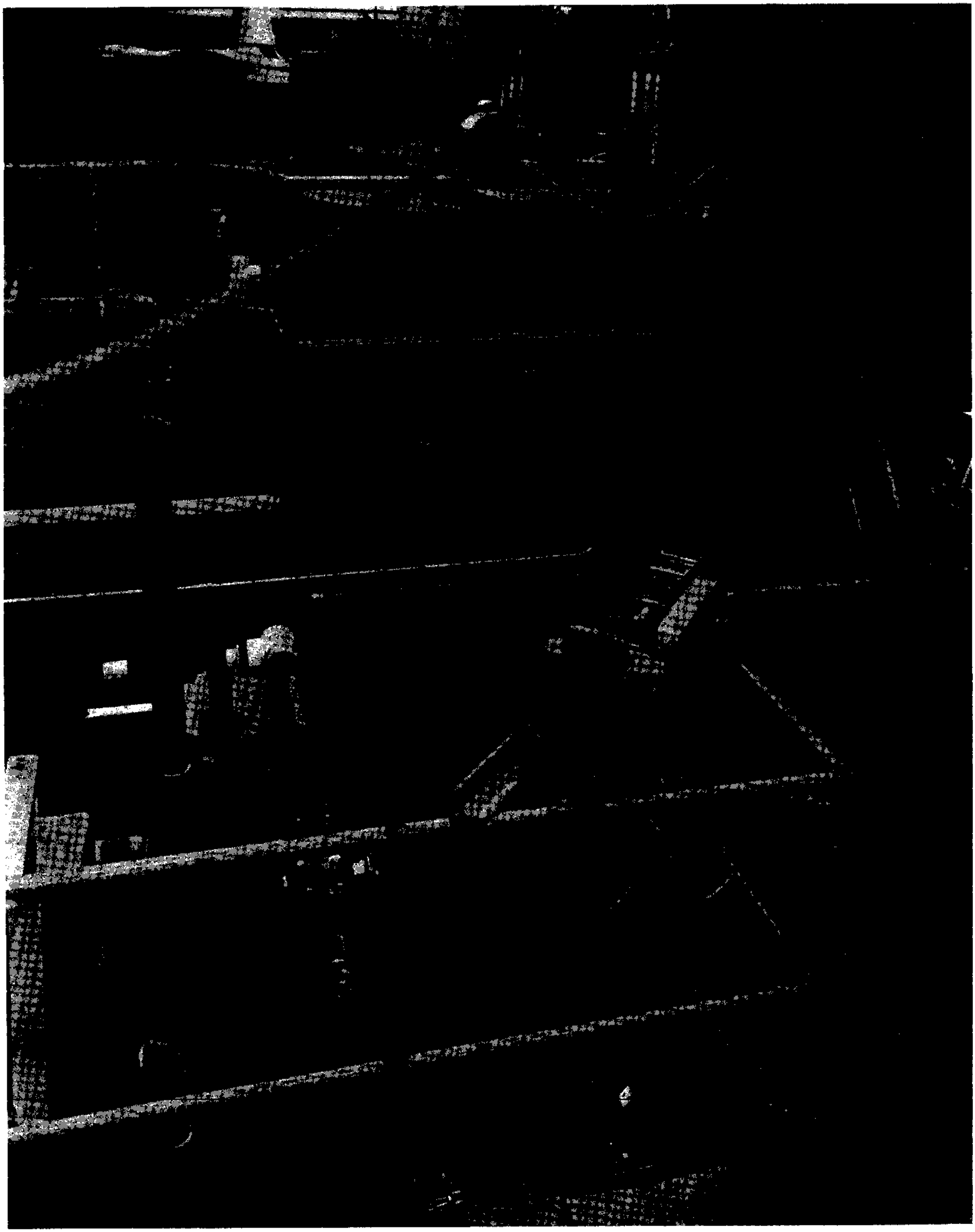


Fig. 12 Sand filter
(Permission of New England Plating Co., Inc.)

5.3 COMPLEX METALS REMOVAL

Complexed metals are metals with a tendency to remain in solution rather than form precipitates and settle out. These metals have reacted with or are tied up with chemical complexing agents such as ammonia or citrates, tartrates, quadrol and EDTA. Complexed metal wastes are found in wastestreams from electroless plating, immersion plating, etching and printed circuit board manufacturing. Cadmium, copper, lead, nickel and zinc are the most common complexed metals found in wastestreams. These complexed metals will not be effectively precipitated out by the hydroxide precipitation process. Therefore, complexed metal wastestreams must be kept segregated from other metal wastestreams and treated separately. Complexed metal wastestreams may be treated by (1) high pH precipitation, (2) chemical reduction, (3) sulfide precipitation, or several other processes (Table 7).

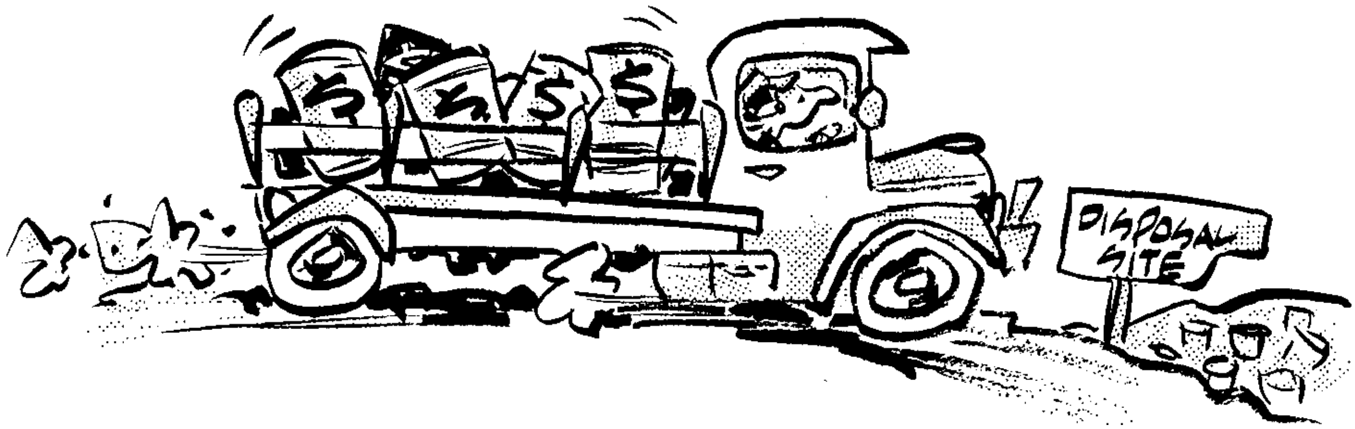


TABLE 6 COMPARISON OF HYDROXIDE AND SULFIDE PRECIPITATION PROCESSES

ITEM	HYDROXIDE	SULFIDE
1. Effluent quality	Satisfactory metal concentrations	Very low metal concentrations. Toxic sulfide may be present
2. Treatment removal efficiency	Satisfactory	Very high
3. pH range for precipitation	Narrow	Wider
4. Hexavalent chromium	Not removed	Effective removal without reduction to trivalent state
5. Complexed metals	Will not precipitate	Will precipitate
6. Hydrogen sulfide gas (toxic)	Not a problem	Generated at pH 8 or lower
7. Cost of precipitating chemicals	Low	High
8. Sludge volume	Large quantity	Smaller quantity
9. Sludge disposal	Dewatered, containerized and disposed of in approved landfills.	Dewatered, containerized and disposed of in approved landfills.
10. Frequency of use	Common	Rare

TABLE 7 pH RANGES FOR VARIOUS COMPLEXED METAL WASTE TREATMENT PROCESSES

PROCESS	pH RANGE[a]
Ammonia Stripping	11-12
Ferrous Sulfide	8-9
Ferrous Sulfate	11-12
(with formaldehyde)	3
Sodium Borohydride	5-7
Ion Exchange	7
EDTA Precipitation	2-3
Starch Xanthate	b
Ferric Chloride & Calcium Chloride	11.6-12.5[c]

[a] *pH ranges depend on many variables including complexing and batch or continuous treatment processes*

[b] *The removal of hexavalent chromium is achieved by lowering the pH to below 3 and then raising it to above 7.*

[c] *Treatment of solutions of complexed copper.*

High-pH precipitation is a process requiring the addition of chemicals which drastically increase the pH of the wastestream to approximately 12. This very high pH produces a shift in the complex dissociation equilibrium, breaks the complexing bond, and results in the production of free metal ions. These metal ions can then be precipitated by available hydroxide ions and removed by sedimentation.

Complexed metals can also be removed from wastestreams by the chemical reduction process. This treatment process lowers the pH of the wastestream to break up the various metal complexes. The pH level depends on the complexed metals. Some require a pH in the 4 to 6 range while others require a pH of 2.0 to 2.5 or lower. After the pH has been lowered sufficiently, a reducing agent (sulfur dioxide, SO_2; sodium bisulfite, $NaHSO_3$; sodium metabisulfite, $Na_2S_2O_5$; or ferrous sulfate $FeSO_4$) is added to reduce the metals to an oxidation state which permits the precipitation of metals. Basic chemicals are then added to increase the pH to a level (Figure 9) where metallic hydroxide precipitation will occur. The precipitates are removed from the wastestream by sedimentation. Polymers or coagulating agents may be added to enhance sedimentation. Bench tests are run on complexed metal wastestreams to determine optimum reducing agent, doses, pH, and polymer.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 86.

5.2A Why are two different pH levels sometimes necessary for effective hydroxide precipitation of metals?

5.2B List the major limitations of the sulfide precipitation process.

5.3A Why are complexed metals difficult to treat?

5.3B How can complexed metal wastewaters be treated?

5.4 REDUCTION OF HEXAVALENT CHROMIUM

Hexavalent chromium-bearing wastewaters are produced in chromium electroplating, chromium conversion coatings, etching with chromic acid, and in metal finishing operations carried out on chromium as a basis material. Many common plating solutions contain hexavalent chromium concentrations between 10 to 500 mg/L; however, concentrations of over 100,000 mg/L can be encountered. Hexavalent chromium may be present in the form of chromic acid, chromate, or dichromate in an acid solution. To remove chromium from wastestreams, highly toxic hexavalent chromium (Cr^{6+}) must be reduced to trivalent chromium (Cr^{3+}) which can then be removed from the wastestream by hydroxide precipitation. Strong reducing agents used in this chemical treatment process include sulfur dioxide, sodium bisulfite, sodium metabisulfite, sodium hydrosulfite and ferrous sulfate. Gaseous sulfur dioxide is the most economic reducing agent used to reduce hexavalent chromium to trivalent chromium for large flow applications. This reaction takes place at a very low pH (around 2.0 for complete reduction). The reduction rate decreases with increasing pH and is extremely slow for pH levels above 5.

Chromium wastes are commonly treated by a two-step batch process. The first step is to reduce the highly toxic hexavalent chromium to the less toxic trivalent form. The trivalent form is removed by hydroxide precipitation in the second step.

STEP 1

Highly toxic hexavalent chromium (Cr^{6+}) is reduced to trivalent chromium (Cr^{3+}). Sulfuric acid is added to lower the pH to 2.0 or lower. In an acid solution the following reduction reactions will occur, depending on the reducing agent.

Using sulfur dioxide, Cr^{6+} to Cr^{3+}

SO_2	$+ H_2O$	$\rightarrow H_2SO_3$
Sulfur Dioxide	Water	Sulfurous Acid

$3H_2SO_3$	$+ 2H_2CrO_4$	$\rightarrow Cr_2(SO_4)_3$	$+ 5H_2O$
Sulfurous Acid	Chromic Acid	Chromic Sulfate	Water

Using bisulfites, Cr^{6+} to Cr^{3+}

$2H_2CrO_4$	$+ 3NaHSO_3$	$+ 3H_2SO_4$	$\rightarrow Cr_2(SO_4)_3$	$+ 3NaHSO_4$	$+ 5H_2O$
Chromic Acid	Sodium Bisulfite	Sulfuric Acid	Chromic Sulfate	Sodium Bisulfate	Water

When using sodium bisulfite, the pH is dropped to 2.0 or lower to hasten the reduction of hexavalent chromium by the bisulfite.

Some shops use sodium hydrosulfite for manual additions of chemicals where it is not practical to drop the pH to 2. Hydrosulfite works well at a pH of around 4 which is a pH range where hexavalent chromium reduction by bisulfite is way too slow. Hydrosulfite is not practical to use on continuous processes because it is more expensive than bisulfite and is oxidized by air once it is in solution and allowed to stand. Sodium hydrosulfite is very convenient to use when chemicals are added manually.

Using ferrous sulfate, Cr^{6+} to Cr^{3+}

$2H_2CrO_4$	$+ 6FeSO_4$	$+ 6H_2SO_4$	$\rightarrow 3Fe_2(SO_4)_3$	$+ Cr_2(SO_4)_3$	$+ 8H_2O$
Chromic Acid	Ferrous Sulfate	Sulfuric Acid	Ferric Sulfate	Chromic Sulfate	Water

STEP 2

The trivalent chromium (Cr^{3+}) compounds formed in Step 1 are removed by alkaline precipitation at a pH between 8.0 and 8.5. Caustic soda (NaOH) is the preferred base, but hydrated lime ($Ca(OH)_2$) is also used.

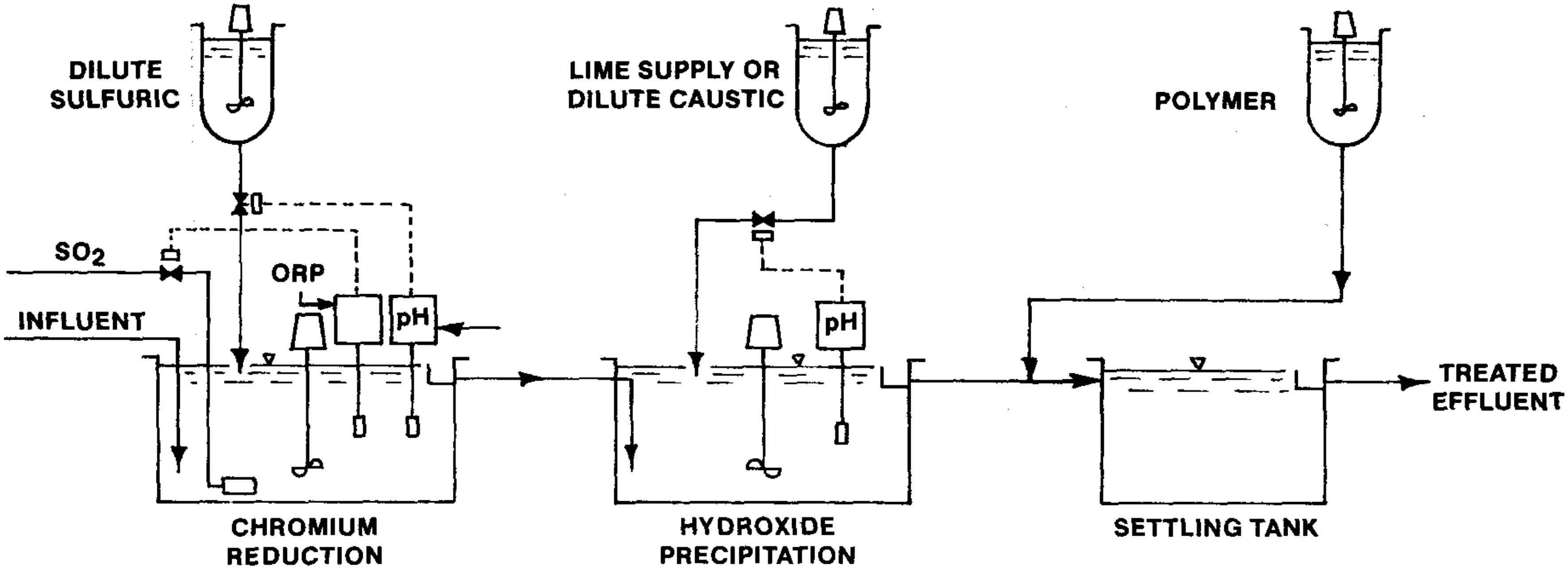
Using caustic soda to precipitate chromic hydroxide

$6NaOH$	$+ Cr_2(SO_4)_3$	$\rightarrow 2Cr(OH)_3\downarrow$	$+ 3Na_2SO_4$
Sodium Hydroxide	Chromic Sulfate	Chromic Hydroxide	Sodium Sulfate

Using lime to precipitate chromic hydroxide.

$3Ca(OH)_2$	$+ Cr_2(SO_4)_3$	$\rightarrow 2Cr(OH)_3\downarrow$	$+ 3CaSO_4$
Lime	Chromic Sulfate	Chromic Hydroxide	Calcium Sulfate

Reduction of hexavalent chromium requires an equalization tank if the flows fluctuate considerably; two reaction tanks can be connected in series (Figure 13). Sulfuric acid is added to maintain a pH below 2. Gaseous sulfur dioxide or sodium bisulfite is added to each reaction tank to produce an ORP (oxidation-reduction potential) around +250 mV (millivolts) or less. Use a color comparator or hand-held colorimeter kit to determine if all of the hexavalent chromium has been converted to the trivalent form. If not, increase the sulfur dioxide dose. Observe and record the ORP value at which all hexavalent chromium is converted to the trivalent form. Set the sulfonator (SO_2) or chemical feeder of sulfur dioxide to maintain the desired ORP level. Regardless of whether sulfur dioxide or sulfite is used, the tanks should be exhausted to the atmosphere to prevent people being exposed to sulfur dioxide gas (can be produced from bisulfite).



CONTINUOUS TREATMENT PROCESS FOR CHROMIUM BEARING RINSE WATER

1. Equalization of flows and concentrations in influent is not shown.
2. Hexavalent Chromium Reduction by adding acid for pH = 2.0 or lower and SO_2 (using a diffuser) for ORP = +250 mV. or lower at retention time of 15 to 30 minutes. Tank exhaust is not shown.
3. Precipitate hydroxide by adding alkali to maintain a pH of 8.0 to 8.5 with retention time of 10 to 20 minutes.
4. During gravity transfer to Settling Tank, polymer is added to improve flocculation.
5. Gravity settling of suspended solids during 1 to 3 hr retention period prior to discharge of treated effluent.

Fig. 13 Reduction of hexavalent chromium and hydroxide precipitation for rinse waters by Joe Shockcor.

Each reaction tank has a propeller mixer and the detention time in each tank is from 15 to 45 minutes. Reaction times vary for different wastes, reducing agents, temperatures, pH, and chromium concentrations.

After the hexavalent chromium has been reduced to trivalent chromium, the wastestream can be combined with other wastestreams containing common metals. These combined wastestreams can be treated by the hydroxide precipitation process to remove chromium and the other common metals.

NOTE:

1. pH and ORP levels given in this manual are approximate. Values cited in references may vary slightly. Optimum levels for your metal waste treatment facilities may be slightly different due to the "mix" of wastes being treated.
2. See Appendix II, *OXIDATION-REDUCTION POTENTIAL (ORP)*, for a detailed definition and discussion of the meaning, application and control of ORP.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 86.

5.4A List the possible forms of hexavalent chromium in an acid solution.

5.4B Why does hexavalent chromium have to be converted to trivalent chromium?

5.4C How can hexavalent chromium be reduced to trivalent chromium?

5.4D List what happens in a two-step process to reduce hexavalent chromium to the trivalent state and remove the chromium by hydroxide precipitation.

5.5 CYANIDE DESTRUCTION BY OXIDATION

5.50 SAFETY

The cyanide ion (CN^-) is extremely toxic and must be removed from metal wastes before discharge to sewers or the environment. Cyanide toxicity (poisoning) in humans is caused by an irreversible reaction with the iron in hemoglobin that results in loss of the blood's ability to transport oxygen. If there is an equipment failure during the treatment of wastes containing cyanide, extremely toxic gases could be released. Therefore, all tanks or pits used for cyanide destruction must be properly located and ventilated so that any gases produced will never enter an area occupied by people.

5.51 CYANIDE SOURCES AND TREATMENT

Cyanide compounds are used in copper, zinc, cadmium, silver and gold plating solutions, in the immersion stripping of various electrodeposits and in some activating solutions. Flowing rinse waters after these production operations can become contaminated with cyanide. Cyanide may be present as the simple alkali cyanides of sodium or potassium, or complexed with heavy metals such as zinc, cadmium, silver, gold, copper, nickel, or iron. For waste treatment control purposes, the two major groupings of cyanide compounds are segregated into those that can be oxidized by chlorination (also know as cyanides amenable to chlorination) and those that resist oxidation by chlorination (also known as refractory cyanides). Both types are considered to be toxic and must be removed or have their concentrations below toxic levels prior to discharge of the rinse waters.

Those compounds that are readily oxidized by chlorination are sodium, potassium, cadmium, and zinc cyanides. The copper cyanide complex is also considered amenable to chlorination, although longer reaction times are required (also for silver and gold cyanide complexes). The nickel cyanide complex is more resistant to chlorination than the copper complex, yet can be considered as amenable to chlorination under extreme oxidizing conditions. The iron complexes (most commonly the sodium ferrocyanide salt) *are not considered* to be oxidizable by chlorination.

Pretreatment permits prescribe maximum limits for cyanides oxidizable by chlorination and for total cyanide (the sum of those that can be chlorinated and those that cannot). The average limits for amenable cyanides is 0.05 mg/L and for total cyanide is 0.28 mg/L. The maximum concentrations for amenable and total cyanide are 0.65 mg/L and 1.2 mg/L, respectively.

5.52 CHEMISTRY INVOLVED

The waste treatment systems are designed to oxidize cyanide compounds with sodium hypochlorite (NaOCl). The hypoclorite is purchased at a 14 to 15 percent by weight concentration. This solution has been produced by the reaction between chlorine and sodium hydroxide according to the reaction:

Cl_2	+ 2NaOH	= NaOCl	+ NaCl	+ H_2O
Chlorine	Sodium *Hydroxide*	Sodium *Hypochlorite*	Sodium *Chloride*	Water

Sodium cyanate (NaCNO) is formed by the reaction of hypochlorite and cyanide. This reaction is actually a simplification of the chlorination of cyanide. Intermediate reactions that are very rapid take place. Chlorine is freed from the hypochlorite by disassociation (a reversal of the formation of hypochlorite shown above). The chlorine actually reacts with the cyanide to form cyanogen chloride according to:

NaCN	+ Cl_2	= CNCl	+ NaCl
Sodium Cyanide	Chlorine	Cyanogen Chloride	Sodium Chloride

The cyanogen chloride then reacts with the sodium hydroxide to form the cyanate according to:

CNCl	+ 2NaOH	= NaCNO	+ NaCl	+ H_2O
Cyanogen Chloride	Sodium Hydroxide	Sodium Cyanate	Sodium Chloride	Water

The cyanogen chloride is a gas that has limited solubility at neutral or low pH values. At pH *values of 10 or higher, the reaction* producing the cyanate is quite rapid for cyanides that are not too tightly complexed with heavy metals. At lower pH values, not only is the reaction too slow, but there is a good probability of liberating the cyanogen chloride gas to the atmosphere. This gas is a lacrymator (produces tears) and its liberation is readily apparent to those nearby.

Oxidation of cyanate is possible by chlorination where the reaction is:

2NaCNO	+ 3NaOCl	+ H_2O	= $2CO_2$	+ N_2	+ 3NaCl	+ 2NaOH
Sodium Cyanate	Sodium Hypochlorite	Water	Carbon Dioxide	Nitrogen Gas	Sodium Chloride	Sodium Hydroxide

The carbon dioxide formed will react with alkali to produce carbonate. Any excess is liberated into the atmosphere. The nitrogen has a limited solubility and also escapes into the air. This second stage oxidation reaction is faster at pH values slightly lower than the initial reaction of cyanide to cyanate. If the pH drops too low (below 7.0) then another reaction takes place with cyanate. This reaction will hydrolyze with water to produce ammonia compounds.

From this discussion it is important to realize that the pH is a critical factor. The rate of reaction as well as the end products depend upon maintaining proper pH values. Also, the escape of cyanogen chloride is inhibited by high pH values. Another impact of pH is shown by the oxidizing potential required to chlorinate cyanide to cyanate. At a pH of 10.5 to 11.0, the oxidizing potential must be at +550 mV for the reaction to go to completion. If the pH drops to 9.5, a potential of +650 mV must be maintained to get the same results. If the pH drops much lower, the liberation of cyanogen chloride as an escaping gas essentially stops the reaction so higher potentials (above the +650 mV) do not solve the problem.

Operators must realize the extreme hazards that can develop and produce toxic cyanide gas. Whenever cyanide treatment processes are accidentally carried on at an acidic pH where significant levels of cyanides exist, extremely hazardous conditions can develop very quickly. Also when treating cyanides be sure to determine the pH at the start of the treatment process. The adjustment of pH and the various set points for the treatment system are to some extent dependent upon the concentration of cyanide and cyanate and the initial pH of the wastestreams. Adjusting the pH downward to 9.0 for a treatment process when the initial pH of a cyanide solution is significantly higher could result in the evolution of toxic cyanide gas.

Cyanides complexed with zinc and cadmium react with the same rate as the simple sodium and potassium cyanides. As the various other metal complexes are more resistant to oxidation by chlorination, long contact times are required. In order to maintain a fast reaction rate, higher oxidizing potentials (additional excess chlorine) are employed. This is most important for the complexes of silver and nickel.

When cadmium cyanide complex is oxidized, the cadmium precipitates from solution as cadmium oxide. When copper, nickel, and zinc cyanide complexes are oxidized, these metals precipitate from solution as the hydroxides. However, the presence of silver cyanide presents an additional concern. The silver cyanide complex, when oxidized, can precipitate as silver chloride (a white precipitate) and silver oxide (a black precipitate). Silver oxide is preferred as it is denser than the silver chloride, with the result that its removal from the wastewater is easier. Higher oxidizing conditions favor the oxide formation; lower conditions, the chloride.

In practice, the control devices are set to control the pH within the ranges of 10.5 to 11.5 for the first stage reaction (cyanide to cyanate) and 8.5 to 9.0 for the second stage reaction (cyanate to carbon dioxide and nitrogen). The control devices are set to maintain minimum oxidizing potentials of +600 mV in the first stage and +850 mV in the second stage.

Another control phenomenon influences the success of this process. For the first stage reaction, a minimum pH must be maintained (as discussed earlier). The top limit (11.5) is established for a different reason. Excessive alkali (as measured by pH) results in suppression of ORP values. The ORP value selected considers the need to have excess hypochlorite present to dominate the reaction. Sodium hypochlorite always contains free sodium hydroxide. When the ORP controller requests the addition of hypochlorite, the pH can rise because of this simultaneous addition of alkali. When the pH rises, the ORP value decreases, establishing an out-of-control condition. Adding more hypochlorite results in the instrumentation requesting still more hypochlorite, even though there is no cyanide present. This phenomenon is eliminated by the addition of acid whenever the pH rises too high.

5.53 BATCH OR CONTINUOUS TREATMENT

Cyanide destruction by the alkaline chlorination oxidation process may be accomplished in either a batch (Figure 4) or a continuous treatment process (Figure 14). If the cyanide wastes are maintained separate from other wastes (Figure 2), the batch process is usually the most cost effective treatment process.

In the batch process, the cyanide waste flows into one tank. When the tank is full or at an appropriate time interval, the waste is either stopped or diverted to a second tank while the cyanide waste is treated in the first tank. You will need a pH controller with two set points (for the two steps) and one pH sensor. You'll also need an ORP or chlorine controller with two set points and one ORP sensor. The tank must be equipped with a mixer, and a sequential programmer is used to add chlorine and sodium hydroxide at the correct times as determined by the pH and ORP controllers.

The high set point for the pH controller is at a pH of 10.5 and the low set point is a pH of 8.8. The high set point for the ORP controller is at +790 mV and the low point is at +670 mV. The ORP set point may need to be set at a higher or lower level to maintain the desired concentration, but the difference between the ORP set points should be 120 mV.

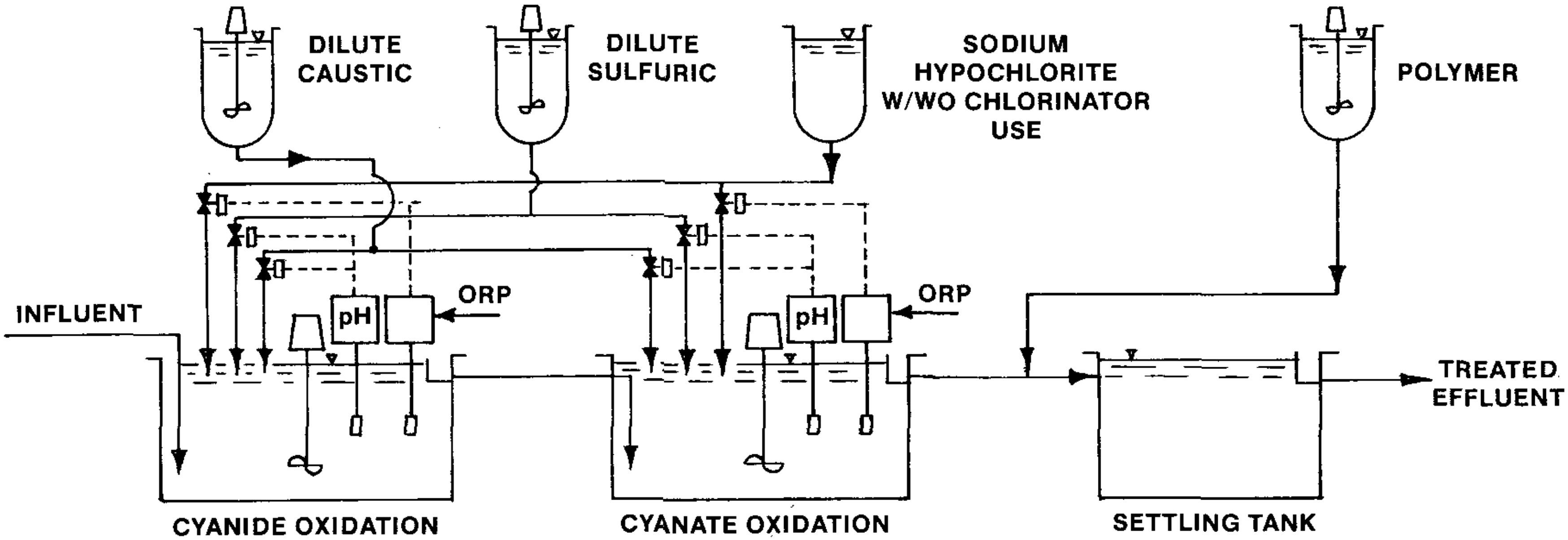
The chemical addition and adjustment sequence proceeds in a programmed fashion. Add sodium hydroxide until the pH reaches 10.5. Then add chlorine to produce an ORP level of +670 mV for 10 to 30 minutes. Next, allow the pH to drop to 8.8 (acid may have to be added to lower the pH) and adjust the ORP to +790 mV by the regulation of chlorine. The reactions are usually complete after 90 minutes.

Two tanks are used to treat cyanide in the continuous flow process shown in Figure 14. The first tank will have a retention time of at least 45 minutes and the second tank requires 90 minutes' retention time. Some shops use a "rule of thumb" that the retention time in the second tank should be at least two times the retention time in the first tank. Actual retention times to achieve desired results depend on metal concentrations and the mixture of metals in the wastestream being treated. Each tank should have a mixer capable of completely mixing the tank. Both tanks must have pH and ORP sensors and controllers.

In order to have sufficient chlorine present for the cyanide oxidation reactions in both the batch and continuous processes, at least 10 mg/L of free chlorine must be present as analyzed by the *DPD METHOD*[13] or by using PAO or a similar titration. The oxidation-reduction potential (ORP) is used to control the chlorine concentration. A platinum electrode with a reference electrode is used to sense ORP. These two electrodes are usually combined in one sensor probe. In water containing chlorine, the platinum electrode is sensitive to both chlorine and pH. For every tenfold increase in chlorine concentration, the oxidation-reduction potential increases by approximately 60 mV. For every one unit of pH increase, the oxidation-reduction potential decreases by approximately 60 mV.

At a pH of 8.0 and a free chlorine concentration of 10 mg/L, the ORP will be apprxoimately +790 mV when a silver

[13] *DPD Method. A method of measuring the chlorine residual in water. The residual may be determined by either titrating or comparing a developed color with standards. DPD stands for N, N-diethyl-p-phenylene-diamine.*



CONTINUOUS TREATMENT PROCESS FOR CYANIDE BEARING RINSE WATER

1. Equalization of flows and concentrations in influent is not shown.
2. Cyanide Oxidation by adding caustic and acid to keep pH in range of 10.5 to 11.5 and hypochlorite to keep ORP above +670 mV. with retention time of 20 to 45 minutes.
3. Cyanate Oxidation by adding caustic and acid to keep pH in range of 8.5 to 9.5 and hypochlorite to keep ORP above +800 mV. with retention time of 45 to 90 minutes.
4. During gravity transfer to Settling Tank, polymer is added to improve flocculation.
5. Gravity settling of suspended solids during 1 to 3 hr retention period prior to discharge of treated effluent.

Fig. 14 Continuous flow oxidation of cyanide by alkaline chlorination and hydroxide precipitation for rinse waters by Joe Shockcor.

chloride reference electrode is used. Thus, at a pH of 10 and a free chlorine concentration of 10 mg/L, the oxidation-reduction potential will be +670 mV (a reduction of 120 mV).

The response of the electrode to changes in pH is almost immediate. The response of the electrode to changes in free chlorine concentration occurs within 5 to 15 minutes. To minimize chlorine waste and to ensure complete destruction of cyanide, use the DPD method to analyze the water being treated to be sure a free chlorine residual is being maintained. After the chlorine concentration has been determined, adjust the ORP to the correct level based on the effects of chlorine concentration and pH level. The pH level must be carefully controlled because if the pH is allowed to drift up or down by 1.0 unit, the chlorine concentration will be adjusted up or down by the controller by a factor of 10. Do not rely on the chlorine residual as an indication that all cyanide has been oxidized to cyanate. The only way to know for sure is to collect a sample and analyze for cyanide.

Efficient operation of a cyanide oxidation system requires exact control of the pH. If the pH control is not accurate, there will be excessive use of chlorine and/or the system will not completely destroy the cyanide. A practical approach is to automatically correct the ORP when the pH values fluctuate. By the use of a glass pH electrode and a microprocessor, the ORP signal can be converted to a chlorine concentration signal which may be read out in milligrams per liter of free chlorine.

A problem develops with the alkaline chlorination treatment of cyanide if soluble iron or certain other transition metal ions are present. The iron forms very stable ferrocyanide complexes which prevent the cyanide from being oxidized. The best solution to this problem is to segregate the wastestreams to keep the cyanide and soluble iron separated.

If the pH is allowed to drop too low in the second stage, all of the cyanate is not converted to carbon dioxide and nitrogen gas. Ammonium compounds are formed (reacting with the nitrogen) which can complex copper and prevent the subsequent precipitation of copper as a hydroxide.

Chlorine is a very toxic gas and must be handled with extreme care. Always follow safe procedures for operating and maintaining chlorination facilities.

Alternative treatment techniques for the destruction of cyanide include oxidation by ozone, ozone with ultraviolet radiation, hydrogen peroxide, and electrolytic oxidation.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 86.

5.5A How do cyanide compounds get into metal wastestreams?

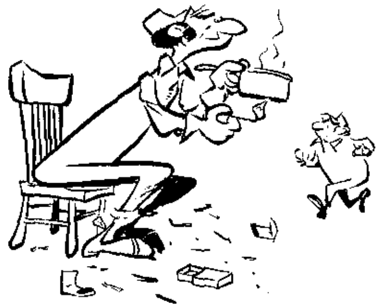
5.5B What safety hazard could occur if there is an equipment failure during the treatment of metal wastes containing cyanide?

5.5C What is the most practical and economical method of treating metal wastestreams containing cyanide?

5.5D Why does efficient operation of a cyanide oxidation system require exact control of the pH?

5.6 PRECIOUS METAL RECOVERY

Precious metal recovery is achieved by evaporation, ion exchange, reverse osmosis, and electrolytic metal waste treatment processes. Each of these processes separates or recovers the precious metal from wastestreams.



Evaporation is used to recover precious metals by boiling off the wastewater portion of the wastestream containing the precious metal and removing the metal. The evaporation process allows for the recovery of several process chemicals. The greatest limitation of the evaporation process is the high cost of energy to evaporate the wastewater. New ambient temperature evaporation processes are being developed which could be considerably less expensive.

Ion exchange is the process in which ions, held by electrostatic forces to charged functional groups on the surface of an ion exchange resin, are exchanged for ions of similar charge from the solution in which the resin is immersed. In this treatment process, a precious metal in a wastestream can be exchanged for another similar, but harmless and less precious, ion of the resin. Ion exchange units are used not only to recover precious metals, but also to recover other metal plating chemicals and to concentrate and purify plating baths.

Precious metals recovered by the ion exchange process include copper, molybdenum, cobalt, nickel, gold and silver. Metal plating chemicals recovered by ion exchange include chromium, nickel, phosphate solution, sulfuric acid from anodizing and chromic acid recovery. Ion exchange units also have been used to treat metal wastes containing aluminum, arsenic, cadmium, chromium (hexavalent and trivalent), cyanide, iron, lead, manganese, selenium, tin and zinc. The advantage of using the ion exchange process is that a specific metal can be recovered, whereas in the precipitation processes all of the metals are precipitated together and removed in the sludge.

The chemistry involved in the ion exchange process for chromium recovery can be illustrated by the following reactions. The influent plating rinse waters contain metal ions (M^{n+}) and chromate ions (CrO_4^{2-}). The R^- symbol represents the resin of a cation exchanger. This means the resin will exchange one type of cation (such as H^+) for the cation to be removed from the wastestream (such as M^{n+}). The R^+ symbol indicates an anion exchanger.

CATION EXCHANGER

M^{n+}	$+ CrO_4^{2-}$	$+ R^-H^+$	$\rightarrow R^-M^{n+}$	$+ H^+$	$+ CrO_4^{2-}$
Metal Ions	Chromate Ions	Cation Exchanger	Cation Exchanger	Hydrogen Ions	Chromate Ions

ANION EXCHANGER

H^+	$+ CrO_4^{2-}$	$+ R^+OH^-$	$\rightarrow R^+CrO_4^{2-}$	$+ H_2O$
Hydrogen Ions	Chromate Ions	Anion Exchanger	Anion Exchanger	Product Water

ANION EXCHANGER REGENERATE TO CATION EXCHANGER

Na_2CrO_4	$+ R^-H^+$	$\rightarrow R^-Na^+$	$+ H_2CrO_4$
Sodium Chromate (Regenerate)	Cation Exchanger	Cation Exchanger	Chromic Acid (Recovered)

Figure 15 illustrates the application of an ion exchange system for treating metal wastes for the recovery of hexavalent chromium (Cr^{6+}) as chromic acid (H_2CrO_4) and producing treated water for reuse. The metal wastestream is first passed through a cation exchanger to remove other metals such as iron, copper, zinc, nickel, and trivalent chromium. The hexavalent chromium in the metal wastes passes through the cation exchanger as the chromate ion (CrO_4^{2-}), and is subsequently removed in the anion exchanger. The effluent from the anion exchanger is a demineralized water suitable for reuse. To recover the hexavalent chromium (Cr^{6+}) from the anion exchanger, the water being treated must be stopped, the anion exchanger regenerated with sodium hydroxide, and sodium chromate (Na_2CrO_4) is released. This sodium chromate solution is then passed through another cation exchanger, which exchanges sodium for hydrogen, thus releasing chromic acid (H_2CrO_4) in the effluent for recovery.

When an ion exchange resin loses its exchange capacity, the resin must be regenerated. Regeneration consists of passing a chemical solution through the unit and exchanging or replacing ions removed from the wastestream with ions that can later be exchanged with precious metals from wastestreams after the ion exchange resin has been regenerated. Ion exchange resins must be cleaned when they occasionally become clogged or fouled.

Concentrated regeneration streams require special treatment for recovery of wastes and safe disposal. The regeneration flows from ion exchange units, especially for deionized waters, are frequently very acidic and may require pH adjustment prior to discharge to sewers. These flows may also be high in salt content. Regeneration flows must be properly treated to remove any toxic substances or excess salts. Spent or degraded ion exchange materials (resins) must be properly cleaned to remove any hazardous substances present before disposal. If degraded resins contain toxic metals, the resins must be properly containerized and then disposed of in an approved landfill. Disposal of these wastes must conform with both federal and state laws regulating the disposal of hazardous wastes.

Certain plating operations in the electronics and hi-tech industries require water of extremely high purity (very low dissolved solids). Water of high quality can be obtained by using a series of water treatment processes consisting of a reverse osmosis unit, degassifier, strong-acid cation exchanger, strong-base anion exchanger, and finally a mixed-bed ion exchange unit (Figure 16).

Electrolytic recovery is particularly applicable to precious metals recovery because the precious metals offer a faster payback on equipment and energy costs than other recovery processes. In this process, an electrochemical reduction of metal ions at the cathode changes these ions to the elemental state of the metal. This process is used to recover copper, silver and tin from plating and etching bath dragout.

Table 8 is a summary of recovery techniques.

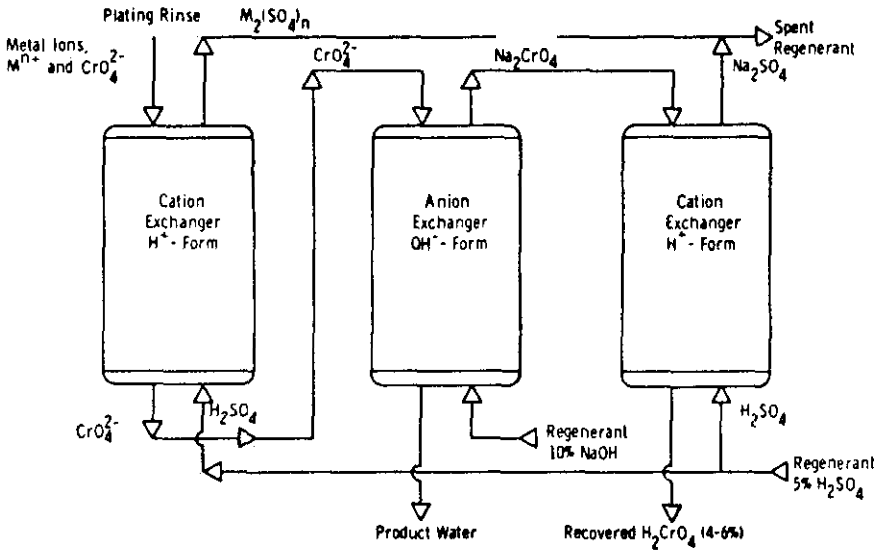


Fig. 15 Schematic illustration of plating waste treatment and chromium recovery

Reproduced by permission of Wiley-Interscience, Copyright 1972, from *PHYSICOCHEMICAL PROCESSES FOR WATER QUALITY CONTROL* by Walter J. Weber, ed.

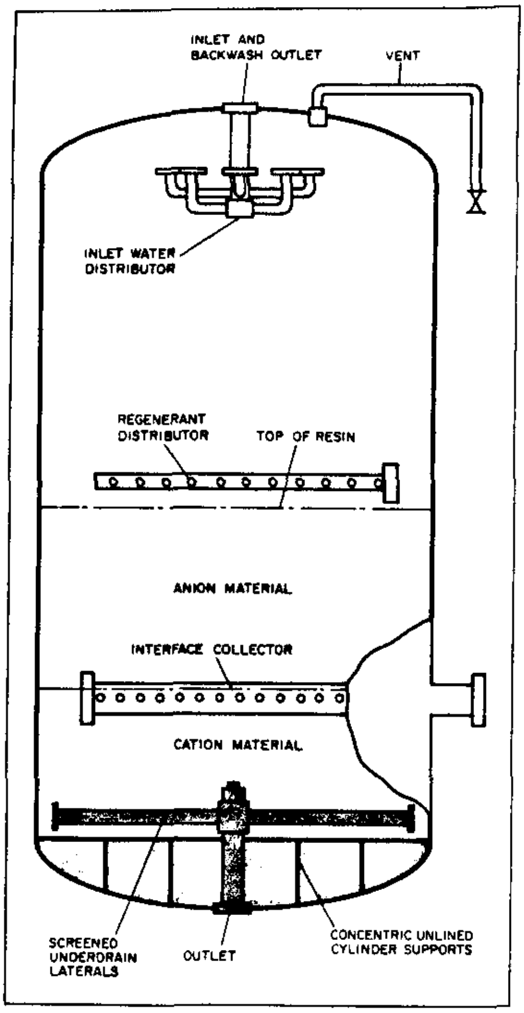


Fig. 16 Mixed-bed ion exchange unit, showing internal distributors

Reproduced by permission of Betz Laboratories, Inc. Copyright 1980, from BETZ Handbook of Industrial Water Conditioning, Eighth Edition, 1980

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 86.

5.6A How can precious metals be recovered from metal wastestreams?

5.6B List the major uses of ion exchange units in treating metal wastestreams.

5.6C What precious metals may be recovered by the ion exchange process?

5.6D What metal plating chemicals can be recovered by ion exchange?

5.7 OILY WASTE REMOVAL[14]

Oily wastes come from process coolants and lubricants, wastes from cleaning operations, wastes from painting processes, and machinery lubricants. Techniques commonly used by electroplaters and metal finishers to remove oils include skimming, coalescing, emulsion breaking, flotation, centrifugation, ultrafiltration, and reverse osmosis. Treatment of oily wastes is most efficient and cost effective if oils are segregated from other wastes and treated separately. The process of separation varies depending on the type of oil involved.

TABLE 8 SUMMARY OF RECOVERY TECHNIQUES[a]

Technique	Common Applications	Comments
I. Ion exchange	Gold, silver, chromium, nickel plating, phosphoric acid, anodizing solutions, aluminum etchants.	Suited for metal complexed solution, low concentration removal, and selective process bath stabilization.
II. Electrolyte	Gold, silver, tin, copper, chromium plating solutions, cadmium.	Suited for metal recovery from concentrated waste stream.
III. Electrodialysis	Gold, silver, copper, chromic acid, nickel, zinc, cobalt plating.	Ion exchange membrane allows minimal objectionable inorganic return.
IV. Evaporation	Chromic acids, chrome, lead-tin, nickel, copper, cadmium, brass, bronze, gold, zinc plating.	Efficient for low volume, high concentration recovery of plating or process solutions.
V. Reverse osmosis	Nickel plating.	Recovers brighteners and other organics. Suited for plating or process solution and rinse water recovery.

[a] *Reproduced by permission of TMSI Contractors from METAL FINISHING PLATING BUYERS GUIDE.*

[14] *American Petroleum Institute has some excellent references and literature. Contact American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Phone 202-682-8000. Also a publication, "A Guide to the Treatment of Oily Wastes," may be obtained from AFL Industries, Inc., 3661 W. Blue Heron Blvd., Riviera Beach, FL 33404. Phone 305-844-5200.*

In general, three types of oily wastes are encountered by operators: free oils, emulsified or water soluble oils, and greases. Manufacturing areas can produce segregated oily wastes, sometimes in concentrations as high as 400,000 mg/L. Lower oil and grease concentrations are found in combined oily wastes from the washing or rinsing of oily parts, spills and leaks.

Treatment of oily wastes depends on the types of wastes. Free or floating oils can be separated from wastestreams by the use of API (American Petroleum Institute) oil separators, centrifuges, dissolved air flotation (DAF) units, and nitrification. Emulsified oils are treated with emulsion breaking procedures such as steam, heat cracking, acids, or the use of emulsion breakers (polymers) with the addition of chemicals to cause the necessary separation of the oils. Oils must be removed from wastestreams before any further processing of the wastestreams occurs. Their presence can disrupt any subsequent operation in the treatment process train affected with a sensor feedback loop which can fail due to sensor fouling. Also regulatory pretreatment standards have an oil limitation.

Oil removal may be achieved by skimming. Once the oils and greases have been removed from the wastestream, the wastewater can be combined with other wastestreams containing common metals. The waste metals may then be removed by the hydroxide precipitation processes followed by sedimentation to remove the precipitates.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 86.

5.7A List the possible sources of oily wastes in wastestreams.

5.7B What techniques are commonly used to remove oily wastes from metal wastestreams?

5.7C What treatment processes are used to treat (a) free or floating oil and (b) emulsified oil?

5.7D What are the principal reasons to minimize the discharge of oily waters from a wastestream?

5.8 SOLVENT CONTROL

Spent degreasing solvents must be segregated from other process wastewaters to maximize the value of the recoverable solvents, to avoid contamination of other segregated wastes, and to prevent the discharge of toxic organics to any wastewater collection systems or the environment. To encourage your operators to segregate these wastes, provide clearly identified storage containers, establish clear disposal procedures, and train operators in the use of the proper techniques. Check periodically (monthly) to ensure that proper segregation is occurring. Segregated waste solvents are appropriate for on-site solvent recovery or may be contract hauled to another site for disposal or reclamation.

Alkaline cleaning (sodium hydroxide baths) is a feasible substitute for solvent degreasing. The major advantage of alkaline cleaning over solvent degreasing is the elmination or reduction in the quantity of pollutants being discharged. Major disadvantages include high energy consumption and the tendency to dilute oils removed and to discharge these oils as well as the cleaning additive. The aerospace industry is using aqueous cleaners (concentrated soap solutions) instead of degreasers for small flat parts such as circuit boards. When slug discharges of these alkaline cleansers have occurred, foaming problems have developed at small wastewater treatment plants.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 86.

5.8A Why must spent degreasing solvents be segregated from other process wastewaters?

5.8B How can you encourage operators to segregate spent degreasing solvents from other process wastewaters?

5.8C List two alternative cleaning methods that are being used instead of solvent degreasing procedures.

5.8D List ways to reduce the amount of solvents entering wastestreams.

5.9 CONTROL OF TOXIC ORGANICS[15]

Toxic organics may be found with oily wastes and solvents used for cleaning. In manufacturing operations, the toxic organics combine with oils such as process coolants and lubricants, wastes from cleaning operations, wastes from painting processes, and machinery lubricants. Toxic organics can be controlled by proper storage of the chemicals. When they are used, they should be kept separated from other wastes that will enter wastestreams and must be treated. Spent degreasing solvents may be segregated from other wastes by providing and identifying the necessary storage containers. Operators must be trained in the proper use, collection and storage of toxic organics. Periodic inspections (monthly) must be conducted to be sure that proper segregation is occurring. The containers holding the different waste solvents can then be taken to recovery facilities or hauled to disposal sites.

The quantity of toxic organics reaching wastestreams can be reduced by proper housekeeping procedures and by using cleaning techniques that require no solvents. These cleaning techniques include wiping, immersion, spray techniques using water, alkaline and acid mixtures, and solvent emulsions. Toxic organics can be kept segregated from other wastestreams by parts racking to avoid pockets of solvents, air drying to cause volatilization before next step in process, and physical separation/segregation/containment to avoid contamination due to spills.

Toxic organics that enter wastestreams can be removed by treatment processes used for the control of other pollutants. Toxic organics tend to be more soluble in oil and grease than in water. Therefore, the removal of oil and grease from wastestreams will reduce the discharge of toxic organics. Aeration or carbon adsorption are the processes commonly used to remove toxic organics from wastestreams. Other treatment processes used to remove toxic organics include settling and volatilization, which can occur during the treatment of metals, cyanide, and oil and grease. In some situations the activated sludge process may be used if a biological culture can be developed in the aeration tanks which is acclimated to the wastes. Aerobic decomposition, bacterial decomposition and ozonation have also been used to treat toxic organics.

[15] *Total Toxic Organics allowed in effluents are as follows: captive shops, 2.13 mg/L and job shops, 4.57 mg/L.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 87.

5.9A How can the quantity of toxic organics reaching wastestreams be reduced?

5.9B How can toxic organics that enter wastestreams be removed?

6 SLUDGE TREATMENT AND DISPOSAL

6.0 SOURCES AND TREATMENT

Sludges are created by the precipitation, sedimentation and other processes which remove solids from wastestreams. Sludge thickening concentrates dilute sludges with mechanical devices such as centrifuges and gravity thickeners. Increasing the solids content of a sludge will reduce capital and operating costs as well as the costs for hauling and ultimate disposal of the final residue. Vacuum filters, belt presses, and filter presses are used to dewater sludges by passing the dilute sludge through a filter material which will hold the solids but allow the liquid portion of the sludge to pass through the filter media.

Many sludges must be placed in noncorrosive and leakproof containers before they can be transported to an ultimate disposal site. These special containers are essential to prevent the escape of hazardous wastes to the environment during transportation, storage and disposal. Containerized sludges may be disposed of in approved landfills.

6.1 PLATE AND FRAME FILTER PRESSES

Plate and frame filter presses (Figures 17 and 18) are a common type of filter used to dewater industrial sludges. This type of filter press consists of an assembly of plates between which there are two layers of cloth and filter material (Figure 19). Sludge is pumped into the space between the two cloths by means of a central passageway. The plates have grooves on their face to allow the water from the sludge to drain away. The resulting sludge cake can reach a solids level as high as 35 percent. The sludge supply pump typically operates at a discharge pumping pressure in the 80 to 110 psi range. Therefore, the plates must be held in position using a frame and a hydraulic cylinder.

When the filter cloths are filled with dewatered sludge, the supply pump is shut off, the pressure released, and the hydraulic cylinder is retracted. The plates are then opened, one at a time, and the filter cake (dewatered sludge) removed by hand (Figure 20). In most cases the bulk of the cake releases by itself; however, there is usually a portion which needs to be hand scraped.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 87.

6.0A How are sludges created from metal wastestreams?

6.0B How are filter presses used to process sludges?

6.0C How are sludges ultimately disposed of?

6.2 ARITHMETIC ASSIGNMENT

Turn to Appendix III at the back of this manual and read the following sections:

G. Chemical Solutions,

H. Chemical Feeders, and

I. Polymers and Coagulants.

Check all of the arithmetic for example problems 9 through 29. You should be able to get the same answers on your electronic pocket calculator.

6.3 ADDITIONAL READING

1. *OPERATION OF WASTEWATER TREATMENT PLANTS*, Volume I. "Chlorine Safety and Handling," pp. 319-396.
2. *OPERATION OF WASTEWATER TREATMENT PLANTS*, Volume III.
   "Adsorption," pp. 635-658.
   "Coagulation and Precipitation," pp. 612-634.
   "Conditioning of Sludges," pp. 173-185.
   "Dewatering of Sludges," pp. 186-207.
   "Flotation," pp. 554-567.
   "Industrial Waste Treatment," pp. 531-704.
   "Microscreening," pp. 568-587.
   "Neutralization," pp. 588-611.
   "Polymer Doses for Sludges," pp. 173-185.
   "Solids Handling and Disposal," pp. 119-280.
   "Solids Removal from Secondary Effluents," pp. 281-352.
   "Thickening of Sludges," pp. 135-162.
   "Volume Reduction of Sludges," pp. 207-234.
3. *WATER TREATMENT PLANT OPERATION*, Volume II. "Ion Exchangers," pp. 91-111.

These three manuals are available from Office of Water Programs, California State University, Sacramento.

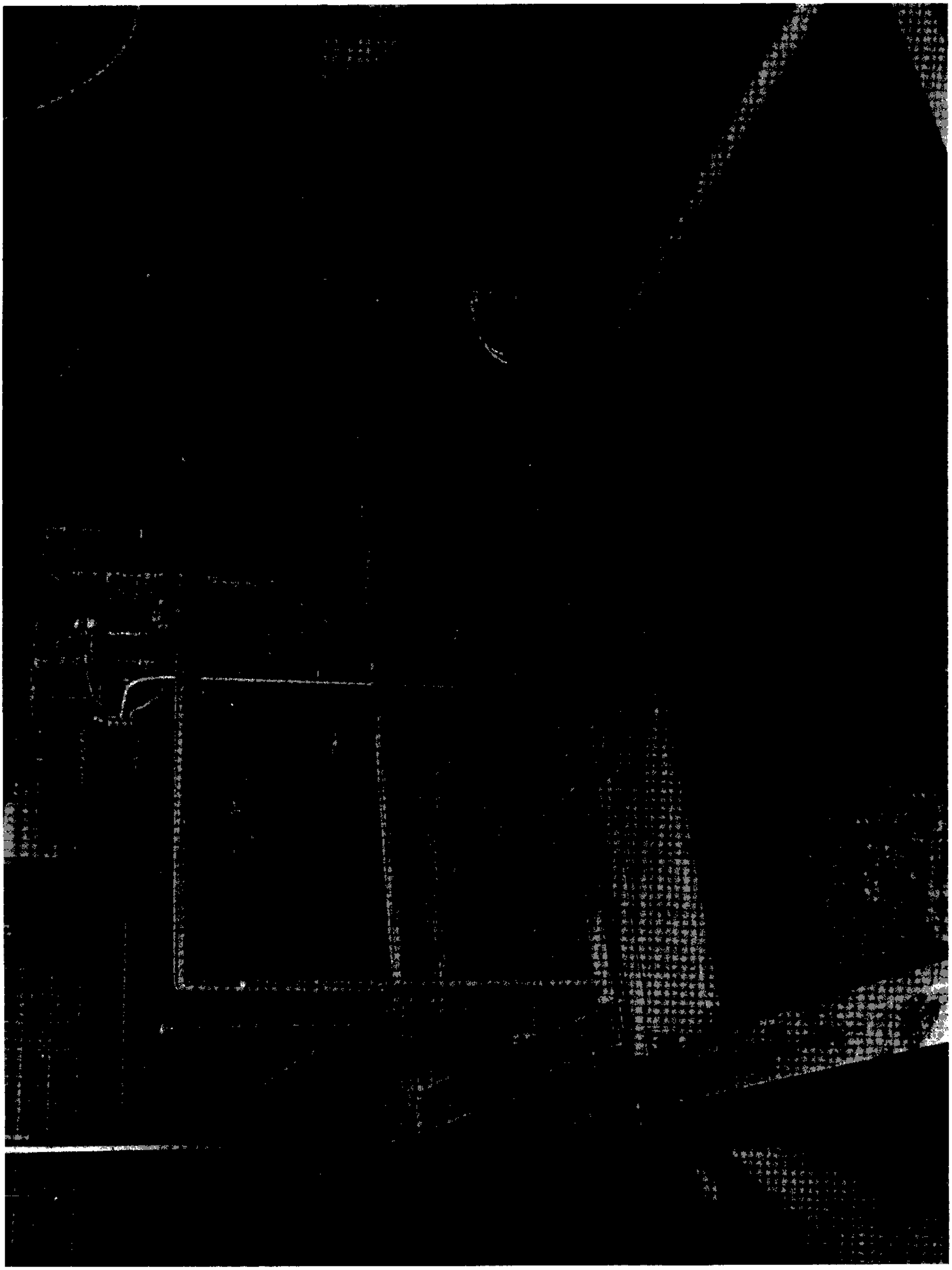
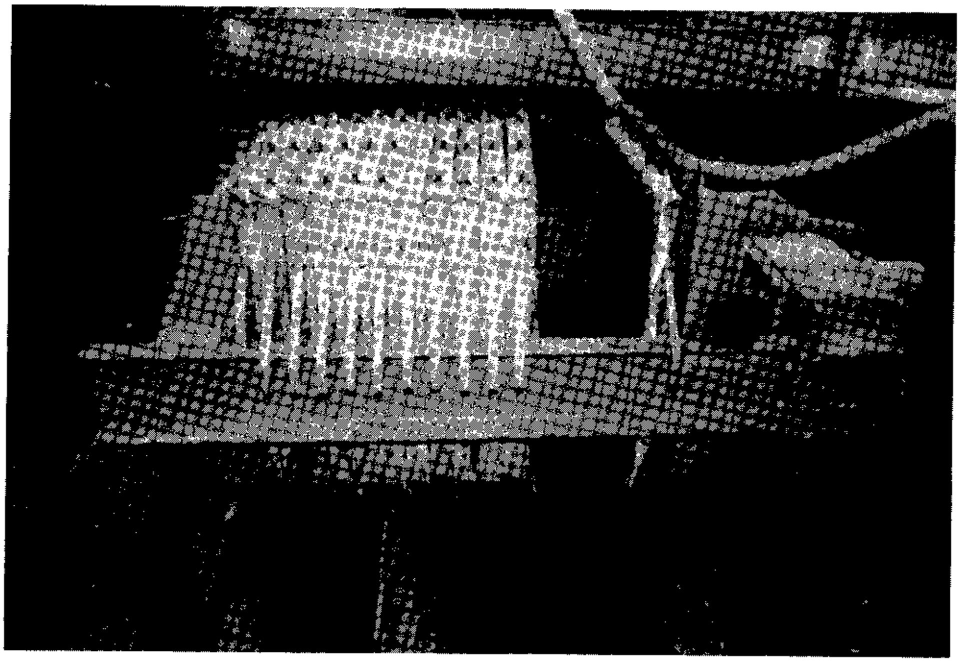


Fig. 17 Plate and frame filter press
(Permission of New England Plating Co., Inc.)



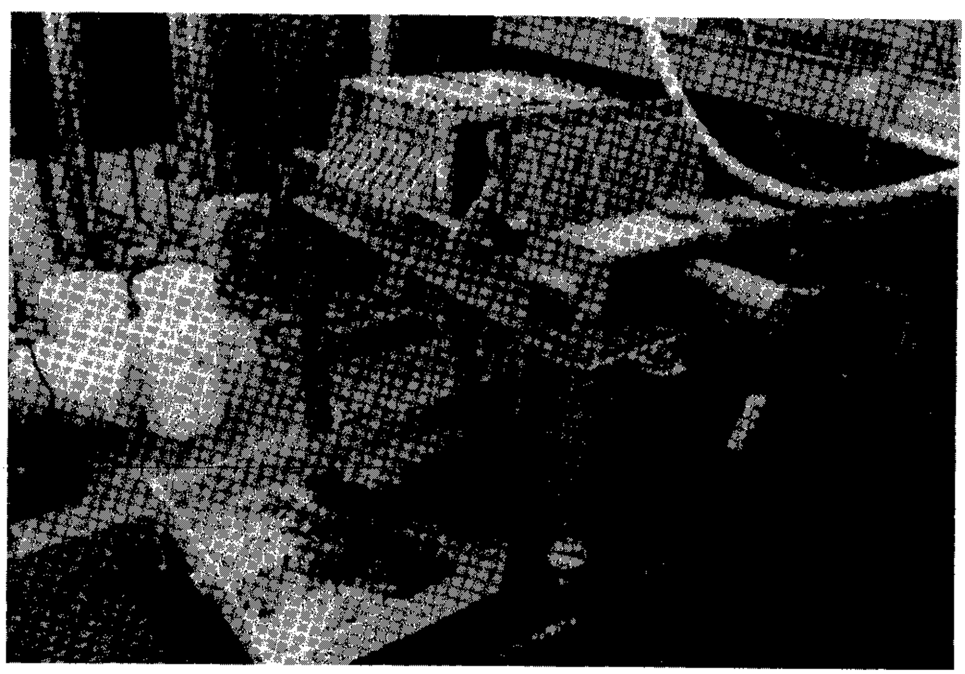


Fig. 18 Plate and frame filter press
(Permission of Lee, Strangio & Associates, Inc.)

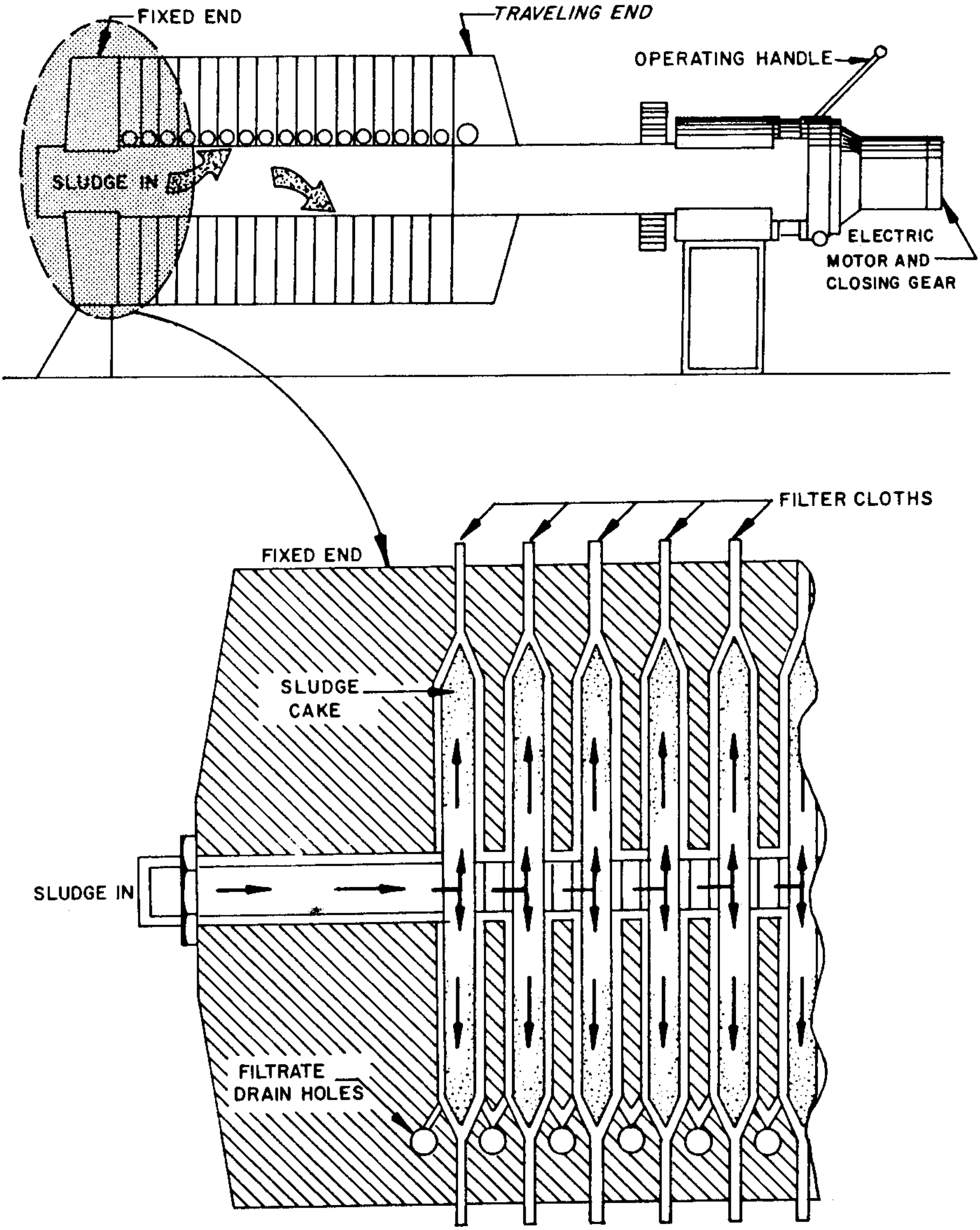
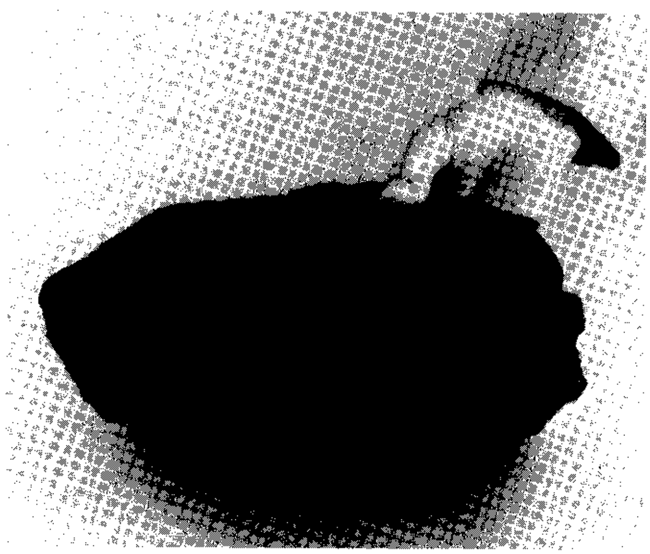


Fig. 19 Plate and frame filter press

Permission of Lee, Strangio & Associates



Permission of Edwards and Jones, Inc.

Fig. 20 Filter press cake

Permission of Edwards and Jones, Inc.
(Permission of Lee, Strangio & Associates)

DISCUSSION AND REVIEW QUESTIONS

(Lesson 2 of 3 Lessons)

Write the answers to these questions in your notebook before continuing with the Objective Test. The question numbering continues from Lesson 1.

11. Why must operators be very careful whenever highly acidic and basic solutions are mixed?
12. How are chromium wastes commonly treated?
13. What is the most practical and economical method of treating cyanide wastes? Describe the process.
14. How can the ion exchange process be used to treat metal wastes?
15. Why must spent degreasing solvents be segregated from other process wastewaters?
16. How can toxic organics be controlled?
17. Why must metal waste sludges be placed in special containers?
18. When using the batch process for hydroxide precipitation, why is the final pH adjustment in a separate tank?
19. Why should a spent process solution (a pickle, for example) be treated as a batch process and not dumped directly into the rinse water for treatment?
20. How can waste treatment costs be reduced?

OBJECTIVE TEST

(Lesson 2 of 3 Lessons)

Please write your name and mark the correct answers on the special answer sheet as directed at the end of Lesson 1. There may be more than one correct answer to these multiple-choice questions.

PLEASE MARK CHAPTER 32 ON YOUR ANSWER SHEET.

1. Types of wastes that must be treated at metal finishing and plating facilities include
   1. Cyanide from plating processes.
   2. Highly basic solutions.
   3. Highly neutral solutions.
   4. Toxic metals from basic plating solutions.
   5. Toxic organic solvents.
2. Metal finishing wastestreams containing __________ must be treated separately before metals removal by hydroxide precipitation and sedimentation.
   1. Complexed metals
   2. Cyanide
   3. Gold
   4. Oily wastes
   5. Trivalent chromium
3. Batch processes are used to treat metal wastes because they are
   1. Dependable.
   2. Easy to control.
   3. Effective for treating large flows.
   4. Regulated until wastewater being treated receives satisfactory treatment.
   5. Simple.
4. High pH wastewaters can be neutralized by
   1. Carbon dioxide.
   2. Lime.
   3. Sodium hydroxide.
   4. Sulfur dioxide.
   5. Sulfuric acid.
5. Wastewaters with a low pH can be neutralized by
   1. Calcium hydroxide.
   2. Caustic soda.
   3. Flue gases.
   4. Hydrochloric acid.
   5. Magnesium oxide.
6. The common metals usually treated in electroplating and metal finishing wastestreams are
   1. Cyanide.
   2. Iron.
   3. Lead.
   4. Silver.
   5. Zinc.
7. Common metals can be removed from wastestreams by __________ precipitation.
   1. Acid
   2. Chloride
   3. Chlorine
   4. Hydroxide
   5. Sulfide
8. Limitations of the hydroxide precipitation process for treating common heavy metals include
   1. A dense, heavy floc is formed.
   2. Cyanide will interfere with the removal of dissolved metals.
   3. Hexavalent chromium is not removed.
   4. Large volumes of sludge are produced.
   5. Toxic hydrogen sulfide is produced.
9. Advantages of the sulfide precipitation process for the removal of common metals include
   1. Both chromate and dichromate can be removed without preliminary reduction of hexavalent chromium to trivalent chromium.
   2. Most complexed metals can be precipitated.
   3. Most metal sulfides are more soluble than metal hydroxides at high pH.
   4. Toxic hydrogen sulfide is not produced by the process.
   5. Very high metal removal efficiencies can be achieved.
10. Complexed metals are metals with a
    1. Facility to form organic complexes.
    2. High reaction rate with other metals.
    3. Lower level of toxicity than most metals.
    4. Molecular weight greater than 100.
    5. Tendency to remain in solution.

11. The most common complexed metals found in wastestreams include
    1. Cadmium.
    2. Copper.
    3. Gold.
    4. Silver.
    5. Zinc.

12. Complexed metal wastestreams may be treated by
    1. Chemical oxidation.
    2. Chemical reduction.
    3. High pH precipitation.
    4. Low pH precipitation.
    5. Sulfide precipitation.

13. Strong reducing agents used to treat metal wastes include
    1. Chlorine.
    2. Ferrous sulfate.
    3. Sodium bisulfite.
    4. Sodium metabisulfite.
    5. Sulfur dioxide.

14. Strong oxidizing agents used to treat metal finishing wastes include
    1. Chlorine.
    2. Ferrous sulfate.
    3. Sodium bisulfite.
    4. Sodium metabisulfite.
    5. Sulfur dioxide.

15. Highly toxic hexavalent chromium may be present in wastestreams in the form of
    1. Chromate.
    2. Chromic acid.
    3. Chromic hydroxide.
    4. Chromic sulfate.
    5. Dichromate.

16. Cyanide wastes may be treated by the use of
    1. Chlorine.
    2. Ferrous sulfate.
    3. Hydrogen peroxide.
    4. Ozone.
    5. Sulfur dioxide.

17. Potential safety hazards that operators may encounter when treating cyanide wastes include ________ gas.
    1. Carbon dioxide
    2. Chlorine
    3. Cyanide
    4. Hydrogen sulfide
    5. Nitrogen

18. Precious metal recovery may be achieved by ________ metal waste treatment processes.
    1. Alkaline chlorination
    2. Electrolytic
    3. Evaporation
    4. Hydroxide precipitation
    5. Ion exchange

19. Precious metals that may be recovered by the ion exchange process include
    1. Aluminum.
    2. Arsenic.
    3. Cobalt.
    4. Molybdenum.
    5. Nickel.

20. Techniques used by electroplaters and metal finishers to remove oils from wastestreams include
    1. Centrifugation.
    2. Emulsion breaking.
    3. Flotation.
    4. Reverse osmosis.
    5. Skimming.

21. Treatment processes used to remove toxic organics from wastestreams include
    1. Aeration.
    2. Carbon adsorption.
    3. Dual-media filtration.
    4. Screening.
    5. Settling and volatilization.

22. Metal waste sludges may be dewatered by
    1. Belt presses.
    2. Incineration.
    3. Landfills.
    4. Plate and frame filter presses.
    5. Vacuum filters.

23. How many pounds of chlorine are in a 50-gallon container full of a 2 percent hypochlorite solution?
    1. 2 lbs
    2. 5 lbs
    3. 8 lbs
    4. 10 lbs
    5. 21 lbs

24. Determine the sulfonator setting for an industrial wastestream of 75 GPM that requires a sulfur dioxide dose of 15 mg/*L*.
    1. 5 lbs/24 hrs
    2. 7 lbs/24 hrs
    3. 9 lbs/24 hrs
    4. 14 lbs/24 hrs
    5. 97 lbs/24 hrs

25. How many pounds of polymer are required to make up 100 gallons of 0.2 percent polymer solution?
    1. 1.7 lbs
    2. 4.2 lbs
    3. 8.3 lbs
    4. 12 lbs
    5. 17 lbs

END OF OBJECTIVE TEST

TABLE 9 COMMON TREATMENT PROCESS CHEMICALS

	CHEMICAL NAME (COMMON NAME)	FORM	STRENGTH	USE	SAFETY WARNING[a]
1	Sodium Hydroxide (Caustic)	Liquid Pellet and Flake Form	20-50% Solution	Raise pH	Causes painful burns if it enters breaks in the skin or gets under skin around fingernails. Will cause blindness if gets into eyes.
2	Calcium Hydroxide (Lime)	Powder or Slurry		Raise pH	Same hazards as sodium hydroxide.
3	Sulfuric Acid	Liquid	90-96% Solution	Lower pH in chrome reduction process. Lower pH of final effluent.	Causes severe burns and blindness. Nylon and rayon fall apart if subject to mist. Most cloth is badly damaged by slight exposure.
4	Hydrochloric Acid	Liquid	37% Solution	Clean probes. Lower pH.	Same hazards as sulfuric acid. Attacks many types of stainless steel. Vapors.
5	Chlorine	Gas, Liquid or Solid	100% gas; 12.5% liquid industrial bleach.	Oxidizing agent.	Toxic gas which damages respiratory system.
6	Sulfur Dioxide and Sulfide Compounds	Gas or Powders	100% gas	Reducing agent. Hexavalent chromium treatment.	Toxic gas which can cause respiratory edema[b] and pneumonia.
7	Polymers and Polyelectrolytes			Organic compounds used to speed up the removal of precipitated material.	Polymers spilled on surfaces present an extreme slipping hazard.

[a] *See Section 7.03, "First Aid," for procedures.*
[b] *Edema. The flow of fluids into the body tissues or cavities.*

7.02 Storage and Handling of Chemicals

All chemical storage and handling facilities must have proper spill containment measures. These measures must prevent the mixing of acid and cyanide wastes as well as avoid major sewer problems as a result of accidents and spills. Absolutely no floor drains connected to public sewers shall be allowed in warehouses and other facilities that store toxic or flammable materials. Spill containment systems may consist of diking or self-contained tanks.

Diking must be capable of containing the volume of the largest tank within a containment area. Diking usually consists of concrete blocks and concrete curbing. The concrete or mortar surfaces exposed to a spilled chemical must be coated or otherwise protected against acidic deterioration. Absolutely no openings, manual or electrical discharge gates, or valves of any kind are allowed in spill containment diking.

A self-contained tank is a tank with two independent structural shells with the outer shell being capable of containing any leakage from the inner one. A one-inch air gap must be provided between the walls and bottoms of these tanks and the top of the inner tank should be at least one inch lower than the top of the outer tank. Absolutely no discharge valves are allowed in the outer shell. Pits that are constructed or coated with an acid resistant material and without sewer access are acceptable as self-containment if the containment volume is adequate.

SEE MATERIAL SAFETY DATA SHEETS (MSDSs) FOR SPECIFIC STORAGE AND HANDLING INSTRUCTIONS FOR EACH CHEMICAL.

Most chemicals are stored and used in a concentrated form. Lime and sodium hydroxide (caustic) are often mixed with water at the treatment site. The heat generated during the mixing reaction can be sufficient to weaken plastic tanks and cause them to split open. Dilution of concentrated acids or the mixing of acids and caustics can lead to "splatter" or "explosions" which can be extremely hazardous to operators. Remember, *SAFETY COMES FIRST.*

Acids must be contained in rubber, glass or plastic-lined equipment. Store acids in clean, cool, well ventilated areas. The areas should have an acid-resistant floor and adequate containment. Keep acids away from oxidizing agents, alkaline or basic materials, and cyanides. Protect the containers from damage or breakage. Avoid contact with skin and provide emergency neutralization materials and safety equipment in use areas. Vinegar can be used to neutralize bases and baking soda will neutralize acids.

When you are handling acids, wear protective clothing and equipment to prevent body contact with the acid. Wear rubber gloves, safety goggles and/or a face shield for eye protection against splashing. Also wear a rubber apron, rubber boots, and a long-sleeved polyester shirt. An eye wash station and safety shower must be located nearby where any acids are being handled. A respirator may be needed in some situations. Although such precautions may seem like too much bother or the safety equipment may be uncomfortable, a serious acid burn is even more uncomfortable. *PROTECT YOURSELF BY USING PROPER EQUIPMENT. REMEMBER, ALWAYS POUR ACID INTO WATER, NEVER THE REVERSE.* You *POUR ACID INTO* a swimming pool, never pour the pool water into an acid bottle.

Sodium hydroxide (caustic soda) is one of the most common and most dangerous bases used in waste treatment processes. Sodium hydroxide is available in pellet, flake, and solution forms; caustic soda solutions usually come as 20 to 50 percent solution of sodium hydroxide. This base is a strong alkali and is very hazardous to operators. Sodium hydroxide is extremely reactive; it reacts violently or explosively with acid and a number of organic compounds. Caustic soda (1) dissolves human skin, (2) when mixed with water causes heat, and (3) reacts with amphoteric metals (such as a aluminum) generating hydrogen gas which is flammable and may explode if ignited. Sodium hydroxide can be dissolved in water and the solution used for the adjustment of pH because it is a liquid and easy to feed. *ALWAYS POUR CAUSTIC INTO WATER, JUST LIKE POURING ACID INTO WATER.* If the solution being mixed "bumps" or splatters, the dilute solution of mostly water will splatter and cause less damage than a concentrated solution.

Special precautions to be taken when handling or storing caustic soda include (1) prevent eye and skin contact, (2) do not breathe dusts, particulates, or mists, and (3) avoid storing this chemical next to strong acids or cyanide. Dissolving sodium hydroxide in water or other substances generates excessive heat, causes splattering and mists. Solutions of sodium hydroxide are viscous and slippery and only trained and protected operators should undertake spill cleanup. The operator must act cautiously, dilute the spill with water and neutralize with a dilute acid, preferably acetic. Neutralizing absorbents can also be used.

If a strong alkaline solution floods the eyes, it is practically impossible to prevent serious impairment of vision no matter how fast the first aid is applied.

When handling caustic soda, control the mists with good ventilation. Protect your nose and throat with an approved respiratory system. For eye protection, you must wear chemical worker's goggles and/or a full face shield to protect your eyes. There must be an eye wash and safety shower at or near the work station for this chemical. Protect your body by being fully clothed and by using impervious gloves, boots, apron and face shield.

If a bucket of dry cleaner salts is accidentally dumped into a hot alkaline cleaner solution, the resulting eruption (explosion) can flood the operator with a hot alkali solution. The result is a very serious injury and in some cases there has been loss of life. *YOU MUST KNOW WHAT YOU ARE DOING WHEN WORKING WITH CHEMICALS.*

Certain dry chemicals such as alum, ferric chloride, and soda ash are *HYGROSCOPIC*[16]. These chemicals require special considerations to protect them from moisture during storage. Dry quicklime should be kept dry because of the tremendous heat which is generated when it comes in contact with water. This heat is sufficient to cause a fire. Dry forms of sodium hydroxide can cause operators to be exposed to dust.

Some liquid chemicals such as sodium hydroxide (caustic soda) should not be exposed to air because they may react with the carbon dioxide and form calcuium carbonate (a solid). Also, some liquid chemicals may "freeze." A 50 percent sodium hydroxide solution becomes crystalized (forms a solid) at temperatures below 55°F (13°C). Therefore a heater may be required to keep the storage area warm or the solution may need to be diluted down to a 25 percent solution, which remains liquid at temperatures below 32°F (0°C). Some shops order 50 percent sodium hydroxide and add the correct amount of water to the storage tank before delivery to produce a 25 percent dilution after the order has been delivered. The resulting 25 percent dilution will raise the temperature of the mixture to about 160°F (71°C). Therefore, fill the chemical feed tank with 25 percent sodium hydroxide before delivery to give the new mix time to cool down.

Polymer solutions can be degraded (lose their strength) by biological contamination. Clean polymer tanks before a new shipment is delivered to the plant. The tanks may be cleaned by hosing or washing them out with water.

Liquid chemical storage tanks should have an impervious berm or earth bank around the tanks to contain any chemicals released if the tank fails due to an earthquake, corrosion or any other reason.

The long-term storage of hypochlorite salts in a tightly closed container could produce a hazardous situation. These salts tend to gasify in time, thus creating the possibility of sufficient pressure in the container to cause an explosion.

Some chemicals such as chlorine and fluoride compounds are harmful to the human body when they are released as the result of a leak. Continual surveillance and maintenance of the storage and feeding systems are required.

These guidelines for handling and storage of hazardous chemicals are only general guidelines. Your chemical suppliers should be able to provide you with more detailed information about suitable storage conditions and safe handling procedures. Ask your supplier for this information and then take the time to read and follow the manufacturers' suggestions.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 87.

7.0D What problems can be caused by the mixing of caustics?

7.0E How must acids be contained and stored?

7.0F What special precautions should an operator take when handling or storing caustic soda?

7.03 First Aid

By definition, first aid means emergency treatment for injury or sudden illness before regular medical treatment is available. Everyone in an organization should be able to give some degree of prompt treatment and attention to an injury.

First aid training in the basic principles and practices of life-saving steps that can be taken in the early stages of an

[16] *Hygroscopic (HI-grow-SKOP-ick). Absorbing or attracting moisture from the air.*

injury are available through the local Red Cross, Heart Association, local fire departments and other organizations. Such training should periodically be reinforced, so that the operator has a complete understanding of water safety, cardio-pulmonary resuscitation (CPR) and other life-saving techniques. All operators need training in first aid, but it is especially important for those who regularly work with electrical equipment or must handle acids, bases, chlorine and other dangerous chemicals.

First aid has little to do with preventing accidents, but it has an important bearing upon the survival of the injured patient. A well-equipped first aid chest or kit is essential for proper treatment. The kit should be inspected regularly by the safety officer to assure that supplies are available when needed. First aid kits should be prominently displayed throughout the treatment plant and in company vehicles. Special consideration must be given to the most hazardous areas of the plant such as shops, laboratories, and chemical handling facilities.

Have immediately available for each supervisor the first aid instructions for each chemical used in the shop. This information can be copied from the Material Safety Data Sheets (MSDSs) supplied by the chemical manufacturers or suppliers.

ACIDS

The antidote to all acids is neutralization. However, one must be careful in how this is performed. Most often large amounts of water will serve the purpose, but if the acid is ingested (swallowed), then lime water or milk of magnesia may be needed. If vapors are inhaled, first aid usually consists of providing fresh air, artificially restoring breathing (CPR), or supplying oxygen. In general, acids are neutralized by a base or alkaline substance. Baking soda is often used to neutralize acids on skin because it is not harmful on contact with your skin.

BASES

First aid for the eyes consists of irrigating the eyes immediately and continuously with flowing water for at least 30 minutes. Vinegar (dilute acetic acid) is a good neutralizer on humans. Prompt medical attention is essential. For skin burns, immediate and continuous thorough washing in flowing water for 30 minutes is important to prevent damage to the skin. Consult a physician if required. In case of inhalation, move the victim to fresh air, call a physician, or transport the injured person to a medical facility; *DO NOT INDUCE VOMITING.*

You may also have occasion to use sodium hydroxide as flakes or pellets. All of the precautions stated for liquid caustic also apply for the flake and pellet forms.

EYE BURNS (GENERAL)

1. Apply a steady flow of water to eyes for at least 15 minutes.
2. Call a physician immediately.
3. *DO NOT* remove burned tissue from the eyes or eyelids.
4. *DO NOT* apply medication (except as directed by a physician).
5. *DO NOT* use compresses.

SKIN BURNS (GENERAL)

1. Remove contaminated clothing immediately (preferably in a shower).
2. Flush affected areas with generous amounts of water.
3. Call a physician immediately.
4. *DO NOT* apply medication (except as directed by a physician).

SWALLOWING OR INHALATION (GENERAL)

1. Call a physician immediately.
2. Read antidote on label of any chemical swallowed. For some chemicals vomiting should be induced, while for other chemicals vomiting should not be induced. Follow the instructions on the label.

CHLORINE GAS CONTACT

1. If the victim is breathing, place on back with head and back in a slightly elevated position. Keep the victim warm and comfortable. *CALL A PHYSICIAN IMMEDIATELY.*
2. If breathing has ceased, *IMMEDIATELY* start CPR (cardio-pulmonary resuscitation) or oral (mouth-to-mouth) resuscitation (artificial respiration). Oxygen should only be administered by *TRAINED* personnel.
3. Eye irritation caused by chlorine gas should be treated by flushing the eyes with generous amounts of water for not less than 15 minutes. Hold eyelids apart to ensure maximum flushing of exposed areas. *DO NOT* attempt to neutralize with chemicals. *DO NOT* apply any medication (except as directed by a physician).
4. Minor throat irritation can be relieved by drinking milk. *DO NOT* give the victim any drugs (except as directed by a physician).

LIQUID CHLORINE CONTACT

1. Flush the affected area with water. Remove contaminated clothing while flushing (preferably in a shower). Wash affected skin surfaces with soap and water while continuing to flush. *DO NOT* attempt to neutralize with chemicals. Call a physician. *DO NOT* apply medication (except as directed by a physician).
2. If liquid chlorine has been swallowed, immediately give the victim large amounts of water or milk, followed with milk of magnesia, vegetable oil, or beaten eggs. *DO NOT* give sodium bicarbonate. *NEVER* give anything by mouth to an unconscious victim. Call a physician immediately.

EMERGENCY PHONE NUMBERS

A list of emergency phone numbers should be located near a telephone that is unlikely to be affected in an emergency. This list should include:

1. Hospital and/or physician,
2. Ambulance,
3. Poison Control Center,
4. Police,
5. Fire,
6. Responsible Plant Officials,
7. Local Emergency Disaster Office,
8. CHEMTREC (800) 424-9300,
9. Emergency Teams (if your plant has one), and
10. Regulatory Agencies.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 87.

7.0G Define first aid.

7.0H What should be done if acid comes in contact with your skin?

7.0I What should be done if your eyes become irritated by chlorine gas?

7.1 KNOW THE CHEMICAL PROCESSES INVOLVED

The chemical processes used to treat wastewaters from electroplating, metal finishing and printed circuit board manufacturing have been described in Section 5.0, "Methods of Treatment." The actual chemical process or processes used in your treatment facilities to obtain the desired effluent results will depend on a given combination of factors involved in your specific industrial situation. The factors which influence the types and complexity of the processes include the:

1. Particular wastestream characteristics,
2. Space available for treatment,
3. Costs of the processes, and
4. Effluent discharge requirements.

Frequently industrial operators are required to operate treatment processes that they know little about or have no experience operating. Under these circumstances, the ingenuity of the operator is challenged. Helpful resources that are available to the operator include:

1. This training manual;
2. System O & M manuals (all manufacturers should provide detailed procedures on how to operate and maintain their equipment);
3. System construction drawings (especially the electrical, mechanical and instrumentation drawings);
4. Manufacturers' technical representatives (troubleshooters);
5. Instrumentation service company representatives;
6. Wastewater treatment specialists and consultants; and
7. Operators that treat wastewater for other companies or shops.

After you have become familiar with your systems and processes, you must continue to develop your knowledge of how these facilities work and how to "fine tune" the treatment processes. You can expect the characteristics of the wastewaters being treated to change hourly, daily, weekly and seasonally due to changes in the production processes or maintenance procedures, thus requiring continuous monitoring and adjustment of the treatment processes. You must be aware of the variations in the wastes and be prepared to change the settings of treatment systems accordingly.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 87.

7.1A List the factors which influence the types and complexity of the processes used to treat metal wastes.

7.1B Why do metal waste treatment processes require continuous monitoring and adjustment of the treatment processes?

7.2 OPERATION

7.20 Visual Observation

Effective operation requires visual observations of wastewater being treated and the treatment processes; reading, recording and analysis of instrument readouts and printouts; collection, analysis and interpretations of sample test results; and physical adjustment of process control settings.

Operators must learn how the treatment system and effluent should look when everything is operating correctly. For instance, if precipitation is one of the treatment processes, then the water in the precipitation phase should look cloudy or full of solids. A clear wastewater would indicate that the precipitation tank is not receiving treatment chemicals, or that some component of the wastewater (ammonia, chelates or acids) is defeating the precipitation process. An alert operator will then follow a logical process of deduction to determine what is causing the problem.

Operators should be present at all times during the operation of batch and continuous wastestream treatment facilities. Every time an operator inspects or walks through an industrial wastewater treatment facility, the visual observations in the following list should be performed. These observations should be made at least daily. At many industrial treatment facilities the operator will walk through the facility and perform the visual observations at the start of a shift and also at the end of a shift. The end of the shift tour prepares the departing operator to inform the incoming operator of the current status of the processes. The incoming shift operator should also walk through the facility at the start of the shift to confirm existing conditions and to take action on any items requiring operator attention. The following is a list of items for operators to check when they walk through their facilities.

1. Survey control panel for alarm conditions (Figure 21).
2. Examine effluent to determine if it appears normal (for example, is it clear? color free? is there evidence of floc or sludge carryover?).
3. Look at flocculation tank to see that the waste is flocculating properly (large floc and clear water surrounding the floc). Observe the settling characteristics (settleability) of the floc.
4. Observe the precipitation processes for the proper appearance and pH.
5. Review the control readings in the preliminary treatment processes to be sure they are in the proper range. For example,
   Cyanide pH = 8.5 and ORP = +650
   Chromium pH = 2.5 and ORP = +250
6. Look at clarifier or settling tank to be sure there is no pin floc or solids washout in the effluent.
7. Inspect sludge levels in the clarifiers and sludge storage tanks. Use a sludge judge or some other device to determine level of sludge blanket.
8. Determine polymer tank levels.
9. Check chemical tank levels.
10. Survey area for flooding, leaks, spills or equipment problems.

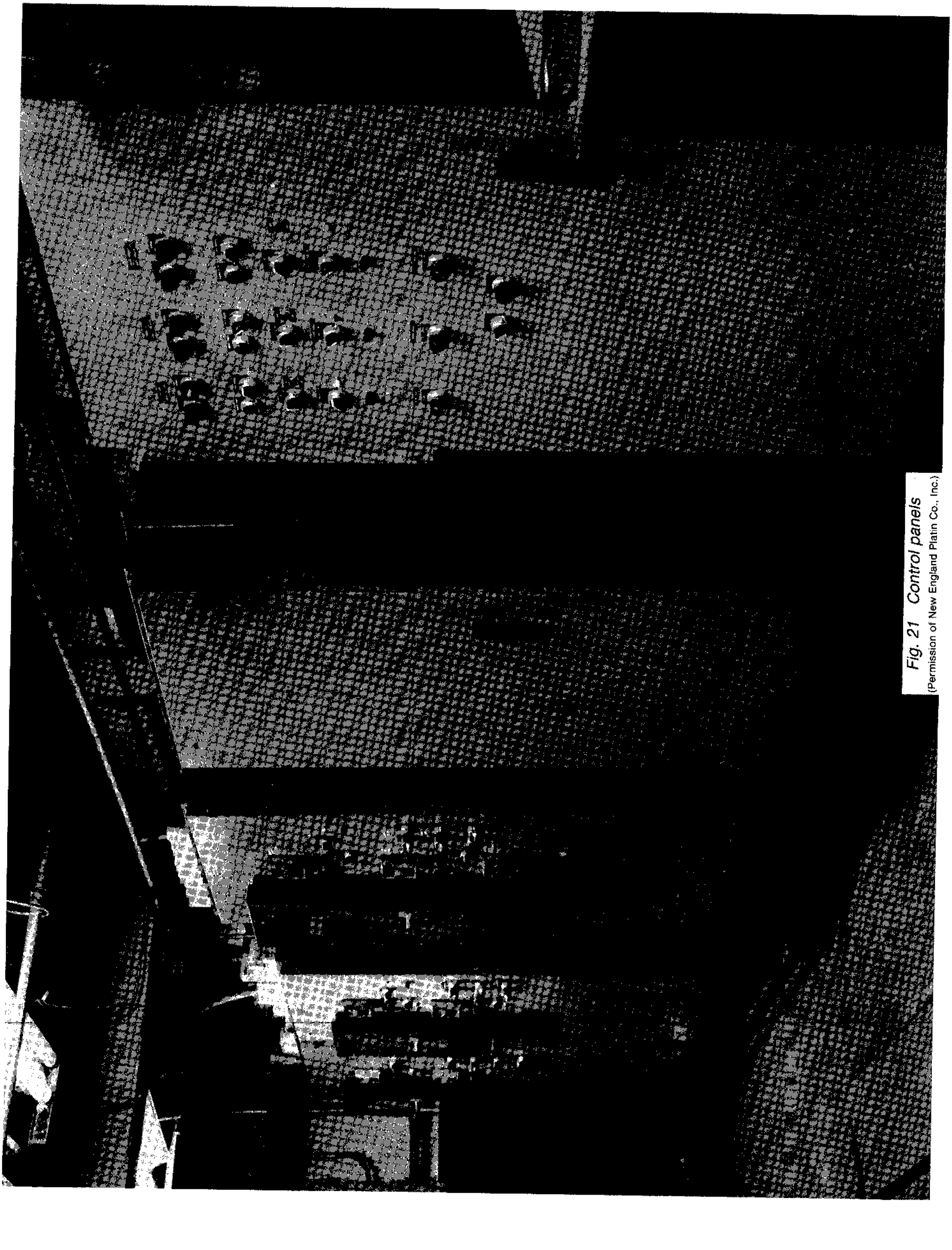


Fig. 21 Control panels
(Permission of New England Platin Co., Inc.)

11. Scan motor control and instrumentation panels to determine if
    a. Switches are in correct position,
    b. All equipment is operating properly,
    c. Proper lights are on, and
    d. No circuit breakers are tripped.
12. Look for signs of turbulence in oil separation facilities. Turbulent conditions are an indication of overloading.

In addition to visual observations which must be performed at the beginning and end of each shift, as well as whenever an operator walks through treatment facilities, there are many physical tasks which must be performed on a regular basis. The frequency of performance of the tasks depends on each particular situation (volumes of waste flows, wastes being treated and their concentrations) and the importance of the task in the production of an acceptable effluent quality. Typical tasks and recommended frequencies are listed in the remainder of this section.

7.21 Daily

1. Exercise H-O-A (Hand-Off-Automatic) switches to determine that all motors and pumps are working.
2. Clean all screens and filters.
3. Exercise all solenoid valves.
4. Calibrate polymer pump rates. See Section 7.45, "Waste Is Not Flocculating, 2. Polymer Flow Rate," for detailed procedures.
5. Verify instrumentation values using pH test strips, hand-held pH meter, or bring sample to laboratory for immediate pH measurement using laboratory pH meter.
6. Determine performance of waste treatment units by
    a. Using colorimetric test kits (HACH kits) or colorimetric test procedures with portable colorimetric/spectrophotometer and prepared testing reagents,
    b. Collecting composite samples and sending them to an approved commercial laboratory for analysis, or
    c. Verifying performance on site by the use of your laboratory's atomic adsoprtion instrument to measure metal concentrations.
7. Keep neat and accurate records of
    a. Test results, including time, date and comments,
    b. Amount of each chemical used,
        (1) Polymer rate and renewal,
        (2) Caustics and acids, and
        (3) Other chemicals.
    c. Frequency and volume of sludge hauled.

7.22 Weekly

1. Push all "Press to Test" motor running lights and alarm lights to determine light bulb condition.
2. Fill all oilers.
3. Inspect water traps and regulators on air lines.
4. Measure sump pump rates.
5. Clean pH and ORP probes to remove precipitates which occur in the precipitation steps and the cyanide destruction step. Also remove any accumulated oily wastes. See Section 7.51, "Cleaning," for detailed procedures.
6. Calibrate pH and ORP probes and meters. See Section 7.52, "Calibration," for detailed procedures.

7.23 Monthly

Prepare and submit monthly reports.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 87.

7.2A What activities are required of operators for effective operation of wastewater treatment facilities?

7.2B What can an operator determine about a precipitation process by visual observations?

7.2C How should the normal effluent from metal waste treatment processes look?

7.24 Sampling

7.240 Importance

The basis for any treatment plant monitoring program rests upon information obtained by sampling. Decisions based upon incorrect data may be made if sampling is performed in a careless and thoughtless manner. Obtaining good results will depend to a great extent upon the following factors:

1. Ensuring that the sample taken is truly representative of the wastestream,
2. Using proper sampling techniques, and
3. Protecting and preserving the samples until they are

analyzed. *THE GREATEST ERRORS PRODUCED IN LABORATORY TESTS ARE USUALLY CAUSED BY IMPROPER SAMPLING, POOR PRESERVATION, OR LACK OF ENOUGH MIXING DURING COMPOSITING*[17] *AND TESTING.*

7.241 Representative Sampling

You must always remember that wastestream flows can vary widely in quantity and composition over a 24-hour period. Also, composition can vary within a given stream at any single time due to partial settling of solids or floating of light materials. Samples should therefore be taken from the wastestream where it is well mixed. Obtaining a representative sample should be of major concern in any sampling and monitoring program.

Laboratory equipment, in itself, is generally quite accurate. Analytical balances weigh to 0.1 milligram. Graduated cylinders, pipets, and burets usually measure to 1 percent accuracy, so that the errors introduced by these items should total less than 5 percent, and under the worst possible conditions only 10 percent.

EVEN THOUGH A TEST IS ACCURATELY PERFORMED, THE RESULTS MAY BE ENTIRELY ERRONEOUS AND MEANINGLESS INSOFAR AS USE FOR PROCESS CONTROL IS CONCERNED, UNLESS A GOOD REPRESENTATIVE SAMPLE IS TAKEN. FURTHERMORE, A GOOD SAMPLE IS HIGHLY DEPENDENT UPON THE SAMPLING STATION. Whenever possible, select a place where mixing is thorough and the wastestream quality is uniform. The job of sample location and sampling must be taken seriously.

7.242 Time of Sampling

Let us consider next the time and frequency of sampling. In carrying out a testing program, particularly where personnel and time are limited due to the press of operational responsibilities, testing may necessarily be restricted to about one test day per week.

The time and day of sampling is quite important. Samples should be taken to represent typical weekdays or even varied from day to day within the week for a good indication of the characteristics of the wastestreams. The time of sampling should be based on production, start up, shut down, cleaning and maintenance schedules.

7.243 Types of Samples

The two types of samples collected in treatment plants are known as (1) grab samples, and (2) composite samples, and either may be obtained manually or automatically.

GRAB SAMPLES

A grab sample is a single sample of wastewater taken at neither a set time nor flow. The grab samples show the waste characteristics at the time the sample is taken. A grab sample may be preferred over a composite sample when:

1. The wastewater to be sampled does not flow on a continuous basis,
2. The wastewater characteristics are relatively constant,
3. You wish to determine whether or not a composite sample obscures extreme conditions of the waste, and
4. The wastewater is to be analyzed for dissolved gases (H_2S), residual chlorine, temperature, and pH. (*NOTE:* Grab samples for these water quality indicators may be collected at set times or specific time intervals.)

COMPOSITE SAMPLES

Since the wastewater quality changes from moment to moment and hour to hour, the best results would be obtained by using some sort of continuous sampler-analyzer. However, since operators are usually the sampler-analyzer, continuous analysis would leave little time for anything but sampling and testing. Except for tests which cannot wait due to rapid chemical or biological change of the sample, such as tests for pH and sulfide, a fair compromise may be reached by taking samples throughout the day at hourly or two-hour intervals.

When the samples are taken, they should be refrigerated immediately to preserve them from any chemical decomposition. When all of the samples have been collected for a 24-hour period, the samples from a specific location should be combined or composited together according to flow to form a single 24-hour composite sample.

To prepare a composite sample, (1) the rate of wastewater flow must be known and (2) each grab sample must then be taken and measured out in direct proportion to the volume of flow at that time. For example, Table 10 illustrates the hourly flow and sample volume to be measured out for a 12-hour proportional composite sample.

A very important point should be emphasized. *DURING COMPOSITING AND AT THE EXACT MOMENT OF TESTING, THE SAMPLES MUST BE VIGOROUSLY REMIXED*[18] *SO THAT THEY WILL BE OF THE SAME COMPOSITION AND AS WELL MIXED AS WHEN THEY WERE ORIGINALLY SAMPLED.* Sometimes such remixing may become lax, so that all the solids are not uniformly suspended. Lack of mixing can cause low results in samples of solids that settle out rapidly. Samples must therefore be mixed thoroughly and poured quickly before any settling occurs. If this is not done, errors of 25 to 50 percent may easily occur.

TABLE 10 DATA COLLECTED TO PREPARE PROPORTIONAL COMPOSITE SAMPLE

TIME	FLOW MGD	FACTOR	SAMPLE VOLUME
6 AM	0.2	100	20
7 AM	0.4	100	40
8 AM	0.6	100	60
9 AM	1.0	100	100
10 AM	1.2	100	120
11 AM	1.4	100	140
12 N	1.5	100	150
1 PM	1.2	100	120
2 PM	1.0	100	100
3 PM	1.0	100	100
4 PM	1.0	100	100
5 PM	0.9	100	90
		Total =	1140

A sample composited in this manner would total 1140 m*L*.

[17] *COMPOSITE (PROPORTIONAL) SAMPLES (come-POH-zit). A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.*

[18] *NOTE: If the sample has a low buffer capacity and the real pH is 6.5 or less, vigorous shaking can cause a significant change in pH level.*

7.244 Sampling Devices

Automatic sampling devices are wonderful timesavers and should be used where possible. However, as with anything automatic, problems do arise and the operator should be aware of potential difficulties. Sample lines to auto-samplers may build up with precipitates which may periodically slough off and contaminate the sample. Very regular cleanout of the intake line is required.

Manual sampling equipment includes dippers, weighted bottles, hand-operated pumps, and cross-section samplers. Dippers consist of wide-mouth corrision-resistant containers (such as cans or jars) on long handles that collect a sample for testing. A weighted bottle is a collection container which is lowered to a desired depth. At this location a cord or wire removes the bottle stopper so the bottle can be filled. Sampling pumps allow the inlet to the suction hose to be lowered to the sampling depth.

For sample containers, wide-mouth plastic bottles are recommended. Plastic bottles, though somewhat expensive initially, not only greatly reduce the problem of breakage and metal contamination, but are much safer to use. The wide-mouth bottles ease the washing problem. For regular samples, sets of plastic bottles bearing identification labels should be used.

7.245 Preservation of Samples

Sample deterioration starts immediately after collection for most wastewaters. The shorter the time that elapses between collection and analysis, the more reliable will be the analytical results.

In many instances, however, laboratory analysis cannot be started immediately due to the remoteness of the laboratory or workload. A summary of acceptable EPA (U.S. Environmental Protection Agency) methods of preservation appear in Table 11.

7.246 Quality Control in the Wastewater Laboratory

Having good equipment and using the correct methods are not enough to ensure correct analytical results. Each operator must be constantly alert to factors in the plant which can cause poor data quality. Such factors include: sloppy laboratory technique, deteriorated reagents, poorly operating instruments, and calculation mistakes.

7.247 Summary

1. Representative samples must be taken before any tests are made.
2. Select a good sampling location.
3. Collect samples and, if necessary, properly preserve them.
4. Mix samples thoroughly before compositing and at time of test.

7.248 Additional Reading

1. *HANDBOOK FOR MONITORING INDUSTRIAL WASTEWATER,* U.S. Environmental Protection Agency. Obtain from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Order No. PB 259146. Price $19.95.
2. *HANDBOOK FOR ANALYTICAL QUALITY CONTROL IN WATER AND WASTEWATER LABORATORIES,* Center for Environmental Research Information, U.S. Environmental Protection Agency, 26 West St. Clair Street, Cincinnati, Ohio 45268.

TABLE 11 U.S. EPA RECOMMENDED PRESERVATION METHODS FOR WATER AND WASTEWATER SAMPLES[a]

Test	Preservation Method	Max. Recommended Holding Time
Acidity Alkalinity	Store at 4°C	14 days
Ammonia	Add H_2SO_4 to pH <2 Store at 4°C	24 hours
BOD	Store at 4°C	48 hours
COD	Add H_2SO_4 to pH <2	28 days
Chloride	None required	28 days
Chlorine, residual	Det. on site	No holding
Cyanide	Add NaOH to pH >12 Store at 4°C	14 days
Dissolved Oxygen	Det. on site	No holding
Fluoride	None required	28 days
Mercury	Add HNO_3 to pH <2	28 days (in glass) 13 days (in plastic)
Metals	Add HNO_3 to pH <2	6 months
Nitrate	Add H_2SO_4 to pH <2 Store at 4°C	48 hours
Nitrite	Store at 4°C	48 hours
Oil & Grease	Add H_2SO_4 to pH <2	28 days
Organic Carbon	Add H_2SO_4 to pH <2 Store at 4°C	28 days
pH	Store at 4°C	No holding
Phenolics	Add H_3PO_4 to pH <4 & 1.0 g $CuSO_4$/L Store at 4°C	28 days
Phosphorus, ortho	Filter on site	48 hours
Phosphorus, total	Add H_2SO_4 to pH <2 Store at 4°C	28 days
Solids	Store at 4°C	7 days
Specific Conductivity	Store at 4°C	28 days
Sulfate	Store at 4°C	28 days
Sulfide	Add 2ml 1 *M* zinc acetate & 1 *N* NaOH to pH >9 Store at 4°C	7 days
Temperature	Det. on site	No holding
T. Kjeldahl Nitrogen	Add H_2SO_4 to pH <2 Store at 4°C	28 days
Turbidity	Store at 4°C	48 hours

[a] *FEDERAL REGISTER, Vol. 49, No. 209. Friday, October 26, 1984.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 88.

7.2D What are the largest sources of errors found in laboratory results?

7.2E Why must a representative sample be collected?

7.2F How would you prepare a proportional composite sample?

7.25 Flow Measurements - Meters and Maintenance

7.250 Flow Measurements, Use and Maintenance

Flow measurement is the determination of the quantity of a mass in movement within a known length of time (Figure 22). The mass may be solid, liquid, or gas and is usually contained within physical boundaries such as tanks, pipelines, and open channels or flumes. The limits of such physical or mechanical boundaries provide a measurable dimensional *AREA* that the mass is passing through. The speed at which the mass passes through these boundaries is related to dimensional distance and units of time; it is referred to as *VELOCITY*. Therefore, we have the basic flow formula:

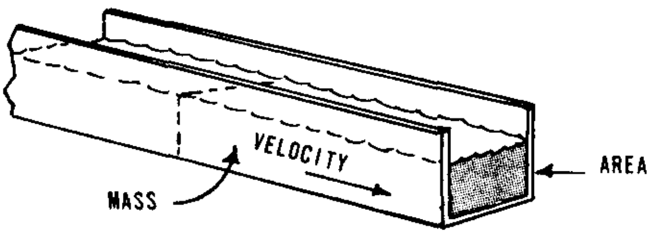


Fig. 22 Flow mass

Quantity = Area x Velocity

$$Q = AV$$

or

$$Q, \text{cu ft/sec} = (\text{Area, sq ft})(V, \text{ft/sec})$$

or

$$Q, \text{cu m/sec} = (\text{Area, sq m})(V, \text{m/sec})$$

The performance of a treatment facility cannot be evaluated or compared with other plants without flow measurement. Individual treatment units or processes in a treatment plant must be observed in terms of flow to determine their efficiency and loadings. Flow measurement is important to plant operation as well as to records of operation. The devices used for such measurement must be understood, be used properly, and most important, be maintained so that information obtained is accurate and dependable.

7.251 Operators' Responsibilities

Instrumentation and flow measurement devices should be considered as fragile mechanisms. Rough handling will damage the units in as serious a manner as does neglect. Treat the devices with care, keep them clean, and they will perform their designed functions with accuracy and dependability.

7.252 Various Devices for Flow Measurement

The selection of a type of flow-metering device, and its location, is made by the designer in the case of new plant construction. It is also possible that a metering device will have to be added to an existing facility. In both cases the various types available, their limitations, and criteria for installation should be known. Often the criteria for installation must be understood for the proper use and maintenance of a fluid flow meter. Metering devices commonly used in treatment facilities are listed in Table 12.

CONSTANT DIFFERENTIAL - A mechanical device called the "float" is placed in a tapered tube in the flow line (Figure 23). The difference in pressures above and below the float causes the float to move with flow variations. Instantaneous rate of flow is read out directly on a calibrated scale attached to the tube. Read scale behind top of float to obtain flow rate.

TABLE 12 SUMMARY OF FLOW METERING DEVICES

Type	Common Name	Application
Constant Differential	Rotameter	Liquids and Gases a. Chlorination
Head Area	Weirs Rectangular Cipoletti V-Notch Proportional	Liquids - partially filled channels, basins, or clarifiers a. Influent b. Basin control c. Effluent d. Effluent
	Flumes Parshall Palmer-Bowlus Nozzles	Liquids - partially filled pipes and channels a. Influent b. Basin control c. Effluent d. Distribution
Velocity Meter	Propeller	Liquids - channel flow, clean water piped flow
	Magnetic	Liquids and sludge in closed pipe a. Influent b. Basin control c. Sludge d. Distribution
Differential Head	Venturi Tube Flow Nozzle Orifice	Gases and liquids in closed pipes a. Influent b. Basin control c. Effluent d. Gas e. Distribution
Displacement	Piston Diaphragm	Gases and liquids in closed pipes a. Plant water b. Chemical feeders

A description of how each device works is in reality a definition of the meter type.

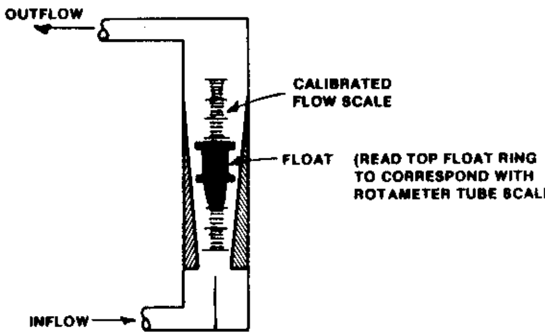


Fig. 23 Rotameter

HEAD AREA - A mechanical constriction or barrier is placed in the open flow line causing an upstream rise in liquid level (Figures 24, 25, and 26). The rise of "head" (H) is mathematically related to velocity (speed) of the flow. The head measurement can be used in a formula to calculate flow rate.

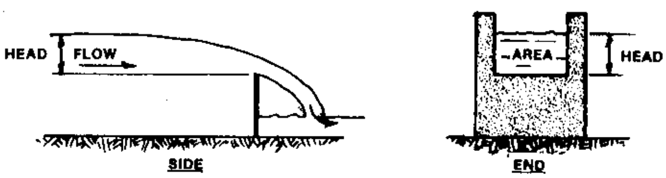


Fig. 24 Rectangular weir

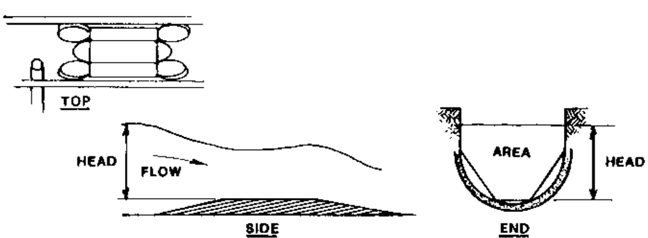


Fig. 25 Palmer-Bowlus

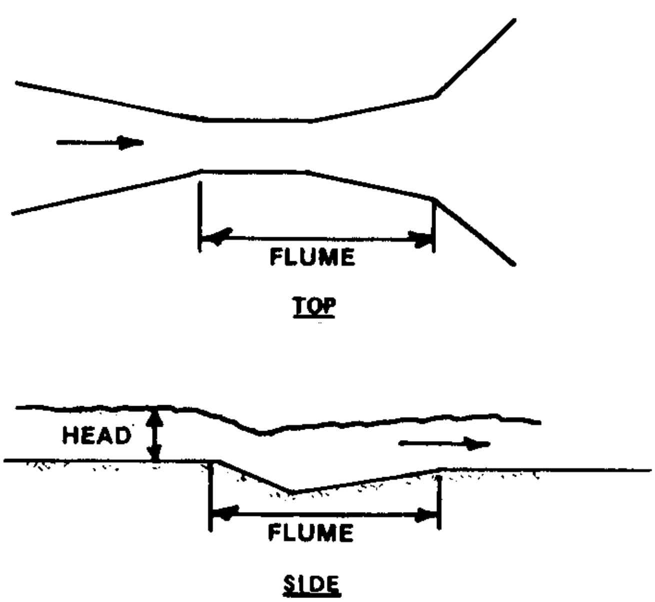


Fig. 26 Parshall flume

VELOCITY METERS - The velocity of the liquid flowing past the measurement point through a given area gives a direct relation to flow rate. The propeller type is turned by fluid flow past propeller vanes which move gear trains. These gear trains are used to indicate the fluid velocity or flow rate. The velocity of liquid flow past the probes of a magnetic meter is related to flow of electrical current between the probes and is read out as the flow rate through secondary instrumentation. Pitot tubes are used to measure the velocity head (H) in flowing water to give the flow velocity ($V = \sqrt{2gH}$). (Figure 27)

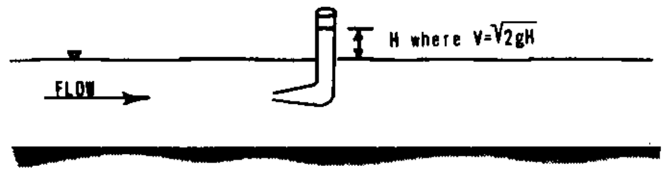


Fig. 27 Pitot tube

DIFFERENTIAL PRODUCERS - A mechanical constriction (Figure 28) in pipe diameter (reduction in pipe diameter) is placed in the flow line shaped to cause the velocity of flow to increase through the restriction. When the velocity increases, a pressure drop is created at the restriction. The difference between line pressure at the meter inlet and reduced pressure at the throat section is used to determine the flow rate which is indicated by a secondary instrument.

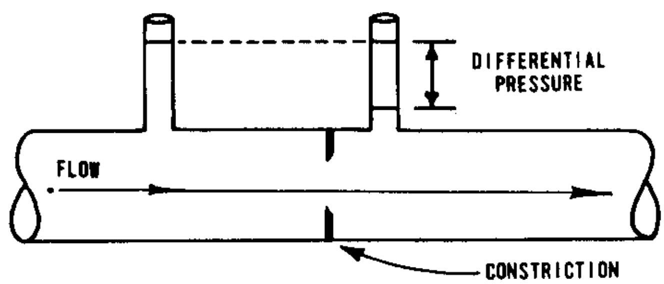


Fig. 28 Differential producer

DISPLACEMENT UNITS - Liquid or gas enters, fills a tank or chamber of known dimensions, activates a mechanical counter, and empties the tank in readiness for another filling. As the chamber fills and empties, mechanical gearing activates a counter which measures the amount of time the cycle takes. Flow rate can then be calculated using the size of the tank and the time factor.

7.253 Location of Measuring Devices

The selection of a particular type of meter or measuring device and its location in a particular flow line or treatment facility is usually a decision made by the plant designer. Ideally the flow should be in a straight section before the meter. The device must be accessible for servicing. In open channels the flow should not be changing directions, nor should waves be present in the metering section above the measuring device. Valves, elbows, and other fixtures that could disrupt the flow ahead of a meter can upset the accuracy and reliability of a flow meter. Most flow meters are calibrated (checked for accuracy) in the factory, but they also should be checked in their actual field installation. When a properly installed and field-calibrated meter starts to give strange results, check for obstructions in the flow channel and the flow-metering device.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 88.

7.2G What is flow measurement?

7.2H Write the basic flow formula.

7.2I Why should flow be measured?

7.2J List several types of flow-measuring devices.

7.2K If a flow meter does not read properly, what items should be checked as potential causes of error?

7.3 MAINTENANCE

7.30 Safety

Maintenance of equipment and treatment facilities requires special and diverse talents. Frequently operators are also expected to perform maintenance duties. Operators must become very familiar with how their treatment facilities work so they can understand what is happening when there is a breakdown or failure. This means that both operators and maintenance people must familiarize themselves with the electrical diagrams of their system. *WARNING.* If you do not understand electricity and electronic systems, are not qulaified and/or are not authorized to do electrical maintenance or repairs, then *DON'T DO IT.* Many facilities have an "electrician" who repairs all electrical and electronic problems. However, operators should learn as much as possible about electricity *FOR THEIR OWN SAFETY* and to enable them to analyze electrical problems and to communicate effectively with electricians.

7.31 Preventive Maintenance Program

All waste treatment facilities *NEED A PREVENTIVE MAINTENANCE PROGRAM.* The purpose of this program is to keep the equipment and treatment processes working as intended, to minimize breakdowns, failures and repairs, and also to keep overall O & M costs down both today and in the future. An effective preventive maintenance program consists of procedures which notify maintenance people when tasks should be performed, records who performed the maintenance, and records when it was done. Many operators use computers to notify them of scheduled maintenance activities and also to record information on tasks completed.

Consult your equipment manufacturers' maintenance manuals for instructions on equipment maintenance procedures and frequencies. Use this information to develop a specific preventive maintenance program for your facilities. Typical preventive maintenance tasks and their frequencies are listed in the remainder of this section.

7.32 Daily

1. Fix all leaks when they occur. Slow leaks typically leave a deposit or crust near the leak.
2. Change all mechanical seals when they start to leak.

7.33 Weekly

1. Clean or change any meter faces which are becoming cloudy (opaque) or hard to read.
2. Clean or change any clear hoses or pipes that are becoming opaque. You need to be able to see if anything is moving through these hoses when the pumps are supposed to be operating.
3. Clean pH and ORP probes (if not done by operators). See Section 7.51, "Cleaning."
4. Calibrate pH and ORP probes and meters (also listed under 7.2, "Operation", 7.22, "Weekly".) See Section 7.52, "Calibration," for detailed procedures.

7.34 Monthly

NOTE: Some manufacturers recommend a more frequent time interval.

1. Grease bearings.
2. Inspect drive belts, starter contacts and other consumable items and change when necessary.

7.35 Semi-annually

Change lubricant in gear boxes.

7.36 Annually

Clean, neutralize, prime and paint all painted items. If a paint coating becomes damaged due to splashes, clean, neutralize, prime and paint as soon as possible to protect the equipment.

7.37 Inventory

An important part of every preventive maintenance program is an inventory of spare parts for repairs of equipment needed for critical service. Many manufacturers recommend a spare parts inventory for their equipment. Computers are being used today to maintain an inventory of all equipment being used as well as spare parts and substitute equipment for critical service. Typical items that should be included in an inventory are listed below.

1. Spare pump for each critical service.
2. Spare seals.
3. Motor heaters.
4. Fuses.
5. Solenoid valves.
6. Instrumentation circuit boards.
7. pH and ORP probes (these have a limited shelf life, so don't overstock).
8. Paint.
9. Motor starter contacts.
10. Critical valves.
11. Belts, gears, and specialized parts, such as check valves and diaphragms.
12. Running lights.
13. Recorder charts and ink.
14. Tools.

7.38 Ventilation and Exhaust Systems

Properly operating ventilation systems are of greatest importance in metal plating and metal finishing waste treatment facilities. The possibility exists that acid mists and extremely toxic gases such as cyanide, hydrogen sulfide and chlorine may be released or escape into the work environment. Toxic gas monitors and their alarm systems must be inspected and calibrated on a daily basis. The actual ventilation systems must be maintained in strict accordance with the manufacturer's recommendations.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 88.

7.3A Why should operators learn as much as possible about electricity?

7.3B What is the purpose of a preventive maintenance program?

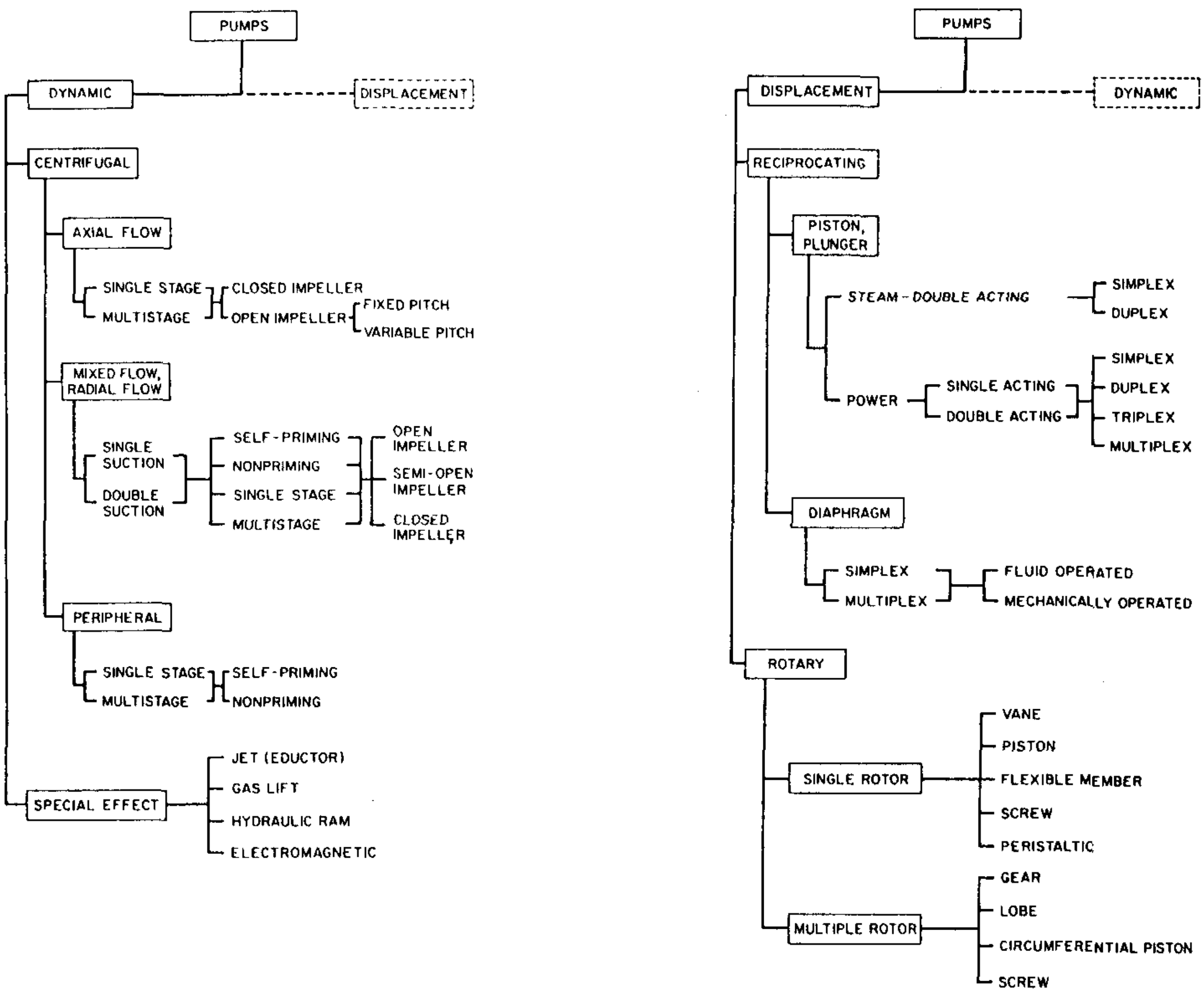
7.3C How can an operator obtain instructions on how to maintain equipment and the frequency of each maintenance task?

7.3D Why are properly operating ventilation systems important in metal plating and metal finishing facilities?

7.39 Pumps

7.390 Types of Pumps

Pumps serve many purposes in treatment plants. They may be classified by the character of the material handled, such as influent or treated wastewater. Or, they may relate to the conditions of pumping: high lift, low lift, or high capacity. They may be further classified by principle of operation, such as centrifugal, propeller, reciprocating, and turbine (Figure 29).



Dynamic types of pumps

Displacement types of pumps

Fig. 29 Classification of pumps

The type of material to be handled and the function or required performance of the pump vary so widely that the designing engineer must use great care in preparing specifications for the pump and its controls. Similarly, the operator must conduct a maintenance and management program adapted to the peculiar characteristics of the equipment.

7.391 Cavitation

Cavitation is a condition that can cause a drop in pump efficiency, vibration, noise and rapid damage to the impeller of a pump. Cavitation occurs due to unusually low pressures within a pump. These low pressures can develop when pump inlet pressures drop below the design inlet pressures or when the pump is operated at flow rates considerably higher than design flows. When the pressure within the flowing water drops very low, the water starts to boil and vapor bubbles form. These bubbles then collapse with great force which knocks metal particles off the pump impeller. Excessive suction lift is a frequent cause of cavitation.

7.392 Starting a New Pump

The initial startup work described in this paragraph should be done by a competent and trained person, such as a manufacturer's representative, consulting engineer, or an experienced operator. The operator can learn a lot about pumps and motors by accompanying and helping a competent person put new equipment into operation.

Before starting a pump, lubricate it according to the lubrication instructions. Turn the shaft by hand to see that it rotates freely. Then check to see that the shafts of the pump and motor are aligned and the flexible coupling adjusted. Check the electric voltage with the motor characteristics and inspect the wiring. See that thermal overload units in the starter are set properly. Turn on the motor just long enough to see that it turns the pump in the direction indicated by the rotational arrows marked on the pump. If separate water seal units or vacuum primer systems are used, these should be started. Finally, make sure lines are open. Sometimes there is an exception (see following paragraph) in the case of the discharge valve.

A pump should not be run without first having been primed. To prime a pump, the pump must be completely filled with water. In some cases, automatic primers are provided. If they are not, it is necessary to vent the casing. Most pumps are provided with a valve to accomplish this. Allow the trapped air to escape until water flows from the vent; then replace the vent cap. In the case of suction-lift applications, the pump must be filled with water unless a self-primer is provided. In nearly every case, you may start a pump with the discharge valve open. Exceptions to this, however, are where water hammer or pressure surges might result, or where the motor does not have sufficient margin of safety or power. Sometimes there are no check valves in the discharge line. In this case (with the exception of positive displacement pumps) it is necessary to start the pump and then open the discharge lines. Where there are common discharge headers, it is essential to start the pump and then open the discharge valve. A positive displacement pump (reciprocating or piston types) should never be operated against a closed discharge line.

After starting the pump, again check to see that the direction of rotation is correct. Packing-gland boxes (stuffing boxes) should be observed for slight leakage (approximately 60 drops per minute). Check to see that the bearings do not overheat from over- or under-lubrication. The flexible coupling should not be noisy; if it is, the noise may be caused by misalignment or improper clearance or adjustment. Check to be sure pump anchorage is tight. Compare delivered pump flows and pressures with pump performance curves. If pump delivery falls below performance curves, look for obstructions in the pipelines and inspect piping for leaks.

7.393 Pump Shutdown

When shutting down a pump for a long period, the motor disconnect switch should be opened, locked out, and tagged with reason for tag noted. If the electric motor is equipped with winding heaters, check to be sure they are turned on. This helps to prevent condensation from forming which can weaken the insulation on the windings. All valves on the suction, discharge, and water-seal lines should be shut tightly. Completely drain the pump by removing the vent and drain plugs.

Inspect the pump and bearings thoroughly so that all necessary servicing may be done during the inactive period. Drain the bearing housing and then add fresh lubricant. Follow any additional manufacturer's recommendations.

7.394 Pump-Driving Equipment

Driving equipment used to operate pumps includes electric motors and internal combustion engines. In rare instances, pumps are driven with steam turbines, steam engines, air and hydraulic motors.

In all except the large installations, electric motors are used almost exclusively, with synchronous and induction types being the most commonly used. Synchronous motors operate at constant speeds and are used chiefly in large sizes. Three-phase, squirrel-cage induction motors are most often used in treatment plants. These motors require little attention and, under average operating conditions, the factory lubrication of the bearing will last approximately one year. (Check with the manufacturer for average number of operating hours for bearings.) When lubricating motors, remember that too much grease may cause bearing trouble or damage the winding.

Clean and dry all electrical contacts. Inspect for loose electrical contacts. Make sure that hold-down bolts on motors are secure. Check voltage while the motor is starting and running. Examine bearings and couplings.

7.395 Electrical Controls

A variety of electrical equipment is used to control the operation of pumps or to protect electric motors. If starters, disconnect switches, and cutouts are used, they should be installed in accordance with the local regulations (city and/or county codes) regarding this equipment. In the case of larger motors, the power company often requires starters which do not overload the power lines.

The electrode-type, bubbler-type, and diaphragm-type water level control systems are all similar in effect to the float-switch system. Scum is a problem with many waste-stream level controls that operate pumps and must be removed on a regular basis.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 88.

7.3E What is cavitation?

7.3F Where would you find out how to lubricate a pump?

7.3G What problems can develop if too much grease is used in lubricating a motor?

7.396 Operating Troubles

The following list of operating troubles includes most of the causes of failure or reduced operating efficiency. The remedy or cure is either obvious or may be identified from the description of the cause.

SYMPTOM A — PUMP WILL NOT START

CAUSES:

1. Blown fuses or tripped circuit breakers due to:
   - A. Rating of fuses or circuit breakers not correct,
   - B. Switch (breakers) contacts corroded or shorted,
   - C. Terminal connections loose or broken somewhere in the circuit,
   - D. Automatic control mechanism not functioning properly,
   - E. Motor shorted or burned out,
   - F. Wiring hookup or service not correct,
   - G. Switches not set for operation,
   - H. Contacts of the control relays dirty and arcing,
   - I. Fuses or thermal units too warm,
   - J. Wiring short-circuited, and
   - K. Shaft binding or sticking due to rubbing impeller, tight packing glands, or clogging of pump.
2. Loose connections, fuse, or thermal unit

SYMPTOM B — REDUCED RATE OF DISCHARGE

CAUSES:

1. Pump not primed
2. Air in the water
3. Speed of motor too low
4. Improper wiring
5. Defective motor
6. Discharge head too high
7. Suction lift greater than anticipated
8. Impeller clogged
9. Discharge line clogged
10. Pump rotating in wrong direction
11. Air leaks in suction line or packing box
12. Inlet to suction line too high, permitting air to enter
13. Valves partially or entirely closed
14. Check valves stuck or clogged
15. Incorrect impeller adjustment
16. Impeller damaged or worn
17. Packing worn or defective
18. Impeller turning on shaft because of broken key
19. Flexible coupling broken
20. Loss of suction during pumping may be caused by leaky suction line, ineffective water or grease seal
21. Belts slipping
22. Worn wearing ring

SYMPTOM C — HIGH POWER REQUIREMENTS

CAUSES:

1. Speed of rotation too high
2. Operating heads lower than rating for which pump was designed, resulting in excess pumping rates
3. Sheaves on belt drive misaligned or maladjusted
4. Pump shaft bent
5. Rotating elements binding
6. Packing too tight
7. Wearing rings worn or binding
8. Impeller rubbing

SYMPTOM D — NOISY PUMP

CAUSES:

1. *Pump not completely primed*
2. Inlet clogged
3. Inlet not submerged
4. Pump not lubricated properly
5. Worn impellers
6. Strain on pumps caused by unsupported piping fastened to the pump
7. Foundation insecure
8. Mechanical defects in pump
9. Misalignment of motor and pump where connected by flexible shaft
10. Rocks in the impeller
11. Cavitation

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 88.

7.3H What items would you check if a pump will not start?

7.3I How would you attempt to increase the discharge from a pump if the flow rate is lower than expected?

7.397 Starting and Stopping Pumps

The operator must determine what treatment processes will be affected by either starting or stopping a pump. The pump discharge point must be known and valves either opened or closed to direct flows as desired by the operator when a pump is started or stopped.

7.3970 Centrifugal Pumps. Basic rules for the operation of centrifugal pumps include the following items.

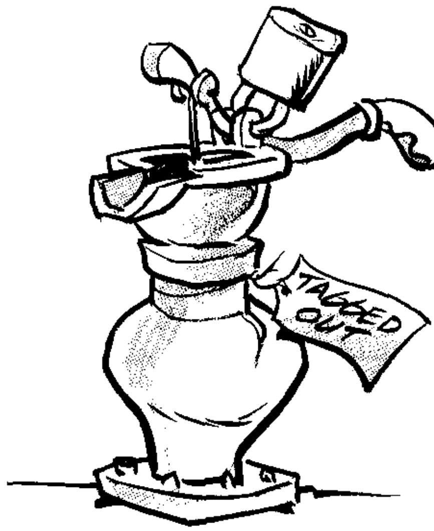
1. Do not operate the pump when safety guards are not installed over or around moving parts.
2. Do not start a pump that has been locked or tagged out for maintenance or repairs.
3. Never run a centrifugal pump when the impeller is dry. Always be sure the pump is primed.
4. Never attempt to start a centrifugal pump whose impeller or shaft is spinning backwards.
5. Do not operate a centrifugal pump that is vibrating excessively after startup. Shut unit down and isolate pump from system by closing the pump suction and discharge valves. Look for a blockage in the suction line and the pump impeller.

There are several situations in which it may be necessary to start a *CENTRIFUGAL* pump against a *CLOSED* discharge valve. Once the pump is primed, running and indicating a discharge pressure, slowly open the pump discharge valve until the pump is fully on line. This procedure is used with treatment processes or piping systems with vacuums or pressures that cannot be dropped or allowed to fluctuate greatly while an alternate pump is put on the line.

Most centrifugal pumps used in treatment plants are designed so that they can be easily started even if they haven't been primed. This is accomplished with a positive static suction head or a low suction lift. On most of these arrangements, the pump will not require priming as long as the pump and the piping system do not leak. Leaks would allow the water to drain out of the pump volute. When pumps in water systems lose their prime, the cause is often a faulty check valve on the pump discharge line. When the pump stops, the discharge check valve will not seal (close) properly. Water previously pumped then flows back through the check valve and through the pump. The pump is drained and has lost its prime.

About ninety-five percent of the time, the centrifugal pumps in treatment plants are ready to operate with suction and discharge valves open and seal water turned on. When the automatic start or stop command is received by the pump from the controller, the pump is ready to respond properly.

When the pumping equipment must be serviced, take it off the line by locking and tagging out the pump controls until all service work is completed.



QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 88.

7.3J Why should a pump that has been locked or tagged out for maintenance or repairs not be started?

7.3K Under what conditions might a centrifugal pump be started against a closed discharge valve?

STOPPING PROCEDURES

This section contains a typical sequence of procedures to follow to stop a centrifugal pump. Exact stopping procedures for any pumping system depend upon the condition of the discharge system. The sudden stoppage of a pump could cause severe *WATER HAMMER*[19] problems in the piping system.

1. Inspect process system affected by pump, start alternate pump if required, and notify supervisor or log action.
2. Before stopping and operating pump, check its operation. This will give an indication of any developing problems, required adjustments, or problem conditions of the unit. This procedure only requires a few minutes. Items to be inspected include:
   a. Pump packing gland.
      1) Seal water pressure
      2) Seal leakage (too much, sufficient or too little leakage)
      3) Seal leakage drain flowing clear
      4) Mechanical seal leakage (if equipped)

[19] *Water Hammer. The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.*

b. Pump operating pressures.

1) Pump suction (Pressure Vacuum)

A higher vacuum than normal may indicate a partially plugged or restricted suction line. A lower vacuum may indicate a higher suction water level or a worn pump impeller or wearing rings.

2) Pump discharge pressure

System pressure is indicated by the pump discharge pressure. Lower than normal discharge pressures can be caused by:

a) Worn impeller or wearing rings in the pump;

b) A different point of discharge can change discharge pressure conditions;

c) A broken discharge pipe can change the discharge head.

NOTE: To determine the maximum head a centrifugal pump can develop, slowly close the discharge valve at the pump. Read the pressure gage between the pump and the discharge valve when the valve is fully closed. This is the maximum pressure the pump is capable of developing. Do not operate the pump longer than a few minutes with the discharge valve closed completely because the energy from the pump is converted to heat and water in the pump can become hot enough to damage the pump.

c. Motor temperature and pump bearing temperature.

If motor or bearings are too hot to touch, further checking is necessary to determine if a problem has developed or if the temperature is normal. High temperatures may be measured with a thermometer.

d. Unusual noises, vibrations, or conditions about the equipment.

If any of the above items indicate a change from the pump's previous operating condition, additional service or maintenance may be required during shutdown.

3. Actuate stop switch for pump motor and lock out switch. If possible use switch next to equipment so that you may observe the equipment stop. Observe the following items:

a. Check valve closes and seats.

Valve should not slamp shut, or discharge piping will jump or move in their supports. There should not be any leakage around the check valve shaft. If check valve is operated automatically, it should close smoothly and firmly to the fully closed position.

NOTE: If the pump is not equipped with a check valve, close discharge valve before stopping pump.

b. Motor and pump should wind down slowly and not make sudden stops or noises during shutdown.

c. After equipment has completely stopped, pump shaft and motor should not start back-spinning. If back-spinning is observed in a pump with a check valve or foot valve, close the pump discharge valve *SLOWLY!* Be extra careful if there is a plug valve on a line with a high head because when the discharge valve is part way closed, the plug valve could slam closed and damage the pump or piping.

4. Go to power control panel containing the pump motor starters just shut down and *OPEN* motor breaker switch, lock out, and tag.

5. Return to pump and close:

a. Discharge valve,

b. Suction valve,

c. Seal water supply valve, and

d. Pump volute bleed line (if so equipped).

6. If required, close and open appropriate valves along piping system through which pump was discharging.

Starting Procedures

This section contains a typical sequence of procedures to follow to start a centrifugal pump.

1. Check motor control panel for lock and tags. Examine tags to be sure that *NO* item is preventing startup of equipment.

2. Inspect equipment.

a. Be sure stop switch is locked out at equipment location.

b. Guards over moving parts must be in place.

c. Clean-out on pump volute and drain plugs should be installed and secure.

d. Valves should be in closed position.

e. Pump shaft must rotate freely.

f. Pump motor should be clean and air vents clear.

g. Pump, motor, and auxiliary equipment lubricant level must be at proper elevations.

h. Determine if any special considerations or precautions are to be taken during startup.

3. Follow pump discharge piping route. Be sure all valves are in the proper position and that the pump flow will discharge where intended.

4. Return to motor control panel.
   a. Remove tag.
   b. Remove padlock.
   c. Close motor main breaker.
   d. Place selector switch to manual (if you have automatic equipment).
5. Return to pump equipment.
   a. Open seal water supply line to packing gland. Be sure seal water supply pressure is adequate.
   b. Open pump suction valve slowly.
   c. Bleed air out of top of pump volute in order to prime pump. Some pumps are equipped with air relief valves or bleed lines back to the wet well for this purpose.
   d. When pump is primed, slowly open pump discharge valve and recheck prime of pump. Be sure no air is escaping from volute.
   e. Unlock stop switch and actuate start switch. Pump should start.
6. Inspect equipment.
   a. Motor should come up to speed promptly. If ammeter is available, test for excessive draw of power (amps) during startup and normal operation. Most three-phase induction motors used in treatment plants will draw 5 to 7 times their normal running current during the brief period when they are coming up to speed.
   b. No unusual noise or vibrations should be observed during startup.
   c. Check valve should be open and no chatter or pulsation should be observed.
   d. Pump suction and discharge pressure readings should be within normal operating range for this pump.
   e. Packing gland leakage should be normal.
   f. If a flow meter is on the pump discharge, record pump output.
7. If the unit is operating properly, return to the motor control panel and place the motor mode of operation selector in the proper operating position (manual-auto-off).
8. The pump and auxiliary equipment should be inspected routinely after the pump has been placed back into service.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 88.

7.3L What should be done before stopping an operating pump?

7.3M What could cause a pump shaft or motor to spin backwards?

7.3N Why should the position (open or closed) of all valves be checked before starting a pump?

7.3971 Positive Displacement Pumps. Steps for starting and stopping positive displacement pumps are outlined in this section. There are two basic differences in the operation of positive displacement pumps as compared with centrifugal pumps. Centrifugal pumps (due to their design) will permit an operator error, but a positive displacement pump will not and someone will have to pay for correcting the damages.

Important rules for operating positive displacement pumps include:

1. NEVER, NEVER OPERATE A POSITIVE DISPLACEMENT PUMP AGAINST A CLOSED VALVE, ESPECIALLY A DISCHARGE VALVE.

1. Excessive pressure could rupture the equipment and possibly seriously injure or kill someone nearby.
2. Positive displacement pumps are used to pump sludge and to meter and pump chemicals. Care must be exercised to avoid venting chemicals to the atmosphere.
3. Never operate a positive displacement pump when it is dry or empty, especially the progressive-cavity types that use rubber stators. A small amount of liquid is needed for lubrication in the pump cavity between the rotor and the stator.

In addition to *NEVER* closing a discharge valve on an operating positive displacement pump, the only other difference (when compared with a centrifugal pump) may be that the positive displacement pump system may or may not have a check valve in the discharge piping after the pump. Installation of a check valve depends upon the designer and the material being pumped.

Other than the specific differences mentioned in this section, the starting and stopping procedures for positive displacement pumps are similar to the procedures for centrifugal pumps.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 88.

7.3O What is the most important rule regarding the operation of positive displacement pumps?

7.3P What could happen if a positive displacement pump is started against a closed discharge valve?

7.4 TROUBLESHOOTING

Operators performing the visual observations listed in Section 7.2, "Operation," may discover that a treatment process is "upset." Process upsets may be caused by equipment, instrumentation or control system failure or operator error. Operators should prepare troubleshooting checklists for their facilities to aid both new and experienced operators to correct the cause of the upset. This section contains some typical troubleshooting checklists.

7.40 pH Meters

If pH meter readings appear to be incorrect, check the chemical feed systems.

DIRECT CHEMICAL FEED SYSTEM

1. Chemical Pump Is Not Pumping
   a. Pump is turned off.
   b. Supply line is clogged.
   c. Tank shut-off valve is closed.
   d. Pump impeller is jammed.
   e. Pump diaphragm is ruptured.
   f. Pump rate controls have been turned off or set very low.
   g. Pump check valves are stuck open or closed.
   h. Pump is plugged.
   i. Pump has burned its fuse or tripped its circuit breaker.
   j. Chemical feed tank is empty.

INDIRECT CHEMICAL FEED SYSTEM

1. Transfer Pump Is Not Working
   a. See all of the above reasons for "Chemical Pump Is Not Pumping."
2. Level Controls Are Not Working
   a. Probes are coated with precipitates.
   b. Probes are shorted out with moisture and chemicals.
   c. Probe rods have vibrated loose.
   d. Chemical encrustations (coatings) limit probe movement (types of float switches or magnetic reed switches).
   e. Power is off.
3. Solenoid Valve Is Not Working
   a. *Check valve action* by exercising the valve with the H-O-A switch. If the valve works in the *HAND* position, the valve is not the problem. If the valve does not work in either the *HAND* or *AUTOMATIC* position, disconnect the coil and test it with a volt meter for continuity, resistance, and shorts in the circuit. If the coil is OK, check the circuit for:
      1) Blown fuses.
      2) Shorted or loose wires at the panel switch.
      3) Tripped circuit breakers.
      4) Continuity from the panel to the valve location. Also check for shorts due to moisture in junction boxes and conduits.
      5) Bad switch.

   If the valve does not work in the *AUTO* position, check the trip point setting (the setting at which the control relay is supposed to work). Vary the trip point setting above and below the pH or ORP that the instrument is reading. If the relay then works and the solenoid or pump works, then the problem is in the chemical supply and not in the instrumentation. If the relay will not operate when the switch is in the *AUTO* position, the problem could be a:
      1) broken or blown relay,
      2) blown fuses,
      3) "burned" circuit board, or
      4) broken or loose connection or wire on the board.

Operators should not attempt repairs beyond this level of difficulty. Problems of this type require the services of a specialist who is familiar with the specific instrumentation.

OTHER REASONS FOR pH METER READINGS OUT OF SCALE

1. Extra-high concentrations of chemicals in the waste discharge. Check to see if there is a tank leak in the plant or on the treatment pad.
2. Chemical mixer may not be working properly due to:
   a. Broken belt,
   b. Stripped gears,
   c. Loose impeller, or
   d. Tripped circuit breaker.

7.41 ORP Meter

ORP (oxidation-reduction potential) is considered an independent operating guideline. However, for an ORP value to be meaningful for treatment process control purposes, ORP readings must be taken at a relatively fixed or constant pH level. Therefore, if the pH varies, the ORP reading will also vary either up or down depending on the chemical reaction in question (either oxidation or reduction). If an ORP reading is out of its proper range, the first thing you should do is measure the pH. If the pH value is not in its proper range, make the necessary adjustments to get the pH back to its proper level; then observe the ORP values to determine if they are at the expected values. If ORP readings are still out of the proper range, check the items listed below:

1. Supply tank chemical level
   a. Refill empty tanks
   b. Inspect shut-off valves or switches
2. Defective pumps
3. Clogged chemical supply lines
4. Chemical supply rate to the reactor tank
5. Leaks from tanks within the plant (inspect specialized use tanks such as chrome or cyanide)

In order to get the ORP reaction back to the proper state, you may have to hand transfer chemicals. If hand transfer must be done, *USE EXTREME CAUTION* and always use the proper equipment to transfer any chemical.

7.42 Instrumentation

If none of the instrumentation is functioning, check the following items.

1. Inspect the instrumentation circuit breaker. If the circuit breaker is not tripped, use a volt meter to test for incoming power to the panel circuit breaker.
2. If incoming power is not present at the panel circuit breaker, examine the circuit breakers at the facility distribution panels.
3. Reset any circuit breakers that have been tripped to the *OFF* position, after checking for shorts (why did it trip?).
4. If power is present and the instrumentation is not working, check for:
   a. Blown fuses on *"MOTHER" CIRCUIT BOARDS*[20],
   b. Blown fuses on instrumentation power packs (transformers),
   c. Blown transformers, and
   d. Loose wires.

If one specific item of instrumentation is not functioning, inspect the following:

1. Probes for damage,
2. Probe assembly and junction boxes for moisture,
3. Individual unit fuses,
4. Circuit boards for "burned" condition (examine the "traces" on the boards to see if they are intact),
5. Wires and components for looseness, and
6. Voltages at locations specified by the manufacturer.

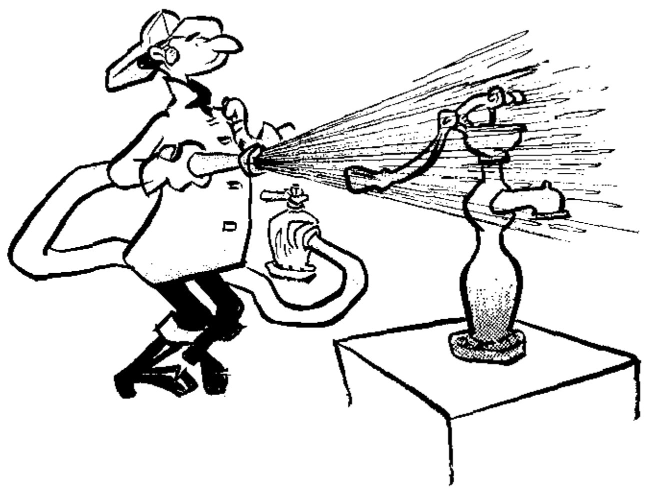
Replace defective components on the circuit boards.

If an instrumentation problem cannot be identified and corrected by these procedures, request specialized help.

7.43 Centrifugal Pump

If a centrifugal pump is not operating properly, check the following items.

1. Pump is on (motor is running).
2. Fluid level of supply.
3. Vapor lock conditions in pump.
4. All valves on supply and discharge sides of the pump are open.
5. Concentration level of chemicals. If the concentration level of a chemical being pumped has increased, this may cause an increase in the *SPECIFIC GRAVITY*[21] of the chemical solution which could require a larger horsepower motor. Magnetically coupled pumps may not be physically capable of pumping the heavier or more viscous chemical solution, so the magnetic coupling may "stall" or "slip out." This problem can sometimes be corrected by reducing the diameter of the pump impeller. However, reducing the impeller diameter will also reduce the chemical pumping rate.
6. If the pump's motor switch is on but the motor is not running, turn the motor switch off immediately. The motor is in a tripped condition. Reset starter. If the starter will not reset, inspect the motor "heaters" to see if they are "burned." If they are burned, disconnect the motor and examine the windings for shorts. Replace all defective items.
7. If the pump's impeller is jammed, the cause may be due to:
   a. Stress on the pump body which has warped the pump,
   b. Impurities in the liquid being pumped (clean the pump), or
   c. Accumulation of a crust within the pump body (clean the pump).



7.44 Diaphragm Pump

If a diaphragm pump is not working properly, check the following items.

1. Power supply (electricity or air),
2. Air pressure,
3. Fuses or circuit breakers,
4. Shut valves on the delivery side of the pump, and
5. Stuck supply valve on air-powered pumps. To fix a stuck supply valve, spray the valve with WD 40 and make sure the air line oil mister has a supply of low viscosity oil.

[20] *"Mother" Circuit Board. The base circuit board or the main circuit board.*
[21] *Specific Gravity. Weight of a particle, substance or chemical solution in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (39°F).*

If a diaphragm pump is operating but not pumping, make sure the:

1. Supply line is not clogged,
2. Valves are open on both the supply and discharge sides of the pump,
3. Check valves are operational, and
4. Diaphragm is not ruptured.

7.45 Waste Is Not Flocculating

If the waste being treated is not flocculating, check the following items.

1. pH. The pH must be in the appropriate range for the waste being treated. In most of the waste treatment systems being discussed in this section, the pH range is near 10.5; however, desired pH levels can vary from 7.0 to 12.0.
2. Polymer flow rate. The polymer flow rate can be measured by diverting the flow into a graduated cylinder and measuring the time with a stop watch.

   EXAMPLE. The polymer feed pump fills a 500 milliliter graduated cylinder in 2 minutes and 12.2 seconds. What is the polymer feed rate in gallons per day (GPD)?

$$\text{Flow Rate, GPD} = \frac{(\text{Volume Pumped, mL})(60\text{ sec/min})(60\text{ min/hr})(24\text{ hr/day})}{(\text{Time, sec})(1000\text{ mL/L})(3.785\text{ L/Gal})}$$

$$= \frac{(500\text{ mL})(60\text{ sec/min})(60\text{ min/hr})(24\text{ hr/day})}{[(2\text{ min})(60\text{ sec/min}) + 12.2\text{ sec}](1000\text{ mL/L})(3.785\text{ L/Gal})}$$

$$= 86\text{ GPD}$$

3. Adequacy of the polymer flow rate (chemical dosage). Add more polymer by hand and observe whether flocculation improves. Adjust the polymer feed pump if an improvement is observed.
4. Change in waste characteristics causing interference with the polymer reactions.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 89.

7.4A What major factors could be the cause of a pH meter not working properly in (1) direct chemical feed systems, and (2) indirect chemical feed systems?

7.4B What factors could cause level controls to not work properly?

7.4C What items should be checked if ORP readings are out of the proper range?

7.4D What items should be checked if a centrifugal pump is not operating properly?

7.4E If a waste being treated is not flocculating properly, what items should be checked?

7.5 pH AND ORP PROBES

7.50 Description

Operators must clean and calibrate pH and ORP probes on a regularly scheduled basis because the probes must have a "good" contact with the fluid they are measuring. Probes should be cleaned weekly unless special circumstances require more frequent cleaning. pH probes usually have more fouling problems than ORP probes. However, since ORP probes are always used with pH probes, the recommended procedure is to clean both probes at the same time.

pH probes consist of a glass electrode and a reference electrode (Figures 30 and 31). Both of these electrodes may be filled with a potassium chloride (KCl) electrolyte solution. A temperature thermocouple also may be a part of the electrode assembly. The pH probes require the presence of potassium chloride, but if large reservoirs of KCl solution were provided, the probes would be large and clumsy to use. Therefore, a compromise must be achieved by manufacturers between reducing the size of probes (which causes a shorter probe life) and the use of a gel instead of KCl (which decreases probe sensitivity). Probes currently being manufactured usually last between six months and two years depending on the type of service. Some manufacturers of pH and ORP electrodes are producing easily refillable reference cells because the electrolyte is continually being depleted.

The four electrodes shown in the upper left photo of Figure 30 are described below.

1. Epoxy bodied electrode (sensing cell only).
2. Combination electrode (section shown in drawing on Figure 30). This is both a sensing and double reference electrode. Rings (junction) at top serve as a filter-protection device between the reference electrode and the process solution that is being sensed.
3. Combination electrode. This is both a sensing double reference electrode. A single junction is shown at the bottom above the bulb.
4. Combination electrode cartridge. The cartridge contains the electrode and facilitates the replacement of electrodes. This cartridge is very easy to insert in and remove from tank walls and wastestreams.

ORP probes commonly consist of a platinum electrode and a reference electrode identical to the pH electrode (Figures 32 and 33).

7.51 Cleaning

Both pH and ORP probes are cleaned by using the same procedures. Remove the probes from their working location in the wastestream when they are to be cleaned. Do not clean probes in a cyanide destruct system with acid when the probes are on line. If acid spills into a tank containing cyanide, toxic hydrogen cyanide gas could be released into the atmosphere. You must know which cleaning chemicals, process control chemicals, and chemicals in wastestreams are compatible and which chemicals are not compatible.

1. Precipitate Removal

   Precipitates are the most common type of electrode fouling material. All high pH systems tend to precipitate metallic hydroxides as well as calcium and magnesium salts. These precipitates are easily removed by briefly (2 to 3 seconds) dipping a DRY probe in a concentrated hydrochloric acid (HCl) solution. The short dipping time should be sufficient to clean the electrode. Longer dipping times may result in damage to the electrode. Some shops clean probes using a 10 percent hydrochloric acid solution and "Q-Tips." Next, rinse the probe in clean water and then allow the probe to equalize (soak in clean water and rehydrate) for five minutes or so before calibrating the probe.

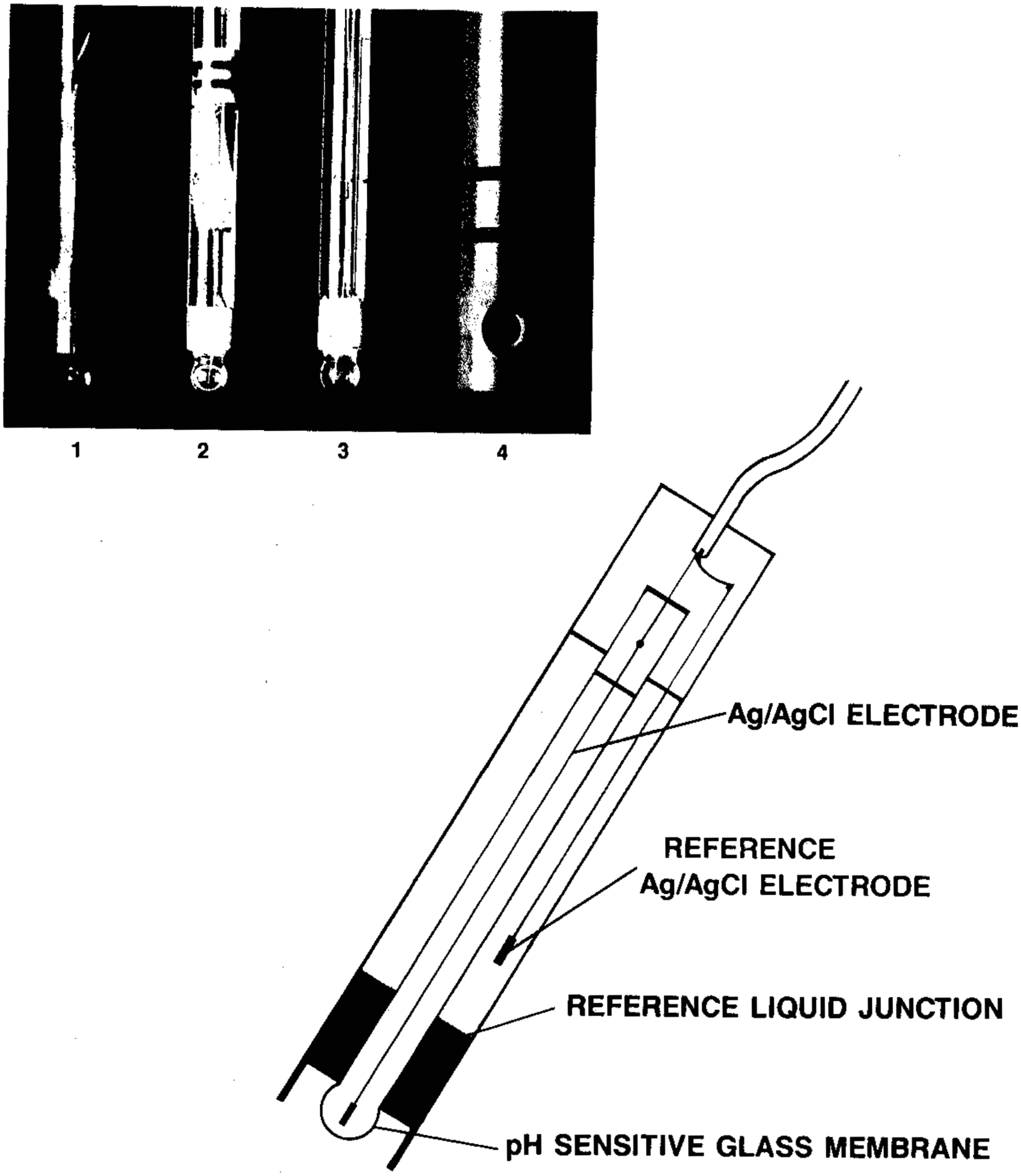


Fig. 30 pH probe
(Permission of Signet Scientific)

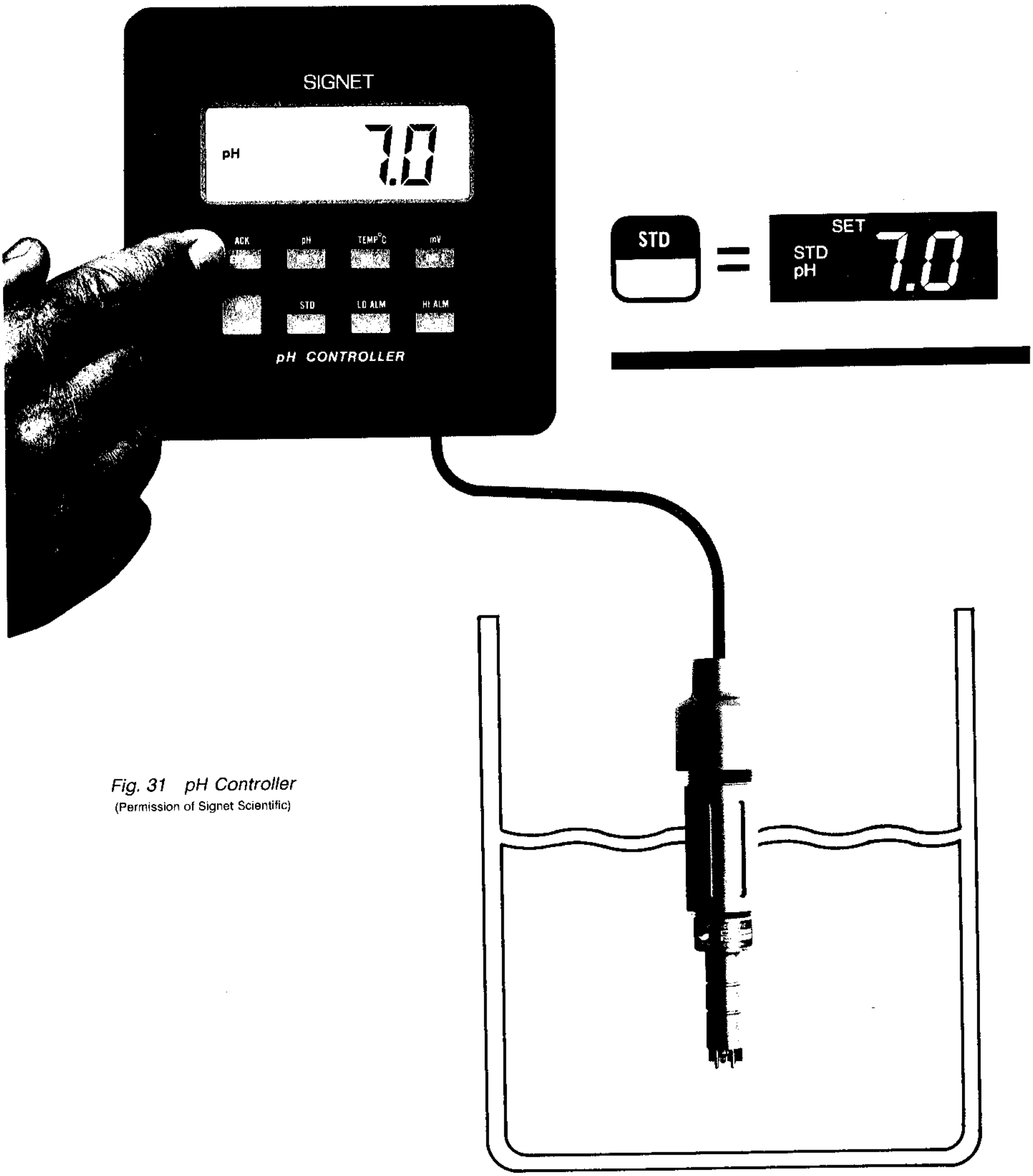


Fig. 31 pH Controller
(Permission of Signet Scientific)

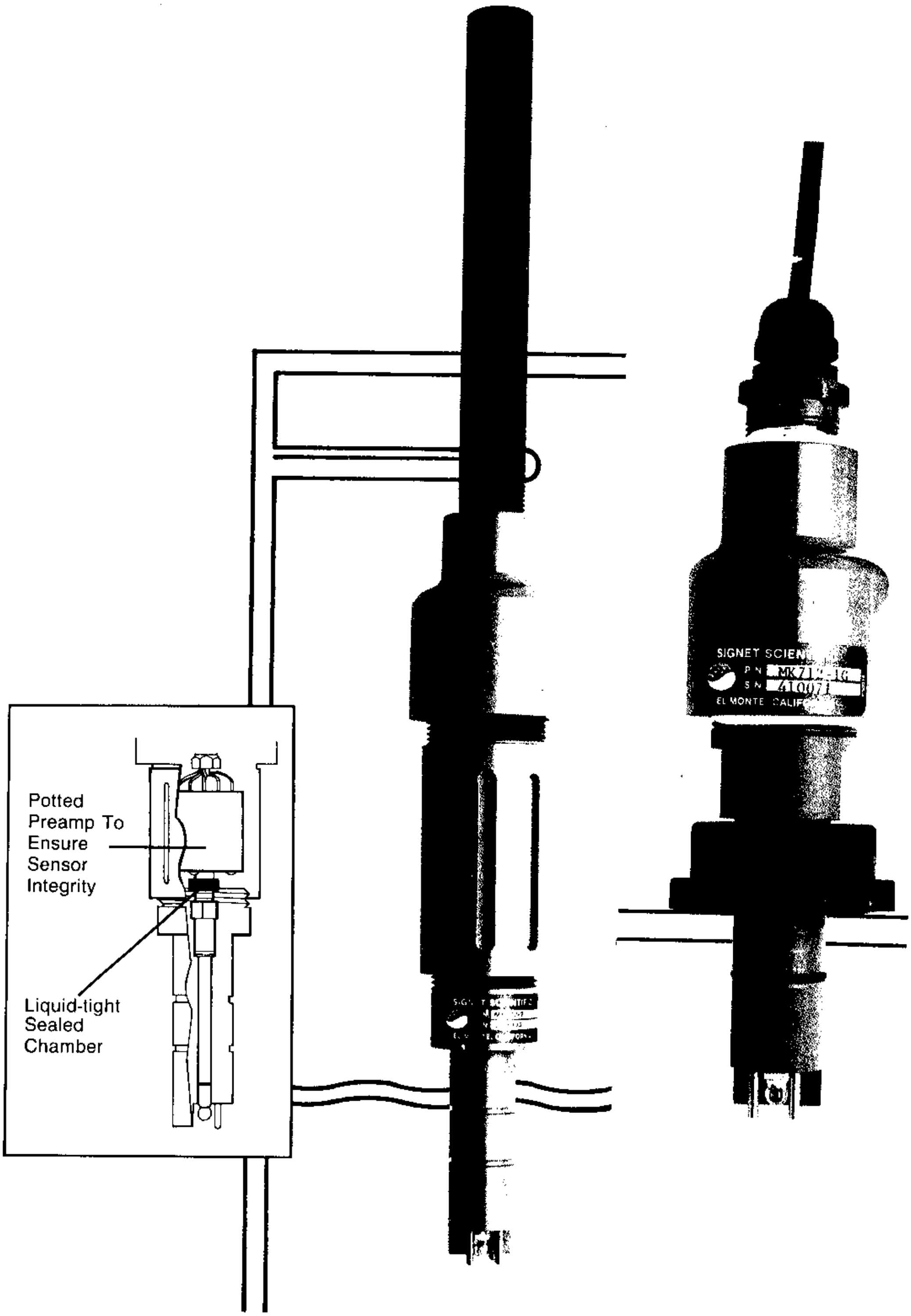


Fig. 32 ORP sensors
(Permission of Signet Scientific)

Fig. 33 ORP monitor
(Permission of Signet Scientific)

2. Oil and Grease Removal

Removal of oil and grease from electrodes is not as common a problem as precipitate removal in treatment systems for most industrial wastestreams. Many oils exist as an emulsion due to high pH conditions and therefore do not form a coating on probes.

If the oils and greases which form the coatings are from a known source, it may be possible to find an appropriate solvent which will dissolve the residues on the probe. Before applying any solvent to a probe, contact the probe manufacturer to be sure the solvent will not damage the probe's compenents since many of the *POTTING COMPOUNDS*[22] and O-rings are made or rubber or plastic.

If you are unable to determine the source and/or type of oils or greases, try cleaning the probe with 100 percent isopropanol. If isopropanol does not work, use a soft brush and dishwashing liquid. Lightly scrub both the glass electrode and the reference electrode. If the greasy scum is still present, soak the probe in a 33 percent sodium hydroxide (NaOH) solution for five minutes. Next scrub the probe lightly with a soft brush, rinse the probe, and then repeat the detergent cleaning process. If none of these procedures work, dip the probe in a concentrated hydrochloric acid solution used to remove precipitates.

7.52 Calibration

1. pH Probes

Two standard buffer solutions are commonly used to calibrate pH probes. The buffer solutions can be purchased in bottles in the "already mixed" or "ready to use" form from a chemical supply house. Buffer solutions also can be prepared when they are needed by purchasing the buffer in packet or tablet form and then mixing the dry chemical with distilled water. A pH 7.0 buffer is used as the "standard" buffer, while a pH of 4 or 10 is used as the "slope" buffer. The choice between the 4 or 10 buffer depends on where the system pH will usually operate. If you are measuring the pH in a metal precipitation process (high pH) or the cyanide destruction process (high pH), use the 10 pH buffer as the slope. Low pH processes such as chrome reduction require the use of a low pH (4.0) buffer.

To calibrate pH probes, remove them from the reaction tanks and clean them according to the instructions in Section 7.51, "Cleaning." Place each of the two buffer solutions in a 250 to 500 m*L* beaker (use three beakers if both high and low pH probes are being calibrated). Also place a one-liter beaker full of clean water near the probe. Use the following procedure to calibrate the probes.

(a) Place the probe in the pH 7 buffer.

NOTE: All pH buffers must be temperature correct. For example, if the temperature of the buffer solution is 25°C, the actual pH may 6.85 instead of the expected 7.0. The buffer bottle or packet will indicate the appropriate pH values for various temperatures.

(b) The "standard" pot is used to adjust the pH reading on the pH meter to agree with the pH of the buffer. The pot is an adjustable condenser which is the adjustment mechanism or device in the pH meter. This pot may be in the form of a dial or a screw. Some manufacturers require that a non-metallic screwdriver be used to make the pH adjustment.

(c) Rinse the probe with deionized water from a squeeze bottle and then place the probe in the "slope" buffer.

(d) Adjust the "slope" pot so the pH reading will agree with the pH buffer. The "slope" pot may not be able to adjust the pH on the meter all the way to the desired calibration or buffer pH value on the first try. This problem is not too unusual. If the pH meter cannot be adjusted to read the calibration pH value, go on to step (e).

(e) Rinse the probe in clean water and then place the probe in the "standard" buffer.

(f) The meter pH value will no longer read 7.0, the "standard" value. Readjust the pH meter reading to agree with the "standard" buffer value using the "standard" pot. The standard and slope pH meter reading values are interconnected by the electronics of the pH meter system. By

[22] *Potting Compounds. Sealing and holding compounds used in electrode probes.*

making these adjustments you are actually "warping" an electronic circuit to "fit" your probe system.

(g) Rinse the probe in clean water and then place the probe in the "slope" buffer solution.

(h) Readjust the slope pH meter reading using the "slope" pot so the meter reading will agree with the pH of the "slope" buffer solution. This time the pH meter should be adjustable to the expected value or very close to it.

(i) Repeat these steps until the pH meter correctly reads both the "standard" and "slope" pH values without any adjustment.

2. ORP Probes

ORP probes are calibrated using a different procedure than the pH probe calibration procedures. Only one standard solution is needed to calibrate an ORP probe. A typical ORP probe calibration procedure uses the following steps.

(a) Switch the ORP system from "Read" to "Standby." In most ORP systems this "grounds out" the input to the millivolt meter. The standard pot is then used to precisely adjust the needle or solid state readout to zero. Operators should realize that it is possible to have negative millivolt readings on an ORP scale. Most ORP scales are capable of reading ORP values of +/− 1400 mV (the device in Figure 33 measures +/− 1000 mV).

Some ORP systems do not have "Read" and "Standby" switches. When calibrating such a system, you must ground out the probe leads using a paper clip. The clip is inserted to bridge between the two wires which lead from the ORP unit to where they connect with the probe wires.

(b) After adjusting the scale to read exactly zero, the probe is reattached or placed in "Read" and put in the buffer solution.

The buffer solution for ORP probes is not as easy to obtain as pH buffer solutions due to the instability of ORP buffer solutions. Whether the ORP buffer solution is mixed from liquids on site or from a chemical manufacturer's powder packet, the ORP buffer solution must be used within 10 to 30 minutes of its preparation. Discard the solution after 30 minutes.

Some ORP meter manufacturers recommend the use of a pH 7 standard buffer to which a certain amount of hydroquinone is added. The exact proportions of hydroquinone and the ORP value which results varies according to each manufacturer's recipe. One manufacturer, Horiba, Inc.,[23] makes a very convenient powder packet which, when mixed with 250 m*L* of distilled water, produces an ORP value of 262.5 mV.

(c) The slope pot is used to adjust the meter reading to the buffer ORP value.

(d) Repeat the procedure to be sure that both the standard and slope values are realized. The standard is the zero reading and the slope reading is the 262.5 mV reading.

7.53 Troubleshooting (Both pH and ORP Probes)

If problems develop when using either pH or ORP probes, use the following checklists to locate and correct the causes of the problems.

1. Indicator does not move off of one position.
   a. Check Read-Standby switch. The switch may be on Standby.
   b. Clean the probe and calibrate the assembly. The reference electrode may need to be changed.
   c. Inspect the probe connections, they may be disconnected.
   d. Cross check the pH with a pH test strip or a lab pH meter. The waste characteristics may be unusually consistent.
2. Indicator has no reading.
   a. Inspect panel circuit breaker.
   b. Examine fuses and overloads.
   c. Check L.E.D. (Light Emitting Diode or red light) to be sure it is on or check indicator connector to the unit's circuits.
   d. Inspect probe connections.
3. Indicator has a very low reading.
   a. Cross check with pH test strips or lab pH meter.
   b. Check the glass electrode. Clean and calibrate the assembly.
4. Indicator moves very slowly.
   a. Clean the probe assembly (clean the glass and reference probes).
   b. If a clean probe is still sluggish or halting, one of the electrodes is failing, probably the glass electrode. The reference electrode usually lasts longer.
   c. If a clean probe cannot be adjusted to both the standard and slope values, both electrodes will probably have to be changed. However, always change one electrode at a time (if possible), starting with the glass electrode.
5. Indicator moves erratically.

If a pH reading is behaving erratically, look for

(1) electrode contamination, or

(2) ground-loop problem.

To determine the cause of the problem, measure the pH of a solution in the laboratory. Next measure the pH of the same solution with the electrode.

(1) If the electrode does not give the same pH, then the

[23] *May be obtained by contacting McHaney Engineering, 1717 Solano Way, Unit 18, Concord, CA 94520, phone (415) 676-2900. Buffer Kit, ORP, Model No. AS111, Part No. 251278-1, ORP of +262.5 mV. @ 20° C. Cost, $79.00 for kit. Pack of 10 Buffers, Model No. 160-22, Part No. 350065. Cost, $40.00.*

problem is probably a contaminated electrode that must be replaced.

(2) If the electrode gives the same pH as measured in the lab, then look for a ground-loop problem. A ground-loop problem is caused by stray electrical currents in the wastestream being treated. The problem may be detected during start up or in a system that has been functioning perfectly for some time, but a new pump or other facilities have been connected to the system. These stray electrical currents may not be present all of the time and may fluctuate considerably, thus causing pH readings to fluctuate radically.

A ground-loop problem may be corrected by either of three approaches.

(1) Find source of stray current and prevent current from flowing through wastestream.

(2) Place a ground-loop into the tank by inserting a copper rod into the wastestream flowing through the tank. Run a wire from the copper rod to a rod in the ground to complete the ground-loop.

(3) If the copper rod can't be tied to an earth ground, tie it back to the shield of the instrument.

6. Probe exposed to air.

If a probe used in a batch process is exposed to air when a tank is emptied, the probe must be recalibrated before the next batch is added to the tank.

This recalibration problem may be avoided by placing the electrode in a position where it will always be submerged. The electrode could be placed in a shallow cup which will keep the electrode submerged, but will expose the electrode to the contents of the wastestream when it flows through the tank. If tank levels fluctuate considerably, the electrode may be placed on a styrofoam float with the tip submerged below the wastestream's surface. This approach may encounter problems if there are density currents through the tank or a scum layer on the surface of the wastestream in the tank.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 89.

7.5A Why must pH and ORP probes be cleaned and calibrated on a weekly basis or more frequently?

7.5B What types of materials must be removed from pH and ORP materials?

7.5C What metal waste treatment processes require a high pH "slope" buffer and which one requires a low pH "slope" buffer?

7.5D List the problems that could develop with the indicator when using pH and ORP probes.

7.6 POLYMER CALCULATION

For the polymer to work correctly, it must be applied at the proper rate and dosage so that the polymer concentration in the flocculation tank will produce a good settling floc.[24] This section contains the procedures for calculating the rate and concentration. For additional examples and procedures, see Appendix III, "How to Solve Arithmetic Problems." A detailed description and discussion of polymers is provided in Appendix I, "Polymers."

Helpful conversion factors for polymer calculations are listed below.

1 Gallon per minute, GPM	= 3.785 Liters per minute
1 Cubic foot	= 7.48 Gallons
1 mg/mL	= 1 Gram/Liter
1 Pound	= 454 Grams
1 Gallon	= 8.34 Pounds

1. Compute the flow rate of the wastewater to be treated. One accurate way for small pumps is to use a five gallon bucket and a stop watch. Use the stop watch to measure the time required to fill the bucket. Usually you must lower the liquid level in the heavy metal tank in order to expose the discharge pipe carrying the wastewater to the tank to be treated. When the discharge pipe is exposed, the bucket can be placed below the open end of the pipe to collect the flow of wastewater and fill the bucket.

   EXAMPLE: Determine the waste flow rate in gallons per minute if the 5 gallon bucket fills in 20 seconds.

$$\text{Flow, GPM} = \frac{(\text{Volume, Gal})(60\ \text{sec/min})}{\text{Time, sec}}$$
$$= \frac{(5\ \text{Gal})(60\ \text{sec/min})}{20\ \text{sec}}$$
$$= 15\ \text{GPM}$$

2. Convert the waste flow rate from gallons per minute to liters per minute.

$$\text{Flow, Liters/min} = (\text{Flow, GPM})(3.785\ L/\text{Gal})$$
$$= (15\ \text{GPM})(3.785\ L/\text{Gal})$$
$$= 56.8\ \text{Liters/min}$$

3. The polymer concentration in the flocculation tank must be at least 2 mg/*L*. Therefore, we must provide a polymer dosage rate to the waste flow to produce the 2 mg/*L* concentration.

$$\text{Polymer Dosage, mg/min} = (\text{Flow, } L/\text{min})(\text{Concentration, mg}/L)$$
$$= (56.8\ L/\text{min})(2\ \text{mg}/L)$$
$$= 113.6\ \text{mg polymer/min}$$

4. If we need 113.6 mg polymer per minute, we need to pump that much polymer with the polymer pump. The pump usually provided in this situation is capable of pumping between 0 and 240 milliters of polymer solution per minute. If we mix the polymer to produce a 1.0 mg/m*L* polymer concentration,[25] determine the polymer pumping rate.

$$\text{Polymer Pumping Rate, m}L/\text{min} = \frac{\text{Polymer Dose, mg/min}}{\text{Polymer Concentration, mg/m}L}$$
$$= \frac{113.6\ \text{mg/min}}{1.0\ \text{mg/m}L}$$
$$= 113.6\ \text{m}L\ \text{polymer/min}$$

5. To prepare a polymer concentration of 1.0 mg/m*L*, we need to know the volume of the polymer tank and the amount of polymer that must be added. Calculate the volume of the polymer tank.

---

[24] *The level of polymer concentration will vary with the specific brand of polymer being used and the water being treated. Usually jar tests (batch or bench tests) must be run to determine the optimum level of polymer.*

[25] *NOTE: A 1% polymer solution = 10,000 mg/L = 10 mg/mL.*

Volume, cu ft = (Length, ft)(Width, ft)(Depth, ft)

= (2 ft)(2 ft)(26 in)/(12 in/ft)

= 8.67 cu ft

Volume, gal = (8.67 cu ft)(7.48 gal/cu ft)

= 64.8 gal

Volume, *L* = (64.8 gal)(3.785 *L*/gal)

= 245.4 Liters

6. Calculate the total amount of polymer that must be added to the polymer tank to produce a polymer concentration of 1 mg polymer per milliliter. *NOTE:* 1 mg/m*L* = 1 g/*L* = 0.1% polymer solution.

Polymer, g = (Polymer Concentration, g/*L*)(Volume, *L*)

= (1 g/*L*)(245.4 *L*)

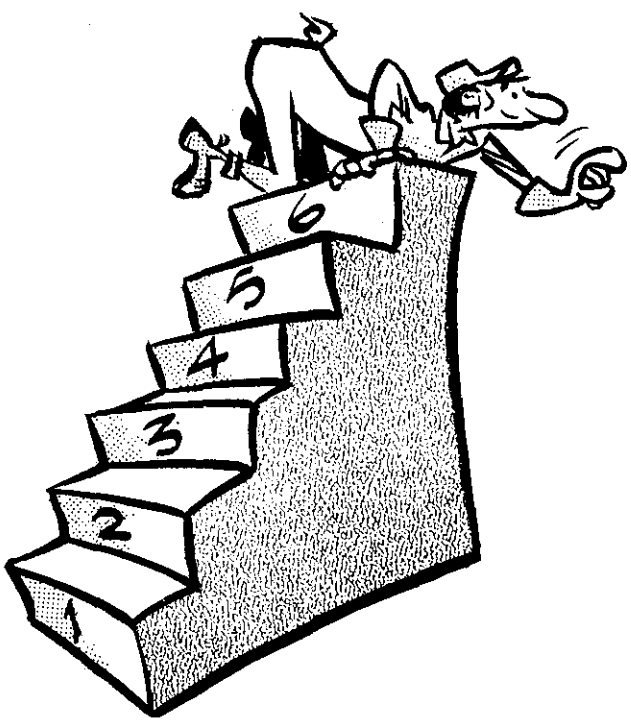
= 245.5 g

$$\text{Polymer, lbs} = \frac{\text{Polymer, g}}{\text{454 g/lb}}$$

$$= \frac{\text{245.5 g}}{\text{454 g/lb}}$$

= 0.54 lbs

Therefore, if you mix 0.54 lbs or 245.5 grams of polymer in 64.8 gallons of water and pump it into a wastestream flowing at a rate of 15 GPM using a polymer pumping rate of 113.6 m*L* of polymer per minute, the final concentration of the polymer in the wastestream will be 2 mg/*L*.



This next example is similar to the previous one except the waste flow is higher, which will require a higher polymer concentration. The steps are numbered the same as in the previous example.

1. Waste Flow, GPM = 65 GPM

2. Convert the waste flow to liters per minute.

Flow, Liters/min = (Flow, GPM)(3.785 *L*/Gal)
= (65 GPM)(3.785 *L*/Gal)
= 246 Liters/min

3. Determine the polymer dosage in milligrams per minute.

Polymer Dosage, mg/min = (Flow, *L*/min)(Concentration, mg/*L*)

= (246 *L*/min)(2 mg/*L*)

= 492 mg/min

4. Determine the polymer pumping rate in milliliters per minute.

$$\text{Polymer Pumping Rate, m}L\text{/min} = \frac{\text{Polymer Dose, mg/min}}{\text{Polymer Solution, mg/m}L}$$

$$= \frac{\text{492 mg/min}}{\text{1 mg/m}L}$$

= 492 m*L*/min

This pumping rate is greater than the maximum rate for the pump of 240 milliliters per minute. Try increasing the polymer concentration from 1 to 2 mg/m*L*.

$$\text{Polymer Pumping Rate, m}L\text{/min} = \frac{\text{Polymer Dose, mg/min}}{\text{Polymer Concentration, mg/m}L}$$

$$= \frac{\text{492 mg/min}}{\text{2 mg/m}L}$$

= 246 m*L*/min

This pumping rate is still too high. Try increasing the polymer concentration to 3 mg/m*L*.[26]

$$\text{Polymer Pumping Rate, m}L\text{/min} = \frac{\text{Polymer Dose, mg/min}}{\text{Polymer Concentration, mg/m}L}$$

$$= \frac{\text{492 mg/min}}{\text{3 mg/m}L}$$

= 164 m*L*/min

This polymer pumping rate is satisfactory because it is less than the 240 m*L*/min capacity of the polymer pump.

5. Use a 300 gallon tank to prepare the polymer solution. Determine the tank volume in liters.

Volume *L* = (Volume, gal)(3.785 *L*/gal)

= (300 gal)(3.785 *L*/gal)

= 1136 Liters

6. Calculate the total amount of polymer that must be added to the tank to produce a polymer concentration of 3 mg polymer per milliliter. *NOTE:* 1 mg/m*L* = 1 g/*L* = 0.1% polymer solution.

[26] *NOTE: This is a 0.3% polymer solution which is pretty viscous for most anionic polymer solutions. The maximum concentration commonly used is 0.25% polymer solution.*

$$\text{Polymer, g} = (\text{Polymer Concentration, g/}L)(\text{Volume, }L)$$
$$= (3\text{ g/}L)(1136\ L)$$
$$= 3408\text{ g}$$

$$\text{Polymer, lbs} = \frac{\text{Polymer, g}}{454\text{ g/lb}}$$

$$\text{Polymer, lbs} = \frac{3408\text{ g}}{454\text{ g/lb}}$$
$$= 7.51\text{ lbs}$$

Therefore, if you mix 7.51 lbs or 3408 grams of polymer in 300 gallons of water and pump it at a rate of 164 milliliters per minute into a wastestream flowing at 65 GPM, the final concentration of polymer in the wastestream will be 2 mg/*L*.

To prepare a 0.15 percent polymer solution in a 55 gallon drum, how much dry polymer will be needed? Assume the polymer container indicates that the purity or active ingredient is 91 percent.

Known	Unknown
Polymer solution, % = 0.15%	Polymer, lbs
Volume, gal = 55 gal	
Active ingredient, % = 91%	

Calculate the amount of pure polymer needed to produce a 0.15 percent polymer solution.

$$\text{Pure Polymer, lbs} = \frac{(\text{Polymer Solution, \%})(\text{Vol, gal})(8.34\text{ lbs/gal})}{100\%}$$

$$= \frac{(0.15\%)(55\text{ gal})(8.34\text{ lbs/gal})}{100\%}$$

$$= 0.688\text{ lbs}$$

Determine the actual amount of polymer to be added to the 55 gallon drum.

$$\text{Actual Polymer, oz} = \frac{(\text{Pure Polymer, lbs})(16\text{ oz/lb})(100\%)}{\text{Active Ingredient, \%}}$$

$$= \frac{(0.688\text{ lbs})(16\text{ oz/lb})(100\%)}{91\%}$$

$$= 12.1\text{ ounces}$$

The next two pages are graphs (Figures 34 and 35) titled, "Preparation of Polymer Solution" and "Polymer Solution Pumping Rate at 1 mg/m*L*," Using the procedures in this section, calculate and plot these curves for your own facilities. You will save considerable time and avoid possible errors in calculations by using charts such as these.

To develop the curves for "Preparation of Polymer Solution," assume you wish to prepare 1 mg/m*L* solutions of a polymer. Select the volume for your batch of 100, 300 and 500 gallons. Calculate the pounds of polymer needed for each batch. Plot three points of *VOLUME* (gallons) and *POLYMER* (pounds). Draw a line through the three points and this will be the 1 mg/m*L* line. If the three points are not in a straight line, recheck the calculations and plotting points.

To determine the "Polymer Solution Pumping Rate at 1 mg/m*L*," assume three waste flow rates such as 40, 100 and 200 GPM with a "Dosage of 3 mg/*L*" and calculate three "Polymer Rates, m*L*/min." Plot three points of *FLOW RATE* (GPM) and *POLYMER RATE* (m*L*/min). Draw a line through the three points and this will be the *DOSAGE* 3 mg/*L* line. If the three points are not in a straight line, recheck the calculations and plotting points.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 89.

7.6A If the flow of metal wastes into a treatment facility fills a 10-gallon bucket in 5 seconds, what is the flow rate in gallons per minute (GPM) and liters per minute?

7.6B How many pounds of polymer must be added to a 55-gallon drum to produce a solution containing one milligram of polymer per milliliter (0.1% polymer solution)?

7.6C If a metal wastestream flows at 100 liters per minute and the desired polymer concentration in the wastestream is 2 mg/*L*, what should be the polymer pumping rate in milliliters per minute if the polymer solution concentration is one milligram polymer per milliliter (0.1% polymer solution)?

7.7 LABORATORY SUPPORT

To successfully and continuously produce an acceptable effluent from wastewater treatment facilities, analytical laboratory support must be available. The type of support and the amount of support depends on the complexity of the waste being treated, the treatment facilities and the effluent monitoring requirements. This section outlines various levels of analytical laboratory support. Your requirements will probably be different and may require some type of support from more than one level.

7.70 The Simplest Solutions

1. pH test strips. These test strips are pieces of paper which are placed in the water whose pH is to be determined. The color of the wet strip is matched with a standardized color which allows the determination of the pH within 0.5 to 1 pH unit.
2. pH test tape. These test tapes are similar to pH test strips, but usually are not as accurate.

7.71 Slightly More Critical or Complex Situations

1. pH measurement. pH may be measured by using pH test strips or pH test tapes. The preferred method of pH measurement is by the use of a portable (hand-held) pH meter (Figure 36) or by the use of a laboratory pH meter. Samples that are not tested for pH in the field should be tested for pH immediately upon delivery to the lab.
2. Metal detection and measurement. Portable color comparison test kits (Figure 37) can be used to measure the concentrations of metals in industrial wastewaters. A portion of the sample to be tested is placed in a clear tube and a measured amount of a chemical reagent is added to the tube. If the metal being tested is present, various intensities or hues of colors will develop. The color developed is compared with colors which have been standardized with known concentrations of the metal being measured. These color comparison kits can give reasonable results *PROVIDED* there are no complexing agents such as EDTA, cyanide and high levels of calcium or suspended solids present in the water being tested. Also, the chemical reagent sometimes causes secondary precipitates (especially in water with a high calcium content) which will throw off the results. Unidentified color species in water may also interfere with test results.

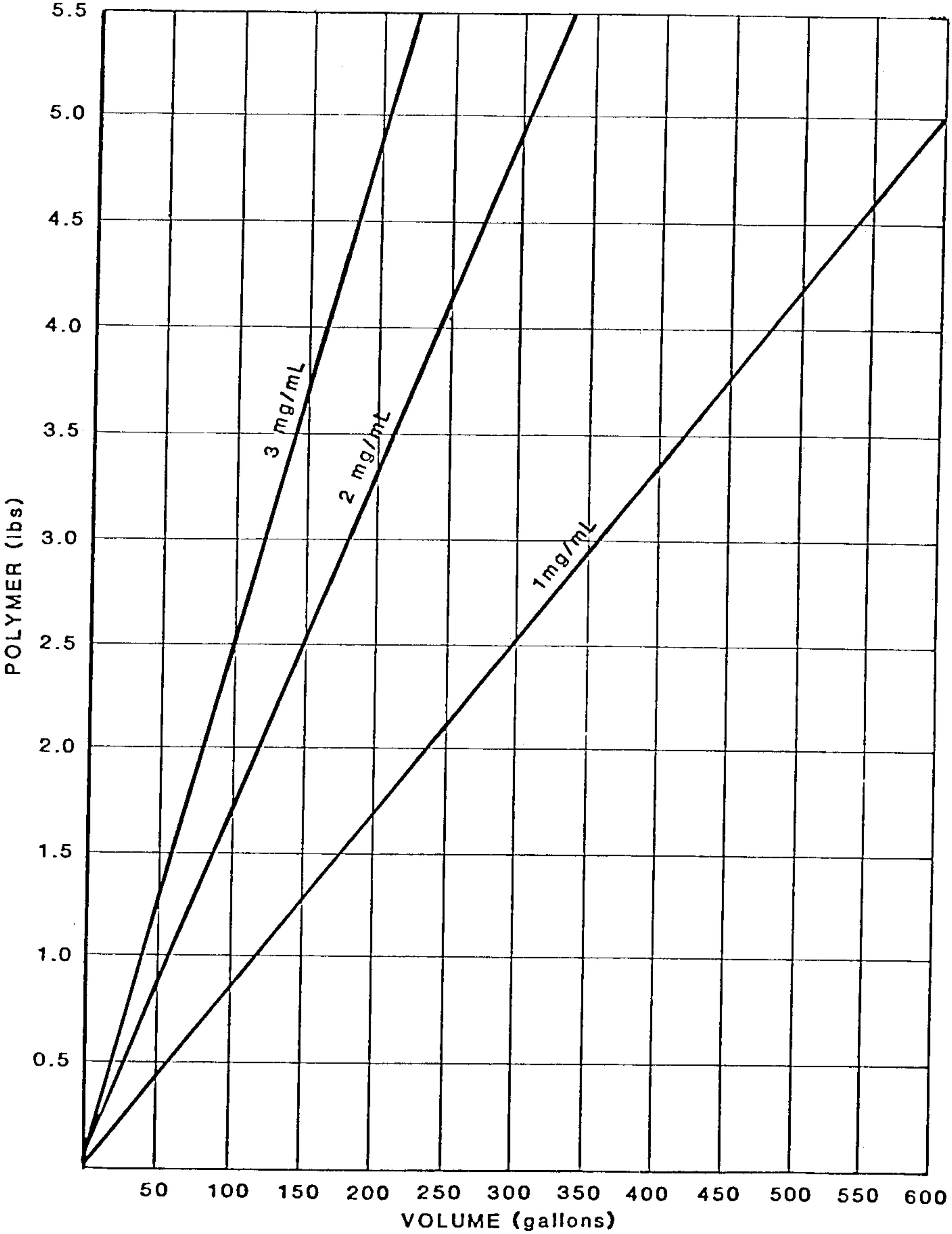


Fig. 34 Preparation of polymer solution
(Permission of Lee, Strangio and Associates)

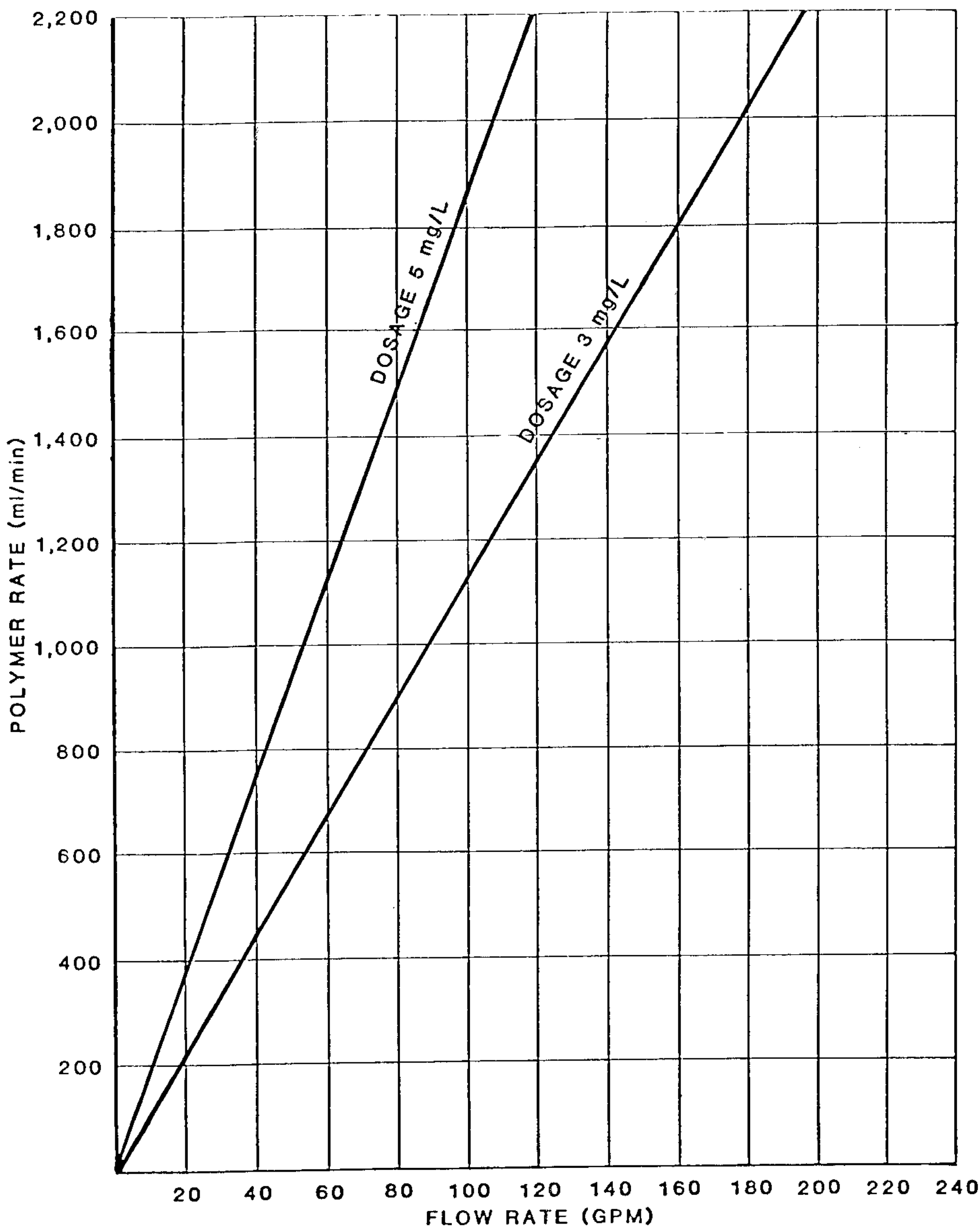


Fig. 35 Polymer solution pumping rate at 1 mg/mL
(Permission of Lee, Strangio and Associates)

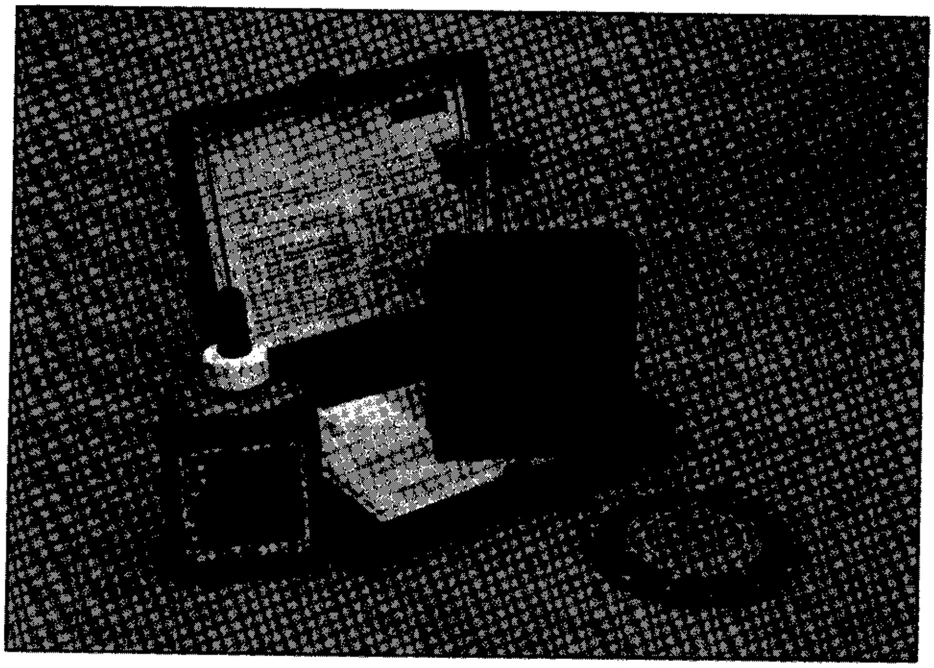


Fig. 36 Portable pH test kit
Permission of HACH Company

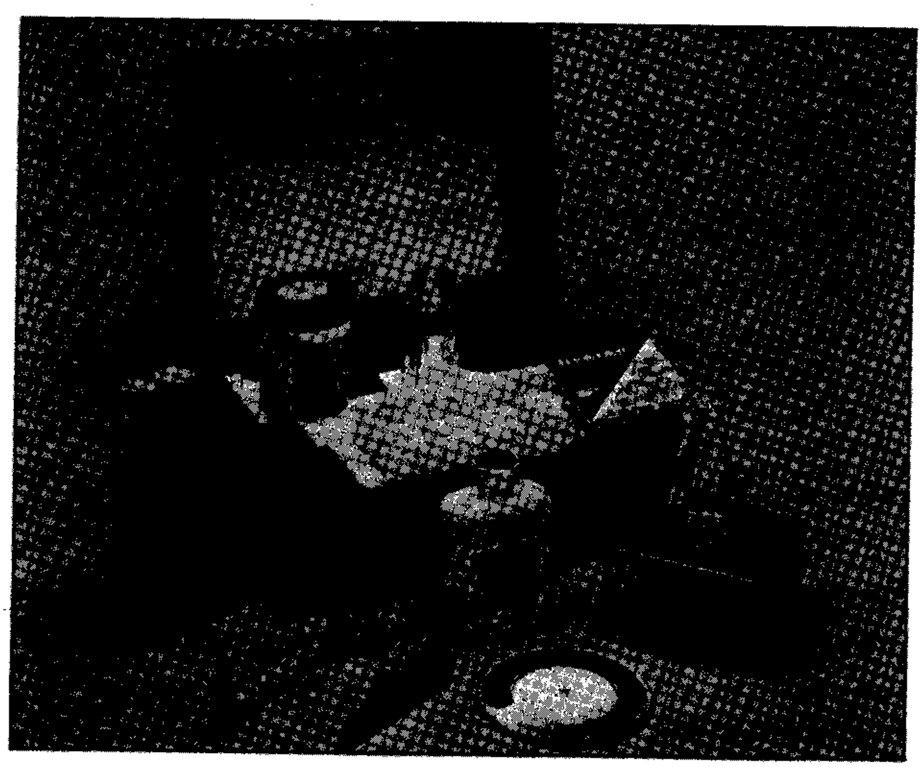


Fig. 37 Total chromium color comparison test kit
Permission of the HACH Company

7.72 Normal Situations (Typical Medium-Sized Industry)

1. pH measurement. pH is measured by the use of a portable or laboratory pH meter.

2. Metal detection and measurement. Metals are measured by the use of color comparison kits (Figure 38) in the treatment facilities or by a spectrophotometer in the field or laboratory. Before metal contents are measured with a spectrophotometer, the sample is put through a digestion step to dissolve solids and to destabilize complexed metals. Since the concentration of each specific metal is measured at a specific light wave length, spectrophotometers give much more accurate and reproducible readings than the color comparison kits. Color comparison kit test results are subject to the ability of each person's eyes to match colors. Any time test results are based on the intensity or hue of a color, unidentified color species in the sample can interfere with the results.

3. Verification of results. Daily or weekly composite samples are split with half the sample sent to a commercial laboratory for analysis and verification with the test results obtained by the treatment facility's laboratory analysis of the other half.

7.73 Complex Wastestream Situations

1. pH and metal measurement. pH and metals are measured by procedures as described in Section 7.72, Normal Situation.

2. Complexed metals. Complexed metals and other wastes are measured on an hourly or daily basis with an atomic adsorption (AA) unit at the treatment facility's on-site laboratory.

3. Total toxic organics (TTO). Total toxic organics can be measured using a gas chromatograph.

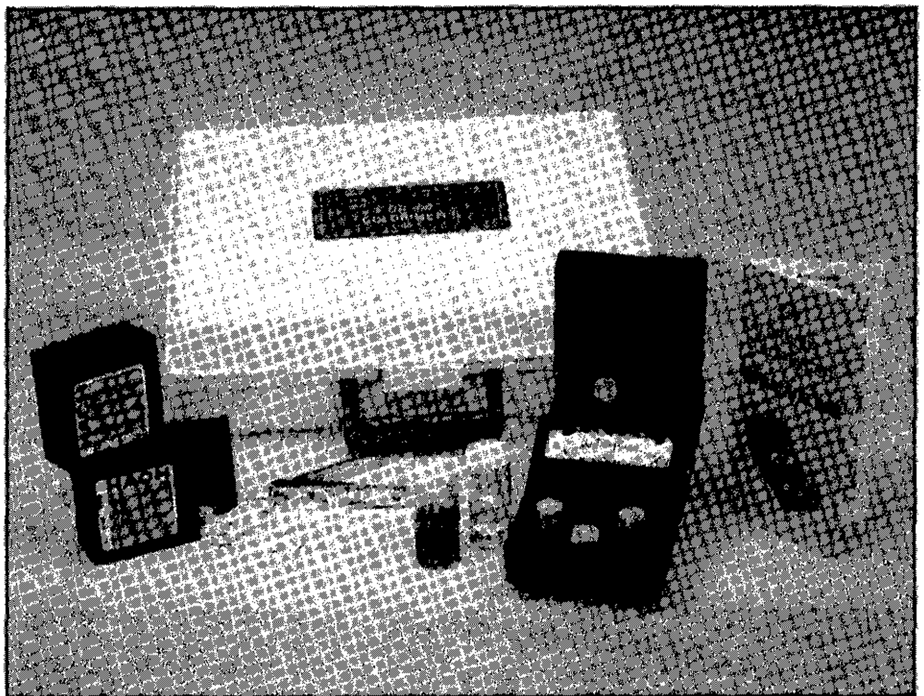
4. Verification of results. Daily or weekly composite samples are split and sent to an outside commercial laboratory for analysis and verification with test results obtained by the on-site laboratory.

5. Special test kits. The analytical instrumentation industry has developed test kits especially for the metal finishing industry. The HACH Company[27] manufacturers an "Electroless Copper Titration Test Kit" ($60.00) capable of measuring concentrations of copper, hydroxide and formaldehyde. Another test kit available from HACH is the "Etch Bath Analysis Test Kit" ($145.00) for measuring copper, acidity and peroxide concentrations in etch baths. Other colorimetric test kits are available to measure chromium, cyanide and zinc.

6. Analytical procedures. For detailed procedures on how to analyze wastewater samples see:

   a. *OPERATION OF WASTEWATER TREATMENT PLANTS*, Volume II, Chapter 16, "Laboratory Procedures and Chemistry," and

   b. *PROCEDURES FOR WATER AND WASTEWATER*



The Photometric Test Kit – Each DR 100 Colorimeter with built-in precalibrated meter scale is fitted into a portable water test kit with cell adapter that doubles as a zeroing device, capped sample cells, testing apparatus, alkaline batteries and complete instructions. Most DR 100 test kits also include prepared reagents to complete approximately 100 tests.

Fig. 38 Direct reading colorimeter

Permission of the HACH Company

[27] *HACH Company, PO Box 389, 57th Street and Lindbergh Parkway, Loveland, Colorado 80539.*

ANALYSIS and *CONTROL OF INDUSTRIAL WATER AND WASTEWATER,* both available from the HACH Company, P.O. Box 389, 57th Street and Lindbergh Parkway, Loveland, Colorado 80539.

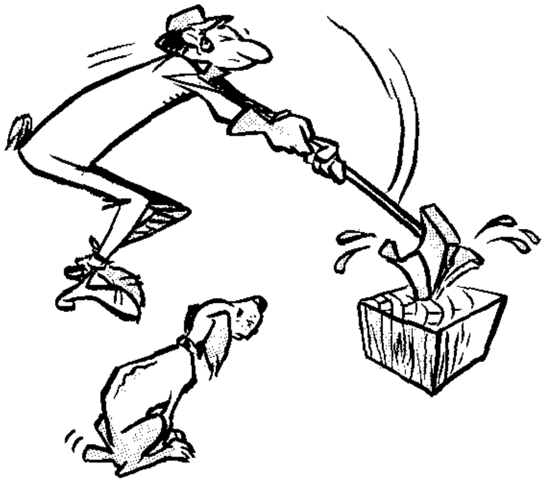
c. *STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER,* 16th Edition, 1985. Order number S0026SPO from Water Pollution Control Federation, 2626 Pennsylvania Avenue, NW, Washington, DC 20037. Price $72 to WPCF members; $90 to others.

d. *METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES,* Center for Environmental Research Information, U.S. Environmental Protection Agency, 26 West St. Clair Street, Cincinnati, Ohio 45268.

The shelf life of chemical reagents will vary. Usually chemicals have a shelf life of around one year. A good practice is to verify your testing procedures on the first day of every month. Measure the concentrations of metals you analyze in samples using your chemical reagents and standards of known concentrations near the actual concentrations you measure every day. If the test results are not the same as the concentrations of the known standards, perhaps the chemical reagents have deteriorated and should be discarded.

Sampling activities and laboratory test results must be recorded systematically and accurately. For each sample taken, record the name of the sample collector, location, time, date and any other pertinent observations such as flow and the presence or absence of color and floatable or suspended solids. The "chain of possession" from the sampler to the laboratory analyst must also be recorded. The test results must include the name of the analyst, time, date, test procedure used and any other important information. If the test results are not within an expected range or within the effluent discharge requirements, the cause or reason must be noted along with the corrective actions taken. This log of activities represents proof that diligent, reasonable efforts were taken to attain and sustain the required levels of treatment.

Experienced operators and laboratory analysts realize that there may be times when laboratory results may not be correct. Errors can be introduced by poor sampling procedures, improper analytical procedures, incorrect reading of laboratory instruments, accidental recording of test results in the wrong space on the lab bench sheet and/or writing down the wrong numbers. A good practice is to split each sample and save a portion in case retesting of the sample is necessary.



Whenever a municipal inspector collects a sample from an industrial facility, the sample should be split and half of the sample delivered to the industry for testing by the industry's laboratory analyst. This procedure will allow industry to verify any questionable or controversial results.

If your industrial treatment facility is using an outside commercial laboratory, a good practice is to periodically (monthly) test the validity of the lab's results. To do this, send in a sample of known strength (metal concentration) that you have labeled similar to all other regular samples; all samples should be submitted at the same time. The results should be fairly close to the known concentration, but don't expect them to be exactly the same. If the test results are not close enough, have the tests run again. If the results are still not satisfactory, perhaps a different laboratory can achieve better results.

7.74 Alternative pH and ORP Scales

On the next three pages you will find Figures 39, 40 and 41 with the headings of:

1. 0-14 Scale,
2. 2-12 pH Scale, and
3. −1400 −0− +1400 MV.

Operators and lab analysts use these scales to calibrate pH meters and ORP meters. These pages can be helpful because the scales on these meters may have two divisions side by side, (1) the actual pH or ORP scale, and (2) a scale with even divisions from zero to one hundred (% of scale).

Refer to Figure 39 with the heading of 0-14 Scale. If the pH was 0, the scale would read 0, if the pH was 1.0, the scale would read 7.14 and so on up to a pH of 14.0 equal to 100.00. The "Control Points" column on the right contains *pH* and *SCALE* values commonly used by operators. If you wished to calibrate your pH meter at a pH of 2.5 or adjust pH levels in treatment processes to a pH of 2.5, this pH value would be the same as a scale reading of 17.86. The same procedure applies for pH values of 8.5 and 9.5.

O - 14 SCALE

		CONTROL POINTS	
pH	**SCALE**	**pH**	**SCALE**
0	0		
1.0	7.14		
2.0	14.28		
		2.5	17.86
3.0	21.42		
4.0	28.57		
5.0	35.71		
6.0	42.85		
7.0	50.00		
8.0	57.14		
		8.5	60.71
9.0	64.29		
		9.5	67.86
10.0	71.43		
11.0	78.57		
12.0	85.71		
13.0	92.85		
14.0	100.00		

Fig. 39 pH scale from 0 to 14

2 - 12 pH

		CONTROL POINTS	
pH	SCALE	pH	SCALE
2	0	2.5	.5
3	1		
4	2		
5	3		
6	4		
		6.5	4.5
7	5		
8	6		
9	7		
		9.5	7.5
10	8		
		10.5	8.5
11	9	11.5	9.5
12	10		

Fig. 40 pH scale from 2 to 12

−1400 −0− +1400 mV

		CONTROL POINTS	
pH	SCALE	pH	SCALE
−100	46.29		
0	50.00		
+100	53.71		
+200	57.14		
		+250	58.93
+300	60.71		
+400	64.29		
+500	67.86		
+600	71.43		
		+650	73.21
+700	75.00		
+800	78.57		
+900	82.14		
		+900	82.14
+1000	85.71		

Fig. 41 ORP scale from −1400 to +1400 mV

Some pH meters have a pH range from pH 2 to pH 12 and a scale range from 0 to 10. Figure 40 with the heading "2-12 pH" shows the scale control points equivalent to frequently used pH control points.

ORP meters can measure ORP values from -1400 to +1400 and may have a scale ranging from 0 to 100. Figure 41 has a heading "-1400 -0- +1400." This page can be used to select scale points equal to ORP values of +250, +650 and +900.

QUESTIONS

Write your answers in a notebook and then compare your answer with those on page 90.

7.7A What is the simplest procedure for measuring pH?

7.7B What factors can cause unreasonable results when using color comparison test kits to measure metal concentrations?

7.7C Why are spectrophotometer test results more accurate and reproducible than color comparison kits when measuring metal concentrations?

7.7D How would you attempt to test the validity of the results provided by a commercial laboratory?

7.8 ARITHMETIC ASSIGNMENT

Turn to Appendix III at the back of this manual and read the following sections:

J. Neutralization,

K. Hydroxide Precipitation,

L. Complexed Metal Precipitation,

M. Reduction of Hexavalent Chromium,

N. Cyanide Destruction, and

O. Sludge Treatment.

Check all of the arithmetic for example problems 30 through 46. You should be able to get the same answers on your electronic pocket calculator.

8 REFERENCES

These references were used in the preparation of material in this Manual. They contain excellent information and additional details.

1. *GUIDANCE MANUAL FOR ELECTROPLATING AND METAL FINISHING PRETREATMENT STANDARDS,* Effluent Guidelines Division and Permits Division, United States Environmental Protection Agency, Washington, DC 20460, February 1984.

2. *PLATING WASTE TREATMENT* by Kenneth F. Cherry, Ann Arbor Science Publishers, Inc/Butterworth Publishers, 80 Montvale Avenue, Stoneham, MA 02180, 1982.

3. *ELECTROPLATING ENGINEERING HANDBOOK,* Fourth Edition, by A. Kenneth Graham, VanNostrano Reinhold Company, 450 W. 33rd Street, New York, NY, 1971.

4. *UNIT OPERATIONS FOR TREATMENT OF HAZARDOUS INDUSTRIAL WASTES* by Joan B. Berkowitz, John T. Funkhouser, and James I. Stevens, Noyes Data Corporation, Noyes Building, Park Ridge, New Jersey, 07656, 1978.

5. *INDUSTRIAL WATER POLLUTION* by Nelson L. Nemerow, Addison-Wesley Publishing Company, 2725 Sand Hill Road, Menlo Park, CA 94025, 1978.

6. *PHYSICOCHEMICAL PROCESSES FOR WATER QUALITY CONTROL* by Walter J. Weber, Jr., Wiley-Interscience, John Wiley & Sons, 1530 South Redwood Road, Salt Lake City, Utah 84104, 1972.

7. *EPA TREATABILITY MANUALS*

   Volume I. Treatability Data
   Volume II. Industrial Descriptions
   Volume III. Technologies for Control/Removal of Pollutants
   Volume IV. Cost Estimating (No longer in print due to out of date cost data)
   Volume V. Summary

   Obtain from Superintendent of Documents, US Government Printing Office, Washington, DC 20402. Order #055-000-00215-1; cost approximately $50.00.

8. *PRETREATMENT OF INDUSTRIAL WASTES,* MOP FD-3, Water Pollution Control Federation, 2626 Pennsylvania Avenue, NW, Washington, DC 20037. Order No. MOP FD-35PO. Price, $10.50 for WPCF members; $14.00 for others.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 3 of 3 Lessons)

Write the answers to these questions in your notebook before continuing with the Objective Test. The question numbering continues from Lesson 2.

21. What skills and knowledge are required of operators for successful operation and maintenance of industrial wastewater treatment facilities?
22. How would you safely store acids?
23. When handling acids, what type of protective clothing would you wear?
24. Why is cautic soda very hazardous to operators?
25. Why is a knowledge of first aid important?
26. Why should operators learn as much as possible about electricity?
27. How would you attempt to determine the cause of the problem if a waste being treated is not flocculating properly?
28. Under what conditions would you use a high pH "slope" buffer and also a low pH "slope" buffer?
29. What factors influence the optimum level of polymer used to flocculate precipitates?
30. How would you determine the type and amount of laboratory support required by an industrial wastewater treatment facility?

OBJECTIVE TEST

(Lesson 3 of 3 Lessons)

Please write your name and mark the correct answers on the special answer sheet as directed at the end of Lesson 1. There may be more than one correct answer to these multiple-choice questions.

PLEASE MARK CHAPTER 33 ON YOUR ANSWER SHEET.

1. The most important safety warning for polymers is
    1. Attacks many types of stainless steel.
    2. Causes blindness.
    3. Causes severe burns.
    4. Extreme slipping hazard when spilled on surfaces.
    5. Produces a toxic gas.

2. The heat generated during the mixing reaction between ________ and water can be sufficient to weaken plastic tanks and can cause them to split open.
    1. Acetic acid
    2. Caustic
    3. Chlorine
    4. Lime
    5. Salts

3. Extremely hazardous chemical "splatters" or "explosions" can be caused by
    1. Dilution of concentrated acids.
    2. Dilution of concentrated salts.
    3. Mixing of acids and caustics.
    4. Mixing of chrome wastes.
    5. Mixing of complexed metal wastes.

4. Acids must be contained in ________ containers.
    1. Glass
    2. Metal
    3. Plastic-lined
    4. Rubber
    5. Wooden

5. Special precautions to be taken when handling or storing caustic soda include
    1. Avoiding breathing dusts or mists.
    2. Having an eye wash and safety shower nearby.
    3. Keeping caustic away from strong acids.
    4. Preventing eye and skin contact.
    5. Wearing protective clothing.

6. Protective clothing to be worn when handling caustic soda includes
    1. Apron.
    2. Boots.
    3. Face shield.
    4. Impervious gloves.
    5. Short sleeved-shirt.

7. Polymer solutions can be degraded (lose their strength) due to
    1. Air.
    2. Biological contamination.
    3. Cool temperatures.
    4. Dirty storage tanks.
    5. Moisture.

8. Operators must continuously monitor and adjust treatment processes in order to
    1. Gather data for annual reports.
    2. Justify need for equipment.
    3. Meet effluent waste discharge requirements.
    4. Minimize costs of treatment.
    5. Respond to changing characteristics of the waste.

9. Visual observations that should be performed when an operator inspects an industrial wastewater treatment facility include
    1. Calibrate polymer pump rates.
    2. Check chemical tank levels.
    3. Clean all screens and filters.
    4. Examine effluent.
    5. Survey instrument panel for alarm conditions.

10. When scanning motor control and instrument panels, operators should determine if
    1. All equipment is operating properly.
    2. Effluent discharge requirements are being met.
    3. No circuit breakers are tripped.
    4. Proper lights are on.
    5. Switches are in correct position.

11. The purposes of a preventive maintenance (PM) program include
    1. Analyzing electrical hazards.
    2. Communicating effectively with electricians.
    3. Keeping equipment working as intended.
    4. Keeping overall O & M costs down.
    5. Minimizing breakdowns, failures and repairs.

12. Computers can be used to
    1. Clean pH and ORP probes.
    2. Maintain an inventory of spare parts.
    3. Paint coatings damaged due to splashes.
    4. Record information on tasks completed.
    5. Schedule maintenance activities.

13. Typical items that should be included in an inventory list include
    1. Fuses.
    2. Lab reports.
    3. pH probes.
    4. Sludge produced.
    5. Solenoid valves.

14. Possible causes of a chemical feed pump not pumping include
    1. Check valves are stuck open or closed.
    2. Chemical feed tank is too full.
    3. Circuit breaker is tripped.
    4. Pump diaphragm is ruptured.
    5. Supply line is open.

15. Possible causes of level controls not working in a chemical feed system include
    1. Leak in bottom of tank.
    2. Probe rods have vibrated loose.
    3. Probes coated with precipitates.
    4. Probes shorted out with moisture.
    5. Waste flows fluctuating.

16. If an ORP reading is out of range, the first item to check is the
    1. Chemical supply lines for stoppages.
    2. Chemical supply tank level.
    3. Leaks from tanks within plant.
    4. pH.
    5. Pump.

17. A centrifugal pump's impeller could become jammed due to
    1. Accumulation of a crust within the pump body.
    2. Discharge valve closed.
    3. Impurities in the liquid being pumped.
    4. Stress on the pump body which has warped the pump.
    5. Tripped circuit breaker.

18. If a diaphragm pump is not working properly, check the
    1. Air pressure.
    2. Circuit breakers.
    3. Impeller.
    4. Power supply.
    5. Sampling program.

19. What types of materials must be removed from pH and ORP probes when they are cleaned?
    1. Acids
    2. Bases
    3. Liquids
    4. Oils and greases
    5. Precipitates

20. Possible causes of a pH indicator not moving off of one position include
    1. ORP values fluctuating.
    2. Probe connections disconnected.
    3. Probe dirty.
    4. Read-Standby switch on standby.
    5. Waste characteristics are constant.

21. Information that must be recorded for each sample includes
    1. Data.
    2. Location.
    3. Name of collector.
    4. Test procedure.
    5. Time.

22. Information that must be recorded with test results includes
    1. Date.
    2. Name of analyst.
    3. Test procedure.
    4. Time.
    5. Weather.

23. Errors in laboratory results can be caused by
    1. Improper analytical procedures.
    2. Incorrectly reading laboratory instrument.
    3. Performing test on wrong day.
    4. Poor sampling procedures.
    5. Writing down wrong numbers.

24. How many pounds of polymer must be added to a 100-gallon tank to produce a solution containing two milligrams of polymer per milliliter?
    1. 0.83 lbs
    2. 1.20 lbs
    3. 1.67 lbs
    4. 2.40 lbs
    5. 3.96 lbs

25. If a metal wastestream flows at 80 liters per minute and the desired polymer concentration in the wastestream is 2.5 mg/*L*, what should be the polymer pumping rate in milliliters per minute if the polymer solution concentration is two milligrams of polymer per milliliter?
    1. 80 m*L*/min
    2. 100 m*L*/min
    3. 120 m*L*/min
    4. 150 m*L*/min
    5. 200 m*L*/min

END OF OBJECTIVE TEST

SUGGESTED ANSWERS

ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 1.

1.0A Adequate treatment or pretreatment of industrial wastewaters before discharge to wastewater collection systems is important to prevent toxic, corrosive, flammable or explosive wastes from damaging the collection system, the treatment plant, the operators of these facilities, and the public which lives, works or plays near these facilities.

1.0B Toxic pollutants from industrial facilities must be controlled to prevent the
1. Introduction of pollutants into publicly owned treatment works (POTW) which could interfere with its operation (often called interference or inhibition),
2. Pass through of untreated pollutants which could violate applicable water quality standards or National Pollutant Discharge Elimination System (NPDES) effluent limitations (pass through), and
3. Contamination of POTW sludge which would limit the selected sludge uses or disposal practices (sludge contamination).

1.0C A sewer-use ordinance is a rule or regulation adopted by municipalities or wastewater collection system agencies which provide the necessary authority to require industrial pretreatment in order to control the discharge of industrial wastes into sewers.

1.0D An NPDES (National Pollutant Discharge Elimination System) permit is issued to industries who discharge treated wastewater to the environment. The permit specifies the discharge limitations necessary to protect the environment from the disposal of any harmful substances in the water.

Answers to questions on page 3.

2.0A Wastewaters come from several different sources at industrial facilities such as cleaning, preparation, production and rinsing processes, as well as the washing of equipment and production facilities.

2.0B The ideal situation for treating industrial wastewaters is to have the ability to treat each wastestream individually rather than as one combined industrial wastestream.

Answers to questions on page 10.

3.0A A Material Safety Data Sheet (MSDS) is a document which provides pertinent information and a profile or description of a particular hazardous substance or mixture.

3.0B Information that an operator can obtain from a Material Safety Data Sheet regarding a hazardous substance includes both the chemical and any common name, the CAS number, the potential for fire, explosion and/or reactivity, acute and chronic health effects, potential routes of exposure, symptoms of overexposure, proper precautions, handling practices, necessary personal protective equipment, safety precautions, emergency procedures for spills and fire, disposal procedures, first aid procedures, health risks, date information was compiled, and manufacturer responsible for preparing information.

3.0C A hazardous ingredient is a substance or form of a substance in a mixture, in sufficient concentration to produce a flammable vapor or gas, or to produce acute or chronic adverse effects in persons exposed to the product either in normal use or predictable misuse of it.

3.0D The "flammable or exposive limits" for a flammable vapor means the range of concentrations over which the flammable vapor mixed with proper portions of air will flash or explode if an ignition source is present.

3.0E Types of information that should be listed under "Spill or Leak Procedures" on an MSDS include (1) steps to be taken in case the material is released or spilled, including applicable precautions, and (2) waste disposal method.

Answers to questions on page 11.

4.0A Employee "Right-To-Know" legislation was enacted to require employers to inform employees (operators) of the health effects resulting from possible contact with hazardous substances.

4.0B An operator training program must include the following information in order to comply with "Right-To-Know" legislation:
1. Any health hazards known to be associated with exposure to the hazardous substances encountered in the workplace;
2. Proper instructions for handling hazardous materials and notice of personal protective equipment or other safety precautions necessary to prevent or minimize exposure to the hazardous substances; and
3. Emergency procedures to be followed for spills, fire, disposal and first aid.

4.0C An operator may have the right to refuse to work with a hazardous substance if your employer fails to produce a Material Safety Data Sheet (MSDS) or evidence that your employer has tried to obtain the requested MSDS.

ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 26.

5.0A Usually small wastewater flows are treated by the batch process because the storage requirements for the wastewater prior to treatment are minimal. Also concentrated wastes which cannot be handled otherwise are treated by the batch method.

5.1A Wastewaters with high pH levels are neutralized by the addition of acids such as sulfuric acid and hydrochloric acid. Carbon dioxide and sulfur dioxide can be applied in the gaseous form to lower the pH of liquids. Some industries use flue gases (high in carbon dioxide or sulfuric acid fumes) to lower the pH of waters when the gas is available and this is an economical solution.

5.1B Low pH wastewaters are neutralized by the addition of calcium oxide or lime, magnesium oxide, calcium hydroxide, magnesium hydroxide, or sodium hydroxide.

5.1C Operators must be very careful whenever highly acidic and basic solutions are mixed because of the potential for splattering, the generation of heat and the production of toxic gases. Highly acidic or basic solutions are very harmful to your skin, can cause loss of eyesight, and the fumes are extremely irritating to your lungs and to the mucous membranes in your body.

Answers to questions on page 32.

5.2A Two different pH levels may be necessary for hydroxide precipitation of metals when the metals present have considerably different pH levels for optimum hydroxide precipitation.

5.2B The major limitations of the sulfide precipitation process include:
1. Generation of toxic hydrogen sulfide gas if the pH drops below 8. Production of hydrogen sulfide gas can be minimized by using ferrous sulfide as the source of sulfide, and
2. Disposal of toxic metal sulfide sludges.

5.3A Complexed metals are difficult to treat because they have a tendency to remain in solution rather than form precipitates and settle out.

5.3B Complexed metal wastestreams may be treated by (1) high pH precipitation, (2) chemical reduction, or (3) sulfide precipitation.

Answers to questions on page 34.

5.4A Hexavalent chromium may be present in the form of chromic acid, chromate, or dichromate in an acid solution.

5.4B Hexavalent chromium must be converted to trivalent chromium so chromium can be removed from the wastestream by hydroxide precipitation.

5.4C Hexavalent chromium can be reduced to trivalent chromium by strong reducing agents such as sulfur dioxide, sodium bisulfite, sodium hydrosulfite, sodium metabisulfite and ferrous sulfate.

5.4D List what happens in a two-step treatment process of hexavalent chromium.

STEP 1 1. Add acid to lower pH to 2.0.
2. Add SO_2 or bisulfite to ORP of 250 mV.

STEP 2 1. Add caustic to increase pH up to 8.0 to 8.5.
2. Add polymer to improve flocculation if necessary.

Answers to questions on page 36.

5.5A Cyanide compounds get into metal wastestreams as a result of their use as metal salts for plating and conversion coating or they are active components in plating and cleaning baths.

5.5B If there is an equipment failure during the treatment of metal wastes containing cyanide, extremely toxic cyanide gases could be released. Therefore, all tanks or pits used for cyanide destruction must be properly located and ventilated so that any gases produced will never enter an area occupied by people.

5.5C The most practical and economical method of treating metal wastestreams containing cyanide is the *alkaline chlorination treatment process.*

5.5D Efficient operation of a cyanide oxidation system requires exact control of pH to prevent excessive use of chlorine and to ensure complete destruction of cyanide.

Answers to questions on page 39.

5.6A Precious metals can be recovered from metal wastestreams by evaporation, reverse osmosis, ion exchange and electrolytic metal waste treatment processes.

5.6B Ion exchange units are used to treat metal wastestreams to recover precious metals and other plating chemicals and to concentrate and purify plating baths.

5.6C Precious metals recovered by the ion exchange process include copper, molybdenum, cobalt, nickel, gold and silver.

5.6D Metal plating chemicals that can be recovered by ion exchange include chromium, nickel, phosophate solution, sulfuric acid from anodizing and chromic acid recovery.

Answers to questions on page 40.

5.7A Possible sources of oily wastes in wastestreams include process coolants and lubricants, wastes from painting processes, and machinery lubricants.

5.7B Oily wastes can be removed from metal wastestreams by skimming, coalescing, emulsion breaking, flotation, centrifugation, ultrafiltration, and reverse osmosis.

5.7C a. Free or floating oils can be separated from wastestreams by the use of gravity API oil separators, centrifuges, dissolved air flotation thickeners, and nitrification.
b. Emulsified oils are treated by the use of emulsion breaking procedures such as steam, heat cracking or acid emulsion breakers (polymers) with the addition of chemicals to cause the necessary separation and removal of oils. Oil removal may be achieved by skimming.

5.7D The principal reasons to minimize the discharge of oily wastes is to prevent the fouling of sensors and to comply with pretreatment discharge limitations.

Answers to questions on page 40.

5.8A Spent degreasing solvents must be segregated from the process wastewaters to maximize the value of the recoverable solvents, to avoid contamination of other segregated wastes, and to prevent the discharge of toxic organics to any wastewater collection systems or the environment.

5.8B Spent degreasing solvents can be segregated from other process wastewaters by providing and identifying the necessary storage containers, establishing clear disposal procedures, training operators in the use of these techniques, and checking periodically (monthly) to ensure that proper segregation is occurring.

5.8C Instead of using solvent degreasing procedures, possible alternatives include alkaline cleaning (sodium hydroxide baths) and the use of aqueous cleaners (high soap solutions).

5.8D The amount of solvents entering wastestreams can be reduced by:
1. Segregating spent solvents from other process wastewaters,
2. Encouraging operators to keep wastes segregated,
3. Providing clearly identified storage containers,
4. Establishing clear disposal procedures,
5. Training operators in the use of proper techniques, and
6. Checking monthly to be sure proper segregation is occurring.

Answers to questions on page 41.

5.9A The quantity of toxic organics reaching wastestreams can be reduced by proper housekeeping procedures and by using cleaning techniques that require no solvents. These cleaning techniques include wiping, immersion, spray techniques using water, alkaline and acid mixtures, and solvent emulsions.

5.9B Toxic organics that enter wastestreams can be removed by treatment processes used for the control of other pollutants. Aeration and carbon adsorption are the processes commonly used. Other treatment processes include settling and volatilization. In some situations, the activated sludge process is appropriate if a biological culture can be developed which is acclimated to the wastes.

Answers to questions on page 41.

6.0A Sludges are created from metal wastestreams by the precipitation, sedimentation and other processes which are used to remove solids from wastewater.

6.0B Filter presses are used to process sludges by dewatering the sludges by passing the dilute sludge through a filter material which will hold the solids, but allow the liquid portion of the sludge to pass through the filter media.

6.0C Sludges may be ultimately disposed of in approved landfills.

ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 48.

7.0A An operator can be exposed to hazardous chemicals by (1) storing and handling chemicals used in the treatment processes and (2) treating hazardous chemicals in wastestreams.

7.0B Chemicals are used in waste treatment processes to raise or lower the pH and to serve as oxidizing or reducing agents in chemical reactions.

7.0C Operators should be very careful when working with sodium hydroxide (caustic) because this chemical causes painful burns if it enters breaks in the skin or gets under skin around fingernails. Caustic will cause blindness if it gets into your eyes.

Answers to questions on page 50.

7.0D The mixing of caustics can generate sufficient heat to weaken plastic tanks and cause them to break open. Mixing of acids and caustics can lead to "splatter" or "explosions" which can be extremely hazardous to operators.

7.0E Acids must be contained in rubber, glass or plastic-lined equipment. Store acids in clean, cool, well-ventilated areas. The areas should have an acid-resistant floor and adequate drainage. Keep acids away from oxidizing agents, alkaline or basic material, and cyanide.

7.0F Special precautions to be taken when handling or storing caustic soda include (1) prevent eye and skin contact, (2) do not breathe dusts or mists, and (3) avoid storing caustic next to strong acids. Also protect your nose and throat with an approved respiratory system, protect your eyes by wearing chemical workers' goggles and/or a full face shield, and protect your body by being fully clothed and by using impervious gloves, boots, apron and face shield.

Answers to questions on page 52.

7.0G First aid means emergency treatment for injury or sudden illness, before regular medical treatment is available.

7.0H If acid comes in contact with your skin, wash the area with large amounts of water. Baking soda may be used to neutralize acid on skin because it is not harmful on contact with skin.

7.0I Eye irritation caused by chlorine gas should be treated by flushing the eyes with generous amounts of water for not less than 15 minutes.

Answers to questions on page 52.

7.1A The factors which influence the types and complexity of the processes used to treat metal wastes include the:
1. Particular wastestream characteristics,
2. Space available for treatment,
3. Costs of the processes, and
4. Effluent discharge requirements.

7.1B Metal waste treatment processes require continuous monitoring and adjustment of the treatment processes because the flows and characteristics of the wastewaters being treated change hourly, daily, weekly and seasonally due to changes in the production processes and maintenance procedures.

Answers to questions on page 54.

7.2A For effective operation of wastewater treatment facilities, operators must visually observe the wastewater being treated; read, record and analyze instrument readouts and printouts; collect,analyze and interpret sample test results; and physically adjust process control settings.

7.2B An operator can determine if a precipitation process is working properly by visual observations. The water in the precipitation phase of a precipitation process should look cloudy or full of solids if the process is functioning properly. A clear wastewater would indicate that the precipitation tank is not receiving treatment chemicals, or that some component of the wastewater (ammonia, chelates or acids) is defeating the precipitation process.

7.2C The effluent from normal metal waste treatment processes should appear clear, color free, and with no floc or sludge carryover.

Answers to questions on page 56.

7.2D The largest sources of errors found in laboratory results are usually caused by improper sampling; poor preservation; and lack of sufficient mixing, compositing, and testing.

7.2E A representative sample must be collected or the test results will not have any significant meaning. To efficiently operate a wastewater treatment plant, the operator must rely on test results to indicate what is happening in the treatment process.

7.2F A proportional composite sample may be prepared by collecting a sample every hour. The size of this sample is proportional to the flow when the sample is collected. All of these proportional samples are mixed together to produce a proportional composite sample. If an equal volume of sample was collected each hour and mixed, this would simply be a composite sample.

Answers to questions on page 59.

7.2G Flow measurement is the determination of the RATE of flow past a certain point, such as the inlet to the headworks structure of a treatment plant. Flow is measured and recorded as a quantity (gallons or cubic feet) moving past a point during a specific time interval (seconds, minutes, hours, or days). Thus we obtain a flow rate or quantity in cu ft/sec or MGD.

7.2H Quantity = Area x Velocity, or Q = AV.

7.2I Flow should be measured in order to determine wastewater treatment plant loadings and efficiencies.

7.2J Different types of flow measuring devices include constant differential, head area, velocity meter, differential head, and displacement.

7.2K Potential causes of flow meter errors include foreign objects fouling the system or the meter may not be installed in the intended location. (Liquids should flow smoothly through the meter and flow should not be changing directions, nor should waves be present on the liquid surface above the measuring device.) Check the primary sensor, transmitter, receiver, and power supply.

Answers to questions on page 60.

7.3A Operators should learn as much as possible about electricity *FOR THEIR OWN SAFETY* and to enable them to analyze electrical problems and to communicate effectively with electricians.

7.3B The purpose of a preventive maintenance program is to keep the equipment and treatment processes working as intended, to minimize breakdowns, failures and repairs, and also to keep overall O & M costs down both today and in the future.

7.3C Operators must consult equipment manufacturers' maintenance manuals for instructions regarding how to maintain equipment and the frequency of each task.

7.3D Properly operating ventilation systems are of utmost importance in metal plating and metal finishing facilities because the possibility exists that extremely toxic gases such as cyanide, hydrogen sulfide and chlorine may be released or escape into the work environment.

Answers the questions on page 62.

7.3E Cavitation is the formation and collapse of a gas pocket or bubble on the blade of an impeller. The collapse of this gas pocket or bubble drives water into the impeller with a terrific force that can cause pitting on the impeller surface.

7.3F Pumps must be lubricated in accordance with manufacturer's recommendations. Quality lubricants should be used.

7.3G In lubricating motors, too much grease may cause bearing trouble or damage the winding.

Answers to question on page 63.

7.3H If a pump will not start, check for blown fuses or tripped circuit breakers and the cause. Also check for a loose connection, fuse or thermal unit.

7.3I To increase the rate of discharge from a pump, you should look for something causing the reduced rate of discharge, such as pumping air, motor malfunction, plugged lines or valves, impeller problems, or other factors.

Answers to questions on page 63.

7.3J If a pump that has been locked or tagged out for maintenance or repairs is started, an operator working on the pump could be seriously injured and also equipment could be damaged.

7.3K Normally a centrifugal pump should be started after the discharge valve is opened. Exceptions are treatment processes or piping systems with vacuums or pressures that cannot be dropped or allowed to fluctuate greatly while an alternate pump is put on the line. If the pump is not equipped with a check valve and the discharge pressure is higher than the suction pressure under static conditions, the pump could run backwards and cause damage to the equipment.

Answers to questions on page 65.

7.3L Before stopping an operating pump:
1. Start another pump (if appropriate), and
2. Inspect the operating pump by looking for developing problems, required adjustments, and problem conditions of the unit.

7.3M A pump shaft or motor will spin backwards if water being pumped flows back through the pump when the pump is shut off. This will occur if there is a faulty check valve or foot valve in the system.

7.3N The position of all valves should be checked before starting a pump to ensure that the water being pumped will go where intended.

Answers to questions on page 65.

7.3O The most important rule regarding the operation of positive displacement pumps is to *NEVER* start the pump against a closed discharge valve.

7.3P If a positive displacement pump is started against a closed discharge valve, the pipe, valve or pump could rupture from excessive pressure. The rupture will damage equipment and possibly seriously injure or kill someone standing nearby.

Answers to questions on page 68.

7.4A Major factors that could be the cause of a pH meter not working properly include

(1) *DIRECT CHEMICAL FEED SYSTEMS*

a. Chemical pump is not pumping

(2) *INDIRECT CHEMICAL FEED SYSTEMS*

a. Transfer pump is not working
b. Level controls are not working
c. Solenoid valve is not working
d. Extra high concentrations of chemicals in the waste discharge
e. Chemical mixer not working properly

7.4B Level controls may not work properly due to:

1. Probes coated with precipitates.
2. Probes shorted out with moisture and chemicals.
3. Probe rods have vibrated loose.
4. Chemical encrustations (coatings) limit probe movement (types of float switches or magnetic reed switches).

7.4C If ORP readings are out of the proper range, the following items should be checked:

1. pH values,
2. Supply tank chemical level,
3. Defective pumps,
4. Clogged chemical supply lines,
5. Chemical supply rate to the reactor tank, and
6. Leaks from tanks within the plant (inspect specialized use tanks such as chrome or cyanide).

7.4D If a centrifugal pump is not operating properly, check the following items:

1. Pump is on (motor is running),
2. Fluid level of supply,
3. Vapor lock conditions in pump,
4. All valves on supply and discharge sides of the pump are open,
5. Concentration level (specific gravity) of chemicals,
6. Pump's motor swtich, motor heaters and windings, and
7. Impeller.

7.4E If a waste being treated is not flocculating properly, check

1. pH,
2. Polymer flow rate, and
3. Adequacy of polymer flow rate (chemical dosage).

Answers to questions on page 74.

7.5A pH and ORP probes must be cleaned on a weekly basis or more frequently because the probes must have a "good" contact with the fluid they are measuring.

7.5B Both pH and ORP probes must be cleaned to remove precipitates as well as oil and grease.

7.5C Treatment processes requiring the use of a high pH "slope" buffer include metal precipitation and cyanide destruction processes, while chrome reduction requires the use of a low pH "slope" buffer.

7.5D Problems that could develop with the indicator when using pH and ORP probes include:

1. Indicator does not move off of one position,
2. Indicator has no reading,
3. Indicator has a very low reading, and
4. Indicator moves very slowly.

Answers to questions on page 76.

7.6A If the flow of metal wastes into a treatment facility fills a 10-gallon bucket in 5 seconds, what is the flow rate in gallons per minute (GPM) and liters per minute?

Known	Unknown
Volume, Gal = 10 Gal	Flow, GPM
Time, sec = 5 sec	Flow, *L*/min

Calculate the flow rate in gallons per minute.

$$\text{Flow, GPM} = \frac{(\text{Volume, Gal})(60\text{ sec/min})}{\text{Time, sec}}$$

$$= \frac{(10\text{ Gal})(60\text{ sec/min})}{5\text{ sec}}$$

$$= 120\text{ GPM}$$

Calculate the flow rate in liters per minute.

$$\text{Flow, Liters/min} = (\text{Flow, GPM})(3.785\ L/\text{Gal})$$

$$= (120\text{ GPM})(3.785\ L/\text{Gal})$$

$$= 454\text{ Liters/min}$$

7.6B How many pounds of polymer must be added to a 55-gallon drum to produce a solution containing one milligram of polymer per milliliter (0.1% polymer solution)?

Known	Unknown
Volume, Gal = 55 Gal	Polymer, lbs
Conc, mg/*L* = 1 mg/m*L*	
= 1 g/*L*	
= 0.1% polymer	

Convert volume from gallons to liters.

$$\text{Volume, } L = (\text{Vol, Gal})(3.785\ L/\text{Gal})$$

$$= (55\text{ Gal})(3.785\ L/\text{Gal})$$

$$= 208\ L$$

Determine the amount of polymer in pounds.

$$\text{Polymer, lbs} = \frac{(\text{Polymer Conc, g}/L)(\text{Volume, }L)}{454\text{ g/lb}}$$

$$= \frac{(1\text{ g}/L)(208\ L)}{454\text{ g/lb}}$$

$$= 0.46\text{ lbs polymer}$$

7.6C If a metal wastestream flows at 100 liters per minute and the desired polymer concentration in the wastestream is 2 mg/*L*, what should be the polymer pumping rate in milliliters per minute if the polymer solution concentration is one milligram polymer per milliliter (0.1% polymer solution)?

Known	Unknown
Flow, *L*/min = 100 *L*/min	Polymer Pumping Rate, m*L*/min
Polymer Conc, mg/*L* = 2 mg/*L*	
Polymer Sol, mg/m*L* = 1 mg/m*L*	
= 0.1%	

Determine the polymer dosage in milligrams per minute.

$$\text{Polymer Dosage, mg/min} = (\text{Flow, }L/\text{min})(\text{Polymer Conc, mg}/L)$$

$$= (100\ L/\text{min})(2\text{ mg}/L)$$

$$= 200\text{ mg/min}$$

Calculate the polymer pumping rate in milliliters per minute.

$$\text{Polymer Pumping} = \frac{\text{Polymer Dose, mg/min}}{\text{Polymer Solution, mg/m}L}$$

$$= \frac{200 \text{ mg/min}}{1 \text{ mg/m}L}$$

$$= 200 \text{ m}L\text{/min}$$

Answers to questions on page 82.

7.7A The *simplest* procedure for measuring pH is by the use of pH test strips or pH test tapes.

7.7B Color comparison test kits may *give unreasonable* results when measuring metals if the water being tested contains complexing agents or suspended solids.

7.7C Spectrophotometer test results are more accurate and reproducible than color comparison kits when measuring metal concentrations because the spectrophotometer uses a specific light wave length for each metal. The color comparison kit test results are *subject to the ability of each person's eyes to match* color.

7.7D The validity of results provided by a commercial laboratory can be tested by submitting a sample of known strength (metal concentration) to the commercial laboratory along with other regular samples.

FINAL EXAMINATION

This final examination was prepared *TO HELP YOU* review the material in the manual. The questions are divided into three types:

1. Multiple choice,
2. Short answers, and
3. Problems.

To work this examination:

1. Write the answer to each question in your notebook,
2. After you have worked a group of questions (you decide how many), check your answers with the suggested answers at the end of this exam, and
3. If you missed a question and don't understand why, reread the material in the manual.

You may wish to use this examination for review purposes when preparing for civil service and certification examinations.

Since you have already completed this course, you do not have to send your answers to California State University, Sacramento.

MULTIPLE CHOICE

1. Toxic pollutants from industrial facilities must be controlled to prevent the
   1. Clogging of bar screens in POTWs.
   2. Contamination of sludge from PTOWs.
   3. Introduction of pollutants which could interfere with the operation of POTWs.
   4. Overloading of activated sludge processes in POTWs.
   5. Passage of untreated pollutants through POTWs.

2. Metal wastestreams from a metal finishing shop should be kept separate to cause
   1. Each individual pollutant to be treated separately.
   2. Formation of metal hydroxides.
   3. Neutralization of the wastestream.
   4. Oxidation of cyanide.
   5. Reduction of chromium.

3. Flammable or explosive data in an MSDS contain information on range of __________ over which a flammable vapor will flash or explode.
   1. Boiling points
   2. Concentrations
   3. Solubility products
   4. Temperatures
   5. Vapor pressures

4. Fire fighting substances that are used to extinguish fires include
   1. Dry chemicals.
   2. Fumes.
   3. Solvents.
   4. Vapors.
   5. Water.

5. If you work with any hazardous substances, employee "Right-To-Know" laws require that your employer must provide you with
   1. Detailed procedures on how to contact the regulatory agencies in case of treatment process failures.
   2. Examples of safe and unsafe practices.
   3. Information on the health implications resulting from contact with the substances.
   4. Material Safety Data Sheets.
   5. Training for working safely with the hazardous substances.

6. Topics usually covered in an "Employee-Right-To-Know" law include
   1. Access to operator exposure records.
   2. Frequency shop has violated sewer discharge standards.
   3. Notification of operators of hazardous substances in workplace.
   4. Operators' rights to refuse to work with a hazardous substance.
   5. Results of OSHA inspections.

7. Wastestreams that should be pretreated separately before they are combined with source wastestreams of common metals include
   1. Complexed metal wastes.
   2. Hexavalent chromium.
   3. Nickel.
   4. Oily wastes.
   5. Zinc.

8. A complexed metal is a metal that has reacted with or is tied up with a chemical complexing agent such as
   1. Ammonia.
   2. Bisulfite.
   3. Chlorine.
   4. Citrates.
   5. Quadrol.

9. Advantages of batch treatment processes over continuous flow treatment processes include
   1. Better job of treating acid dumps.
   2. Better suited to treat relatively large wastewater flows.
   3. Closer control when treating fluctuating waste concentrations.
   4. Less space required to treat rinse waters.
   5. Produces more dilute sludge solids.

10. Wastewaters with high pH levels are neutralized by the addition of
    1. Calcium oxide.
    2. Carbon dioxide.
    3. Caustic soda.
    4. Soda ash.
    5. Sulfuric acid.

11. Limitations of the metal hydroxide precipitation process include
    1. Changes in optimum pH can reduce removal efficiencies.
    2. Costs of hydroxide chemicals are higher than for sulfide chemicals used for precipitation.
    3. Hydroxide precipitation effluents are more toxic than sulfide precipitation effluents.
    4. Large quantities of sludge are produced.
    5. Presence of complexing ions may adversely affect metal removal efficiencies.

12. Chemicals that may be used in the reduction of hexavalent chromium to trivalent chromium include
    1. Lime.
    2. Permanganate.
    3. Sodium bisulfite.
    4. Sodium hydrosulfite.
    5. Sulfuric acid.

13. Chemicals that may be used in the oxidation of cyanide include
    1. Chlorine gas.
    2. DPD.
    3. Sodium hydroxide.
    4. Sodium hypochlorite.
    5. Sulfur dioxide.

14. Precious metal recovery may be achieved by
    1. Acidification.
    2. Electrolytic processes.
    3. Evaporation.
    4. Hydroxide precipitation.
    5. Oxidation.

15. Free or floating oils can be separated from wastestreams by the use of
    1. Acids.
    2. API oil separators.
    3. Centrifuges.
    4. ~~Dissolved air flotation~~ units.
    5. Steam.

16. Chemical storage and handling facilities must have proper spill containment measures to prevent
    1. Hydroxide precipitation of metal wastes.
    2. Leaching of sludges into groundwater.
    3. Mixing of acids and cyanide wastes.
    4. Mixing of incompatible wastes.
    5. Sewer problems as a result of accidents and spills.

17. Which of the following items should operators check or perform when they walk through their waste treatment facility?
    1. Determine sludge level in settling tank.
    2. Examine status of monthly report.
    3. Inspect area for flooding, leaks, spills or equipment problems.
    4. Observe floc conditions and settling characteristics.
    5. Survey control panel for alarm conditions.

18. Good sampling procedures require
    1. Ensuring that the sample taken is truly representative of the wastestream.
    2. Following proper analytical procedures in the laboratory.
    3. Protecting and preserving the samples until they are analyzed.
    4. Recording test results properly.
    5. Using proper sampling techniques.

19. Items that should be included in the spare parts inventory of a preventive maintenance program include
    1. Belts.
    2. Chemical reagents.
    3. Motor heaters.
    4. pH probes.
    5. Solenoid valves.

20. Which of the following items could be the cause of a pump not starting?
    1. Blown fuses.
    2. Cavitation.
    3. Loose electrical connections.
    4. Tripped circuit breakers.
    5. Worn impellers.

21. Wastestream treatment process "upsets" may be caused by
    1. Control system failure.
    2. Equipment failure.
    3. Instrumentation failure.
    4. Operator error.
    5. Troubleshooting checklists.

22. Possible causes of a pH meter not moving off of one position include
    1. Ground-loop problem.
    2. Probe connections may be disconnected.
    3. Probe may need cleaning.
    4. Switch on standby instead of read.
    5. Waste characteristics may be unusually constant.

23. Color comparison kits used to test metal concentrations can give reasonable results provided there are no ____________ present in the water being tested.
    1. Complexing agents
    2. Cyanide
    3. High levels of suspended solids
    4. Hydroxides
    5. Unidentified color species

24. The term "chain of possession" refers to
    1. Control of metal wastestreams.
    2. Handling of samples from collection to laboratory analyst.
    3. Permit limitations imposed by regulatory agencies.
    4. Possession of trade secrets by a shop.
    5. Procedures used in the lab to analyze samples.

25. Laboratory results may not be correct due to
    1. Improper sampling procedures.
    2. Incorrect reading of lab instruments.
    3. Proper laboratory analytical procedures.
    4. Recording test results in wrong space on lab bench sheet.
    5. Writing down wrong number.

SHORT ANSWERS

1. How could a metal plating shop reduce the costs of treating wastewater?
2. List the sources of wastewater in an electroplating shop.
3. Prepare a list of important informational items available on an MSDS.
4. List three methods that could be either an acceptable or a prohibited method for disposing of spilled solids or liquids.
5. What procedures should be followed to clean up a spill or leak of liquid caustic soda?
6. The steepness of the titration curves of wastestreams near the equivalence points is a good indication of the difficulty of pH control. What other factors also can make pH control difficult?
7. Why are complexed metals difficult to treat?
8. Which cyanide compounds may be treated by chlorination and which ones may not?
9. When destroying cyanide by the chemical oxidation process, why must acid be added if the pH becomes too high?
10. What is the relationship between chlorine concentrations, pH and ORP when oxidizing cyanide?
11. Why must spent degreasing solvents be segregated from other process wastewaters?
12. What tasks must be performed by operators for successful operation and maintenance of industrial wastewater treatment facilities?
13. What protective clothing should be worn when handling acids?
14. Where should first aid kits be located?
15. Why do metal waste treatment processes require continuous monitoring and adjustment of the treatment processes?
16. What items should be considered when selecting the location of a flow metering device?
17. Why should operators learn as much as possible about electricity?
18. If a metal wastestream being treated is not flocculating, what would you do?
19. What problems may develop with the indicator of either a pH or ORP probe?
20. How can a ground-loop problem be corrected?

PROBLEMS

1. Determine the percent reduction in flows achieved by a water conservation program if wastestream flows are reduced from 320 GPM to 275 GPM.
2. Calculate the total amount of polymer in pounds and also in ounces that must be added to a sixty gallon polymer tank to produce a polymer concentration of 0.5 mg polymer per milliliter.
3. How many pounds of chlorine are in a 50-gallon container full of a five percent hypochlorite solution?
4. Determine the chlorinator setting for a wastestream flow of 75 GPM that requires a chlorine dose of 12 mg/*L*.
5. A chemical feed pump is set to deliver 55 gallons per day. What is the feed rate in milliliters per minute?
6. A chemical feed pump delivers 430 m*L* in three minutes. What is the pump feed rate in gallons per day?
7. Determine the gallons of waste delivered to a chemical treatment tank if the pumping rate is 60 GPM for three hours.
8. Estimate the retention time in a 6000 gallon chemical mix tank when the flow is 300 GPM.
9. Estimate the chemical feed rate in GPD when a chemical feed pump lowers a chemical solution 10 inches in a 15-inch diameter chemical container in 4 hours.
10. The calculated pure chemical dose for a chemical solution is 1.2 pounds. The chemical delivered to the shop contains 95 percent active chemical. Calculate the pounds of chemical delivered to the shop to produce the desired dose.
11. The effluent from a filter press treating an industrial sludge must have its pH adjusted before additional treatment. If a 100 m*L* sample of effluent requires 10.7 m*L* of 0.5 N sulfuric acid to lower the pH to 8.0, how many gallons of 2 N sulfuric acid will be required to lower the pH of 600 gallons of filter press effluent to a pH of 8.0?
12. A plating solution contains 0.6 ounces per gallon of hexavalent chromium. What is the concentration in milligrams per liter?
13. Determine the polymer pumping rate in gallons per day if a 0.2 polymer solution is delivered to a wastestream with a flow of 200 GPM. The desired polymer dose in the wastestream is 1.5 mg/*L*.
14. A cyanide-bearing waste is to be treated by a batch process using the alkaline chlorination method. The cyanide holding tank contains 7500 gallons with a cyanide concentration of 18 mg/*L*. Seven pounds of caustic and eight pounds of chlorine are required to oxidize one pound of cyanide to carbon dioxide and nitrogen gas.
    a. How many pounds of chlorine are needed?
    b. How long will the hypochlorinator have to operate if the hypochlorite solution is 2.0 percent chlorine and the hypochlorinator can deliver 240 GPD?
    c. How long should the caustic soda feed pump operate if the pump delivers 140 gallons per day of a ten percent caustic soda solution?

SUGGESTED ANSWERS FOR FINAL EXAMINATION

MULTIPLE CHOICE

1. 2, 3, 5 Toxic pollutants from industrial facilities must be controlled to prevent the introduction of pollutants which could interfere with operation, the passage of untreated pollutants and the contamination of sludges from POTWs.

2. 1 Metal wastestreams from a metal finishing shop should be kept separate to cause each individual pollutant to be treated by a separate process.

3. 2 Flammable or explosive data in an MSDS contain information on the range of concentrations over which a flammable vapor will flash or explode.

4. 1, 5 Dry chemicals and water are fire fighting substances that are used to extinguish fires.

5. 3, 4, 5 If you work with any hazardous substances, "Employee Right-To-Know" laws require that your employer must provide you with information on the health implications resulting from contact with the substances, Material Safety Data Sheets, and training for working safely with the hazardous substances.

6. 1, 3, 4 Topics usually covered in an "Employee Right-To-Know" law include access to operator exposure records, notification of operators of hazardous substances in workplace, and operators' rights to refuse to work with a hazardous substance.

7. 1, 2, 4 Wastestreams that should be pretreated separately before they are combined with source wastestreams of common metals include complexed metal wastes, hexavalent chromium and oily wastes.

8. 1, 4, 5 A complexed metal is a metal that has reacted with or is tied up with chemical complexing agents such as ammonia, citrates or quadrol.

9. 1, 3 Advantages of batch treatment processes over continuous flow treatment processes include better job of treating acid dumps and closer control when treating flocculating waste concentrations.

10. 2, 5 Wastewaters with high pH levels are neutralized by the addition of carbon dioxide and sulfuric acid.

11. 1, 4, 5 Limitations of the metal hydroxide precipitation process include changes in optimum pH can reduce removal efficiencies, large quantities of sludge are produced, and presence of complexing ions may adversely affect metal removal efficiences.

12. 3, 4, 5 Chemicals that may be used in the reduction of hexavalent chromium to trivalent chromium include sodium bisulfite, sodium hydrosulfite and sulfuric acid.

13. 1, 3, 4 Chemicals that are used in the oxidation of cyanide include chorine gas, sodium hydroxide and sodium hypochlorite.

14. 2, 3 Precious metal recovery may be achieved by electrolytic processes and evaporation.

15. 2, 3, 4 Free or floating oils can be separated from wastestreams by the use of API oil separators, centrifuges and dissolved air flotation units.

16. 3, 4, 5 Chemical storage and handling facilities must have proper spill containment measures to prevent mixing of acids and cyanide wastes, mixing of incompatible wastes and sewer problems as a result of accidents and spills.

17. 1, 3, 4, 5 When walking through a waste treatment facility, the operators should check sludge level, area for flooding, leaks, spills or equipment problems, floc conditions and settling characteristics, and control panel for alarm conditions.

18. 1, 3, 5 Good sampling procedures require ensuring that the sample taken is truly representative of the wastestream, protecting and preserving the samples until they are analyzed, and using proper sampling techniques.

19. 1, 3, 4, 5 Items that should be included in the spare parts inventory of a preventive maintenance program include belts, motor heaters, pH probes and solenoid valves.

20. 1, 3, 4 A pump may not start due to blown fuses, loose electrical connections, or tripped circuit breakers.

21. 1, 2, 3, 4 Process upsets may be caused by equipment, instrumentation or control system failure or operator error.

22. 2, 3, 4, 5 Possible causes of a pH meter not moving off of one position include probe may need cleaning, probe connections may be disconnected, switch on standby instead of read, and waste characteristics may be unusually constant.

23. 1, 2, 3, 5 Color comparison kits used to test metal concentrations can give reasonable results provided there are no complexing agents, cyanide, high levels of suspended solids, or unidentified color species present in the water being tested.

24. 2 The term "chain of possession" refers to the handling of samples from collection to laboratory analyst.

25. 1, 2, 4, 5 Laboratory test results may not be correct due to improper sampling procedures, incorrect reading of lab instruments, recording test results in wrong space on lab bench sheet and writing down wrong number.

SHORT ANSWERS

1. A metal plating shop could reduce the cost of treating wastewater by minimizing the use of water and maximizing the recovery and recycling of both water and raw or waste materials to reduce waste treatment and disposal costs. Costs can be lowered by using conductivity meters to control rinse flows, installing spray rinses, and proper racking to reduce metal drag out. The use of aqueous cleaners instead of organic solvents and the elimination of cyanide plating baths can help reduce costs. Keeping wastestreams separate and treating each pollutant individually will lower costs.

2. The sources of wastewater in an electroplating shop include:
   1. Cleaning,
   2. Preparation,
   3. Production,
   4. Rinsing, and
   5. Washing.

3. Important informational items available to operators on an MSDS include:
   1. Emergency telephone numbers,
   2. Hazardous ingredients,
   3. Fire and explosion hazards,
   4. Health hazards,
   5. Emergency and first aid procedures,
   6. Steps to be taken in case material is released or spilled,
   7. Waste disposal method,
   8. Protection procedures and equipment, and
   9. Precautions to be taken in handling and storing.

4. Three methods that could be either an acceptable or a prohibited method for disposing of spilled solids or liquids include:
   1. Flushing with water,
   2. Returning to container, and
   3. Burning.

5. To clean up a spill or leak of liquid caustic soda, wear an alkali-resistant slicker suit and complete protective equipment including rubber gloves, rubber boots, chemical goggles and face shield. For small spills or drips, mop or wipe up and dispose of in DOT (Department of Transportation)-approved waste containers. For large spills, contain by diking with soil or other absorbent material and carefully neutralize with dilute hydrochloric acid. Keep non-neutralized material out of sewers, storm drains, surface waters and soil. Comply with all applicable government regulations on spill reporting, and handling and disposal of waste.

6. In addition to steep titration curves near the equivalence points, pH control can be difficult when mixing times are short, tankage is too small, titrant concentrations are too high and feed equipment including pumps as well as instrumentation are marginally sized.

7. Complexed metals are difficult to treat because they have a tendency to remain in solution rather than form precipitates and settle out.

8. Cyanide compounds that are readily oxidized by chlorination are sodium, potassium, cadmium, and zinc cyanides. Copper, nickel, silver and gold cyanide complexes may also be treated by chlorination. The iron complexes are not considered to be oxidizable by chlorination.

9. When destroying cyanide by the chemical oxidation process, acid must be added whenever the pH becomes too high to keep the process under control. Excessive alkali (too high a pH) results in the suppression of ORP values. When the ORP value drops, the ORP controller will request more hypochlorite. Sodium hypochlorite always contains free sodium hydroxide. When the pH rises, the ORP value decreases, thus establishing an out-of-control situation. This problem is eliminated by the addition of acid whenever the pH rises too high.

10. When oxidizing cyanide for every tenfold increase in chlorine concentration, the oxidation-reduction potential increases by approximately 60 mV. For every one unit of pH increase, the ORP decreases by approximately 60 mV.

11. Spent degreasing solvents must be segregated from the process wastewaters to maximize the value of the recoverable solvents, to avoid contamination of other segregated wastes, and to prevent the discharge of toxic organics to any wastewater collection system or to the environment.

12. Tasks performed by operators for succesful operation and maintenance of industrial wastewater treatment facilities include:
    1. Ability to recognize safety hazards and to follow safe procedures at all times,
    2. Knowledge of the chemical processes involved,
    3. Knowledge of how the equipment is supposed to function,
    4. Knowledge of waste treatment facility operations and maintenance (O & M) manual,
    5. Methodic and periodic observation of system,
    6. Ability to collect samples, analyze results and verify expected performance,
    7. Use of laboratory analytical support facilities, and
    8. Ability to develop and implement routine preventive maintenance program.

13. When handling acids, wear protective clothing and equipment to prevent body contact with the acid. Wear rubber gloves, safety goggles and/or a face shield for eye protection against splashing. Also wear a rubber apron, rubber boots, and a long-sleeved polyester shirt.

14. First aid kits should be prominently displayed throughout the treatment plant and in company vehicles. *Special consideration must be given* to the most hazardous areas of the plating shop such as equipment shops, laboratories and chemical handling facilities.

15. Metal waste treatment processes require continuous monitoring and adjustment of the treatment processes because the flows and characteristics of the wastewater being treated change hourly, daily, weekly and seasonally, due to changes in the production processes and maintenance procedures.

16. When selecting the location of a flow metering device, items that should be considered include being sure the *flow is in a straight line before* the flow meter, the device must be accessible for servicing, there should not be waves in open channels, and there should not be any valves, elbows or other fixtures that could disrupt the flow ahead of the meter.

17. Operators should learn as much as possible about electricity for their own safety and to enable them to analyze electrical problems and to communicate effectively with electricians.

18. If a metal wastestream being treated is not flocculating, check the pH, polymer flow rate, chemical dosage and *possible change in waste characteristics.*

19. Problems that may develop with the indicator of either a pH or ORP probe include the probe not moving off of one position, not having any reading, having a very low reading, moving very slowly and moving erratically.

20. A ground-loop problem can be corrected by (1) finding the source of the stray current and preventing the current from flowing through the *wastestream, (2) placing* a ground-loop into the tank by inserting a copper rod into the wastestream flowing through the tank and running a wire from the rod to the ground or (3) running a wire back to the shield of the instrument.

PROBLEMS

1. Determine the percent reduction in flows achieved by a water conservation program if wastestream flows are reduced from 320 GPM to 275 GPM.

Known	Unknown
Original Flow, GPM = 320 GPM	Flow Reduction, %
Reduced Flow, GPM = *200 GPM*	

Calculate the percent reduction in flow.

$$\text{Reduction, \%} = \frac{(\text{Original Flow, GPM} - \text{Reduced Flow, GPM})(100\%)}{\text{Original Flow, GPM}}$$

$$= \frac{(320 \text{ GPM} - 275 \text{ GPM})(100\%)}{320 \text{ GPM}}$$

$$= 14\%$$

2. Calculate the total amount of polymer in pounds and also in ounces that must be added to a sixty gallon polymer tank to produce a polymer concentration of 0.5 mg polymer per milliliter.

Known	Unknown
Tank Vol, gal = 60 gal	Polymer, lbs
Poly Conc, mg/m*L* = 0.5 mg/m*L*	Polymer, oz

Convert milligrams per milliliter to a percent.

$$\text{Poly Conc, \%} = \frac{(\text{Poly Conc, mg/m}L)(1000 \text{ m}L/L)(100\%)}{1{,}000{,}000 \text{ mg}/L}$$

$$= \frac{(0.5 \text{ mg/m}L)(1000 \text{ m}L/L)(100\%)}{1{,}000{,}000 \text{ mg}/L}$$

$$= 0.05\%$$

Calculate the pounds and also ounces of polymer required.

$$\text{Polymer, lbs} = \frac{(\text{Tank Vol, gal})(8.34 \text{ lbs/gal})(\text{Poly Conc, \%})}{100\%}$$

$$= \frac{(60 \text{ gal})(8.34 \text{ lbs/gal})(0.05\ \%)}{100\%}$$

$$= 0.25 \text{ lbs}$$

$$= (0.25 \text{ lbs})(16 \text{ oz/lb})$$

$$= 4 \text{ oz}$$

3. How many pounds of chlorine are in a 50-gallon container full of a five percent hypochlorite solution?

Known	Unknown
Volume, gal = 50 gal	*Chlorine*, lbs
Hypochlorite, % = 5%	

Calculate the pounds of chlorine in the container.

$$\text{Chlorine, lbs} = \frac{(\text{Volume, gal})(8.34 \text{ lbs/gal})(\text{Hypochlorite, \%})}{100\%}$$

$$= \frac{(50 \text{ gal})(8.34 \text{ lbs/gal})(5\%)}{100\%}$$

$$= 20.85 \text{ lbs}$$

4. Determine the chlorinator setting for a wastestream flow of 75 GPM that requires a chlorine dose of 12 mg/*L*.

Known	Unknown
Flow, GPM = 75 GPM	Chlorinator Setting, lbs/24 hrs
Dose, mg/*L* = 12 mg/*L*	

Calculate the chlorinator setting in pounds of chlorine per 24 hours.

$$\text{Chlorinator Setting, lbs/24 hrs} = \frac{(\text{Flow, GPM})(\text{Dose, mg}/L)(8.34 \text{ lbs/gal})}{694 \text{ GPM/MGD}}$$

$$= \frac{(75 \text{ GPM})(12 \text{ mg}/L)(8.34 \text{ lbs/gal})}{694 \text{ GPM/MGD}}$$

$$= 10.8 \text{ or } 11 \text{ lbs/24 hrs}$$

5. A chemical feed pump is set to deliver 55 gallons per day. What is the feed rate in milliliters per minute?

Known	Unknown
Pump Feed, GPD = 55 GPD	Pump Feed, m*L*/min

Convert the pump feed rate from gallons per day to milliliters per minute.

$$\text{Pump Feed, m}L\text{/min} = \frac{(\text{Pump Feed, gal/day})(3.785\ L\text{/gal})(1000\ \text{m}L/L)}{(24\ \text{hr/day})(60\ \text{min/hr})}$$

$$= \frac{(55\ \text{gal/day})(3.785\ L\text{/gal})(1000\ \text{m}L/L)}{(24\ \text{hr/day})(60\ \text{min/hr})}$$

$$= 145\ \text{m}L\text{/min}$$

6. A chemical feed pump delivers 430 m*L* in three minutes. What is the pump feed rate in gallons per day?

Known	Unknown
Volume, m*L* = 430 m*L*	Pump Feed, GPD
Time, min = 3 min	

Calculate the pump feed rate in gallons per day.

$$\text{Pump Feed, GPD} = \frac{(\text{Volume, m}L)(24\ \text{hr/day})(60\ \text{min/hr})}{(\text{Time, min})(3.785\ L\text{/gal})(1000\ \text{m}L/L)}$$

$$= \frac{(430\ \text{m}L)(24\ \text{hr/day})(60\ \text{min/hr})}{(3\ \text{min})(3.785\ L\text{/gal})(1000\ \text{m}L/L)}$$

$$= 54.5\ \text{GPD}$$

7. Determine the gallons of waste delivered to a chemical treatment tank if the pumping rate is 60 GPM for three hours.

Known	Unknown
Pumping Rate, GPM = 60 GPM	Volume, gal
Time, hrs = 3 hrs	

Determine the gallons of waste pumped to the chemical treatment tank.

$$\text{Volume, gal} = (\text{Flow, GPM})(\text{Time, hr})(60\ \text{min/hr})$$

$$= (60\ \text{GPM})(3\ \text{hrs})(60\ \text{min/hr})$$

$$= 10{,}800\ \text{gal}$$

8. Estimate the retention time in a 6000 gallon chemical mix tank when the flow is 300 GPM.

Known	Unknown
Volume, gal = 6000 gal	Retention Time, min
Flow, GPM = 300 GPM	

Calculate the retention time in minutes.

$$\text{Time, min} = \frac{\text{Volume, gal}}{\text{Flow, gal/min}}$$

$$= \frac{6000\ \text{gal}}{300\ \text{gal/min}}$$

$$= 20\ \text{min}$$

9. Estimate the chemical feed rate in GPD when a chemical feed pump lowers a chemical solution 10 inches in a 15-inch diameter chemical container in 4 hours.

Known	Unknown
Diameter, in = 15 in	Feed Rate, GPD
Drop, in = 10 in	
Time, hr = 4 hr	

Calculate the chemical feed rate in gallons per day.

$$\text{Feed Rate, GPD} = \frac{(0.785)(\text{Diam, in})^2(\text{Drop, in})(24\ \text{hr/day})}{(231\ \text{cu in/gal})(\text{Time, hr})}$$

$$= \frac{(0.785)(15\ \text{in})^2(10\ \text{in})(24\ \text{hr/day})}{(231\ \text{cu in/gal})(4\ \text{hr})}$$

$$= 46\ \text{GPD}$$

10. The calculated pure chemical dose for a chemical solution is 1.2 pounds. The chemical delivered to the shop contains 95 percent active chemical. Calculate the pounds of chemical delivered to the shop to produce the desired dose.

Known	Unknown
Pure Chemical, lbs = 1.2 lbs	Actual Chemical Required, lbs
Active Chemical, % = 95%	

Calculate the pounds of chemical delivered to the shop for the chemical dose.

$$\text{Actual Chemical Required, lbs} = \frac{(\text{Pure Chemical, lbs})(100\%)}{\text{Active Chemical, \%}}$$

$$= \frac{(1.2\ \text{lbs})(100\%)}{95\%}$$

$$= 1.26\ \text{lbs}$$

11. The effluent from a filter press treating an industrial sludge must have its pH adjusted before additional treatment. If a 100 m*L* sample of effluent requires 10.7 m*L* of 0.5 N sulfuric acid to lower the pH to 8.0, how many gallons of 2 N sulfuric acid will be required to lower the pH of 600 gallons of filter press effluent to a pH of 8.0?

Known	Unknown
Sample, m*L* = 100 m*L*	2 N Acid, gal
Acid, m*L* = 10.7 m*L*	
Acid, N = 0.5 N for sample	
Waste, gal = 600 gal	
Acid, N = 2 N for treatment	

Determine normality of waste.

$$\text{Waste, Normality} = \frac{(\text{Acid, m}L)(\text{Acid, N})}{\text{Sample, m}L}$$

$$= \frac{(10.7\ \text{m}L)(0.5\ \text{N})}{100\ \text{m}L}$$

$$= 0.0535\ \text{N}$$

Calculate the gallons of 2 N sulfuric acid to lower the pH of the filter press effluent to 8.0.

$$\text{2 N Sulfuric} = \frac{(\text{Waste, gal})(\text{Waste, Normality})}{\text{Acid, gal 2 N}}$$

$$= \frac{(600\ \text{gal})(0.0535\ \text{N})}{2\ \text{N}}$$

$$= 16\ \text{gal}$$

12. A plating solution contains 0.6 ounces per gallon of *hexavalent chromium*. What is the concentration in milligrams per liter?

Known	Unknown
Hexavalent Chromium, oz/gal = 0.6 oz/gal	Hexavalent Chromium, mg/*L*

Convert the hexavalent chromium solution from ounces per gallon to milligrams per liter.

$$\text{Conc, mg}/L = \frac{(\text{Conc, oz/gal})(454 \text{ gm/lb})(1000 \text{ mg/gm})}{(16 \text{ oz/lb})(3.785\ L/\text{gal})}$$

$$= \frac{(0.6 \text{ oz/gal})(454 \text{ gm/lb})(1000 \text{ mg/gm})}{(16 \text{ oz/lb})(3.785\ L/\text{gal})}$$

$$= 4500 \text{ mg}/L$$

13. Determine the polymer pumping rate in gallons per day if a 0.2 percent polymer solution is delivered to a wastestream with a flow of 200 GPM. The desired polymer dose in the wastestream is 1.5 mg/*L*.

Known		Unknown
Poly Sol, %	= 0.2%	Poly Pump, GPD
Flow, GPM	= 200 GPM	
Poly Dose, mg/*L*	= 1.5 mg/*L*	

Calculate the rate of polymer needed.

$$\text{Poly Needed, mg/min} = (\text{Flow, GPM})(\text{Poly Dose, mg}/L)(3.785\ L/\text{gal})$$

$$= (200 \text{ GPM})(1.5 \text{ mg}/L)(3.785\ L/\text{gal})$$

$$= 1136 \text{ mg/min}$$

Determine the polymer pumping rate in gallons per day.

$$\text{Pumping Rate, GPD} = \frac{(\text{Poly Needed, mg/min})(60 \text{ min/hr})(24 \text{ hr/day})}{(\text{PolySol, \%})(10{,}000 \text{ mg}/L/\%)(3.785\ L/\text{gal})}$$

$$= \frac{(1136 \text{ mg/min})(60 \text{ min/hr})(24 \text{ hr/day})}{(0.2\%)(10{,}000 \text{ mg}/L/\%)(3.785\ L/\text{gal})}$$

$$= 216 \text{ GPD}$$

14. Cyanide-bearing waste is to be treated by a batch process using the alkaline chlorination method. The cyanide holding tank contains 7500 gallons with a cyanide concentration of 18 mg/*L*. Seven pounds of caustic and eight pounds of chlorine are required to oxidize one pound of cyanide to carbon dioxide and nitrogen gas.

a. How many pounds of chlorine are needed?
b. How long will the hypochlorinator have to operate if the hypochlorite solution is 2.0 percent chlorine and the hypochlorinator can deliver 240 GPD?
c. How long should the caustic soda feed pump operate if the pump delivers 240 gallons per day of a ten percent caustic soda solution?

Known		Unknown
Cyanide Vol, gal	= 7500 gal	a. Chlorine Req'd, lbs
Cyanide Conc, mg/*L*	= 18 mg/*L*	b. Hypochlorinator Time, hr
Chlorine Dose, lb/lb	= 8 lbs Cl/lb CN	c. Caustic Pump Time, hr
Caustic Dose, lb/lb	= 7 lbs NaOH/lb CN	
Hypochlorite, %	= 2.0%	
Hypochlorinator, GPD	= 240 GPD	
Caustic Soda, %	= 10%	
Caustic Pump, GPD	= 140 GPD	

1. Calculate the pounds of cyanide to be treated.

$$\text{Cyanide, lbs} = \frac{(\text{CN Vol, gal})(\text{CN Conc, mg}/L)(8.34 \text{ lbs/gal})}{1{,}000{,}000/M}$$

$$= \frac{(7500 \text{ gal})(18 \text{ mg}/L)(8.34 \text{ lbs/gal})}{1{,}000{,}000/M}$$

$$= 1.13 \text{ lbs cyanide}$$

2. Calculate the pounds of chlorine and caustic needed.

$$\text{Chlorine Required, lbs} = (\text{Cyanide, lbs})(\text{Chlorine Dose, lb/lb})$$

$$= (1.13 \text{ lbs CN})(8 \text{ lbs Cl/lb CN})$$

$$= 9.0 \text{ lbs chlorine}$$

$$\text{Caustic Required, lbs} = (\text{Cyanide, lbs})(\text{Caustic Dose, lb/lb})$$

$$= (1.13 \text{ lbs CN})(7 \text{ lbs NaOH/lb CN})$$

$$= 7.9 \text{ lbs caustic}$$

3. Calculate the time of operation of the hypochlorinator in hours.

$$\text{Time, hr} = \frac{(\text{Chlorine Required, lbs})(100\%)(24 \text{ hr/day})}{(\text{Hypo, GPD})(8.34 \text{ lbs/gal})(\text{Hypochlorite, \%})}$$

$$= \frac{(9.0 \text{ lbs})(100\%)(24 \text{ hr/day})}{(240 \text{ GPD})(8.34 \text{ lbs/gal})(2.0\%)}$$

$$= 5.4 \text{ hrs}$$

$$= 5 \text{ hr } 24 \text{ min}$$

4. Calculate the time of operation of the caustic soda pump.

$$\text{Time, hr} = \frac{(\text{Caustic Required, lbs})(100\%)(24 \text{ hr/day})}{(\text{Caustic, GPD})(8.34 \text{ lbs/gal})(\text{Caustic Soda, \%})}$$

$$= \frac{(7.9 \text{ lbs})(100\%)(24 \text{ hr/day})}{(140 \text{ GPD})(8.34 \text{ lbs/gal})(10\%)}$$

$$= 1.62 \text{ hrs}$$

$$= 1 \text{ hr } 37 \text{ min}$$

APPENDIX

I. POLYMERS

POLYMERS[28] or *POLYELECTROLYTES*[29] are added to the wastewater being treated after the precipitates have had the opportunity to form, such as hydroxide metal precipitation. These chemicals are added to enhance or to cause the clumping together of particles and precipitates into larger, more rapidly settling floc.

There are three types of polymers, anionic, cationic and nonionic. Usually anionic polymers are used to treat metallic precipitates and sludges. The selection of a polymer must be determined by on-site testing to choose the most effective polymer and the optimum dosage.

To visualize how polymers work, think of polymers as being long-chained molecules resembling a long *FUZZY SCARF*. The molecules on the outer surface of the scarf are oriented so that more of the positively charged ends (+), or more of the negatively charged ends (−), are pointed towards the exterior. Thus, the polymer may be described as anionic, cationic, or nonionic (no net charge, but has both + and − sites). Since opposite electrical charges attract each other, a polymer with positively charged ends will attract and hold onto particles and wastes with negative charges. Therefore the flocs will become heavier and settle out.

Polymers are long-chained molecules which cause polymer solutions to be viscous (syrup-like) and difficult to disperse in the wastewater being treated. When a polymer is spilled on a concrete surface, the surface becomes *VERY SLIPPERY* and is a serious safety hazard.

Table 13 summarizes some of the important characteristics of polymers.

Dry Polymers

Dry polymers are usually shipped in 50 pound bags. Because of the low dose that is normally used, a 50 pound bag will last for an extended period. Frequently operators will purchase enough dry polymer to last from a year to a year and a half. The shelf life of dry polymers is usually more than two years if kept completely dry. Opened bags should be folded closed and kept in a plastic garbage can or container with a tight fitting lid to keep out moisture.

In general dry polymers are *MUCH* less expensive to purchase than liquid polymers. However, the liquid polymers have an advantage of not being subject to the formation of lumps and fish-eyes which are due to incomplete "wetting" of the dry polymer. These problems can generally be avoided if proper care is taken during mixing. An aspirated wetting cone (Figure 42) is very helpful. The cone consists of a funnel that is attached to a venturi-type aspirator. Water running through the aspirator causes a suction which pulls the dry powder through the aspirator and wets each particle thereby avoiding lumps. Such devices cost from $75 to $100 and are well worth the cost.

If this device is not on hand, the procedure for wetting the polymer is as follows:

1. Fill the polymer tank until the mixer blade is submerged an inch or two under the water surface.
2. Turn on the mixer and sift the dry polymer into the area of maximum turbulence. Use caution because too fast a rate will result in lumps of dry polymer in the solution.
3. As you sift the polymer into the tank, also spray water so that the polymer is subjected to the wetting action of the spray.
4. Fill the tank and mix for 1 hour; then shut the mixer off. In general, it is not necessary to remix the tank contents prior to refilling the tank.

The polymer tank should be sized so that a new batch is mixed every few days. Use the entire contents of the tank within one week (7 days) since the mixed polymer can deteriorate. The tank should be kept clean and free from debris and corrosion, algae growths should be removed, and all tubing should be replaced as soon as the tubing becomes cloudy, opaque, or brittle.

TABLE 13 IMPORTANT CHARACTERISTICS OF POLYMERS

TYPE	USE	TYPICAL DOSAGE, mg/L (Range, mg/L)	FORM	COMMENTS
Anionic	Metallic hydroxides Water treatment	2 (1-10)	Dry or Liquid	0.1 to 1.0% working solutions
Cationic	Sludge conditioning Work clarification	20 (5-300)	Dry or Liquid	Liquid is most common form
Nonionic	Emulsion breaking General waste Agglomeration	Varies	Dry or Liquid	

[28] *Polymer. A chemical formed by the union of many monomers (a molecule of low molecular weight). Polymers are used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water. All polyelectrolytes are polymers, but not all polymers are polyelectrolytes.*

[29] *Polyelectrolyte (POLLY-ee-LECT-tro-lite). A high-molecular-weight (relatively heavy) substance having points of positive or negative electrical charges that is formed by either natural or man-made processes. Natural polyelectrolytes may be of biological origin or derived from starch products and cellulose derivatives. Man-made polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water. Often called a POLYMER.*

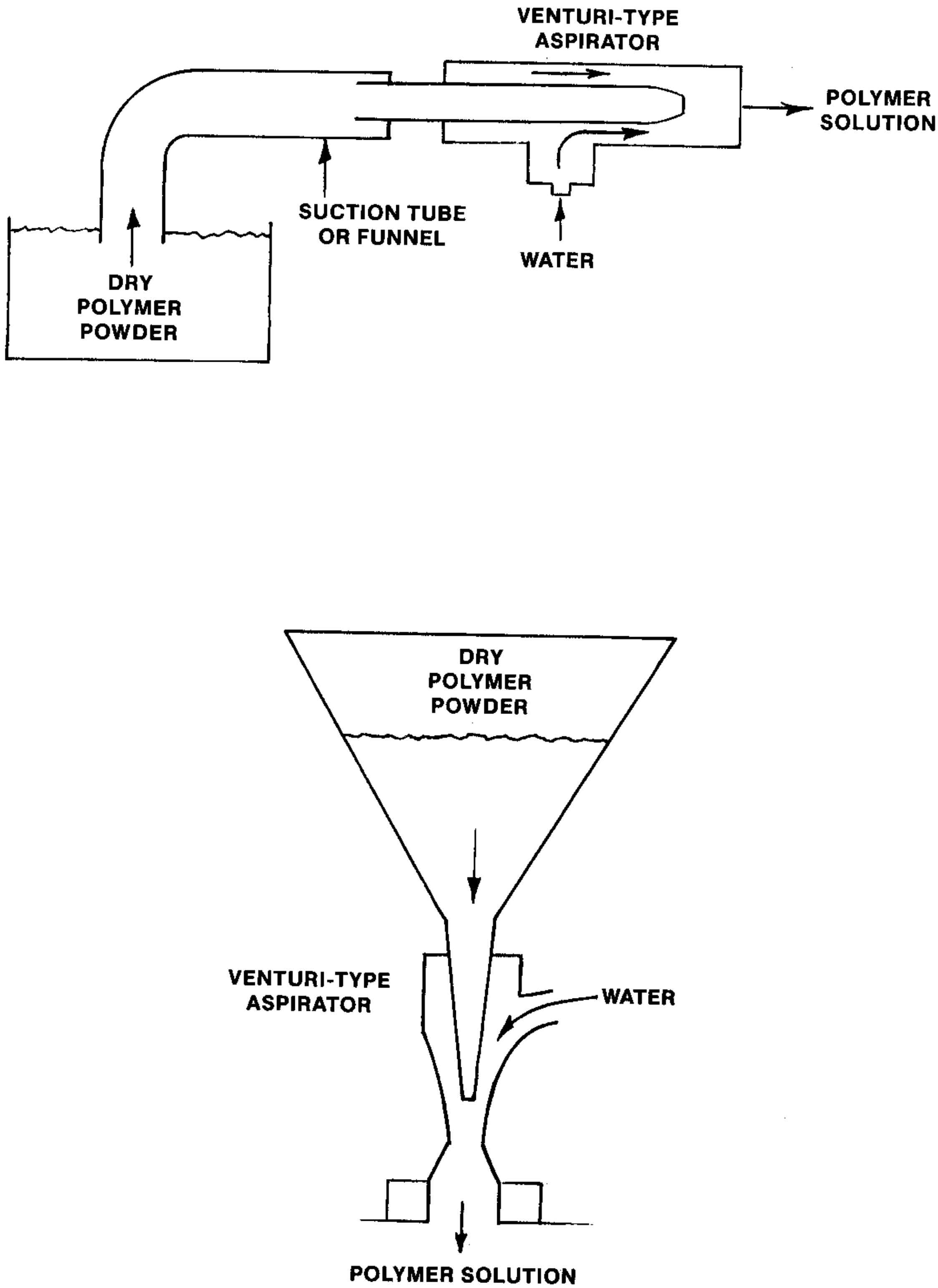


Fig. 42 Venturi-type aspirators for wetting dry polymers

If the tank does not have a cover, one should be made. Leaves and insects falling into the tank will result in stuck check valves and clogged polymer solution lines.

Wet Polymers

Wet polymers are usually shipped in 55 gallon drums. They are typically sold in 20 to 40 percent polymer solutions,[30] and therefore have to be diluted prior to use. Some manufacturers have a "set" procedure to "invert" the solution. These procedures may require the use of a solvent such as isopropanol. However, most manufacturers just require dilution with water and then a mixing and aging period. Normal working solutions are in the range of one percent polymer solutions or less.

Polymer Testing

Because polymers are somewhat specific to the "mix" of the wastewater, it is necessary to run tests to arrive at the most appropriate chemical and its optimum dosage level. The procedure is as follows:

1. Use 0.5 liter or 1 liter samples. The samples can be raw wastewater or precipitated waste (sludge). If raw wastewater, adjust the pH to the proper level 9.5-11.0 (usually 10-10.5) and allow time for the precipitate to form.

2. Mix the water using a mixing bar (teflon coated) and an electric mixing device, gang stirrer, or lacking these, use a glass stirring rod.

3. As the water is rapidly mixed, add an appropriate amount of polymer. With anionic polymers this is usually a concentration 2 mg/L of polymer in the waste. For example, if 0.1 percent polymer solution is used (1 mg/mL is what the solution contains), two milliliters of solution would be added to 1 liter of waste.

   Since the polymer will be viscous, the use of a syringe greatly eases the problems of applying the right amount. If syringes are not available, a wide-mouthed pipette can be substituted.

4. After the initial period of rapid mixing to disperse the polymer, usually 10 seconds or so, the mixture is slow mixed for 10 minutes, and then allowed to settle.

Observations on the settled sample that should be made are:

1. Does the floc settle rapidly?
2. Does the floc completely settle, or are there floating floc?
3. Is the water highly clarified?
4. Are some "off" colors visible?
5. Is the settled sludge compact or voluminous?
6. Is the floc easily disturbed and fragile?
7. Are there lower and upper limits beyond which the polymer dosage causes no effects or harmful effects?

By dosing a series of beakers or jars lined up side by side, it is possible to arrive at the most effective polymer and optimum dosage. Once this information is obtained, a further step can be taken to determine the cost involved. Since polymer prices may vary greatly, a polymer that is only marginally better certainly should not be purchased for many times the cost of a less expensive polymer if almost all other quality criteria can be met. Base your selection of a polymer on the cost of polymer per amount of sludge treated (such as $ of polymer/ton of sludge).

When polymers are used to dewater sludges, various doses of polymers are mixed with the sludge in a manner similar to the plant's polymer mixing and sludge dewatering facilities. In the laboratory a Buchner funnel (Figure 43) or some other device is used to dewater the sludge. The optimum polymer dose for dewatering sludge is the dose which produces the best dewatered sludge.

A Buchner funnel is used to separate solids from a mixture. It is used with a filter flask and a vacuum.

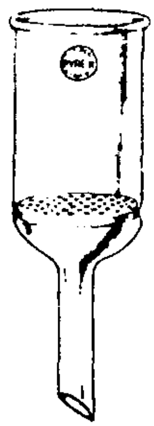


Fig. 43 Buchner funnel

[30] *Solutions are generally in the range of 5 to 40 percent chemical. Water is the carrying agent and premixing is not required. Emulsions are generally in the range of 25 to 40 percent chemical. An oil-type carrying agent is used. Premixing is required and a good wetting action is required to break the emulsion and put it into a solution. Emulsions have a longer shelf life than solutions.*

The determination of the optimum polymer dose to condition a sludge for dewatering follows procedures similar to the procedures used to treat wastewaters with polymers. A sample of sludge is collected. One hundred milliliters of sludge is added to several beakers. A series of increasing volumes in milliliters of a given percent strength polymer are added to beakers containing the sludge. The sludge and polymer are mixed.

A millipore filter is inserted in a Buckner funnel. A vacuum is applied. The sludge and polymer mixture is poured into the funnel. The vacuum pulls the liquid (filtrate) out of the sludge. The time to filter the sludge is recorded. The volume of filtrate is measured. The filtration rate is calculated using the following formula:

$$\text{Filtration Rate, } mL/sec = \frac{\text{Volume of Filtrate, } mL}{\text{Time, sec}}$$

The highest filtration rate indicates the optimum polymer dosage.

II. OXIDATION-REDUCTION POTENTIAL (ORP)

DEFINITION. The electrical potential required to transfer electrons from one compound or element (the oxidant) to another compound or element (the reductant). ORP is used as a qualitative measure of the state of oxidation in metal waste treatment systems. Important examples include the oxidation of cyanide and the reduction of hexavalent chromium to the trivalent state.

ORP is measured by electrodes in a manner similar to the measurement of pH. The reference electrodes can be identical, but a noble-metal (gold or platinum) electrode replaces the glass pH electrode. ORP readings usually are not adjusted for temperature. The signal from the ORP electrodes is fed into an amplifier for readout on an ORP meter.

The inert metal electrode (usually gold or platinum) in a well mixed oxidation-reduction system serves mainly to acquire the electrochemical potential of electrons, depending on the prevailing *REDOX*[31] (reduction-oxidation potential) equilibrium in the solution. The actual ORP measured is the difference between that of the noble-metal electrode and the reference electrode. The reference electrode is usually a silver-silver chloride or calomel electrode.

In most metal waste treatment reactions, the oxidation-reduction potential is controlled at a point or ORP millivolt reading level that insures excess of one reactant. The operator or the automatic controls adjust the chemical feed to be sure the ORP reading indicates an excess. This excess provides sufficient chemical to make the chemical reaction go to completion.

pH is an important measurement in treatment processes being controlled by ORP levels, especially if the hydrogen ion is involved in the reactions. ORP levels are influenced considerably by pH values, so pH is often regulated or controlled as well as the chemical dosage which is adjusted on the basis of ORP readings.

When treating metal wastestreams the target or desired ORP level often must be determined experimentally (rather than theoretically) due to the "mix" of wastes that the treatment chemical (chlorine, for example) oxidizes and reduces simultaneously. ORP responds to the concentrations and activities of all chemical reactions occurring in the metal wastestream being treated.

The noble-metal ORP electrode in a wastestream being chemically treated will rapidly acquire the electrochemical potential determined by the redox equilibrium. The rate of electron transfer across the metal's surface, however, depends on the condition of the surface. Electrode poisoning can cause a significant reduction in the exchange of current. Platinum electrodes can be poisoned by cyanide and sulfide ions. Poisoned electrodes can be restored by following proper cleaning procedures (see Section 7.51, "Cleaning"). To determine if an electrode is operating properly and has not been poisoned, solutions of known ORP can be developed by saturating buffer solutions with quinhydrone (see Section 7.52, "Calibration, 2. ORP Probes"). If poisoned platinum electrodes are a problem, gold electrodes can be used.

ORP is an important control guideline which must be understood by operators treating metal wastestreams.

III. HOW TO SOLVE ARITHMETIC PROBLEMS

A. HOW TO STUDY THIS APPENDIX

This appendix may be worked early in your training program to help you gain the greatest benefit from your efforts. Whether to start this appendix early or wait until later is your decision. The chapters in this manual were written in a manner requiring very little background in arithmetic. You may wish to concentrate your efforts on the chapters and refer to this appendix when you need help. Some operators prefer to complete this appendix early so they will not have to worry about how to do the arithmetic when they are studying the chapters. You may try to work this appendix early or refer to it while studying the other chapters.

After you have worked a problem involving your job, you should check your calculations, examine your answer to see if it appears reasonable, and if possible have another operator check your work before making any decisions or changes.

B. STEPS IN SOLVING PROBLEMS

B.0 Identification of Problem

To solve any problem, you have to identify the problem, determine what kind of answer is needed, and collect the information needed to solve the problem. A good approach to this type of problem is to examine the problem and make a list of *KNOWN* and *UNKNOWN* information.

Example: Find the theoretical detention time in a rectangular sedimentation tank 8 feet deep, 30 feet wide, and 60 feet long when the flow is 1.4 MGD.

Known	Unknown
Depth = 8 ft	Detention Time, hours
Width = 30 ft	
Length = 60 ft	
Flow = 1.4 MGD	

Sometimes a drawing or sketch will help to illustrate a problem and indicate the knowns, unknowns, and possibly additional information needed.

[31] *Redox. Reduction-oxidation reactions in which the oxidation state of at least one reactant is raised while that of another is lowered.*

B.1 Selection of Formula

Most problems involving mathematics in treatment plant operation can be solved by selecting the proper formula, inserting the known information, and calculating the unknown. Here is an example of how to calculate the detention time for a tank or clarifier in hours.

$$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

To convert the known information to fit the terms in a formula sometimes requires extra calculations. The next step is to find the values of any terms in the formula that are not in the list of known values.

$$\text{Flow, gal/day} = 1.4\text{ MGD}$$

$$= 1{,}400{,}000\text{ gal/day}$$

$$\text{Tank Volume, cu ft} = (\text{Length, ft})(\text{Width, ft})(\text{Height, ft})$$

$$= 60\text{ ft} \times 30\text{ ft} \times 8\text{ ft}$$

$$= 14{,}400\text{ cu ft}$$

Solution of Problem:

$$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

$$= \frac{(14{,}400\text{ cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{1{,}400{,}000\text{ gal/day}}$$

$$= 1.85\text{ hr}$$

The remainder of this section discusses the details that must be considered in solving this problem.

B.2 Arrangement of Formula

Once the proper formula is selected, you may have to rearrange the terms to solve for the unknown term.

$$\text{Velocity, ft/sec} = \frac{\text{Flow Rate, cu ft/sec}}{\text{Cross-Sectional Area, sq ft}}$$

or

$$V = \frac{Q}{A}$$

In this equation if Q and A were given, the equation could be solved for V. If V and A were known, the equation would have to be rearranged to solve for Q. To move terms from one side of an equation to another, use the following rule:

When moving a term or number from one side of an equation to the other, move the numerator (top) of one side to denominator (bottom) of the other; or from the denominator (bottom) of one side to the numerator (top) of the other.

$$V = \frac{Q}{A} \text{ or } Q = AV \text{ or } A = \frac{Q}{V}$$

If the volume of a sedimentation tank and the desired detention time were given, the detention time formula could be rearranged to calculate the design flow.

$$\text{Detention Time, hrs} = \frac{(\text{Tank Vol., cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

By rearranging the terms

$$\text{Flow, gal/day} = \frac{(\text{Tank Vol., cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Detention Time, hrs}}$$

B.3 Unit Conversions

Each term in a formula or mathematical calculation must be of the correct units. The area of a rectangular clarifier (Area, sq ft = Length, ft × Width, ft) can't be calculated in square feet if the width is given as 246 inches or 20 feet 6 inches. The width must be converted to 20.5 feet. In the example problem, if the tank volume were given in gallons, then the 7.48 gal/cu ft would not be needed. THE UNITS IN A FORMULA MUST ALWAYS BE CHECKED BEFORE ANY CALCULATIONS ARE PERFORMED TO AVOID TIME-CONSUMING MISTAKES.

$$\text{Detention Time, hrs} = \frac{(\text{Tank Vol., cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

$$= \cancel{\text{cu ft}} \times \frac{\cancel{\text{gal}}}{\cancel{\text{cu ft}}} \times \frac{\text{hr}}{\cancel{\text{day}}} \times \frac{\cancel{\text{day}}}{\cancel{\text{gal}}}$$

= hr (all other units cancel)

NOTE: We have hours = hr. One should note that the hour unit on both sides of the equation can be cancelled out and nothing would remain. This is one more check that we have the correct units. By rearranging the detention time formula, other unknowns could be determined.

If the design detention time and design flow were known, the required capacity of the tank could be calculated.

$$\text{Tank Volume, cu ft} = \frac{(\text{Detention Time, hr})(\text{Flow, gal/day})}{(7.48\text{ gal/cu ft})(24\text{ hr/day})}$$

If the tank volume and design detention time were known, the design flow could be calculated.

$$\text{Flow, gal/day} = \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Detention Time, hrs}}$$

Rearrangement of the detention time formula to find other unknowns illustrates the need to always use the correct units.

B.4 Calculations

In general, do the calculations inside parentheses ( ) first and brackets [ ] next. Calculations should be done above and below the division line before dividing.

$$\text{Detention Time, hrs} = \frac{[(\text{Tank, Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})]}{\text{Flow, gal/day}}$$

$$= \frac{[(14{,}400\text{ cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})]}{1{,}400{,}000\text{ gal/day}}$$

$$\frac{2{,}585{,}088\text{ gal-hr/day}}{1{,}400{,}000\text{ gal/day}}$$

$$= 1.85\text{, or}$$

$$= 1.9\text{ hr}$$

B.5 Significant Figures

In calculating the detention time in the previous section, the answer is given as 1.9 hr. The answer could have been calculated:

$$\text{Detention Time, hrs} = \frac{2{,}585{,}088\text{ gal-hr/day}}{1{,}400{,}000\text{ gal/day}}$$

$$= 1.846491429\ldots\text{ hours}$$

How does one know when to stop dividing? Common sense and significant figures both help.

First, consider the meaning of detention time and the measurements that were taken to determine the knowns in the formula. Detention time in a tank is a theoretical value and assumes that all particles of water throughout the tank move through the tank at the same velocity. This assumption is not correct; therefore detention time can only be a representative time for some of the water particles.

Will the flow of 1.4 MGD be constant throughout the 1.9 hours, and is the flow exactly 1.4 MGD, or could it be 1.35 MGD or 1.428 MGD? A carefully calibrated flow meter may give a reading within 2% of the actual flow rate. Flows into a tank fluctuate and flow meters do not measure flows extremely accurately; so the detention time again appears to be a representative or typical detention time.

Tank dimensions are probably satisfactory within 0.1 ft. A flow meter reading of 1.4 MGD is less precise and it could be 1.3 or 1.5 MGD. A 0.1 MGD flow meter error when the flow is 1.4 MGD is (0.1/1.4) × 100% = 7% error. A detention time of 1.9 hours, based on a flow meter reading error of plus or minus 7%, also could have the same error or more, even if the flow was constant. Therefore, the detention time error could be 1.9 hours × 0.07 = ± 0.13 hours.

In most of the calculations in the operation of treatment plants, the operator uses measurements determined in the lab or read from charts, scales, or meters. The accuracy of every measurement depends on the sample being measured, the equipment doing the measuring, and the operator reading or measuring the results. Your estimate is no better than the least precise measurement. Do not retain more than one doubtful number.

To determine how many figures or numbers mean anything in an answer, the approach called "significant figures" is used. In the example the flow was given in two significant figures (1.4 MGD), and the tank dimensions could be considered accurate to the nearest tenth of a foot (depth = 9.0 ft) or two significant figures. Since all measurements and the constants contained two significant figures, the results should be reported as two significant figures or 1.9 hours. The calculations are normally carried out to three significant figures (1.85 hours) and rounded off to two significant figures (1.9 hours).

Decimal points require special attention when determining the number of significant figures in a measurement.

Measurement	Significant Figures
0.00325	3
11.078	5
21,000.	2

Example: The distance between two points was divided into three sections, and each section was measured by a different group. What is the distance between the two points if each group reported the distance if measured as follows:

Group	Distance, ft	Significant Figures
A	11,300.	3
B	2,438.9	5
C	87.62	4
Total Distance	13,826.52	

Group A reported the length of the section it measured to three significant figures; therefore, the distance between the two points should be reported as 13,800 feet (3 significant figures).

When adding, subtracting, multiplying, or dividing, the number of significant figures in the answer should not be more than the term in the calculations with the least number of significant figures.

B.6 Check Your Results

After having completed your calculations, you should carefully examine your calculations and answer. Does the answer seem reasonable? If possible, have another operator check your calculations before making any operational changes.

C. BASIC CONVERSION FACTORS

UNITS		
1,000,000	= 1 Million	1,000,000/1 Million
LENGTH		
12 in	= 1 ft	12 in/ft
3 ft	= 1 yd	3 ft/yd
5280 ft	= 1 mi	5280 ft/mi
AREA		
144 sq in	= 1 sq ft	144 sq in/sq ft
43,560 sq ft	= 1 acre	43,560 sq ft/ac
VOLUME		
7.48 gal	= 1 cu ft	7.48 gal/cu ft
1000 m*L*	= 1 liter	1000 m*L*/*L*
3.785 *L*	= 1 gal	3.785 *L*/gal
231 cu in	= 1 gal	231 cu in/gal
WEIGHT		
1000 mg	= 1 gm	1000 mg/gm
1000 gm	= 1 kg	1000 gm/kg
454 gm	= 1 lb	454 gm/lb
2.2 lbs	= 1 kg	2.2 lbs/kg
POWER		
0.746 kw	= 1 HP	0.746 kw/HP
DENSITY		
8.34 lbs	= 1 gal	8.34 lbs/gal
62.4 lbs	= 1 cu ft	62.4 lbs/cu ft
DOSAGE		
17.1 mg/*L*	= 1 grain/gal	17.1 mg/*L*/gpg
64.7 grains	= 1 mg	64.7 grains/mg
PRESSURE		
2.31 ft water	= 1 psi	2.31 ft water/psi
0.433 psi	= 1 ft water	0.433 psi/ft water
1.133 ft water	= 1 in Mercury	1.133 ft water/in Mercury
FLOW		
694 GPM	= 1 MGD	694 GPM/MGD
1.55 CFS	= 1 MGD	1.55 CFS/MGD
TIME		
60 sec	= 1 min	60 sec/min
60 min	= 1 hr	60 min/hr
24 hr	= 1 day	24 hr/day

NOTE: In our equations the values in the right hand column may be written either as 24 hr/day or 1 day/24 hours depending on which units we wish to convert or our desired results.

D. BASIC FORMULAS

FLOW CONSERVATION AND EQUALIZATION

1. $$\text{Reduction, \%} = \frac{(\text{Original Flow, GPM} - \text{Reduced Flow, GPM})(100\%)}{\text{Original Flow, GPM}}$$

2. $\text{Volume, MG} = \dfrac{(\text{Flow, MGD})(\text{Time, hr})}{24 \text{ hrs/day}}$

3. $\text{Average Daily Flow, GPD} = \dfrac{\text{Total Flow at End, gal} - \text{Total Flow at Start, gal}}{\text{Time, days}}$

4. $\text{Discharge, GPM} = \dfrac{\text{Volume, gal}}{(\text{Time, hr})(60 \text{ min/hr})}$

5. $\text{Capacity, GPM} = \dfrac{(\text{Volume, cu ft})(7.48 \text{ gal/cu ft})}{\text{Time, min}}$

SAMPLING AND ANALYSIS

6. $\text{Composite Sample, Size, m}L = \dfrac{(\text{Max Sample Size, m}L)(\text{Flow, GPM})}{\text{Max Flow, GPM}}$

7. $\text{Average Conc, mg/}L = \dfrac{\text{Sum of Concentrations, mg/}L}{\text{Number of Measurements}}$

8. $\text{Total Metals, mg/}L = \text{Copper, mg/}L + \text{Nickel, mg/}L + \text{Chromium (T), mg/}L + \text{Lead, mg/}L$

CHEMICAL SOLUTIONS

9. $\text{Weight, lbs} = (\text{Volume, gal})(8.34 \text{ lbs/gal})$

10. $\text{Chlorine, lbs} = \dfrac{(\text{Volume, gal})(8.34 \text{ lbs/gal})(\text{Hypochlorite, \%})}{100\%}$

11. $\text{Hypochlorite Mixture, \%} = \dfrac{(\text{Vol 1, gal})(\text{Hypo 1, \%}) + (\text{Vol 2, gal})(\text{Hypo 2, \%})}{\text{Vol 1, gal} + \text{Vol 2, gal}}$

12. $\text{Desired Hypo, \%} = \dfrac{(\text{Hypo, gal})(\text{Actual Hypo, \%}) + (\text{Water, gal})(\text{Hypo, \%})}{\text{Hypo, gal} + \text{Water, gal}}$

or

$\text{Water, gal} = \dfrac{(\text{Hypo, gal})(\text{Actual Hypo, \%}) - (\text{Hypo, gal})(\text{Desired Hypo, \%})}{\text{Desired Hypo, \%}}$

13. $\text{NaOH, mg/}L = (\text{NaOH, \%})(10{,}000 \text{ mg/}L\text{/\%})$

14. $\text{NaOH Solution, \%} = \dfrac{(\text{NaOH, lbs})(100\%)}{(\text{Water, gal})(8.34 \text{ lbs/gal})}$

CHEMICAL FEEDERS

15. $\text{Chlorinator Setting, lbs/24 hrs} = (\text{Flow, MGD})(\text{Dose, mg/}L)(8.34 \text{ lbs/gal})$

16. $\text{Chlorinator Setting, lbs/24 hrs} = \dfrac{(\text{Flow, MGD})(\text{Dose, mg/}L)(8.34 \text{ lbs/gal})}{694 \text{ GPM/MGD}}$

17. $\text{Pump Feed, m}L\text{/min} = \dfrac{(\text{Pump Feed, gal/day})(3.785\ L\text{/gal})(1000 \text{ m}L/L)}{(24 \text{ hr/day})(60 \text{ min/hr})}$

18. $\text{Pump Feed, GPM} = \dfrac{(\text{Volume, m}L)(24 \text{ hr/day})(60 \text{ min/hr})}{(\text{Time, min})(3.785\ L\text{/gal})(1000 \text{ m}L/L)}$

19. $\text{Volume, gal} = (\text{Flow, GPM})(\text{Time, hr})(60 \text{ min/hr})$

20. $\text{Feed Rate, GPD} = \dfrac{(0.785)(\text{Diam, in})^2(\text{Drop, in})(24 \text{ hr/day})}{(231 \text{ cu in/gal})(\text{Time, hr})}$

21. $\text{Feed Rate, lbs/min} = \dfrac{\text{Feed Rate, lbs/day}}{(24 \text{ hr/day})(60 \text{ min/hr})}$

POLYMERS AND COAGULANTS

22. $\text{Polymer Req'd, lbs} = \dfrac{(\text{Vol, gal})(8.34 \text{ lbs/gal})(\text{Polymer, \%})}{100\%}$

23. $\text{Dose, mg/min} = (\text{Flow, gal/min})(\text{Dose, mg/}L)(3.785\ L\text{/gal})$

$\text{Polymer Solution, mg/m}L = \dfrac{(\text{Polymer, \%})(10{,}000 \text{ mg/}L\text{/\%})}{1000 \text{ m}L/L}$

$\text{Polymer Feed Rate, m}L\text{/min} = \dfrac{\text{Dose, mg/min}}{\text{Polymer Solution, mg/m}L}$

24. $\text{Chemical Feeder Setting, m}L\text{/min} = \dfrac{(\text{Flow, MGD})(\text{Alum Dose, mg/}L)(3.785\ L\text{/gal})(1{,}000{,}000\text{/M})}{(\text{Liquid Alum, mg/m}L)(24 \text{ hr/day})(60 \text{ min/hr})}$

25. $\text{Chemical Feeder Setting, GPD} = \dfrac{(\text{Flow, MGD})(\text{Alum Dose, mg/}L)(8.34 \text{ lbs/gal})}{\text{Liquid Alum, lbs/gal}}$

26. $\text{Chemical Feed, lbs} = \dfrac{\text{Chemical Applied, lbs}}{\text{Length of Application, day}}$

27. $\text{Polymer Feed, lbs/day} = \dfrac{(\text{Poly Conc, mg/}L)(\text{Vol Pumped, m}L)(60 \text{ min/hr})(24 \text{ hr/day})}{(\text{Time Pumped, min})(1000 \text{ m}L/L)(1000 \text{ mg/gm})(454 \text{ gm/lb})}$

28. $\text{Pump, Flow, GPM} = \dfrac{(\text{Pump Flow, GPM})(60 \text{ min/hr})(24 \text{ hr/day})}{1{,}000{,}000\text{/M}}$

$\text{Pump Setting, \%} = \dfrac{(\text{Desired Feed Pump, GPD})(100\%)}{\text{Maximum Feed Pump, GPD}}$

29. $\text{Actual Chemical Required, lbs} = \dfrac{(\text{Pure Chemical, lbs})(100\%)}{\text{Active Chemical, \%}}$

NEUTRALIZATION AND pH ADJUSTMENT

30. $\text{Sulfuric Acid, gal} = \dfrac{(\text{Waste, gal})(\text{Waste, Normality})}{\text{Sulfuric Acid, Normality}}$

$\text{Waste Normality} = \dfrac{(\text{Acid, m}L)(\text{Acid, N})}{\text{Waste Sample, m}L}$

31. $\text{Caustic, gal (To treat waste)} = \dfrac{\left(\begin{matrix}\text{Caustic to}\\\text{Sample, gal}\end{matrix}\right)\left(\begin{matrix}\text{Caustic to}\\\text{Sample, \%}\end{matrix}\right)\left(\begin{matrix}\text{Waste to}\\\text{Treatment, gal}\end{matrix}\right)}{(\text{Sample, gal})(\text{Treatment Caustic, \%})}$

32. $\text{Acid Feed, GPD} = \dfrac{(\text{Waste Flow, GPM})(\text{Waste Normality})(60 \text{ min/hr})(24 \text{ hr/day})}{\text{Acid Feed, N}}$

HYDROXIDE PRECIPITATION

33. $\text{NaOH, gal} = \dfrac{(\text{Wastewater, gal})(\text{m}L \text{ NaOH})}{(1000 \text{ m}L/L)(1\ L \text{ Wastewater})}$

34. $\text{NaOH Feed, GPD} = \dfrac{(\text{Zinc Flow, gal/min})(\text{m}L \text{ NaOH})(60 \text{ min/hr})(24 \text{ hr/day})}{(1000 \text{ m}L/L)(1\ L \text{ Zinc})}$

COMPLEXED METAL PRECIPITATION

35. $\text{NaOH, gal} = \dfrac{(\text{Wastewater, gal})(\text{m}L \text{ NaOH})}{(1000 \text{ m}L/L)(1\ L \text{ Wastewater})}$

36. $\text{NaOH Feed, GPD} = \dfrac{(\text{Copper Flow, GPM})(\text{m}L \text{ NaOH})(60 \text{ min/hr})(24 \text{ hr/day})}{(1000 \text{ m}L/L)(1\ L \text{ Copper})}$

REDUCTION OF HEXAVALENT CHROMIUM

37. $Cr^{6+} \text{ Treated, lbs} = (\text{Waste, MG})(Cr^{6+}, \text{ mg/}L)(8.34 \text{ lbs/gal})$

$\text{Dosage, lbs } SO_2 = (Cr^{6+} \text{ Treated, lbs})(\text{Treatment, lbs } SO_2\text{/lb } Cr^{6+})$

38. $\text{Sulfonator Feed, lbs/min} = \dfrac{(\text{Flow, GPM})(\text{Waste, mg/}L)(8.34 \text{ lbs/gal})(\text{Treat, lb/lb})}{1{,}000{,}000\text{/M}}$

39. $\text{Time, min} = \dfrac{(\text{Waste, lbs } Cr^{6+})(\text{Treat, lbs } SO_2\text{/lb } Cr^{6+})(1440 \text{ min/day})}{\text{Feed, lbs } SO_2\text{/day}}$

40. $\text{Ferrous Sulfate, lbs} = (\text{Chromium, lbs})(\text{Ferrous Sulfate Dose, mg/}L\text{/mg/}L)$

$\text{Time, hr} = \dfrac{(\text{Ferrous Sulfate, lbs})(100\%)}{(\text{Ferrous Sulfate, GPH})(8.34 \text{ lbs/gal})(\text{Ferrous Sulfate, \%})}$

41. $\text{Ferrous Sulfate Feed, GPD} = \dfrac{(\text{Ferrous Sulfate Feed, lbs/day})(100\%)}{(8.34 \text{ lbs/gal})(\text{Ferrous Sulfate, \%})}$

42. $\text{Conc, mg/}L = \dfrac{(\text{Conc, oz/gal})(454 \text{ gm/lb})(1000 \text{ mg/gm})}{(16 \text{ oz/lb})(3.785\ L\text{/gal})}$

43. $\text{Conc, oz/gal} = \dfrac{(\text{Conc, mg}/L)(16\text{ oz/lb})(3.785\ L/\text{gal})}{(1000\text{ mg/gm})(454\text{ gm/lb})}$

CYANIDE DESTRUCTION

44. $\text{Cyanide, lbs} = \dfrac{(\text{CN Vol, gal})(\text{CN Conc, mg}/L)(8.34\text{ lbs/gal})}{1{,}000{,}000/M}$

$\text{Chlorine Req'd, lbs} = (\text{Cyanide, lbs})(\text{Chlorine Dose lb/lb})$

$\text{Time, hr} = \dfrac{(\text{Chlorine Req'd, lbs})(100\%)(24\text{ hr/day})}{(\text{Flow, GPD})(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}$

45. $\text{Cyanide, lbs/day} = \dfrac{(\text{Flow, GPM})(\text{Cyanide, mg}/L)(8.34\text{ lbs/gal})}{694\text{ GPM/MGD}}$

$\text{Caustic Feed, lbs/day} = (\text{Cyanide, lbs/day})(\text{Caustic Dose, lb/lb})$

$\text{Caustic Pump, GPD} = \dfrac{(\text{Caustic Feed, lbs/day})(100\%)}{(8.34\text{ lbs/gal})(\text{Caustic, }\%)}$

SLUDGE TREATMENT

46. $\text{Polymer Dosage, lbs/ton} = \dfrac{(\text{Poly Sol, }\%)(\text{Poly Added, m}L)(2)}{(\text{Sludge Vol, }L)(\text{Sludge Solids, }\%)}$

E. FLOW CONSERVATION AND EQUALIZATION

EXAMPLE 1

Determine the percent reduction in flows achieved by an industrial water conservation program if wastewater flows are reduced from 500 GPM to 420 GPM

Known	Unknown
Original Flow, GPM = 500 GPM	Reduction, %
Reduced Flow, GPM = 420 GPM	

Calculate the percent reduction in flow.

$$\text{Reduction, }\% = \frac{(\text{Original Flow, GPM} - \text{Reduced Flow, GPM})(100\%)}{\text{Original Flow, GPM}}$$

$$= \frac{(500\text{ GPM} - 420\text{ GPM})(100\%)}{500\text{ GPM}}$$

$$= 16\%$$

EXAMPLE 2

A strip-chart recorder indicates that the average inflow to an industrial wastewater treatment plant was 1.1 MGD during a certain time period. How many million gallons of wastewater entered the plant during eight hours of this period?

Known	Unknown
Average Flow, MGD = 1.1 MGD	Volume, MG
Time, hr = 8 hr	

Calculate the volume of flow in million gallons during the eight hours.

$$\text{Volume, MG} = \frac{(\text{Flow, MGD})(\text{Time, hr})}{24\text{ hrs/day}}$$

$$= \frac{(1.1\text{ MGD})(8\text{ hr})}{24\text{ hrs/day}}$$

$$= 0.37\text{ MG}$$

EXAMPLE 3

On Monday morning at 8:00 AM, the totalizer on the flow meter to an industrial wastewater plant read 13,287,470 gallons. At the end of the week on Saturday morning at 8:00 AM the flow meter totalizer read 13,321,880 gallons. What was the average daily flow during the week in gallons per day?

Known	Unknown
Mon. Flow, gal = 13,287,470 gallons	Average Daily Flow, gallons per day
Sat. Flow, gal = 13,321,880 gallons	
Time, days = 5 days	

Calculate the average flow from Monday morning to Saturday morning (5 days).

$$\text{Average Daily Flow, GPD} = \frac{(\text{Sat Flow, gal} - \text{Mon Flow, gal})}{\text{Time, days}}$$

$$= \frac{13{,}321{,}880\text{ gal} - 13{,}287{,}470\text{ gal}}{5\text{ days}}$$

$$= \frac{34{,}410\text{ gallons}}{5\text{ days}}$$

$$= 6{,}882\text{ GPD}$$

EXAMPLE 4

A flow equalization tank contains 18,000 gallons of wastewater to be treated. If the wastewater is to be released at a constant flow rate during an eight-hour period, what should be the discharge rate in gallons per minute?

Known	Unknown
Volume, gal = 18,000 gal	Discharge, GPM
Time, hr = 8 hr	

Calculate the discharge flow rate in gallons per minute.

$$\text{Discharge, GPM} = \frac{\text{Volume, gal}}{(\text{Time, hr})(60\text{ min/hr})}$$

$$= \frac{18{,}000\text{ gal}}{(8\text{ hr})(60\text{ min/hr})}$$

$$= 37.5\text{ GPM}$$

EXAMPLE 5

Estimate the flow capacity of a wastewater pump in GPM if the pump lowers the wastewater in an 8 foot by 6 foot rectangular sump 10 inches in 5 minutes.

Known	Unknown
Length, ft = 8 ft	Capacity, GPM
Width, ft = 6 ft	
Depth, in = 10 in	
Time, min = 5 min	

Estimate the flow capacity of the pump in GPM.

$$\text{Capacity, GPM} = \frac{(\text{Length, ft})(\text{Width, ft})(\text{Depth, ft})(7.48\text{ gal/cu ft})}{\text{Time, min}}$$

$$= \frac{(8\text{ ft})(6\text{ ft})(10\text{ in})(7.48\text{ gal/cu ft})}{(5\text{ min})(12\text{ in/ft})}$$

$$= 60\text{ GPM}$$

F. SAMPLING AND ANALYSIS

EXAMPLE 6

Twelve grab samples are collected at two-hour intervals to prepare a flow-proportioned 24-hour composite sample. Determine the maximum volume in milliliters for this 24-hour composite sample if the 50-m*L* grab samples were collected every two hours from an industrial process wastewater flow. Flow meter records produced the following results.

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
Time, hr	2	4	6	8	10	12	14	16	18	20	22	24
Flow, GPM	100	400	700	650	750	600	580	450	400	200	50	50

Known	Unknown
Sample Size, m*L* = 50 m*L*	Composite Sample Volume, m*L*
Times and Flows given	

PROCEDURE

The maximum flow is 750 GPM. Therefore, use the entire 50-m*L* sample number 5 for the composite sample. The portion of the 50-m*L* sample for the other samples is proportional to the flow or

$$\text{Sample Size, m}L = \frac{(50\ \text{m}L)(\text{Flow, GPM})}{750\ \text{GPM}}$$

$$= (50\ \text{m}L)(\text{Factor})$$

Sample No.	Time, hr	Flow, GPM	Factor, Flow/750	Sample Size, m*L*
1	2	100	0.13	7
2	4	400	0.53	27
3	5	700	0.93	47
4	8	650	0.87	43
5	10	750	1.00	50
6	12	600	0.80	40
7	14	580	0.77	39
8	16	450	0.60	30
9	18	400	0.53	27
10	20	200	0.27	13
11	22	50	0.07	3
12	24	50	0.07	3
			Total =	329 m*L*

Composite Sample Volume, m*L* = 329 m*L*

EXAMPLE 7

Calculate the total chromium maximum four-day average from the results of daily samples collected from an electroplating wastewater flow.

Day	1	2	3	4	5	6	7	8	9	10
Chromium (T), mg/*L*	4.2	2.3	8.6	6.1	7.3	5.4	4.0	3.6	5.9	4.7

Known	Unknown
Given Data	Total Chromium Maximum 4-Day Average

Calculate the total chromium maximum four-day average.

Day	Chromium (T), mg/*L*	4-Day Sum, mg/*L*	4-Day Average, mg/*L*
1	4.2		
2	2.3		
3	8.6		
4	6.1	21.2	5.3
5	7.3	24.3	6.1
6	5.4	27.4	6.9 ← Max
7	4.0	22.8	5.7
8	3.6	20.3	5.1
9	5.9	18.9	4.7
10	4.7	18.2	4.6

EXAMPLE 8

Determine the "Total Metals" concentration in the wastewater from an electroplating facility if an analysis of the wastewater yielded the following results:

Pollutant	Concentration, mg/*L*
Cadmium (T)	0.5
Chromium (T)	1.7
Copper (T)	0.6
Cyanide (T)	0.8
Lead (T)	0.3
Nickel (T)	0.7
Zinc (T)	1.1

"Total Metals" is defined by EPA[32] as the sum of the concentrations of copper, nickel, total chromium and lead.

Known	Unknown
Given Lab Results	Total Metals, mg/*L*

Calculate the "Total Metals" concentration according to EPA's definition.

$$\begin{aligned}\text{Total Metals, mg}/L &= \text{Copper} + \text{Nickel} + \text{Chromium (T)} + \text{Lead} \\ &= 0.6\ \text{mg}/L + 0.7\ \text{mg}/L + 1.7\ \text{mg}/L + 0.3\ \text{mg}/L \\ &= 3.3\ \text{mg}/L\end{aligned}$$

G. CHEMICAL SOLUTIONS

EXAMPLE 9

What is the total weight of a tank and its contents if the tank weighs one ton empty and contains 14,000 gallons of a liquid chemical with a specific gravity of 0.85?

Known		Unknown
Volume of Contents, gal	= 14,000 gal	Total Weight, lbs
Sp Gr	= 0.85	
Tank Weight, ton	= 1 ton	

Calculate the weight of tank and contents

$$\begin{aligned}\text{Total Weight, lbs} &= \text{Tank, lbs} + \text{Contents, lbs} \\ &= (\text{Tank Wt, ton})(2000\ \text{lbs/ton}) + (\text{Vol, gal})(\text{Sp Gr})(8.34\ \text{lbs/gal}) \\ &= (1\ \text{ton})(2000\ \text{lbs/ton}) + (14{,}000\ \text{gal})(0.85)(8.34\ \text{lbs/gal}) \\ &= 2000\ \text{lbs} + 99{,}246\ \text{lbs} \\ &= 101{,}246\ \text{lbs}\end{aligned}$$

[32] *GUIDANCE MANUAL FOR ELECTROPLATING AND METAL FINISHING PRETREATMENT STANDARDS, Effluent Guidelines Division and Permits Division, U.S. Environmental Protection Agency, Washington, DC 20460, February 1984.*

EXAMPLE 10

How many pounds of chlorine are in a 10-gallon container full of a five percent hypochorite solution?

Known		Unknown
Volume, gal	= 10 gal	Chlorine, lbs
Hypochlorite, %	= 5%	

Calculate the pounds of chlorine in the container.

$$\text{Chlorine, lbs} = \frac{(\text{Volume, gal})(8.34\ \text{lbs/gal})(\text{Hypochlorite, \%})}{100\%}$$

$$= \frac{(10\ \text{gal})(8.34\ \text{lbs/gal})(5\%)}{100\%}$$

$$= 4.2\ \text{lbs}$$

EXAMPLE 11

If 10 gallons of a 5 percent hypochlorite solution were mixed with 50 gallons of a 1.5 percent hypochlorite solution, what would be the percent hypochlorite of the resulting mixture? A 1% solution is equal to 1 gram per 100 m*L* or 10,000 mg/*L*.

Known		Unknown
Volume 1, gal	= 10 gal	Hypochlorite Mixture, %
Hypochlorite 1, %	= 5%	
Volume 2, gal	= 50 gal	
Hypochlorite 2, %	= 1.5%	

Calculate the percent hypochlorite of the resulting mixture.

$$\text{Hypochlorite Mixture, \%} = \frac{(\text{Vol 1, gal})(\text{Hypo 1, \%}) + (\text{Vol 2, gal})(\text{Hypo 2, \%})}{\text{Vol 1, gal} + \text{Vol 2, gal}}$$

$$= \frac{(10\ \text{gal})(5\%) + (50\ \text{gal})(1.5\%)}{10\ \text{gal} + 50\ \text{gal}}$$

$$= \frac{50\% + 75\%}{60}$$

$$= 2.1\%$$

EXAMPLE 12

How many gallons of water must be added to ten gallons of a five percent hypochlorite solution to produce a 1.5 percent hypochlorite solution?

Known		Unknown
Hypochlorite, gal	= 10 gal	Water Added, gal
Desired Hypochlorite, %	= 1.5%	
Actual Hypochlorite, %	= 5%	

Calculate the water added by rearranging the mixture formula in Example 10.

$$\text{Desired Hypo, \%} = \frac{(\text{Hypo, gal})(\text{Actual Hypo, \%}) + (\text{Water, gal})(\text{Hypo, \%})}{\text{Hypo, gal} + \text{Water, gal}}$$

Since Hypo, % for the Water, gal, is zero percent, this term drops out and we have

$$(\text{Desired Hypo, \%})(\text{Hypo, gal} + \text{Water, gal}) = (\text{Hypo, gal})(\text{Actual Hypo, \%})$$

$$(\text{Desired Hypo, \%})(\text{Hypo, gal}) + (\text{Desired Hypo, \%})(\text{Water, gal}) = (\text{Hypo, gal})(\text{Actual Hypo, \%})$$

$$(\text{Desired Hypo, \%})(\text{Water, gal}) = (\text{Hypo, gal})(\text{Actual Hypo, \%}) - (\text{Desired Hypo, \%})(\text{Hypo, gal})$$

$$\text{Water, gal} = \frac{(\text{Hypo, gal})(\text{Actual Hypo, \%}) - (\text{Hypo, gal})(\text{Desired Hypo, \%})}{\text{Desired Hypo, \%}}$$

$$= \frac{(10\ \text{gal})(5\%) - (10\ \text{gal})(1.5\%)}{1.5\%}$$

$$= \frac{50\ \text{gal} - 15\ \text{gal}}{1.5}$$

= 43.3 gallons of water to be added to 5% hypochlorite solution

EXAMPLE 13

A four percent or one normal sodium hydroxide solution is equivalent to how many milligrams per liter of sodium hydroxide solution? A 1% solution is the same as 1 gram per 100 m*L* or 10,000 mg/*L*.

Known	Unknown
NaOH, % = 4%	NaOH, mg/*L*

Convert 4 percent to milligrams per liter.

$$\text{NaOH, mg/}L = (\text{NaOH, \%})(10{,}000\ \text{mg/}L/\%)$$

$$= (4\%)(10{,}000\ \text{mg/}L/\%)$$

$$= 40{,}000\ \text{mg/}L$$

EXAMPLE 14

How many ounces of sodium hydroxide must be added to five gallons of water to produce a four percent sodium hydroxide solution?

Known		Unknown
NaOH Solution, %	= 4%	NaOH, oz
Water, gal	= 5 gal	

Formula

$$\text{NaOH Solution, \%} = \frac{(\text{NaOH, lbs})(100\%)}{\text{Water, lbs}}$$

or

$$= \frac{(\text{NaOH, oz})(100\%)}{(16\ \text{oz/lb})(\text{Water, gal})(8.34\ \text{lbs/gal})}$$

Calculate the ounces of sodium hydroxide required to produce a four percent solution in five gallons of water. Rearrange the terms in the above equation and solve for the ounces of sodium hydroxide.

$$\text{NaOH, oz} = \frac{(\text{NaOH, \%})(16\ \text{oz/lb})(\text{Water, gal})(8.34\ \text{lbs/gal})}{100\%}$$

$$= \frac{(4\%)(16\ \text{oz/lb})(5\ \text{gal})(8.34\ \text{lbs/gal})}{100\%}$$

$$= 26.7\ \text{oz}$$

or

$$= \frac{26.7\ \text{oz}}{16\ \text{oz/lb}}$$

$$= 1.67\ \text{lbs}$$

$$= 1\ \text{lb and}\ (0.67\ \text{lbs})(16\ \text{oz/lb})$$

$$= 1\ \text{lb and}\ 10.7\ \text{oz}$$

H. CHEMICAL FEEDERS

When calculating the setting on a chemical in pounds of chemical per day or pounds of chemical per 24 hours, the following formula is used:

$$\text{Chemical Feeder Setting, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg/}L)(8.34\ \text{lbs/gal})$$

The units in the equation do not appear to cancel out. The units will cancel out by making the following substitutions:

1 L = 1,000,000 mg

or 1 L = 1 Million mg

$$\text{Now the Dose, mg}/L = \frac{\text{mg chemical}}{\text{M mg water}} = \frac{\text{lbs chemical}}{\text{M lbs water}}.$$

If the dose is on a weight basis, then the term milligrams of chemical per million milligrams of water is going to be the same as pounds of chemical per million pounds of water or parts of chemical per million parts of water. This is where the familiar term, parts per million (ppm) comes from. Therefore, by substituting a chemical dose of pounds of chemical per million pounds of water for a dose in milligrams per liter, the units would be OK.

$$\text{Chemical Feeder Setting, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})$$

$$= (\text{Flow}, \frac{\text{M Gal}}{\text{day}})(\frac{\text{Dose, lbs Chemical}}{\text{M lbs water}})(\frac{8.34\ \text{lbs water}}{\text{gal}})$$

$$= \text{lbs chemical/day}$$

A convenient conversion factor is a flow of one million gallons per day is equal to a flow of 694 gallons per minute.

$$1\ \text{MGD} = 1\ \text{MGD}$$

$$= \frac{1{,}000{,}000\ \text{gal/day}}{(24\ \text{hr/day})(60\ \text{min/hr})}$$

$$= 694\ \text{gal/min}$$

EXAMPLE 15

Determine the chlorinator setting for an industrial waste flow of 60,000 GPD that requires a chlorine dose of 12 mg/L.

Known		Unknown
Flow, GPD	= 60,000 GPD = 0.06 MGD	Chlorinator Setting, lbs/24 hr
Chlorine Dose, mg/L	= 12 mg/L	

Calculate the chlorinator setting in pounds of chlorine per 24 hours.

$$\text{Chlorinator Setting, lbs/24 hrs} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})$$

$$= (0.06\ \text{MGD})(12\ \text{mg}/L)(8.34\ \text{lbs/gal})$$

$$= 6\ \text{lbs/24 hrs}$$

EXAMPLE 16

Determine the chlorinator setting for an industrial waste flow of 50 GPM that requires a chlorine dose of 8 mg/L.

Known		Unknown
Flow, GPM	= 50 GPM	Chlorinator Setting, lbs/24 hr
Dose, mg/L	= 8 mg/L	
1 MGD	= 694 GPM	

Calculate the chlorinator setting in pounds of chlorine per 24 hours.

$$\text{Chlorinator Setting, lbs/24 hr} = \frac{(\text{Flow, GPM})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})}{694\ \text{GPM/MGD}}$$

$$= \frac{(50\ \text{GPM})(8\ \text{mg}/L)(8.34\ \text{lbs/gal})}{694\ \text{GPM/MGD}}$$

$$= 4.8\ \text{lbs/24 hr}$$

EXAMPLE 17

A chemical feed pump is set to deliver 40 gallons per day. What is the feed rate in milliliters per minute?

Known	Unknown
Pump Feed, GPD = 40 GPD	Pump Feed, mL/min

Convert the pump feed rate from gallons per day to milliliters per minute.

$$\text{Pump Feed, m}L\text{/min} = \frac{(\text{Pump Feed, gal/day})(3.785\ L/\text{gal})(1000\ \text{m}L/L)}{(24\ \text{hr/day})(60\ \text{min/hr})}$$

$$= \frac{(40\ \text{gal/day})(3.785\ L/\text{gal})(1000\ \text{m}L/L)}{(24\ \text{hr/day})(60\ \text{min/hr})}$$

$$= 105\ \text{m}L\text{/min}$$

EXAMPLE 18

A chemical feed pump delivers 240 mL in four minutes. What is the pump feed rate in gallons per day?

Known	Unknown
Volume, mL = 240 mL	Pump Feed, GPD
Time, min = 4 min	

Calculate the pump feed rate in gallons per day.

$$\text{Pump Feed, GPD} = \frac{(\text{Volume, m}L)(24\ \text{hr/day})(60\ \text{min/hr})}{(\text{Time, min})(3.785\ L/\text{gal})(1000\ \text{m}L/L)}$$

$$= \frac{(240\ \text{m}L)(24\ \text{hr/day})(60\ \text{min/hr})}{(4\ \text{min})(3.785\ L/\text{gal})(1000\ \text{m}L/L)}$$

$$= 23\ \text{GPD}$$

EXAMPLE 19

Determine the gallons of industrial waste delivered by a pump to a chemical treatment tank if the pumping rate is 25 GPM for five hours.

Known	Unknown
Pumping Rate, GPM = 25 GPM	*Volume, gal*
Time, hrs = 5 hrs	

Determine the gallons of industrial waste pumped to the chemical treatment tank.

$$\text{Volume, gal} = (\text{Flow, GPM})(\text{Time, hr})(60\ \text{min/hr})$$

$$= (25\ \text{gal/min})(5\ \text{hr})(60\ \text{min/hr})$$

$$= 7{,}500\ \text{gallons}$$

EXAMPLE 20

Estimate the chemical feed rate in GPD when a chemical feed pump lowers a chemical solution 23 inches in a 30-inch diameter chemical container in 4 hours and 15 minutes.

Known	Unknown
Diameter, in = 30 in	Feed Rate, GPD
Drop, in = 23 in	
Time, hr = 4 hr + 15 min/60 min/hr = 4.25 hr	

Calculate the chemical feed rate in gallons per day.

$$\text{Feed Rate, GPD} = \frac{(0.785)(\text{Diam, in})^2(\text{Drop, in})(24\ \text{hr/day})}{(231\ \text{cu in/gal})(\text{Time, hr})}$$

$$= \frac{(0.785)(30\ \text{in})^2(23\ \text{in})(24\ \text{hr/day})}{(231\ \text{cu in/gal})(4.25\ \text{hr})}$$

$$= 400\ \text{GPD}$$

EXAMPLE 21

A sulfonator will feed at a maximum rate of 2400 pounds of sulfur dioxide per day. What is the maximum feed rate in pounds of sulfur dioxide per minute?

Known	Unknown
Feed Rate, lbs/day = 2400 lbs/day	Feed Rate, lbs/min

Calculate the maximum feed rate in pounds of sulfur dioxide per minute.

$$\text{Feed Rate, lbs/min} = \frac{\text{Feed Rate, lbs/day}}{(24\text{ hr/day})(60\text{ min/hr})}$$

$$= \frac{2400\text{ lbs/day}}{(24\text{ hr/day})(60\text{ min/hr})}$$

$$= 1.67\text{ lbs } SO_2\text{/min}$$

I. POLYMERS AND COAGULANTS

EXAMPLE 22

How many pounds of polymer are required to make up 500 gallons of 0.50 percent polymer solution?

Known	Unknown
Volume, gal = 500 gallons	Polymer, lbs
Polymer Sol, % = 0.50%	

Calculate the pounds of polymer required.

$$\text{Polymer Req'd, lbs} = \frac{(\text{Vol, gal})(8.34\text{ lbs/gal})(\text{Polymer, \%})}{100\%}$$

$$= \frac{(500\text{ gal})(8.34\text{ lbs/gal})(0.50\%)}{100\%}$$

$$= 21\text{ lbs}$$

EXAMPLE 23

A liquid polymer feeder is treating a flow of 500 GPM. The specific gravity of the 0.50 percent liquid polymer solution is 1.0. What should be the polymer feed rate in milliliters per minute when the polymer dose is 0.40 mg/*L*?

Known	Unknown
Flow, GPM = 500 GPM	Polymer Feed, m*L*/min
Dose, mg/*L* = 0.40 mg/*L*	
Polymer, % = 0.50%	

1. Determine the polymer dose required in milligrams of polymer per minute.

$$\text{Dose, mg/min} = (\text{Flow, gal/min})(\text{Dose, mg/}L)(3.785\ L\text{/gal})$$

$$= (500\text{ gal/min})(0.40\text{ mg/}L)(3.785\ L\text{/gal})$$

$$= 757\text{ mg polymer/min}$$

2. Convert the polymer solution from percent to milligrams per milliliter. 1% = 10,000 mg/*L*

$$\text{Polymer Solution, mg/m}L = \frac{(\text{Polymer, \%})(10{,}000\text{ mg/}L\text{/\%})}{1000\text{ m}L/L}$$

$$= \frac{(0.50\%)(10{,}000\text{ mg/}L\text{/\%})}{1000\text{ m}L/L}$$

$$= 5.0\text{ mg/m}L$$

3. Calculate the polymer feed rate in milliliters per minute.

$$\text{Polymer Feed Rate, m}L\text{/min} = \frac{\text{Dose, mg/min}}{\text{Polymer Solution, mg/m}L}$$

$$= \frac{757\text{ mg polymer/min}}{5.0\text{ mg polymer/m}L}$$

$$= 151\text{ m}L\text{/min}$$

EXAMPLE 24

The optimum liquid alum dose from the jar tests is 12 mg/*L*. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the plant flow is 4.7 MGD. The liquid alum delivered to the plant contains 642.3 milligrams of alum per milliliter of liquid solution.

Known	Unknown
Alum Dose, mg/*L* = 12 mg/*L*	Chemical Feeder Setting, m*L*/min
Flow, MGD = 4.7 MGD	
Liquid Alum, mg/m*L* = 642.3 mg/m*L*	

Calculate the liquid alum chemical feeder setting in milliliters per minute.

$$\text{Chemical Feeder Setting, m}L\text{/min} = \frac{(\text{Flow, MGD})(\text{Alum Dose, mg/}L)(3.785\ L\text{/gal})(1{,}000{,}000\text{/M})}{(\text{Liquid Alum, mg/m}L)(24\text{ hr/day})(60\text{ min/hr})}$$

$$= \frac{(4.7\text{ MGD})(12\text{ mg/}L)(3.785\ L\text{/gal})(1{,}000{,}000\text{/M})}{(642.3\text{ mg/m}L)(24\text{ hr/day})(60\text{ min/hr})}$$

$$= 231\text{ m}L\text{/min}$$

EXAMPLE 25

The optimum liquid alum dose from the jar tests is 12 mg/*L*. Determine the setting on the liquid alum chemical feeder in gallons per day when the flow is 4.7 MGD. The liquid alum delivered to the plant contains 5.36 pounds of alum per gallon of liquid solution.

Known	Unknown
Alum Dose, mg/*L* = 12 mg/*L*	Chemical Feeder Setting, GPM
Flow, MGD = 4.7 MGD	
Liquid Alum, lbs/gal = 5.36 lbs/gal	

Calculate the liquid alum chemical feeder setting in gallons per day.

$$\text{Chemical Feeder Setting, GPD} = \frac{(\text{Flow, MGD})(\text{Alum Dose, mg/}L)(8.34\text{ lbs/gal})}{\text{Liquid Alum, lbs/gal}}$$

$$= \frac{(4.7\text{ MGD})(12\text{ mg/}L)(8.34\text{ lbs/gal})}{5.36\text{ lbs/gal}}$$

$$= 88\text{ GPD}$$

NOTE: If $\text{Chemical Feeder Setting, lbs/day} = (\text{Flow, MGD})(\text{Alum Dose, mg/}L)(8.34\text{ lbs/gal})$ then dividing the terms on the right by liquid alum, lbs/gal, will give the chemical feeder setting in gallons per day (GPD).

EXAMPLE 26

Determine the actual chemical feed in pounds per day from a dry chemical feeder. A bucket placed under the chemical feeder weighed 0.3 pounds empty and 2.1 pounds after 30 minutes.

Known		Unknown
Empty Bucket, lbs	= 0.3 lbs	Chemical Feed, lbs/day
Full Bucket, lbs	= 2.1 lbs	
Time to Fill, min	= 30 min	

Determine the chemical feed in pounds of chemical applied per day.

$$\text{Chemical Feed, lbs/day} = \frac{\text{Chemical Applied, lbs}}{\text{Length of Application, day}}$$

$$= \frac{(2.1 \text{ lbs} - 0.3 \text{ lbs})(60 \text{ min/hr})(24 \text{ hr/day})}{(30 \text{ min})}$$

$$= 86 \text{ lbs/day}$$

EXAMPLE 27

Determine the chemical feed in pounds of polymer per day from a chemical feed pump. The polymer solution is 1.5 percent or 15,000 mg polymer per liter. Assume a specific gravity of the polymer solution of 1.0. During a test run the chemical feed pump delivered 800 m*L* of polymer solution during five minutes.

Known		Unknown
Polymer Solution, %	= 1.5%	Polymer Feed, lbs/day
Polymer Conc, mg/*L*	= 15,000 mg/*L*	
Polymer Sp Gr	= 1.0	
Volume Pumped, m*L*	= 800 m*L*	
Time Pumped, min	= 5 min	

Calculate the polymer fed by the chemical feed pump in pounds of polymer per day.

$$\text{Polymer Feed, lbs/day} = \frac{(\text{Poly Conc, mg}/L)(\text{Vol Pumped, m}L)(60 \text{ min/hr})(24 \text{ hr/day})}{(\text{Time Pumped, min})(1000 \text{ m}L/L)(1000 \text{ mg/gm})(454 \text{ gm/lb})}$$

$$= \frac{(15{,}000 \text{ mg}/L)(800 \text{ m}L)(60 \text{ min/hr})(24 \text{ hr/day})}{(5 \text{ min})(1000 \text{ m}L/L)(1000 \text{ mg/gm})(454 \text{ gm/lb})}$$

$$= 7.6 \text{ lbs polymer/day}$$

EXAMPLE 28

Determine the settings in percent stroke on a chemical feed pump for various doses of a chemical in milligrams per liter. (The chemical could be chlorine, polymer, potassium permanganate or any other chemical solution fed by a pump.) The pump delivering the water to be treated pumps at a flow rate of 400 GPM. The solution strength of the chemical being pumped is 4.8 percent. The chemical feed pump has a maximum capacity of 92 gallons per day at a setting of 100 percent capacity.

Known		Unknown
Pump Flow, GPM	= 400 GPM	Setting, % stroke for various doses in mg/*L*
Solution Strength, %	= 4.8%	
Feed Pump, GPD (100% stroke)	= 92 GPD	

1. Convert the pump flow from gallons per minute to million gallons per day.

$$\text{Pump Flow, MGD} = (\text{Pump Flow, GPM})(60 \text{ min/hr})(24 \text{ hr/day})$$

$$= (400 \text{ gal/min})(60 \text{ min/hr})(24 \text{ hr/day})$$

$$= 576{,}000 \text{ gal/day}$$

$$= 0.576 \text{ MGD}$$

2. Change the chemical solution strength from a percent to pounds of chemical per gallon of solution. A 4.8 percent solution means we have 4.8 pounds of chemical in a *solution of water and chemical weighing 100 pounds.*

$$\text{Chemical Solution, lbs/gal} = \frac{4.8 \text{ lbs chemical}}{100 \text{ lbs of chemical and water}}$$

$$= \frac{(4.8 \text{ lbs})(8.34 \text{ lbs/gal})}{100 \text{ lbs}}$$

$$= 0.4 \text{ lbs chemical/gallon solution}$$

3. Calculate the chemical feed in pounds per day for a chemical dose of 0.5 milligrams per liter. We are going to assume various chemical doses of 0.5, 1.0, 1.5, 2.0, 2.5 mg/*L* and upward so that if we know the desired chemical dose, we can easily determine the setting (percent stroke) on the chemical feed pump.

$$\text{Chemical Feed, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34 \text{ lbs/gal})$$

$$= (0.576 \text{ MGD})(0.5 \text{ mg}/L)(8.34 \text{ lbs/gal})$$

$$= 2.4 \text{ lbs/day}$$

4. Determine the desired flow from the chemical feed pump in gallons per day.

$$\text{Feed Pump, GPD} = \frac{\text{Chemical Feed, lbs/day}}{\text{Chemical Solution, lbs/gal}}$$

$$= \frac{2.4 \text{ lbs/day}}{0.4 \text{ lbs/gal}}$$

$$= 6 \text{ GPD}$$

5. Determine the setting on the chemical feed pump as a percent. In this case, we want to know the setting as a percent of the pump stroke.

$$\text{Setting, \%} = \frac{(\text{Desired Feed Pump, GPD})(100\%)}{\text{Maximum Feed Pump, GPD}}$$

$$= \frac{(6 \text{ GPD})(100\%)}{92 \text{ GPD}}$$

$$= 6.5\%$$

6. If we changed the chemical dose in Step 3 from 0.5 mg/*L* to 1.0 mg/*L* and other higher doses and repeated the remainder of the steps, we could calculate the data in Table 14.

7. Plot the data in Table 14 (Chemical Dose, mg/*L* vs. Pump setting, % stroke) to obtain Figure 44. Only three points were needed since the data plotted a straight line. For any desired chemical dose in milligrams per liter, you can use Figure 44 to determine the necessary chemical feed pump setting.

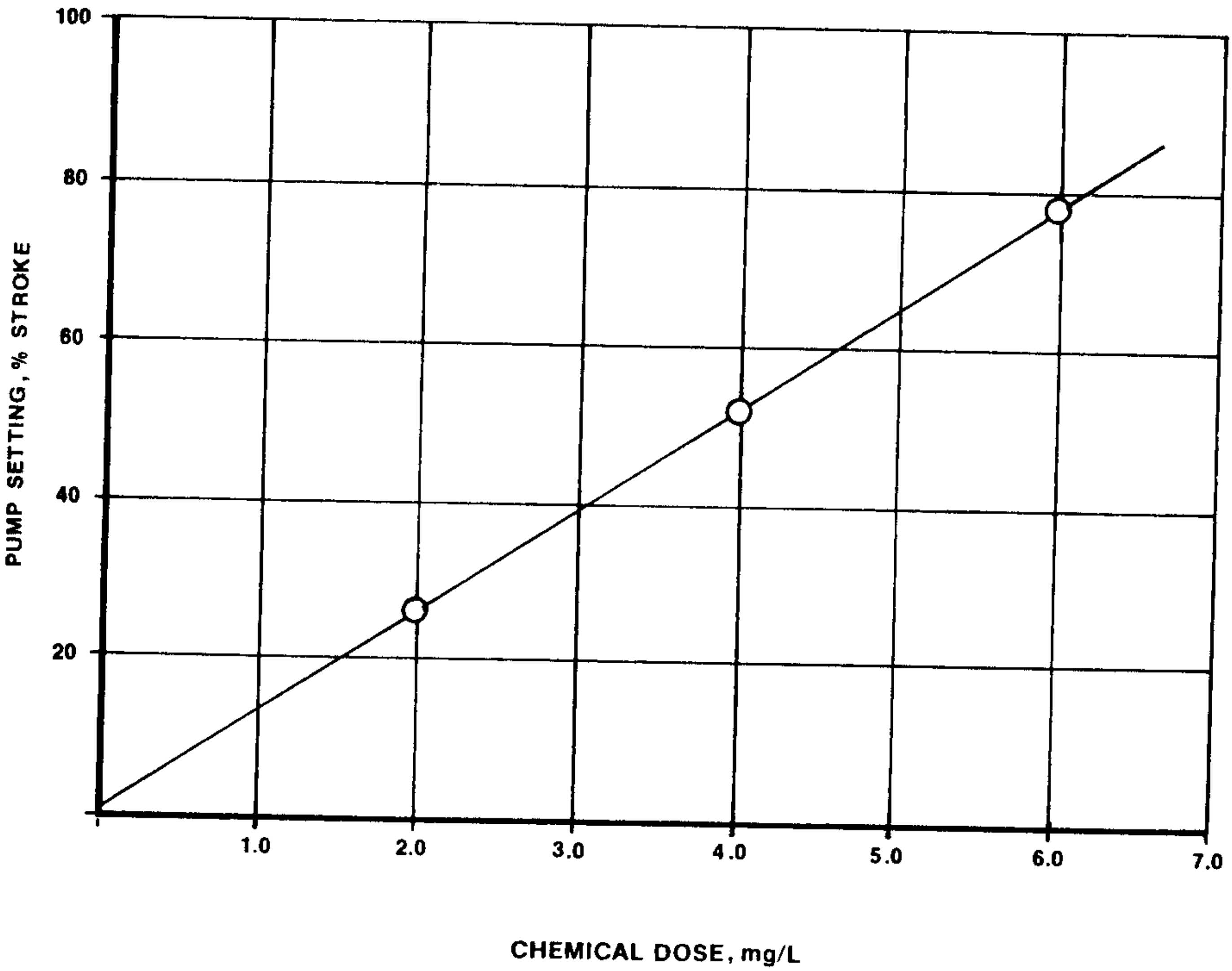


Fig. 44 Chemical feed pump settings for various chemical doses

TABLE 14 SETTINGS FOR CHEMICAL FEED PUMP

PUMP FLOW, GPM = 400 GPM

SOLUTION STRENGTH, % = 4.8%

Chemical Dose, mg/L	Chemical Feeds, lb/day	Feed Pump, GPD	Pump Setting % stroke
0.5	2.4	6.0	6.5
1.0	4.8	12.0	13.0
1.5	7.2	18.0	19.5
2.0	9.6	24.0	26.1
2.5	12.0	30.0	32.6
3.0	14.4	36.0	39.1
3.5	16.8	42.0	45.6
4.0	19.2	48.0	52.2
4.5	21.6	54.0	58.7
5.0	24.0	60.0	65.2
5.5	26.4	66.0	71.7
6.0	28.8	72.0	78.2
6.5	31.2	78.0	84.8
7.0	33.6	84.0	91.3
7.5	36.0	90.0	97.8

EXAMPLE 29

The calculated pure chemical dose for a chemical solution is 3.56 pounds. The chemical manufacturer has indicated on the chemical container label that the chemical purity or percent active chemical is 91 percent. Calculate the pounds of chemical from the container that must be added to water to produce the desired percent solution or concentration.

Known	Unknown
Pure Chemical, lbs = 3.56 lbs Active Chemical, %= 91%	Actual Chemical Required, lbs

Calculate the pounds of chemical from the container that must be added to the water.

$$\text{Actual Chemical Required, lbs} = \frac{(\text{Pure Chemical, lbs})(100\%)}{\text{Active Chemical, \%}}$$

$$= \frac{(3.56 \text{ lbs})(100\%)}{91\%}$$

$$= 3.91 \text{ lbs}$$

$$= 3 \text{ lbs} + (0.91 \text{ lbs})(16 \text{ oz/lb})$$

$$= 3 \text{ lbs, } 15 \text{ oz}$$

J. NEUTRALIZATION AND pH ADJUSTMENT

EXAMPLE 30

The effluent from a filter press treating an industrial sludge must be neutralized before additional treatment. If a 50 mL sample of effluent requires 6.2 mL of 0.5 N sulfuric acid to lower the pH to 7.0, how many gallons of 2 N sulfuric acid will be required to neutralize 3200 gallons of filter press effluent to a pH of 7.0?

NOTE: Frequently a permit will specify a maximum pH limit of 8.0 or 8.5. Use the same procedure to determine the amount of acid to adjust the pH to the necessary level.

Known	Unknown
Sample, mL = 50 mL Acid, mL = 6.2 mL Acid, N = 0.5 N for sample Waste, gal = 3200 gal Acid, N = 2 N for waste treatment	2 N Acid, gal

Determine normality of waste.

Millequivalents = (mL)(N)

$$\text{Waste Normality} = \frac{(\text{Acid, mL})(\text{Acid, N})}{\text{Sample, mL}}$$

$$= \frac{(6.2 \text{ mL})(0.5 \text{ N})}{50 \text{ mL}}$$

$$= 0.062 \text{ N}$$

Calculate the gallons of 2 N Sulfuric acid to neutralize the filter press effluent.

$$\text{2 N Sulfuric Acid, gal} = \frac{(\text{Waste, gal})(\text{Waste, Normality})}{\text{Sulfuric Acid, Normality}}$$

$$= \frac{(3200 \text{ gal})(0.062 \text{ N})}{2 \text{ N}}$$

$$= 100 \text{ gallons}$$

EXAMPLE 31

A metal wastestream has a pH of 7.2. A one quarter gallon (0.25 gal) sample of the wastestream requires 0.1 gallons of 1 percent caustic to increase the pH to 10 for hydroxide precipitation. How many gallons of 4 percent caustic are required for 100 gallons of the wastestream using a batch treatment process?

Known	Unknown
Sample, gal = 0.25 gal Caustic, gal = 0.1 gal Caustic, % = 1% for sample Caustic, % = 4% for treatment Waste, gal = 100 gal	4% Caustic, gal

Calculate the gallons of 4% caustic needed.

$$\text{4\% Caustic, gal} = \frac{\left(\text{Caustic to Sample, gal}\right)\left(\text{Caustic to Sample, \%}\right)\left(\text{Waste to Treatment, gal}\right)}{(\text{Sample, gal})(\text{Treatment Caustic, \%})}$$

$$= \frac{(0.1 \text{ gal})(1\%)(100 \text{ gal})}{(0.25 \text{ gal})(4\%)}$$

$$= 10 \text{ gallons}$$

EXAMPLE 32

An industrial wastewater with a pH of 10.8 flows from an equalization tank to a neutralization mixing tank at a rate of 9 GPM. Lab tests indicate that a 100 mL sample of the waste requires 11.3 mL of 0.5 N sulfuric acid to lower the pH to 7.0. Determine the setting in gallons per day on a chemical feed pump which is pumping 2 N sulfuric acid to the neutralization mixing tank.

Known		Unknown
Waste Flow, GPM	= 9 GPM	Acid Feed, GPD
Waste Sample, mL	= 100 mL	
Acid Vol, mL	= 11.3 mL	
Acid, N	= 0.5 N	
Acid Feed, N	= 2 N	

Determine normality of waste.

Millequivalents = (mL)(N)

$$\text{Waste Normality} = \frac{(\text{Acid Vol, mL})(\text{Acid, N})}{\text{Waste Sample, mL}}$$

$$= \frac{(11.3\ mL)(0.5\ N)}{100\ mL}$$

$$= 0.0565\ N$$

Calculate the flow to be delivered by the chemical feed pump.

$$\text{Acid Feed, GPD} = \frac{(\text{Waste Flow, GPM})(\text{Waste Normality})(60\ min/hr)(24\ hr/day)}{\text{Acid Feed, N}}$$

$$= \frac{(9\ GPM)(0.0565\ N)(60\ min/hr)(24\ hr/day)}{2\ N}$$

$$= 366\ GPD$$

K. HYDROXIDE PRECIPITATION

EXAMPLE 33

Zinc is being removed in a plating wastestream by hydroxide precipitation. Laboratory tests indicate that 1.8 milliliters of a four percent or one normal sodium hydroxide solution will increase the pH of one liter of wastewater to 10 and precipitate the zinc. How many gallons of the four percent sodium hydroxide are required to treat 500 gallons of zinc wastewater?

Known	Unknown
Lab Results	NaOH, gal
1.8 mL NaOH/L wastewater	
Wastewater, gal = 500 gal	

Calculate the gallons of sodium hydroxide needed.

$$\text{NaOH, gal} = \frac{(\text{Wastewater, gal})(\text{mL NaOH})}{(1000\ mL/L)(1\ L\ \text{Wastewater})}$$

$$= \frac{(500\ gal)(1.8\ mL\ NaOH)}{(1000\ mL/L)(1\ L)}$$

$$= 0.9\ \text{gallons NaOH}$$

EXAMPLE 34

Zinc is being removed in a plating wastestream by hydroxide precipitation. Laboratory tests indicate that 1.8 milliliters of a four percent or one normal sodium hydroxide solution will increase the pH of one liter of wastewater to 10 and precipitate the zinc. Determine the setting on the sodium hydroxide feed pump in gallons per day to treat a zinc wastewater flow of 10 GPM.

Known	Unknown
Lab Results	NaOH Feed, GPD
1.8 mL NaOH/L wastewater	
Zinc Flow, GPM = 10 GPM	

Calculate the sodium hydroxide feed rate in gallons per day.

$$\text{NaOH Feed, GPD} = \frac{(\text{Zinc Flow, gal/min})(\text{mL NaOH})(60\ min/hr)(24\ hr/day)}{(1000\ mL/L)(1\ L\ \text{zinc})}$$

$$= \frac{(10\ GPM\ \text{zinc})(1.8\ mL\ NaOH)(60\ min/hr)(24\ hr/day)}{(1000\ mL/L)(1\ L\ \text{zinc})}$$

$$= 26\ GPD$$

L. COMPLEXED METAL PRECIPITATION

EXAMPLE 35

Complexed copper is being removed in a plating wastestream by hydroxide precipitation. Laboratory results indicate that 10 milliliters of four percent or one normal sodium hydroxide will increase the pH of one liter of wastewater to 12 and precipitate the copper. How many gallons of four percent sodium hydroxide are required to treat 400 gallons of complexed copper wastewater?

Known	Unknown
Lab Results	NaOH, gal
10 mL NaOH/L wastewater	
Wastewater, gal = 400 gal	

Calculate the gallons of sodium hydroxide needed.

$$\text{NaOH, gal} = \frac{(\text{Wastewater, gal})(\text{mL NaOH})}{(1000\ mL/L)(1\ L\ \text{wastewater})}$$

$$= \frac{(400\ gal)(10\ mL\ NaOH)}{(1000\ mL/L)(1\ L\ \text{wastewater})}$$

$$= 4\ \text{gallons NaOH}$$

EXAMPLE 36

Complexed copper is being removed in a plating wastestream by hydroxide precipitation. Laboratory results indicate that 10 milliliters of four percent or one normal sodium hydroxide will increase the pH of one liter of wastewater to 12 and precipitate the copper. Determine the setting on the sodium hydroxide feed pump in gallons per day to treat a complexed copper wastewater flow of 12 GPM.

Known	Unknown
Lab Results	NaOH Feed, GPD
10 mL NaOH/L wastewater	
Copper Flow, GPM = 12 GPM	

Calculate the sodium hydroxide feed rate in gallons per day.

$$\text{NaOH Feed, GPD} = \frac{(\text{Copper Flow, gal/min})(\text{mL NaOH})(60\ min/hr)(24\ hr/day)}{(1000\ mL/L)(1\ L\ \text{Copper})}$$

$$= \frac{(12\ GPM\ \text{Copper})(10\ mL\ NaOH)(60\ min/hr)(24\ hr/day)}{(1000\ mL/L)(1\ L\ \text{Copper})}$$

$$= 173\ GPD$$

M. REDUCTION OF HEXAVALENT CHROMIUM

EXAMPLE 37

How much sulfur dioxide is required to treat 1100 gallons of chromic acid containing 1400 mg/L of hexavalent chromium? Assume that one pound of hexavalent chromium is reduced to the trivalent state by the addition of three pounds of sulfur dioxide.

Known		Unknown
Waste, gal	= 1100 gal	Dosage, lbs SO_2
Conc, mg/L	= 1400 mg Cr^{6+}/L	
Treat, lbs/lb	= 3 lbs SO_2/lb Cr^{6+}	

1. Calculate the pounds of Cr^{6+} to be treated.

Cr^{6+} Treated, lbs = (Waste, MG)(Cr^{6+}, mg/L)(8.34 lbs/gal)

= (0.0011 MG)(1400 mg/L)(8.34 lbs/gal)

= 12.8 lbs Cr^{6+}

2. Calculate the dosage of sulfur dioxide.

Dosage, lbs SO_2 = (Cr^{6+} Treated, lbs)(Treatment, lbs SO_2/lb Cr^{6+})

= (12.8 lbs Cr^{6+})(3 lbs SO_2/lb Cr^{6+})

= 38.4 lbs SO_2

EXAMPLE 38

A chrome waste flowing at a rate of 50 GPM from a manufacturing process contains 240 mg/L of hexavalent chromium. Determine the sulfonator feed rate in pounds of sulfur dioxide per minute if one pound of hexavalent chromium is reduced to the trivalent state by the addition of three pounds of sulfur dioxide.

Known	Unknown
Flow, GPM = 50 GPM	Sulfonator Feed, lbs/min
Waste, mg/L = 240 mg Cr^{6+}/L	
Treat, lb/lb = 3 lbs SO_2/lb Cr^{6+}	

Calculate the sulfonator feed rate in pounds of sulfur dioxide per minute.

$$\text{Sulfonator Feed, lbs/min} = \frac{(\text{Flow, GPM})(\text{Waste, mg/L})(8.34\text{ lbs/gal})(\text{Treat, lb/lb})}{1{,}000{,}000/\text{M}}$$

$$= \frac{(50\text{ GPM})(240\text{ mg }Cr^{6+}/L)(8.34\text{ lbs/gal})(3\text{ lbs }SO_2)}{(1{,}000{,}000/\text{M})\qquad(1\text{ lb }Cr^{6+})}$$

$$= 0.3\text{ lbs }SO_2/\text{min}$$

EXAMPLE 39

How much time will be required to completely reduce 15,000 gallons of chrome waste with a concentration of 240 mg/L of hexavalent chromium if the sulfonator is set to feed 1200 pounds of sulfur dioxide per day? Assume one pound of hexavalent chromium is reduced to the trivalent state by three pounds of sulfur dioxide.

Known	Unknown
Waste Vol, gal = 15,000 gal	Time, min
Conc, mg/L = 240 mg Cr^{6+}/L	
Feed, lbs/day = 1200 lbs SO_2/day	
Treat, lb/lb = 3 lbs SO_2/lb Cr^{6+}	

Calculate the pounds of hexavalent chromium to be treated.

Waste, lbs Cr^{+} = (Waste Vol, MG)(Conc, mg Cr^{6+}/L)(8.34 lbs/gal)

= (0.015 MG)(240 mg Cr^{6+}/L)(8.34 lbs/gal)

= 30 lbs Cr^{6+}

Calculate the time required to add the sulfur dioxide.

$$\text{Time, min} = \frac{(\text{Waste, lbs }Cr^{6+})(\text{Treat, lbs }SO_2/\text{lb }Cr^{6+})(1440\text{ min/day})}{\text{Feed, lbs }SO_2/\text{day}}$$

$$= \frac{(30\text{ lbs }Cr^{6+})(3\text{ lbs }SO_2/\text{lb }Cr^{6+})(1440\text{ min/day})}{1200\text{ lbs }SO_2/\text{day}}$$

$$= 108\text{ min}$$

EXAMPLE 40

A batch treatment process is used by a plating shop to treat 800 gallons of a chrome-plating waste by the reduction and precipitation process to reduce the hexavalent chromium in the waste to the trivalent stage. Assume one mg/L of hexavalent chromium will require 16 mg/L of ferrous sulfate ($FeSO_4 \cdot 7H_2O$), 6 mg/L of sulfuric acid, and 9.5 mg/L lime. The hexavalent chromium concentration in the wastes is 320 mg/L.

a. If the ferrous sulfate is fed as a four percent solution at a rate of 80 gallons per hour, how long should the ferrous sulfate feed pump operate?

b. If the sulfuric acid is fed as a 2.8 percent or 0.57 normal sulfuric acid solution at a rate of 35 gallons per hour, how long should the sulfuric acid feed pump operate?

c. If the lime slurry feeder mixes 0.5 pounds of lime per gallon of water and delivers a lime slurry of 50 gallons per hour to the mixing tank, how long should the lime slurry feeder operate?

Known

Volume Cr Waste, gal	= 800 gal
Cr^{6+} Conc, mg/L	= 320 mg/L
Ferrous Sulfate Dose, mg/L/mg/L	= 16 mg/L/mg/L
Ferrous Sulfate, %	= 4%
Ferrous Sulfate Feed, GPH	= 80 GPH
Sulfuric Dose, mg/L/mg/L	= 6 mg/L/mg/L
Sulfuric Acid, %	= 2.8%
Sulfuric Feed, GPH	= 35 GPH
Lime Dose, mg/L/mg/L	= 9.5 mg/L/mg/L
Lime Conc, lbs/gal	= 0.5 lbs/gal
Lime Feed, GPH	= 50 GPH

Unknown

Time to Operate:
a. Ferrous Sulfate Feed, hr
b. Sulfuric Feed, hr
c. Lime Feed, hr

1. Calculate the pounds of hexavalent chromium to be treated.

$$\text{Chromium, lbs} = \frac{(\text{Vol Cr Waste, gal})(Cr^{6+}\text{ Conc, mg/L})(8.34\text{ lbs/gal})}{1{,}000{,}000/\text{M}}$$

$$= \frac{(800\text{ gal})(320\text{ mg/L})(8.34\text{ lbs/gal})}{1{,}000{,}000/\text{M}}$$

= 2.14 lbs hexavalent chromium

2. Calculate the pounds of ferrous sulfate needed to treat the chromium.

Ferrous Sulfate, lbs = (Chromium, lbs)(Ferrous Sulfate Dose, mg/L/mg/L)

= (2.14 lbs Cr^{6+})(16 mg/L/mg/L)

= 34.3 lbs ferrous sulfate

3. Calculate the length of time to operate the ferrous sulfate feed pump.

$$\text{Time, hr} = \frac{(\text{Ferrous Sulfate, lbs})(100\%)}{(\text{Ferrous Sulfate, GPH})(8.34\text{ lbs/gal})(\text{Ferrous Sulfate, \%})}$$

$$= \frac{(34.3\text{ lbs})(100\%)}{(80\text{ GPH})(8.34\text{ lbs/gal})(4\%)}$$

= 1.28 hr

= 1 hr and (0.28 hr)(60 min/hr)

= 1 hr and 17 min

4. Calculate the pounds of sulfuric acid needed to treat the chromium.

Sulfuric Acid, lbs = (Chromium, lbs)(Acid Dose, mg/L/mg/L)

= (2.14 lbs Cr^{6+})(6 mg/L/mg/L)

= 12.9 lbs sulfuric acid

5. Calculate the length of time to operate the sulfuric acid feed pump.

$$\text{Time, hr} = \frac{\text{(Sulfuric Acid, lbs)(100\%)}}{\text{(Acid Feed, GPH)(8.34 lbs/gal)(Acid, \%)}}$$

$$= \frac{\text{(12.9 lbs)(100\%)}}{\text{(35 GPH)(8.34 lbs/gal)(2.8\%)}}$$

= 1.58 hr

= 1 hr and (0.58 hr)(60 min/hr)

= 1 hr and 35 min

6. Calculate the pounds of lime needed to treat the chromium.

Lime, lbs = (Chromium, lbs)(Lime Dose, mg/*L*/mg/*L*)

= (2.14 lbs Cr^{6+})(9.5 mg/*L*/mg/*L*)

= 20.3 lbs lime

7. Calculate the length of time to operate the lime slurry feeder.

$$\text{Time, hr} = \frac{\text{Lime, lbs}}{\text{(Lime Feed, gal/hr)(Lime, lbs/gal)}}$$

$$= \frac{\text{20.3 lbs}}{\text{(50 gal/hr)(0.5 lbs/gal)}}$$

= 0.81 hr

= (0.81 hr)(60 min/hr)

= 49 min

EXAMPLE 41

A continuous flow treatment process is used by a plating shop to treat a chrome-plating waste by the reduction and precipitation process to reduce the hexavalent chromium in the waste to the trivalent state. One mg/*L* of hexavalent chromium requires 16 mg/*L* of ferrous sulfate, 6 mg/*L* of sulfuric acid, and 9.5 mg/*L* of lime. The hexavalent chromium concentration is 320 mg/*L* and is fed to the mixing tank by a five gallon per minute pump.

a. If the ferrous sulfate is fed as a four percent solution, what should be the feed setting on the ferrous sulfate pump?

b. If the sulfuric acid is fed as a 2.8 percent or 0.57 normal sulfuric acid solution, what should be the feed setting on the sulfuric acid pump?

c. If the lime slurry feeder mixes 0.5 pounds of lime per gallon of water, what should be the lime slurry feeder setting in pounds of lime per hour?

Known

Chromium Pump, GPM	= 5 GPM
Chromium Conc, mg/*L*	= 320 mg/*L*
Ferrous Sulfate Dose, mg/*L*/mg/*L*	= 16 mg/*L*/mg/*L*
Ferrous Sulfate, %	= 4%
Acid Dose, mg/*L*/mg/*L*	= 6 mg/*L*/mg/*L*
Acid, %	= 2.8%
Lime Dose, mg/*L*/mg/*L*	= 9.5 mg/*L*/mg/*L*
Lime Slurry, lbs/gal	= 0.5 lbs/gal

Unknown

a. Ferrous Sulfate Feed, GPD
b. Acid Feed, GPD
c. Lime Feed, lbs/hr

1. Calculate the hexavalent chromium feed rate.

$$\text{Chromium Feed, lbs/day} = \frac{(Cr^{6+}\text{ Pump, GPM})(Cr^{6+}\text{ Conc, mg/}L\text{)(8.34 lbs/gal)}}{\text{694 GPM/MGD}}$$

$$= \frac{\text{(5 GPM)(320 mg/}L\text{)(8.34 lbs/gal)}}{\text{694 GPM/MGD}}$$

= 19.2 lbs/day

2. Calculate the ferrous sulfate feed in pounds per day.

Ferrous Sulfate, Feed, lbs/day = (Chromium Feed, lbs/day)(Ferrous Sulfate Dose, mg/*L*/mg/*L*)

= (19.2 lbs/day)(16 mg/*L*/mg/*L*)

= 307.2 lbs/day

3. Calculate the setting on the ferrous sulfate feed pump in gallons per day.

$$\text{Ferrous Sulfate Feed, GPD} = \frac{\text{(Ferrous Sulfate Feed, lbs/day)(100\%)}}{\text{(8.34 lbs/gal)(Ferrous Sulfate, \%)}}$$

$$= \frac{\text{(307.2 lbs/day)(100\%)}}{\text{(8.34 lbs/gal)(4\%)}}$$

= 921 GPD

4. Calculate the sulfuric acid feed in pounds per day.

Acid Feed, lbs/day = (Chromium Feed, lbs/day)(Acid Dose, mg/*L*/mg/*L*)

= (19.2 lbs/day)(6 mg/*L*/mg/*L*)

= 115.2 lbs/day

5. Calculate the setting on the sulfuric acid feed pump in gallons per day.

$$\text{Acid Feed, GPD} = \frac{\text{(Acid Feed, lbs/day)(100\%)}}{\text{(8.34 lbs/gal)(Acid, \%)}}$$

$$= \frac{\text{(115.2 lbs/day)(100\%)}}{\text{(8.34 lbs/gal)(2.8\%)}}$$

= 493 GPD

6. Calculate the lime feed in pounds per day.

Lime, lbs/day = (Chromium Feed, lbs/day)(Lime Dose, mg/*L*/mg/*L*)

= (19.2 lbs/day)(9.5 mg/*L*/mg/*L*)

= 182 lbs/day

7. Calculate the lime slurry feeder setting in pounds of lime per hour.

$$\text{Lime Feed, lbs/hr} = \frac{\text{Lime, lbs/day}}{\text{24 hr/day}}$$

$$= \frac{\text{182 lbs/day}}{\text{24 hr/day}}$$

= 7.6 lbs/hr

N. CYANIDE DESTRUCTION

EXAMPLE 42

'A cyanide-bearing waste is to be treated by a batch process using the alkaline chlorination method. The cyanide holding tank contains 6000 gallons with a cyanide concentration of 15 mg/*L*. Seven pounds of caustic soda and eight pounds of chlorine are required to oxidize one pound of cyanide to nitrogen gas.

a. How many pounds of chlorine are needed?

b. How long will a hypochlorinator have to operate if the hypochlorite solution is 2.0 percent chlorine and the hypochlorinator can deliver 250 GPD?

c. How long should the caustic soda feed pump operate if the pump delivers 120 gallons per day of a ten percent caustic soda solution?

Known

Cyanide Vol, gal = 6000
Cyanide Conc, mg/*L* = 15 mg/*L*
Chlorine Dose, lb/lb = 8 lbs Cl/lb CN
Caustic Dose, lb/lb = 7 lbs NaOH/lb CN
Hypochlorite, % Cl = 2% Cl
Hypochlorinator, GPD = 250 GPD
Caustic Soda, % = 10%
Caustic Pump, GPD = 120 GPD

Unknown

a. Chlorine Required, lbs
b. Hypochlorinator Time, hr
c. Caustic Pump Time, hr

1. Calculate the pounds of cyanide to be treated.

$$\text{Cyanide, lbs} = \frac{(\text{CN Vol, gal})(\text{CN Conc, mg}/L)(8.34\text{ lbs/gal})}{1{,}000{,}000/\text{M}}$$

$$= \frac{(6000\text{ gal})(15\text{ mg}/L)(8.34\text{ lbs/gal})}{1{,}000{,}000/\text{M}}$$

$$= 0.75\text{ lbs cyanide}$$

2. Calculate the pounds of chlorine and caustic needed.

$$\text{Chlorine Required, lbs} = (\text{Cyanide, lbs})(\text{Chlorine Dose, lb/lb})$$

$$= (0.75\text{ lbs CN})(8\text{ lbs Cl/lb CN})$$

$$= 6.0\text{ lbs chlorine}$$

$$\text{Caustic Required, lbs} = (\text{Cyanide, lbs})(\text{Caustic Dose, lb/lb})$$

$$= (0.75\text{ lbs CN})(7\text{ lbs NaOH/lb CN})$$

$$= 5.25\text{ lbs caustic}$$

3. Calculate the time of operation of the hypochlorinator in hours.

$$\text{Time, hr} = \frac{(\text{Chlorine Required, lbs})(100\%)(24\text{ hr/day})}{(\text{Flow, GPD})(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(6.0\text{ lbs})(100\%)(24\text{ hr/day})}{(250\text{ GPD})(8.34\text{ lbs/gal})(2\%)}$$

$$= 3.45\text{ hours}$$

$$= 3\text{ hr} + (0.45\text{ hr})(60\text{ min/hr})$$

$$= 3\text{ hrs } 27\text{ min}$$

4. Calculate the time of operation of the caustic soda pump.

$$\text{Time, hr} = \frac{(\text{Caustic Required, lbs})(100\%)(24\text{ hr/day})}{(\text{Flow, GPD})(8.34\text{ lbs/gal})(\text{Caustic Soda, }\%)}$$

$$= \frac{(5.25\text{ lbs})(100\%)(24\text{ hr/day})}{(120\text{ GPD})(8.34\text{ lbs/gal})(10\%)}$$

$$= 1.26\text{ hrs}$$

$$= 1\text{ hr} + (0.26\text{ hr})(60\text{ min/hr})$$

$$= 1\text{ hr } 16\text{ min}$$

EXAMPLE 43

A plating solution contains 2 ounces per gallon of hexavalent chromium. What is the concentration in milligrams per liter?

Known		Unknown
Hexavalent Chromium, oz/gal	= 2 oz/gal	Hexavalent Chromium, mg/*L*

Convert the hexavalent chromium solution from ounces per gallon to milligrams per liter.

$$\text{Conc, mg}/L = \frac{(\text{Conc, oz/gal})(454\text{ gm/lb})(1000\text{ mg/gm})}{(16\text{ oz/lb})(3.785\ L/\text{gal})}$$

$$= \frac{(2\text{ oz/gal})(454\text{ gm/lb})(1000\text{ mg/gm})}{(16\text{ oz/lb})(3.785\ L/\text{gal})}$$

$$= 15{,}000\text{ mg}/L$$

EXAMPLE 44

The concentration of hexavalent chromium in the effluent from a reduction process is 2 mg/*L*. What is the concentration in ounces per gallon?

Known		Unknown
Hexavalent Chromium, mg/*L*	= 2 mg/*L*	Hexavalent Chromium, oz/gal

Convert the hexavalent chromium solution from milligrams per liter to ounces per gallon.

$$\text{Conc, oz/gal} = \frac{(\text{Conc, mg}/L)(16\text{ oz/lb})(3.785\ L/\text{gal})}{(1000\text{ mg/gm})(454\text{ gm/lb})}$$

$$= \frac{(2\text{ mg}/L)(16\text{ oz/lb})(3.785\ L/\text{gal})}{(1000\text{ mg/gm})(454\text{ gm/lb})}$$

$$= 0.00027\text{ oz/gal}$$

EXAMPLE 45

A cyanide-bearing waste is to be treated by a continuous flow process using the alkaline chlorination method. The cyanide holding tank contains 6000 gallons with a cyanide concentration of 15 mg/*L*. Seven pounds of caustic soda and eight pounds of chlorine are required to oxidize one pound of cyanide to nitrogen gas. The cyanide wastes are delivered to a mixing tank by a 25 GPM pump.

a. What should be the setting on the hypochlorinator in gallons per day if the hypochlorite solution is 2.0 percent chlorine?

b. What should be the setting on the caustic feed pump in gallons per day if the caustic soda is a 10 percent solution?

Known		Unknown
Cyanide Vol, gal	= 6000 gal	Hypochlorinator, GPD
Cyanide Conc, mg/*L*	= 15 mg/*L*	Caustic Pump, GPD
Cyanide Flow, GPM	= 25 GPM	
Chlorine Dose, lb/lb	= 8 lbs Cl/lb CN	
Caustic Dose, lb/lb	= 7 lbs NaOH/lb CN	
Hypochlorite, % Cl	= 2%	
Caustic Soda, %	= 10%	

1. Calculate the cyanide feed rate in pounds per day.

$$\text{Cyanide, lbs/day} = \frac{(\text{Flow, GPM})(\text{Cyanide Conc, mg}/L)(8.34\text{ lbs/gal})}{694\text{ GPM/MGD}}$$

$$= \frac{(25\text{ GPM})(15\text{ mg}/L)(8.34\text{ lbs/gal})}{694\text{ GPM}}$$

$$= 4.5\text{ lbs/day}$$

2. Determine the chlorine feed rate in pounds per day.

$$\text{Chlorine Feed, lbs/day} = (\text{Cyanide, lbs/day})(\text{Chlorine Dose, lb/lb})$$

$$= (4.5\text{ lbs CN/day})(8\text{ lbs Cl/lb CN})$$

$$= 36\text{ lbs Cl/day}$$

$$\text{Caustic Feed, lbs/day} = (\text{Cyanide, lbs/day})(\text{Caustic Dose, lb/lb})$$

$$= (4.5\text{ lbs CN/day})(7\text{ lbs NaOH/lb CN})$$

$$= 31.5\text{ lbs caustic/day}$$

3. Determine the hypochlorinator setting in gallons per day.

$$\text{Hypochlorinator, GPD} = \frac{(\text{Chlorine Feed, lbs/day})(100\%)}{(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(36\text{ lbs/day})(100\%)}{(8.34\text{ lbs/gal})(2\%)}$$

$$= 216\text{ GPD}$$

4. Determine the caustic pump setting in gallons per day.

$$\text{Caustic Pump, GPD} = \frac{(\text{Caustic Feed, lbs/day})(100\%)}{(8.34\text{ lbs/gal})(\text{Caustic, }\%)}$$

$$= \frac{(31.5\text{ lbs/day})(100\%)}{(8.34\text{ lbs/gal})(10\%)}$$

$$= 38\text{ GPD}$$

O. SLUDGE TREATMENT

Either dry or liquid polymers may be used to treat sludges. The purpose of mixing a polymer solution with a sludge is to make the sludge more dewaterable by filter presses or centrifuges. The optimum polymer dosage is determined by the measurement of the filtration rate (volume of filtrate/unit time, see Appendix I, Polymers) using a Buchner funnel. The results of the test are reported in terms of pounds of polymer per ton of sludge solids.

$$\text{Polymer Dosage, lbs Poly/ton Sl} = \frac{\frac{\text{Poly Sol, }\%}{100\%} \times \frac{\text{Polymer}}{\text{Added, m}L} \times \frac{1\text{ gal}}{3780\text{ m}L} \times \frac{8.34\text{ lbs}}{\text{gal}} \times \frac{2000\text{ lbs}}{\text{ton}}}{\text{Sludge Vol, }L \times \frac{1\text{ gal}}{3.78\text{ }L} \times \frac{8.34\text{ lbs}}{\text{gal}} \times \frac{\text{Sl Solids, }\%}{100\%}}$$

By cancelling out similar terms, this equation can be simplified to:

$$\text{Dosage, lbs/ton} = \frac{(\text{Poly Sol, }\%)(\text{Poly Added, m}L)(2)}{(\text{Sl Vol, }L)(\text{Sl Solids, }\%)}$$

EXAMPLE 46

Calculate the polymer dosage in pounds of polymer per ton of sludge if the optimum polymer dosage in a Buchner funnel test is 4 milliliters of a two percent polymer solution. The sludge sample tested was a 100 milliliter sample with a five percent solids content.

Known	Unknown
Poly Added, mL = 4 mL	Polymer Dosage, lbs/ton
Poly Sol, % = 2%	
Sludge Vol, L = 0.1 L = 100 mL	
Sl Solids, % = 5%	

Calculate the dosage in pounds of polymer per ton of sludge.

$$\text{Dosage, lbs/ton} = \frac{(\text{Poly Sol, }\%)(\text{Poly Added, m}L)(2)}{(\text{Sl Vol, }L)(\text{Sl Solids, }\%)}$$

$$= \frac{(2\%)(4\text{ m}L)(2)}{(0.1\text{ }L)(5\%)}$$

$$= 32\text{ lbs polymer/ton sludge}$$

Other examples of how to solve arithmetic problems involving the handling and treatment of metal waste sludges are given in *OPERATION OF WASTEWATER TREATMENT PLANTS*, Volume III. Please refer to pages listed below:

1. "Dissolved Air Flotation Thickeners," pages 502 to 514.
2. "Polymers," pages 525 to 541.
3. "Filter Presses," pages 548 to 551.
4. "Vacuum Filters," pages 554 to 556.
5. "Drying Beds," pages 561 to 563.

(INSERT ILLUSTRATION MARKED PG 19)

SUBJECT INDEX

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