Small Water Systems

Course # 309

Fleming Training Center
Your Partner in Clean Water

TN Department of Environment & Conservation

Updated 12/2023

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Section 1

Overview

Overview of Water Treatment

Purpose of water treatment – to provide safe drinking water that does not contain objectionable taste, odor or color; to provide adequate quantities of water for domestic, commercial, industrial and fire protection needs.

All water produced by public water systems must be drinking water quality, even though only about 1% of water produced is used for drinking and cooking.

Schematic of conventional water treatment:

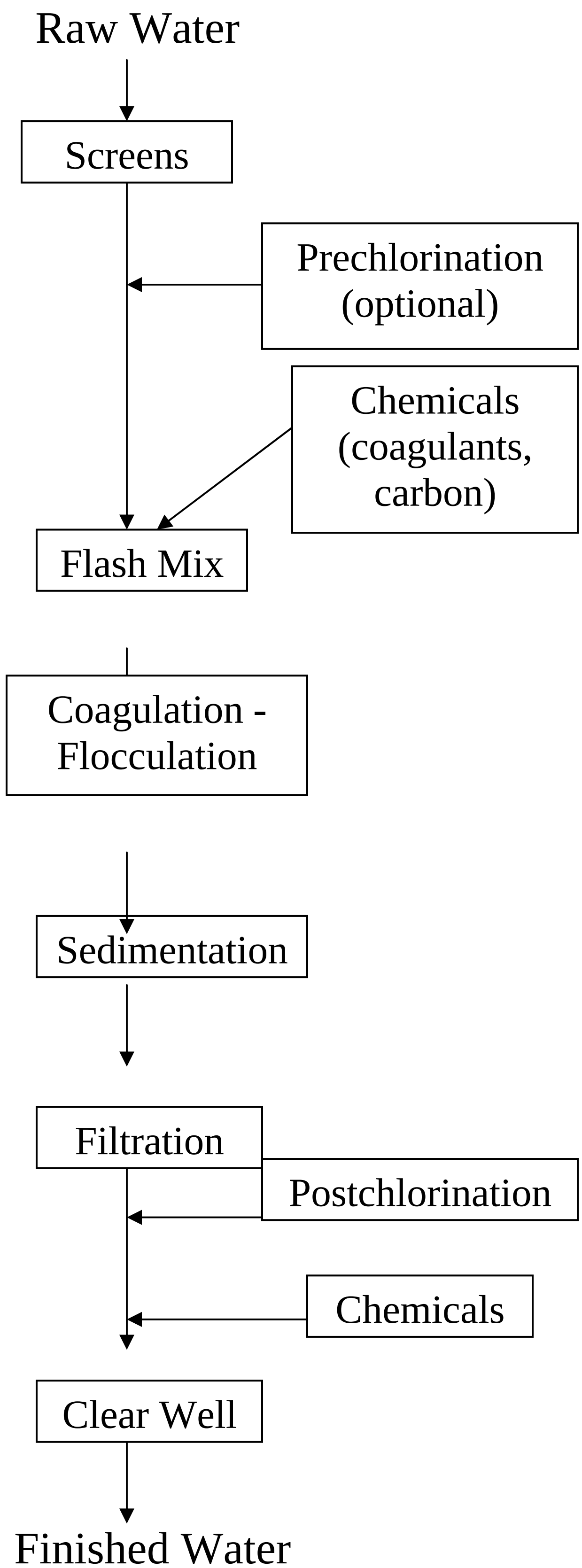
- Water is withdrawn from a lake, reservoir or river at the intake
- It is screened to remove debris
- Water then enters the flash mixing tank where coagulants and other chemicals are added
- Then it is divided into the flocculation basin
- After flocculation, the water enters the settling basins where solids are removed
- Filtration then removes particles that are too small to settle by gravity
- The water is disinfected using some form of chlorine
- Other chemicals such as fluoride, phosphate corrosion inhibitors or pH adjustment chemicals may be added
- After a minimum detention time, the water may be pumped to the distribution systems

Other processes may occur, such as pre-oxidation or activated carbon treatment.

Groundwater treatment is much less involved than surface water treatment. Groundwater has fewer impurities. Aeration may be required to remove dissolved gases and aid in the removal of dissolved minerals. Fluoride is sometimes added, but often the only step is disinfection. Addition of chemicals to reduce corrosion may also be needed.

Various regulations exist to control contaminants in drinking water in order to ensure public safety. Part of an operator’s job is to collect samples, test them and report the results to the state, which enforces these regulations. Operators must be able to recognize problems in the treatment process that could result in violations. They should also be familiar with the limits of certain substances in water so they can recognize when lab tests indicate violations.

Treatment Process / Purpose



Screens: Removes leaves, sticks, fish and other large debris.

Prechlorination (optional): Kills most disease-causing organisms and helps control taste and odor causing substances.

Chemicals (coagulants, carbon): Coagulants cause very fine particles to clump together into larger particles.
Carbon can be added in the flash mix to help control taste and odor causing substances.

Flash Mix: Mixes chemicals with raw water containing fine particles that will not readily settle or filter out of the water.

Coagulation - Flocculation: Gathers together fine, light particles to form larger particles (floc) to aid the sedimentation and filtration process.

Sedimentation: Settles out larger suspended particles.

Filtration: Filters out remaining suspended particles.

Postchlorination: Kills/inactivates disease causing organisms. Provides chlorine residual for distribution system.

Chemicals: Phosphates control corrosion, fluoride helps prevent dental decay.

Clear Well: Provides chlorine contact time for disinfection. Stores water for high demand.

Common Abbreviations

ASTM – America Society for Testing and Materials
AWWA – America Water Works Association
CCR – consumer confidence report
CWS – community water system
DBP – disinfection byproduct
DO – dissolved oxygen
EBCT – empty bed contact time
GAC – granular activated carbon
HAA – haloacetic acids
HPC – heterotrophic plate count
HTH – high test hypochlorite; calcium hypochlorite
LCR – lead and copper rule
LSI – Langelier saturation index
MCL – maximum contaminant levels
MCLG – maximum contaminant level goal
MF – membrane filter
MGD – million gallons per day
MPN – most probable number
MRDL – maximum residual disinfection level
MTF - multiple-tube fermentation
NCWS – non-community water system
NOM – natural organic material
NSF – National Sanitation Foundation
NTNCWS – non-transient non-community water system
NTU – nephelometric turbidity units
OSHA – Occupational Safety and Health Act
P-A – presence-absence
PAC – powder activated carbon
PN – public notification
PPE – personal protective equipment
PPM – parts per million; mg/L
PSI – pounds per square inch
PWS – public water system
RPBP – reduced pressure backflow preventor
RTCR – revised total coliform rule
SCBA – self-contained breathing apparatus
SCD – streaming current detector
SDS - safety data sheet
SDWA – Safe Drinking Water Act
sMCL – secondary maximum contaminant level
SOC – synthetic organic carbon
SOP – standard operating procedures
TDS – total dissolved solids
THM – trihalomethane
TOC – total organic carbon
TWS – transient non-community water system
USEPA – United States Environmental Protection Agency
UV – ultraviolet
VOC – volatile organic chemical

Chemical Formula	Common Name(s)
$Al(OH)_3$	aluminum hydroxide; jellylike floc particles
$Al_2(SO_4)_3 \bullet 7H_2O$	alum; aluminum sulfate
AsO_3	arsenite
AsO_4	arsenate
Br_2	bromine
$CaCl_2$	calcium chloride
$CaCO_3$	calcium carbonate
$Ca(HCO_3)_2$	calcium bicarbonate
CaO	calcium oxide; unslaked lime; quicklime
$Ca(OCl)_2$	calcium hypochlorite; HTH
$Ca(OH)_2$	calcium hydroxide; lime; hydrated lime; slaked lime
$CaSO_4$	calcium sulfate
CH_4	methane
Cl_2	chlorine gas; liquid chlorine
ClO_2	chlorine dioxide
CO_2	carbon dioxide
$CuSO_4 \bullet 5H_2O$	copper sulfate; bluestone; copper sulfate pentahydrate
Fe	iron
$FeCl_3$	ferric chloride
$Fe(OH)_3$	ferric hydroxide
Fe_2S_2	iron sulfide
$Fe_2(SO_4)_3$	ferric sulfate
$Fe_2(SO_4)_3 \bullet 7H_2O$	ferrous sulfate
HCl	hydrochloric acid; muriatic acid
H_2O	water
$HOCl$	hypochlorous acid
H_2S	hydrogen sulfide
H_2SiF_6	fluorosilicic acid; hydrofluorosilicic acid; silly acid
H_2SO_4	sulfuric acid
I_2	iodine
$KMnO_4$	potassium permanganate
Mg	magnesium
$MgCl_2$	magnesium chloride
$MgCO_3$	magnesium carbonate
$Mg(HCO_3)_2$	magnesium bicarbonate
$Mg(OH)_2$	magnesium hydroxide
$MgSO_4$	magnesium sulfate
Mn	manganese
$Mn(OH)_2$	manganese hydroxide

Chemical Formula	Common Name(s)
$Na_2Al_2O_4$	sodium aluminate
Na_2CO_3	sodium carbonate; soda ash
NaF	sodium fluoride
$NaHCO_3$	sodium bicarbonate; baking powder
$NaMnO_4$	sodium permanganate
$Na_2O \bullet (SiO_2)_3$	sodium silicate
$NaOCl$	sodium hypochlorite; bleach
$NaOH$	sodium hydroxide; caustic soda
$Na_4P_2O_7$	tetrasodium pyrophosphate
$(NaPO)_{14}Na_2O$	sodium hexametaphosphate; sodium polyphosphate
Na_2SiF_6	sodium fluorosilicate; sodium silicofluoride
NCl_3	trichloramine
NH_2Cl	monochloramine
$NHCl_2$	dichloramine
NO_3	nitrate
O_3	ozone
OCl^-	hypochlorite ion
SO_4	sulfate
$Zn_3(PO_4)_2$	zinc orthophosphate

ABC Need-to-Know Criteria for Very Small Water System Operators

ABC
Association of Boards of Certification

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- Jess Jones (Chair), Operator Training Committee of Ohio
- Richard Bond, Colorado Springs (CO) Utilities
- Don Jackson, South Carolina Environmental Certification Board
- Ken Kerri, California State University, Sacramento, Office of Water Programs
- Thomas Rothermich, City of St. Louis (MO) – Water Division
- Russ Glaser, Clark Public Utilities, Vancouver, Washington
- Martin Nutt, Arkansas Drinking Water Advisory and Operators Licensing Committee
- Wes Haskell, Old Town Water District, Old Town, Maine
- Shawn Bradford, Aquarion Water Company
- Cindy Cook, Minnesota Department of Health, Drinking Water Protection

Introduction

As part of the development of very small water system certification exams, the Association of Boards of Certification (ABC) conducted a job analysis of very small water system operators during 1998. The definition of a very small water system used during the job analysis was a system serving a maximum population of 500 with no treatment other than disinfection. The Need-to-Know Criteria was developed from the results of ABC's 1998 very small water system operator job analysis.

In 2005, ABC's Distribution Validation and Examination (V&E) Committee revised the need-to-know criteria to reflect current terminology used in the item bank. The information in this document reflects the essential job tasks performed by operators and their requisite capabilities. This document is intended to be used by certification programs and trainers to help prepare operators for entry into the profession.

How the Need-to-Know Criteria Was Developed

In 1998, a seven-member job analysis committee was formed to provide technical assistance in the development of the very small water system operator job analysis. During their meeting, this committee developed the list of the important job tasks performed by very small water system operators. The committee also verified the technical accuracy, clarity, and comprehensiveness of the job tasks. The committee then identified the capabilities (i.e., knowledge, skills, and abilities) required to perform the identified job tasks. Identification of capabilities was done on a task by task basis, so that a link was established between each task statement and requisite capability. This process resulted in a final list of 238 job tasks and 178 capabilities.

Task Inventory

A task inventory was developed from the data collected during the committee meeting. The inventory included 8-point rating scales for frequency of performance and seriousness of inadequate or incorrect performance. These two rating scales were used because they provide useful information (i.e., how critical each task is and how frequently each task is performed) pertaining to certification. The task inventory was sent to 220 certified very small water system operators throughout the United States and Canada. Ninety-three out of the 220 inventories mailed were returned for a response rate 42%.

Analysis of Ratings

The mean, standard deviation, and the percentage of respondents performing each task statement were computed. The mean was used to determine the importance of items and the standard deviation was used to identify items with a wide variation in responses. The percentage of respondents performing each task statement was used to identify tasks and capabilities commonly performed by operators throughout the United States and Canada.

A criticality value of 2(mean seriousness rating) + mean frequency rating was calculated for each item on the inventory. This formula gives extra weight to the seriousness rating in determining critical items and was appropriate because it emphasized the purpose of certification—to provide competent operators.

Core Competencies

The criticality ratings and percentage of operators reporting that they performed the tasks were used to determine what is covered on the very small water system exam. The essential tasks and capabilities that were identified through this process are called the core competencies. The following pages list the core competencies for very small water system operators. The core competencies are clustered into the following job duties:

- Operate System
- Water Quality Parameters and Sampling
- Operate Equipment
- Install, Maintain and Evaluate Equipment
- Perform Safety Duties
- Perform Administrative and Compliance Duties

Core Competencies for Very Small Water System Operators

Operate System

System Design
- Assess system demand
- Flushing program
- System layout
- System map
- Perform pressure readings
- Read blueprints, readings, and maps
- Select materials
- Select type of pipes
- Size mains

System Inspection
- Cross connection surveys/control
- Sample site plan
- Sanitary surveys
- Well inspection

Chlorine Disinfection
- Monitor disinfection process
- Evaluate disinfection process
- Adjust disinfection process

Required capabilities:
- Ability to adjust flow patterns and system units
- Ability to communicate verbally and in writing
- Ability to diagnose/troubleshoot system units
- Ability to discriminate between normal and abnormal conditions
- Ability to evaluate system units
- Ability to inspect pumps
- Ability to maintain system in normal operating condition
- Ability to monitor and adjust equipment
- Ability to perform basic math
- Knowledge of blueprint readings
- Knowledge of cathodic protection
- Knowledge of different types of joints, restraints and thrust blocks
- Knowledge of disinfection concepts and design parameters
- Knowledge of disinfection process
- Knowledge of fireflow requirements
- Knowledge of general chemistry, biology and physical science
- Knowledge of general electrical and hydraulic principles
- Knowledge of hydrology
- Knowledge of measuring instruments
- Knowledge of monitoring requirements
- Knowledge of piping material, type and size
- Knowledge of principles of measurement
- Knowledge of regulations
- Knowledge of sampling procedures and requirements
- Knowledge of sanitary survey process
- Knowledge of standards
- Knowledge of start-up and shut-down procedures
- Knowledge of testing instruments
- Knowledge of well drilling principles
- Knowledge of well-head protection

Core Competencies (continued)

Water Quality Parameters and Sampling

- Chlorine demand/residual/dosage
- Coliforms
- pH
- Temperature
- Turbidity

Required capabilities:

- Ability to calibrate instruments
- Ability to follow written procedures
- Ability to interpret Material Safety Data Sheets
- Ability to perform basic math
- Ability to recognize normal and abnormal analytical results
- Knowledge of basic laboratory equipment
- Knowledge of chemical handling and storage
- Knowledge of general biology, chemistry and physical science
- Knowledge of normal characteristics of water
- Knowledge of principles of measurement
- Knowledge of public notification requirements
- Knowledge of quality control/quality assurance practices
- Knowledge of regulations
- Knowledge of reporting requirements
- Knowledge of safety procedures
- Knowledge of sampling procedures

Operate Equipment

- Blowers and compressors
- Centrifugal pumps
- Chemical feeders
- Chlorinators
- Hydrants
- Hydraulic equipment
- Instrumentation
- Leak detectors
- Positive-displacement pumps
- Valves

Required capabilities:

- Ability to monitor, evaluate and adjust equipment
- Knowledge of drinking water concepts
- Knowledge of function of tools
- Knowledge of general electrical and mechanical principles
- Knowledge of hydraulic and pneumatic principles
- Knowledge of regulations
- Knowledge of safety procedures
- Knowledge of start-up and shut-down procedures
- Knowledge of system operation and maintenance

Core Competencies (continued)

Install, Maintain and Evaluate Equipment

Install and maintain equipment:

- Backflow prevention devices
- Chemical feeders
- Chlorinators
- Corrosion control
- Electric motors
- Hydrants
- Meters
- Pipe repair
- Pumps
- Service connection
- Storage tanks
- Taps
- Valves
- Water mains

Evaluate operation of equipment:

- Inspect equipment for abnormal conditions
- Read charts
- Read meters
- Read pressure gauges
- Troubleshoot electrical equipment

Required capabilities:

- Ability to calibrate equipment
- Ability to diagnose/troubleshoot equipment
- Ability to differentiate between preventive and corrective maintenance
- Ability to discriminate between normal and abnormal conditions
- Ability to evaluate and adjust equipment
- Ability to follow written procedures
- Ability to order necessary spare parts
- Ability to perform general maintenance
- Ability to record information
- Knowledge of corrosion control processes
- Knowledge of dechlorination and disinfection processes
- Knowledge of different types of cross-connections and approved backflow methods and devices
- Knowledge of general electrical, mechanical, hydraulic and pneumatic principles
- Knowledge of lubricant and fluid characteristics
- Knowledge of pipe fittings and joining methods
- Knowledge of piping material, type and size
- Knowledge of regulations
- Knowledge of start-up and shut-down procedures
- Knowledge of system operation and maintenance

Core Competencies (continued)

Perform Safety Procedures

- Chemical handling
- Confined space entry
- Electrical hazards
- Fire safety
- Lock-out/tag-out
- Personal protective equipment
- Traffic/work zone

Required capabilities:

- Ability to communicate verbally and in writing
- Ability to interpret Material Safety Data Sheets
- Ability to recognize unsafe work conditions/safety hazards
- Ability to select and operate safety equipment
- Knowledge of emergency plans
- Knowledge of potential causes and impact of system disasters
- Knowledge of risk management
- Knowledge of safety procedures

Perform Administrative and Compliance Duties

Administrative and Security

- Administer compliance, emergency preparedness and safety program
- Develop budget
- Develop operation and maintenance plan
- Plan and organize work activities
- Record and evaluate data
- Respond to complaints
- Write regulatory authority reports

Comply with Drinking Water Regulations

United States Exams –

- Code of Federal Regulations, Title 40, Part 141 - National Primary Drinking Water Regulations:
  - Subpart A - General definitions
  - Subpart B - Maximum contaminant levels
  - Subpart C - Monitoring and analytical requirements
  - Subpart D - Reporting and recordkeeping
  - Subpart I - Control of lead and copper
  - Subpart Q - Public notification of drinking water violations

Canadian Exams

- Provincial and territorial regulations

Required capabilities:

- Ability to assess likelihood of disaster occurring
- Ability to communicate verbally and in writing
- Ability to coordinate emergency response with other organizations
- Ability to generate written policies and procedures
- Ability to interpret and transcribe data
- Ability to organize information and review reports
- Ability to perform basic math
- Ability to perform impact assessments
- Ability to translate technical language into common terminology
- Knowledge of emergency plans
- Knowledge of local codes and ordinances
- Knowledge of monitoring and reporting requirements
- Knowledge of potential causes and impact of system disasters
- Knowledge of principles of finance
- Knowledge of principles of management
- Knowledge of principles of public relations
- Knowledge of public notification requirements
- Knowledge of public participation process
- Knowledge of recordkeeping function and policies
- Knowledge of regulations
- Knowledge of risk management
- Knowledge of system operation and maintenance

Very Small Water System Certification Exam

The very small water system certification exam evaluates an operator's knowledge of tasks related to the operation of small water systems. The content of the exam was determined from the results of the job analysis. To successfully take an ABC exam, an operator must demonstrate knowledge of the core competencies in this document.

The very small water system exam consists of 50 multiple-choice questions. The specifications for the exams are based on a weighting of the job analysis results so that they reflect the criticality of tasks performed on the job. The specifications list the percentage of questions on the exam that fall under each job duty. For a list of tasks and capabilities associated with each job duty, please refer to the list of core competencies on the previous pages.

ABC Very Small Water System Exam Specifications

Job Duty	**Percent of Exam**
Operate System	22%
Water Quality Parameters and Sampling	20%
Operate Equipment	10%
Install, Maintain and Evaluate Equipment	16%
Perform Safety Duties	14%
Perform Administrative and Compliance Duties	18%

Suggested References

The following are approved as reference sources for the ABC very small water system examination. Operators should use the latest edition of these reference sources to prepare for the exam.

American Water Works Association (AWWA)
- *Water Transmission and Distribution*
- *Water Quality*
- *Basic Science Concepts and Applications*
- *Water Distribution Operator Training Handbook*
- *Water System Security, A Field Guide*

To order, contact: American Water Works Association
6666 West Quincy Ave.
Denver, CO 80235

Web site: www.awwa.org
Phone: (800) 926-7337
Fax: (303) 347-0804
E-mail: custsvc@awwa.org

California State University, Sacramento (CSUS) Foundation, Office of Water Programs

- *Water Distribution System Operation and Maintenance*
- *Small Water System Operation and Maintenance*
- *Utility Management*
- *Manage for Success*

To order, contact: Office of Water Programs
California State University, Sacramento
6000 J Street
Sacramento, CA 95819-6025

Web site: www.owp.csus.edu
Phone: (916) 278-6142
Fax: (916) 278-5959
E-mail: wateroffice@owp.csus.edu

Regulations

For United States exams:

- *Code of Federal Regulations*, Title 40, Part 141 (www.gpo.gov)
- State regulations (contact information for state certification programs is available on the Certification Contacts page of ABC's web site, www.abccert.org)

For Canadian exams:

- *Guidelines for Canadian Drinking Water Quality*. Federal-Provincial-Territorial Subcommittee on Drinking Water. Ottawa, ON: Health Canada (www.hc-sc.gc.ca/waterquality)
- Provincial and territorial regulations (contact information for provincial/territorial certification programs is available on the Certification Contacts page of ABC's web site, www.abccert.org)

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Introduction and Purpose of the Guidebook

The purpose of this guidebook is to help operators of very small water systems serving a maximum population of 100 understand the provisions and purpose of the *Final Guidelines for the Certification and Recertification of the Operators of Community and Nontransient Noncommunity Public Water Systems*. This guidebook describes the certification requirements of the EPA *Guidelines*, operator need-to-know job tasks and capabilities, exam specifications, sample test questions, and additional information relating to operator training opportunities.

Summary of the National Certification Guidelines

The *Final Guidelines for the Certification and Recertification of the Operators of Community and Nontransient Noncommunity Public Water Systems*[1] require that all community and nontransient noncommunity public water systems have a certified operator in responsible charge. A community water system is defined by the EPA as a public water system that provides water "to at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents." A nontransient noncommunity water system is defined by the EPA as a "public water system that is not a community water system and that regularly serves at least 25 of the same persons over six months per year" (p. 5921, section IV).

The objectives of the *Guidelines* are to ensure that:

- "Customers of any public water system be provided with an adequate supply of safe, potable drinking water.
- Consumers are confident that their water is safe to drink.
- Public water system operators are trained and certified and that they have knowledge and understanding of the public health reasons for drinking water standards" (p. 5919, section II.A).

To achieve these objectives the EPA developed the following operator certification guidelines. Please note that the EPA guidelines are minimum requirements. States may impose more strict requirements so it is essential for operators to contact their State Certification Program listed in the last section of this guidebook for specific state requirements.

Regulations for Certification

Each community and nontransient noncommunity water system must be under the responsible charge of an operator certified at a level equal to or greater than the system classification. This person has the authority to make decisions that affect water quality or quantity. In addition, "all operating personnel that make process control/system integrity decisions about water quality or quantity that affect public health must be certified" (p. 5919, section II.C.2). A certified operator must be available during each operating shift.

Requirements for Certification

To become certified an operator must satisfy minimum education and experience requirements and pass the appropriate certification examination. The EPA minimum requirements for certification are:

- Education - The operator must possess a high school diploma or general equivalency diploma (GED). States may allow experience and/or training to be substituted for the education requirement.
- Experience - The operator must meet the State's on-the-job experience requirement.
- Examination - The operator must pass a certification exam. The exam will cover the knowledge, skills, ability and judgment necessary to operate systems within the State.

Current operators that do not meet these newly imposed requirements may be eligible to be grandparented through the State Certification Program. If grandparenting is allowed by the State Certification Program, operators may be permitted to become certified, with the system owner's consent, without meeting all of the certification requirements. This is a restricted certificate and grandparented operators must meet all certification renewal requirements.

Among other restrictions, the *Guidelines* specify that "grandparenting is permitted only to existing operator(s) in responsible charge of existing systems which, because of State law changes to meet these guidelines, must for the first time have a certified operator." If allowed by the State, "certification for the grandparented operator must be site specific and non-transferable to other operators." "If the classification of the plant or distribution system changes to a higher level, then the grandparented certification will no longer be valid";

1. Environmental Protection Agency, 1999. Final Guidelines for the Certification and Recertification of the Operators of Community and Nontransient Noncommunity Public Water Systems. *Federal Register*, Vol. 64, No. 24–Friday, February 5, 1999.

and "if the grandparented operator chooses to work for a different water system, he or she must meet the initial certification requirements of that system" (p. 5920, section II.C.3).

Renewal

Operators that meet the certification requirements and pass the certification exam will be certified by the State Certification Program for a specific period of time. The *Guidelines* require certificates to be renewed within a period of three years. Operators must attend State approved training in order to renew their certificates.

Need-to-Know Job Tasks and Capabilities

ABC conducted a very small water system operator job analysis to identify the most critical job tasks performed by operators and the capabilities required to competently perform these job tasks. Over 450 operators were surveyed by ABC as part of this process. In the survey, operators provided data on how frequently job tasks are performed and the potential seriousness of performing these tasks incorrectly.

The results of this survey were used to develop the following Need-to-Know Criteria. The Need-to-Know Criteria is a list of the subjects that a small water system operator needs to know to properly operate a system. Tasks and their requisite capabilities performed by at least 50% of the survey respondents and with a high seriousness rating are included in this list. This list includes both community and nontransient noncommunity public water systems. Examples of nontransient noncommunity systems include schools, day-care centers, and factories.

This type of information is used as the basis for developing certification exams.

Evaluate characteristics of source water	
Job tasks	**Capabilities**
Evaluate characteristics of source water, such as:	Ability to communicate observations verbally and in writing
Bacteriological	Ability to discriminate between normal/abnormal conditions
Biological	Knowledge of normal characteristics of water
Chemical	Knowledge of wellhead protection
Physical	
Operate system	
Job tasks	**Capabilities**
Add liquid disinfectants	Ability to adjust disinfectant feed rates
Monitor, evaluate, adjust chlorine disinfection	Ability to calculate dosage rates
Inspect, maintain, repair flow measurements	Ability to confirm disinfectant strength
Inspect, maintain, repair well operation	Ability to diagnose/troubleshoot process units
Perform leak detection	Ability to interpret Material Safety Data Sheets
	Ability to maintain processes in normal operating condition
	Ability to measure disinfectant weight and volume
	Ability to perform basic math
	Ability to prepare and apply disinfectants
	Knowledge of general biology and chemistry
	Knowledge of disinfectant concepts and properties
	Knowledge of disinfectant processes and design parameters
	Knowledge of general electrical and mechanical principles
	Knowledge of normal chemical range
	Knowledge of personal protective equipment
	Knowledge of principles of measurement
	Knowledge of proper handling and storage of disinfectants
	Knowledge of proper lifting procedures
	Knowledge of regulations

Need-to-Know Criteria (Continued)

Collect, perform, and interpret laboratory analyses	
Job tasks	**Capabilities**
Collect, perform, and interpret laboratory analyses, such as:	Ability to calibrate instruments
	Ability to follow written procedures
Chlorine demand	Ability to interpret Material Safety Data Sheets
Chlorine residual	Ability to perform disinfection calculations
Microbiological	Ability to recognize abnormal analytical results
	Knowledge of general chemistry
	Knowledge of laboratory equipment
	Knowledge of principles of measurement
	Knowledge of proper disinfectant handling and storage
	Knowledge of proper safety procedures
	Knowledge of proper sampling techniques and procedures
	Knowledge of quality control and assurance practices
	Knowledge of regulations, such as the Safe Drinking Water Act
Establish safety plans and apply safety procedures	
Job tasks	**Capabilities**
Establish safety plans and apply safety procedures, in areas such as:	Ability to communicate safety hazards verbally and in writing
	Ability to demonstrate safe work habits
Chemical hazard communication	Ability to follow written procedures
Confined space entry	Ability to identify potential hazards and unsafe work conditions
Electrical grounding	Ability to operate safety equipment
General safety and health	Knowledge of potential impact of disasters on facility
Lifting	Knowledge of regulations
Lock-out/tag-out	Knowledge of risk management
Personal hygiene	
Personal protective equipment	
Slips, trips, and falls	
Operate equipment	
Job tasks	**Capabilities**
Operate equipment, such as:	Ability to evaluate and adjust operation of equipment
Chemical feeders	Ability to monitor electrical and mechanical equipment
Electronic testing equipment	Knowledge of disinfection concepts
Instrumentation	Knowledge of function of tools
Motors	Knowledge of general electrical and mechanical principles
Power tools	Knowledge of proper safety procedures
Pumps	Knowledge of regulations
	Knowledge of start-up/shut-down procedures

Need-to-Know Criteria (Continued)

Evaluate operation of equipment	
Job tasks	**Capabilities**
Check speed of equipment	Ability to adjust equipment
Inspect equipment for abnormal conditions	Ability to calibrate equipment
Perform maintenance on chemical feeders	Ability to diagnose/troubleshoot process units
Perform maintenance on pumps	Ability to discriminate between normal/abnormal conditions
Read meters	Ability to follow written procedures
Read pressure gauges	Ability to monitor electrical and mechanical equipment
	Ability to perform general maintenance and repairs
	Ability to record information
	Ability to report findings
	Ability to use hand tools
	Knowledge of facility operation and maintenance
	Knowledge of general electrical and mechanical principles
	Knowledge of proper safety procedures
	Knowledge of safety regulations
	Knowledge of start-up/shut-down procedures
Perform administrative duties	
Job tasks	**Capabilities**
Establish recordkeeping system for facility operation	Ability to communicate verbally and in writing
Organize work activities	Ability to demonstrate safe work habits
Record information relating to facility performance	Ability to determine what information needs to be recorded
Write reports	Ability to evaluate facility performance
	Ability to follow written procedures
	Ability to identify potential hazards and unsafe work conditions
	Ability to interpret and transcribe data
	Ability to operate safety equipment
	Ability to perform basic math
	Knowledge of facility operation and maintenance
	Knowledge of monitoring and reporting requirements
	Knowledge of recordkeeping function and policies
	Knowledge of regulations

Exam Specifications

The very small water system certification exam evaluates an operator's knowledge, skills, ability and judgment related to the operation of very small water systems. The Need-to-Know Criteria presented in the previous section of this guidebook results in the recommended specifications shown below for an exam. Each state determines the content of its certification exams. Please contact your State Certification Program listed in the last section of the guidebook for any information they may provide to applicants.

Recommended Very Small Water System Exam Specifications

Job Duty	Percent of Exam
Evaluate characteristics of source water	7%
Operate system	18%
Collect, perform, and interpret laboratory analyses	11%
Establish safety plans and apply safety procedures	25%
Operate equipment	10%
Evaluate operation of equipment	13%
Perform administrative duties	16%

Please refer to the Need-to-Know Criteria on the previous pages for a listing of the tasks and capabilities associated with each job duty.

Sample Test Questions

The following questions are provided as examples of the types of questions that might be covered on your certification exam. These questions may help prepare you for certification by identifying areas in which you need additional study. The correct answers and reference material for each question are found in the following section. If you cannot answer a question correctly, read the reference material listed for the question. The reference material will help you better understand the topic and may help you answer similar questions that may be on the certification exam.

It is unlikely that you will find any of these question duplicated on a certification exam, so don't try to memorize the questions and answers. Many operators find it is helpful to contact their State Certification Program listed in the last section of the guidebook to request information about the certification exam. Some, but not all, certification programs will provide a list of suggested study material, topics covered on the exam and sample exam questions.

These sample questions should not be used in place of other training materials and courses. The “Training Opportunities and Resources” section of this guidebook contains additional information.

1. If a customer complains about the drinking water characteristics, the operator should record the complaint and
   A. Investigate immediately
   B. Investigate only if more complaints are received
   C. Inform the customer that the water should be boiled
   D. Inform the customer that the water is safe

2. What term is used when a water utility divides its total operating expenses into the total revenue?
   A. Debt ratio
   B. Operating ratio
   C. Credit ratio
   D. Coverage ratio

3. How often should operation data, such as flow rate, amount of water treated, dosage of chemical, and reservoir levels be recorded?
   A. Twice a day
   B. Daily
   C. Weekly
   D. Monthly

4. Which of the following is the most important reason to keep daily records of operational data?
   A. Maintain records for customer billing
   B. Document the need for an increased budget
   C. Provide insurance data
   D. Document that safe drinking water has been delivered to customers

5. Under the requirements of the Safe Drinking Water Act, it is the duty of the water purveyor to deliver potable water of proper quantity only as far as the
   A. Entry point of the distribution system
   B. Customer's curb box and service connection
   C. Consumer's tap inside the home
   D. Furthest water main blow-off or sampling point

6. According to the Safe Drinking Water Act, the basic definition of a public water supply system is any water system that supplies water for human consumption that serves
   A. 25 homes or more for over 120 days a year
   B. The public in any capacity, no matter how small
   C. 25 or more persons for at least 30 days a year
   D. 15 service connections or over 25 persons for over 60 days a year

7. What agent is responsible for reporting lab results to the regulatory agency?
   A. Water system owner
   B. Board of Health chairperson
   C. Lab technician
   D. Sample collector

8. According to the USEPA drinking water regulations, the owner or operator of a public water system which fails to comply with applicable monitoring requirements must give notice to the public within
   A. 45 days of the violation by posting a notice at the town hall
   B. 1 year of the violation by including a letter with the water bill
   C. 3 months of the violation in a daily newspaper in the area served by the system
   D. 1 week of the violation in a letter hand delivered to customers

9. What federal law is designed to protect the safety and health of operators?
   A. OSHA
   B. FMLA
   C. FLSA
   D. ADEA

10. What federal law regulates public water supplies?
    A. Safe Drinking Water Act
    B. Clean Water Act
    C. Taft-Hartley Act
    D. Standard Methods

11. What causes water to move through pores in soil and rocks?
    A. Temperature
    B. Viscosity
    C. Barometric pressure
    D. Gravity

12. What is a commonly used indicator of possible health problems found in plants, soil, water and the intestines of humans and warm-blooded animals?
    A. Viruses
    B. Coliform bacteria
    C. Intestinal parasites
    D. Pathogenic organisms

13. What are disease producing bacteria called?
    A. Parasites
    B. New strain
    C. Sour type
    D. Pathogenic

14. What are the two main causes of hardness in water?
    A. Gold and silver
    B. Calcium and magnesium
    C. Phosphate and nitrate
    D. Oxygen and methane

15. Which source of water has the greatest natural protection from bacterial contamination?
    A. Shallow well
    B. Deep well in gravel
    C. Surface water
    D. Spring

16. What device measures the flow rate of gases?
    A. Parshall flume
    B. Rotameter
    C. Float
    D. Weir

17. How often should preventive maintenance for equipment be performed?
    A. Once every week
    B. After a breakdown
    C. According to manufacturer recommendations
    D. When time permits

18. Dynamic head is best described as the
    A. Velocity of water in a main at full pumping pressure
    B. Total energy that a pump must develop for pumping to take place
    C. Total pressure in feet of head, measured at the pump discharge during periods of rest in the system
    D. Pumping end of any device used to force water into a pressure system

19. Which of the following terms refers to excessive internal pressure, which may be several times the normal operating pressure and can seriously damage hydropneumatic tanks, valves, and the piping network?
    A. Air charge
    B. Flow rate pressure
    C. Water hammer
    D. Hydraulic charge

20. Which of the following should an operator investigate first when well pump and control problems occur?
    A. Depth of supply
    B. Piping
    C. Electricity
    D. Water leaks

21. Most pumps must be primed before startup in order to
    A. Calculate flow rate
    B. Prevent reverse flow
    C. Start the flow of water
    D. Prevent hammer

22. What is the purpose of a check valve?
    A. Regulate the rate of flow through the discharge pipe
    B. Act as automatic shutoff valve when the pump stops
    C. Permit air to escape from the pipe
    D. Prevent clogging of the suction line

23. What is the primary purpose of a preventive maintenance program?
    A. Increase the use of backup equipment
    B. Correct equipment breakdowns
    C. Eliminate inventory of spare parts
    D. Avoid future equipment problems

24. A mixture of air and gas is considered hazardous when the mixture exceeds what percentage of the lower explosive limit (LEL)?
    A. 0%
    B. 3%
    C. 7%
    D. 10%

25. Which of the following duties should <u>not</u> be performed by a small system operator?
    A. Disinfect water mains
    B. Observe pump motors to detect unusual noises, vibrations or excessive heat
    C. Repair and overhaul chlorinators
    D. Wire pump, compressors and electrical components of the water system

26. What are the most important methods of ensuring operator safety?
    A. Appointing a safety officer and administrator
    B. Alerting operators of unsafe acts and conducting mandatory safety training
    C. Providing handbooks and copies of regulations
    D. Working with proper light and ventilation

27. What safety procedure should an operator always follow when mixing a solution of sodium hypochlorite (liquid bleach) and fresh water?
    A. Attend a training course on liquid chlorine from an accredited school
    B. Wear gloves and a mask when opening the containers of bleach
    C. Ask a second individual to stand nearby with an emergency breathing apparatus
    D. Wear goggles and gloves when handling hypochlorite

28. Which form of hypochlorite is the most dangerous to handle?
    A. Sodium
    B. Fluoride
    C. Calcium
    D. Chlorine

29. What are the two most important safety concerns when entering a confined space?
    A. Corrosive chemicals and falls
    B. Bad odors and claustrophobia
    C. Extreme air temperatures and slippery surfaces
    D. Oxygen deficiency and hazardous gases

30. What piece of safety equipment must an operator wear when entering a confined space?
    A. Boots
    B. Harness
    C. Gloves
    D. Goggles

31. What type of fire extinguisher should be used for fires with live electricity present?
    A. Class A
    B. Class B
    C. Class C
    D. Class D

32. Which document provides a profile of hazardous substances?
    A. CERCLA
    B. SARA
    C. CFR
    D. MSDS

33. What safety measure must an operator follow prior to working on electrical equipment?
    A. Lock out and tag out all electrical switches
    B. Put on canvas gloves
    C. Remove fuses from switch box
    D. Tell one coworker not to turn on the switch

34. What is the correct procedure for mixing acid and water?
    A. Water is added slowly to the acid
    B. Acid is added slowly to the water
    C. Water is added quickly to the acid
    D. Acid is added quickly to the water

35. What is the purpose of a pump guard?
    A. Allows operators to turn off pump in emergency situations
    B. Notifies operators of excessive temperatures
    C. Allows operators to pump against a closed discharge valve
    D. Protects operators from rotating parts

36. The most important responsibility of an operator is to provide
    A. Adequate water pressure
    B. Palatable drinking water
    C. Adequate amounts of water
    D. Safe drinking water

37. To ensure that the water supplied by a public water system meets federal and state requirements, the water system operator must regularly collect samples and
    A. Test the water at the nearest water testing laboratory
    B. Determine a sampling schedule based on the lab's recommendations
    C. Send all analysis results to the State periodically
    D. Count the number of active wells in the system

38. The major source of error when obtaining water quality information is improper
    A. Sampling
    B. Preservation
    C. Tests of samples
    D. Reporting of data

39. A composite sample should never be used when sampling for which contaminant?
    A. Benzene
    B. Nitrate
    C. Barium
    D. Bacteria

40. When should water quality samples for chlorine residual be analyzed?
    A. Immediately
    B. Within 1 hour
    C. Within 8 hours
    D. Within 24 hours

41. How many coliform samples are required per month for a water system serving a population between 25 and 100?
    A. 1
    B. 2
    C. 3
    D. 4

42. Water laboratory test calculations and results use which system?
    A. English
    B. Metric
    C. SWAG
    D. British

43. Factors of what number are used in the metric system?
    A. 5
    B. 10
    C. 12
    D. 64

44. What is the chemical formula for sulfuric acid?
    A. SA_2
    B. H_2SO_4
    C. NaOH
    D. H_2O

45. Which of the following should not be used to draw a sample into a pipet?
    A. Mouth
    B. Bulb
    C. Pump
    D. Straw

46. Which of the following are two types of samples?
    A. Dessicator and gooch
    B. Wet and dry
    C. Buret and flask
    D. Grab and composite

47. What two types of devices are used to collect samples?
    A. Left and right
    B. Upper and lower
    C. Automatic and manual
    D. Gas and diesel

48. How should samples that cannot be analyzed immediately be maintained until the analysis is conducted?
    A. Shaken every hour
    B. Preserved
    C. Held in an open container
    D. Stored bottom up

49. What is the most common method used in labs to test for total coliform and *E. coli*?
    A. DMA
    B. Green
    C. Colilert
    D. Lamp

50. What test method best determines chemical feed/dosage rates?
    A. Jar
    B. Turbidity
    C. Hammer
    D. Hardness

51. An empty atmospheric storage tank is 8 feet in diameter and 32 feet high. How long will it take to fill 90% of the tank volume if a pump is discharging a constant 24 gallons per minute into the tank?
    A. 7 hours 31 minutes
    B. 8 hours 21 minutes
    C. 8 hours 23 minutes
    D. 9 hours 17 minutes

52. Two columns of water are filled completely at sea level to a height of 88 feet. Column A is 0.5 inches in diameter. Column B is 5 inches in diameter. What will two pressure gauges, one attached to the bottom of each column, read?

	Column A	Column B
A.	3.8 psi	38.0 psi
B.	8.8 psi	8.0 psi
C.	20.3 psi	20.3 psi
D.	38.0 psi	38.0 psi

53. A ditch that is 4.5 feet wide, 6 feet deep, and 120 feet long has to be dug for a water line. How many cubic yards of material must be removed?
    A. 120 cubic yards
    B. 240 cubic yards
    C. 850 cubic yards
    D. 1,200 cubic yards

54. How many cubic feet of water will a rectangular tank that is 20 feet long by 15 feet wide and 10 feet high hold?
    A. 2,000 cubic feet
    B. 3,000 cubic feet
    C. 4,000 cubic feet
    D. 5,000 cubic feet

55. Calculate the chlorine demand using the following data.
    -Raw water flow is 0.75 MGD.
    -Chlorinator feed rate is 4.0 mg/L.
    -Chlorine residual is 1.8 mg/L.
    A. 0.8 mg/L
    B. 2.2 mg/L
    C. 4.0 mg/L
    D. 5.8 mg/L

56. Convert 60.5 degrees Fahrenheit to degrees Celsius.
    A. 15.8 degrees Celsius
    B. 20.6 degrees Celsius
    C. 72.0 degrees Celsius
    D. 101.2 degrees Celsius

57. Calculate drawdown, in feet, using the following data.
    -The water level in a well is 20 feet below the ground surface when the pump is not in operation.
    -The water level is 35 feet below the ground surface when the pump is in operation.
    A. 15 feet
    B. 20 feet
    C. 35 feet
    D. 55 feet

58. Calculate the volume, in gallons, of a tank that is 75 feet long, 20 feet wide, and 10 feet deep.
    A. 15,000 gallons
    B. 112,200 gallons
    C. 150,000 gallons
    D. 224,400 gallons

59. How many pounds of a chemical applied at the rate of 3 mg/L are required to dose 200,000 gallons?
    A. 3 lbs
    B. 5 lbs
    C. 16 lbs
    D. 50 lbs

60. Calculate the average weekly flow for a system with the following data.
    Sunday - 3,000 gallons Monday - 4,000 gallons Tuesday - 3,500 gallons
    Wednesday - 2,000 gallons Thursday - 3,000 gallons Friday - 3,500 gallons
    Saturday - 2,000 gallons
    A. 2,000 gpd
    B. 3,000 gpd
    C. 4,000 gpd
    D. 5,000 gpd

61. After a new water main is installed and pressure tested it should be
    A. Flushed with clean water for 24 hours and put into service
    B. Filled with a solution of 25 ppm to 50 ppm free chlorine for at least 24 hours prior to flushing
    C. Filled with clean water and allowed to sit for 5 days at full pressure before turning the water into the system
    D. Photographed so that mapping can be avoided until the system is complete

62. Chlorine demand is satisfied at the point when
    A. The reaction of chlorine with organic and inorganic materials stops
    B. Free chlorine residuals reach 2.5 mg/L
    C. An odor of chlorine is present
    D. Chlorine reaches the last tap

63. What chlorine concentration should be produced when disinfecting a well or well pump?
    A. 25 mg/L
    B. 50 mg/L
    C. 75 mg/L
    D. 100 mg/L

64. When disinfecting a new or repaired main, what is the minimum chlorine residual at the extreme end of the main after standing for 24 hours?
    A. 15 mg/L
    B. 20 mg/L
    C. 25 mg/L
    D. 30 mg/L

65. Chlorine will destroy bacteria most rapidly at what pH?
    A. 7.5
    B. 8.5
    C. 9.5
    D. 10.5

66. What is the process of adding chlorine to water until the chlorine demand has been satisfied called?
    A. Contact time
    B. Reliquefaction
    C. Hypochlorination
    D. Breakpoint chlorination

67. Which of the following pH ranges would deposit a thin film of calcium carbonate on the inside surface of a pipe?
    A. 2.0 - 3.0
    B. 4.0 - 5.0
    C. 6.0 - 7.0
    D. 8.0 - 9.0

68. Where should sodium hypochlorite (liquid bleach) be stored?
    A. Away from flammable objects, as it is a fire hazard
    B. Away from equipment that is susceptible to corrosion
    C. In closed containers at room temperature for no longer than 6 months
    D. Near the chemical feed pump day tank, to lessen operator handling risks

69. What is the most important reason for maintaining a continuous positive pressure throughout the distribution system?
    A. Prevent damage to water meters
    B. Keep pipe joints sealed
    C. Prevent contamination from backflow
    D. Maintain chlorine residual

70. A weir should be used to measure water in which of the following locations?
    A. Above ground storage tanks
    B. Household service lines
    C. Open channels
    D. Water mains

71. The pumping water level is best defined as the distance from the top of the well to the
    A. Intake screen of the pump
    B. Location where the main flow of water enters a well
    C. Water after the pump has been operating for a period of time
    D. Water level from the start of a pump test to the end of the test

72. The space between the inner or protective casing and the outer casing or drill hole should be filled with cement grout to a minimum of how many feet?
    A. 10 feet
    B. 15 feet
    C. 20 feet
    D. 35 feet

73. When bringing community water service to a home with a private well, what is the most positive method of preventing a cross connection between the two systems?
    A. Residential dual check valve
    B. Reduced pressure zone backflow preventer
    C. Complete isolation between the two systems using an air gap
    D. Pressure vacuum breaker in addition to an RPZ

74. What is the physical connection, direct or indirect, which provides the opportunity for nonpotable water to enter a conduit, pipe or receptacle containing potable water?
    A. Well testing
    B. Pump injection
    C. Bell joint clamp
    D. Cross connection

75. Which of the following causes taste problems and has a rotten egg odor?
    A. Chlorine
    B. Benzene
    C. Nitrate
    D. Hydrogen sulfide

References and Correct Answers

Information on obtaining the references listed below may be found in the "Training Opportunities and Resources" section of this guidebook.

1. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 1
   Answer: A

2. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 8.
   Answer: B

3. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 4.
   Answer: B

4. Reference: *Water Distribution System Operation and Maintenance, A Field Study Training Program*, American Water Works Association, Ch. 1.
   Answer: D

5. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 4.
   Answer: C

6. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 3.
   Answer: D

7. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
   Answer: A

8. Reference: USEPA 40 *Code of Federal Regulations* 141.32(b)(l)
   Answer: C

9. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
   Answer: A

10. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 2.
    Answer: A

11. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
    Answer: D

12. Reference: *Water Distribution System Operation and Maintenance*, California State University, Ch. 6.
    Answer: B

13. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
    Answer: D

14. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
    Answer: B

15. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
    Answer: B

16. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: B

17. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 4.
Answer: C

18. Reference: *Basic Science Concepts and Applications*, American Water Works Association, Ch. 6.
Answer: B

19. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: C

20. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: C

21. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: C

22. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: B

23. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 4.
Answer: D

24. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: D

25. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 1.
Answer: D

26. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: B

27. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 19.
Answer: D

28. Reference: *Introduction to Water Treatment, Principles and Practices of Water Supply Operations*, American Water Works Association, Vol. 2.
Answer: C

29. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: D

30. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: B

31. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: C

32. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: D

33. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: A

34. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: B

35. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 6.
Answer: D

36. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 1.
Answer: D

37. Reference: *Water Distribution Operator Training Handbook,* American Water Works Association Ch. 3.
Answer: C

38. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A

39. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: D

40. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A

41. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: A

42. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

43. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

44. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

45. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A

46. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: D

47. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: C

48. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

49. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: C

50. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A

51. Reference: *Basic Science Concepts and Applications*, American Water Works Association, Ch. 10 and 11.
Answer: A
Solution: 8 feet x 8 feet x 32 feet x .785 = 1607.68 cu ft
1607.68 cu ft x 7.48 gallons per cu ft = 12,025 gallons
12,025 gallons x 0.90 = 10,823 gallons
10,823 gallons / 24 gpm = 451 minutes
451 minutes = 7 hours 31 minutes

52. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 2.
Answer: D
Solution: 88 feet x 0.433 = approximately 38 psi.

53. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: A
Solution: 3 ft x 3 ft x 3 ft = 27 cubic yards
4.5 ft x 6 ft x 120 ft / 27 cubic yards = 120 cubic yards

54. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: B
Solution: 20 ft x 15 ft x 10 ft = 3,000 cubic feet

55. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B
Solution: 4.0 mg/L - 1.8 mg/L = 2.2 mg/L

56. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: A
Solution: 60.5 ^{o} F- 32 / 1.8 = 15.8 ^{o} C

57. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: A
Solution: 35 feet - 20 feet = 15 feet

58. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: B
Solution: 75 ft x 20 ft x 10 ft = 15,000 cu ft
15,000 cu ft x 7.48 gal/cu ft = 112,200 gal

59. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: B
Solution: 3 mg/L x 0.2 MGD x 8.34 lbs/gal = 5 lbs

60. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix.
Answer: B
Solution: 3,000 + 4,000 + 3,500 + 2,000 + 3,000 + 3,500 + 2,000 = 21,000 gal
21,000 gallons per week / 7 days per week = 3,000 gallons per day

61. Reference: *Water Transmission and Distribution*, American Water Works Association, Ch. 5.
Answer: B

62. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: A

63. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 7.
Answer: B

64. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: C

65. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: A

66. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: D

67. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 4.
Answer: D

68. Reference: *Water Treatment*, American Water Works Association, Ch. 7.
Answer: B

69. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: C

70. Reference: *Small Water System Operation and Maintenance*, California State University, Appendix - Water Words.
Answer: C

71. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 16.
Answer: C

72. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: A

73. Reference: *Water Distribution Operator Training Handbook*, American Water Works Association, Ch. 14.
Answer: C

74. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 3.
Answer: D

75. Reference: *Small Water System Operation and Maintenance*, California State University, Ch. 5.
Answer: D

Training Opportunities and Resources

There are many sources of training for very small water system operators. Operator training classes may be offered by the American Water Works Association (AWWA), local water utilities, community colleges, vocational-technical schools, and so on. Training must be approved by the State to satisfy the certification and training requirements. Therefore, it is important to contact your State Certification Program listed in the next section of the guidebook for a list of State-approved training.

In addition to training opportunities available in your state, there are general reference materials that may help prepare you for certification. The following is a partial list of reference material available in the United States.

California State University, Sacramento

- *Small Water System Operation and Maintenance*
- *Water Distribution System Operation and Maintenance*
- *Water Treatment Plant Operation,* Vol. I & II

Materials may be ordered from:
Office of Water Programs
California State University, Sacramento
6000 J Street
Sacramento, CA 95819
Phone: (916) 278-6142
E-mail: wateroffice@csus.edu
Web site: http://www.owp.csus.edu

American Water Works Association

- *Water Distribution Operator Training Handbook*
- *Water Distribution System Operation and Maintenance, A Field Study Training Program*
- *Introduction to Water Treatment, Principles and Practices of Water Supply Operations*
- *Water Transmission and Distribution*
- *Water Treatment*
- *Basic Science Concepts and Applications*
- *Design and Construction of Small Water Systems*

Materials may be ordered from:
AWWA Customer Service
6666 W. Quincy Avenue
Denver, CO 80235
Phone: (800) 926-7337
E-mail: custsvc@awwa.org
Web site: http://www.awwa.org

State Certification Programs

Alabama Water & Wastewater Operator Certification Program
Water Division
AL Dept. of Environmental Mgmt.
P.O. Box 301463
Montgomery, AL 36130-1463
Phone: (334) 274-4221
Web site: http://www.adem.state.al.us/h2owebpg.html

Alaska Department of Environmental Conservation, Facility Construction & Operation
Operations Assistance Unit
410 Willoughby Ave., Ste. 105
Juneau, AK 99801-1795
Phone: (907) 465-5140
Web site: http://www.state.ak.us/local/akpages/ENV.CONSERV/dfco/dec_dfco.htm

Arizona Operator Certification Program
Arizona DEQ
3033 N. Central Av., Rm 214, MO 248B
Phoenix, AZ 85012-2801
Phone: (602) 207-4643
Web site: http://www.adeq.state.az.us/environ/water/dw/opcert.html

Arkansas Drinking Water Advisory and Operators Licensing Committee
Dept. of Health
4815 W. Markham St. MS37
Little Rock, AR 72205-3867
Phone: (501) 661-2623
Web site: http://health.state.ar.us/eng/operfram.htm

California Water Treatment Operator Certification
DHS, Certification Unit, MS 92
601 North 7th Street
P.O. Box 942732
Sacramento, CA 94234-7320
Phone: (916) 323-1221
Web site: http://www.dhs.ca.gov/ps/ddwem/technical/dwp/dwpindex.htm

Colorado Plant Operators Certification Board
4300 Cherry Creek Drive South
Denver, CO 80246-1530
Phone: (303) 692-3558
Web site: http://www.cdphe.state.co.us

Connecticut Department of Public Health - Water Supplies Section
410 Capitol Ave., MS #51 WAT
Hartford, CT 06134-0308
Phone: (860) 509-7333
Web site: http://www.state.ct.us/dph/

Delaware Office of Drinking Water
Department of Public Health
Blue Hen Corp. Center, Suite 203
655 S. Bay Road
Dover, DE 19901-4615
Phone: (302) 739-5410

Florida DEP Water/Wastewater Operator Certification Program
Bureau of Water Facilities Funding
2600 Blair Stone Rd., MS 3506
Tallahassee, FL 32399-2400
Phone: (850) 921-4019
Web site: http://www.dep.state.fl.us/water/wff/ocp/default.htm

Georgia Board of Examiners for Certification of Water & Wastewater Treatment Plant Operators & Laboratory Analysts
State Examining Boards
237 Coliseum Drive
Macon, GA 31217-3858
Phone: (912) 207-1400
Web site: http://www.sos.state.ga.us/ebd-water/

Hawaii Board of Certification of Operating Personnel in Water Treatment Plants
Safe Drinking Water Branch
Env. Mgmt. Divn., State Dept./Health
919 Ala Moana Blvd., Room 308
Honolulu, HI 96814-4920
Phone: (808) 586-4258
Web site: http://mano.icsd.hawaii.gov/doh/rules/ei1125.html
(Regulations document)

Idaho Water & Wastewater Operators Certification Boards Inc.
IWWOCB Inc.
P.O. Box 551
Lewiston, ID 83501-0551
Phone: (208) 750-1195

Illinois Drinking Water Operator Certification Program
IL EPA, Compliance Assur. Sect. #19
1021 North Grand Ave. East
P.O. Box 19276
Springfield, IL 62794-9276
Phone: (217) 785-0561
Web site: http://www.epa.state.il.us/water/drinking-water-operator

Indiana Department of Environmental Management
100 N. Senate Avenue
P.O. Box 6015
Indianapolis, IN 46206-6015
Phone: (317) 308-3307
Web site: http://www.state.in.us/idem/owm/index.html

Iowa Operator Certification Program
Water Supply Section
IA Dept. of Natural Resources
502 East 9th St.
Des Moines, IA 50319
Phone: (515) 281-8998
Web site: http://www.state.ia.us/epd/wtrq/opercert.htm

Kansas Water and Wastewater Operator Certification
Kansas Dept. of Health & Env't.
Forbes Field, Bldg. # 283
Topeka, KS 66620-0001
Phone: (785) 296-2976
Web site: http://www.kdhe.state.ks.us/water/tech.html

Kentucky Board of Certification of Water Treatment & Distribution System Operators
KY DEP, Division of Water
14 Reilly Road
Frankfort, KY 40601-1189
Phone: (502) 564-3410
Web site: http://water.nr.state.ky.us/dow/trngcat.htm

Louisiana Committee of Certification for Water and Wastewater Operators
LA Dept. of Health
Operator Certification Program
6867 Bluebonnet Blvd., Box 6
Baton Rouge, LA 70810
Phone: (225) 765-5058

Maine Board of Licensure of Water Treatment Plant Operators
ME Drinking Water Program
157 Capitol Street
10 State House Station
Augusta, ME 04333-0010
Phone: (207) 287-5678
Web site: http://janus.state.me.us/dhs/eng/water/operator.htm

Maryland State Board of Waterworks and Waste Systems Operators
2500 Broening Highway
Baltimore, MD 21224-6617
Phone: (410) 631-3167
Web site: http://www.mde.state.md.us/permit/permit_guide98/index.html
(Permit Guide document)

Massachusetts Board of Certification of Operators of Drinking Water Supply Facilities
Massachusetts DEP
Division of Water Supply
One Winter Street, 6th Floor
Boston, MA 02108
Phone: (617) 556-1191
Web site: http://www.state.ma.us/reg/boards/dw/default.htm

Michigan Advisory Board of Examiners
Environmental Assistance Division
Town Center Building
333 S. Capitol Ave., 2nd Floor
Lansing, MI 48933-2022
Phone: (517) 373-4752
Web site: http://www.deq.state.mi.us/ead/tasect/otu/

Minnesota Advisory Council on Water Supply Systems & Wastewater Treatment Facilities
MN Dept./Health, Drinking Water Prot.
121 East 7th Place, Suite 220
P.O. Box 64975
St. Paul, MN 55164-0975
Phone: (651) 215-0751
Web site: http://www.health.state.mn.us/divs/eh/dwp/pws/dwopcert/dwopmain.html

Mississippi State Department of Health
Division of Water Supply
2423 North State Street, Ste. 241
P.O. Box 1700
Jackson, MS 39215-1700
Phone: (601) 576-7518
Web site: http://www.msdh.state.ms.us/watersupply/index.htm

Missouri Department of Natural Resources
Technical Assistance Program
P.O. Box 176
Jefferson City, MO 65102-0176
Phone: (800) 361-4827
or (573) 751-1600
Web site: http://www.dnr.state.mo.us/deq/tap/oprtrain.htm

Montana Water and Wastewater Operators' Advisory Council
Department of Envir. Quality
Community Services Bureau
P.O. Box 200901
Helena, MT 59620-0901
Phone: (406) 444-2691
Web site: http://www.deq.state.mt.us/pcd/csb/certify.htm

Nebraska Department of Health & Human Services
Dept./Reg. & Licensure
301 Centennial Mall South
P.O. Box 95007
Lincoln, NE 68509-5007
Phone: (402) 471-2541
Web site: http://www.hhs.state.ne.us

Nevada State Health Division
NV Bureau of Health Prot. Services
1179 Fairview Dr. Ste. 101
Carson City, NV 89701-5405
Phone: (775) 687-6615 ext. 235
Web site: http://www.state.nv.us/health/bhps/PHE/sdwp.htm

New Hampshire Department of Environmental Services
Engineering Bureau, Water Supply
6 Hazen Drive
P.O. Box 95
Concord, NH 03302-0095
Phone: (603) 271-2410
Web site: http://www.des.state.nh.us/wseb

New Jersey Water & Wastewater Board of Examiners
NJ DEP Administrator's Office
P.O. Box 420
Trenton, NJ 08625-0420
Phone: (609) 984-7743
Web site: http://www.state.nj.us/dep

New Mexico Utility Operators Certification Program
New Mexico Environment Dept.
Facility Oper. Section / SWQB
P.O. Box 26110
Santa Fe, NM 87502-0110
Phone: (505) 827-2799
Web site: http://www.nmenv.state.nm.us/

New York Community Water System Operator Certification Program
NY State Dept. of Health
Bureau/Public Water Supply Prot.
Flanigan Square, 547 River St.
Troy, NY 12180-2216
Phone: (518) 402-7712

North Carolina Water Treatment Facility Operators Certification Board
NC DENR, Divn. of Environ. Health
1635 Mail Service Center
Raleigh, NC 27699-1635
Phone: (919) 715-9572
Web site: http://www.deh.enr.state.nc.us/

North Dakota Department of Health
1200 Missouri Avenue
P.O. Box 5520
Bismarck, ND 58502-5520
Phone: (701) 328-6626
Web site: http://www.health.state.nd.us/ndhd/environ/mf/index.htm

Ohio EPA - Certification Unit
DDAGW
122 South Front Street
P.O. Box 1049
Columbus, OH 43216-1049
Phone: (614) 644-2888
Web site: http://www.epa.ohio.gov/ddagw/ddagwmain.html

Oklahoma Waterworks & Wastewater Works Advisory Council
Oklahoma DEQ
Certification and Compliance Section
P.O. Box 1677
Oklahoma City, OK 73101-1677
Phone: (405) 702-8100
Web site: http://www.deq.state.ok.us/Water1/operatorcertification/

Oregon Water Operator Certification Program
OR Health Division
Drinking Water Section
P.O. Box 14450
Portland, OR 97293-0450
Phone: (503) 731-4899
Web site: http://www.ohd.hr.state.or.us/dwp/certif.htm

Pennsylvania State Board for Certification of Sewage Treatment Plant and Waterworks Operators
DEP - Certif., Licensing & Bonding
400 Market Street, Room 102
P.O. Box 8454
Harrisburg, PA 17105-8454
Phone: (717) 787-5236
Web site: http://www.dep.state.pa.us/dep/deputate/waterops/

Rhode Island Drinking Water Certification Board
Department of Health
Office of Drinking Water Quality
3 Capitol Hill, Room 209
Providence, RI 02908-5097
Phone: (401) 222-6867
Web site: http://www.health.state.ri.us

South Carolina Environmental Certification Board
110 Centerview Drive
P.O. Box 11409
Columbia, SC 29211-1409
Phone: (803) 896-4430
Web site: http://www.llr.state.sc.us/ecb.htm

South Dakota Operator Certification Program
DWP/DENR
Foss Building-Lower Level
523 E. Capitol Ave.
Pierre, SD 57501-3181
Phone: (605) 773-4208
Web site: http://www.state.sd.us/opercert

Tennessee Water & Wastewater Operator Certification Board
J R Fleming Training Center
2022 Blanton Drive
Murfreesboro, TN 37129-2912
Phone: (615) 898-8090
Web site: http://www.state.tn.us/environment/dca/fleming.htm

Texas Operator Certification Program
TNRCC, MC 178
P.O. Box 13087
Austin, TX 78711-3087
Phone: (512) 239-6139
Web site: http://www.tnrcc.state.tx.us/enforcement/csd/ocs/

Utah Water Operator Certification Commission
Utah Divn. of Drinking Water
150 North 1950 West
P.O. Box 144830
Salt Lake City, UT 84114-4830
Phone: (801) 536-4200
Web site: http://www.deq.state.ut.us/eqdw/

Vermont Department of Environmental Conservation
Water Supply Division
Old Pantry Building
103 South Main Street
Waterbury, VT 05671-0403
Phone: (802) 241-3400
Web site: http://www.anr.state.vt.us/dec/watersup/wsd.htm

Virginia Board for Waterworks and Wastewater Works Operators
Dept. of Profess. and Occup. Reg.
3600 West Broad Street, 5th Floor
Richmond, VA 23230-4917
Phone: (804) 367-8595
Web site: http://www.state.va.us/dpor/indexne.html

Washington Water Works Operator Certification Program
Department of Health
Division of Drinking Water
P.O. Box 47822
Olympia, WA 98504-7822
Phone: (360) 236-3137
Web site: http://www.doh.wa.gov/ehp/dw/

West Virginia Office of Environmental Health Services
Bureau for Public Health
815 Quarrier Street, Suite 418
Charleston, WV 25301-2616
Phone: (304) 558-2981
Web site: http://www.wvdhhr.org/oehs/eed/organization.html

Wisconsin Water and Wastewater Operator Certification Program
Wisconsin DNR
101 S. Webster Street
P.O. Box 7921
Madison, WI 53707-7921
Phone: (608) 266-0498
Web site: http://www.dnr.state.wi.us/org/es/science/opcert

Wyoming Operator Certification Program
WY DEQ/Water Quality Division
4th Floor Herschler Building, 4W
122 West 25th Street
Cheyenne, WY 82002-5011
Phone: (307) 777-7781
Web site: http://deq.state.wy.us/wqd/certop.htm

Record Maintenance
Water and Distribution Systems
State of Tennessee

Record	Must be kept for	Source
Bacteriological Analysis	5 years	0400-45-1-.20(1)(a)
Chemical Analysis	10 years	0400-45-1-.20(1)(a)
Actions to correct violations	3 years after last action	0400-45-1-.20(1)(b)
Written reports, summaries, communications relating to sanitary surveys	10 years after sanitary survey	0400-45-1-.20(1)(c)
Variances/exemptions	5 years after expiration	0400-45-1-.20(1)(d)
Turbidity	Next sanitary survey	0400-45-1-.20(1)(f)
Daily worksheets and shift logs	Next sanitary survey	0400-45-1-.20(1)(g)
Cross connection plans & inspection records	5 years	0400-45-1-.20(1)(h)
Complaint logs	5 years	0400-45-1-.20(1)(h)
Facility maintenance records	5 years	0400-45-1-.20(1)(h)
Storage tank inspections	5 years (required) life of tank recommended	0400-45-1-.20(1)(h)
Lead & copper	12 years	0400-45-1-.33(12)
Bacteriological records indicating disinfection of mains, tanks, filters, wells	5 years	0400-45-1-.17(8)
Flush and free chlorine residual for new taps where main is uncovered	Next sanitary survey or 3 years	0400-45-1-.17(33)
SDS	At least 30 years	29 CFR1910.1020

Section 2

Water Sources

Water Sources & Characteristics

Developing the Water Supply
AWWA WSO: Water Sources

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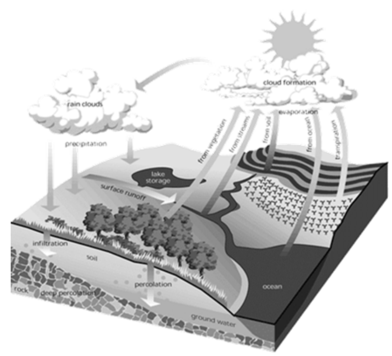
Learning Objectives

- Hydrologic Cycle
- Characteristics of Groundwater and Surface Water
- Sources of Groundwater and Surface Water
- Water Rights
- Source Development and Protection
- Wells Operation and Maintenance
- Regulatory Publications and Rules

Water Supply Hydrology & the Hydrologic Cycle

- Hydrologic Water Cycle
  - Movement of water from the surface of the earth to the atmosphere and back
- Process of evaporation and transpiration
- Condensation forms water vapor droplets
- Precipitation returns water to earth
- Water penetrates ground via infiltration, percolation, and runoff
  - Surface runoff occurs when ground is saturated

Hydrologic Cycle



Hydrologic Cycle

- Infiltration and Percolation
  - As precipitation falls, it soaks into the ground
  - Infiltration
    - The movement of water through the soil
  - Some of the water goes back to the surface due to *capillary action*
    - The movement of water above a water surface
  - The rest percolates (movement of water downward through soil) to the water table
- Surface Runoff
  - When the soil can hold no more water, it flows downward over the ground surface
  - It flows into streams or lakes or, eventually, the ocean

Groundwater

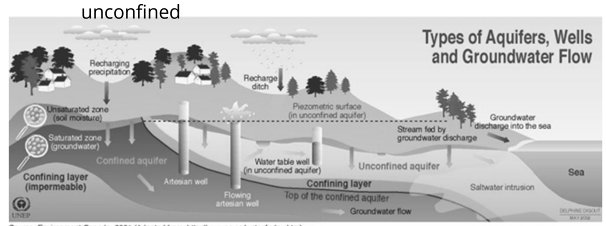
- Sources
  - Aquifers
    - Confined and unconfined
  - Springs
- Half of the world's groundwater resource is located within one mile of the ground surface
- Other half is found in deep aquifers

Unconfined Aquifer

- Upper surface is free to rise and fall
- Water table wells
  - Wells constructed to reach an unconfined aquifer
- Amount of water produced varies widely as water table rises and falls in relation to rainfall
- Indicates water table level of surrounding aquifer

Aquifers

- Characteristics
  - Underground layer of gravel, sand, sandstone, shattered rock, or limestone
  - Impermeable layer of rock, clay or granite keeps water from sinking downward
  - Water table is upper surface of an aquifer
  - Classified as water table or artesian and confined or unconfined



Source: Environment Canada, 2001 (Adapted from: http://www.ec.ca/water/index.htm)

Confined Aquifers

- Also known as Artesian Aquifer
- Permeable layer confined by an upper level and lower level of low permeability material
- Water recharge area usually higher than main part of aquifer
  - Water in aquifer is usually under pressure
- Piezometric surface
  - height that water rises
- Flowing artesian well
  - pressure causes water to rise above ground surface
- Non-flowing artesian well
  - water doesn't rise to the surface

Aquifers Terms & Materials

- Porosity
  - Amount of water the material will hold
- Hydraulic conductivity
  - How easily the water will flow thought the aquifer material
- Both determine how much the aquifer will yield
- Pumping rates are higher in coarser material and cost less
  - Less pumping head loss
- Consolidated aquifer formations consist of limestone and fractured rock and produce large quantities of water

Groundwater Movement Characteristics

- Movement of water is naturally downhill
- Rainfall percolates down to the water table
- Water moves slowly through soil which removes suspended particles
- Soil acts as a natural filtration process
  - Dissolved pollutants cannot be removed
  - Contaminants can be picked up
- Water table is never completely level

Springs

- Occur if water table intersects the ground surface
- Difficult to determine source of springs
- They should be considered contaminated until sanitary survey is conducted
- Flows vary considerably and are influenced by artesian pressures
- Enclose intake in a concrete spring box

Surface Water Characteristics

- Higher turbidity
- Suspended solids
- More color
- Microbial contamination
- Impurities in snow and rain
- Impurities from runoff
  - soluble formations such as limestone, gypsum, & rock salt affect characteristics
- Precipitation dissolves gases in atmosphere
- Dust and solids from industrial processes
- Usually soft, low in solids and alkalinity, and pH slightly below 7
- Usually corrosive
- Seasonal changes

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Water Source Protection

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Surface Water Source Development

- Surface water is defined as all water open to the atmosphere & subject to surface runoff
  - Includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake
- Factors
  - Quantity
  - Quality
  - Structures
  - Impoundments and reservoirs
    - Site preparation
    - Construction
- Tennessee Public Water System Design Criteria part 3

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Groundwater Source Development

- Includes all water obtained from drilled wells or springs
- Water found underground surface in a porous substrate (aquifer)

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Safe Drinking Water Act (SDWA)

- Establishes primary drinking water standards
- Secondary standards
- Public notification procedures and requirements
- Federal Enforcement
- Established a cooperative program among local, state, and federal agencies
- EPA executive agency
- Established MCL's (Maximum Contaminant Level)
- Established sampling and testing requirements

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Physical Characteristics of Water

- Relates to sensory qualities of water
- Temperature
  - most familiar characteristic
  - effects lake turnovers, dissolving of chemicals and palatability
  - most desirable drinking water is considered cool
- Turbidity
  - cloudiness of water
  - indicator of health significance
  - operational considerations
  - aesthetics
- Color
  - indicates contamination, dissolved organics, and humic substances that could form THMs
- Taste & odor
  - degradation aesthetic quality

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Chemical Characteristics of Water

- Inorganic
  - pH
    - indicator of acidity or alkalinity
  - Hardness
  - Dissolved oxygen
    - measured in mg/L
  - Dissolved solids
    - toxic minerals include
      - chromium
      - lead
      - mercury
      - silver
      - arsenic
      - barium
      - fluoride
      - nitrate
- Organic
  - Includes
    - pesticides
    - herbicides
    - domestic wastes
    - industrial wastes
    - watershed runoff
  - Can cause taste, odor, and toxicity problems

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Biological Characteristics of Water

- Aquatic life (algae)
- Bacteria
- Coliform bacterial (TC, FC, EC)
- Viruses
- Protozoa
- Spores
- Cysts
- Many originate with fecal discharges
- Not easily identified and isolated

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Radiological Factors in Water

- Development of atomic energy and mining of radioactive materials made it necessary to examine safe limits
- Divided into two categories:
  - Natural and Man-made
- Sources are
  - Natural deposits and Man-made deposits

If someone is glowing, Be Suspicious! ☺

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Benefits of Source Water Protection Program

- Source control is the first barrier in a multiple-barrier treatment plan
- Water treatment methods are not 100% effective in removing contaminants
  - The risks of residual contaminants can be too high
- As the quality of source water deteriorates, the cost of treatment goes up and can become prohibitive
- Increase in public confidence
- Decrease in public health risks
- Due to difficulty to analyze, remove, and/or disinfect pathogens with conventional methods, keeping pathogens out of the source water may be the only way of providing protection

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Developing a Source Water Protection Program

- Inventory and characterize the water source
- Identify pollutant sources and relative impact
- Assess vulnerability of intake to contaminants
- Establish source water protection goals
- Develop source water protection strategies
- Implement the program
- Monitor and evaluate program effectiveness

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Developing a Groundwater Source Protection Program

- Identify area that needs protection and who has an interest in protecting it
  - For wellhead protection
    - aquifer delineation
  - For surface water sources
    - watershed mapping

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Developing a Groundwater Source Protection Program

- Aquifer Delineation (**Wellhead Protection Area**)
  - Define the land area over the portion of the aquifer that influences the quality of the water
  - Should be identified and inventoried for potential of contamination
  - For microbiological contaminants, a small area is suitable
  - Chemical contaminants can travel from several thousand feet for relatively deep wells
  - USGS maps are a good place to start
  - 1986 SDWA amendments require each state to develop a Wellhead Protection Program
  - Limit activities in area to protect well and aquifer from contamination

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Developing a Source Water Protection Program

- Identify Pollutant Sources and Relative Impact
  - Sewage disposal, runoff, animal population, recreation
- Assess Vulnerability of Intake to Contaminants
  - identify contaminant & amount of contaminant
  - correlate land use to contaminant level
  - Assessment methods
    - water quality monitoring, modeling, onsite assessment
- Strategies
  - Land use controls
    - buffer zones
    - land acquisition
    - comprehensive planning
    - watershed/recharge area inspections

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Developing a Source Water Protection Program

- Vandalism and Terrorism
  - Protect intakes; safeguard area around source, if possible
  - Monitoring and surveillance may be required
  - Be alert of suspicious events
- Title IV Drinking Water Security and Safety
  - Must have assessment of system
  - ERPs (Emergency Response Plans) are due 6 months after assessment
  - Plans include actions, procedures, and identification of equipment which can prevent or lessen the impact of a terrorist act
- Source of Contamination
  - After WHPA or watershed boundary has been determined, inventory of potential contaminant sources is to be performed

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Vocabulary

A. Aesthetic
B. Appropriative Rights
C. Aquifer
D. Artesian
E. Capillary Fringe
F. Contamination
G. Cross Connection
H. Direct Runoff
I. Drawdown
J. Evaporation
K. Evapotranspiration
L. Hydrologic Cycle
M. Infiltration

1. _____ The process by which water or other liquid becomes a gas.
2. _____ The porous material just above the water table that may hold water by capillarity in the smaller void spaces
3. _____ The seepage of groundwater into a sewer system, including service connections
4. _____ Attractive or appealing
5. _____ A natural, underground layer of porous, water-bearing materials (sand, gravel) usually capable of yielding a large amount or supply of water
6. _____ The process by which water vapor is released to the atmosphere from living plants
7. _____ The introduction into water of microorganisms, chemicals, toxic substances, wastes, or wastewater in a concentration that makes the water unfit for its next intended use
8. _____ The process of evaporation of water into the air and its return to earth by precipitation.
9. _____ Water rights to or ownership of a water supply that is acquired for the beneficial use of water by following a specific legal procedure
10. _____ A connection between a potable water and an unapproved water supply.
11. _____ Pertaining to groundwater, a well, or underground basin where the water is under a pressure greater that atmospheric and will rise above the level of its upper confining surface if given an opportunity to do so
12. _____ Water that flows over the ground surface directly into streams, rivers, or lakes
13. _____ The drop in the water table or level of water in the ground when water is being pumped from a well

Answers

1. J	8. L
2. E	9. B
3. M	10. G
4. A	11. D
5. C	12. H
6. K	13. I
7. F	

Section 3

Wells

Wells

1

SMALL WATER SYSTEM OPERATION AND MAINTENANCE
CALIFORNIA STATE UNIVERSITY: SACRAMENTO

Updated 11/16/2023

Groundwater

2

Importance of Groundwater

3

- Function of well is to intercept ground water moving through aquifers and bring water to surface
- Reasons for choosing groundwater source:
  - Generally available in all regions, though quantities may be limited
  - Less costly than surface treatment facilities
  - Less bacterial and viral contamination
  - Water quality parameters generally constant
  - Well suited to the needs of smaller communities

Water Cycle

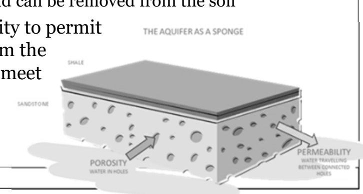
4

- Hydrologic cycle is the continuous circulation of water on our planet
- Subsurface water - water that infiltrates the soil
  - Not all will become groundwater
- Capillary action may pull water back to the surface
  - Will then be evaporated
- Water may be absorbed by plant roots
  - Reenters atmosphere through transpiration
- Infiltrated water may be drawn down to the zone of saturation – groundwater reservoir that supplies water to wells

Aquifers

5

- To qualify as an aquifer:
  - Porosity, area, & thickness to store adequate water supply
    - Porosity - a measure of the opening or voids (pores) in a particular soil
  - Sufficient specific yield to allow water to drain to a well.
    - Specific yield – the volume of water that is affected by gravitational forces and can be removed from the soil
  - Hydraulic transmissivity to permit well to drain water from the aquifer fast enough to meet flow requirements



Overdraft

6

- Overdraft – pumping of water from aquifer in excess of the safe yield
- Overdraft can lead to the drained soils settling resulting in compaction and closing of pores
  - Subsidence of the land

Wellhead Protection

7

- Contamination can originate on the ground surface, in the ground above the well, or in the ground below the water table
  - Best method to guarantee continued supplies of clean groundwater is to prevent contamination
- Potential problems
  - Agriculture – pesticides, manure, nitrates
  - Gas stations – minor leaks, incidental spills
  - Fuel storage – underground tank failure, above ground tanks, buried & abandoned tanks
  - Photo labs, Dry cleaners, Furniture strippers, Medical Labs – solvents are very persistent
  - Septic systems – nitrates and other chemicals & solvents

Structure and Components

8

Types of Wells

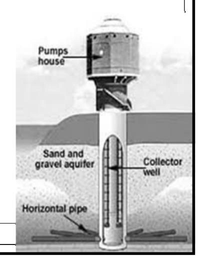
9

- Dug Wells
  - Excavated with hand tools; limited yield and higher chance of contamination due to shallow construction
- Bored Wells
  - Constructed with earth augers typically less than 100 ft deep
  - Cased with suitable material
  - Construction completed by installing well screen or perforated casing
- Driven Wells
  - Simplest and least expensive
  - Constructed by driving well drive point into the ground with a maul or special weight

Types of Wells

10

- Drilled Wells
  - Percussion (cable tool) method
  - Hydraulic rotary drilling method
  - Reverse circulation rotary drilling method
  - Air rotary drilling method
- Shallow Collector Wells – Ranney Type
  - Dug well 12-16 ft in diameter near the bank of a river or lake



Subsurface Features of a Well

11

Subsurface Features of a Well

12

- Conductor Casing
  - Outer casing of well designed to prevent contaminants from surface waters
  - Should extend into an impervious stratum where no liquid can flow in or out but never less than 50 feet in depth
- Well Casing
  - Maintains well hole by preventing walls from collapsing
  - Provides a way to get the water to the pumping unit
  - Forms chamber or housing for well pump
  - Protects quality of water pumped

Subsurface Features of a Well

13

- Intake Section of a Well
  - Located at or near the bottom of the well and attached to the end of the well casing
  - Permits the free flow of water from water-bearing formations into the well itself
  - Supports the water-bearing formation and prevents collapsing
  - Prevents sand from entering well
  - May take the form of
    - Well screen
    - Mill-cut slots
    - Formed louvers
    - Torch-cut/chisel-cut slots
    - Slots made by mechanical perforator

Subsurface Features of a Well

14

- Intake Section of a Well
  - Well screen
    - 3 types : Continuous slot, Bar, Wire wound
    - Constructed of stainless steel, monel metal, nickel alloys, alloy steel, red brass
    - Length and diameter determined by expected yield of the well
    - Size of screen openings determined by effective size and uniformity coefficient of sand in water-bearing strata
    - Should not allow more than 0.1 ft/sec to flow through screen

Subsurface Features of a Well

15

- Intake Section of a Well
  - Mill-cut Slots
    - Openings are machine milled (cut) into the wall of the casing pipe parallel to the axis of the casing
    - Openings uniformly spaced around casing pipe
    - Slot width determined by size of aquifer material to be kept out
    - Rarely used due to increased popularity of louvered casing

Subsurface Features of a Well

16

- Intake Section of a Well
  - Formed Louvers
    - Openings or louvers in casing are horizontal to the casing
    - Louvers shaped to create upward flow as water enters well
  - Torch-cut Slots
    - Should be avoided
    - Near impossible to control the size of the openings in the well casing
  - Hydraulic or Mechanical Slots
    - Cable-tool wells are slotted after the well has been drilled using a casing perforator lowered into the well

Subsurface Features of a Well

17

- Annular Grout Seal
  - Purpose
    - To seal out water of any unsatisfactory quality
    - To protect the well casing or conductor casing pipe against exterior corrosion
    - To stabilize soil formations
  - Grouting (cementing) – filling of annular space between well casing and conductor casing, the space between casing and the borehole, or the space between the well casing and the borehole with cement or other suitable material
    - Uses neat cement grout, sand-cement grout, or bentonite clay

Subsurface Features of a Well

18

- Annular Grout Seal
  - Flush annular space with water before grouting
  - Three basic methods for placing sealing material
    - Grout pipe outside casing
    - Grout pipe inside casing
    - Haliburton Method
- Gravel Pack
  - Purpose is to control the entrance of sand into the well
  - Size of gravel will depend on grain size of water-bearing formation and expected yield
  - Gravel must be disinfected before installation

Surface Features of a Well

19

Well Surface Features

20

- Openings in the top of the well allow for entrance or escape of air or gas
  - Provides access for adding gravel, taking water level readings, adding disinfectant or cleaning chemicals
- Openings are second most important part of well
- Well casing vent
  - Prevents vacuum forming during initial drawdown by allowing air to enter well
    - Drawdown – drop in water level in the ground when water is being pumped from a well
  - Prevents pressure buildup during recovery period by allowing air to escape
  - 3 inch diameter minimum
  - Wells over 14 inches should have a dual vent
  - Should be 36 inches above finished surface of well lot

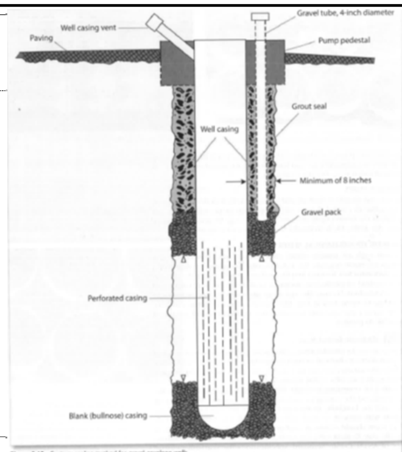


Figure 1.18 Sanitary sealing method for gravel-envelope wells

Well Surface Features

22

- Well-casing vent (1)
  - Allows air to enter well during drawdown to prevent vacuum conditions; vents excess air during well recovery period
- Gravel Tube (2)
  - Permits operator to see level of gravel and add gravel as needed
- Sounding tube (3)
  - Permits insertion of water level measuring device
  - Allows addition of chlorine or well cleaning agents

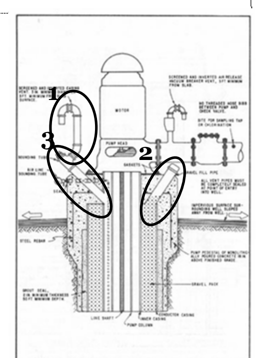


Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

Well Surface Features

23

- Air line water level measuring device (1)
  - Aka Sounding line
  - Permits measurement of water level by means of air pressure measurements
- Pump pedestal(2)
  - Supports the weight of the pumping unit (concrete)
- Pump motor base seal (3)
  - Provides watertight seal between the motor base and the concrete support pedestal

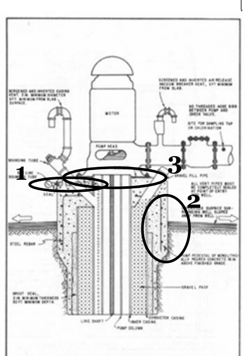


Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

Well Surface Features

24

- Sampling taps (1)
  - Permit sampling of pumped water
- Air release and vacuum breaker valve (2)
  - Permits discharge of air in column pipe during start-up and admits air during shutdown
- Pump blowoff (drain line) (not shown)
  - Removes first water (usually sandy) pumped at start up

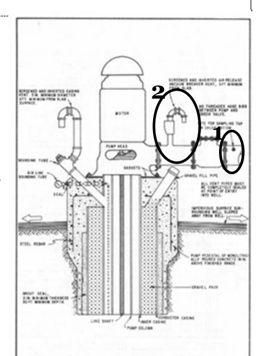


Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

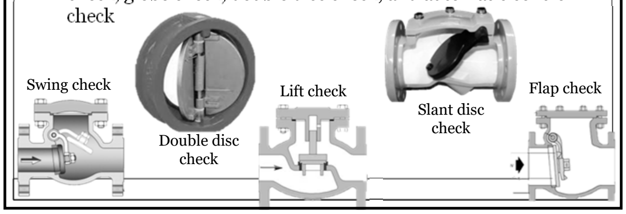
Well Appurtenances

25

Valves

26

- Check valves
  - Prevents draining of system and keeps pressurized water from flowing back into the well
    - Flow reversal will not occur in pumps with a foot valve
  - Types: swing check, lift check, foot check, slant disc check, flap check, globe check, double disc check, and automatic control check



Valves

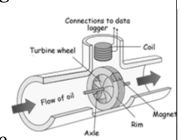
27

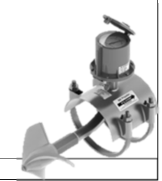
- Pump control valves
  - Diaphragm-type valve designed to eliminate pipeline surges when the pump is started and stopped (water hammer)
  - Types: normally open, normally closed
    - Both types hydraulically operated
  - Normally closed installed on main discharge line
  - Normally open installed in bypass line on discharge side
- Foot valves
  - Placed in the inlet to pump suction line
  - Maintains the prime of the pump
  - Prevents reversal of flow into the well when pump shuts off
  - Eliminates problems of air entering system

Flowmeters

28

- Used to measure the amount of water being pumped to the system
  - Should be at least 5 pipe diameters distance downstream from any pipe bend, elbow or valve
  - Should be at least 2 pipe diameters distance upstream from any pipe bend, elbow or valve
  - Should be calibrated in place
  - Types:
    - Positive displacement, propeller, turbine, orifice plate, electronic sensor
  - Propeller or turbine type with magnetic drive most common in well pump applications

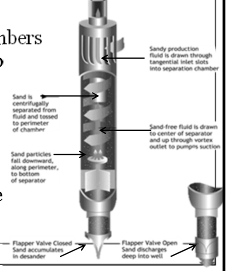




Sand Traps and Sand Separators

29

- Sand should not be allowed to enter the distribution system
  - Reduced pump efficiencies, worn impellers, sanded water mains, excessive meter wear & plugging, customer complaints
- Sand traps
  - Large tank with series of baffles or chambers installed on discharge side of well pump
  - Costly and inefficient
- Sand separators
  - Uses centrifugal force to efficiently remove fine sand, scale, etc. from water
  - Can remove approximately 95% of large sand particles



More Appurtenances

30

- Tank coatings
  - 0400-45-01-.17(34) Paints and coatings accepted by the Environmental Protection Agency (EPA) and/or the National Sanitation Foundation (NSF) for potable water contact are generally acceptable to the Department
- Surge suppressors
  - Installed on discharge side of booster pump to absorb shock waves in the water system and prevent water hammer
- Air and vacuum valves
  - Large venting orifice used to exhaust large quantities of air very rapidly
- Pressure relief valve
  - Installed on all hydropneumatic tanks to prevent water hammer

Air Chargers

31

- Add air to hydropneumatic system
- Hydraulic principle air charger
  - Uses water pressure of tank to force air into tank
  - Air is added to tank on upward compression stroke and releases water on downward exhaust stroke
- Air compressor air charger
  - When water level switch exceeds preset level, air gets pumped into the tank to push out water
  - Pump runs until pressure rises enough to open pressure switch OR the water level descend below preset level
- Air to water ratio
  - 2/3 water to 1/3 air
  - Improper ratio will lead to short cycling

Well Maintenance and Rehabilitation

32

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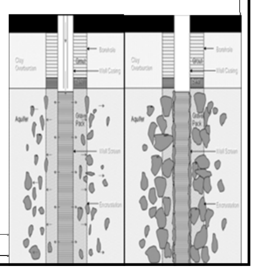
Factors Affecting Maintenance of Well Performance

33

- Overpumping (aka overdraft)
  - Can damage aquifer and production capacity
  - Can lead to pumping air, water cascading into the well, sand pumping, excessive pump wear, reduced pump efficiency, sand locking
- Clogging or encrustation of screen
  - Well screens will filter sand out of water entering the well
  - Clogging/encrustation can limit number of available openings for water to move through
    - Encrusting waters usually alkaline
  - Most common cause of decrease in a well's capacity
  - Carbonate, sulfate, and iron deposits most common causes of encrustation



Factors Affecting Maintenance of Well Performance

34

- Corrosion or collapse of screen
  - Corrosion is a process that results in the gradual decomposition or destruction of metals
  - Typical corrosive water characteristics
    - Acidic (low pH)
    - High dissolved oxygen (DO)
    - High carbon dioxide (CO_2)
    - High total dissolved solids (TDS)
    - High hydrogen sulfide (H_2S)
    - High velocity water
    - Connection of dissimilar metals in water (galvanic corrosion)
  - Can enlarge screen openings allowing unwanted, larger particles through

Factors Affecting Maintenance of Well Performance

35

- Biofouling
  - Bacterial growth is responsible for more than 80% of the blockages in wells and a major portion of corrosion
  - Biofilm is habitat of bacteria
  - Results in blockage, corrosion, or water quality problems
- Field testing of deposits
  - Black deposit: iron sulfide or manganese
  - Dark to reddish brown: ferric iron oxide (soluble/dissolved)
  - Bright yellow: sulfur
  - Light tan deposit: mixture of calcium and magnesium carbonate
  - Very light color to white: calcium carbonate
  - Very heavy or dense deposit: predominately mineral
  - Very light or low density deposit: biological or organic material

Well Maintenance

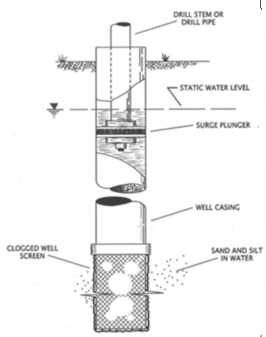
36

- Adequate recordkeeping is a must
  - Water level measurements before and after pumping
  - Flow rates
  - Water quality samples
  - Time length of pumping
  - Pump repairs
- Casing and screen maintenance
  - Material selection vital to life of well

Casing and Screen Maintenance

37

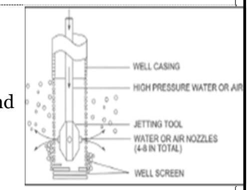
- Surging
  - Procedure used for opening pores in the screen and cleaning gravel pack
  - Common in new well development to purge sand around well screen
  - Effective at combating encrustation when used with acid treatment



Casing and Screen Maintenance

38

- High velocity jetting
  - Spraying water at a high velocity to backwash screen and reopen pores of the aquifer and remove sand around well screen
    - Jet should be 1-2 inches smaller than well casing diameter
    - 100-150 psi at 10-12 gpm
- Chlorine treatment
  - Shock treatment @ 100-200 mg/L
  - More effective than acid treatment removing biofilms and iron oxide deposits
  - Calcium hypochlorite or sodium hypochlorite
  - May be alternated with acid treatment



Casing and Screen Maintenance

39

- Polyphosphates
  - Disperse silts, clays, and deposits of iron & manganese
  - Dislodged solids easily removed by pumping
- Acid treatment
  - Used to loosen encrustation to remove from well and casing
  - Hydrochloric acid or sulfamic acid
    - Dissolves calcium and magnesium carbonates
    - HCl – dissolves iron and magnesium hydroxides
  - Use caution to not damage well materials
  - Always add acid to water, never add water to acid
  - Pump well to waste until well discharge pH has returned to normal

Acid Treatment

Characteristic	Slight	Moderate	High
Corrosiveness to metal	Phosphoric acid Hydroxyacetic acid Citric acid	Sulfamic acid	Hydrochloric acid
Characteristic	**Poor**	**Good**	**Very Good**
Reactivity to: • Carbonate Scale	• Citric acid	• Hydroxyacetic acid	• Sulfamic acid, Hydrochloric acid, Phosphoric acid
• Sulfate Scale	• Hydroxyacetic acid, Citric acid	• Sulfamic acid, Hydrochloric acid, Phosphoric acid	
• Fe/Mn Oxides		• Sulfamic acid, Hydroxyacetic acid, Phosphoric acid, Hydrochloric acid	
• Biofilm	• Sulfamic acid, Hydrochloric acid, Phosphoric acid, Citric acid	• Hydroxyacetic acid	

Troubleshooting

41

- Decline in yield
  - Yield depends on three factors: aquifer, well, pump
    - Decline in yield will be due to a change in one of these factors
  - Specific capacity – measure of the adequacy of an aquifer or well
    - Measures the yield of a well in gallons per minute per unit of drawdown during a specific time period (gpm/ft)
- Changes in water quality
  - Biological, chemical, or physical quality
  - Can be attributed to changes in the aquifer or well
    - Changes in aquifer – biological or chemical quality deterioration
    - Changes in well – physical quality deterioration

Troubleshooting

42

Analysis of Declines in Well Yields

Symptom	Cause	Corrective Action
Decline in drawdown with no change in specific capacity	Aquifer – groundwater level decline due to reduced recharge or overpumping	Increase spacing of new supply wells. Institute artificial recharge methods.
Decline in specific capacity with no change in drawdown	Well – screen blockage; reduction in open hole by sediment	Clean well with surge block or other means. Acid wash to dissolve encrustations.
No change in drawdown and no change in specific capacity	Pump – wear of impeller or other moving parts	Recondition/replace motor or parts

Troubleshooting

43

Analysis of Changes in Water Quality

Quality Change	Cause	Corrective Action
Biological	Movement of polluted water from surface through pipe liner and inside of pipe	Seal space and mound dirt around well
Chemical	Movement of polluted water into well from land surface	Seal space; extend casing to a deeper level
Physical	Migration of rock particles into well through screen or from water bearing fractures; Collapse of well screen or rupture of well casing	Remove pump and redevelop well Replace screen; install smaller casing inside original casing

Well Pumps and Service Guidelines

44

Well Pumps

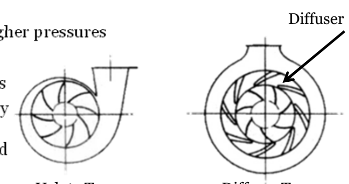
45

- Two basic groups
  - Positive displacement pumps – deliver same volume of water against any head
    - Piston or diaphragm
  - Dynamic pumps – deliver water with the volume varying inversely with the head
    - The greater the head the less the volume or flow
    - Centrifugal, jet, and air-lift
- Shallow well pump – installed above a well and takes water by suction lift
- Deep well pump –installed in well with inlet submerged below pumping level
  - Can be used in any type of well

Types of Pumps

46

- Centrifugal pumps
  - Raises water by centrifugal created by impeller in a casing; water passes through a channel or diffuser vanes
  - Volute-type pumps
    - No diffuser
    - Lower velocity with higher pressures
  - Turbine-type pumps
    - Most common for wells
    - Impeller surrounded by diffuser vanes that transform velocity head to pressure head



Volute Type Diffuser Type

Types of Pumps

47

- Deep Well Turbine Pumps
  - Standard
    - Driven through rotating line shaft connected to electric motor on top of well
      - Oil lubricated or water lubricated
  - Submersible
    - Similar to standard deep well turbine except motor is mounted below pump
- Jet pumps
- Piston pumps
- Rotary pumps

Well Pumps

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- Column pipe
  - Connects to bottom of surface discharge head, extends down into well, and connects to the top of the well pump
  - Delivers water under pressure from well pump to surface
  - Keeps line shaft and shaft enclosing tube assembly in straight line
- Right-angle gear drives
  - Can replace electric motor on top of well
  - Can be used with electric motor as a standby or for emergency purposes

Well Pumps

49

- Selecting a pump
  - Must know required capacity, location & operating conditions, and total head
- Service guidelines
  - Deep well turbine, oil lubricated pumps have electric oiler system that includes an adjusting needle and sight glass
    - Oil drip rate depends on well column length
    - Should never be less that 5 drops of oil per minute
- Motors
  - Oil in bearing container changed annually
    - Be sure to use proper oil
  - Greased bearings require weekly attention during heavy pumping season
    - Do NOT over grease bearings, will cause overheating

Disinfection of Wells and Pumps

50

New Wells

51

- For well disinfection procedures, follow AWWA A100
  - AWWA A100 says to follow AWWA C654
- Equipment and material should be sprayed with 200 mg/L chlorine just prior to installation
- After installation of equipment
  - Treat water in well casing to provide residual of 50 mg/L
  - Circulate chlorinated water within casing and well column
  - Pump well to waste to remove chlorinated water

Disinfection After Equipment Installation

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- Treating water in well casing
  - Must have 50 mg/L chlorine residual in entire volume of water
  - Calcium hypochlorite (HTH)
    - Dribble down the casing vent and at least 30 minutes shall pass to allow the tablets to fall through the water and dissolve
  - Sodium hypochlorite
    - Suspend tube through well casing vent to bottom of well
    - Withdraw tube as sodium hypochlorite solution pumped through tube
  - Well shall be surged at least 3 times
    - Improves mixing and induces contact of chlorine with adjacent aquifer
  - Chlorinated water shall sit at least 12 hours but less than 24 hrs

Disinfection After Equipment Installation

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- Circulating the chlorinated water
  - Make pressure tight connection (at least 2 inch diameter) from pump discharge to casing vent
  - Operate pump against throttled discharge
    - This will circulate some water through well while discharging the remainder
  - Test discharge water periodically for chlorine residual
    - When zero residual is measured, pump to waste for 15 minutes
  - Sample for bacteriological
  - Dispose of contaminated or highly chlorinated water properly

Disinfection After Equipment Installation

54

- Bacteriological evaluation (according to AWWA C654)
  - Collect 2 samples (duplicates) not less than 30 minutes apart
  - If any sample comes back total coliform positive
    - Pump well to waste for 15+ minutes, then take duplicate samples not less than 30 minutes apart
    - If still get positive
      - Re-chlorinate well using aforementioned steps OR
      - Take corrective action determined by qualified engineer
- If repeated attempts to disinfect the well are unsuccessful, a detailed investigation to determine the cause or source of the contamination should be undertaken

Disinfecting Existing Wells

55

- Wells should be disinfected after repairs and/or parts replacement
  - Swab inside of well casing with non-foaming detergent
  - Add chlorine to provide 100 mg/L in water
    - Based of well diameter and water depth
  - Add chlorine through hose that is raised and lowered to reach all areas of well, including that portion above the water
  - Clean and disinfect pump and other equipment prior to lowering into well
  - Disinfect well using proper AWWA standards

Sand in Well Systems

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Sand in Well Systems

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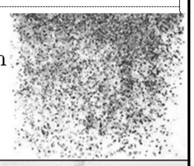

- Wells in alluvial formations are particularly susceptible to sand production
  - Nearly all wells will produce some sand
- Problems caused by sand
  - Equipment damage: pumps, plumbing fixtures, appliances, water meters, etc.
  - Deposition in distribution leading to decreased carrying capacity
  - Increased customer complaints
- Solutions:
  - Install sand separator
  - Lower flow rate
- Sand concentrations should not exceed 0.3 cu. ft./million gallons

Sand in Well Systems

58

Flushing Mains

- Sand in small diameter pipes is typically due to sand in larger mains supplying the water
  - Flush large mains to resolve complaints on small mains
- Must have sufficient velocity to remove sand during main flushing
- Sand may not appear immediately when flushing, but once it does flushing should continue until sand is no longer evident

Sand in Well Systems

59

Test for Sand, Volumetric Method

- Rossum sand sampler
  - Centrifugal sampler installed on the pump's discharge piping
  - Can be used to determine if new wells meet the specifications for sand volume
    - Sand concentrations greater when well is first started than after a period of continuous operation
  - When used daily, can alert operator of increase in sand production so steps can be taken before it enters the distribution system
  - Water velocity should be greater than 5 ft/sec for representative sampling

Sand in Well Systems

60

- Acceptable Concentrations
  - Should not exceed 0.1 ft^3/MG
    - When above 0.3 ft^3/MG, sanded meters and customer complaints will occur
- Customer Complaints
  - Try to determine source of sand and how many others experiencing same problem
  - Take corrective action:
    - Remove sand at well, flush main, move customer tap to top portion of main
  - Sand complaint can be isolated to one or two homes if customer's service lateral is tapped into the side of the main near a fitting or valve causing turbulence
    - Move tap to top portion of main

Abandoning and Plugging Wells

61

- A well that is no longer useful must be properly abandoned and plugged:
  - To ensure that the groundwater supply is protected and preserved
  - To eliminate the potential physical hazard to people
  - To protect nearby wells from contamination
- Residential wells can cause a cross-connection if home is connected to public water supply
- "Abandoned" after one year of no use, pumping unit has been removed, and well serves no useful purpose
- Objective is to restore those subsurface conditions that existed before well construction and prevent cross contamination between different aquifers

Abandoning and Plugging Wells

62

- Contact local regulator before making any changes that could change the status of your well
- "A well shall be considered permanently discontinued if it has not been used for a two (2) year period and is not included as a part of the wellhead protection plan as either an emergency backup well or future growth well for the water system." 0400-45-01-.34(5)(a)3
- "Abandoned wells within wellhead protection areas which are a potential threat to contamination of the public water supply shall be properly plugged and closed in compliance with provisions in the Water Well Act, T.C.A. § 69-11-106(11) by the property owner or other responsible party." 0400-45-01-.34(1)(d)1

Abandoning and Plugging Wells

63

- TN Design Criteria
  - Wells to be abandoned shall:
    - be sealed to prevent exchange of water from one geological strata to another, ideally mimicking the existing geological strata through which the well was drilled,
    - be filled with clay and sand, clay and concrete, or other suitable impermeable material,
    - if filled with concrete the latter shall not be dropped through water.

Abandoning and Plugging Wells

64

- "'Abandoned well' means any well the use of which has been accomplished or permanently discontinued because necessary operating equipment has been removed or a well is in such a state of disrepair that continual use for the purpose for which it was constructed is impractical. A well shall be considered permanently discontinued if it has not been used for a two (2) year period and is not included as a part of the wellhead protection plan as either an emergency backup well or future growth well for the water system. Emergency backup wells and future growth wells must be properly maintained and/or secured. Emergency wells that are not in continuous use must be properly maintained, pumped and tested at least annually. Wells used for the regular, ongoing, collection of water-levels, water-quality, or other scientific measurements are not abandoned, but are considered observation wells. Observation wells must be properly maintained and have adequate protection to prevent their becoming a route for contamination. " 0400-45-01-.34(5)(a)3

Abandoning and Plugging Wells

65

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Vocabulary

A. Alluvial
B. Appurtenance
C. Aquifers
D. Available chlorine
E. Brake horsepower
F. Cone of depression
G. Drawdown
H. Evaporation
I. Foot valve
J. Head
K. Hydrologic Cycle
L. Overdraft
M. Pet cock
N. Pore
O. Porosity
P. Prime
Q. Sounding tube
R. Specific yield
S. Suction lift
T. Transmissivity
U. Transpiration
V. Water hammer
W. Zone of saturation

1. _____ a natural underground layer of porous, water-bearing materials usually capable of yielding a large amount or supply of water
2. _____ the process of evaporation of water into the air and its return to earth by precipitation
3. _____ the process by which water or other liquid becomes a gas
4. _____the process by which water vapor is released to the atmosphere by living plants
5. _____ the soil or rock located below the top of the groundwater table
6. _____ a measure of the spaces or voids in a material or aquifer
7. _____ the quantity of water that a unit volume of saturated permeable rock or soil will yield when drained by gravity
8. _____ the measure of the ability to transmit (as in the ability of an aquifer to transfer water)
9. _____ a very small open space in a rock or granular material
10. _____ the pumping of water from a groundwater basin or aquifer in excess of the supply flowing into the basin
11. _____ the depression, roughly conical in shape, produced in the water table by the pumping of water from a well
12. _____ the drop in the water table or level of water in the ground when water is being pumped from a well.
13. _____ a pipe or tube used for measuring the depths of water
14. _____ a small valve or faucet used to drain a cylinder or fitting
15. _____ a special type of check valve located at the bottom end of the suction pipe on a pump; holds pump's prime
16. _____ machinery, appliances, structures, or other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure

17. _____ the result of opening or closing a valve too quickly causing a change in pressure that can lead to main damage
18. _____action of filing a pump casing with water to remove the air
19. _____ a measure of the amount of chlorine available in chlorinated lime, hypochlorite compounds, and other materials that are used as a source of chlorine
20. _____ the vertical distance, or energy of water above a reference point; may be measured in feet or psi
21. _____ the negative pressure on the suction side of a pump
22. _____ the horsepower required at the top or end of a pump shaft; the energy provided by a motor or other power source
23. _____ relating to mud or sand deposited by flowing water; these deposits my occur after a heavy rain

Answers

1. C	13. Q
2. K	14. M
3. H	15. I
4. U	16. B
5. W	17. V
6. O	18. P
7. R	19. D
8. T	20. J
9. N	21. S
10. L	22. E
11. F	23.A
12. G	

Section Review Questions

1. What is the purpose of a well?

2. What is the hydrologic cycle?

3. What does porosity measure?

4. Why are there openings in the top of a well?

5. What is the purpose of the well-casing vent?

6. How would you determine the distance down to the water level in a well?

7. What is the purpose of a check valve?

8. What is the purpose of pump control valves?

9. Why must flows be known when chemicals are being applied at a well pumping station?

10. What is the purpose of surge suppressors that are sometimes installed on the discharge side of a booster pump?

11. What is the purpose of and air release and vacuum breaker valve?

12. What is the purpose of an air charger?

13. List three major well maintenance problems.

14. How can overpumping an aquifer damage the aquifer?

15. Encrusting waters are usually (circle one) alkaline/acidic; while corrosive water are usually alkaline/acidic.

16. Why should the use of two or more different types of metals be avoided in a well?

17. What records should be kept regarding a well?

18. What is the purpose of surging?

19. How can the pores in a well screen and the gravel pack around the screen be cleaned?

20. How can encrustation be removed from the well casing and well?

21. How can bacterial growths and slime deposits be removed from well screens?

22. When the yield of a water well declines, what three factors should be investigated to determine the cause?

23. What are the two basic groups of well pumps and the difference between them?

24. When should a well be disinfected?

25. What would you do if repeated attempts to disinfect a well are unsuccessful?

26. Why does the disinfection of existing wells after well or pump repairs require special disinfection methods?

Section Review Questions – Answers

1. to intercept groundwater moving through aquifers and bring water to the surface for use by people

2. he continuous circulation of water on our planet; the process of evaporation of water into the air and its return to the earth by precipitation

3. the openings or voids in a particular soil; quantifies the amount of water that a particular soil type or rock can store

4. to permit the entrance or escape of air or gas and to provide access to the well for taking water level measurements, adding gravel, or for applying disinfection or well cleaning agents

5. to prevent vacuum conditions inside a well by admitting air into the well during the drawdown period when the well pump is first started; to prevent pressure buildup inside the well casing by allowing excess air to escape during the well recovery period after the well pump shuts off

6. inserting a measuring tape into the sounding tube, lowering it down the tube to the water level, and recording the distance; or, air pressure in a sounding line may be used

7. acts as an automatic shutoff valve when the pump stops to prevent draining of the system or the tank being pumped to, and to prevent pressurized water from flowing back down the pump column into the well

8. to eliminate the pipeline surges when the pump is started and stopped

9. in order to calculate the correct chemical feed rate

10. to absorb shock waves in the water system and prevent their transmittal through the line; to prevent water hammer

11. to exhaust large quantities of air very rapidly from a deep well pump column when the pump is started, and to allow air to re-enter the pump column and prevent a vacuum from developing when the pump stops

12. adding air to hydropneumatic tanks

13. overpumping and lowering of the water table
    clogging or collapse of a screen or perforated section
    corrosion or encrustation

14. by reducing storage and production capacity of groundwater systems

15. alkaline; acidic

16. corrosion is usually greatest at the points of contact of the different metals or where they come closest to contact; galvanic corrosion

17. water level measurements in the well before and after pumping; flow rates; water quality samples; length of time pumping; accurate data on pump repairs and causes

18. to open pores in the screen and for cleaning the gravel pack around the screen

19. high velocity jetting

20. acid treatment

21. chlorine treatments

22. the aquifer, the well, and the pump

23. positive displacement pumps - deliver the same volume of water against any head
    dynamic pumps - deliver water with the volume or flow varying inversely with the head

24. following development, testing for yield, and before the test pump is removed from the well, or when there is evidence of contamination

25. a detailed investigation to determine the cause or source of the contamination should be undertaken

26. during repair work, deposits of slime, bacterial growth, and other debris are dislodged from the inside surfaces of the well pump column pipe; these deposits can be smeared on the inside surfaces of the well casing which will require swabbing of the inside of the well casing

Section 4

Small Water Plant Operation

Small Water Treatment Plants

California State University: Sacramento
Small Water System Operation and Maintenance

Updated 11/13/2023

Groundwater

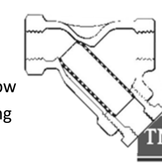
- Iron and manganese control (Fe and Mn)
  - Controlled by oxidation – converting the dissolved form to the insoluble form
    - e.g. liquid ferrous iron (Fe^{2+}) to solid ferric iron (Fe^{3+})
  - Feed oxidizing agent (e.g. chlorine or potassium permanganate) with oxygen to oxidize iron and manganese and form the insoluble (precipitated) form
  - Remove precipitates with sedimentation and/or filtration
- Softening
  - Hardness due to calcium and magnesium ions (Ca and Mg)
  - Softening achieved by ion exchange or chemical precipitation (lime-soda ash softening)

Surface Waters

- Raw water storage
- Diversion works
- Flow measurement
- Disinfection
- Coagulation
- Flocculation
- Settling
- Filtration
- Corrosion Control
- Treated Water Storage
- High service pumps

Surface Water

- Raw Water Storage
  - Slows influent water quality changes
  - Maintain production during source shutdown
- Diversion Works
  - Diversion dam, bar & trash screens, intake pipe/structure, pumps, water conveyance piping, flow control valves
- Flow measurement
  - Should indicate instantaneous flow and total flow
  - Install wye strainer upstream to prevent clogging



Surface Water

- Disinfection
  - Chlorine is recommended disinfectant
  - Prechlorination minimizes organic growth in treatment units
- Coagulation
  - Chemical feed with rapid mix to create microfloc
- Flocculation
  - Slowly mixing water to create larger settleable floc (macrofloc)
- Settling
  - Allows suspended matter to separate from water by gravity

Surface Water

- Filtration
  - Removes remaining suspended matter after sedimentation
- Corrosion control
  - Water stability to minimize corrosion and scaling
- Treated water storage
  - Reservoirs allow treated water to be stored to meet peak demands and provide water during outages
- High service pumps
  - Draws finished water from storage and supply it under pressure

Package Plants

- Most commonly used for filtration of turbid water and removal of dissolved iron and manganese
- Includes all treatment equipment, pumps, chemical feeders, and controls
  - May choose instead to select a custom designed package plant with materials supplied by different manufacturers
- Advantages
  - Design and equipment have already proven effective
  - All bugs eliminated giving purchaser a high degree of confidence and performance
- No plant is completely automatic - still requires maintenance, repair, and occasional process control changes.

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Coagulation & Flocculation

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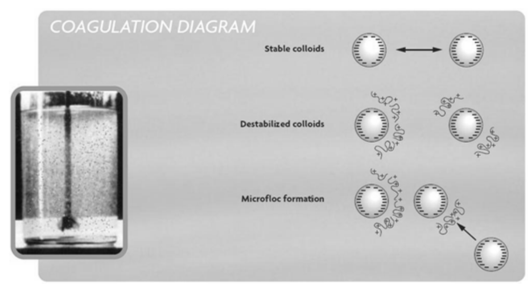
Coagulation

- Chemical reaction when coagulating chemical is added to water
  - Most common is aluminum sulfate (alum)
- Coagulant reacts physical with fine particles of suspended matter in the water
  - Colloidal particles have a net negative charge causing them to repel each other
    - Zeta Potential
  - Coagulant neutralizes negative charge to destabilize particles allowing them to come together
    - Van Der Waals force
  - Reaction occurs within 2-5 seconds of chemical application
  - Maximum detention time: 30 seconds

TN

Coagulation



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Factors Affecting Coagulation

- Coagulant used and dosage
  - Chemical and dosage must be optimized based on source water
- Water pH
  - 6.5 – 8.5
- Alkalinity
  - Must have sufficient alkalinity when using metallic salt
- Mineral content of water
  - Different minerals will affect coagulation differently
- Water temperature
  - Better coagulation in warmer water

TN

Coagulation Optimization

- Is the pH after addition of the coagulant the same as when good coagulation occurs?
  - Daily pH records should be maintained
- Is adequate alkalinity present for coagulation reaction?
  - Consider increasing alkalinity to have at least 30 mg/L remaining after chemical reaction complete by adding lime
- Is chemical feeder supplying correct dosage of coagulant?
  - Dry chemical – collect sample of chemical for selected amount of time to compare to set feed rate
  - Solution chemical – use site tube to measure actual feed rate versus set rate

TN

Coagulation Optimization

- Does the chemical feeder inject a steady chemical feed into the water?
  - Want consistent pulses vs long interval slug
- Is chemical injector distributing coagulant throughout flow of water?
  - Injectors with multiple-feed orifices better than single orifice
- Is violent rapid mixing provided just after chemical if feed?
  - Install mechanical mixer or relocate injection point to zone of turbulent flow
- Is a coagulant aid needed?
  - Polymer or weighting agent

TN

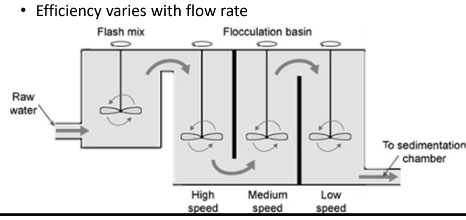
Flocculation

- Process of slow, gentle mixing of the water to bring smaller floc particles together to form macrofloc
- Mixing must be strong enough to encourage floc formation without settling, but not so strong to break floc apart
- Mechanical mixing
  - Consists of slowly rotating paddles
  - Mixing becomes progressively more gentle as water flows through flocculation basin
  - Preferred method due to flexibility to maintain mixing regardless of flow rate and adjustable agitation rates

TN

Flocculation

- Hydraulic mixing
  - Water flows around obstructions of baffles or through interconnected chambers
  - Disadvantages
    - Less uniform and controllable
    - Efficiency varies with flow rate



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Factors Affecting Flocculation

- Degree of mixing
  - Too gentle – particles will not be brought into contact with one another, and larger floc will not form
  - Too violent – floc will be torn apart (sheared) preventing size large enough to settle out independently
- Time
  - Minimum 30 minutes with 45 minutes recommended
  - Minimize short circuiting – water travelling through basin is less than designed time
    - Add baffles or compartments – three recommended
- Number of particles
  - Clean water is harder to treat due to decreased collisions between particles

TN

Flocculation Optimization

- Correct any deficiencies in the coagulation process
- Check degree of mixing – neither too violent nor too gentle
- Adequate mixing time
  - Do actual flow rates exceed design flows?
- Minimize short circuiting through basin
- Adjust plant to run on a more continuous basis and minimize frequent on/off operation

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Sedimentation

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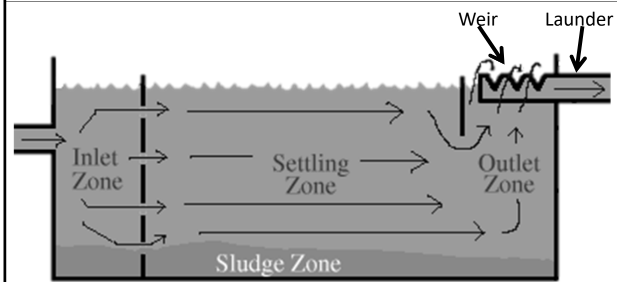
Sedimentation or Clarification

- Process of holding water in quiet, low-flow condition to allow for settling of suspended particles by gravity
- Tank has four zones
  - Inlet zone – water entering tank distributed across tank with a slow uniform flow velocity
    - Aka influent zone
  - Settling zone – water flows slowly through tank allowing suspended particles to settle out
  - Sludge zone - area where settled material lands in bottom of tank
  - Outlet zone – water is collected in weirs or launders and flows to tank outlet
    - Aka Effluent zone

Zones of Sedimentation Tank



Sedimentation

Factors Affecting sedimentation

- Time
  - Minimum 4 hours for conventional sedimentation
  - Maybe reduced to 1 hour with tube or plate settlers
- Suspended matter characteristics
  - Denser material settles faster than light, fluffy particles
  - Determined by coagulation/flocculation process
- Short-circuiting
  - Long narrow tank more effective than short, wide tank
- Tank inlet/outlet arrangement –
  - Minor changes can cause drastic changes in settling efficiency
  - Inlet should distribute water evenly both horizontally and vertically while avoiding high velocities and eddy currents
  - Outlet should collect water uniformly and near the surface

Factors Affecting sedimentation

- Surface overflow rate (SOR)
  - aka surface loading rate (SLR)
  - Lower rate is better than a higher rate
  - Should be between 0.25 – 0.38 gpm/ft^2
- Currents in tank
  - Caused by flow inertia, wind action, temperature differences, and poor design
  - Can cause short-circuiting, resuspend settled particles
- Water temperature
  - Particles settle faster in warm water than in cold water
  - Cold water is more viscous and creates more resistance
- Wind
  - Can cause currents and turbulence decreasing settling

Settling Optimization

- Check coagulation/flocculation process operation
- Decrease rate of flow to lower surface overflow rate and flow velocity
- Improve inlet conditions to reduce velocity, distribute flow uniformly, create uniform flow velocities
  - If more than one tank used, ensure flow divided equally across tanks
- Improve outlet conditions to eliminate velocities
- Remove accumulated sludge
- Cover tank to minimize currents caused by wind and weather
- Recycle sludge to inlet to increase number of particles in water

Sedimentation

- High-rate settlers (tube or plate settlers) increase settling efficiency in sedimentation basins
  - Provides surface area for particles to settle on

Tube Settler

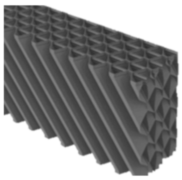
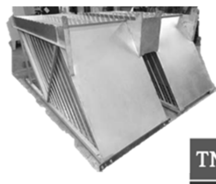


Plate Settler



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Filtration

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Filtration

- Process of passing water through a porous bed of material to remove suspended matter from the water
- Two types
  - Gravity filter – water enters tank near the top and flows downward through media under force of gravity
    - Slow sand filter – uses biological process as well as physical straining
  - Pressure filter – water is forced through enclosed tank through filter media under pressure created by an external force

TN

Filter Media layers

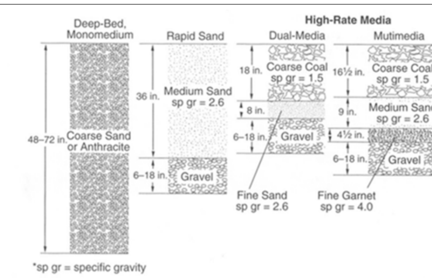

FIGURE 6–8 Comparison of deep-bed, rapid sand, and high-rate filter media

TN

Filtration Modes

- Conventional filtration
  - Used with highly variable raw water quality and large volumes of water are required
  - Filtration accomplished by straining and adsorption
  - Includes coagulation, flocculation, & sedimentation prior to filtration
- Direct filtration
  - Used with waters low in turbidity, color, plankton, & coliforms
  - Includes coagulation & flocculation prior to filtration
    - Sedimentation step is omitted
    - This method must be approved by State

These filters are cleaned by backwashing

TN

Filtration Modes

- Diatomaceous earth (precoat) filtration
  - DE is added as a slurry to water being treated and collects on a screening device
  - Water is filtered by passing it through the screening device coated in DE
  - Used where very high particle removal efficiencies required
  - Can be operated as gravity or pressure filter
- Slow sand filtration
  - Particles removed by straining, adsorption, and biological action
  - Majority of particulate removal in top few inches of sand
  - Schmutzdecke
  - Filter cleaned by remove the top 2 inches of filter media

TN

Filtration Media

- Anthracite – hard coal prepared by crushing coal and sieving to get proper size
  - effective size of 0.8 mm to 1.2 mm with a uniformity coefficient not greater than 1.85
  - 1.5 times heavier than water
- Sand – should be hard material like quartz that will not erode or easily dissolve in water
  - effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70
  - 2.5 times heavier than water
- In 30 inch dual media filter, anthracite should be 18-20 inches deep and sand should be 10-12 inches deep

Filtration Media

- Garnet – group of hard, reddish, glassy mineral sands with high density used at bottom of filter
  - When added, this makes filter a multimedia filter
- Underdrain – under filtering media
  - Supports filter media and prevents media passing through bottom of filter
  - Collects filtered water and conveys water from filter
  - Uniformly distributes backwash water across filter bed
    - Most important function

Filtration Rates

- Slow sand filters – max 2 gpm/ft^2
  - Assumed Log Removals by Filtration Method
    - Giardia – 2.0 log removal
    - Viruses (crypto) – 2.0 log removal
- High-rate filters – max 4 gpm/ft^2
  - Assumed Log Removals by Filtration Method
    - Giardia – 2.5 log removal
    - Viruses (crypto) – 2.0 log removal
  - Includes
    - Rapid sand filters
    - Dual media filters
    - Multimedia filters

Filtration

- Filter continuously removes suspended matter while in operation
  - Matter clogs openings and decreases flow through filter
    - Will eventually lead to turbidity breakthrough
    - Head loss will gradually build up
- When terminal head loss is achieved, filter must be cleaned
  - Backwash – reversal of flow direction through filter to flush collected dirt out of media
    - Filter bed expands allowing media grains to scrub against each other and knock off dirt particles
    - Want to leave the filter cleaner but not too clean
      - Ripen filter (filter to waste) before placing filter back in service

Filtration

- Backwashing frequency varies from facility to facility
  - Based on time, flow, head loss, and/or effluent turbidity
  - Consistency is key – have a good SOP
- Bed should be expanded to at least 50% its normal depth
  - Not so much that media overflows into troughs
- Minimum backwash rate for sand filters – 18.75 gpm/ft^2
- Surface wash or subsurface wash required
- Good backwashing increases filter run lengths, finished water production, finished water quality, etc
- Poor backwashing increases finished turbidity, mudball formation, filter short circuiting, decreases filter run time and finished water production

Filter Optimization

- Optimize coagulation, flocculation and sedimentation
  - Settled water turbidity should not exceed 5.0 ntu
- Ensure filtration rate is not higher than designed
- Backwash filter effectively to prevent mudballs
- Operate filter to minimized rapid filter rate changes
  - Eliminate on/off operation
- Inspect media condition frequently
  - Look for loss in depth, mudballs, caking, surface cracks, and mounding or unevenness

Filter Optimization

- Observe filters during backwash and filtering periods to determine condition of underdrain
  - Gravel disturbance and broken underdrains will allow media to pass through in finished water during filtration
  - Mounded media, sand boils, or evidence of uneven upward flow during backwash indicates underdrain issues
- Provide accurate flow and headloss gauges
- Consider feeding a polymer filter aid

Corrosion Control

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Corrosion

- Electrochemical reaction
- Decrease flow capacity of pipelines
- Increase pumping costs
- Decrease delivered water quality
- Cause water to become discolored or turbid from rust particles
- May lead to water containing harmful concentrations of metals

Corrosion Control

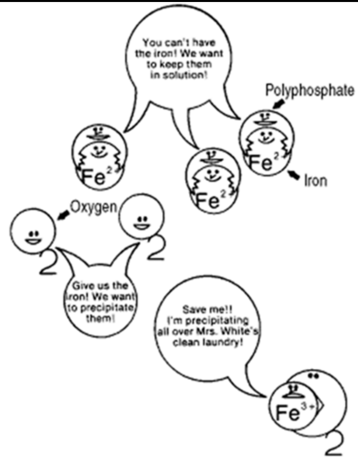
- 2 General Methods
  - Use corrosion resistant materials during construction
  - Treat water with chemicals to make it noncorrosive
    - Increasing pH of water using lime, soda ash, caustic soda,
    - Sodium silicate or polyphosphates
- Chemical Corrosion Control
  - Set to adjust the pH so a thin film of calcium carbonate is deposited on the pipe surface
    - Langelier Saturation Index
  - Applied after all other treatment has been accomplished
    - To avoid negatively impacting coagulation and disinfection with a high pH
    - To avoid a carbonate coating on filter media

Corrosion Control

- pH of water can be used as day-to-day indicator of corrosive nature of water
  - High pH is less corrosive than low pH
  - Examine coupons from system pipelines
- Tests to monitor corrosivity
  - Langelier Saturation Index
    - Negative number = aggressive water
    - Positive number = scale forming tendencies
  - Marble Test
    - Performed in lab
  - Coupon Test
    - Performed in finished water

Corrosion Control

- Chemical Corrosion Control Program
  - Orthophosphates
    - Create calcium carbonate coating on interior of pipeline
  - Polyphosphates
    - Sequester (tie up) those constituents that could lead to aggressive water



Slow Sand Filtration

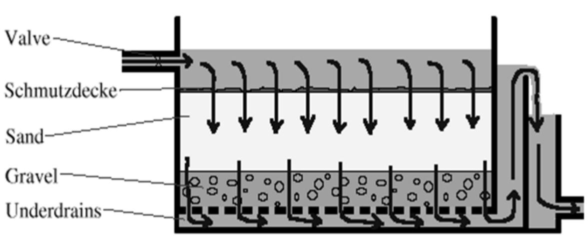
Procedure for Treating Water

- Filtration rate is 50-100 times slower than rapid sand filtration
- Simple design with easy operation
- Able to remove Giardia cysts as well as Cryptosporidium
- No chemical pretreatment
- Biological process aids in removal of suspended matter
  - Dense population of microorganisms develops as the layer of trapped matter builds up – schmutzdecke
    - Mat is only about an inch thick
  - Organisms within film/mat feed on and break down incoming organic matter
    - Thus, thickening the mat and increasing the physical straining action

Procedure for Treating Water

- Other varieties of organisms form a biofilm deeper in the sand media
  - Organic material passing through media sticks to biofilm
  - Organisms use the material and remove it or convert it to CO_2 and water
- Filter is "ripened" when schmutzdecke and biofilm are developed enough to produce acceptable filtered water
- To clean, simply scrape off the top layer of sand and accumulated material (generally less than 1 inch)
  - With time, the bed will ripen again
- Principal removal mechanism is physical straining or entrapment of particles in the schmutzdecke and biofilm

Procedure for Treating Water



Components

- Filter Tank
  - May be built onsite or prebuilt
  - May be circular, square or rectangular
  - Should consist of two or more equal sized chambers or cells
    - Can be operated independent of each other
  - Surface area of filter will vary from site to site, but depth is less variable
    - Sum of gravel support layer, sand bed, and maximum water depth above the filter and the freeboard (distance between media and bottom of trough)

Components

- Underdrain System
  - Supports filtering media and prevents media passing through bottom of filter
  - Collects filtered water & conveys water out of filter
  - Perforated pipe collects filtered water, flows through the header, and flows out to clearwell
  - Bed of gravel covers perforated piping to
    - Reduce water velocity
    - Support sand media
    - Prevent sand from being carried into underdrain pipes
    - Help distribute water evenly when tank is being filled

TN

Components

- Sand Media Bed
  - Generally silica sand
  - Goal is to construct a bed that produces acceptable quality finished water while ensuring that the bulk of the particulate matter accumulates on the upper layers without reducing filter run times
    - Too small sand will tend to clog and shorten run times
    - Too large sand will allow particulate buildup deeper in the media
  - New sand must be clean and free of particles of dirt, clay, or organic matter
    - Since no backwashing, high turbidity levels could continue for extended periods of time

TN

Components

- Flow Control Piping, Valves, and Gauges
  - Slow sand filter requires a constant flow of water through the filter
  - Headloss increases over time as the schmutzdecke develops and more material is retained in the top layer of sand
    - Maintain flow as headloss increases
      - By adjusting raw water influent valve
        - "Rising water level" method - headwater surface level rises as head loss through filter increases
      - Adjusting finished water effluent valve
        - As headloss increases, valve is opened to lower head loss through the valve and achieve the desired flow rate

TN

Components

- Outlet Chamber
  - Maintains 3+ inches of water over top of sand bed during operation
    - Prevents accidental dewatering and drying of the filter
    - Prevents air from entering and becoming trapped in media
      - Air binding
  - Adjustable weir allows weir crest to be about 1 foot
    - As headloss builds up, weir can be lowered to maintain 1 foot of water above sand bed
  - Use hook gauge test to determine actual flow rate

TN

Components

- Finished Water Holding Facility
  - Based on capacity needed to
    - provide detention time for disinfection
    - Meet peak daily demand & fire protection requirements
    - Provide emergency reserves expected in case of power outages
  - Slow sand filters work best under steady flow rates
  - Should have 12 hours of storage capacity
  - If water is chlorinated before entering holding facility, the time that water is in the holding facility is part of the contact time when calculating CT value

TN

Components

- Hydraulic Controls and Monitoring Devices
  - Influent valve - used to isolate filter for maintenance
  - Supernatant drain valve - permits tank water level adjustment
  - Filter overflow drain - prevents flooding of facility if filter clogs
  - Filter-to-waste valve - permits disposal of water during the ripening period
  - Backfilling valve – used to fill filter through underdrain system
  - Treated water waste valve – permits disposal of excess finished water
  - Valve to clear well – used to isolate filter during maintenance
  - Flow meters – measures flow throughout treatment process

TN

Typical Filter Operating Cycle

- Small Water System Operation and Maintenance
  Office of Water Programs
  Collection of Engineering and Computer Science
  California State University, Sacramento
  Chapter 4

Find more information on the subject of
- Solids-contact Clarification
- Slow Sand Filtration
- Iron and Manganese Control
- Softening
- Operation
- Maintenance

Small Plants – Vocabulary

A. adsorption
B. alkalinity
C. clear well
D. coagulation
E. diatomaceous earth
F. flocculation
G. garnet
H. jar test
I. mudballs
J. precipitate
K. short-circuiting
L. slurry
M. trihalomethanes
N. wye strainer

1. _____ a screen shaped like the letter Y; water flows through upper part of Y and debris is trapped by screen at the fork

2. _____ derivatives of methane in which three halogen atoms are substituted for three of the hydrogen atoms; often formed during chlorination by reactions with natural organic materials in the water

3. _____ the clumping together of very fine particles into larger particles (microfloc) caused by the use of chemicals

4. _____ a reservoir for the storage of filtered water of sufficient capacity to prevent the need to vary the filtration rate with variations in demand; also used to provide chlorine contact time for disinfection

5. _____ capacity of water to neutralize acids; caused by water's content of carbonate, bicarbonate, and hydroxide.

6. _____ laboratory procedure in which varying dosages of coagulant are tested in a series of jars under identical conditions

7. _____ the gathering together of fine particles after coagulation to form larger particles called macrofloc by a process of gentle mixing

8. _____ a condition that in tanks or basins when some of the flowing water entering a tank or basin flows along a nearly direct pathway from the inlet to the outlet

9. _____ an insoluble, finely divided substance that is a product of a chemical reaction within a liquid

10. _____ a fine, siliceous earth composed mainly of the skeletal remains of diatoms

11. _____ a water mixture or suspension of insoluble matter

12. _____ the gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another material

13. _____ a group of hard, reddish, glass, mineral sands made up of silicates of base metals

14. _____ material, approximately round in shape, that forms in filters and gradually increases in size when not removed by the backwashing process

Vocabulary -Answers

1. N	8. K
2. M	9. J
3. D	10. E
4. C	11. L
5. B	12. A
6. H	13. G
7. F	14. I

Small Plants Review Questions

1. How does the storage of raw water in lakes, ponds, or reservoirs help the water treatment plant operator?

2. What information does an operator obtain from a flowmeter?

3. How can a flowmeter be protected?

4. Groundwaters may require what types of treatment?

5. What is the influence of temperature on the coagulation process?

6. How can the alkalinity of the water being treated be increased?

7. What is flocculation?

8. What happens if the flocculation mixing is too strong or too weak?

9. What is the purpose of settling?

10. Short-circuiting is influenced by what factors?

11. How does temperature influence particle settling?

12. Why is sludge recycled to the inlet of the settling tank?

13. What is included in the suspended matter removed by filtration?

14. Why do anthracite and sand stay separated during and after backwashing?

15. What is a mixed media (multimedia) filter?

16. Under what conditions will mudballs form in filters?

Small Plants Review Questions – Answers

1. by slowing the rate of change in water quality due to rainstorms and other factors

2. the instantaneous rate of flow as well as the total quantity of water that has flowed through it

3. by a fine screen or wye strainer installed upstream from the meter to prevent clogging or damage by trash or rocks

4. disinfection, iron and manganese control, and softening

5. the warmer the water, the faster the coagulation chemical reactions

6. by adding lime or soda ash prior to coagulation

7. a process of slow, gentle mixing of the water to encourage the tiny floc in the flocculation basin, but the mixing must not be so strong that it breaks apart the floc particles already formed

8. mixing must be strong enough to prevent premature settling of floc in the flocculation basin, but no so strong that it breaks apart the floc particles already formed

9. to remove as much of the floc and other suspended material as possible before the water flows to the filter

10. (1) the shape and dimensions of the tank, and (2) the inlet and outlet arrangements of the tank

11. the warmer the water, the faster the particles settle

12. to increase the number of particles in the water and improve flocculation of the settling particles

13. mainly particles of floc, soil, and debris; but also living organisms such as algae, bacteria, viruses, and protozoa

14. sand is 2.5 times heavier than water and anthracite is 1.5 times heavier than water

15. a mixed media filter contains three layers of media: garnet, sand, and anthracite

16. mudballs form if backwashing does not effectively clean the media

Section 5

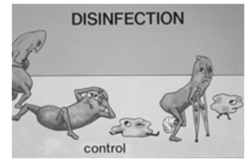
Disinfection

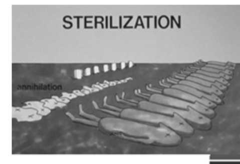
Disinfection

California State University: Sacramento
Water Treatment Plant Operation Vol. I

Disinfection vs. Sterilization

- Water is the universal solvent
- Disinfection – the destruction of pathogenic organisms
  - Prevents waterborne disease outbreaks
  - Destroys only disease-causing organisms
- Sterilization – the destruction of all organisms in the water
  - Not all microorganisms are bad!





Safe Drinking Water Laws

- USEPA (US Environmental Protection Agency)
  - Responsible for setting drinking water standards
- SDWA (Safe Drinking Water Act)
  - Sets MCLs (maximum contaminant levels)for substances known to be hazardous to human health
- GWR (Ground Water Rule)
  - Designed to reduce incidence associated with harmful microorganisms in drinking water

Process of Disinfection

Purpose of Disinfection

- To destroy harmful organisms
- Physical disinfection
  - Removes the organisms from the water, or
  - Introduces motion that will disrupt the cells' biological activity and kill or inactivate them
- Chemical disinfection
  - Alter the cell chemistry causing microorganism to die
  - Most widely used is chlorine because it is easily obtained and leaves a measurable residual chlorine

Factors Influencing Disinfection

- pH — ↑ pH ↓ efficiency
- Temperature — ↑ temp ↑ efficiency
- Microorganisms — ↑ bacteria ↓ efficiency
- Reducing Agents — ↑ reducing agents ↓ efficiency
  - Substances in water that donate (give up) electrons easily
  - Examples:
    - Turbidity - physical cloudiness of water
    - Organic Matter - contains carbon
    - Inorganic Matter - does not contain carbon
      - Hydrogen sulfide gas (H_2S)
      - Ferrous ion (Fe^{2+})
      - Nitrite ion (NO_2^-)
      - Manganous ion (Mn^{2+})
      - Ammonia (NH_3)

Physical Disinfection

- Ultraviolet Rays (UV)
  - UV radiation is absorbed by the microorganism's cells and damages the genetic material so that they are no longer able to grow or reproduce, thus killing them
  - Rays must come in contact with each microorganism
  - Lack of measurable residual
- Heat
  - Boiling water for 5 minutes will destroy essentially all microorganisms (sterilize)
- Ultrasonic Waves
  - Sonic waves destroy microorganisms by vibration

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Chemical Disinfection

- Iodine
  - Limited to emergency use due to high cost and negative health effects
- Bromine
  - Very limited due to handling difficulties
- Bases (sodium hydroxide and lime)
  - High pH leaves a bitter taste in water
- Ozone
  - High costs, lack of chlorine residual, difficult to store, high maintenance requirements

TN

Chemical (Chlorine) Disinfectants

- Chlorine gas -- Cl_2
  - 100% pure
  - Gas or liquid
  - Liquid chlorine
- Calcium hypochlorite -- $Ca(OCl)_2$
  - 65% pure
  - Solid
  - HTH – high test hypochlorite
- Sodium hypochlorite -- NaOCl
  - 5-15% pure
  - Liquid
  - Bleach

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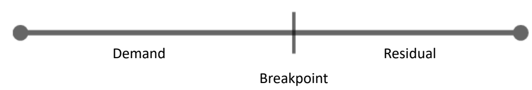
Breakpoint Chlorination

- The process of adding chlorine to water until the chlorine demand has been satisfied
  - Further additions of chlorine will result in a chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint



  - Chlorine dose = residual + demand
  - Total Residual Chlorine (TRC) = Free residual + Combined residual

TN

Breakpoint Chlorination

- <u>Chlorine demand</u> - the point where the reaction with organic and inorganic materials (aka reducing agents) stops
- <u>Chlorine residual</u> – the total of all the compounds with disinfecting properties plus any remaining free chlorine
- <u>Chlorine dose</u> – the amount of chlorine needed to satisfy the chlorine demand and the amount of chlorine residual needed for disinfection

Dose = Demand + Residual

Demand = Dose - Residual

TN

Chlorine Gas Reaction

$$Cl_2 + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{hydrochloric acid}}{HCl}$$

Lowers pH (HCl)

- Free chlorine combines with water to form hypochlorous acid
  - Most effective disinfectant
  - Dissociates at higher pH (greater than 7)

$$\underset{\text{hypochlorous acid}}{HOCl} \rightarrow H^+ + \underset{\text{hypochlorite ion}}{OCl^-}$$

  - Hypochlorous acid (HOCl) has a much higher disinfection potential than hypochlorite ion (OCl^-)

TN

Chlorine and Impurities in Water

- Ammonia (NH_3)
  - Reacts with chlorine to form chloramines
- Organics
  - React with chlorine to form suspected carcinogenic compounds (THMs)
- Hydrogen Sulfide
  - Inorganic reducing agent
  - Causes rotten egg odor
  - Reacts with chlorine to form:
    - Elemental sulfur (causes odor problems and precipitate as finely divided white particles)
    - Sulfuric acid (lowers pH)

TN

Chlorine Gas

- Properties of Chlorine
  - Greenish-yellow gas
  - 2.5 times heavier than air
  - Volume of gas will increase by almost 90% when temperatures rise
  - Liquid expands to 460 times the volume as a gas
  - Nonflammable and nonexplosive, but will support combustion

TN

Hypochlorite

- Achieves same result as chlorine gas
- May be applied in the form of calcium hypochlorite ($Ca(OCl)_2$) or sodium hypochlorite (NaOCl)
- Reactions with Water

$$Ca(OCl)_2 + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{calcium hydroxide}}{Ca(OH)_2}$$

$$NaOCl + H_2O \rightarrow \underset{\text{hypochlorous acid}}{HOCl} + \underset{\text{sodium hydroxide}}{NaOH}$$

  - Raises pH due to addition of OH^- ion

TN

Chlorine Residual

- Chlorine is effective in control biological agents and eliminating coliform bacteria
- To ensure adequate control of coliform aftergrowth, a chlorine residual of 0.2 mg/L in the distribution system can be a good indicator
  - A lack of this residual could indicate the presence of a heavy contamination
  - Perform daily chlorine residual tests
- Any sudden absence of a residual needs prompt investigation:
  - Retest chlorine residual
  - Check chlorination feed and testing equipment
  - Search for source of contamination

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Factors Affecting Chlorination

- Effectiveness of upstream treatment processes (reducing agents)
  - Lower turbidity = better (more efficient) disinfection
- Injection point and method of mixing to ensure complete contact
- Temperature
  - Higher temp = more rapid the disinfection
- Dosage and type of chemical
  - Higher doses = faster disinfection
- pH
  - Lower pH = better (more efficient) disinfection

MOST IMPORTANT!

- **Contact time**
  - Longer contact time = better (more efficient) disinfection
- **Concentration**
  - Higher chlorine residual = faster disinfection

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Operation of Chlorination Equipment

Fleming Training Center — Your Partner in Clean Water
TN Department of Environment & Conservation

Fleming Training Center
TN Department of Environment & Conservation

Chlorinators

Chlorinator

- Chlorine gas may be removed from chlorine containers by a valve and piping arrangement to the chlorinators
- Chlorine gas is controlled, metered, and introduced into a stream of injector water, and then is conducted as a solution to the point of application
- Safety
  - Protective clothing: gloves and rubber suit
  - Self-contained pressure-demand air supply system (SCBA)
  - Chlorine leak detector set at floor level
    - Warning device located outside chlorine room

Chlorinator Parts & Purposes

Parts	Purpose
Pressure gauge	Indicate chlorine gas pressure at from chlorine manifold and supply
Gas supply	Provides source of chlorine gas from containers to chlorinator system
Vacuum regulator – check unit	Maintains constant vacuum on chlorinator
Standby pressure relief	Relieves excess gas pressure on chlorinator
Vent	Discharges any excess chlorine gas (pressure) to atmosphere outside of building
Gas inlet	Allows gas to flow from chlorine container through supply line and gas manifold into chlorinator inlet

Chlorinator Parts & Purposes

Parts	Purpose
Heater	Prevents reliquefaction (return of gas to liquid form)of chlorine gas
Vacuum gauge	Indicates vacuum on chlorinator system
Rotameter tube and float	Indicates chlorinator feed rate by reading top of float or center of ball for rate marked on tube
Differential regulating (reducing) valve	Regulates (reduces) chlorinator chlorine gas
V-notch plug and variable orifice	Control chlorine fed rate by regulating flow of chlorine gas
Vacuum relief valve	Relieves excess vacuum by allowing air to enter system and reduce vacuum
Injection vacuum gauge	Indicates vacuum at the injector

Chlorinator Parts & Purposes

Parts	Purpose
Diaphragm check valve	Regulates chlorinator vacuum, which adjusts chlorinator feed rate
Manual feed rate adjuster	Regulates chlorine feed rate manually instead of the more common automatic
Injector water supply	Provides source of water for chlorine solution with sufficient pressure and volume to operator the injector
Injector	Mixes or injects chlorine gas into water supply by creating vacuum to operate chlorinator
Solution discharge	Discharges solution mixture of chlorine and water

chlorinators (gas) Startup

- Be sure chlorine gas valve at chlorinator is closed
- Be sure all chlorine valves on the supply line should are still closed since shutdown
- Inspect all tubing, manifolds, and valve connections for leaks and be sure all joints are properly gasketed
- Check chlorine solution distribution lines to ensure proper valving setup
- Open chlorine metering orifice slightly
- Start injector water supply system pumping water at an appropriate flow rate to create sufficient vacuum in the injector to draw chlorine
  - Protected by air gap

chlorinators (gas) Startup

- Examine injector water supply system
  - Note reading of injector supply pressure gauge
    - Should operate at not less than 50 psi inlet pressure
  - Note reading of injector vacuum gauge
    - If no gauge installed, install one
    - Lower than normal vacuum readings may cause the machine to function at a lower feed rate and unable to reach rated delivery capacity
- Inspect chlorinator vacuum lines for leaks
- Crack open chlorine container valve and allow gas to enter the line
  - Check for leaks with ammonia-soaked rag
    - Use concentrated ammonia solution containing 28-30% ammonia as NH_3 / 58% NH_4OH / commercial 26° Baume

chlorinator (gas) Startup

- Inspect the chlorinator
  - Chlorine gas pressure 20-30 psi, but may exceed 150 psi on very hot summer days (should store inside)
  - Operator chlorinator over full range of feed rates
  - Check operation of manual and automatic settings
- Chlorinator ready for use
  - Set desired feed rate
  - Log time system is placed into operation and injection point

Chlorinators

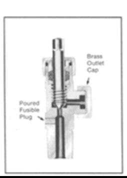
- Startup of chlorinators with evaporators
  - Only very large plants require chlorinators equipped with evaporators that must pull liquid chlorine instead of gas
- Chlorinator Shutdown
  - Short-term
    - Have safety equipment available in case of a leak
    - Close chlorine container gas outlet
    - Allow chlorine gas to completely evacuate the system through the injector (pressure gauges = 0 psi)
    - Close chlorinator gas discharge valve
  - Long-term
    - Perform steps 1-4 of short-term shutdown
    - Turn off chlorinator power switch, lock out and tag
    - Secure chlorinator gas manifold and chlorinator valve in closed position

Chlorinators, including injectors

- Check injector water supply pressure (40-90 psi)
- Determine injector vacuum (15-25 inches of mercury)
- Check chlorinator vacuum (5-10 inches of mercury)
- Determine chlorinator supply pressure after pressure regulating valve (20-40 psi)
- Read the chlorinator feed rate on the rotameter tube; record reading and time
- Calculate chlorine usage
- Examine and record mode of control
  - Manual / single-input auto / dual-input auto

Chlorine Steel Cylinders

- Contain 100 to 150 pounds
- Fusible plug is placed in the valve below the valve seat
  - Safety device to prevent buildup of excessive pressures
  - Melts at 158°-165°F (70°-74°C)

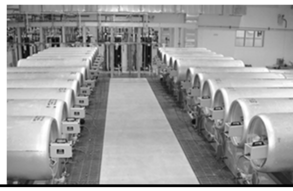


Chlorine Steel Cylinders (150 lb)

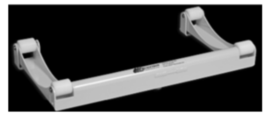
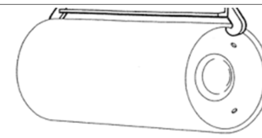
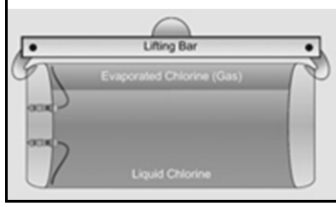
- Safety for handling and storing
  - Move cylinders with a properly balanced hand truck
  - Can be rolled in a vertical position
  - Always replace the protective cap when moving a cylinder
  - Keep cylinders away from direct heat and direct sun
  - Transport and store cylinders in an upright position
  - Store empty cylinders separate from full cylinders
    - Never store near turpentine, ether, anhydrous ammonia, finely divided metals, hydrocarbons, or other materials that are flammable
  - Remove outlet cap from cylinder and inspect outlet threads
  - Test chlorine cylinders at 800 psi every 5 years

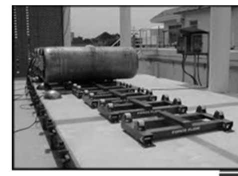
Chlorine Ton Tanks

- Loaded weight of about 3,700 pounds
- Openings for fusible plugs and valves
  - 2 operating valves
  - 6 fusible plugs (3 on each end)


Chlorine Ton Tanks



Hypochlorinators

Hypochlorinators

- A piece of equipment used to feed hypochlorite solutions
- Consists of chemical solution tank, diaphragm-type pump, power supply, water pump, pressure switch, water storage tank

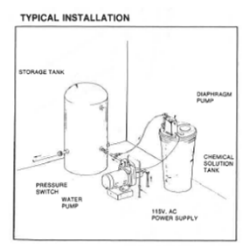


Fig. 7.7 Typical hypochlorinator installation
(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

Hypochlorinators

- 2 methods of feeding
  - Directly pumped into water
  - Pump through an ejector (injector)
    - Draws in additional water for dilution of solution

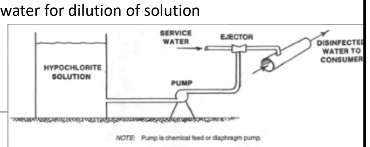


Fig. 7.11 Hypochlorinator injector feed system

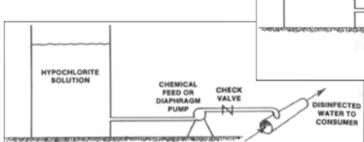


Fig. 7.10 Hypochlorinator direct pumping system

Hypochlorinators

- Startup of Hypochlorinators
  - Prepare chemical solution
  - Lock out then inspect the electric circuit; turn power back on if no issues
  - Turn on chemical pump
    - Never adjust pump while it is off, or damage will occur
  - Calibrate pump
  - Check that solution is being fed into the system
  - Measure chlorine residual at the most remote locations in system (> 0.2 mg/L)

Hypochlorinators

- Shutdown of Hypochlorinators
  - Short duration
    - First, turn off water supply to pump to prevent pumping unchlorinated water then turn off
    - Lockout circuit or unplug when making repairs
  - Long duration
    - Obtain and place another hypochlorinator in service
- Normal Operation of Hypochlorinators
  - Requires routine observation and preventative maintenance

Hypochlorinators

- Perform Daily
  - Inspect building to ensure no unauthorized entry
  - Read and record level of solution tank at same time every day
  - Read meters and record amount of water pumped
  - Check chlorine residual in system and adjust feed rate as necessary
    - Suggested free chlorine residual is 0.5 mg/L at the point of application
  - Check chemical feed pump operation

Hypochlorinators

- Perform Weekly
  - Clean the building
  - Replace chemicals and wash chemical storage tank(s)
    - Prepare only enough solution for 2 - 3 days' supply
    - Have 15 - 30 days' total chemical supply on hand
- Perform Monthly
  - Check operation of check valve
  - Perform any required preventative maintenance
  - Remove carbonate scale that tends to accumulate on the poppet valves in the solution feeder
    - Prevent scale build-up by obtaining softened water

Hypochlorinators

- Normal Operation Checklist
  - Check chemical usage
    - Record solution level and water pump meter reading OR number of hours of pump operation
    - Calculate desired feed rate
  - Determine if every piece of equipment is operating
  - Inspect equipment lubrication
  - Check building for any possible problems
  - Clean up the area

Hypochlorinators

- Abnormal Operation of Hypochlorinators
  - Inform supervisor of problem
  - Repair or replace malfunctioning equipment immediately
  - Solution tank level
    - Too low: check adjustment of pump; check hour meter on water pump
    - Too high: check the chemical pump; check the hour meter on the water pump
- Maintenance of Hypochlorinators
  - Normally minor such as oil changes and lubrication of moving parts

Hypochlorite Containers

- Plastic
  - Commonly used for storage of hypochlorite solution
  - Should be large enough to hold 2-3 days' supply
    - Fresh solution should be prepared every 2-4 days
    - Sodium hypochlorite will lose 2-4% concentration per month at room temperature
    - Recommended shelf life of 60-90 days

Safety around chlorine

- Every person should be trained in the use of self-containing breathing apparatus (SCBA), methods of detecting hazards, and should know what to do in case of emergencies
- Clothing exposed to chlorine can be saturated with chlorine, which will irritate the skin if exposed to moisture or sweat
- Self-contained air supply and demand-breathing equipment must fit and be used properly
  - Pressure-demand and rebreather kits may be safer
- Wear protective clothing to enter an area containing a chlorine leak
  - Chemical suit will prevent chlorine from contacting the sweat on the body and forming hydrochloric acid

Removing Chlorine from Containers

- Whenever performing any work or maintenance on chlorine cylinders, a self-contained breathing apparatus (SCBA)should be worn or at least readily available
  - Greater than maximum feed rate will result in freezing and a decreased rate of delivery
    - Steel (150 lb)cylinder = 40 lbs/day
    - Ton cylinder = 400 lb/day
      - With evaporator = 9,600 lb/day
- Frosting may cause gas to condense to liquid which could plug the chlorine supply lines

Measurement of Chlorine Residual

Measuring chlorine residual

- All subpart H systems (surface water systems and groundwater systems under the influence of surface water) must provide disinfection
- Must collect residual chlorine sample at the same frequency and location as total coliform samples

Methods of Measuring Chlorine Residual

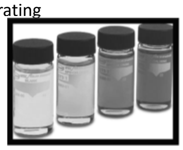
- Amperometric titration
  - A means of measuring concentrations of certain substances in water based on the electric current that flows during a chemical reaction
  - To titrate a sample, a chemical solution of known strength is added drop by drop until a certain end point is reached
- Colorimetric (DPD) tests
  - Based on a chemical reaction that produces a color whose intensity is proportional to the concentration of chlorine

Methods of Measuring Chlorine Residual

- Amperometric titration
  - A means of measuring concentrations of certain substances in water based on the electric current that flows during a chemical reaction
  - 1. place a 200 mL sample of water in titrator
  - 2. Start the agitator
  - 3. Add 1 mL of pH 7 buffer
  - 4. Titrate with phenylarsene oxide solution (PAO)
  - 5. End point is reached when one drop will cause a deflection on the microammeter and the deflection will remain
  - 6. mL of PAO used in titration is equal to mg/L of free chlorine residual

Methods of Measuring Chlorine Residual

- Colorimetric test (DPD)
  - A method of measuring the chlorine residual in water
  - N,N-diethyl-p-phenylene-diamine
  - The residual may be determined by either titrating or comparing a developed color with color standards
    1. Collect a sample
       - Typically 10 mL or 25 mL
    2. Zero instrument with sample blank
    3. Add color reagent
    4. Read colored sample in spectrophotomer or colorimeter
  - "False positive" can occur when sample contains a combined chlorine residual



TN

Disinfection Vocabulary

A. Amperometric Titration
B. Bacteria
C. Breakpoint Chlorination
D. Carcinogen
E. Chlorination
F. Chlorine Demand
G. Chlorine Requirement
H. Chlorine Residual
I. Chlororganic
J. Colorimetric Measurement
K. Combined Available Chlorine
L. Combined Available Chlorine Residual
M. Combined Chlorine
N. Combined Residual Chlorination
O. DPD
P. Dew Point
Q. Disinfection
R. Eductor
S. Enteric
T. Free Available Residual Chlorine
U. HTH
V. Hydrolysis
W. Hypochlorination
X. Hypochlorite
Y. IDLH
Z. MPN
AA. Oxidation
BB. Oxidizing Agent
CC. Pathogenic Organisms
DD. Postchlorination
EE. Potable Water
FF. Prechlorination
GG. Precursor, THM
HH. Reagent
II. Reducing Agent
JJ. Reliquefaction
KK. Sterilization
LL. Titrate
MM. Total Chlorine
NN. Total Chlorine Residual
OO. Trihalomethanes
PP. Turbidity
QQ. Ultraviolet

_____ 1. The Most Probable Number of coliform group organisms per unit volume of sample water

_____ 2. Any substance which tends to produce cancer in an organism

_____ 3. A chemical reaction in which a compound is converted into another compound by taking up water.

_____ 4. Any substance that will readily donate electrons

_____ 5. The application of chlorine to water to produce combined available chlorine residual

_____ 6. A hydraulic devise used to create a negative pressure by forcing a liquid through a restriction, such as a Venturi.

_____ 7. Organic compounds combined with chlorine

_____ 8. Organisms capable of causing diseases in a host

_____ 9. The total concentration of chlorine in water, including the combined chlorine and the free available chlorine

_____ 10. Pertaining to a band of electromagnetic radiation just beyond the visible light spectrum; used to disinfect water

_____ 11. Addition of chlorine to water until the chlorine demand has been satisfied; additional chlorine beyond this point will result in a free chlorine residual

_____ 12. Immediately Dangerous to Life or Health; the atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses and immediate threat to life or would cause irreversible or delayed adverse health effects

_____ 13. The amount of chlorine that is needed for a particular purpose

_____ 14. The addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound

_____ 15. The removal or destruction of all microorganisms

_____ 16. The cloudy appearance of water caused by the presence of suspended and colloidal matter

_____ 17. A pure chemical substance that is used to make new products or is used in chemical tests to measure, detect, or examine other substances

_____ 18. The application of hypochlorite compounds to water for the purpose of disinfection.

_____ 19. The sum of the chlorine species composed of free chlorine and ammonia

_____ 20. The total chlorine, present as chloramine or other derivatives, that is present in a water and is still available for disinfection and for oxidation of organic matter

_____ 21. The application of chlorine to water generally for the purpose of disinfection

_____ 22. The addition of chlorine at the headworks of the plant prior to other treatment processes mainly for disinfection and control of tastes, odors, and aquatic growths

_____ 23. That portion of the total available residual chlorine composed of dissolved chlorine gas, hypochlorous acid, and or hypochlorite ion remaining in water after chlorination.

_____ 24. A method of measuring the chlorine residual in water

_____ 25. An substance, such as oxygen or chlorine, that will readily add electrons

_____ 26. The return of a gas to the liquid state e.g. a condensation of chlorine gas to return it to its liquid form by cooling

_____ 27. The concentration of residual chlorine that is combined with ammonia, organic nitrogen, or both in water as a chloramine and is still available to oxidize organic matter and kill bacteria

______ 28. The difference between the amount of chlorine added to water and the amount of residual chlorine remaining after a given contact time

______ 29. Living organisms, microscopic in size, which usually consist of a single cell

______ 30. The addition of chlorine to the plant effluent, following plant treatment, for disinfection purposes

______ 31. The total amount of chlorine residual present in a water sample after a given contact time

______ 32. Of intestinal origin, especially applied to wastes or bacterias

______ 33. Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking

______ 34. The temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air

______ 35. A means of measuring unknown chemical concentrations in water by measuring a sample's color intensity

______ 36. A means of measuring concentrations of certain substances in water based on the electric current that flows during a chemical reaction

______ 37. A chemical solution of known strength is added drop by drop until a certain color change, precipitate, or pH change in the sample is observed (end point)

______ 38. Natural organic compounds found in all surface and groundwaters that may react with halogens such as chlorine

______ 39. Calcium hypochlorite. $Ca(OCl)_2$

______ 40. The process designed to kill or inactivate most microorganisms in water, including essentially all pathogenic bacteria

______ 41. The concentration of chlorine present in water after chlorine demand has been satisfied

______ 45. Derivatives of methane in which three halogen atoms are substituted for three of the hydrogen atoms

______ 43. Chemical compounds containing available chlorine

Answers

1. Z	12. Y	23. T	34. P
2. D	13. G	24. O	35. J
3. V	14. AA	25. BB	36. A
4. II	15. KK	26. JJ	37. LL
5. N	16. PP	27. L	38. GG
6. R	17. HH	28. F	39. U
7. I	18. W	29. B	40. Q
8. CC	19. M	30. DD	41. H
9. MM	20. K	31. NN	42. OO
10. QQ	21. E	32. S	43. X
11. C	22. FF	33. EE	

Disinfection
Review Questions

1. What are pathogenic organisms?

2. What is disinfection?

3. Drinking water standards are established by what agency of the United States government?

4. MCL stands for what words?

5. How does pH influence the effectiveness of disinfection?

6. How does the temperature of the water influence disinfection?

7. What two factors influence the effectiveness of disinfection on microorganisms?

8. List the physical agents that have been used for disinfection (chlorine is not a physical agent).

9. List the chemical agents other than chlorine that have been used for disinfection.

10. What is a major limitation to the use of ozone?

11. How is the chlorine dosage determined?

12. List two organic reducing chemicals with which chlorine reacts rapidly.

13. What does chlorine produce when it reacts with organic matter?

14. How do chlorine gas and hypochlorite influence pH?

15. How does pH influence the relationship between HOCl and OCl^-?

16. What is breakpoint chlorination?

17. List the two most common points of chlorination in a water treatment plant.

18. Under what conditions should waters not be prechlorinated?

19. What are the benefits of prechlorination?

20. List the major parts of a typical hypochlorinator system.

21. What are the two common methods of feeding hypochlorite to the water being disinfected?

22. What type of container is commonly used to store hypochlorite?

23. How large a supply of hypochlorite should be available?

24. What is the purpose of the fusible plug?

25. What is removed by the upper and lower valves of ton chlorine tanks?

26. Why are one-ton tanks placed on their sides with the valves in a vertical position?

27. If chlorine is escaping from a cylinder, what would you do?

28. How can chlorine leaks around valve stems be stopped?

29. How can chlorine leaks at the valve discharge outlet be stopped?

30. What properties make chlorine gas so hazardous?

31. What type of breathing apparatus is recommended when repairing chlorine leaks?

32. What first-aid measures should be taken if a person comes in contact with chlorine gas?

33. The UV light intensity that reaches the pathogens in the water is affected by what factors?

34. Routine maintenance of UV disinfection systems includes which tasks?

35. How often should quartz sleeves be cleaned?

36. The service life of UV lamps depends on which factors?

37. How can operators determine the proper way to dispose of used UV lamps?

38. Why is ozone generated on site?

39. The effectiveness of ozone disinfection depends on which factors?

Disinfection
Review Questions

1. Pathogenic organisms are disease-producing organisms
2. Disinfection is the selective destruction or inactivation of pathogenic organisms.
3. The US Environmental Protection Agency establishes drinking water standards.
4. MCL stands for Maximum Contaminant Level.
5. Most disinfectants are more effective in water with a pH around 7.0 than at a pH over 8.0.
6. Relatively cold water requires longer disinfection time or greater quantities of disinfectants.
7. The number and type of organisms present in water influence the effectiveness of disinfection on microorganisms.
8. (1) Ultraviolet rays (2) heat, and (3) ultrasonic waves
9. (1) Iodine (2) bromine (3) bases (sodium hydroxide and lime) (4) ozone
10. The inability of ozone to provide a residual in the distribution system
11. Dose = demand + residual
12. Hydrogen sulfide and ammonia
13. Suspected carcinogenic compounds (trihalomethanes)
14. Chlorine gas lowers the pH; hypochlorite increases the pH
15. The higher the pH the greater the percent of OCl^-
16. The addition of chlorine to water until the chlorine demand has been satisfied and further additions of chlorine result in a free available residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.
17. Prechlorination ahead of any other treatment processes and postchlorination after the water has been treated and before it enters the distribution system
18. When the raw waters contain organic compounds
19. (1) Control of algal and slime growths (2) control of mudball formation (3) improved coagulation (4) reduction of tastes and odors (5) increased chlorine

contact time (6) increased safety factor in disinfection of heavily contaminated water

20. Chemical solution tank for the hypochlorite, diaphragm-type pump, power supply, water pump, pressure switch, and water storage tank
21. (1) Pumping directly into the water (2) pumping through an ejector which draws in additional water for dilution of the hypochlorite solution
22. Plastic containers
23. A week's supply of hypochlorite should be available
24. The fusible is a safety device. The fusible metal softens or melts at 158-165^{o}F to prevent buildup of excessive pressures and the possibility of rupture due to fire or high surrounding temperatures.
25. The upper valve discharges chlorine gas, and the lower valve discharges liquid chlorine from ton chlorine tanks.
26. In this position, either chlorine gas or liquid chlorine may be removed.
27. Turn the cylinder so that the leak is on top and the chlorine will escape as a gas.
28. By closing the valve or tightening the packing gland nut. Tighten the nut or stem by turning it clockwise.
29. By replacing the gasket or adapter connection.
30. Chlorine gas is extremely toxic and corrosive in moist atmospheres.
31. A properly fitting self-contained air or oxygen supply type of breathing apparatus, positive/demand breathing equipment, or rebreather kits are used when repairing a chlorine leak
32. First aid measures depend on the severity of the contact. Move the victim away from the gas area, remove the contaminated clothes and keep the victim warm and quiet. Call a doctor and fire department immediately. Keep the patient breathing.
33. The UV light intensity that reaches the pathogens in the water is affected by the condition of the UV lamps and the quality of the water.
34. (1) Checking the UV monitor for significant reduction in lamp output (2) monitoring the process changes in normal flow conditions (3) checking for fouling of the quartz sleeves and the UV intensity monitor probes (4) checking the indicator light display to ensure that all of the UV lamps are energized (5)

monitoring the elapsed time meter, microbiological results, and lamp log sheet (6) checking the quartz sleeves for discoloration

35. Depends on the quality of the water being treated and the treatment chemicals used prior to disinfection
36. Depends on (1) the level of suspended solids in the water to be disinfected and the fecal coliform level to be achieved (2) the frequency of the on/off cycles (3) the operating temperature of the lamp electrodes
37. Contact the appropriate regulatory agency. Do not throw UV bulbs in trash because they contain mercury.
38. It is unstable and decomposes to elemental oxygen in a short time after generation.

Section 6

Pumps

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PUMPS

California State University: Sacramento

Updated 11/20/2019

Fleming Training Center | TN Department of Environment & Conservation

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Necessity Of Pumps

- Pumps are required when gravity cannot supply water with sufficient pressure to all parts of the distribution system
- Pumps account for the largest energy cost for a water supply operation

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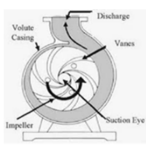
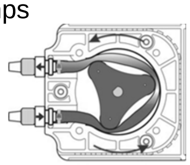
Types of Pumps

- Velocity Pumps



- Positive-Displacement Pumps



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Types of Pumps

- Positive-Displacement Pumps
  - Metering pumps
    - sometimes used to feed chemicals
  - Piston pump
  - Screw pump
- Velocity Pumps
  - Vertical turbine
  - Centrifugal

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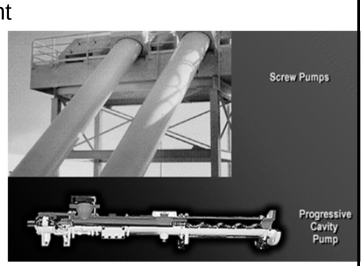
Positive-Displacement Pumps

- Chemical feed pumps
- Delivers a constant volume with each stroke
- Less efficient than centrifugal pumps
- **Cannot operate against a closed discharge valve**
- Types: piston, diaphragm, gear, screw pump, etc.



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Positive-Displacement Pumps

- Metering pumps – most common type of solution feeder
- Delivers precise volume of solution with each stroke or rotation
- Typically have variable-speed motor that can be adjusted to control chemical flow

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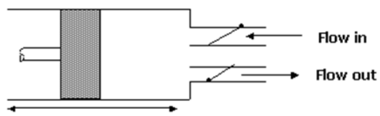
Positive-Displacement Pumps

- Reciprocating (piston) pump - piston moves back and forth in cylinder, liquid enters and leaves through check valves



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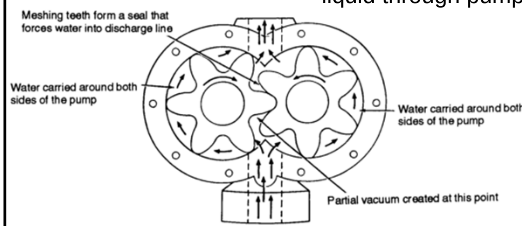
Positive-Displacement Pumps

- Rotary pump - Use lobes or gears to move liquid through pump



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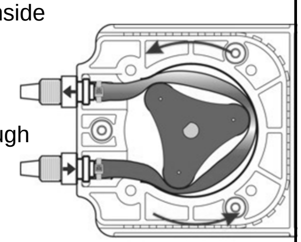
Positive Displacement Pumps

- Peristaltic Pump
  - Fluid to be pumped flows through flexible tube inside a pump casing
  - Rotor inside turns and compresses the tube
  - Rotor forces fluid through tube



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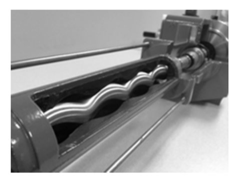
Screw Pumps

Incline screw pumps handle large solids without plugging

- Aka progressive cavity pumps
- Screw pumps are used to lift wastewater to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge point



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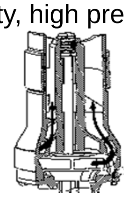
Velocity Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)
- High velocity, low pressure water is converted to low velocity, high pressure water


Volute


Diffuser

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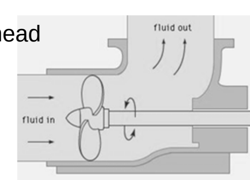
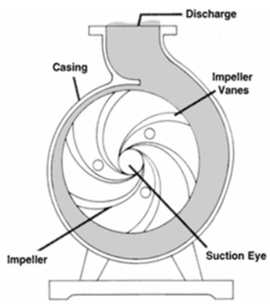
Velocity Pump Design Characteristics

- Axial - flow designs
  - Propeller shaped impeller adds head by lifting action on vanes
  - Water moves parallel to pump instead of being thrown outward
  - High volume, but limited head
  - Not self-priming



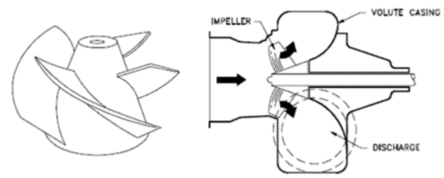
Velocity Pump Design Characteristics

- Radial flow designs
  - Water comes in through center (eye) of impeller
  - Water thrown outward from impeller to diffusers that convert velocity to pressure
  - The discharge is perpendicular to the pump shaft



Velocity Pump Design Characteristics

- Mixed - flow designs
  - Has features of axial and radial flow
  - Works well for water with solids



Centrifugal Pump

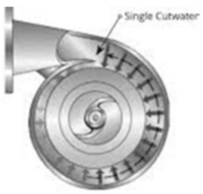
- Basically a very simple device: an impeller rotating in a casing
- The impeller is supported on a shaft, which in turn, is supported by bearings
- Liquid coming in at the center (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and then is thrown out by centrifugal force into the discharge

Centrifugal Pumps

- Volute-casing type most commonly used in water utilities
- Impeller rotates in casing - radial flow
- Single or multi-stage
- By varying size, shape, and width of impeller, a wide range of flows and pressures can be achieved

Advantages of Centrifugal Pumps

- Wide range of capacities
- Uniform flow at a constant speed and head
- Low cost
- Ability to be adapted to various types of drivers
- Moderate to high efficiency
- No need for internal lubrication



Single Volute

Disadvantages of Centrifugal Pumps

- Efficiency is limited to very narrow ranges of flow and head
- Flow capacity greatly depends on discharge pressure
- Generally no self-priming ability
- Can run backwards if check valve fails and sticks open
- Potential impeller damage if pumping abrasive water

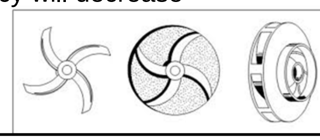
Let's Build a Centrifugal Pump

- First we need a device to spin liquid at high speeds – an impeller
  - As the impeller spins, liquid between the blades is impelled outward by centrifugal force
  - As liquid in the impeller moves outward, it will suck more liquid behind it through this eye

#1: If there is any danger that foreign material may be sucked into the pump, clogging or wearing of the impeller unduly, provide the intake end of the suction piping with a suitable screen

Impeller

- Bronze or stainless steel
- Closed; some single-suction have semi-open; open designs
- Inspect regularly
- As the impeller wears on a pump, the pump efficiency will decrease



Let's Build a Centrifugal Pump

- Now we need a shaft to support and turn the impeller
  - It must maintain the impeller in precisely the right place
  - But that ruggedness does not protect the shaft from the corrosive or abrasive effects of the liquid pumped, so we must protect it with sleeves slid on from either end

#2: Never pump a liquid for which the pump was not designed

Shaft and Sleeves

- Shaft
  - Connects impeller to pump; steel or stainless steel
  - Should be repaired/replaced if grooves or scores appear on the shaft
- Shaft Sleeves
  - Protect shaft from wear from packing rings
  - Generally they are bronze, but various other alloys, ceramics, glass or even rubber-coating are sometimes required.

Let's Build a Centrifugal Pump

- We mount the shaft on sleeve, ball or roller bearings
  - If bearings supporting the turning shaft and impeller are allowed to wear excessively and lower the turning units within a pump's closely fitted mechanism, the life and efficiency of that pump will be seriously threatened.

#3: Keep the right amount of the right lubricant in bearings at all times.

Bearings

- Anti-friction devices for supporting and guiding pump and motor shafts
- Get noisy as they wear out
- If pump bearings are over lubricated, the bearings will overheat and can be damaged or fail
  - Tiny indentations high on the shoulder of a bearing or race is called brinelling
  - When greasing a bearing on an electric motor, the relief plug should be removed and replaced after the motor has run for a few minutes. This prevents you from damaging the seals of the bearing.
- Types: ball, roller, sleeve

Let's Build a Centrifugal Pump

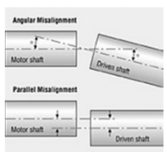
- To connect with the motor, we add a coupling flange
  - Our pump is driven by a separate motor, and we attach a flange to one end of the shaft through which bolts will connect with the motor flange
  - If shafts are met at an angle, every rotation throws tremendous extra load on bearings of both pump and the motor

#4: See that pump and motor flanges are parallel and vertical and that they stay that way.

Couplings

- Connect pump and motor shafts
- Lubricated require greasing at 6 month intervals
- Dry has rubber or elastomeric membrane
- Calipers and thickness gauges can be used to check alignment on flexible couplings

Misalignment of Pump & Motor



- Excessive bearing loading
- Shaft bending
- Premature bearing failure
- Shaft damage
- Checking alignment should be a regular procedure in pump maintenance.
  - Foundations can settle unevenly
  - Piping can change pump position
  - Bolts can loosen
  - Misalignment is a major cause of pump and coupling wear.

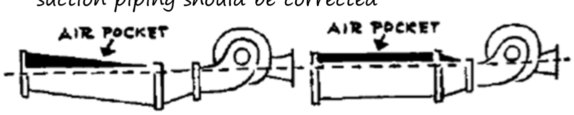
Common Pump & Motor Connections

- Direct coupling
- Angle drive
- Belt or chain
- Flexible coupling
- Close-coupled

Let's Build a Centrifugal Pump

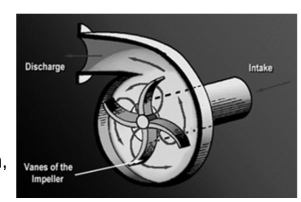
- Now we need a "straw" through which liquid can be sucked
  - The horizontal pipe slopes upward toward the pump so that air pockets won't be drawn into the pump and cause loss of suction

#5: Any down-sloping toward the pump in suction piping should be corrected



Let's Build a Centrifugal Pump

- We contain and direct the spinning liquid with a casing
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape



#6: See that piping puts absolutely no strain on the pump casing.

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Mechanical Details of Centrifugal Pumps

- Casing
  - Housing surrounding the impeller; also called the volute
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape

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Let's Build a Centrifugal Pump

- Now our pump is almost complete, but it would leak like a sieve
  - As water is drawn into the spinning impeller, centrifugal force causes it to flow outward, building up high pressure at the outside of the pump (which will force water out) and creating low pressure at the center of the pump (which will draw water in)
    - Water tends to be drawn back from pressure to suction through the space between the impeller and casing – this needs to be plugged

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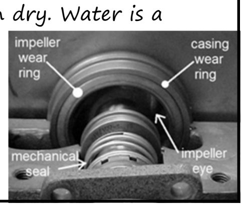
Let's Build a Centrifugal Pump

- So we add wear rings to plug internal liquid leakage
  - Wear rings fill the gaps without having to move the parts of the pump closer together

#7: Never allow a pump to run dry. Water is a lubricant between the rings and impeller.



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Wear Rings

- Restrict flow between impeller discharge and suction
- Leakage reduces pump efficiency
- Installed to protect the impeller and pump casing from excessive wear
- Provides a replaceable wearing surface
- Inspect regularly

#8: Examine wearing rings at regular intervals. When seriously worn, their replacement with greatly improve pump efficiency.

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Let's Build a Centrifugal Pump

- To keep air from being drawn in, we use stuffing boxes
  - We have two good reasons for wanting to keep air out of our pump
    - We want to pump water, not air
    - Air leakage is apt to cause our pump to lose suction
  - Each stuffing box we use consists of a casing, rings of packing and a gland at the outside end
    - A mechanical seal may be used instead

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Stuffing Box

#9 – Packing should be replace periodically. Forcing in a ring or two of new packing instead of replacing worn packing is bad practice. It is apt to dislodge the seal cage.

#10 - Never tighten a gland more than necessary as excessive pressure will wear shaft sleeves unduly.

#11 – If shaft sleeves are badly scored, replace them immediately.

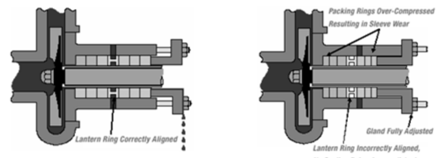
Let's Build a Centrifugal Pump

- To make packing more airtight, we add water seal piping
  - In the center of each stuffing box is a "seal cage"
  - This liquid acts both to block out air intake and to lubricate the packing
  - To control liquid flow, draw up the packing gland just tight enough to allow approximately one drop/second flow from the box

#12 – If the liquid being pumped contains grit, a separate source of sealing liquid should be obtained.

Lantern Rings

- Perforated ring placed in stuffing box
- A spacer ring in the packing gland that forms seal around shaft, helps keep air from entering the pump and lubricates packing



Packing Rings

- Asbestos or metal ring lubricated with Teflon or graphite
- Provides a seal where the shaft passes through the pump casing in order to keep air form being drawn or sucked into the pump and/or the water being pumped from coming out

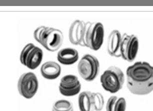
Packing Rings

- If new packing leaks, stop the motor and repack the pump
- Pumps need new packing when the gland or follower is pulled all the way down
- The packing around the shaft should be tightened slowly, over a period of **several hours** to just enough to allow an occasional drop of liquid (**20-60 drops per minute** is desired)
  - Leakage acts as a lubricant
- Stagger joints 180º if only 2 rings are in stuffing box, space at 120º for 3 rings or **90º if 4 rings or more are in set**

Packing Rings

- If packing is not maintained properly, the following troubles can arise:
  - **Loss of suction** due to air being allowed to enter pump
  - **Shaft or shaft sleeve damage**
  - Water or wastewater **contaminating bearings**
  - **Flooding** of pump station
  - Rust corrosion and unsightliness of pump and area

Mechanical Seals



- Located in stuffing box
- Prevents water from leaking along shaft; keeps air out of pump
- **Should not leak**
- Consists of a rotating ring and stationary element
- The operating temperature on a mechanical seal should never exceed 160ºF (71ºC)
- Mechanical seals are always flushed in some manner to lubricate the seal faces and minimize wear
  - The flushing water pressure in a water-lubricated wastewater pump should be **3-5 psi higher** than the pump discharge pressure.

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Mechanical Seals

- Required instead of packing rings for suction head greater than 60 psi
- Prevents water from leaking along shaft, keeps air out of pump
  - Should not leak any water

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Packing vs. Mechanical Seals

- If a pump has packing, water should drip slowly
- If it has a mechanical seal, no leakage should occur

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Packing Rings vs. Mechanical Seal

- Advantages
  - Less expensive, short term
  - Can accommodate some looseness
- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and replacement

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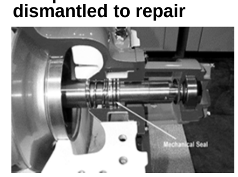
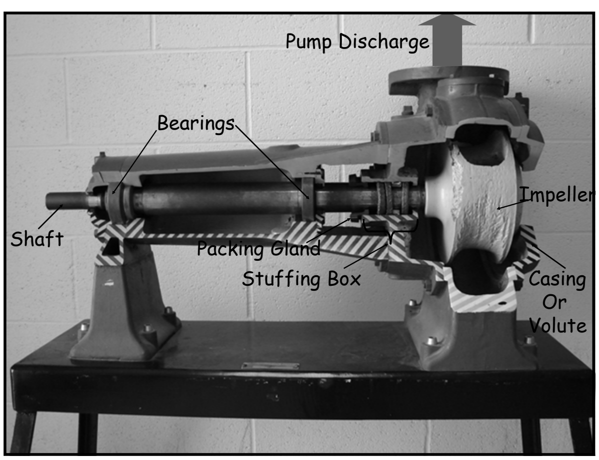
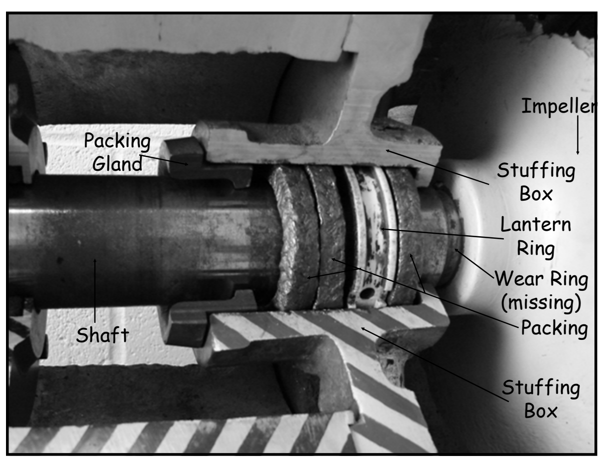
Mechanical Seal vs. Packing Rings

- Advantages
  - **Last 3-4 years**, which can be a savings in labor
  - Usually there is **no damage to shaft sleeve**
  - **Continual adjusting, cleaning or repacking is not required**
  - Possibility of flooding lift station because a pump has thrown its packing is eliminated; however mechanical seals can fail and lift stations can be flooded
- Disadvantages
  - **High initial cost**
  - **Great skill and care needed to replace**
  - When they fail, the pump must be shut down
  - **Pump must be dismantled to repair**







Centrifugal Pump Operation

- Pump Starting -
  - Impeller must be submerged for a pump to start
    - Should never be run empty, except momentarily, because parts lubricated by water would be damaged
  - Foot valve helps hold prime
  - Discharge valve should open slowly to control water hammer
  - In small pumps, a check valve closes immediately when pump stops to prevent flow reversal
  - In large pumps, discharge valve may close before pump stops

Centrifugal Pump Operation

- Pump shut down for extended period of time -
  - Close the valve in the suction line
  - Close the valve in the discharge line
  - Drain the pump casing

Flow Control

- Flow usually controlled by starting and stopping pumps
- Throttling flow should be avoided - wastes energy
- Variable speed drives or motor are best way to vary flow
  - Variable speed pumping equipment can be adjusted to match the inflow rate

Monitoring Operational Variables

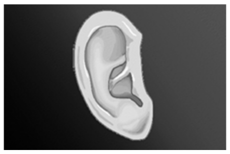
- Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operation

Monitoring Operational Variables

- Suction and Discharge Heads
  - Pressure gauges
- Bearing and Motor Temperature
  - Temp indicators can shut down pump if temp gets too high
  - Check temp of motor by feel

Monitoring Operational Variables

- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds



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Monitoring Operational Variables

- Likely causes of vibration
  - Bad bearings or bearing failure
  - Imbalance of rotating elements, damage to impeller
  - Misalignment from shifts in underlying foundation
  - Improper motor to pump alignment

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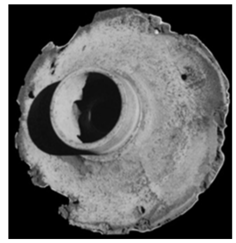
Monitoring Operational Variables



- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

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Monitoring Operational Variables

- Cavitation is a noise coming from a centrifugal pump that sounds like marbles trapped in the volute
- A condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound
- Best method to prevent it from occurring is to reduce the suction lift

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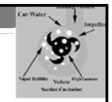

Suction Cavitation

- Suction Cavitation occurs when the pump suction is under a low pressure/high vacuum condition where the liquid turns into a vapor at the eye of the pump impeller.
- This vapor is carried over to the discharge side of the pump where it no longer sees vacuum and is compressed back into a liquid by the discharge pressure.
- This imploding action occurs violently and attacks the face of the impeller.
- An impeller that has been operating under a suction cavitation condition has large chunks of material removed from its face causing premature failure of the pump.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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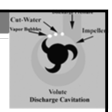

Discharge Cavitation

- Discharge Cavitation occurs when the pump discharge is extremely high.
- It normally occurs in a pump that is running at less than 10% of its best efficiency point.
- The high discharge pressure causes the majority of the fluid to circulate inside the pump instead of being allowed to flow out the discharge.
- As the liquid flows around the impeller it must pass through the small clearance between the impeller and the pump cutwater at extremely high velocity.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

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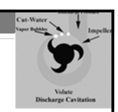


Discharge Cavitation

- This velocity causes a vacuum to develop at the cutwater similar to what occurs in a venturi and turns the liquid into a vapor.
- A pump that has been operating under these conditions shows premature wear of the impeller vane tips and the pump cutwater.
- In addition due to the high pressure condition premature failure of the pump mechanical seal and bearings can be expected and under extreme conditions will break the impeller shaft.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

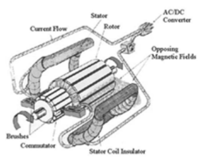
Inspection and Maintenance

- Inspection and maintenance prolongs life of pumps
  - Checking operating temperature of bearings
  - Checking packing glands
  - Operating two or more pumps of the same size alternatively to equalize wear
  - Check parallel and angular alignment of the coupling on the pump and motor
    - A feeler gauge, dial indicator calipers are tools that can be used to check proper alignment
- Necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

Inspection: Impellers

- Wear on impeller and volute
- Cavitation marks
- Chips, broken tips, corrosion, unusual wear
- Tightness on shaft
- Clearances
- Tears or bubbles (if rubber coated)

Pump Won't Start?



- Incorrect power supply
- No power supply
- Incorrectly connected
- Fuse out, loose or open connection
- Rotating parts of motor jammed mechanically
- Internal circuitry open

Pump Safety

- Machinery should always be turned off and locked out/tagged out before any work is performed on it
- Make sure all moving parts are free to move and all guards in place before restarting
- Machinery creating excessive noise shall be equipped with mufflers.

Pump Safety: Wet Wells

- Confined spaces
- Corrosion of ladder rungs
- Explosive atmospheres
- Hydrogen sulfide accumulation
- Slippery surfaces

Manhole Cover, London

Pump Vocabulary

1. Axial-Flow Pump – a pump in which a propeller-like impeller forces water out in the direction parallel to the shaft. Also called a propeller pump.
2. Bearing – anti-friction device used to support and guide a pump and motor shafts.
3. Casing – the enclosure surrounding a pump impeller, into which the suction and discharge ports are machined.
4. Cavitation – a condition that can occur when pumps are run too fast or water is forced to change direction quickly. A partial vacuum forms near the pipe wall or impeller blade causing potentially rapid pitting of the metal.
5. Centrifugal Pumps – a pump consisting of an impeller on a rotating shaft enclosed by a casing having suction and discharge connections. The spinning impeller throws water outward at high velocity, and the casing shape converts this velocity to pressure.
6. Closed-Coupled Pump – a pump assembly where the impeller is mounted on the shaft of the motor that drives the pump.
7. Diffuser Vanes – vanes installed within a pump casing on diffuser centrifugal pumps to change velocity head to pressure head.
8. Double-Suction Pump – a centrifugal pump in which the water enters from both sides of the impeller. Also called a split-case pump.
9. Foot Valve – a check valve placed in the bottom of the suction pipe of a pump, which opens to allow water to enter the suction pipe but closes to prevent water from passing out of it at the bottom end. Keeps prime.
10. Frame-Mounted Pump – a centrifugal pump in which the pump shaft is connected to the motor shaft with a coupling.
11. Impeller – the rotating set of vanes that forces water through the pump.
12. Jet Pump – a device that pumps fluid by converting the energy of a high-pressure fluid into that of a high-velocity fluid.
13. Lantern Ring – a perforated ring placed around the pump shaft in the stuffing box. Water from the pump discharge is piped to this ring. The water forms a liquid seal around the shaft and lubricates the packing.
14. Mechanical Seal – a seal placed on the pump shaft to prevent water from leaking from the pump along the shaft; the seal also prevents air from entering the pump.
15. Mixed-Flow Pump – a pump that imparts both radial and axial flow to the water.
16. Packing – rings of graphite-impregnated cotton, flax, or synthetic materials, used to control leakage along a valve stem or a pump shaft.
17. Packing Gland – a follower ring that compressed the packing in the stuffing box.
18. Positive Displacement Pump – a pump that delivers a precise volume of liquid for each stroke of the piston or rotation of the shaft.
19. Prime Mover – a source of power, such as an internal combustion engine or an electric motor, designed to supply force and motion to drive machinery, such as a pump.

20. Radial-Flow Pump – a pump that moves water by centrifugal force, spinning the water radially outward from the center of the impeller.
21. Reciprocating Pump – a type of positive-displacement pump consisting of a closed cylinder containing a piston or plunger to draw liquid into the cylinder through an inlet valve and forces it out through an outlet valve.
22. Rotary Pump – a type of positive-displacement pump consisting of elements resembling gears that rotate in a close-fitting pump case. The rotation of these elements alternately draws in and discharges the water being pumped.
23. Single-Suction Pump – a centrifugal pump in which the water enters from only one side of the impeller. Also called an end-suction pump.
24. Stuffing Box – a portion of the pump casing through which the shaft extends and in which packing or a mechanical seal is placed to prevent leakage.
25. Submersible Pump – a vertical-turbine pump with the motor placed below the impellers. The motor is designed to be submersed in water.
26. Suction Lift – the condition existing when the source of water supply is below the centerline of the pump.
27. Velocity Pump – the general class of pumps that use a rapidly turning impeller to impart kinetic energy or velocity to fluids. The pump casing then converts this velocity head, in part, to pressure head. Also known as kinetic pumps.
28. Vertical Turbine Pump – a centrifugal pump, commonly of the multistage, diffuser type, in which the pump shaft is mounted vertically.
29. Volute – the expanding section of pump casing (in a volute centrifugal pump), which converts velocity head to pressure head..
30. Water Hammer – the potentially damaging slam that occurs in a pipe when a sudden change in water velocity (usually as a result of too-rapidly starting a pump or operating a valve) creates a great increase in water pressure.
31. Wear Rings – rings made of brass or bronze placed on the impeller and/or casing of a centrifugal pump to control the amount of water that is allowed to leak from the discharge to the suction side of the pump.

Pump and Motor Facts

Pump Facts

High-service pump – discharges water under pressure to the distribution system.

Booster pump – used to increase pressure in the distribution system and to fill elevated storage tanks.

Impeller or centrifugal pump used to move water.

Likely causes of vibration in an existing pump/motor installation:

1. bad bearings
2. imbalance of rotating elements
3. misalignment from shifts in underlying foundation

Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operations.

Calipers and thickness gauges can be used to check alignment on flexible couplings.

Packing/Seals Facts

If new packing leaks, stop the motor and repack the pump.

Pumps need new packing when the gland or follower is pulled all the way down.

The packing around the shaft should be tightened just enough to allow an occasional drop of liquid.

Joints of packing should be staggered at least 90°.

Mechanical seals consist of a rotating ring and stationary element.

The operating temperature on a mechanical seal should never exceed 160°F (72°C).

Motor Facts

Motors pull the most current on start up.

In order to prevent damage, turn the circuit off immediately if the fuse on one of the legs of a three-phase circuit blows.

An electric motor changes electrical energy into mechanical energy.

Power factors on motors can be improved by:
1. changing the motor loading
2. changing the motor type
3. using capacitors

Routing cleaning of pump motors includes:
1. checking alignment and balance
2. checking brushes
3. removing dirt and moisture
4. removal of obstructions that prevent air circulation

Cool air extends the useful life of motors.

A motor (electrical or internal combustion) used to drive a pump is called a prime mover.

The speed at which the magnetic field rotates is called the motor synchronous speed and is expressed in rpm.

If a variable speed belt drive is not to be used for 30 days or more, shift the unit to minimum speed setting.

Emory cloth should not be used on electric motor components because it is electrically conductive and may contaminate parts.

Ohmmeters used to test a fuse in a motor starter circuit.

The most likely cause of a three-phase motor not coming to speed after starting – the motor has lost power to one or more phases.

Transformer Facts

Transformers are used to convert high voltage to low voltage.

High voltage is 440 volts or higher.

Standby engines should be run weekly to ensure that it is working properly.

Relays are used to protect electric motors.

Pump and Motor Review Questions

1. Leakage of water around the packing on a centrifugal pump is important because it acts as a (n):
   a. Adhesive
   b. Lubricant
   c. Absorbent
   d. Backflow preventer

2. What is the purpose of wear rings in a pump?
   a. Hold the shaft in place
   b. Hold the impeller in place
   c. Control amount of water leaking from discharge to suction side
   d. Prevent oil from getting into the casing of the pump

3. Which of the following does a lantern ring accomplish?
   a. Lubricates the packing
   b. Helps keep air from entering the pump
   c. Both (a.) and (b.)

4. Closed, open and semi-open are types of what pump part?
   a. Impeller
   b. Shaft sleeve
   c. Casing
   d. Coupling

5. When tightening the packing on a centrifugal pump, which of the following applies?
   a. Tighten hand tight, never use a wrench
   b. Tighten to 20 foot pounds of pressure
   c. Tighten slowly, over a period of several hours
   d. Tighten until no leakage can be seen from the shaft

6. Excessive vibrations in a pump can be caused by:
   a. Bearing failure
   b. Damage to the impeller
   c. Misalignment of the pump shaft and motor
   d. All of the above

7. What component can be installed on a pump to hold the prime?
   a. Toe valve
   b. Foot valve
   c. Prime valve
   d. Casing valve

8. The operating temperature of a mechanical seal should not exceed:
   a. 60°C
   b. 150°F
   c. 160°F
   d. 71°C
   e. c and d

9. What is the term for the condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound?
   a. Corrosion
   b. Cavitation
   c. Aeration
   d. Combustion

10. The first thing that should be done before any work is begun on a pump or electrical motor is:
    a. Notify the state
    b. Put on safety goggles
    c. Lock out the power source and tag it
    d. Have a competent person to supervise the work

11. Under what operating condition do electric motors pull the most current?
    a. At start up
    b. At full operating speed
    c. At shut down
    d. When locked out

12. Positive displacement pumps are rarely used for water distribution because:
    a. They require too much maintenance
    b. They are no longer manufactured
    c. They require constant observation
    d. Centrifugal pumps are much more efficient

13. Another name for double-suction pump is
    a. Double-jet pump
    b. Reciprocating pump
    c. Horizontal split-case pump
    d. Double-displacement pump

14. As the impeller on a pump becomes worn, the pump efficiency will:
    a. Decrease
    b. Increase
    c. Stay the same

15. How do the two basic parts of a velocity pump operate?

16. What are two designs used to change high velocity to high pressure in a pump?

17. In what type of pump are centrifugal force and the lifting action of the impeller vanes combined to develop the total dynamic head?

18. Identify one unique safety advantage that velocity pumps have over positive-displacement pumps.

19. What is the multistage centrifugal pump? What effects does the design have on discharge pressure and flow volume?

20. What are two types of vertical turbine pump, as distinguished by pump and motor arrangement, which are commonly used to pump ground water from wells?

21. What type of vertical turbine pump is commonly used as an inline booster pump?

22. Describe the two main parts of a jet pump.

23. What is the most common used of positive-displacement pumps in water plants today?

24. What is the purpose of the foot valve on a centrifugal pump?

25. How is the casing of a double-suction pump disassembled?

26. What is the function of wear rings in centrifugal pumps of the closed-impeller design? What is the function of the lantern rings?

27. Describe the two common types of seals used to control leakage between the pump shaft and the casing.

28. What feature distinguishes a close-coupled pump and motor?

29. What is the value of listening to a pump or laying a hand on the unit as it operates?

30. Define the term “racking” as applied to pump and motor control.

31. When do most electric motors take the most current?

32. What are three major ways of reducing power costs where electric motors are used?

33. What effect could over lubrication of motor bearings have?

34. Why should emery cloth not be used around electrical machines?

35. What are the most likely causes of vibration in an existing pump installation?

36. What can happen when a fuse blows on a single leg of a three-phase circuit?

37. Name at least three common fuels for internal-combustion engines.

38. List the type of information that should be recorded on a basic data card for pumping equipment.

39. What is the first rule of safety when repairing electrical devices?

Answers:

1. B
2. C
3. C
4. A
5. C
6. D
7. B
8. E
9. B
10. C
11. A
12. D
13. C
14. A
15. A spinning impeller accelerates water to a high velocity within a casing, which changes the high-velocity, low-pressure water to a low-velocity, high-pressure discharge.
16. Volute casing and diffuser vanes.
17. Mixed-flow pump (the design used for most vertical turbine pumps)
18. If a valve is closed in the discharge line, the pump impeller can continue to rotate for a time without pumping water or damaging the pump.
19. A multistage centrifugal pump is made up of a series of impellers and casings (housings) arranged in layers, or stages. This increases the pressure at the discharge outlet, but does not increase flow volume.
20. Shaft-type and submersible-type vertical turbines.
21. A close-coupled vertical turbine with an integral sump or pot.
22. The jet pump consists of a centrifugal pump at the ground surface and an ejector nozzle below the water level.
23. Positive-displacement pumps are generally used in water plants to feed chemical into the water supply.
24. The foot valve prevents water from draining when the pump is stopped, so the pump will be primed when restarted.
25. The bolts holding the two halves of the casing together are removed and the top half is lifted off.
26. Wear rings prevent excessive circulation of water between the impeller discharge and suction area. Lantern rings allow sealing water to be fed into the stuffing box.
27. (1) Packing rings are made of graphite-impregnated cotton, flax, or synthetic materials. They are inserted in the stuffing box and held snuggly against the shaft by an adjustable packing gland. (2) Mechanical seals consist of two machined and polished surfaces. One is attached to the shaft, the other to the casing. Spring pressure maintains contact between the two surfaces.
28. The pump impeller is mounted directly on the shaft of the motor.
29. An experienced operator can often detect unusual vibration by simply listening or touching. Vibration, especially changes in vibration level, are viewed as symptoms or indicators of other underlying problems in foundation, alignment and/or pump wear.
30. Racking refers to erratic operation that may result from pressure surges when the pump starts; it is often a problem when the pressure sensor for the pump control is located too close to the pump station.
31. During start-up.
32. (1) Increase system efficiency; (2) spread the pumping load more evenly throughout the day; (3) reduce power-factor charges
33. The bearings may run hot, and excess grease or oil could run out and reach the motor windings, causing the insulation to deteriorate.
34. The abrasive material on emery cloth is electrically conductive and could contaminate electrical components.
35. Imbalance of the rotating elements, bad bearings and misalignment
36. A condition called single-phasing can occur, causing the motor windings to overheat and eventually fail.

37. gasoline, propane, methane, natural gas and diesel oil (diesel fuel)
38. make, model, capacity, type, date and location installed, and other information for both the driver (motor) and the driven unit (pump)
39. Make sure the power to the device is disconnected. This is critical since rubber gloves, insulated tools and other protective gear are not guarantees against electrical shock.

Section 7

Cross Connection Control

Cross-Connection Control

Updated 11/20/2019

Outline

- Case studies of backflow incidents
- Basics of Cross-Connection Control
- Hydraulics
- Definitions
- Backflow Preventers
- Applications

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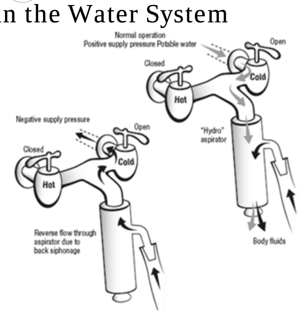
Backflow Case Study

Human Blood in the Water System

Blood observed in drinking fountains at a funeral home

Hydraulic aspirator used to drain body fluids during embalming

Contamination caused by low water pressure while aspirator was in use



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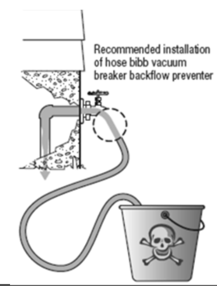
Backflow Case Study

Kool-Aid Laced with Chlordane

Exterminator submerged garden hoses in small buckets while mixing insecticide at the same time a water meter was being installed nearby

During a new water meter installation chlordane was backsiphoned into water lines and became mixed with Kool-Aid

A dozen children and three adults became sick



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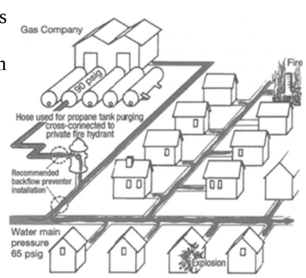
Backflow Case Study

Propane Gas in the Water Mains

Gas company initiated repairs on 30,000 gallon liquid propane tank by flushing with fire hydrant

Vapor pressure of propane residual in the tank exceeded water main pressure

Hundreds evacuated, two homes caught fire, water supply contaminated



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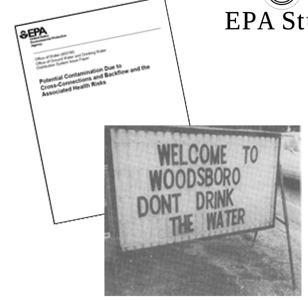
Backflow Case Study

EPA Study



EPA compiled backflow incident data from 1970 to 2001 and found:

459 incidents resulted in **12,093** illnesses

Backflow incidents can result in property damage, personal injury, and even death

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Authority

- Federal
  - Federal Safe Drinking Water Act
- State
  - Tennessee Safe Drinking Water Act
  - Statute
  - Regulation
- Local
  - Ordinance (City) or Policy (Utility)
  - Plumbing Code
  - Cross Connection Control Plan

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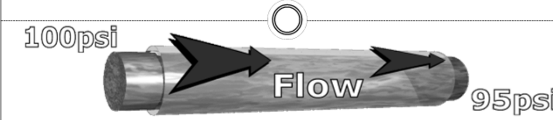
Hydraulics and Pressure



- Water can flow through a pipe in either direction
- The direction of flow will depend on the forces (pressures) acting on the water
- Water pressure naturally tends to equalize
- Therefore, water flows down a gradient from high pressure regions to low pressure regions

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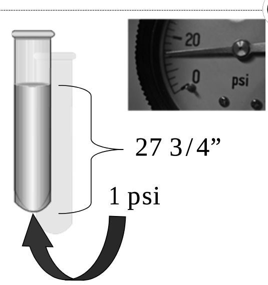
Head Pressure



27 ¾" = 2.31 Feet of Head

- 27 3/4" of water generates a pressure of one pound per square inch (psi)
- The pressure on the bottom of the container is generated by the weight of the water above it

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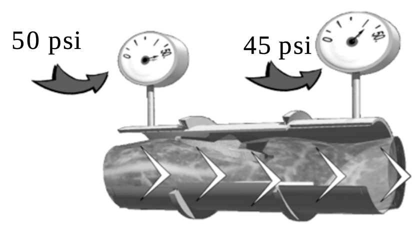
Normal Flow



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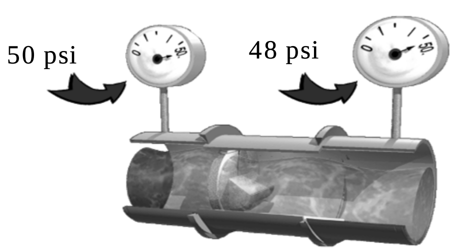
No Flow



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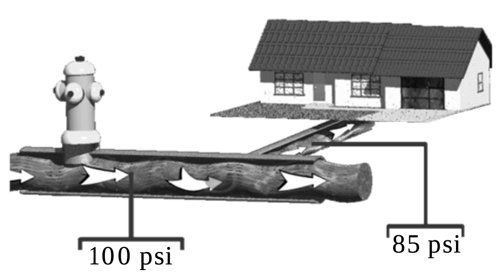
Normal Flow



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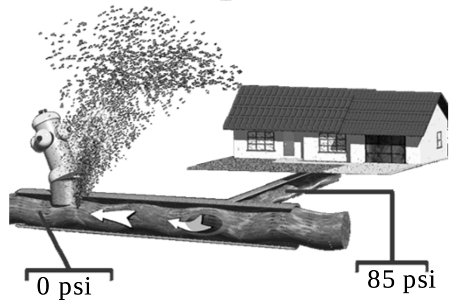
Reverse Flow - Backflow



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Backflow

- The undesirable reversal of flow of water or other substances into the potable water distribution supply
- Occurs due to:
  - Backpressure
  - Backsiphonage

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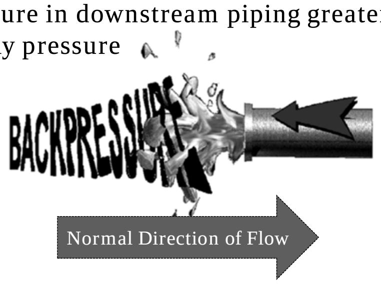
Backpressure

- Pressure in downstream piping greater than supply pressure



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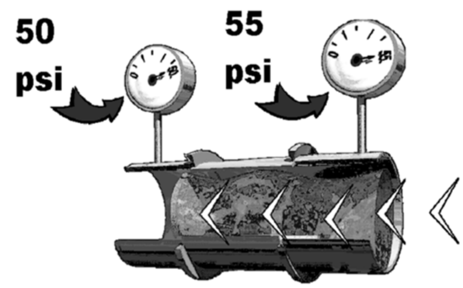
Backpressure



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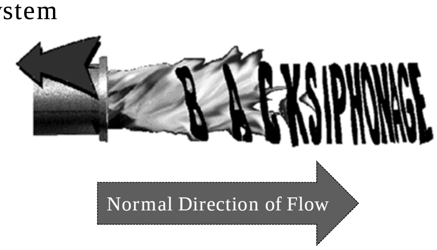
Backsiphonage

- Sub-atmospheric pressure in the water system



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Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?

- As backsiphonage occurs air will be drawn up into the water pipes

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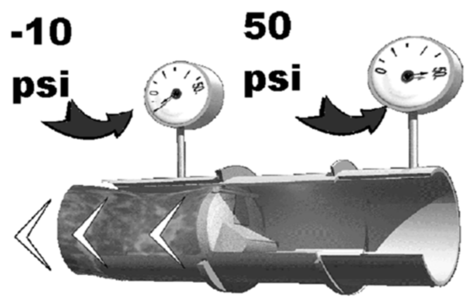
Backsiphonage

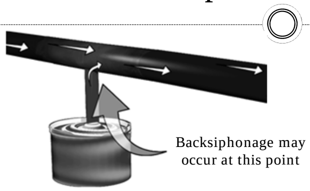
What is drawn into the water pipes if backsiphonage occurs?

- Whatever is in the barrel…

Backsiphonage



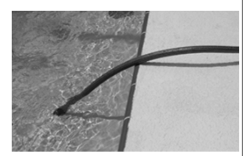
Aspirator Effect



- As water flows through a pipe, the pressure against the walls of the pipe decreases as the speed of the water increases
- If a second pipe is attached there could be a low pressure area created at the point of connection which could siphon water from the attached pipe into the flowing pipe - Backsiphonage

Cross-Connection

- An actual or potential connection between a potable water supply and any non-potable substance or source
- Cross-connection types:
  - Direct
  - Indirect



Direct Cross-Connection

- A direct cross-connection is subject to backpressure or backsiphonage

Indirect Cross-Connection

- An indirect cross-connection is subject to backsiphonage only

Submerged Inlet

Indirect Cross Connection

Submerged Inlet

Low Inlet

Low Inlet

Direct Cross Connection?

Degree of Hazard

- Non-Health Hazard
  - Low hazard
  - Will not cause illness or death
  - **Pollutant**

- Health Hazard
  - High hazard
  - Causes illness or death
  - **Contaminant**

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The Backflow Incident

For backflow to occur three conditions must be met:

1. There must be a cross-connection. A passage must exist between the potable water system and another source.
2. A hazard must exist in this other source to which the potable water is connected.
3. The hydraulic condition of either backsiphonage or backpressure must occur.

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Five Means of Preventing Backflow

- Air Gap Separation (AG) **Best Method**
- Reduced Pressure Principle Assembly (RPZ/RPBP/RP) **Best Device**
- Double Check Valve Assembly (DCVA)
- Pressure Vacuum Breaker (PVB)/ Spill-Resistant Vacuum Breaker
- Atmospheric Vacuum Breaker (AVB)

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Air Gap

- An air gap is the vertical separation between the water supply line outlet and the overflow rim of the non-pressurized receiving fixture or tank

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Air Gap

2 X ID,
not <1 inch

- An air gap is the *BEST* method of protection against backflow
- Approved air gap separation must have a vertical unobstructed distance of at least twice the internal diameter of the outlet pipe, but never less than 1 inch

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Air Gap Separation Limitations

- The air gap is the best method of backflow prevention, but it is easily defeated through modifications or being bypassed
- The air gap separation causes a loss of pressure in the system
- Sanitary control is lost - cannot be installed in an environment containing airborne contamination

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Approved Air Gap Separation

Backflow Protection Against:

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

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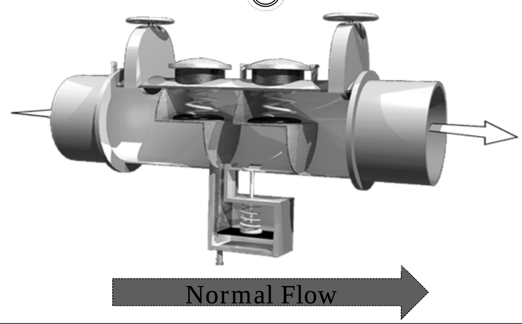
Reduced Pressure Principle Assembly



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Reduced Pressure Principle Assembly

- The reduced pressure principle backflow prevention assembly (RP) consists of two independently operating check valves together with a hydraulically operating, mechanically independent, pressure differential relief valve located between the check valves, all located between two resilient seated shutoff valves and four properly located test cocks.
- *BEST* device to protect against backflow

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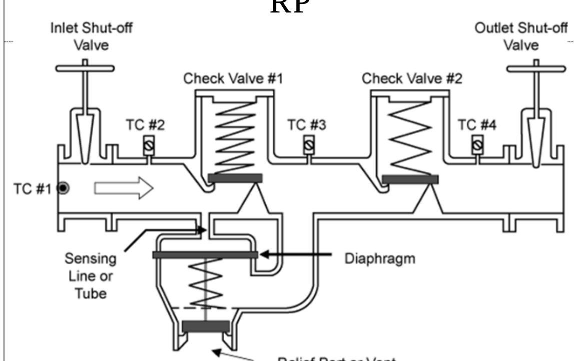
RP



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RP

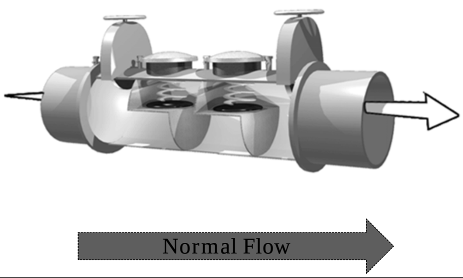
- The two check valves loaded in the closed position mechanically keep the water flowing in one direction through the assembly
- The relief valve assembly is designed to maintain a lower pressure in the zone between the two checks than in the supply side of the unit which hydraulically keeps the water flowing in one direction through the assembly
  - Water always flows from high pressure to low pressure

RP

Backflow Protection Against:

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

Double Check Valve Assembly (DC)

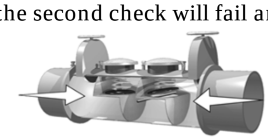


Double Check Valve Assembly (DC)

- The double check valve backflow prevention assembly (DC) consists of two independently operating check valves installed between two tightly closing resilient seated shutoff valves and fitted with four properly located test cocks
- Similar to the RP, but has no relief port so it cannot maintain a lower pressure in the zone between the checks and nowhere for the water to go during a backflow incident or failure

Double Check Valve Assembly (DC)

- Since the water in a DC cannot leave the system during a backflow event or assembly failure then it is a higher risk and therefore cannot be used in a high hazard (contaminant) application
- If one check fails the other will continue to protect, but given enough time the second check will fail and backflow will occur



Second check fouled during backpressure

Double Check Valve Assembly (DC)

Backflow Protection Against:

- Backsiphonage
- Backpressure
- Pollutant only

Proper Installation for DC and RP

- Lowest part of the relief valve should be a minimum of 12 inches above either: the ground, the top of the opening of the enclosure wall, or the maximum flood level
  - Whichever is highest, in order to prevent any part of the assembly from becoming submerged
- Maximum 60” above grade to the center line of assembly, if higher then safe permanent access must be provided for testing and servicing

* Tennessee Cross-Connection Control Manual and Design Criteria for Cross-Connection Control Plans, Ordinances, and Policies (2008) – Appendix B

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Proper Installation for DC and RP

- Assemblies should be installed in accordance with manufacturer's installations otherwise it voids the approval for the assembly
- Protected from vandalism and weather (if needed)
- RP requires adequate drainage – ***cannot*** be installed in a pit or meter box
- Must be accessible for testing and repair

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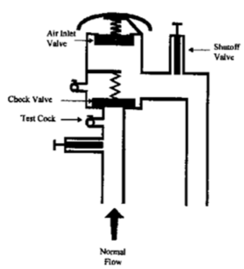
Pressure Vacuum Breaker (PVB)



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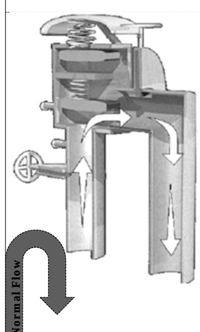
Pressure Vacuum Breaker (PVB)



- The pressure vacuum breaker or spill resistant vacuum breaker consists of an independently operating check valve loaded in the closed position and an independently operating air inlet valve loaded in the open position and located on the discharge side of the check valve, with tightly closing shutoff valves on each side of the check valves, and properly located test cocks for valve testing

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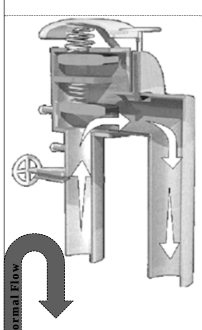
Pressure Vacuum Breaker (PVB)



- Incoming water pressure will compress the spring on the check and flow into the body
- As pressure builds up in the body it will compress the spring on the air valve and close it allowing water to travel downstream

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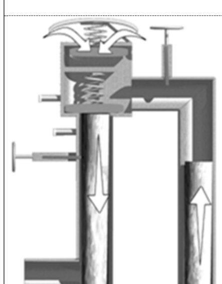
PVB Backsiphonage Condition



- In a backsiphonage condition there is a loss of supply pressure and the check valve is forced closed
- If the body loses pressure the air inlet valve is forced open allowing air into the body of the pressure vacuum breaker and breaking any siphon
- Only to be used to protect against backsiphonage

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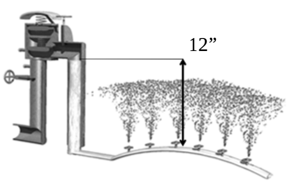
Installation of PVB

- PVB is not designed to protect against backpressure and cannot have any source of backpressure (including head pressure) downstream of the device
- Needs to be installed **12 inches** above the highest point downstream



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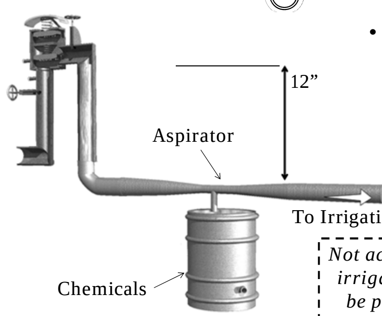
Pressure Vacuum Breaker



- Acceptable installation not subject to backpressure

Not acceptable in TN – all irrigation systems must be protected by an RP

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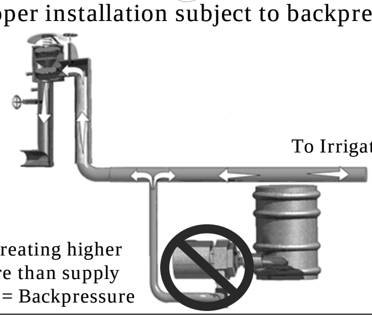
Pressure Vacuum Breaker

- Improper installation subject to backpressure



Pump creating higher pressure than supply pressure = Backpressure

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Pressure Vacuum Breaker

Backflow Protection Against:

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 12" above downstream piping

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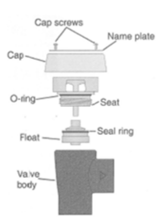
Atmospheric Vacuum Breaker (AVB)



Atmospheric Vacuum Breaker Exploded View

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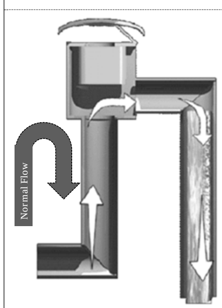
Atmospheric Vacuum Breaker (AVB)



- The atmospheric vacuum breaker is a device designed to prevent backsiphonage. It consists of a body, a single moving float that acts as a check valve when there is no flow and as a air-inlet valve when flow is present, and an air-inlet opening covered by a cap

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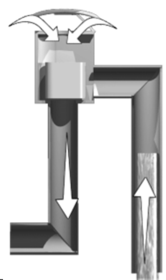
Atmospheric Vacuum Breaker (AVB)

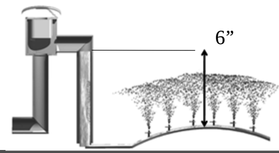
- During a backsiphonage condition the float drops by gravity due to the loss of incoming pressure which automatically opens the air inlet, introducing air into the system to break any siphon that has formed

Loss of supply pressure

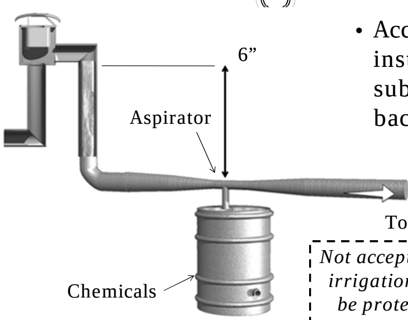


Installation of AVB

- AVB is <u>not</u> designed to protect against backpressure and cannot have any source of backpressure (including head pressure) downstream of the device
- Needs to be installed **<u>6 inches</u>** above the highest point downstream



Atmospheric Vacuum Breaker

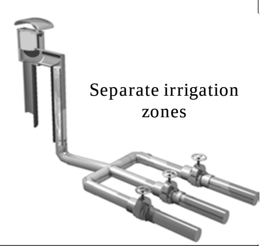


- Acceptable installation not subject to backpressure

Not acceptable in TN – all irrigation systems must be protected by an RP

Atmospheric Vacuum Breaker

- Improper installation: downstream shutoff valves
- Shutoff valves downstream of an AVB can cause a continuous use situation
- The float of an AVB subjected to continuous use could begin to adhere to the air inlet and allow backflow



Atmospheric Vacuum Breaker

<u>Backflow Protection Against</u>:

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 6”
- Non-Continuous Use

	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	PVB	PVB	
		AVB	
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	PVB	
		AVB	

Testing of Assemblies

- Assemblies must be tested when installed, after repair, and at least annually
- Assembly testing must be conducted by certified personnel
- TDEC issues a certification for all assembly testers
- Backflow tester certification courses are offered through the Fleming Training Center

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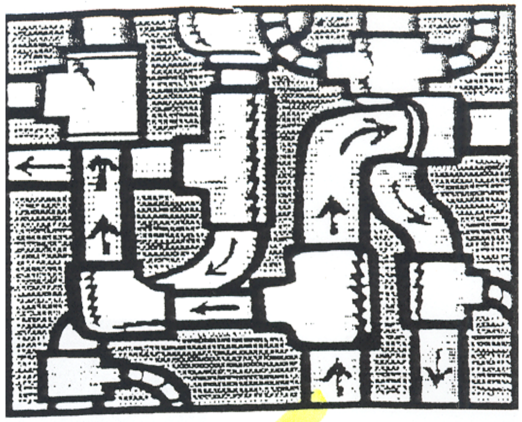


Vocabulary

<u>Absolute Pressure</u> – The total pressure; gauge pressure plus atmospheric pressure. Absolute pressure is generally measured in pounds per square inch (psi).

<u>Air Gap</u> – The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other device, and the flood-level rim of the receptacle. This is the most effective method for preventing backflow.

<u>Atmospheric Pressure</u> – The pressure exerted by the weight of the atmosphere (14.7 psi at sea level). As the elevation above sea increases, the atmospheric pressure decreases.

<u>Backflow</u> – The reversed flow of contaminated water, other liquids or gases into the distribution system of a potable water supply.

<u>Backflow Prevention Device (Backflow Preventer)</u> – Any device, method or construction used to prevent the backward flow of liquids into a potable distribution system.

<u>Back Pressure (Superior Pressure)</u> – (1) A condition in which the pressure in a nonpotable system is greater than the pressure in the potable distribution system. Superior pressure will cause nonpotable liquids to flow into the distribution system through unprotected cross connections. (2) A condition in which a substance is forced into a water systems because that substance is under higher pressure than the system pressure.

<u>Backsiphonage</u> – (1) Reversed flow of liquid cause by a partial vacuum in the potable distribution system. (2) A condition in which backflow occurs because the pressure in the distribution system is less than atmospheric pressure.

<u>Bypass</u> – Any arrangement of pipes, plumbing or hoses designed to divert the flow around an installed device through which the flow normally passes.

Chemical – A substance obtained by a chemical process or used for producing a chemical reaction.

Containment (Policy) – To confine potential contamination within the facility where it arises by installing a backflow prevention device at the meter or curbstop.

Contamination – The introduction into water of any substance that degrades the quality of the water, making it unfit for its intended use.

Continuous Pressure – A condition in which upstream pressure is applied continuously (more than 12 hours) to a device or fixture. Continuous pressure can cause mechanical parts within a device to freeze.

Cross Connection – (1) Any arrangement of pipes, fittings or devices that connects a nonpotable system to a potable system. (2) Any physical arrangement whereby a public water system is connected, either directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture or other waste or liquid of unknown or unsafe quality.

Cross Connection Control – The use of devices, methods and procedures to prevent contamination of a potable water supply through cross connections.

Degree of Hazard – The danger posed by a particular substance or set of circumstances. Generally, a low degree of hazard is one that does not affect health, but may be aesthetically objectionable. A high degree of hazard is one that could cause serious illness or death.

Direct Connection – Any arrangement of pipes, fixtures or devices connecting a potable water supply directly to a nonpotable source; for example, a boiler feed line.

Distribution System – All pipes, fitting and fixtures used to convey liquid from one point to another.

Double Check-Valve System Assembly – A device consisting of two check valves, test cocks and shutoff valves designed to prevent backflow.

Gauge Pressure – Pounds per square inch (psi) that are registered on a gauge. Gauge pressure measures only the amount of pressure above (or below) atmospheric pressure.

Indirect Connection – Any arrangement of pipes, fixtures or devices that indirectly connects a potable water supply to a nonpotable source; for example, submerged inlet to a tank.

Isolation (policy) – To confine a potential source of contamination to the nonpotable system being served; for example, to install a backflow prevention device on a laboratory faucet.

Liability – Obligated by law.

Negative Pressure – Pressure that is less than atmospheric; negative pressure in a pipe can induce a partial vacuum that can siphon nonpotable liquids into the potable distribution system.

Nonpotable – Any liquid that is not considered safe for human consumption.

Nontoxic – Not poisonous; a substance that will not cause illness or discomfort if consumed.

Physical Disconnection (Separation) – Removal of pipes, fittings or fixtures that connect a potable water supply to a nonpotable system or one of questionable quality.

Plumbing – Any arrangement of pipes, fittings, fixtures or other devices for the purpose of moving liquids from one point to another, generally within a single structure.

Poison – A substance that can kill, injure or impair a living organism.

Pollution – Contamination, generally with man-made waste.

Potable – Water (or other liquids) that are safe for human consumption.

Pressure – The weight (of air, water, etc.) exerted on a surface, generally expressed as pounds per square inch (psi).

Pressure Vacuum Breaker – A device consisting of one or two independently operating, spring-loaded check valves and an independently operating, spring-loaded air-inlet valve designed to prevent backsiphonage.

Reduced-Pressure-Principle or Reduced-Pressure-Zone Device (RP or RPZ) – A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the checks designed to protect against both backpressure and backsiphonage.

Refusal of Service (Shutoff Policy) – A formal policy adopted by a governing board to enable a utility to refuse or discontinue service where a known hazard exists and corrective measures are not undertaken.

Regulating Agency – Any local, state or federal authority given the power to issue rules or regulations having the force of law for the purpose of providing uniformity in details and procedures.

Relief Valve – A device designed to release air from a pipeline, or introduce air into a line if the internal pressure drops below atmospheric pressure.

Submerged Inlet – An arrangement of pipes, fittings or devices that introduces water into a nonpotable system below the flood-level rim of a receptacle.

Superior Pressure – See backpressure.

Test Cock – An appurtenance on a device or valve used for testing the device.

Toxic – Poisonous; a substance capable of causing injury or death.

Vacuum (Partial Vacuum) – A condition induced by negative (subatmospheric) pressure that causes backsiphonage to occur.

Venturi Principle – As the velocity of water increases, the pressure decreases. The Venturi principle can induce a vacuum in a distribution system.

Waterborne Disease – Any disease that is capable of being transmitted through water.

Water Supplier (Purveyor) – An organization that is engaged in producing and/or distributing potable water for domestic use.

Cross Connection Vocabulary

______1. Air Gap
______2. Atmospheric Vacuum Breaker
______3. Auxiliary Supply
______4. Backflow
______5. Back Pressure
______6. Backsiphonage
______7. Check Valve
______8. Cross Connection
______9. Feed Water
______10. Hose Bibb
______11. Overflow Rim
______12. Pressure Vacuum Breaker
______13. Reduced Pressure Zone Backflow Preventer
______14. RPBP

A. A valve designed to open in the direction of normal flow and close with the reversal of flow.
B. A hydraulic condition, caused by a difference in pressures, in which non-potable water or other fluids flow into a potable water system.
C. Reduced pressure backflow preventer.
D. In plumbing, the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other container, and the overflow rim of that container.
E. A backflow condition in which the pressure in the distribution system is less than atmospheric pressure.
F. A faucet to which a hose may be attached.
G. A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the check valves.
H. Any water source or system, other than potable water supply, that may be available in the building or premises.
I. Water that is added to a commercial or industrial system and subsequently used by the system, such as water that is fed to a boiler to produce steam.
J. A device designed to prevent backsiphonage, consisting of one or two independently operating spring-loaded check valves and an independently operating spring –loaded air-inlet valve.
K. A backflow condition in which a pump, elevated tank, boiler or other means results in a pressure greater than the supply pressure.
L. Any arrangement of pipes, fittings, fixtures or devices that connects a nonpotable water system.
M. The top edge of an open receptacle over which water will flow.
N. A mechanical device consisting of a float check valve and an air-inlet port designed to prevent backsiphonage.

Answers:
1. D
2. N
3. H
4. B
5. K
6. E
7. A
8. L
9. I
10. F
11. M
12. J
13. G
14. C

Section 8

Safety

SAFETY

Updated 11/20/2019

ACCIDENT

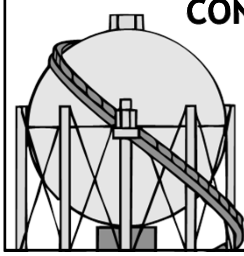
- An accident is caused by either an unsafe act or an unsafe environment

GENERAL DUTY CLAUSE

Federal – 29 CFR 1903.1

- EMPLOYERS MUST:
  - Furnish a place of employment free of recognized hazards that are causing or are likely to cause death or serious physical harm to employees
  - Comply with occupational safety and health standards promulgated under the Williams-Steiger Occupational Safety and Health Act of 1970.

CONFINED SPACES



CONFINED SPACE CONDITIONS

- Defined as any space where BOTH of the following conditions exist at the same time:
  - existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop
  - ready access/egress for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of opening(s)
- Large enough and so configured that an employee can bodily enter and perform assigned work
- Limited or restricted means of entry or exit
- Not designed for continuous employee occupancy

CONFINED SPACE EXAMPLES

- Vaults
- Silos
- Inside filters
- Basins
- Storage tanks
- Pits
- Hoppers

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EQUIPMENT NEEDED

- Safety harness with lifeline, tripod, and winch
- Electrochemical sensors
- Ventilation blower with hose

7

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EQUIPMENT NEEDED cont'd

- PPE
- Ladder
- Rope
- Breathing apparatus

8

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SPACES THAT REQUIRE PERMITS

- Contains or has potential to contain hazardous atmosphere
- Contains material with potential to engulf and entrant
- Entrant could be trapped or asphyxiated

9

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ATMOSPHERIC HAZARDS

- Need to have atmosphere monitored!!!
- Explosive or flammable air
- Toxic air
- Depletion or elimination of breathable oxygen

10

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HYDROGEN SULFIDE - H_2S

- Detected by the smell of rotten eggs
- Loss of ability to detect short exposures
- Not noticeable at high concentrations
- Exposures to 0.07% to 0.1% will cause acute poisoning and paralyze the respiratory center of the body
- At the above levels, death and/or rapid loss of consciousness occur

11

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METHANE GAS - CH_4

- Product of waste decomposition
- Leaks in natural gas pipelines can saturate the soil
- Explosive at a concentration of 5%
- Spaces may contain concentrations above the Lower Explosive Limits (LEL) and still have oxygen above the 19.5% allowable
- Gasoline storage tanks, gas stations, petroleum product pipelines, accidental spills by traffic accidents

12

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CARBON MONOXIDE - CO

- Decreases amount of oxygen present
- ALWAYS VENTILATE
- 0.15% (1500 ppm) = DEATH
- Will cause headaches at 0.02% in a two hour period
- Maximum amount of 0.04% in 60 minute period
- Colorless, odorless, tasteless, flammable and poisonous

13

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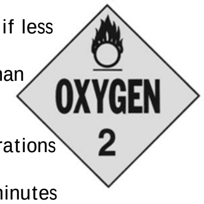
OXYGEN – O_2

- ALWAYS ventilate – normal air contains ~ 21%
- Oxygen deficient atmosphere if less than 19.5%
- Oxygen enriched at greater than 23.5%
  - Speeds combustion
- Leave area if oxygen concentrations approach 22%
- At 8%, you will be dead in 6 minutes
- At 6%, coma in 40 seconds and then you die



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OXYGEN – O_2

- When O_2 levels drop below 16%, a person experiences
  - Rapid fatigue
  - Inability to think clearly
  - Poor coordination
  - Difficulty breathing
  - Ringing in the ears
  - Also, a false sense of well-being may develop

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OXYGEN – O_2

- In a confined space, the amount of oxygen in the atmosphere may be reduced by several factors
  - Oxygen consumption
    - During combustion of flammable substances
    - Welding, heating, cutting or even rust formation
  - Oxygen displacement
    - Carbon dioxide can displace oxygen
  - Bacterial action

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ATMOSPHERIC ALARM UNITS

- Should continuously sample the atmosphere of the area
- Test atmospheres before entering
- Test for oxygen first
- Combustible gases second

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ATMOSPHERIC ALARM UNITS

- Alarms set to read flammable gasses exceeding 10% of the lower explosive limit
  - H_2S exceeds 10 ppm and/or O_2 percentage drops below 19.5%
- Calibrate unit before using
- Most desirable units simultaneously sample, analyze, and alarm all 3 atmospheric conditions

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REQUIRED TRAINING

- Employer shall train all employees on hazards, procedures, and skills to perform their jobs safely
- Employees trained before first assigned duty
- Employer shall certify training of employees
- Maintain individual training records of employees

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RECORD KEEPING

- Identification and evaluation of all hazardous areas in workplace
- Entrance permits filed
- Training certification
- Written confined space program

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GENERAL REQUIREMENTS

- Identify, evaluate, and monitor hazards in permit-required confined spaces
- Post signs “Permit Required”
- Prevent unauthorized entries
- Re-evaluate areas
- Inform contractors
- Have a written program available for employees
- Have proper PPE
- Annual training (OSHA requirement)

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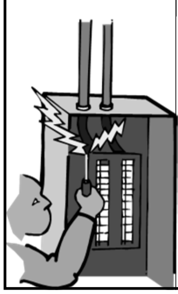
CONFINED SPACE REQUIREMENTS

- All electrodes removed and machines disconnected from power sources
- Gas supply shut off
- Gas cylinders outside of work area
- All employees entering must undergo confined space training
- Ventilation used to keep toxic fumes, gasses, and dusts below max levels



ELECTRICAL SAFETY

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ELECTRICAL SAFETY

OSHA says:

- Any electrical installations shall be done by a professionally trained electrician
- Any employee who is in a work area where there is a danger of electric shock shall be trained
- Employees working on electrical machinery shall be trained in lockout/tagout procedures

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TRANSFORMER

- Allows energy to be transferred in an AC system for one circuit to another
- Used to convert high voltage to low voltage
  - High voltage is 440 volts or higher
- Standby engines should be run weekly to ensure that it is working properly
- Relays are used to protect electric motors

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FIRE PROTECTION

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FIRE PROTECTION

Equipment

- Fire extinguishers shall be located where they are readily accessible
- Shall be fully charged and operable at all times
- All fire fighting equipment is to be inspected at least annually

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FIRE PROTECTION

Fire Protection Equipment

- Portable fire extinguishers inspected at least monthly and records kept
- Hydrostatic testing on each extinguisher every five years
- Fire detection systems tested monthly if battery operated

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TYPES OF FIRE EXTINGUISHERS

- **Class A**

  - Used on combustible materials such as wood, paper or trash
  - Can be water based
- **Class B**

  - Used in areas where there is a presence of a flammable or combustible liquid
  - Shall not be water based
  - Example is dry chemical extinguisher
  - An existing system can be used but not refilled

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TYPES OF FIRE EXTINGUISHERS

- **Class C**

  - Use for areas electrical
  - Best is carbon dioxide extinguisher
  - Using water to extinguish a class C fire risks electrical shock
- **Class D**
  - Used in areas with combustible metal hazards
  - Dry powder type
  - Use no other type for this fire

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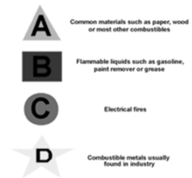
FIRE EXTINGUISHERS

Types of Fire Extinguishers

Class	Material	Method
A	Wood, paper	Water
B	Flammable liquids (oil, grease, paint)	Carbon dioxide, foam, dry chemical, Halon
C	Live electricity	Carbon dioxide, dry chemical, Halon
D	Metals	Carbon dioxide

TYPES OF FIRE EXTINGUISHERS

- Combination ABC are most common
- Have the types of extinguishers available depending upon analyses performed in each area



FIRE EXTINGUISHERS

- To operate a fire extinguisher, remember the word **PASS**
  - **P**ull the pin. Hold the extinguisher with the nozzle pointing away from you.
  - **A**im low. Point the extinguisher at the base of the fire.
  - **S**queeze the lever slowly and evenly.
  - **S**weep the nozzle from side-to-side.

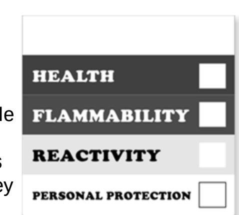
CHEMICAL SAFETY

PERSONAL PROTECTIVE EQUIPMENT (PPE)

- Gloves
- Coveralls/overalls
- Face shield/goggles
- Respirator/SCBA
- Boots
- Ear plugs/muffs

RTK LABELS

- "Right to Know"
  - In 1983, OSHA instituted Hazard Communication Standard 1910-1200, a rule that gives employees the right to know the hazards of chemicals to which they may be exposed in the workplace.



NFPA

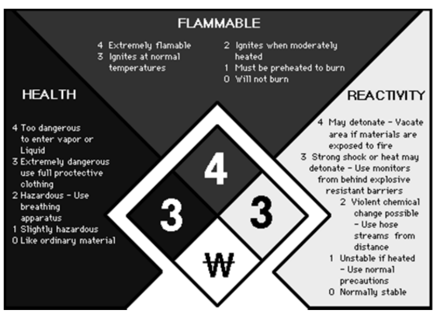
- National Fire Protection Association
- Chemical hazard label
  - Color coded
  - Numerical system
    - Health
    - Flammability
    - Reactivity
  - Special precautions
- Labels are required on all chemicals in the lab

CHEMICAL HAZARD LABEL

Degrees of Hazard

- Each of the colored areas has a number in it regarding the degree of hazard
  - 4 → extreme
  - 3 → serious
  - 2 → moderate
  - 1 → slight
  - 0 → minimal

CHEMICAL HAZARD LABEL



CHEMICAL HAZARD LABEL

Special

- W → water reactive
- Ox → oxidizing agent

OSHA PICTOGRAMS

Flammables Oxidizers Explosives Acute toxicity Corrosives

Gases under pressure Carcinogens Environmental toxicity Irritant

WORKPLACE LABELING

- Can HMIS or NFPA system be used?
- While, the hazard category does not appear on the label, consider

GHS Category	Hazard		HMIS/NFPA Category	Hazard
1	highest		1	slight
2	high		2	moderate
3	medium	→	3	serious
4	low		4	severe

NFPA categories were intended for emergency response, not workplace hazards; only considers acute effects, does not consider chronic effects

TERMS

- Lower Explosive Level (LEL)
  - minimum concentration of flammable gas or vapor in air that supports combustion
- Upper Explosive Level (UEL)
  - maximum concentration of flammable gas or vapor in air that will support combustion
- Teratogen
  - causes structural abnormality following fetal exposure during pregnancy
- Mutagen
  - capable of altering a cell's genetic makeup

CHLORINE & HYPOCHLORITE SAFETY

CHLORINE GAS – Cl_2

- 2.5 times as dense as air
- Liquid expands easily into gas at room temperature 460 times
- Pungent, noxious odor
- Greenish-yellow color
- Toxic by inhalation, ingestion and through skin contact
- May irritate or burn skin

CHLORINE GAS – Cl_2

- Inhalation can cause serious lung damage and may be fatal
  - 1000 ppm (0.1%) is likely to be fatal after a few deep breaths
    - half that concentration, fatal after a few minutes
- It takes as little as 3 ppm to be detected as a distinct odor

CHLORINE SAFETY

Safety Precautions for Chlorine Gas

- Compressed air
  - 30 minute capacity
- Annually inspected
- Trained/fit tested
- PPE
  - Rubber gloves
  - Apron
  - Goggles
  - Safety shower, eyewash

CHLORINE SAFETY

Where Chlorine Gas Is Used:

- Separate room for chlorine, with window to view inside
- Ventilation provided for one complete air change per minute
- Air outlet located near the floor
- Air inlet near the ceiling
- Temperature controlled room, 60ºF
- Switches for lights and fans located outside of room, crash-bar on door inside of chlorine room
- Vents from feeders and storage shall discharge to the outside atmosphere, above grade

CHLORINE SAFETY

Where Chlorine Gas Is Used (cont'd):

- Must have a chlorine gas detection device connected to an alarm that can be heard throughout the treatment plant
- All gaseous feed chlorine installations shall be equipped with appropriate leak repair kits
- A fusible plug, designed to melt at 158º to 165ºF (70-74ºC), is located in the valve on a 150-lb cylinder and on the head of a ton container
  - It is designed to relieve pressure in the cylinder or container when exposed to high heat
- Leak detection – an ammonia solution produces white "smoke" in the presence of chlorine
  - A sensor type leak detector is the best means of detecting small leaks, less than 1ppm

CHLORINE GAS CONTAINERS

- 3 types of Containers
  - 150 lb cylinder – Emergency repair kit A
  - Ton cylinder – Emergency repair kit B
  - Railroad cars – Emergency repair kit C

CHLORINE SAFETY

Calcium Hypochlorite (HTH)

- Dry, white or yellow granular material
- Strong oxidizer
- Reacts with organics and can start fires
- Gives off lots of heat when mixed with water
- Will give off chlorine gas when it reacts
- Always add HTH to water when mixing
  - **NEVER add water to HTH!!**

CHLORINE SAFETY

Calcium Hypochlorite (HTH)

- Granular HTH is safer to work with than tablet or liquid form
- HTH should be stored in a cool dry place away from acids, reducing agents, paints, oils, and grease
- Use a carbon dioxide extinguisher to put out fires started by HTH

CHLORINE SAFETY

Calcium Hypochlorite (HTH)

- If a small amount of calcium hypochlorite is spilled, the chemical should be disposed of by dissolving it in a large amount of water

CHLORINE SAFETY

Calcium Hypochlorite (HTH) – PPE

- Eye protection, protective clothing
- Rubber gloves
  - It will react with leather
- Rubber boots
  - It will react with leather
- SCBA

Section 9

Laboratory

Laboratory Practices

Fleming Training Center | TN Department of Environment & Conservation

Updated 11/20/2019

Water Quality

- Process control monitoring
  - All public water systems that provide some type of treatment must monitor water quality
- Monitored to ensure safety and integrity
- Monitored to meet state and federal requirements
- Monitor raw, finished, and where you expect a physical/chemical change in your plant
- Monitor in distribution system also
  - Quality can degrade due to contamination or growth of organisms

Water Quality

Degradation

- Treated water is disinfected, not sterilized
- Disinfection kills or inactivates harmful organisms (pathogens)
- Organisms can grow in distribution system if conditions are right
- To prevent growth of organisms
  - Keep chlorine residuals up
  - Keep excess nutrients out
  - Prevent stagnation
  - Prevent cross-connections

Water Quality

Analysis

- The first step in water quality analysis is collecting samples which accurately represent the water
  - Representative sample
    - sample which contains basically the same constituents as the body of water from which it was taken
  - Improper sampling is one of the most common causes of error in water quality
- All chemical analysis must be kept for <u>10 years</u>

Sampling

Types of Samples

- Grab sample
  - Single volume of water
  - Representative of water quality at exact time and place of sampling
  - Coliform bacteria, residual chlorine, temperature, pH, dissolved gases
- Composite samples
  - Representative of average water quality of location over a period of time
  - Series of grab samples mixed together
  - Determines average concentration
  - Not suitable for all tests

Sampling

Sample Volume and Storage

- Volume depends on test requirements
- Use proper sampling container
- Follow recommended holding times and preservation methods
  - If bottle already has preservative or dechlorinator in it, don't over fill or rinse out

❖ If you have questions regarding volume, container or holding times, check *Standard Methods* or contact the lab if you have an outside lab do you analysis

Sampling

Sample Labeling

- Specific location (address)
- Date and time sampled
- Chlorine residual
- pH and temperature
- Sample type
- Name or initials of person taking sample

Sampling

Selecting Sampling Points

- Raw-water supply
- Treatment plant
- Distribution system

Sampling

Raw-water Sampling Points

- Install valve or sample cock on raw-water transmission lines or well discharge pipe

Sampling

Treatment Plant Sampling Points

- Sampling from various points helps determine efficiency of processes
- Sample at every point where a change in water quality is expected
- Finished water sample point usually at point of discharge from clearwell

Sampling

Distribution Sampling Points

- Distribution sampling is the best indicator of system water quality
- Water quality changes in the distribution system:
  - Corrosion
    - increase in color, turbidity, taste and odor
  - Microbiological growth
    - slime
  - Cross-connections

Sampling

Distribution Samples

- Determine water quality at customers' taps
- Most common tests are chlorine residual and coliform bacteria
- Number of samples depends on population served or water source

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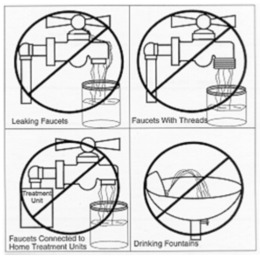
Sampling

Monthly Distribution System Bacteriological Samples

- Samples should never be taken from a hydrant or hose
- Only collect samples from approved faucets
- Don't collect samples from swivel faucets
- Only use cold water tap
- Front yard faucets on homes with short service lines



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Sampling

Monthly Distribution System Bacteriological Samples

- Do not flame faucet with torch
  - Use alcohol or bleach solution to clean
- Turn on faucet to steady flow and flush service line (2-5 min) – getting water from the main line
- Fill bottle to proper level
- Label bottle with pertinent information
- Refrigerate to proper temperature, 4°C
- Test as soon as possible – within 30 hours

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Collection of Samples

- Only approved containers should be used
  - 125 mL volume
  - Pre-sterilized bottles recommended
  - Other bottles sterilized at 121°C for 15 min
  - Should contain sodium thiosulfate

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Collection of Samples

- Remove aerator or screen
- Collect sample from cold water tap
- Sample from homes with short service lines
  - same side of street as water main

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Collection of Samples

- Disinfect faucet with sodium hypochlorite
- Flush service line
- Adjust flow so that no splashing will occur

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Collection of Samples

- Do not touch inside of lid of sample bottle
- Do not set lid down or put it in your pocket
- Do not rinse bottle or allow it to overflow

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Microbiological Indicator Organism

- Always present in contaminated water
- Always absent when no contamination
- Survives longer in water than other pathogens
- Is easily identified
- Water treatment indicator organism

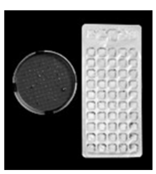
Total Coliforms

EPA Approved Methods

- Multiple-Tube Fermentation
- Presence-Absence Test
- MMO-MUG
- Membrane Filter Method
- Enzyme (chromogenic/fluorogenic) Substrate Tests

Bacteriological Samples

- The MCL for coliform bacteria is based on presence or absence
- Finished and distributed water should be Zero (absent)



Bacteriological Testing

- Results must keep results for 5 years
- Must collect chlorine residual wherever a bac't sample is collected
- Sample must be tested within 30 hours of sample collection (holding time)
- Sample must be incubated at 35 +/-5°C for 24 hours
- Any sample that test positive for total coliform must be tested for e. Coli

State Regulations

- 0400-45-1-.06(4) Microbiological
  - (a)1. If you collect 40 samples/month, no more than 5% can be positive to be in compliance
  - (a)2. If you collect less than 40 samples/month, no more than 1 sample can be positive to be in compliance
  - (c) If any routine or repeat sample test (+) for total coliform, it must be analyzed for fecal or *E. coli*

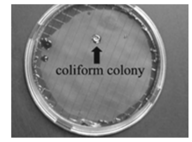
State Regulations

- 0400-45-1-.07(2) Repeat Monitoring
  - (a) If a routine sample is total coliform positive, the system must collect a set of repeat samples within 24 hours of being notified of the positive result. A system which collects one routine sample per month or fewer must collect no fewer than four repeat samples for each total coliform-positive sample found. The Department may extend the 24-hour limit on a case-by-case basis if the system has a problem in collecting the repeat samples within 24 hours that is beyond its control. In the case of an extension, the Department must specify how much time the system has to collect the repeat samples.

State Regulations

- 0400-45-1-.07(2) Repeat Monitoring
  - (b) The system must collect one at original site, at least one repeat within five service connections upstream and at least one repeat within five service connections downstream
  - (c) The system must collect all repeat samples on the same day and within 24 hours of being notified of a positive result, except that the Department may allow a system with a single service connection to collect the required set of repeat samples over a four consecutive day period or to collect a larger volume repeat sample(s) in one or more sample containers of any size, as long as the total volume collected is at least 400 ml (300 ml for systems which collect more than one routine sample per month.)

Testing



Membrane Filter Technique

- 100 mL sample is filtered through a membrane filter under a vacuum
- Filter placed on sterile Petri-dish containing M-Endo broth (food source for bacteria) for Total Coliforms
- Petri-dish labeled, turned upside down, placed in incubator at 35° +/- 0.5°C for 24 hours
- A coliform bacteria colony will grow at each point on filter where a viable bacterium was left during filtering
- The colonies will appear red with a green-gold metallic sheen

Chlorine Residual

- Free chlorine residual must be tested and recorded when bacteriological samples are collected
- Two most common tests:
  - Amperometric titration
    - less interferences as color and/or turbidity
  - DPD (N,N-diethyl-*p*-phenylenediamine)
- Analysis should be performed ASAP
- Exposure to sunlight or agitation of the sample will cause a reduction in the chlorine residual

Chlorine Free Residual

- DPD colorimetric method most commonly used
  - Match color sample to a standard
  - ***<u>Swirl sample for 20 seconds</u>*** to mix
  - Within ***<u>one minute</u>*** of adding reagent, place it into colorimeter
    - Different than Total Residual
- Must maintain a free residual of 0.2 mg/L throughout entire distribution system
  - Chlorine residual must not be less than 0.2 mg/L in more that 5% of samples each month for any two consecutive months

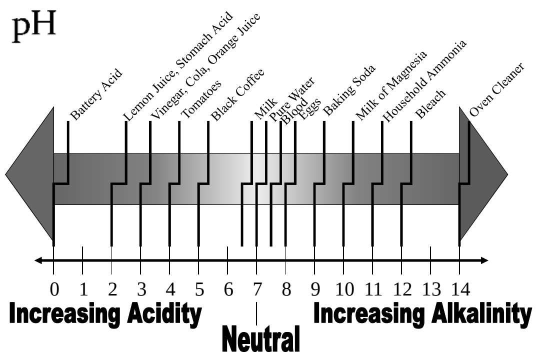
pH

- Power of hydrogen
  - Measurement of the hydrogen concentration
  - Each decrease in pH unit equals 10x increase in acid
- Indicates the intensity of its acidity or basicity
- Scale runs from 0 to 14, with 7 being neutral
- pH probe measures milivolts, then converts into pH units
  - Temperature affects milivolts generated, therefore you need a temperature probe as well for corrections

pH

- Calibrate daily with **<u>fresh buffers</u>**
  - Use at least two buffers
- Gel filled probes are not recommended for water industry
  - Water is too clean for probe to make an accurate measurement
- Store probe in slightly acidic solution
- Replace probes yearly

pH



Fluoride

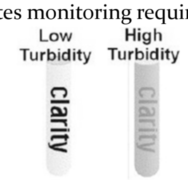
- Added to drinking water for the reduction of dental caries (cavities)
- Interferences
- Primary MCL = 4.0 mg/L
- Secondary MCL = 2.0 mg/L
- State of Tennessee recommends 0.7 mg/L
  - Fluoridation of drinking water in the state of Tennessee is not required

Fluoride

- Methods
  - SPADNS
    - interferences are more common with this test
    - alum or aluminum complexes can interfere
  - Electrode
    - TISAB removes most of the aluminum interferences
      - Total Ionic Strength Adjustment Buffer
      - Contains CDTA – used to tie up interferences
    - store probe in a standard, the higher the better
    - probes can last 3-5 years
    - can clean with toothpaste

Turbidity

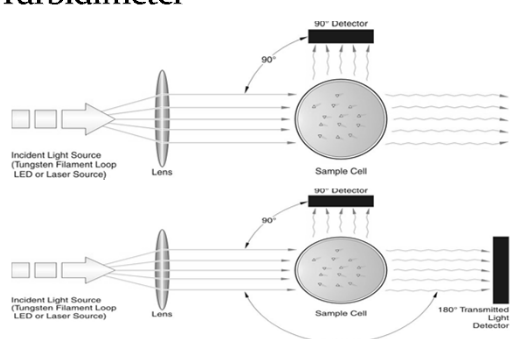
- Physical cloudiness of water
  - Due to suspended silt, finely divided organic and inorganic matter, and algae
- Nephelometric method measures scattered light
  - unit - NTU
- SDWA stipulates monitoring requirements



Turbidity

- Measure samples ASAP
- Keep sample tubes clean and scratch free
- Gently mix samples prior to reading
- Calibrate meter at least quarterly
- Records must be kept until next sanitary survey

Turbidimeter



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Alkalinity

- Capacity of water to neutralize acids
- Due to presence of hydroxides, carbonates, and bicarbonates
- Many water treatment chemicals (alum, chlorine, lime) alter water quality
- Titration using H_2SO_4 to pH endpoint or color change of indicator

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Hardness

- Mainly due to calcium and magnesium ions in solution
- Can cause scale when water evaporates or when heated in water heaters and pipes
- Test involves titration with 0.02 N EDTA standard from a red to a blue endpoint
- Precautions
  - Metal ions may interfere, so an inhibitor may be needed
- Measured as $CaCO_3$, in mg/L

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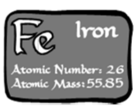
Iron and Manganese

- Can precipitate out in distribution system
- Elevated levels in water can cause staining of plumbing fixtures and laundry
- sMCL for iron is 0.3 mg/L
- sMCL for manganese is 0.05 mg/L



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Lead and Copper Rule

- Established by EPA in 1991
- All community and non-community water systems must monitor for lead and copper at customers' taps
- If aggressive water is dissolving these metals, system must take action to reduce corrosivity
- Samples must be take at high risk locations
  - homes with lead service lines
- Water must sit in lines for at least 6 hours
  - first draw
- One liter of sample collected from cold water tap in kitchen or bathroom
- Test results must be maintained for 12 years

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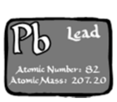
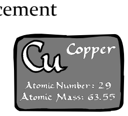
Lead and Copper Rule

- Action levels
  - Lead - 0.015 mg/L
  - Copper - 1.3 mg/L
- If action level is exceeded in more than 10% of samples, steps must be taken to control corrosion
  - Corrosion control program
  - Source water treatment
  - Public Education
  - and/or Lead service line replacement





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Phosphates

- <u>Orthophosphates</u> work well for lead and copper protection
- <u>Polyphosphates</u> work as *sequestering agents* – tie up iron and manganese to prevent color and taste complaints
  - Tie up calcium carbonate as a catalyst
  - Calcium (from alkalinity) is required as a catalyst
  - If low alkalinity, need a blend of polyphosphate and orthophosphate
  - Orthophosphate coats pipe; polyphosphate sequesters

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THM

- Trihalomethane
  - Chloroform
  - Dibromochloromethane
  - Bromodichloromethane
  - Tribromomethane
- MCL = 0.080 mg/L

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HAA5

- Haloacetic acids
  - Monochloracetic acid
  - Dichloroaecitic acid
  - Trichloroacetic acid
  - Monobromoacetic acid
  - Dibromoacetic acid
- MCL = 0.060 mg/L

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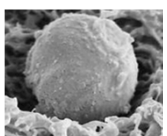
Cryptosporidium (Crypto)

- Protozoan parasite
- Common in surface water
- Resistant to traditional disinfectants
- Can pass through filters
- Causes cryptosporidiosis
- Filtration and alternative disinfectants can remove and/or inactivate



Cryptosporidium Oocyst

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Lab Safety

- Read SDS for all chemicals used in lab
- Store chemicals properly
- Know where safety equipment is stored
- Never pour water into acid
- CPR and First Aid Training (TOSHA requirement)
- Clean chemical spills immediately
- Follow published lab procedures (*Standard Methods*)
- Read and become familiar with Safety SOP

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Lab Safety

Safety Data Sheets (SDS)

- Keep on file for all chemicals purchased
  - According to the Americans with Disabilities Act of 1990, MSDS's should be kept for a minimum of 30 years
- Includes all information shown on chemical label and more

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TDEC - Fleming Training Center

Lab Safety

Safety Data Sheets (SDS)

- Must be readily available for employee review at all times you are in the work place
  - The can't be locked in an office or filing cabinet to which you don't have access to
  - If they are on a computer, everyone must know how to access them
- If you request to see an SDS for a product you use at work and your employer can't show it to you, after one working day you have the right refuse to work with that product until you are shown the correct SDS

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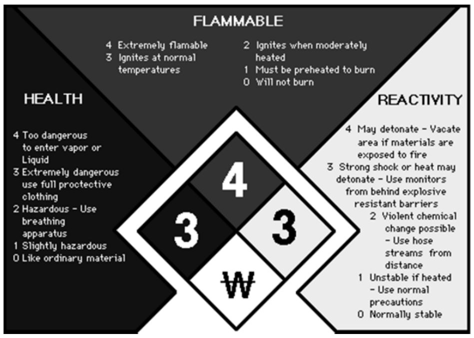
Lab Safety – Chemical Label



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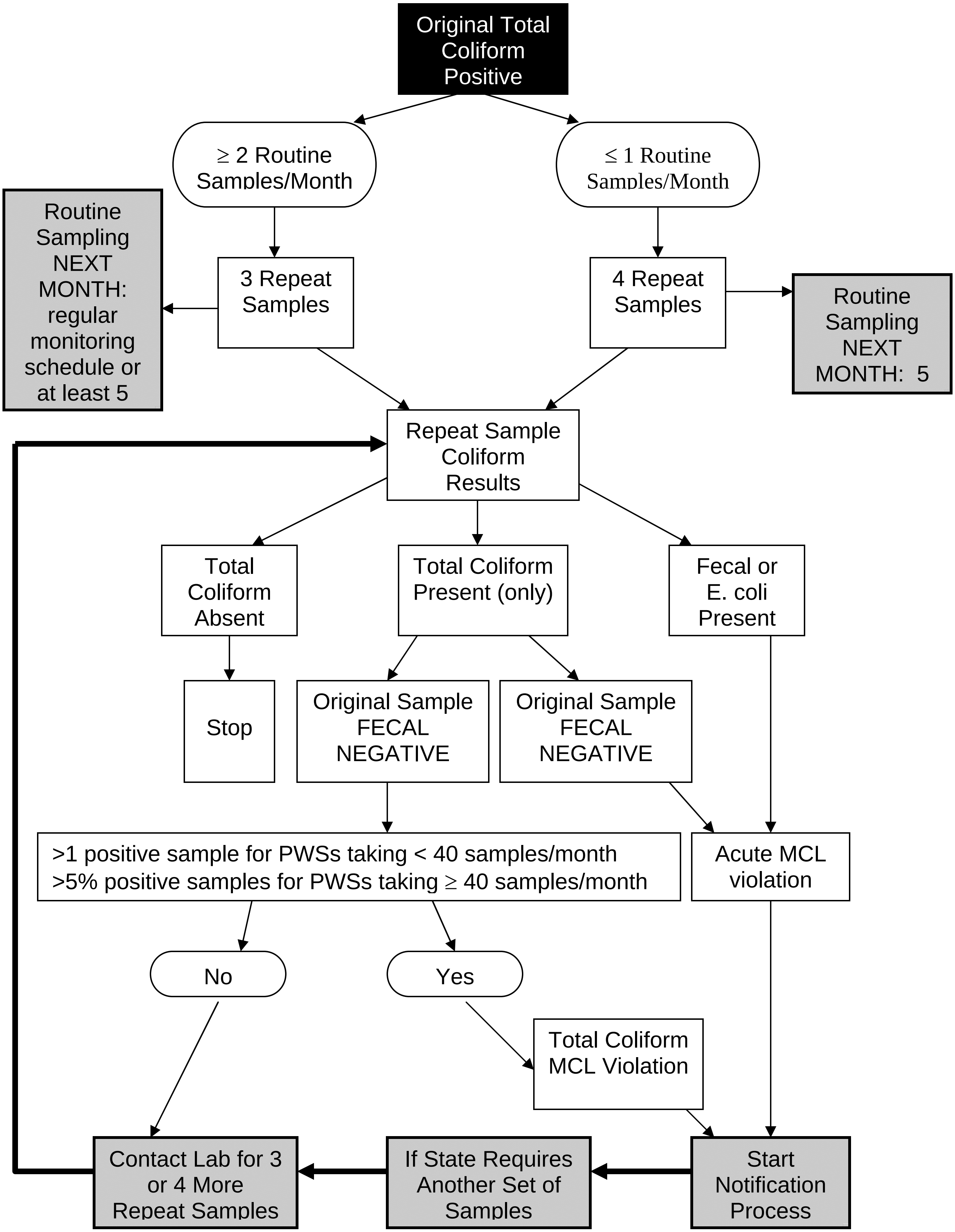
Total Coliform Action Flow Chart



Small Water Systems
Laboratory Practice Quiz

1. The MCL for total coliform bacteria is based on their _______________ .
   a. Concentration in mg/L
   b. Concentration in colonies per 100 mL
   c. Presence or absence
   d. All of the above
   e. None of the above

2. The sample volume to be used when running a membrane filter test for coliform bacteria is ________________ .
   a. 20 mL
   b. 40 mL
   c. 60 mL
   d. 80 mL
   e. 100 mL

3. Records of bacteriological analyses must be kept at least ________________ .
   a. Until the next sanitary survey
   b. Three years or until the next sanitary survey
   c. Five years
   d. Ten years
   e. Twelve years

4. Analysis of samples for determining bacteriological quality of the water must be started within _____________ hours of collection.
   a. 24
   b. 30
   c. 36
   d. 42
   e. 48

5. A bacteriological bottle contains a white powder which is placed in the bottle in order to __________________ .
   a. Keep the bottle clean
   b. Kill any bacteria present
   c. Remove any chlorine residual
   d. All of the above
   e. None of the above

6. Any sample that contains coliform bacteria is a __________________ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

7. Any sample that does not contain coliform bacteria is a _________________ sample.
   a. Grab
   b. Negative
   c. Positive
   d. Representative
   e. Routine

8. For bacteriological sample to be useful, it must contain essentially the same constituents as the body of water from which it was taken. This type of sample is called a _________________ sample.
   a. Grab
   b. Flow-proportional time composite
   c. Representative
   d. Time composite

9. To remove any stagnant water from the customer's service line, and to make certain that water from the distribution main is being sampled, flush the faucet for ________ minutes.
   a. 1 – 3
   b. 2 – 5
   c. 5 – 7
   d. 7 – 9
   e. 10 – 15

10. Bottles for collecting samples for bacteriological analyses should ______________ .
    a. Not be rinsed before use
    b. Be rinsed before use
    c. Be completely filled
    d. All of the above
    e. None of the above

11. Bottles for collecting samples for bacteriological analyses contain ______________, which destroys any chorine residual in the sample.
    a. Sodium arsenite
    b. Sodium chloride
    c. Sodium fluoride
    d. Sodium hydroxide
    e. Sodium thiosulfate

12. Samples for bacteriological analysis should not be taken from ________________.
    a. Swivel faucets
    b. Leaking faucets
    c. Faucets with aerators, strainers or hose attachments
    d. All of the above
    e. None of the above

13. A sample which consists of a number of grab samples taken from the same sampling point at different times and mixed together before analysis is called a _________________ sample.
    a. Composite
    b. Grab
    c. Flow-proportional time composite
    d. Representative
    e. Time composite

15. High fluoride readings can result from all of the following causes except _________.
    a. Polyphosphates can interfere with the SPADNS method, resulting in high fluoride readings
    b. Not accounting for natural fluoride in the water
    c. Dilution of water which has been fluoridated with unfluoridated water in storage tanks
    d. All of the above
    e. None of the above

16. What is the secondary maximum contaminant level for fluoride?
    a. 0.2 mg/L
    b. 0.4 mg/L
    c. 2.0 mg/L
    d. 4.0 mg/L

17. The maximum permissible level of a contaminant in water as specified in the regulations of the Safe Drinking Water Act is the _________________________ .
    e. Maximum contaminant level
    f. Saturation point
    g. Zeta potential
    h. All of the above
    i. None of the above

18. __________________ is an indicator used when measuring the total alkalinity concentration on a water sample.
    j. EDTA
    k. Eriochrome black-T
    l. Bromcresol Green Methyl Red
    m. Phenolphthalein
    n. Sodium thiosulfate

1. C
2. E
3. C
4. B
5. C
6. C
7. B
8. C
9. B
10. A
11. E
12. D
13. E
14. C
15. C
16. A
17. C

Section 10

Regulations

Record Category		Time frame required to keep records		Source
Microbiological Records				0400-45-1-.20(1)(a)
Routine distribution		5 years		
Line repair records		5 years		0400-45-1-.17(8)(a)
New line records		5 years		
Bacteriological sampling plan		Keep updated, at least every 3 years		
Chemical Analysis				0400-45-1-.20(1)(a)
Inorganics/ secondaries		10 years		
SOC's		10 years		
VOC's		10 years		
THM's and HAA5's		10 years		
Radionuclides		10 years		
Lead and copper		12 years		0400-45-1-.33(12)
Miscellaneous				
Action regarding violations		3 years		0400-45-1-.20(1)(b)
Certified Letters to Fire Departments regarding Class C hydrants		5 years		0400-45-1-.17(18)
Complaint file		5 years		0400-45-1-.20(1)(h)
Consumer Confidence Reports		3 years		0400-45-1-.35(h)
Cross connection plans and inspection records		5 years		0400-45-1-.20(1)(h)
Daily worksheets, strip charts, shift logs		5 years		0400-45-1-.20(1)(g)
Disinfection Profile		10 years		
Disinfection SOP		Keep updated		
Distribution map		Keep updated, submit copy to DWS every 5 years		0400-45-1-.17(15)
Distribution SOP		Keep updated		
Emergency Operation Plan		Keep updated		0400-45-1-.34(4)(a)
Facility Maintenance Records		5 years		0400-45-1-.20(1)(h)
Flushing records		Survey to survey or 3 years		0400-45-1-.17(10)
MOR's		5 years		
New tap records		Survey to survey or 3 years		0400-45-1-.17(32)
Notice of Construction		Survey to survey or 3 years		
Plant SOP		Keep updated		
Public Notices		3 years		0400-45-1-.20(i)
SDS (Safety Data Sheet)		At least 30 years		29 CFR 1910.1020
Sanitary surveys		10 years		
Storage Tank Inspection Records		5 years		0400-45-1-.17(33), 0400-45-1-.20(1)(h)
Tank maintenance records		Life of tank		0400-45-1-.17(33)
Turbidity analysis: daily worksheets, calibration data and strip charts		5 years		0400-45-1-.20(1)(f)
Variances or Exemptions		5 years		0400-45-1-.20(1)(d)

RULES
OF
THE TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
BOARD OF WATER AND WASTEWATER OPERATOR CERTIFICATION

CHAPTER 0400-49-01
RULES GOVERNING WATER AND WASTEWATER OPERATOR CERTIFICATION

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0400-49-01-.01 APPLICATION FOR CERTIFICATE.

(1) Application for certification by examination.

(a) A separate application for each certification shall be made on an original form approved by the Board for that purpose and available upon request from the Secretary of the Board.

(b) An application for certification must be submitted to the Secretary of the Board and include the following items:

1. A sworn application signed by the applicant.

2. Payment of a non-refundable $100 fee for each application for examination.

3. A copy of any verifying document in support of an application must be submitted with the application unless the applicant has previously provided such documentation to the Secretary of the Board. This includes, but is not limited to, proof of high school education or equivalent of the applicant. College transcripts, if needed to document experience credit, must be submitted directly from the college and/or university to the Secretary to the Board. Credit for enrollment in special training courses and programs will only be granted to an applicant upon verification that he/she satisfactorily completed all course or program requirements. If training credit is requested, a copy of a course attendance card, a class roster, or a certificate of completion must be submitted to the Secretary. Verification of work experience must be provided in a written document signed by a certified operator of a similar or higher classification, familiar with the applicant's work experience. However, if no such person is available, it may be documented by a person in authority with the system. The Board may exempt applicants from the verification of work experience requirement where there are unusual circumstances.

(c) A complete application must be received by the Secretary sixty (60) days or more in advance of the scheduled examination date for consideration. Applications received less than sixty (60) days prior to an examination date will be reviewed for the next examination. Upon written request by an applicant, the Board may choose to review,

(Rule 0400-49-01-.03, continued)

2. Application fee for Cross Connection Control Renewal Test (Department employees who assist with cross connection control training or testing are exempt)....................... ....$60

(b) Application fees are not refundable or transferable.

(c) The application for testing conducted by the Department must be received a minimum of thirty (30) days in advance of the test he/she wishes to take, however, applications from private institutions may be received the day the test materials are submitted to the Fleming Training Center.

(d) Prior to sitting for a test, an applicant must present proof of completion of training accepted by the Department for the appropriate test. Basic training may be accepted by the Department if it has a minimum class length of 480 minutes (300 minutes minimum in classroom), including but not limited to the following topics: hydraulic and backflow principles, theory of backflow and cross connection, codes and regulations of a cross connection control program, responsibilities and actions in a cross connection control program and mechanical equipment for cross connection control. Acceptable training must also provide a minimum of one working practice station and test kit for each three students. Renewal training may be accepted by the Department if it has a minimum class length of 300 minutes (180 minutes minimum in classroom) including but not limited to the following topics: hydraulic and backflow principles, theory of backflow and cross connection, codes and regulations of a cross connection control program, responsibilities and actions in a cross connection control program and mechanical equipment for cross connection control. Acceptable training must also provide a minimum of one working station and test kit for each three students.

(e) An applicant must take the test within twelve (12) months of receipt of the training certificate.

Authority: *T.C.A. §§ 4-5-201 et seq., 68-203-101 et seq., 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03. Amendments filed January 18, 2017; effective April 18, 2017.*

0400-49-01-.04 GENERAL.

(1) Certification under T.C.A. §§ 68-221-901 et seq., being the “Water and Wastewater Operator Certification Act,” is available to any operator of a water treatment plant, a wastewater treatment plant, a water distribution system, or a wastewater collection system who meets the minimum qualifications of a given classification.

(2) Each person in direct charge at a water treatment plant, a wastewater treatment plant, a water distribution system, or a wastewater collection system shall hold a certificate in a grade equal to or higher than the grade of the treatment plant, distribution system, or collection system he/she operates. The grade of a facility will be established by the criteria set forth in this chapter of rules.

(3) All operating personnel making process control/system integrity decisions about water quality or quantity that affect public health must be certified. A designated certified operator must be available for each operating shift.

(4) Each water supply system and wastewater system required to have a certified operator shall, no later than the first day of August annually, inform the Board, through its designated agent, the Division of Water Resources, in writing of the name of each person who is a certified operator in direct charge of any water treatment plant, wastewater treatment plant, water

(Rule 0400-49-01-.04, continued)

distribution system or wastewater collection system it operates. A system shall notify the Division of Water Resources in writing within thirty (30) days of its loss of the services of a certified operator in direct charge.

(5) A certified operator shall be responsible for keeping the Board Secretary informed of his/her current address.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.05 DEFINITIONS.

(1) "Available" means that a certified operator must be on site or able to be contacted as needed to initiate the appropriate action in a timely manner, based on system size, complexity and the quality of either the source water or the receiving stream.

(2) "Board" means the board of certification as described in T.C.A. § 68-221-905.

(3) "Commissioner" and "Department" mean the Commissioner of the Tennessee Department of Environment and Conservation or his/her duly authorized representative.

(4) "Operating Shift" is that period of time during which operator decisions that affect public health are necessary for proper operation of the system.

(5) "Process control/system integrity decisions" means decisions regarding the manipulation of equipment, chemicals or processes that determine the quality and quantity of the water supplied by a water treatment plant or a water distribution system, or the quality of the effluent from a wastewater treatment plant or the integrity of a wastewater collection system.

(6) "Person in direct charge" as used in these rules means the person or persons expressly designated to be in direct charge and so named in writing to the Board's authorized representative by each water supply system and wastewater system, whose decisions and directions to system personnel control the manipulation of equipment and thereby determine the quality and quantity of the water supplied by a water treatment plant or a water distribution system, or the quality of the effluent from a wastewater treatment plant or the integrity of a wastewater collection system.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.06 CLASSIFICATION OF WATER TREATMENT PLANTS AND WATER DISTRIBUTION SYSTEMS.

(1) Water treatment plants shall be classified by the Board or its authorized representative into one of five groups, designated either as Small Water, Grade I, II, III, or IV. These classifications shall be made according to the number of population served, the type of treatment plant, and the complexity of treatment required for a particular water.

(2) The classification of a water treatment plant or a water distribution system may be changed by the Board or its authorized representative because of changes in the conditions or the circumstances upon which the original classification was based. Notice of such a classification change shall be given to the management officers of the plant or system.

(3) Types of Water Systems:

(Rule 0400-49-01-.09, continued)

Pumps
Lift stations
Valves
Lines and equipment
Pipeline installation
Service connection installation
Leak detection
TV crew activities
Line repairs
Line cleaning
Manhole maintenance
Pretreatment

(5) Summary of Wastewater Treatment Plant and Collection System Operator Education and Experience

Wastewater Treatment Plant Operators

Classification	Experience			Maximum Training or College Classwork Substitution	Maximum Related Work Substitution
	Experience needed with:	HS Education	BS Degree		
Grade IV	Gained at a Grade III or IV Wastewater Plant	*60 months	12 Months	36 Months	24 Months
*Regardless of the substitution allowances, a minimum of 1 year of actual work experience is required					
Grade III	Gained at a Grade II or III Wastewater Plant	12 Months		3 Months	
Grade II	Gained at a Grade I or II Wastewater Plant	12 Months		3 Months	
Grade I	Gained at a Grade I Wastewater Plant	12 Months		3 Months	
	Gained at Biological/Natural and Grade I Wastewater Plant	12 Months 6 Months			
Grade BNS	Gained at a BNS Wastewater Plant	12 Months		3 Months	

COLLECTION SYSTEM OPERATORS

Classification	Experience		Maximum Training or College Classwork Substitution	Maximum Related Work Substitution
	Experience needed with:	HS Education		
Grade II	Gained at a Collection I or II System	12 Months	3 Months	
Grade I	Gained at a Collection I or II System	12 Months	3 Months	

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.10 CONTINUING EDUCATION.

At least once during every continuing education period each certified operator shall satisfactorily complete the required number of continuing education hours approved by the Board for the particular type of certificate he/she holds. The continuing education period for a certified operator shall begin either with the date the certified operator obtained his/her certificate or the date the certified operator last satisfactorily completed the required number of continuing education hours and shall end at the conclusion of the annual continuing education term three (3) calendar years thereafter. An annual continuing education

(Rule 0400-49-01-.10, continued)
term shall begin each year on October 1 and shall end on September 30 of the following year. The failure of an operator to satisfactorily complete the required number of continuing education hours approved by the Board Secretary during his/her continuing education period shall be grounds for the denial of his/her application for the renewal of his/her certificate. An operator shall notify the Board Secretary upon his/her satisfactory completion of the continuing education requirement by furnishing appropriate documentation of course completion. Notification by the operator is not necessary in those cases where an agency notifies the Board Secretary of such activity. An operator that fails to satisfactorily complete the required number of continuing education hours during his/her continuing education period due to an unusual event such as an incapacitating illness or similar unavoidable circumstances may make a written request to the Board for an extension of time to do so. All requests by an operator for an extension of time to meet the continuing education requirement must be made in writing to the Board either within two (2) months of the elapsed continuing education period or by the date of return of the operator to active employment, whichever is later. All such requests must be accompanied by complete supporting documentation of the circumstances causing the failure to meet the continuing education requirement.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.11 SUMMARY SUSPENSION AND REVOCATION OF CERTIFICATE.

(1) An operator's certificate may be revoked when:

(a) In accordance with paragraph (2) of this rule, an operator has not used reasonable care, judgment, or the application of his/her knowledge in the performance of his/her duties as a certified operator, or

(b) In accordance with paragraph (3) of this rule, an operator is incompetent to perform those duties properly; or

(c) In accordance with paragraph (4) of this rule, an operator has practiced fraud or deception.

(2) An operator shall be deemed to have not used reasonable care, judgment, or the application of his/her knowledge in the performance of his/her duties if he/she does not comply with the laws, rules, permit requirements, or orders of any governmental agency or court which govern the water supply system or the wastewater system he/she operates. Such acts of noncompliance include but are not limited to the following:

(a) The intentional or the negligent failure by the operator or persons under his/her supervision to act that results in a water supply system facility or a wastewater system facility not operating in the manner in which it is capable of being operated for the performance of its designed function.

(b) The intentional or the negligent failure by the operator or persons under his/her supervision to comply with the monitoring, sampling, analysis, or reporting requirements for a water supply system facility or a wastewater system facility.

(c) The intentional or the negligent unlawful discharge of wastes from a water supply system facility or a wastewater system facility.

(d) The intentional or the negligent failure by the operator or persons under his/her supervision to notify the Department of conditions: which may affect the quantity or quality of water being supplied to the customers of a water supply system; which cause the pollution of the waters of the State of Tennessee; or, which are violative of a standard of water quality promulgated by any governmental agency.

(Rule 0400-49-01-.11, continued)

not render its decision within ninety (90) days of the operator's summary suspension, the Order of Summary Suspension shall expire and no longer be in force or effect. However, the Commissioner may reissue an Order of Summary Suspension in accordance with this paragraph, for a period not to exceed ninety (90) days.

(7) The revocation hearing before the Board shall be held in accordance with T.C.A. §§ 4-5-301 et seq. and Rule Chapter 1360-04-01 Uniform Rules of Procedure for Hearing Contested Cases Before State Administrative Agencies.

(8) The Board may revoke the certificate of an operator when it is found that the operator has practiced fraud or deception; that reasonable care, judgment or the application of such operator's knowledge was not used in performance of such operator's duties; or that the operator is incompetent to properly perform such operator's duties. If the certificate is revoked and is to be reinstated, the Board shall determine the timing, terms and conditions for reinstatement.

(9) An operator who receives an order of the Board for the revocation of his/her certificate may appeal the order to the Chancery Court of Davidson County within sixty (60) days.

(10) An operator whose certificate is revoked for failure to use reasonable care, judgment or the application of operator knowledge in performing the operator's duties or for incompetency shall be ineligible to again apply for certification as an operator for a minimum of one (1) year. An operator whose certificate is revoked for practicing fraud or deception, willfully violating regulations or permit conditions, or falsifying records and reports shall be ineligible to again apply for certification as an operator for a minimum of five years. When an operator whose certificate has been revoked has applied for a certificate after the minimum time has passed, the Board shall determine whether the operator has taken appropriate action to address the circumstances that were the cause of the revocation. The Board may request records and review his/her experience, education, training and past performance. The Board may request the former operator's presence at a meeting of the Board and interview him/her to assess the potential of future violations. After the reviews, the Board shall decide to accept or refuse the application.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

0400-49-01-.12 CIVIL PENALTIES.

(1) The Commissioner may assess the civil penalty authorized by law against a municipality, utility district, corporation, or any person operating a water supply system or a wastewater system if the competency of the person in direct charge of a system facility has not first been certified in accordance with these rules.

(2) A certified operator may be assessed the civil penalty authorized by law for the same acts and omissions that would constitute grounds for the revocation of his/her certificate by the Board.

(3) Prior to issuing an order that assess a civil penalty, in accordance with paragraphs (1) and (2) of this rule the Commissioner may hold a show cause meeting with the person or entity to whom the order is proposed to be issued.

Authority: *T.C.A. §§ 4-5-201 et seq. and 68-221-901 et seq.* ***Administrative History:*** *Original rule filed May 21, 2014; effective August 19, 2014. Rule renumbered from 1200-05-03.*

RULES
OF
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

DIVISION OF WATER RESOURCES

CHAPTER 0400-45-01
PUBLIC WATER SYSTEMS

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0400-45-01-.01 AUTHORITY.

(1) These rules and regulations are issued under the authority of the Tennessee Safe Drinking Water Act of 1983, T.C.A. §§ 68-221-701 et seq.

(2) The Division of Water Resources is responsible for the supervision of public water systems.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.02 PURPOSE.

(1) The purpose of these rules and regulations is to provide guidelines for the interpretation of T.C.A. §§ 68-221-701 et seq. and to set out the procedures to be followed by the Department in carrying out the Department's primary enforcement responsibility under the Federal Safe Drinking Water Act. These rules and regulations set out the requirements which agents, employees or representatives of public water systems must meet in the following areas: in the preparation and submission of plan documents for public water systems; in the supervision of all phases of construction; in supplying safe drinking water meeting all

(Rule 0400-45-01-.02, continued)

applicable maximum contaminant levels or treatment technique requirements; in providing adequate operation and maintenance of the system; and in complying with procedural requirements for appealing orders issued by the Commissioner of the Tennessee Department of Environment and Conservation against a public water system.

(2) Where the terms “shall” and “must” are used, practice and usage is sufficiently standardized to indicate a mandatory requirement, insofar as any complaint action by the Department is concerned. Other items, such as should, recommend, preferred, and the like, indicate desirable procedures or methods.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.03 SCOPE.

These rules will apply to all public water supply systems that provide water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen (15) service connections or regularly serves an average of at least twenty-five (25) individuals daily at least sixty (60) days out of the year. A public water supply system is either a community water system or a non-community water system. A community water system is a public water supply system which serves at least fifteen (15) service connections used by year-round residents or regularly serves at least twenty-five (25) year-round residents. A non-community water system is a public water supply system that is not a community water system and which generally serves a transient population such as hotels, motels, restaurants, camps, service stations churches, industry, etc. A Non-Transient Non-Community Water System is a non-community water system that regularly serves at least 25 of the same persons over six (6) months per year. These rules do not apply to public water systems which meet all of the following criteria:

(1) Consists only of distribution and storage facilities (and does not have any collection and treatment facilities);

(2) Obtains all of its water from, but is not owned or operated by, a public water system to which such regulations apply;

(3) Does not sell water to any person; and

(4) Is not a carrier which conveys passengers in interstate commerce.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.04 DEFINITIONS.

(1) “Action level” is the concentration of lead or copper in water which may determine the treatment requirements that a water system is required to complete.

(2) “Bag Filters” are pressure-driven separation devices that remove particulate matter larger than 1 micrometer using an engineered porous filtration media. They are typically constructed on a non-rigid fabric filtration media housed in a pressure vessel in which the direction of flow is from the inside of the bag to outside.

(3) “Bank Filtration” is a water treatment process that uses a well to recover surface water that has naturally infiltrated into ground water through a river bed or bank(s). Infiltration is typically enhanced by the hydraulic gradient imposed by nearby pumping water supply or other wells.

(Rule 0400-45-01-.04, continued)

comprehensive performance evaluation must consist of at least the following components: assessment of plant performance; evaluation of major unit processes; identification and prioritization of performance limiting factors; assessment of the applicability of comprehensive technical assistance; and preparation of a CPE report.

(15) “Confluent growth” means a continuous bacterial growth covering the entire filtration area of a membrane filter, or a portion thereof, in which bacterial colonies are not discrete.

(16) “Connection” means the point at which there is a meter or service tap if no meter is present.

(17) “Consecutive system is a public water system that receives some or all of its finished water from one or more wholesale systems. Delivery may be through a direct connection or through the distribution system of one or more consecutive systems.

(18) “Contaminant” means any physical, chemical, biological, or radiological substance or matter in water.

(19) “Conventional filtration treatment” means a series of processes including coagulation, flocculation, sedimentation, and filtration resulting in substantial particulate removal.

(20) “Corrosion inhibitor” means a substance capable of reducing the corrosivity of water toward metal plumbing materials, especially lead and copper, by forming a protective film on the interior surface of those materials.

(21) “CT” or “CTcalc” is the product of “residual disinfectant concentration” (C) in mg/1 determined before or at the first customer, and the corresponding “disinfectant contact time” (T) in minutes, i.e., “C” x “T”. If a public water system applies disinfectants at more than one point prior to the first customer, it must determine the CT of each disinfectant sequence before or at the first customer to determine the total percent inactivation or “total inactivation ratio”. In determining the total inactivation ratio, the public water system must determine the residual disinfectant concentration of each disinfection sequence and corresponding contact time before any subsequent disinfection application point(s). “CT99.9” is the CT value required for 99.9 percent (3 log) inactivation of Giardia lamblia cysts. CT99.9 for a variety of disinfectants and conditions appear in Tables 1.1 through 1.6, 2.1, and 3.1 of part (5)(b)3. of Rule 0400-45-01-.31.

$$\frac{CTcalc}{CT_{99.9}}$$

is the inactivation ratio. The sum of the inactivation ratios, or total inactivation ratio shown as

$$\Sigma \frac{(CTcalc)}{(CT_{99.9})}$$

is calculated by adding together the inactivation ratio for each disinfection sequence. A total inactivation ratio equal to or greater than 1.0 is assumed to provide a 3 log inactivation of Giardia lamblia cyst. Disinfectant concentrations must be determined by tracer studies or an equivalent demonstration approved by the Department.

(22) “Department” when used in these rules means the Division of Water Resources, Tennessee Department of Environment and Conservation, or one of the Division's field offices.

(23) “Diatomaceous earth filtration” means a process resulting in substantial particulate removal in which (1) a precoat cake of diatomaceous earth filter media is deposited on a support membrane (septum), and (2) while the water is filtered by passing through the cake on the

(35) "Enhanced coagulation" means the addition of sufficient coagulant for improved removal of disinfection byproduct precursors by conventional filtration treatment.

(36) "Enhanced softening" means the improved removal of disinfection byproduct precursors by precipitative softening.

(37) "Filter profile" is a graphical representation of individual filter performance, based on continuous turbidity measurements or total particle counts versus time for an entire filter run, from startup to backwash inclusively, that includes an assessment of filter performance while another filter is being backwashed.

(38) "Filtration" means a process for removing particulate matter from water by passage through porous media.

(39) "Finished water" is water that is introduced into the distribution system of a public water system and is intended for distribution and consumption without further treatment, except as treatment necessary to maintain water quality in the distribution system (e.g., booster disinfection, addition of corrosion control chemicals).

(40) "First draw sample" means a one liter sample of tap water, for the purposes of the lead and copper rules, that has been standing in plumbing pipes at least 6 hours and is collected without flushing the tap.

(41) "Flooculation" means a process to enhance agglomeration or collection of smaller floc particles into larger, more easily settleable particles through gentle stirring by hydraulic or mechanical means.

(42) "Flowing stream" is a course of running water flowing in a definite channel.

(43) "GAC10" means granular activated carbon filter beds with an empty-bed contact time of 10 minutes based on average daily flow and a carbon reactivation frequency of every 180 days, except that the reactivation frequency for GAC10 used as best available technology for compliance with disinfection byproducts shall be 120 days.

(44) "GAC20" means granular activated carbon filter beds with an empty-bed contact time of 20 minutes based on average daily flow and a carbon reactivation frequency of every 240 days.

(45) "Gross Alpha Particle Activity" means the total radioactivity due to alpha particle emission as inferred from measurements on a dry sample.

(46) "Gross Beta Particle Activity" means the total radioactivity due to beta particle emission as inferred from measurements on a dry sample.

(47) "Ground water under the direct influence of surface water" means any water beneath the surface of the ground with significant occurrence of insects or other macroorganisms, algae, or large diameter pathogens such as Giardia lamblia or Cryptosporidium, or significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions. Direct influence must be determined for individual sources in accordance with criteria established by the Department. The Department determination of direct influence may be based on site specific measurements of water quality and/or documentation of well construction characteristics and geology with field evaluation.

(48) "Haloacetic acids (five) (HAA5)" mean the sum of the concentrations in milligrams per liter of the haloacetic acid compounds (monochloroacetic acid, dichloroacetic acid, trichloroacetic

(Rule 0400-45-01-.04, continued)

reason that the system triggered the assessment. A Level 2 assessment provides a more detailed examination of the system (including the system's monitoring and operational practices) than does a Level 1 assessment through the use of more comprehensive investigation and review of available information, additional internal and external resources, and other relevant practices. It is conducted by an individual approved by the Department, which may include the system operator. Minimum elements include review and identification of atypical events that could affect distributed water quality or indicate that distributed water quality was impaired; changes in distribution system maintenance and operation that could affect distributed water quality (including water storage); source and treatment considerations that bear on distributed water quality, where appropriate (e.g., whether a ground water system is disinfected); existing water quality monitoring data; and inadequacies in sample sites, sampling protocol, and sample processing. The system must conduct the assessment consistent with any Department directives that tailor specific assessment elements with respect to the size and type of the system and the size, type, and characteristics of the distribution system. The system must comply with any expedited actions or additional actions required by the Department in the case of an E. coli MCL violation.

(58) "Locational running annual average (LRAA)" is the average of sample analytical results for samples taken at a particular monitoring location during the previous four calendar quarters.

(59) "Man-Made Beta Particle and Photon Emitter" means all radionuclides emitting beta particles and/or photons listed in "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, NBS Handbook 69", except the daughter products of thorium 232, uranium 235 and uranium 238.

(60) "Maximum contaminant level" or "MCL" means the maximum permissible level of a contaminant in water which is delivered at the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

(61) "Maximum contaminant level goal" or "MCLG" means that the maximum level of the contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and which allows an adequate margin of safety. Maximum contaminant level goals are non-enforceable health goals.

(62) "Maximum residual disinfectant level (MRDL)" means a level of a disinfectant added for water treatment that may not be exceeded at the consumer's tap without an unacceptable possibility of adverse health effects. For chlorine and chloramines, a PWS is in compliance with the MRDL when the running annual average of monthly averages of samples taken in the distribution system, computed quarterly, is less than or equal to the MRDL. For chlorine dioxide, a PWS is in compliance with the MRDL when daily samples are taken at the entrance to the distribution system and no two consecutive daily samples exceed the MRDL. MRDLs are enforceable in the same manner as maximum contaminant levels under Section 1412 of the Safe Drinking Water Act. There is convincing evidence that addition of a disinfectant is necessary for control of waterborne microbial contaminants. Notwithstanding the MRDLs, operators may increase residual disinfectant levels of chlorine or chloramines (but not chlorine dioxide) in the distribution system to a level and for a time necessary to protect public health to address specific microbiological contamination problems caused by circumstances such as distribution line breaks, storm runoff events, source water contamination, or cross-connections.

(63) "Maximum Total Trihalomethane Potential (MTP)" means the maximum concentration of total trihalomethanes produced in a given water containing a disinfectant residual after 7 days at a temperature of 25°C or above.

(Rule 0400-45-01-.04, continued)

(64) “Medium-size water system” for the purpose of the lead and copper rule means a water system that serves greater than 3,300 and less than or equal to 50,000 persons.

(65) “Membrane filtration” is a pressure or vacuum driven separation process in which particulate matter larger than 1 micrometer is rejected by an engineered barrier, primarily through a size exclusion mechanism, and which has a measurable removal efficiency of a target organism that can be verified through the application of a direct integrity test. This definition includes the common membrane technologies of microfiltration, ultrafiltration, nanofiltration, and reverse osmosis.

(66) “Near the first service connection” means at one of the twenty percent of all service connections in the entire system that are nearest the water supply treatment facility, as measured by the water transport time within the distribution system.

(67) “Non-community water system” means a public water system that is not a community water system. A non-community water system is either a “transient non-community water system” (TNCWS) or a “non-transient non-community water system” (NTNCWS).

(68) “Non-transient non-community water system” or “NTNCWS” means a non-community water system that regularly serves at least 25 of the same persons over six months per year.

(69) “Optimal corrosion control treatment” for the purpose of lead and copper rule only means the corrosion control treatment that minimizes the lead and copper concentrations at user's taps while insuring that the treatment does not cause the water system to violate any primary drinking water regulation.

(70) “Person” means any individual, corporation, company, association, partnership, State, municipality, utility district, water cooperative, or Federal agency.

(71) “Picocurie” (pCi) means that quantity of radioactive material producing 2.22 nuclear transformations per minute.

(72) “Plan documents” means reports, proposals, preliminary plans, survey and basis of design data, general and detailed construction plans, profiles, specifications and all other information pertaining to public water system planning.

(73) “Plant intake” refers to the works or structures at the head of a conduit through which water is diverted from a source (e.g., river or lake) into the treatment plant.

(74) “Point of disinfectant application” is the point where the disinfectant is applied and water downstream of that point is not subject to recontamination by surface water runoff.

(75) “Point-of-Entry Treatment Device” (POE) means a device applied to the drinking water entering a house or building for the purpose of reducing contaminants in the drinking water distributed throughout the house or building.

(76) “Point-of-Use Treatment Device” (POU) means a treatment device applied to a single tap used for the purpose of reducing contaminants in drinking water at that one tap.

(77) “Presedimentation” is a preliminary treatment process used to remove gravel, sand and other particulate material from the source water through settling before the water enters the primary clarification and filtration processes in a treatment plant.

(78) “Primary drinking water regulation” means a rule promulgated by the Board which:

(Rule 0400-45-01-.04, continued)

(a) Applies to public water systems;

(b) Specifies contaminants which, in the judgment of the Department, may have any adverse effect on the health of persons;

(c) Specifies for each such contaminant either:

1. A maximum contaminant level, if, in the judgment of the Department, it is economically and technologically feasible to ascertain the level of such contaminant in water in public water systems, or

2. If, in the judgment of the Department, it is not economically or technologically feasible to so ascertain the level of such contaminant, each treatment technique known to the Department which leads to a reduction in the level of such contaminant sufficient to satisfy the requirements of Rule 0400-45-01-.06; and

(d) Contains criteria and procedures to assure a supply of drinking water which dependably complies with such maximum contaminant levels or treatment techniques, including quality control and testing procedures to insure compliance with such levels and to insure proper operation and maintenance of the system, and requirements regarding (i) the minimum quality of water which may be taken into the system and (ii) siting for new facilities for public water systems.

(79) “Public water system” means a system for the provision of piped water for human consumption if the system serves 15 or more connections or which regularly serves 25 or more individuals daily at least 60 days out of the year and includes:

(a) Any collection, treatment, storage or distribution facility under control of the operator of such system and used primarily in connection with such system; and

(b) Any collection or pre-treatment storage facility not under such control which is used primarily in connection with such system.

The population of a water system shall be determined by actual count or by multiplying the household factor by the number of connections in the system. The household factor shall be taken from the latest federal census for that county or city. Water systems serving multi-family residences such as apartment complexes and mobile home parks shall include each individual residence unit as a connection in determining the population for the system.

(80) “Rem” means the unit of dose equivalent from ionizing radiation to the total body or any internal organ or organ system. A “millerem (mrem)” is 1/1000 of a rem.

(81) “Repeat compliance period” means any subsequent compliance period after the initial compliance period.

(82) “Residual disinfectant concentration” (“C” in CT calculations) means the concentration of disinfectant measured in mg/l in a representative sample of water.

(83) “Safe Drinking Water Act” means the Federal law codified in 42 United States Code 300f et seq., Public Law 93 523, dated December 16, 1974 and subsequent amendments.

(84) “Sanitary defect” is a defect that could provide a pathway of entry for microbial contamination into the distribution system or that is indicative of a failure or imminent failure in a barrier that is already in place.

(Rule 0400-45-01-.04, continued)

(85) “Sanitary survey” means an on-site review of the water source, facilities, equipment, operation and maintenance of a public water system for the purpose of evaluating the adequacy of such sources, facilities, equipment, operation and maintenance for producing and distributing safe drinking water.

(86) “Seasonal system” is a non-community water system that is not operated as a public water system on a year-round basis and starts up and shuts down at the beginning and end of each operating season.

(87) “Secondary drinking water regulation” means a rule promulgated by the Board which applies to public water systems and which specifies the maximum contaminant levels which, in the judgment of the Board, are requisite to protect the public welfare. Such rules may vary according to geographic and other circumstances, and may apply to any contaminant in drinking water which may:

(a) Adversely affect the odor or appearance of such water and consequently may cause the persons served by the public water system providing such water to discontinue its use; or

(b) Otherwise adversely affect the public welfare.

(88) “Sedimentation” means a process for removal of solids before filtration by gravity or separation.

(89) “Service line sample” means a one liter sample of water collected in accordance with part (7)(b)3. of Rule 0400-45-01-.33, that has been standing for at least 6 hours in a service line.

(90) “Single family structure” for the purpose of lead and copper rules means a building constructed as a single family residence that is currently used as either a residence or a place of business.

(91) “Slow sand filtration” means a process involving passage of a raw water through a bed of sand at low velocity (generally less than 0.4 m/h) resulting in substantial particulate removal by physical and biological mechanisms.

(92) “Small water system” for the purpose of the lead and copper rules only, means a water system that serves 3,300 or fewer persons.

(93) “Subpart H systems” means public water systems using surface water or ground water under the direct influence of surface water as a source that are subject to the requirements of Rules 0400-45-01-.17, 0400-45-01-.31 and 0400-45-01-.39.

(94) “Supplier of water” means any person who owns or operates a public water system.

(95) “Surface water” means all water which is open to the atmosphere and subject to surface runoff.

(96) “SUVA” means Specific Ultraviolet Absorption at 254 nanometers (nm), an indicator of the humic content of water. It is a calculated parameter obtained by dividing a sample’s ultraviolet absorption at a wavelength of 254 nm (UV 254/ (in m) by its concentration of dissolved organic carbon (DOC) (in mg/L).

(97) “System with a single service connection” means a system which supplies drinking water to consumers via a single service line.

(Rule 0400-45-01-.04, continued)

(98) "Too numerous to count" means that the total number of bacterial colonies exceeds 200 on a 47 millimeter diameter membrane filter used for coliform detection.

(99) "Total Organic Carbon" (TOC) means total organic carbon in mg/L measured using heat, oxygen, ultraviolet irradiation, chemical oxidants, or combinations of these oxidants that convert organic carbon to carbon dioxide, rounded to two significant figures.

(100) "Total trihalomethane" (TTHM) means the sum of concentration in milligrams per liter of the trihalomethane compounds trihalomethane (chloroform), dibromochloromethane, bromodichloro-methane and tribomomethane (bromoform), rounded to two significant figures.

(101) "Transient non-community water system" or "TNCWS" means a non-community water system that regularly serves at least 25 individuals daily at least 60 days out of the year. A transient non-community water system is a public water supply system that generally serves a transient population such as hotels, motels, restaurants, camps, service stations churches, industry, and rest stops.

(102) "Trihalomethane" (THM) means one of the family of organic compounds, named as derivatives of methane, wherein three of the four hydrogen atoms in methane are each substituted by a halogen atom in the molecular structure.

(103) "Two-stage lime softening" is a process in which chemical addition and hardness precipitation occur in each of two distinct unit clarification processes.

(104) "Uncovered finished water storage facility" is a tank, reservoir, or other facility used to store water that will undergo no further treatment except residual disinfection and is open to the atmosphere.

(105) "Viable water system" means a public water system which has the commitment and the financial, managerial, and technical capacity to consistently comply with the Tennessee Safe Drinking Water Act and these rules.

(106) "Virus" means a virus of fecal origin which is infectious to humans by waterborne transmission.

(107) "Waterborne disease outbreak" means a significant occurrence of acute infectious illness, epidemiologically associated with the ingestion of water from a public water system which is deficient in treatment, as determined by the appropriate local or State agency.

(108) "Wholesale system" is a public water system that treats source water as necessary to produce finished water and then delivers some or all of that finished water to another public water system. Delivery may be through a direct connection or through the distribution system of one or more consecutive systems.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments and new rules filed November 24, 2015; effective February 22, 2016. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.05 SUPERVISION OF DESIGN AND CONSTRUCTION.

(1) Engineering - Plan documents for public water systems shall be submitted to the Department at least thirty (30) days prior to the date on which action by the Department is desired.

(2) Expiration of Approval - Approval of engineering reports, proposals, preliminary plans, survey and basis of design data shall be null and void after a period of one year from the date

(Rule 0400-45-01-.05, continued)

(13) Delegation of Plans Review Authority - Under T.C.A § 68-221-706, any unit of local government may petition the Commissioner for certification to review and approve plans for water distribution facilities within its jurisdiction. The unit of local government must have adequate experience and expertise in water distribution and must adopt standards and impose requirements which are at least as stringent as the Department's. The request for certification must be in writing and contain at least the following:

(a) The names of the individual(s) responsible for the review and approval together with his/her experience and education. This person(s) must be employed by the unit of local government and be a registered professional engineer in Tennessee.

(b) A copy of the standards, requirements and design criteria legally adopted and enforceable by the unit of local government.

(c) The type of projects the unit of local government wishes to receive certification to review. This may include but is not limited to water lines, distribution pumping stations and distribution storage tanks.

(d) Procedures for maintaining records of all projects reviewed and approved by the unit of local government.

(e) The wording to be used on the approval stamp.

(f) Plans review authority fee.

The Division of Water Resources will be responsible for reviewing the application for certification and shall have up to 60 days from the receipt of the complete application to make a written response. Units of local government will not be certified to review projects involving state or federal funds, raw water pump stations, new water sources, treatment facilities, sludge handling facilities, or any project designed by the staff of the local government. Any unit of local government which receives certification for plans review shall submit one copy of any plan documents it has approved to the Division of Water Resources. This shall be done within 10 days of the local government's approval. The commissioner may periodically review the unit of local government's plans review program and prescribe changes as deemed appropriate. The Division of Water Resources may execute a written agreement with a unit of local government which has received plans review certification. Failure to comply with the terms of the agreement may result in revocation of the plans review certification.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.06 MAXIMUM CONTAMINANT LEVELS.

(1) Inorganic Chemicals

(a) The maximum contaminant level for fluoride applies to community water systems. The maximum contaminant levels for nitrate, nitrite and total nitrate and nitrite are applicable to both community water systems and non-community water systems. The maximum contaminant levels for the remaining inorganic chemicals apply only to community water systems and non-transient non-community systems.

(b) The following are the maximum contaminant levels for inorganic chemicals:

CONTAMINANT	LEVEL, MILLIGRAMS PER LITER

(Rule 0400-45-01-.06, continued)

1.	Antimony	0.006
2.	Arsenic	0.010
3.	Asbestos	7 million fibers/liter (longer than 10 microns)
4.	Beryllium	0.004
5.	Barium	2.0
6.	Cadmium	0.005
7.	Chromium	0.1
8.	Cyanide (as free cyanide)	0.2
9.	Fluoride	4.0
10.	Mercury	0.002
11.	Nickel	0.1
12.	Nitrate	10.0 (as Nitrogen)
13.	Nitrite	1.0 (as Nitrogen)
14.	Total nitrate and nitrate	10.0 (as Nitrogen)
15.	Selenium	0.05
16.	Thallium	0.002

(2) Organic Chemicals - The following are the maximum contaminant levels for organic chemicals.

(a) The following maximum contaminant levels for organic contaminants apply to community water systems and non-transient non-community water systems. The maximum contaminant levels for volatile organic chemicals are given in paragraph (2) of Rule 0400-45-01-.25.

CONTAMINANT		LEVEL, MILLIGRAMS PER LITER
1.	Alachlor	0.002
2.	Atrazine	0.003
3.	Carbofuran	0.04
4.	Chlordane	0.002
5.	Dibromo chloropropane (DBCP)	0.0002
6.	2,4 Dichlorophenoxyacetic acid	0.07
7.	Ethylene dibromide	0.00005

(Rule 0400-45-01-.06, continued)

Haloacetic acids (five) - (HAA5).	Improved distribution system and storage tank management to reduce residence time, plus the use of chloramines for disinfectant residual maintenance. Systems serving <10,000: Improved distribution system and storage tank management to reduce residence time.

(c) Maximum residual disinfectant levels.

1. Maximum residual disinfectant levels (MRDLs) are as follows:

Disinfectant residual	MRDL (mg/L)
Chlorine.......................................	4.0 (as Cl_2).
Chloramines..................................	4.0 (as Cl_2).
Chlorine dioxide............................	0.8 (as ClO_2).

(d) Compliance dates.

1. CWSs and NTNCWSs. Subpart H systems serving 10,000 or more persons must comply with MRDLs beginning January 1, 2002. Subpart H systems serving fewer than 10,000 persons and systems using only ground water not under the direct influence of surface water must comply with MRDLs beginning January 1, 2004.

2. Transient NCWSs. Subpart H systems serving 10,000 or more persons and using chlorine dioxide as a disinfectant or oxidant must comply with the chlorine dioxide MRDL beginning January 1, 2002. Subpart H systems serving fewer than 10,000 persons and using chlorine dioxide as a disinfectant or oxidant and systems using only ground water not under the direct influence of surface water and using chlorine dioxide as a disinfectant or oxidant must comply with the chlorine dioxide MRDL beginning January 1, 2004.

(e) Best Available Control Technology

1. The following are identified as the best technology, treatment technology or other means available for achieving compliance with the maximum residual disinfectant level:

(i) Control of the treatment processes to reduce disinfectant demand and control of disinfection treatment processes to reduce disinfectant levels.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments and new rules filed November 24, 2015; effective February 22, 2016. Amendments filed March 7, 2016; effective June 5, 2016.*

0400-45-01-.07 MONITORING AND ANALYTICAL REQUIREMENTS.

(1) Microbiological Contaminant Sampling

(a) Effective April 1, 2016, violations for total coliform and fecal coliform shall no longer be considered MCL violations and violations regarding total coliform shall be treatment

(Rule 0400-45-01-.07, continued)

technique triggers as described in Rule 0400-45-01-.41. Paragraph (5) of this rule further delineates the transition to Rule 0400-45-01-.41.

(b) Reserved

(c) The supplier of water for a community water system shall take coliform samples at regular time intervals and in number proportional to the population served by the system during the reporting period as set forth below:

TOTAL COLIFORM MONITORING FREQUENCY FOR COMMUNITY WATER SYSTEMS

Population Served	Minimum Number of Samples Per Month
25 to 1,000[1]	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6

Population Served	Minimum Number of Samples Per Month
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to 33,000	30
33,001 to 41,000	40
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240
780,001 to 970,000	270
970,001 to 1,230,000	300
1,230,001 to 1,520,000	330
1,520,001 to 1,850,000	360
1,850,001 to 2,270,000	390
2,270,001 to 3,020,000	420
3,020,001 to 3,960,000	450
3,960,001 or more	480

(Rule 0400-45-01-.07, continued)

of the first exceedance, unless the Department determines that the system, for reasons outside the system's control cannot have the sample analyzed within 30 hours of collection. Sample results from this coliform monitoring must be included in determining compliance with the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06.

(g) Special purpose samples, such as those taken to determine whether disinfection practices are sufficient following pipe placement, replacement, or repair, shall not be used to determine whether the coliform treatment technique trigger has been exceeded compliance with the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06 provided the water is not served to customers before negative analytical results are obtained. Samples representing water served to customers prior to obtaining analytical results shall not be special purpose samples and shall not count toward compliance with the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06 with the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06. After March 31, 2016, this subparagraph is no longer applicable.

(2) Repeat Monitoring

(a) If a routine sample is total coliform-positive, the public water system must collect a set of repeat samples within 24 hours of being notified of the positive result. A system which collects more than one routine sample per month must collect no fewer than three repeat samples for each total coliform-positive sample found. A system which collects one routine sample per month or fewer must collect no fewer than four repeat samples for each total coliform-positive sample found. The Department may extend the 24-hour limit on a case-by-case basis if the system has a problem in collecting the repeat samples within 24 hours that is beyond its control. In the case of an extension, the Department must specify how much time the system has to collect the repeat samples.

(b) The system must collect at least one repeat sample from the sampling tap where the original total coliform-positive sample was taken, and at least one repeat sample at a tap within five service connections upstream and at least one repeat sample at a tap within five service connections downstream of the original sampling site. If a total coliform-positive sample is at the end of the distribution system, or one away from the end of the distribution system, the Department may waive the requirement to collect at least one repeat sample upstream or downstream of the original sampling site.

(c) The system must collect all repeat samples on the same day and within 24 hours of being notified of a positive result, except that the Department may allow a system with a single service connection to collect the required set of repeat samples over a four consecutive day period or to collect a larger volume repeat sample(s) in one or more sample containers of any size, as long as the total volume collected is at least 400 ml (300 ml for systems which collect more than one routine sample per month.)

(d) If one or more repeat samples in the set is total coliform-positive, the public water system must collect an additional set of repeat samples in the manner specified in subparagraphs (a), (b), and (c) of this paragraph. The additional samples must be collected within 24 hours of being notified of the positive result, unless the Department extends the limit as provided in subparagraph (a) of this paragraph. The system must repeat this process until either total coliforms are not detected in one complete set of repeat samples or the system determines that the MCL for total coliforms in paragraph (4) of Rule 0400-45-01-.06 has been exceeded and notifies the Department.

(e) If a system normally collecting fewer than five routine samples per monitoring period has one or more total coliform-positive samples and the Department does not

(Rule 0400-45-01-.08, continued)

(b) Surface water systems and ground water systems under the direct influence of surface water - Turbidity measurements must be reported within 10 days after the end of each month the system serves water to the public. Information that must be reported includes but is not limited to:

1. The total number of filtered water turbidity measurements taken during the month.

2. The number and percentage of filtered water turbidity measurements taken during the month which are less than or equal to the applicable limits specified in paragraph (4) of Rule 0400-45-01-.31.

3. The date and value of any turbidity measurements taken during the month which exceed 5 NTU.

(c) Ground water systems under the direct influence of surface water that have qualified to avoid filtration - Information that must be reported includes but is not limited to:

1. The maximum turbidity level measured during the month, the date(s) of occurrence for any measurement(s) which exceeded 5 NTU, and the date(s) the occurrence(s) was reported to the Department.

2. For the first 12 months of recordkeeping, the dates and cumulative number of events during which the turbidity exceeded 5 NTU, and after one year of recordkeeping for turbidity measurements, the dates and cumulative number of events during which the turbidity exceeded 5 NTU in the previous 12 months the system served water to the public.

3. For the first 120 months of recordkeeping, the dates and cumulative number of events during which the turbidity exceeded 5 NTU, and after 10 years of recordkeeping for turbidity measurements, the dates and cumulative number of events during which the turbidity exceeded 5 NTU in the previous 120 months the system served water to the public.

(d) Ground water systems under the direct influence of surface water that has been directed to install filtration but has not yet done so shall monitor as specified in subparagraph (a) of this paragraph.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.09 INORGANIC CHEMICAL SAMPLING AND ANALYTICAL REQUIREMENTS.

(1) Monitoring and analysis for the purpose of determining compliance with the maximum contaminant level for antimony, arsenic, asbestos, barium, beryllium, cadmium, chromium, cyanide, fluoride, mercury, nickel, nitrate, nitrite, total nitrate and nitrite, thallium, and selenium shall be conducted as follows:

(a) Groundwater systems shall take a minimum of one sample at every entry point to the distribution system which is representative of each well after treatment (hereafter called a sampling point) beginning in the compliance period starting January 1, 1993. The system shall take such sample at the same sampling point unless conditions make another sampling point more representative of each source or treatment plant.

(Rule 0400-45-01-.09, continued)

(a) Groundwater systems shall take one sample at each sampling point during each three year compliance period starting January 1, 1993. Surface water systems and combined surface/ground systems shall take one sample annually at each sampling point beginning January 1, 1993.

(b) Systems which exceed the maximum contaminant levels shall monitor quarterly beginning in the next quarter after the violation occurred.

(c) The Department may decrease the quarterly monitoring requirement to the frequencies specified in subparagraph (a) of this paragraph provided a ground water system has collected two consecutive quarterly samples and a surface water system has a minimum of four consecutive quarterly samples below the MCL.

(d) The system may apply to the Department for a waiver from the monitoring frequencies specified in subparagraph (a) of this paragraph. The Department may grant a public water system a waiver for monitoring cyanide, provided that the Department determines that the system is not vulnerable due to the lack of any industrial source of cyanide.

(e) A condition of the waiver shall require that a system shall take a minimum of one sample while the waiver is effective. The term during which the waiver is effective shall not exceed one compliance cycle (i.e., nine years).

(f) The Department may grant a waiver provided surface water systems have monitored annually for at least three years and groundwater systems have conducted a minimum of three rounds of monitoring. (At least one sample shall have been taken since January 1, 1990). Both surface and groundwater systems shall demonstrate that all previous analytical results were less than the maximum contaminant level. Systems that use a new water source are not eligible for a waiver until three rounds of monitoring from the new source have been completed.

(g) In determining the appropriate reduced monitoring frequency, the Department shall consider:

1. Reported concentrations from all previous monitoring;

2. The degree of variation in reported concentrations; and

3. Other factors which may affect contaminant concentrations such as changes in groundwater pumping rates, changes in the system's configuration, changes in the system's operating procedures, or changes in stream flows or characteristics.

(h) A decision by the Department to grant a waiver shall be made in writing and shall set forth the basis for the determination. The determination may be initiated by the Department or upon an application by the public water system. The public water system shall specify the basis for its request. The Department shall review and, where appropriate, revise its determination of the appropriate monitoring frequency when the system submits new monitoring data or when other data relevant to the system's appropriate monitoring frequency become available.

(5) All public water systems (community, non-transient non-community, and transient non-community systems) shall monitor to determine compliance with the maximum contaminant level for nitrate.

(a) Community and non-transient non-community water systems served by ground water system shall monitor annually beginning January 1, 1993. Community and non–

(Rule 0400-45-01-.09, continued)

transient systems served by surface water shall monitor quarterly beginning January 1, 1993.

(b) For community and non-transient non-community water systems, the repeat monitoring frequency for ground water systems shall be quarterly for at least one year following any one sample in which the concentration is greater than or equal to 50 percent of the MCL. The Department may allow a groundwater system to reduce the sampling frequency to annually after the results of four consecutive quarterly samples are below the MCL.

(c) For community and non-transient non-community water systems, the Department may allow a surface water system to reduce the sampling frequency to annually if all analytical results from four consecutive quarters are less than 50 percent of the MCL. A surface water system shall return to quarterly monitoring if any one sample is greater than or equal to 50 percent of the MCL.

(d) Each transient non-community water system shall monitor annually beginning January 1, 1993.

(e) After the initial round of quarterly sampling is completed, each community and non-transient non-community system which has been allowed to reduce its monitoring to annually shall take subsequent samples during the quarter(s) which previously resulted in the highest analytical result.

(6) All public water systems (community, non-transient non-community, and transient non-community systems) shall monitor to determine compliance with the maximum contaminant level for nitrite.

(a) All public water systems shall take one sample at each sampling point during the compliance period beginning January 1, 1993, and ending December 31, 1995.

(b) After the initial sample, systems where an analytical result for nitrite is less than 50 percent of the MCL shall monitor at the frequency determined by the Department in accordance with the criteria in subparagraph (4)(g) of this rule.

(c) For community, non-transient non-community, and transient non-community water systems, the repeat monitoring frequency for any water system shall be quarterly for at least one year following any one sample in which the concentration is greater than or equal to 50 percent of the MCL. The Department may allow a system to reduce the sampling frequency to annually after determining the system has four consecutive quarters of data less than the MCL.

(d) Systems which are monitoring annually shall take each subsequent sample during the quarter(s) which previously resulted in the highest analytical result.

(7) Confirmation samples:

(a) Where the results of sampling for asbestos, antimony, arsenic, barium, beryllium, cadmium, chromium, cyanide, fluoride mercury, nickel, selenium or thallium indicate an exceedance of the maximum contaminant level, the Department may require that one additional sample be collected as soon as possible after the initial sample was taken (but not to exceed two weeks after the date of the initial sample analysis) at the same sampling point.

(b) Where nitrate or nitrite sampling results indicate an exceedance of the maximum contaminant level, the system shall take a confirmation sample within 24 hours of the

(Rule 0400-45-01-.11, continued)

1. The Department may require more frequent monitoring than specified in subparagraphs (a) and (b) of this paragraph, or may require confirmation samples at its discretion. The results of the initial and confirmation samples will be averaged for use in compliance determinations.

2. Each public water systems shall monitor at the time designated by the Department during each compliance period.

3. Compliance: Compliance the radionuclide MCLs will be determined based on the analytical result(s) obtained at each sampling point. If one sampling point is in violation of an MCL, the system is in violation of the MCL.

   (i) For systems monitoring more than once per year, compliance with the MCL is determined by a running annual average at each sampling point. If the average of any sampling point is greater than the MCL, then the system is out of compliance with the MCL.

   (ii) For systems monitoring more than once per year, if any sample result will cause the running average to exceed the MCL at any sample point, the system is out of compliance with the MCL immediately.

   (iii) Systems must include all samples taken and analyzed under the provisions of this Rule in determining compliance, even if that number is greater than the minimum required.

   (iv) If a system does not collect all required samples when compliance is based on a running annual average of quarterly samples, compliance will be based on the running average of the samples collected.

   (v) If a sample result is less than the detection limit, zero will be used to calculate the annual average, unless a gross alpha particle activity is being used in lieu of radium-226 and/or uranium. If the gross alpha particle activity result is less than detection, 1/2 the detection limit will be used to calculate the annual average.

4. The Department has the discretion to delete results of obvious sampling or analytic errors.

5. If the MCL for radioactivity set forth in paragraph (5) of Rule 0400-45-01-.06 is exceeded, the operator of a community water system must give notice to the Department pursuant to Rule 0400-45-01-.20 and to the public as required by Rule 0400-45-01-.19.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.12 SECONDARY DRINKING WATER REGULATIONS.

(1) The following maximum contaminant levels are established to provide a water that is aesthetically pleasing to the consumer. These standards will apply to all community water systems and to those non-community water systems as may be deemed necessary by the Department. Monitoring for these contaminants will be set in the Monitoring Program for each system, but in no event less than once every year for a surface and surface/ground supply and once every three years for a ground water supply.

Maximum Contaminant Level

	Contaminant	Milligrams per Liter (unless otherwise indicated)
(a)	Chloride	250
(b)	Color	15 (Color Units)
(c)	Copper	1
(d)	MBAS (Methyl Blue Active Substance)	0.5
(e)	Iron	0.3
(f)	Manganese	0.05
(g)	Odor	3 (Threshold Odor Number)
(h)	pH	6.5-8.5
(i)	Sulfate	250
(j)	TDS (Total Dissolved Solids)	500
(k)	Zinc	5
(l)	Fluoride	2
(m)	Aluminum	0.2
(n)	Silver	0.1

(2) The system may apply for monitoring waivers from the monitoring frequency specified in paragraph (1) of this rule. The Department may issue monitoring waivers after considering: historical data, whether or not there have been customer complaints concerning the contaminant to be waived, any corrective action taken by the water supplier to correct the secondary contaminant problem, and whether or not the system routinely monitors for the contaminant as part of its treatment process monitoring program. The Department shall determine the frequency, if any, a system must monitor after considering the historical data available, the number and nature of customer complaints and other factors that may affect the contaminant concentration, and specify the decision in writing to the system.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.13 ALTERNATIVE ANALYTICAL TECHNIQUES.

If an alternative analytical technique is acceptable to the Administrator of the U.S. Environmental Protection Agency as being substantially equivalent to the prescribed test in both precision and accuracy as it relates to the determination of compliance with any maximum contaminant level, they shall become a part of these rules and regulations by inference.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

(Rule 0400-45-01-.17, continued)

(b) Non-community water systems which are classified as a surface supply will be required to have a full time operator in attendance unless certain continuous monitoring equipment is installed.

(c) Pursuant to T.C.A. § 68-221-904, all operators in direct responsible charge of a water supply system, including the treatment plant and/or distribution system, must be certified by the Department as competent to operate the water supply system.

(d) Because the proper operation and maintenance of water systems is critical to a system's ability to provide safe water to the public and to comply with these rules, all water supply systems must comply with the provisions of Chapter 0400-49-01. A violation of those rules is a violation of this rule as well.

(2) (a) All community water systems and those non-community water systems classified as a surface source shall compile and maintain accurate daily operating records of the water works system on forms prepared and furnished by the Department. The daily operating records shall be submitted in a timely manner so they are received by the Department no later than ten days after the end of the reporting month. Any special reports, deemed necessary by the Department to assure continuous satisfactory operation of the water system, shall be submitted to the Department.

(b) Water systems which desire to use their own forms to report the daily operating results to the Department must have prior written approval of the form from the Department.

(3) All water quality tests, other than those listed in Rule 0400-45-01-.06 shall be made in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" or alternate methods acceptable to the Department. The schedule of laboratory tests followed in controlling the operation of a waterworks system will vary with the character of the water; therefore, all waterworks systems must have the equipment necessary to perform all laboratory tests pertinent to the control of the plant or system operation, and the equipment shall be maintained in good working order at all times. Laboratory tests pertinent to proper operation shall be prescribed by the Department for each community water system.

(4) Chlorine is the recommended disinfection agent. Other agents will be considered by the Department provided they are effective and testing procedures for their effectiveness are recognized in the latest edition of "Standard Methods for the Examination of Water and Wastewater". All community water systems, using ground water as a raw water source and serving more than 50 connections or 150 persons shall continuously chlorinate (unless other disinfection methods are approved) and shall maintain a free chlorine residual in all parts of the distribution system in the amount of not less than 0.2 mg/l. Public Water Systems using surface water shall continuously chlorinate and maintain a free chlorine residual of 0.2 mg/l in all parts of the distribution system. The residual disinfectant concentration specified by this rule shall not be less than 0.2 mg/l in more than 5 percent of the samples each month, for any two consecutive months the system serves water to the public. All public water systems serving 50 or fewer connections that do not disinfect shall install continuous disinfection if the system fails to comply with the maximum contaminant level for coliform, experiences a disease outbreak or is directed to install disinfection by the department.

(5) All systems submitting samples for microbiological examination to the State laboratory must submit said sample in the bottle(s) provided by the State and return the samples to the proper State laboratory in the shipping carton provided by the State. The cost of postage for shipping the sample to the proper State laboratory shall be paid by the supplier of water. All samples submitted for microbiological examination must be collected and mailed to arrive at the proper State laboratory not later than Thursday noon of any week. Thirty hours is the limit allowed from the time of collection to the time of examination at the proper state laboratory.

(Rule 0400-45-01-.17, continued)

(6) (a) Pursuant to T.C.A. § 68-221-711(6), the installation, allowing the installation, or maintenance of any cross-connection, auxiliary intake, or bypass is prohibited unless the source and quality of water from the auxiliary supply, the method of connection, and the use and operation of such cross-connection, auxiliary intake, or bypass has been approved by the Department. The arrangement of sewer, soil, or other drain lines or conduits carrying sewage or other wastes in such a manner that the sewage or waste may find its way into any part of the public water system is prohibited.

(b) 1. All community water systems must adopt an ordinance or policy outlining the prohibitions in subparagraph (a) of this paragraph and submit a copy of the executed ordinance or policy to the Department for written approval. All community water systems shall develop a written plan for a cross-connection control program to detect and eliminate or protect the system from hazards associated with cross-connections. The written plan must be approved by the Department.

2. After adoption and approval of the cross-connection ordinance or policy and plan, each community water system must establish an ongoing program to detect and eliminate or protect the system from hazards associated with cross-connections. Records of the cross-connection control program must be maintained by the supplier of water and shall include such items as date of inspection, person contacted, recommendations, follow-up, and testing results.

3. Cross-connection plans and policies shall present information in conformance with the “Cross-Connection Control Manual and Design Criteria for Cross-Connection Control Plans, Ordinances and Policies” as published by the Department.

4. Community water systems shall ensure that cross-connections between the distribution system and a consumer’s plumbing are surveyed and/or inspected and determined not to exist or contain a significant risk or are eliminated or controlled by the installation of an approved backflow preventer commensurate with the degree of hazard.

5. Non-community water systems shall ensure that unprotected cross-connections are not allowed to exist within the water system. The non-community water system shall conduct periodic inspections of the water system and maintain a statement of inspection completion to include acknowledgement of the hazards associated with cross-connections.

(7) All community water systems shall prepare and maintain an emergency operations plan in order to safeguard the water supply and to alert the public of unsafe drinking water in the event of natural or man-made disasters. Emergency operation plans shall be consistent with guidelines established by the Department and shall be reviewed and approved in writing by the Department. Systems shall include a drought management plan as a part of the emergency operations plan. The emergency operations plan, including the drought management portion, shall be reviewed, updated, and submitted to the Department at least once every three years. The drought management plan portions of the emergency operations shall be submitted for approval as follows:

(a) Systems serving 3,000 or more connections including consecutive systems: June 30, 2016.

(b) Systems serving more than 1,000 connections and less than 3,000 connections including consecutive systems: June 30, 2017.

(Rule 0400-45-01-.17, continued)

(c) Systems serving 1,000 connections or less: June 30, 2018.

(8) (a) General-Public water systems, construction contractors, and engineers shall follow and document sanitary practices used in inspecting, constructing or repairing water lines, finished water storage facilities, water treatment facilities, and wells. Public water systems, construction contractors, and engineers shall follow the latest edition of the AWWA standards C-651, C-652, C-653, C-654, or equivalent methods provided the method has been approved in writing by the Department and is available during the inspection, construction, maintenance, or repair activity. In lieu of following AWWA standards or approved equivalent methods, public water systems, construction contractors, and engineers may write their own disinfection standard operating procedures. Disinfection standard operating procedures shall be approved in writing by the Department and be available during the inspection, construction, maintenance, or repair activity.

The documentation shall include disinfection procedures used, bacteriological sample results, construction logs, and repair logs and may include photographs where appropriate. All wells, pipes, tanks, filters, filter media and other materials shall be properly disinfected prior to being placed in service. Any disinfectant used to disinfect shall be NSF approved or plain household bleach and used in a manner that assures sufficient contact time and concentration to inactivate any pathogens present. Bacteriological results including line repair records indicating adequacy of disinfection shall be maintained on file by the public water system for five years. Procedures to ensure that water containing excessive concentrations of disinfectant is not supplied to the customers or discharged in such manner as to harm the environment shall be implemented.

All materials used for new or repaired water lines, storage facilities, water treatment facilities, and wells will be inspected prior to use for any evidence of gross contamination. Any contamination observed shall be removed and the materials protected during installation.

(b) Bacteriological Sampling of New Facilities-Bacteriological samples will be collected and analyzed to verify the effectiveness of the disinfection practices prior to placing new facilities in service. Bacteriological samples for finished water storage facilities, water treatment facilities, and wells shall be collected as specified by AWWA standards C-652, C-653, and C-654.

Adequacy of disinfection of new lines shall be demonstrated by collecting two sets of microbiological samples 24 hours apart or collecting a single set of microbiological samples 48 hours or longer after flushing the highly chlorinated water from the lines. In either case microbiological samples in each set will be collected at approximately 2,500-foot intervals with samples near the beginning point, the end point, and at the end of each branch line, unless written approval of alternate sampling frequency and distance between sampling points has been obtained from the Department. If the newly constructed facility yields positive bacterial samples,-the line shall be flushed, and re-sampled. If subsequent samples are positive, the line shall be re-disinfected, flushed and sampled again.

(c) Bacteriological Sampling of Existing Facilities

1. Finished water storage facilities, water treatment facilities, and wells that have been compromised and potential contamination is introduced during inspection or repair shall be disinfected, flushed, and sampled as specified by AWWA standards C-652, C-653, and C-654. Bacteriological samples shall be collected from a location representing the water contained in the compromised facility. The

repaired facility may be returned to service prior to obtaining bacteriological results.

2. Drinking water mains where positive pressure has not been maintained during inspection or repair shall be disinfected and flushed prior to being placed back in service. Disinfection and flushing shall be in accordance with AWWA standard C-651 or other method approved in writing by the Department. Bacteriological samples shall be collected immediately after the repair is completed and from a location representing the water contained in the repaired main. The repaired main may be returned to service prior to obtaining bacteriological results. If the repaired main has been placed back into service and yields positive bacteriological samples, the main shall be flushed and re-sampled. One sample is to be collected at the original positive site, one sample is to be collected upstream of the repair and one sample is to be collected in the downstream area of the repair. Sampling shall continue until the water is coliform free.

3. If one-half or more of the bacteriological samples collected from the repaired facility are total coliform positive, the system shall notify the Department within 30 days that it has reviewed its disinfection and sampling practices in an attempt to identify why the positive samples occurred and revise its disinfection and sampling plans accordingly.

4. If any public water system collects a fecal coliform positive repeat sample or E-coli positive repeat sample or a total coliform positive repeat sample following an initial positive fecal coliform or E-coli sample collected from the repaired facility, the system shall notify the Department within 24 hours and issue a Tier 1 public notice using the language specified in Appendix B of Rule 0400-45-01-.19.

(d) Inspectors, contractors, operators, public water systems or engineers that fail to document and follow adequate disinfection procedures, and fail to collect bacteriological samples during repairs, inspections or maintenance activities that potentially would compromise the microbial quality of the water shall issue a boil water advisory to the customers served by that portion of the public water system prior to returning the facility to service. The boil water advisory shall remain in effect until satisfactory microbial tests results and written approval from the Department are obtained.

(9) All community water systems shall be operated and maintained to provide minimum positive pressure of twenty (20) psi throughout the distribution system. No person shall install or maintain a water service connection to any premises where a booster pump has been installed unless such booster pump is equipped with a low pressure cut-off mechanism designed to cut off the booster pump when the pressure on the suction side of the pump drops to twenty (20) psi gauge.

(10) All community water systems having more than 50 service connections shall establish and maintain an adequate flushing program. The flushing program established shall help ensure that dead end and low usage mains are flushed periodically, drinking water standards are met, sediment and air removal and the free chlorine residual specified under paragraph (4) of this rule is maintained. Records of each flushing are to be maintained by the water system. These records shall include date, time, location, persons responsible and length of flushing. In addition to the above information, the free chlorine residual will have to be measured and recorded on the end of dead end mains after being flushed.

(11) All community public water systems serving more than 50 connections and which have their own source of water shall be required to install, operate and maintain duplicate disinfection equipment. Duplicate disinfection equipment means at least two chlorine cylinders connected

(Rule 0400-45-01-.17, continued)

to at least two chlorinators. Each set of chlorine cylinders consists of one or more cylinders which may be connected together by an automatic switchover valve. The two sets of chlorine cylinders may tee in to a common feed line leading to the chlorinators, but may not be connected together by an automatic switchover valve. The two sets of chlorine cylinders must be weighed independently and operated simultaneously. At least two chlorinators must be operated at all times with each feeding a part of the required dosage. The chlorinators may discharge to a common manifold piping network to allow multiple injection points. Facilities may be exempt from simultaneously operating duplicate disinfection equipment if the facility has a reliable chlorine residual analyzer with an alarm notifying a manned control center capable of immediately shutting down the treatment facility. Facilities, which are staffed during the time water is treated, can use one set of chlorine cylinders with the automatic switchover device provided the free chlorine residual is checked at the facility every two hours. A reliable free chlorine residual analyzer with an alarm system to a manned control center may be used for unmanned facilities that desire to use one set of chlorine cylinders with the automatic switchover device.

Community public water systems serving more than 50 service connections which use a hypochlorinator shall be required to have two solution pumps, two tanks for bleach solution and operate both units at the same time. Noncommunity systems and community systems serving less than 50 connections which use a hypochlorinator and show deficiencies in the disinfection process shall also be required to have duplicate disinfection units.

(12) All public water systems which utilize a filtration system shall use the following bed specifications and not exceed the following rates of filtration.

(a) Rapid Sand Filtration - 2.0 gallons per minute per square foot for turbidity removal, 3.0 gallons per minute per square foot for iron removal.

There must be 30 inches of sand media with an effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70

(b) High Rate Filtration - 4.0 gallons per minute per square foot for turbidity removal, 4.0 gallons per minute per square foot for iron removal.

There must be 30 inches of dual media with 10 to 12 inches of sand and 18 to 20 inches of anthracite. The sand shall have an effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70. The anthracite shall have an effective size of 0.8 mm to 1.2 mm with a uniformity coefficient not greater than 1.85.

(c) Existing water systems with rapid sand filters and approved for higher rates of filtration by the Department will be allowed to continue at that rate provided the drinking water standards are met. The water supplier must be able to document that the Department approved the system for the higher rate.

(d) All mixed media filter beds will be at least 30 inches in depth and approved by the Department.

(e) Filtration rates above 4.0 gallons per minute per square foot will be considered on an individual basis. The Department will take into account the raw water characteristics, the treatment units, operational history, and operating personnel.

(13) All community water systems serving 50 connections or more shall install duplicate pumps for the raw water, finished water, and distribution pumping stations. A water system will not be required to have duplicate pumps in a distribution pumping station under the following conditions: limited number of service connections, availability of replacement pumps, maintaining adequate flows and pressures without the pumping station, and for emergency

(Rule 0400-45-01-.17, continued)

the water mains, sizes of mains, valves, blow-offs or flush hydrants, air-release valves, and fire hydrants. One up-to-date copy of the overall system distribution map(s) is to be submitted to the Division of Water Resources every five years.

(16) All vents on wells, springs, storage tanks, overflows and clearwells shall be properly screened. All overflows on springs and tanks shall be screened and protected.

(17) All buildings and equipment used in and for the production and distribution of water (to include chemical and other storage buildings) must be well maintained and be reliable and fit for the purpose for which they are used. This includes, but is not limited to:

(a) When a water treatment plant is not producing water and an operator is not in attendance, plant entrances must be locked.

(b) Equipment such as chemical feeders, pumps, turbidimeters, pumpage meters, alarm systems, and air tanks shall be maintained and in good working condition. Pumps, tanks, hoses, and other equipment used by system personnel shall be disinfected and dedicated to its use if it comes into contact with water that may be consumed by humans.

(c) Duplicate or backup equipment shall be available as necessary to maintain the production of water meeting drinking water standards. Backup equipment or alternate treatment means shall be available for feeding all chemicals critical for adequate water treatment.

(18) All community water systems planning to or having installed hydrants must protect the distribution system from contamination. All water mains designed for fire protection must be six inches or larger and be able to provide 500 gallons per minute with 20 pounds per square inch residual pressure. Fire hydrants shall not be installed on water mains less than six inches in diameter or on water mains that cannot produce 500 gpm at 20 psi residual pressure unless the tops are painted red. Out of service hydrants shall have tops painted black or covered with a black shroud or tape.

Existing Class C hydrants (hydrants unable to deliver a flow of 500 gallons per minute at a residual pressure of 20 pounds per square inch (psi) shall have their tops painted red by January 1, 2008.

The water system must provide notification by certified mail at least once every five years beginning January 1, 2008, to each fire department that may have reason to utilize the hydrants, that fire hydrants with tops painted red (Class C hydrants) cannot be connected directly to a pumper fire truck. Fire Departments may be allowed to fill the booster tanks on any fire apparatus from an available hydrant by using the water system's available pressure only (fire pumps shall not be engaged during refill operations from a Class C hydrant).

(19) Before any new or modified community water treatment facility can be placed in service, it must be inspected and approved in writing by the Department.

(20) Each public water system adjusting the fluoride content to the finished water must monitor for fluoride quarterly using a certified laboratory and the calculation of the fluoride level will be by running annual average. If the quarterly analysis of a water sample from a public water system by a certified laboratory confirms that the level of fluoride in the sample exceeds 1.5 mg/L, the public water system must provide notification to its customers of the exceedance in the same manner as prescribed in paragraph (8) of Rule 0400-45-01-.19. The water system must begin monthly fluoride monitoring using a certified laboratory for analysis. Once the monthly analyses confirm that the fluoride level is less than 1.5 mg/L for three (3) consecutive months, the public water system may resume quarterly monitoring for fluoride.

(Rule 0400-45-01-.17, continued)

(32) New service taps on existing mains that must be uncovered to make the tap, shall be flushed and the free chlorine residual measured and recorded prior to connecting the service lines. These records shall be retained until the next sanitary survey or for three years.

(33) All public water systems shall properly maintain their distribution system finished water storage tanks and clearwells. Each community water system shall establish and maintain a maintenance file on each of its distribution storage tanks and clearwells. These maintenance files must be available for inspection by Department personnel. These files must include records of all routine water storage tank and clearwell inspections by system personnel, any reports of detailed professional inspections of the water storage facilities by contractor personnel, dates and details of routine tank cleanings and surface flushings, and dates and details of all tank and clearwell maintenance activities. The tank and clearwell inspection records shall include dates of the inspections; the sanitary, coating and structural conditions of the water storage facility; and all recommendations for needed maintenance activities. Community water systems shall have a professional inspection performed and a written report produced on each of their distribution storage tanks and clearwells at least once every five years. Non-community water systems shall have a professional inspection performed and written report produced on each of their atmospheric pressure and distribution storage tanks and clearwells no less frequently than every five years. Records of these inspections shall be available to the Department personnel for inspection. Persons conducting underwater inspections of distribution system finished water storage tanks and clearwells shall comply with AWWA standard C-652-11 or later versions of the standard.

(34) Paints and coatings for the interior of potable water storage facilities must be acceptable to the Department. Paints and coatings accepted by the Environmental Protection Agency (EPA) and/or the National Sanitation Foundation (NSF) for potable water contact are generally acceptable to the Department. Paint systems for steel tanks shall be consistent with AWWA Standard D102-78. Factory coated bolted steel tanks shall be in accordance with AWWA D103-87. Wire-wound circular prestressed concrete tanks shall be in accordance with AWWA D110-86.

(35) By January 1, 1996, public water systems using surface water and ground water systems under the direct influence of surface water that filter shall have rewash capability. Such systems shall perform a rewash cycle, or filter to waste each time a filter is backwashed. The rewash cycle shall be conducted in a way and manner necessary to prevent the introduction of contaminants such as pathogens and turbidity trapped in the filter into the clear well or distribution system.

Existing filter plants may be approved to operate without rewash (filter-to-waste provisions) if existing operational and backwash practices prevent water of unacceptable quality from entering the clearwell or distribution system. To operate without rewash the water system must demonstrate to the Department that filtered water turbidity after backwashing is reliably and consistently below 0.5 NTU immediately after backwashing each filter. Approval to operate without rewash must be approved in writing and approval must be renewed if any modifications are made to the operation or design of the plant. Each filter that operates without rewash must have a continuous recording turbidimeter and retain the records for a period of five years.

(36) By January 1, 1995, all chemicals, additives, coatings or other materials used in the treatment, conditioning and conveyance of drinking water must have been approved by the National Sanitation Foundation (NSF) or American National Standards Institute (ANSI) certified parties as meeting NSF product standard 60 and 61. Until 1995, products used for treatment, conditioning and conveyance of drinking water shall have been listed as approved by the US EPA or NSF.

(Rule 0400-45-01-.17, continued)

(37) Any new Community Water System or Non-Transient Non-Community Water System commencing operation after September 30, 1999 shall have a “Capacity Development Plan” and be a “viable water system.”

(38) Public Water Systems identified as not complying or potentially not complying with the requirements of the Safe Drinking Water Act and in accordance with the priorities established in the Department’s Capacity Development Strategy shall prepare a “Capacity Development Plan” and demonstrate viability.

(39) Public water systems are not permitted to construct uncovered finished water reservoirs after the effective date of this subparagraph.

(40) Benchtop and continuous turbidimeters used to determine compliance with limits set forth in this rule chapter must be calibrated at least every three months with primary standards and documented. Documentation shall be maintained for a period not less than five years. Primary standards are Formazin, AMCO clear, Stablcal, or alternatives approved in writing by the Department. Dilute Formazin solutions are unstable and must be prepared on the day of calibration. Manufacturers’ recommendations on calibration procedure must be followed.

(41) Verifications for benchtop turbidimeters are comparisons to approved reference materials. Verifications for continuous turbidimeters are comparisons to approved reference materials or comparisons to a properly calibrated benchtop turbidimeter. Secondary reference materials are assigned a value immediately after acceptable primary calibration has been completed. Acceptable verifications for turbidity measurements greater than 0.5 NTU must agree within ±10% from the reading assigned to the reference material after primary calibration. Acceptable verifications for measurements 0.5 NTU or less must be within ±0.05 NTU or less from the reading assigned to the reference material after primary calibration. When comparisons are made from a continuous turbidimeter to a benchtop turbidimeter, the continuous measurement must be within ±10% of the benchtop reading for measurements above 0.5 NTU and ±0.05 NTU for reading 0.5 NTU or less. When acceptable verifications are not achieved the instrument must be re-calibrated with primary standards according to paragraph (40) of this rule. Approved reference materials for benchtop and continuous turbidimeters are primary standards and materials suggested by the manufacturer such as sealed sample cells filled with metal oxide particles in a polymer gel and turbid glass tubes. All other reference materials for turbidimeter verifications must be approved in writing by the Department. Verifications for turbidimeters must be performed according to the following:

(a) Verification of benchtop turbidimeters must be performed daily and documented. Verifications must include a sample in the expected working range of the instrument or as close to the working range as possible. Documentation must include: assigned reference material value after calibration, recorded daily reading for all reference standards, instrument identification, and date.

(b) Combined filter effluent turbidimeters as required by part (5)(c)1. of Rule 0400-45-01-.31 must be verified daily and documented. When reference material is utilized documentation must include: instrument identification, date, assigned reference material value after calibration, and daily value for reference material. When comparisons to benchtop turbidimeters are utilized documentation must include: instrument identification, date, continuous turbidimeter value, and benchtop turbidimeter value.

(c) Individual filter turbidimeters as required by part (5)(c)4. of Rule 0400-45-01-.31 must be verified weekly.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments*

(Rule 0400-45-01-.18, continued)

(c) Contaminant(s),

(d) Analytical method(s) used,

(e) Date of sample,

(f) Date of analysis.

(8) It shall be a violation of these regulations for any person, public water system, engineer, operator or certified laboratory to:

(a) Record data or information and/or report any inaccurate, misleading, false or information known or that should be known to be false; or

(b) Report any data or information that is inaccurate, misleading or false because the person reporting has not used reasonable care, judgment or the application of his knowledge in the preparation of the report.

(c) Provide inaccurate or false statements to the Department.

(9) Electronic Reporting. A person is required to submit reports and certifications to the Department in order for a person to comply with this rule chapter (0400-45-01). The Commissioner may make forms available electronically or allow these reports to be submitted electronically and, if submitted electronically, then that electronic submission shall comply with the requirements of Chapter 0400-01-40.

Authority: *T.C.A. §§ 4-5-201, et seq. and 68-221-701, et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01. Amendments filed November 19, 2018; effective February 17, 2019.*

0400-45-01-.19 NOTIFICATION OF CUSTOMERS.

(1) Each owner and operator of a public water system including community, non-transient non-community, and non-community water systems must comply with this rule.

(a) Each owner or operator of a public water system must give public notice for all violations of national primary drinking water regulations and for other situations as listed in Table 0400-45-01-.19(1)(a). The term national primary drinking water regulation is used in this rule to include violations of the maximum contaminant level (MCL), maximum residual disinfectant level (MRDL), treatment technique (TT), monitoring requirements, and testing procedures described in these regulations. Appendix A to this rule identifies the tier assignment for each specific violation or situation requiring a public notice.

(Rule 0400-45-01-.19, continued)

6. Violation of the Surface Water Treatment Rule (SWTR) Rule 0400-45-01-.31, Interim Enhanced Surface Water Treatment Rule (IESWTR) or Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) treatment technique requirement resulting from a single exceedance of the maximum allowable turbidity limit (as identified in Appendix A) where the department determines after consultation that a tier 1 notice is required or where consultation does not take place within 24 hours after the system learns of the violation;

7. Occurrence of a waterborne disease outbreak, as defined in Rule 0400-45-01-.04, or other waterborne emergency (such as a failure or significant interruption in key water treatment processes, a natural disaster that disrupts the water supply or distribution system, or a chemical spill or unexpected loading of possible pathogens into the source water that significantly increases the potential for drinking water contamination);

8. Other violations or situations with significant potential to have serious adverse effects on human health as a result of short-term exposure, as determined by the Department either in its regulations or on a case-by-case basis.

9. Detection of E. coli or enterococci in source water samples as specified in paragraph (3) of Rule 0400-45-01-.40.

(b) When is the Tier 1 public notice to be provided? What additional steps are required? Public water systems must:

1. Provide a public notice as soon as practical but no later than 24 hours after the system learns of the violation;

2. Initiate consultation with the Department as soon as practical, but no later than 24 hours after the public water system learns of the violation or situation, to determine additional public notice requirements; and

3. Comply with any additional public notification requirements (including any repeat notices or direction on the duration of the posted notices) that are established as a result of the consultation with the Department. Such requirements may include the timing, form, manner, frequency, and content of repeat notices (if any) and other actions designed to reach all persons served.

(c) What is the form and manner of the public notice? Public water systems must provide the notice within 24 hours in a form and manner reasonably calculated to reach all persons served. The form and manner used by the public water system are to fit the specific situation, but must be designed to reach residential, transient, and non-transient users of the water system. In order to reach all persons served, water systems are to use, at a minimum, one or more of the following forms of delivery:

1. Appropriate broadcast media (such as radio and television);

2. Posting of the notice in conspicuous locations throughout the area served by the water system;

3. Hand delivery of the notice to persons served by the water system; or

4. Another delivery method approved in writing by the department.

(3) Tier 2 Public Notice–Form, manner, and frequency of notice.

(Rule 0400-45-01-.19, continued)

(a) Which violations or situations require a Tier 2 public notice? Table 0400-45-01-.19(3)(a) lists the violation categories and other situations requiring a Tier 2 public notice. Appendix A to this rule identifies the tier assignment for each specific violation or situation.

Table 0400-45-01-.19(3)(a)

Violation Categories and Other Situations
Requiring a Tier 2 Public Notice

1.	All violations of the MCL, MRDL, and treatment technique requirements, except where a Tier 1 notice is required under subparagraph (2)(a) of this rule or where the department determines that a Tier 1 notice is required;
2.	Violations of the monitoring and testing procedure requirements, where the department determines that a Tier 2 rather than a Tier 3 public notice is required, taking into account potential health impacts and persistence of the violation; and
3.	Failure to comply with the terms and conditions of any variance or exemption in place.
4.	Failure to take corrective action or failure to maintain at least 4-log treatment of viruses (using inactivation, removal, or a Department-approved combination of 4-log virus inactivation and removal) before or at the first customer under subparagraph (4)(a) of Rule 0400-45-01-.40.

(b) When is the Tier 2 public notice to be provided?

1. Public water systems must provide the public notice as soon as practical, but no later than 30 days after the system learns of the violation. If the public notice is posted, the notice must remain in place for as long as the violation or situation persists, but in no case for less than seven days, even if the violation or situation is resolved. The department may, in appropriate circumstances, allow additional time for the initial notice of up to three months from the date the system learns of the violation. The department will not grant an extension to the 30-day deadline for any unresolved violation or to allow across-the-board extensions by rule or policy for other violations or situations requiring a Tier 2 public notice. Extensions granted by the department must be in writing.

2. The public water system must repeat the notice every three months as long as the violation or situation persists, unless the primacy agency determines that appropriate circumstances warrant a different repeat notice frequency. In no circumstance may the repeat notice be given less frequently than once per year. The Department will not through its rules or policies permit across-the-board reductions in the repeat notice frequency for other ongoing violations requiring a Tier 2 repeat notice. The Department will not allow through its rules or policies less frequent repeat notice for an MCL or treatment technique violation under Rule 0400-45-01-.07 (Monitoring) or Rule 0400-45-01-.41 (Revised Total Coliform Rule) or a treatment technique violation under Rule 0400-45-01-.31 (Filtration and Disinfection). Department determinations allowing repeat notices to be given less frequently than once every three months must be in writing.

3. For the turbidity violations specified in this paragraph, public water systems must consult with the Department as soon as practical but no later than 24 hours after the public water system learns of the violation, to determine whether a Tier 1 public notice under subparagraph (2)(a) of this rule is required to protect public

(Rule 0400-45-01-.19, continued)

Appendix A to this rule identifies the tier assignment for each specific violation or situation.

Table 0400-45-01-.19(4)

Violation Categories and Other Situations Requiring a Tier 3 Public Notice

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1. Monitoring violations for the primary drinking water contaminants, except where a Tier 1 notice is required under subparagraph (2)(a) of this rule or where the department determines that a Tier 2 notice is required;

2. Failure to comply with an approved departmental or EPA testing procedure, except where a Tier 1 notice is required under subparagraph (2)(a) of this rule or where the department determines that a Tier 2 notice is required;

3. Operation under a variance granted under Section 1415 or an exemption granted under Section 1416 of the Safe Drinking Water Act;

4. Availability of unregulated contaminant monitoring results, as required under paragraph (7) of this rule;

5. Exceedance of the fluoride secondary maximum contaminant level (SMCL), as required under paragraph (8) of this rule; and

6. Reporting and Recordkeeping violations under Rule 0400-45-01-.41.

(b) When is the Tier 3 public notice to be provided?

1. Public water systems must provide the public notice not later than one year after the public water system learns of the violation or situation or begins operating under a variance or exemption. Following the initial notice, the public water system must repeat the notice annually for as long as the violation, variance, exemption, or other situation persists. If the public notice is posted, the notice must remain in place for as long as the violation, variance, exemption, or other situation persists, but in no case less than seven days (even if the violation or situation is resolved).

2. Instead of individual Tier 3 public notices, a public water system may use an annual report detailing all violations and situations that occurred during the previous twelve months, as long as the timing requirements of part 1. of this subparagraph are met.

(c) What is the form and manner of the Tier 3 public notice? Public water systems must provide the initial notice and any repeat notices in a form and manner that is reasonably calculated to reach persons served in the required time period. The form and manner of the public notice may vary based on the specific situation and type of water system, but it must at a minimum meet the following requirements:

1. Unless directed otherwise by the Department in writing, community water systems must provide notice by:

COMMUNITY

PUBLIC WATER SYSTEMS

DESIGN CRITERIA

Division of Water Resources

Tennessee Department of Environment and Conservation

2018

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INTRODUCTION

This publication is a revised edition of our Design Criteria for Community Public Water Systems. They have been prepared as a guide to water systems, design engineers, and our own staff. There has been no attempt to address every situation. We also know that there will be occasions when these criteria will not apply. Exceptions will be handled on an individual basis.

The Tennessee Safe Drinking Water Act of 1983 requires The Department of Environment & Conservation to:

> "Exercise general supervision over the construction of public water systems throughout the state. Such general supervision shall include all the features of construction of public water systems which do or may affect the sanitary quality or the quantity of the water supply. No new construction shall be done nor shall any change be made in any public water system until the plans for such new construction or change have been submitted and approved by the department."
> (Extract of part of Section 68-221-706, Tennessee Code)

Where the terms shall and must are used, it is intended to be a mandatory requirement. Other terms such as should, recommend, preferred, and the like, are intended to show desirable equipment, procedures, or methods.

We encourage development of new methods and equipment. However, any new developments must be demonstrated to be satisfactory before we can approve their use. Operating data from other installations, or demonstration of the equipment by a manufacturer's representative, or both, may be needed for our review.

These criteria are a compilation of information from a number of sources. The principle source, however, is Recommended Standards for Water Works, 1982 Edition. This publication is a report of "The Committee of the Great Lakes Upper Mississippi River Board of State Sanitary Engineers" and is commonly known as Ten-State Standards.

Part 3 - SOURCE DEVELOPMENT

3.0 GENERAL - In selecting the source of water to be developed, the designing engineer must show to the satisfaction of the Department that the water which is to be delivered to the consumers will meet the current requirements of the Department with respect to bacteriological, physical, chemical and radiological qualities. The Division of Water Resources Field Offices evaluate and approve proposed new sources.

3.1 SURFACE WATER - A surface water source includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake.

3.1.1 Quantity - The quantity of water at the source shall:

a. be adequate to supply the water demand of the service area,

b. provide a reasonable surplus for anticipated growth over a design period of 10 to 20 years,

c. be adequate to compensate for all losses,

d. be evaluated for dependable capacity during drought,

e. be evaluated for impacts on downstream uses.

3.1.2 Quality - A sanitary survey and study should be made of the factors, both natural and man made, which will affect quality. Such survey and study shall include, but shall not be limited to:

a. obtaining samples over a sufficient period of time to assess the biological, physical, chemical and radiological characteristics of the water,

b. assessing degree of hazard to the supply from upstream discharges and by accidental spillage of materials that may be toxic, harmful or detrimental to treatment processes.

3.1.3 Structures - Intake structures design shall:

a. provide withdrawal of water from more than one level,

b. provide adequate protection against rupture by dragging anchors, ice, etc.

c. have motors and electrical controls located above grade and 100-year flood level, except when submersible pumps are approved,

d. be accessible,

e. be designed against flotation,

f. be equipped with removable or traveling screens before the pump suction well,

g. provide chemical feed facilities for raw water transmission main if necessary for water quality control or prevention of infestation by clams, mussels etc.,

h. have intake valves and provisions for backflushing and testing for leaks, where practical,

i. have provisions for surges where necessary,

j. have provisions for sand or gravel removal, 3.1.4 Impoundments and Reservoirs

a. Site preparation should provide for:

1. removal of brush and trees to high water elevation,

2. protection from floods during construction,

3. clearing and grubbing small reservoirs.

b. Construction may require:

1. approval of safety features for stability and spillway design of any structures to be obtained from the Department,

2. permit for controlling stream flow or structure on bed of navigable stream or interstate water, to be obtained from the appropriate agency.

3.2 GROUND WATER - A ground water source includes all water obtained from drilled wells or springs. Drilled wells shall meet requirements for construction and development delineated in the latest AWWA A-100 Standards. Springs shall meet the requirements for protection established by the Department on a case-by-case basis. Ground water sources must be evaluated for direct influence of surface water.

a. Drilled Wells - Two important design questions are involved. One is the provision for the proper depth to which the well casing shall be installed as a watertight conduit. The other is provision for positive sealing of the annulus between the outside of the well casing to prevent seepage of water vertically along the outside of the pipe.

1. Water tight construction of the cased portion of a well shall be carried to such depth as may be required by the Department to prevent polluted or inferior quality water from entering the well.

i. Wells completed in an unconsolidated aquifer such as sand, gravel, or what is commonly referred to as overburden shall be designed with watertight casing extending from the land surface to a depth of at least 10 feet below the lowest expected pumping level. Where the pumping level is less than 25 feet from the surface, the casing shall extend no less than 20 feet below the lowest pumping level.

ii. Wells completed in consolidated rock formations having little or no primary permeability such as limestone, dolomite, sandstone, siltstone and shale shall be designed with watertight casing extending through all overburden material and firmly seated in the bedrock. Where applicable the casing shall extend below any crevices that would release water of inferior quality into the well.

2. Provisions shall be made in the construction of a well for grouting and sealing the annular space between the borehole and the outside of the well casing. This normally means planning an oversize borehole to the proper depth to provide an annulus into which suitable grouting material can be placed. To assure a proper seal, the grout must be placed by a positive displacement method such as pumping or pressure injection from the bottom of the annulus to the top in one continuous operation.

b. Springs

1. Use of springs as a source of supply shall be considered only when it is not feasible to develop an acceptable well or surface supply.

2. Spring supplies shall be protected from entry of surface water.

3. Spring intakes shall be housed in permanent structures.

4. Spring supplies must be evaluated for direct influence of surface water. If determined to be under the direct influence of surface water, treatment must be provided in accordance with Division of Water Supply Filtration and Disinfection rules.

5. Spring supplies must be evaluated for dependable capacity during drought.

6. Downstream impacts of water withdrawals from springs must be considered and appropriate environmental permits obtained.

3.3 GENERAL WELL CONSTRUCTION REQUIREMENTS

a. Location - the Department shall be consulted as to required separation between sources of pollution and the ground water development.

b. Casing and liner pipe of wrought iron or steel:

   1. shall be prime pipe meeting AWWA, ASTM, or APT standard specifications,

   2. shall be surrounded by grout,

   3. shall be capable of withstanding forces to which they are subjected,

   4. shall have additional thickness and weight if standard thickness is not considered sufficient to assure reasonable life expectancy of well,

   5. shall have welded or threaded pipe joints.

c. Pipe other than wrought iron or steel must be adaptable to the stresses to which they will be subjected during installation and to the corrosiveness of the water.

d. Packers shall be of a material that will not impart taste, odor, toxic substances or bacterial contamination to the water in the well.

e. Screens shall:

   1. be constructed of material which will not be damaged by chemical action of ground water or future cleaning operations,

   2. have size of openings to be based on sieve analysis, or based on size of gravel if an artificial gravel pack is installed,

   3. be installed so that exposure above pumping level will not occur,

   4. be designed and installed to permit removal or replacement without adversely affecting watertight construction of well.

f. Yield and drawdown test requirements:

1. Every well shall be tested for yield and drawdown,

2. The method of testing shall be clearly stated in the specifications and shall be subject to the approval of the Department. Acceptable methods include but are not limited to the following:

   i. Constant discharge method - This type of test is preferred for wells completed in unconsolidated aquifers. It is made by maintaining a constant rate of discharge equal to or greater than the desired yield of the well throughout the entire period of pumping. Measurements of pumping rate and water level shall be made every minute for the first 10 minutes of the test, every 2 minutes for the next 10 minutes, every 5 minutes for the next 40 minutes, every 15 minutes for the next hour, every 30 minutes for the next 3 hours, hourly for the remainder of the pumping period. Recovery water-level measurements shall be made with the same frequency beginning with the cessation of pumping and continuing until complete recovery has occurred or until sufficient data have been collected to extrapolate full recovery.

   ii. Variable discharge method - This type of test can be used for wells completed in either consolidated or unconsolidated aquifers. It is made by setting the pump intake at a predetermined level and operating the pump at full capacity until it breaks suction. Thereafter the pump discharge is reduced until the pumping level stabilizes approximately 2 feet above the pump intake for a period of 5 to 10 minutes. The pumping rate shall then be decreased 5 percent and the well pumped at this rate until the pumping level stabilizes or the pump breaks suction again. Should the pump break suction a second time repeat the procedure given above until the pumping level stabilizes for a period of not less than four hours or for the remainder of the test period, whichever is longer. The final pumping rate shall be considered the available production from the well and the observed pumping level during the test shall be considered the production well's pumping level.

   iii. Step drawdown method - This method is preferred for wells completed in consolidated rock formations. It involves the well being "step" tested at rates approximately 1/2, 1, and l-1/2 times the design capacity of the well. Each step should consist of equal periods of pumping except the final step may be continued for a longer period of time if desired by the owner. The pump is operated continuously for the entire period of the test. The discharge must be controlled with a gate valve, if electric driven, or a gate valve and throttle if engine driven. The discharge is controlled and maintained at approximately the desired discharge for each step with an accuracy of ± 5 percent. Pump discharge is measured with a meter such as a circular orifice meter that will permit instantaneous determination of the discharge rate. A half-inch I.D. or larger pipe is installed from a point about 2 feet above the pump intake to the well head. The top of the pipe is readily accessible to insert, remove and read the depth to water using either a steel tape or 2-wire electric sonde. Measurements of pumping rate and water level are made for each step of the test according to the schedule given in the constant discharge method. Recovery water-level measurements are made with the same frequency until the well has fully recovered or until sufficient data have been recovered to extrapolate full recovery.

3. The test pump shall be capable of pumping 150 percent of the desired yield of the well.

4. The pumping equipment shall be capable of operating continuously without interruption for the maximum period contemplated for the test.

5. The duration of the test depends on a number of factors including but not limited to the following:

   (i) Local experience - Where wells have been operated nearby and in the same formation so that the water-yielding character of similar wells is fairly well known, the minimum period of testing shall be not less than 8 hours.

   (ii) Intermittent pumping - If it is anticipated that the well will be pumped for 12 hours or less each day, the minimum period of testing shall be not less than 24 hours.

   (iii) Limited draft - If the capacity of the permanent pump to be installed in the well is to be one-fourth or less of the demonstrated output of the well, the minimum period of testing shall be not less than 8 hours.

   (iv) Season of the year - If the well is tested during the winter and spring months, the minimum period of testing shall be extended by 50 percent of the time otherwise required.

6. Data shall be provided to the Department's central office and appropriate basin office as follows:

   (i) static water level, measurements prior to starting the pump,

   (ii) pumping rates and duration of each period of pumping,

   (iii) water-level measurements during test, and graph of drawdown vs. time,

   (iv) recovery water level measurements, and graph of recovery vs. time,

   (v) depth of pump setting,

   (vi) analytical results of water samples collected during the test,

   (viii) summary of determinations of well capacity, efficiency, aquifer characteristics, safe pumping rates, pump settings and water treatment needs.

g. Grouting requirements:

1. Types of grout:

   (i) Concrete Grout - A mixture of Portland Cement (ASTM C150), sand and water in the proportion of at least 5 bags of cement per cubic yard of concrete to not more than 7 shall be used. Size of gravel should be no greater than 1/3 the diameter of the annular space.

   (ii) Sand Cement Grout - A mixture of Portland Cement (ASTM C150), sand and water in the proportion of not more than two parts by weight of sand to one part of cement with not more than 7 gallons of water per cubic foot of cement shall be used.

(iii) Neat Cement Grout - A mixture of Portland Cement (ASTM C150) and not more than 7 gallons of water per cubic foot of cement shall be used.

The use of additives to reduce permeability, increase fluidity or control time of set may be used up to 5 percent by weight.

2. Placement of grout - To assure that grout will provide a satisfactory seal it must be introduced at the bottom of the annular space to be filled and placed in one continuous operation. Acceptable methods include the following:

(i) Tremie method - Grout material is placed by tremie pouring (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The tremie method shall only be used where there is a minimum annular space of 3 inches between the outside surface of the inside casing and the inside surface of the borehole. The minimum size tremie pipe utilized shall be 2 inches inside diameter. Where concrete grout is used the minimum size tremie pipe used shall be three inches inside diameter. When making a tremie pour, the tremie pipe shall be lowered to the bottom of the zone being grouted, and raised slowly as the grout material is introduced. The tremie pipe shall be kept full continuously from start to finish of the grouting procedure with the discharge end of the tremie pipe being continuously submerged in the grout until the zone to be grouted is completed filled.

(ii) Positive placement exterior method - Grout material is placed by a positive displacement method such as pumping or forced injection by air pressure (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). Grout is injected in the annular space between the inner casing and the borehole. The annular space must be a minimum of l½ inches for sand-and-cement or neat cement grout, and not less than three times the size of the largest coarse aggregate used. The grout pipe shall extend from the surface to the bottom of the zone to be grouted. The grout pipe shall have a minimum inside diameter of one inch for sand cement or neat cement grout. It shall have a minimum diameter of 1-1/2 inches for concrete grout. Grout shall be placed, from bottom to top, in one continuous operation. The grout pipe may be slowly raised as the grout is placed but the discharge end of the grout pipe must be submerged in the emplaced grout at all times until grouting is completed. The grout pipe shall be maintained full, to the surface, at all times until the completion of the grouting of the entire specified zone. In the event of interruption in the grouting operations, the bottom of the pipe should be raised above the grout level and should not be resubmerged until all air and water have been displaced from the grout pipe and the pipe flushed clean with clear water.

(iii) Positive placement - interior method - two plug - Grout is placed by the two-plug cementing method (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The first spacer plug, which is a drillable plug such as a plaster type material, shall then be inserted and the casing capped. A measured volume of grout is pumped in which is a sufficient quantity to grout the casing in place. The casing is then uncapped, the second plug is inserted, and the casing recapped. A measured volume of water slightly less than the volume of the casing shall then be pumped into the casing until the second plug is pushed to the bottom of the casing, expelling the grout from the casing up and <u>into</u> the annular space. The water in the casing shall be maintained constant to prevent backflow until the grout has set. Pressure shall be maintained for a minimum of 24 hours or until such time as a sample of the grout indicates a satisfactory set. Cement grout shall be used for this procedure with a minimum annular space thickness of l½ inches completely surrounding the casing. Concrete grout cannot be used with this method.

(iv) Positive placement - interior method - upper plug - Grout is placed by the upper plug casing method (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). A measured quantity of grout, sufficient to grout the casing in place, shall be pumped into the capped casing. Because this grout is in direct contact with the drilling fluid there will be a narrow zone of weak grout between the drilling fluid and the good grout. The casing is uncapped, and a drillable plug, constructed of plastic or other suitable material is inserted on top of the grout and the casing recapped. A measured volume of water, equal to the volume of the casing, is pumped into the casing, forcing the plug to the bottom of the casing and expelling the grout into the annular space surrounding the casing. Utilizing this method the weak grout zone at the interface of grout and drilling fluid will not be located at the critical position at the bottom of the casing. The water in the casing shall be maintained under pressure to prevent back flow until the grout has set. Pressure shall be maintained for a minimum of 24 hours or until such time as a sample of the grout indicates a satisfactory set. Neat cement or sand-cement grout is used for this procedure, with a minimum annular space opening of l½ inches completely surrounding the casing. Concrete grout cannot be used with this method.

(v) Positive placement - interior method - capped casing Grout is placed by pumping or air pressure injection through the grout pipe installed inside the casing from the casing head to a point 5 feet above the bottom of the casing (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The grout pipe extends airtight, through a sealed cap on the casing head of the well casing. The casing head is equipped with a relief valve and the drop pipe is equipped at the top with a valve permitting injection. The lower end of the drop pipe and the casing is open. Clean water is injected down the grout pipe until it returns through the casing head relief valve. The relief valve is then closed and injection of water is continued until it flows from the bore hole outside of the casing to be grouted in place. This circulation of water is intended to clean the hole and condition it to better take the grout. Without significant interruption, grout is substituted for water and, in a continuous manner, injected down the grout pipe until it returns to the surface outside of the casing. A small amount of water, not to exceed 17 gallons per 100 feet of 2-inch drop pipe may be used to flush the grout pipe, but pressure shall be maintained constant on the inside of the grout pipe and the inside of the casing until the grout has set. Pressure shall be maintained for at least 24 hours, or until such time as a sample of the grout indicates a satisfactory set. Neat cement or sand-cement grout is used for this procedure with a minimum annular space of l½ inches completely surrounding the casing.

(vi) Continuous injection method - Grout is placed by the float shoe continuous injection method (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The bottom of the casing is fitted with a suitable drillable float shoe equipped with a back pressure valve. Tubing or pipe is run to the float shoe to which it is connected by a bayonet fitting, left hand thread coupling, or similar release mechanism. Water or other drilling fluid is circulated through the tubing and up through the annular space outside the casing. when the annular space is clean and open, grout is pumped down the pipe or tubing and forced by continual pumping out into the annular space surrounding the casing. Pumping continues until the entire zone to be grouted is filled. The grout pipe is then detached from the float shoe and raised to the surface for flushing. After the grout has set the float shoe, back pressure valve, and any concrete plug remaining in the bottom of the casing is drilled out. A neat cement or sand-cement grout is used for this procedure with a minimum annular space of 1.5 inches completely surrounding the casing.

(vii) Grout displacement method - The hole is filled with the estimated volume of grout required for the purpose intended. The casing fitted at the bottom with a drillable back pressure valve, metal plate, or similar seal shall be lowered through the grout to the bottom of the hole. If necessary to maintain the bottom of the casing at the bottom of the hole, the casing shall be filled with water, or drilling fluid, and in some cases by applying a load on the bottom with drill pipe. The load is maintained until the grout has set, after which the bottom plug is drilled out and the well deepened. Use of this method is limited to wells not more than 100 feet in depth.

3. Location of grout

(i) Surface formation seal - The annular space to be grouted and surrounding the permanent well casing at the upper terminus of the well, shall be not less than a nominal 2 inches. The length of the grout seal shall be whatever is necessary to prevent the entrance of surface water or undesirable subsurface water into the well. In any circumstance, the length of seal shall not be less than the minimum specified in the state or locally applicable construction code. The entire space to be grouted must be open and available to receive the grout at the time the grouting operation is performed. If a section of larger pipe (conductor pipe) is installed to keep the entire space open (in caving materials), this larger pipe must be removed, as the grout is installed, from the zone where the seal is required. The effective length of grout seal (for sanitary purposes) shall be that distance measured from the deepest limit of the seal up, to the depth of frost penetration. If a pitless adapter or unit is to be installed, the upper limit of the seal shall be one foot below the field connection of the adapter or unit.

(ii) Bottom seal grouting - Grout shall be placed in the annular space surrounding the bottom of the casing by the method specified.

(iii) Selected interval grouting - All zones containing water of unsuitable quality shall be grouted from a point at least 5 feet below, to a point at least 5 feet above the unsuitable zone. The annular space surrounding the casing between grouted zones shall be filled with sand or other suitable granular material.

(iv) Continuous grouting - Grout shall be placed in the annular space surrounding the casing by the method specified. Grouting shall be continuous from the bottom of the permanent casing to the land surface; or, where a filter pack has been installed, from the top of the pack (following development) to the land surface; or, where a well screen only has been installed, from a point 5 feet above the screen to the land surface. When a pitless adapter or unit is to be installed, the grout shall extend from such depth to within one foot of the field connection of the adapter or unit.

4. Guides or centralizers

(i) protective casing must be provided with sufficient guides or centralizers attached or welded to casing to permit unobstructed flow and uniform thickness of grout.

(ii) Guides or centralizers shall be attached to the bottom of the casing and at intervals not greater than 25 feet.

h. Plumbness and alignment requirements:

1. every well shall be tested for plumbness and alignment,

2. test method shall be clearly stated in specifications and shall be in accordance with the latest AWWA A100 standard,

3. test results shall be submitted to the Department prior to permanent pump installation.

i. Geological data shall:

1. be determined from samples collected at 10 foot intervals and at each pronounced change in formation,

2. be recorded and submitted to the Department,

3. be supplemented with information on accurate record of drillhole diameters and depths, assembled order of size and length of casings and liners, grouting depths, formations penetrated, and water levels.

4. be supplemented with complete pumping test data.

j. Upper terminal of well, requirements:

1. protective casing for all ground water sources must project not less than 6 inches, and preferably 12 inches, above pumphouse floor or cover installed,

2. site not subject to flooding must have floor of pumphouse at least one foot above original ground surface,

3. site subject to flooding must have the floor of the pumphouse at least two feet above the highest known flood elevation and be surrounded by earth fill as required by the Department.

k. Capping requirements:

1. properly fitted, firmly driven, solid wooden plug is the minimum acceptable method of capping a well until pumping equipment is installed,

2. a welded metal plate is preferred for capping a well,

3. well must be protected during construction.

l. Bacteriological quality:

1. every new, modified or reconditioned ground water source shall be disinfected upon completion of construction and after placement of final pumping equipment in accordance with AWWA A100 standards,

2. one or more water samples shall be submitted to a state certified laboratory for bacteriological analysis, with the results reported to the Department.

m. Chemical quality:

1. every new, modified or reconditioned ground water source shall be examined for chemical characteristics by tests of a representative sample in a state-certified laboratory with the results reported to the Department,

2. samples shall be collected and tested as soon as practical,

3. determination of pH and C02 shall be made in the field,

4. samples for iron analysis must be acidified,

5. in addition to standard tests, examination shall be made for hydrogen sulfide and methane where these gases are suspected.

n. Water level measurement:

1. provisions shall be made for periodic measurement of static and pumping water levels in completed production wells,

2. installation shall be made in such manner as to prevent entrance of foreign material,

3. reference data shall be stamped on plate affixed to pump base.

o. Well abandonment:

1. test wells and ground water sources which are not in use shall be sealed by such methods as to restore the controlling geological conditions which existed before they were constructed,

2. Wells to be abandoned shall:

(i) be sealed to prevent exchange of water from one geological strata to another, ideally mimicking the existing geological strata through which the well was drilled,

(ii) be filled with clay and sand, clay and concrete, or other suitable impermeable material,

(iii) if filled with concrete the latter shall not be dropped through water.

p. Observation wells:

1. shall be constructed in accordance with the requirements for permanent wells if to remain in service after completion of ground water supply,

2. shall be protected at the upper terminal to preclude entrance of foreign material.

Part 4 - TREATMENT

4.0 GENERAL - The design of treatment processes and devices depends on evaluation of the nature and quality of the particular water to be treated and the desired quality of the finished water. Surface water treatment plants must provide treatment for cryptosporidium, giardia, bacteria and viruses in accordance with the requirements of Division of Water Resources surface water treatment rules. Surface water treatment plants must provide for taste and odor control if there is any history or potential of taste and odor problems/complaints. Surface water treatment plants must be designed for control and reduction of disinfection by-products and their precursors.

4.1 CLARIFICATION - Plants designed for processing surface waters should:

a. provide duplicate units for flocculation and sedimentation,

b. be constructed to permit units to be taken out of service without disrupting operation.

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

a. Basin Design - Pre-sedimentation basins should be designed to hold maximum 3-day usage.

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

c. Bypass - Provisions for bypassing pre-sedimentation basins shall be included.

4.1.2 Mixing (Flash or Quick):

a. Equipment - Basins should be equipped with mechanical mixing devices; other arrangements, such as baffling, and in-line mixers may be acceptable.

b. Mixing - The detention period shall not exceed 30 seconds. Concrete blocks may be placed in the flash mix temporarily to maintain this detention period if the plant is expected to be expanded in the near future.

c. Velocity gradient - The minimum shall be 300 (ft/sec)/ft.

4.1.3 Flocculation (Slow Mixing):

a. Basin Design - Inlet and outlet design shall prevent short circuiting and destruction of floc. A drain shall be provided.

b. Detention - The detention time for floc formation must be at least 30 minutes, with a detention time of 45 minutes being recommended.

c. Equipment - Agitators shall be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 to 2.0 ft/sec. The speed of each successive agitator should be less than the previous one.

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

12. depth of filter media shall be the same as for gravity filters.

4.3 PACKAGE TREATMENT PLANTS, MEMBRANES AND OTHER TECHNOLOGIES - Will be reviewed on a case-by-case basis based on demonstrated performance criteria.

4.3.1 Package Treatment Plants – may be acceptable for source waters that are generally low in turbidity and do not experience large or frequent turbidity spikes. Filter backwash and clarifier flush/rinse frequencies along with water production efficiency must be considered for each application. Adequate detention times must be evaluated for oxidation processes, coagulation, TOC reduction and taste & odor control.

4.3.2 Membrane Filtration – is generally acceptable for turbidity/particulate removal. Each membrane module must have a continuous filtrate turbidity monitor and provisions for direct integrity testing. Other treatment processes such as coagulation, flocculation and oxidation must be used in conjunction with membranes where dissolved constituents such as TOC, iron and manganese are present in sufficient quantities to require treatment/removal. Clarification/sedimentation should be provided prior to membrane filtration where turbidity and suspended solids are very high in the raw water.

4.3.3 Cartridge and Bag Filters – will be considered for approval on a case-by-case basis depending on raw water quality and the size of the water system.

4.4 DISINFECTION - Chlorine is the preferred disinfecting agent. Other agents will be considered by the Department, provided reliable feeding equipment is available and testing procedures for a residual are recognized in "Standard Methods for the Examination of Water and Wastewater," latest edition. Continuous disinfection is recommended for all water supplies and is required at all community public water systems serving more than 50 connections or 150 persons.

4.4.1 Equipment

a. Type - Solution feed gas type chlorinator and hypochlorite feeders of the positive displacement type are acceptable (see Part 5). Alternative chlorine feeders such as tablet chlorinators may be considered for some applications.

b. Capacity - The chlorinator capacity shall be such that a free chlorine residual of at least 2 mg/L can be attained in the water after a contact time of at least 30 minutes when maximum flow rates coincide with anticipated maximum chlorine demands. The equipment shall be of such design that it will operate accurately over the desired feeding range.

c. Dual Chlorination - Two chlorinator shall be provided and operated simultaneously such that each feeds approximately half the chlorine requirement.

d. Spare Parts - Spare parts shall be provided so that either unit could be equipped to supply the entire chlorine requirement.

e. Automatic Switchover - Automatic switchover of chlorine cylinders should be provided where necessary to assure continuous disinfection. This does not take the place of having dual chlorination.

f. Automatic Proportioning - Automatic proportioning chlorinator will be required where the rate of flow either is not reasonably constant or where the quality of the water is subject to rapid changes.

4.4.2 Contact Time and Point of Application

a. Due consideration shall be given to the contact time of the chlorine in water with relation to pH, ammonia, taste producing substances, temperature, bacterial quality, trihalomethanes formation potential and other pertinent factors. Chlorine should be applied at a point which will provide adequate contact time. All basins used for disinfection must be designed to minimize short-circuiting.

b. At plants treating surface water, provisions should be made for applying chlorine to the raw water, top of filters, and filtered water.

c. At plants treating groundwater, provision should be made for applying chlorine to the clearwell inlet and the high lift pump suction.

d. Free residual (breakpoint) chlorination is required; 30 minutes contact time should be provided for ground waters and 2 hours for surface waters.

4.4.3 Chlorinator Piping

a. The water supply piping shall be designed to prevent contamination of the treated water supply by source of questionable quality.

b. Pipe material - The pipes carrying elemental liquid or dry gaseous chlorine under pressure and liquid chlorine must be schedule 80 seamless steel tubing or other materials recommended by the Chlorine Institute (never use PVC). Rubber, PVC, polyethylene, or other materials recommended by the Chlorine Institute must be used for chlorine solution piping and fittings. Nylon products are not acceptable for any part of the chlorine solution piping system.

c. Backflow Protection - All chlorine solution lines feeding into water having less than a full cycle of treatment (ahead of filters) shall be vented to the outside atmosphere. This venting shall be provided in such a manner that backflow into treated waters is prevented. Vacuum breakers and other mechanical devices shall not be substituted for a vent. Vents for chlorine lines shall:

    1. be the same size as the solution line piping,

    2. be connected to the solution line at a point where it is elevated a minimum of 6 feet above the maximum water level in the receiving basin,

    3. have no shut off valves,

    4. be extended to a high enough elevation outside the building that overflow from the vent tube during surges is prevented,

    5. have a nylon or other suitable insert screen covering the vent which has been turned downward near its end,

    6. not be subject to back pressures.

d. Distribution Panels - The Department recommends the use of chlorine solution distribution panels to ease the change of chlorine solution application points or the change of chlorine feed equipment. If a distribution panel is installed all chlorine solution lines except those feeding into the clear well or filter effluent must be vented as specified in section 4.4.3c. This venting is to be located between the distribution panel discharge and the point of application. Where chlorine solution from one chlorine feed unit is to be split to feed at more than one application point, a suitable rotameter shall be installed to allow accurate proportioning of the total flow among the application points.

4.4.4 Housing - Adequate housing must be provided for the chlorination equipment and for storing the chlorine supply (See Section 5.3).

4.4.5 Chlorine Dioxide – may be used for oxidation, disinfection and/or treatment of tastes and odors. Chlorine dioxide may be considered in conjunction with other treatment processes for meeting surface water treatment requirements or as an alternative to raw water chlorination where disinfection by-products must be reduced. Water systems that add chlorine dioxide must monitor for chlorine dioxide residual and chlorite.

4.4.6 UV Light - may be used for disinfection at water treatment plants in conjunction with chlorination and other treatment processes to meet surface water treatment requirements. UV light may also be used at groundwater treatment plants. Water systems using UV light must also provide chlorination for residual disinfection.

4.4.7 Ozone – may be used at water treatment plants for oxidation, disinfection, and meeting surface water treatment requirements. Water systems using ozone must monitor for bromate.

4.4.8 Hydrogen Peroxide – may be used at water treatment plants for raw water oxidation and/or disinfection. Hydrogen peroxide may be used to replace raw water chlorination where disinfection by-products must be reduced.

4.4.9 Permanganates – potassium permanganate or sodium permanganate may be used for raw water oxidation and/or disinfection. Permanganates may be used to replace raw water chlorination where disinfection by-products must be reduced.

4.4.10 Chloramines – will be considered for use in water distribution systems if other methods to reduce disinfection by-products have failed to achieve compliance. Effects of chloramination on water chemistry, corrosivity and microbiological water quality must be evaluated.

4. 5 SOFTENING - In all but a very few locations in Tennessee softening of available raw water is not needed. Unless there is a demonstrated need, softening should be avoided because of the additional expense and because of the increased sodium content of the water when ion exchange softening is used.

4.5.1 Lime-Soda Process - The applicable design standards for mixing, flocculation and sedimentation are the same for the lime-soda process as for conventional clarification. Where softening is included as a treatment process in conjunction with clarification, the clarification criteria shall govern(see sections 4.1.2, 4.1.3 and 4.1.4). For criteria pertaining to softening with solids contact units see section 4.1.5.

a. Aeration - Determinations should be made for the C02 content of the raw water. When concentrations exceed 10 mg/L, the economics of removal by aeration as opposed to removal with lime should be considered (See Section 4.6).

b. Stabilization - Equipment for stabilization of water softened by the lime-soda process is required.

c. Sludge Collection - Mechanical sludge removal equipment shall be provided in the sedimentation basin (see section 4.11 for sludge disposal).

d. Sludge Disposal - Provisions must be included for proper disposal of softening sludges(See Section 4.11).

e. Disinfection - The use of excess lime shall not be considered an acceptable substitution for chlorination or any other approved method of disinfection (See Section 4.4).

4.5.2 Cation Exchange Process - Iron, manganese, or a combination of the two, in the oxidized state or unoxidized state, should not exceed 0.3 mg/L in the water as applied to the ion exchange resin. Pretreatment is required when the content of iron, manganese, or a combination of the two, is 1 mg/L or more.

a. Design - The units may be of pressure or gravity type, using automatic or manual regeneration. Automatic regeneration is suggested for small plants.

b. Exchange Capacity - The design capacity for hardness removal should not exceed 20,000 grains per cubic foot when resin is regenerated with 0.3 pounds of salt per kilogram of hardness removed..

c. Depth of Media - The depth of the exchange material should not be less than 3 feet.

d. Flow Rates - the rate of softening should not exceed 7 gallons per square foot per minute and the backwash rate should be 6 to 8 gallons per square foot per minute. Rate-of-flow controllers or the equivalent must be installed for the above purposes.

e. Freeboard - The freeboard will depend upon the specific gravity of the media. Generally, the washwater collector should be 24 inches above the top of the media.

f. Underdrains and Supporting Gravel - The bottoms strainer systems, and support for the exchange material shall conform to criteria provided for rapid rate gravity filters (See Sections 4.2.lg and 4.2.1h).

g. Brine Distribution - Facilities should be included for even distribution of the brine over the entire surface.

h. Cross Connection Control - Backwash, rinse and air relief discharge pipes should be installed in such a manner as to prevent any possibility of back-siphonage.

i. Bypass - A bypass shall be provided around softening units to produce a blended water of desirable hardness. Meters should be installed on the bypass line and on each softener unit. An automatic proportioning or regulating device and shut-off valve should be provided on the bypass line. In some installations it may be necessary to treat the bypassed water to obtain acceptable levels of iron and/or manganese in the finished water.

j. Additional Limitations - Waters having 1.0 units or more turbidity should not be applied directly to the cation exchange softener. Silica gel materials should not be used for waters having a pH above 8.4 or containing less than 6 mg/L silica and should not be used when iron is present. The cation exchange material shall be a type that is not damaged by residual chlorine. Phenolic resin should not be used.

k. Sampling Taps - Smooth-nose sampling taps must be provided for the collection of representative samples for both bacteriological and chemical analyses. The taps shall be located to provide for sampling of the softener influent, softener effluent, and the blended water. The sampling taps for the blended water shall be at least 20 feet downstream from the point of blending. Petcocks are not acceptable as sampling taps. Sampling taps should be provided on the brine tank discharge piping.

1. Brine and Salt Storage Tanks

1. Salt dissolving or brine tanks and wet storage tanks must be covered and must be corrosion resistant.

2. The make-up water inlet must be protected from back siphonage. Water for filling the tank should be distributed over the entire surface by pipes above the maximum brine level in the tank. The tanks should be provided with an automatic declining level control system on the make-up water line.

3. Wet salt storage basins must be equipped with manholes or hatchways for access and for direct dumping of salt from truck or railcar. Openings must be provided with raised curbs and watertight covers having overlapping edges similar to those required for finished water reservoirs.

4. Overflows, where provided, must be turned down, have a proper free fall discharge and be protected with corrosion resistant screens or self-closing flap valves.

5. Two wet salt storage tanks or compartments designed to operate independently should be provided.

6. The salt is to be supported on graduated layers of gravel under which is a suitable means of collecting the brine.

7. Alternative designs which are conducive to frequent cleaning of the wet salt storage tank may be considered.

m. Storage Capacity - Salt storage basins should have sufficient capacity to store in excess of l-1/2 carloads or truckloads of salt, and to provide for at least 30 days of operation.

n. Stabilization - Stabilization for corrosion control shall be provided (See Section 4.9).

o. Waste Disposal - Suitable disposal must be provided for brine waste (See Section 4.11).

p. Construction Material - Pipes and contact materials must be resistant to the aggressiveness of salt. Plastic and red brass are acceptable piping material. Steel and concrete must be coated with a non-leaching protective coating which is compatible with salt and brine.

q. Housing - Salt Storage tanks and feed equipment should be enclosed and separated from other operating areas in order to prevent damage to equipment.

4.6 AERATION - Aeration treatment devices as described herein may be used for oxidation, separation of gases or for taste and odor control.

4.6.1 Natural Draft Aeration - Design should provide that:

a. water is distributed uniformly over the top tray,

b. water is discharged through a series of three or more trays with separation of trays not less than 12 inches,

c. trays are loaded at a maximum rate of 20 gpm for each square foot of the top tray area,

d. trays have heavy wire mesh or perforated bottoms,

e. perforations are 3/16 to 1/2 inches in diameter, spaced 1 to 3 inches on centers, when perforations are used,

f. 8 to 12 inches of inert media are used, such as coke or limestone, that will not disintegrate due to freezing cycles,

g. aerated water receives disinfection treatment,

h. sufficient trays to reduce carbon dioxide to 10-15 mg/L,

i. location to take advantage of prevailing wind direction.

4.6.2 Forced or Induced Draft Aeration - Devices shall be designed to:

a. provide adequate countercurrent of air through enclosed aeration column,

b. be insect proof and lightproof,

c. be such that air introduced into column shall be screened through insect tight screen and be as free of dust as possible,

d. insure that water outlet is adequately sealed to prevent unwanted loss of air,

e. be such that sections of the aerator can be easily reached and removed for maintenance.

4.6.3 Other Methods of Aeration - Other methods of aeration may be used if applicable to the treatment needs. Such methods include but are not restricted to spraying, diffused air and mechanical aeration. The treatment processes must be designed to meet the particular needs of the water to be treated and are subject to the approval of the Department.

4.6.4 Wind Protection - Aerators that discharge through the atmosphere should be protected by being placed in a louvered enclosure so designed as to provide easy access to the interior.

4.6.5 Protection from Contamination - Aerators that are used for oxidation or removal of dissolved gases from waters that will be given no further treatment other than chlorination shall be protected from contamination from insects and birds.

4.6.6 Bypass - A bypass shall be provided for all aeration units.

4.6.7 Corrosion Control - The aggressiveness of the water after aeration should be determined and corrected by additional treatment, if necessary (See Section 4.9).

4. 7 <u>IRON AND MANGANESE CONTROL</u> - Iron and manganese control, as used herein, refers solely to treatment processes designed specifically for this purpose. The treatment process used will depend upon the character of the raw water. The selection of one or more treatment processes must meet specific local conditions as determined by engineering investigations, including chemical analysis of representative samples of water to be treated, and receive the approval of the Department. It may be necessary to operate a pilot plant in order to gather all information pertinent to the design.

4.7.1 Removal by Oxidation, Detention and Filtration.

a. Oxidation - Oxidation may be by aeration, as indicated in Section 4.6, or by chemical oxidation with chlorine or potassium permanganate.

b. Detention - A minimum detention of 20 minutes shall be provided following oxidation by aeration in order to insure that the oxidation reactions are as complete as possible. The detention basin shall be designed as a holding tank with no provisions for sludge collection but with sufficient baffling to prevent short circuits. Sedimentation basins should be provided when treating water with high iron and/or manganese content or where chemical coagulation is used to reduce the load on the filters.

c. Filtration - Filters shall conform to Section 4.2, except nominal rate shall not exceed 3 gpm/ft2 of filter area.

4.7.2 Removal by Lime-Soda Process - See Section 4.5.1.

4.7.3 Removal by Units Using Continuous Potassium Permanganate "Regeneration" - This process, consisting of a continuous feed of potassium permanganate to the influent of a manganese green-sand filter, is more applicable to the removal of manganese than to the removal of iron, due to economic considerations. The following apply:

a. The permanganate should be applied as far ahead of the filter as practical.

b. other oxidizing agents or processes such as chlorination or aeration may be used prior to the permanganate feed to reduce the cost of the chemical.

c. Anthracite media cap of at least six inches shall be provided over manganese treated greensand.

d. Normal filtration rate is 3 gpm/ft2.

e. Normal wash rate is 8 to 10 gpm/ft2.

f. Air washing should be provided.

g. Sample taps should be provided:

1. prior to application of permanganate,

2. immediately ahead of filtration,

3. at point between anthracite coal media and the manganese treated greensand,

4. halfway down the manganese treated greensand,

5. at the filter effluent.

4.7.4 Sequestration by polyphosphates - This process is only suitable only for concentrations of iron and manganese that are below the respective MCL's. The dosage should not exceed 10 mg/L. Where phosphate treatment is used, satisfactory chlorine residuals should be maintained in the distribution system.

a. Feeding equipment shall conform to requirements of Part 5.

b. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 mg/L chlorine residual.

c. The point of application should be prior to any aeration or oxidation if no iron or manganese removal treatment is provided.

d. Phosphate chemicals must be food grade and meet or exceed AWWA Specifications.

4.7.5 Sampling Equipment - Smooth-nosed sampling taps shall be provided for control purposes. Taps shall be located on each raw water source, each treatment unit influent and each treatment unit effluent.

4.7.6 Testing Equipment - Testing equipment shall be provided for all plants. The equipment should have the capacity to accurately measure the iron content to a minimum of 0.1 mg/L and the manganese content to 0.05 mg/L.

4.8 FLUORIDATION - Commercial sodium fluoride, sodium silicofluoride and hydrofluosilicic acid shall conform to the applicable AWWA Standards. Other chemicals which may be made available must be approved by the Department.

4.8.1 Fluoride Compound Storage - Compounds shall be stored in covered or unopened shipping containers. Bulk storage units and day tanks, including carboys and drums in use for hydrofluosilicic acid, shall be vented to the atmosphere at a point outside any building.

4.8.2 Dry Conveyers - Provision must be made for the proper transfer of dry fluoride compounds from shipping containers to storage bins or hoppers, in such a way as to minimize the quantity of fluoride dust.

4.8.3 Chemical Feed Installations

a. shall conform to Part 5,

b. shall provide scales or loss-of-weight recorders for dry or acid chemical feeds. Dry volumetric feeders are to have percent-of-cycle timer or variable speed SCR drive. A minimum of 35-gallon dissolver with mechanical agitation,

c. shall have an accuracy that actual feed will be within 5% of that intended,

d. shall be such that the point of application of hydrofluosilicic acid, if into a pipe, shall be in the lower third of the pipe and project upward,

e. downflow saturators are not acceptable,

f. shall provide adequate anti-siphon devices for all fluoride feed lines,

g. piping from bulk storage to day tank should be schedule 80 PVC.

4.8.4 Protective Equipment - Suitable protective equipment shall be provided.

4.8.5 Dust Control Equipment - Suitable equipment shall be provided for wet-mopping and hosing dust that might accumulate in the plant.

4.8.6 Testing Equipment - Equipment shall be provided for measuring the quantity of fluoride ion in the water. Such equipment shall be subject to the approval of the Department.

4.9 CORROSION CONTROL - corrosion is caused by a reaction between the pipe material and the water in direct contact with each other. Consequently, there are three basic approaches to corrosion control:

a. Using pipe materials and designing the system so it is not corroded by a given water,

b. Modifying the water quality so it is not corrosive to the pipe material,

c. Placing a protective barrier or lining between the water and the pipe.

4.9.1 System design

   a. Choose compatible materials throughout system where possible to avoid forming galvanic cells,

   b. Avoid dead ends and stagnant areas,

   c. Reduce mechanical stress, sharp turns and elbows,

   d. Provide adequate insulation and avoid uneven heat distribution,

   e. Eliminate grounding of electrical circuits to system.

4.9.2 Cathodic Protection - Metal tanks and reservoirs should be considered for protection from corrosion by this method.

4.9.3 Modification of Water Quality

   a. pH adjustment by addition of lime, caustic soda or soda ash, in order to stabilize the water with regard to calcium carbonate.

   b. Control of oxygen. Advantages of aeration for iron, H2S Or C02 removal should be balanced against the fact that dissolved oxygen is a corrosive agent.

4.9.4 Use of inhibitors. These may be used as appropriate.

   a. Addition of lime or alkalinity increases the tendency of water to deposit CaCO3 forming a protective coating inside of pipe.

   b. Inorganic phosphorus. Care is needed to select a chemical which not only masks the symptoms, but also reduces corrosion. (Sodium hexametaphosphate in low dosages of 2-4 mg/L <u>only</u> masks the symptoms while corrosion continues). Recent developments indicate the addition of zinc with a phosphate is effective in both inhibiting corrosion and controlling red water.

   c. Sodium silicate. Effective in water with low hardness, alkalinity and pH less than 8.4 under relatively high velocity conditions.

4.9.5 Coatings and linings - Metal distribution system components' surfaces in contact with water shall be protected by being coated or lined.

   a. Pipe linings include coal tar enamels, epoxy paint, and cement mortar.

   b. Storage tanks are protected by such coatings as coal tar enamels, paints, vinyls, and epoxy.

4.10 <u>TASTE AND ODOR CONTROL</u>

4.10.1 Chlorination - Chlorination can be used for the removal of some objectionable odors. Adequate contact time must be provided to complete the chemical reactions involved.

4.10.2 Chlorine Dioxide - Chlorine dioxide has been generally recognized as a treatment for tastes caused by industrial wastes, such as phenols; however, chlorine dioxide can be used in the treatment of any taste or odor that is treatable by an oxidizing compound. Provision shall be made for proper storing and handling of sodium chlorite, so as to eliminate any danger of explosion (See Part 5).

4.10.3 Powdered Activated Carbon

a. Powdered activated carbon may be added prior to coagulation to provide maximum contact time, although facilities to allow the addition at several points is preferred, but not near the point of chlorine application.

b. The carbon can be added as a pre-mixed slurry or by means of a dry-feed machine as long as the carbon is properly "wetted".

c. Agitation is necessary to keep the carbon from depositing in the mixing chamber.

d. Provision shall be made for adequate dust control.

e. The required dosage of carbon in a water treatment plant depends upon the tastes and/or odors involved, but provision shall be made for adding 0 mg/L to at least 40 mg/L.

f. Powdered activated carbon shall be handled as a potentially combustible material. It should be stored in a building or compartment as nearly fireproof as possible. Other chemicals should not be stored in the same compartment. Carbon feeder rooms should be equipped with explosion-proof electrical outlets, lights and motors.

4.10.4 Granular Activated Carbon Adsorption Units - Granular activated carbon units shall not be used in place of filters described in Section 4.2. Rates of flow shall be consistent with the type and intensity of the problem. The design used must be supported by the results of pilot plant studies when granular activated carbon units are used for organic removal.

4.10.5 Copper Sulfate and Other Copper Compounds - Continuous or periodic treatment of water with copper compounds to kill algae or other growths shall be controlled to prevent copper in excess of 1.0 mg/L as copper in the plant effluent or distribution system. Care shall be taken in obtaining a uniform distribution:

a. if alkalinity is less than 50 mg/L, dose at 0.9 lb/acre foot,

b. if alkalinity is greater than 50 mg/L, dose at 5.4 lb/acre foot.

4.10.6 Aeration - See Section 4.6.

4.10.7 Potassium Permanganate - Application of potassium permanganate may be considered provided the point of application is prior to filtration.

4.10.8 Ozone - Ozonation can be used as a means of taste and odor control. Adequate contact time must be provided to complete the chemical reactions involved. Ozone is generally more desirable for treating water with high threshold odors.

4.10.9 Other Methods - The decision to use any other methods of taste and odor control should be made only after careful laboratory tests and on consultation with the Department.

4.10.10 Flexibility - Plants treating water that is known to have taste and odor problems should be provided with equipment that makes several of the control processes available so that the operator will have flexibility in operation.

4.11 WASTE DISPOSAL - Provisions must be made for proper disposal of water treatment plant waste such as sanitary, laboratory, clarification, softening and ion sludges, filter backwash, and brines. The quantity of waste produced in water treatment shall be minimized by choice of treatment processes and chemicals. If supernatant water from backwash/sludge holding tanks or lagoons is to be recycled through the treatment plant, potential impacts on the treatment process must be considered. Recycled water must be returned to the head of the treatment plant or to an alternate location approved by the Division of Water Supply. Recycled water should be settled/clarified to reduce contaminants that may be concentrated in sludges and backwash water.

4.11.1 Waste Water and Sludge - The following means of waste and sludge disposal may be considered:

a. Lagoons - Design should provide:

1. location free from flooding,

2. when necessary, dikes, deflecting gutters, or other means of diverting surface water,

3. a minimum usable depth of 4 to 5 feet with adequate freeboard,

4. 3 to 5 years solids storage volume,

5. multiple cells,

6. adjustable decanting devices,

7. convenient cleaning,

8. effluent sampling point,

9. adequate safety provisions.

b. Sludge Beds - Beds for lime softening sludges should provide for an application of slurry of at least 12 inches. Multiple beds should be provided so designed as to permit a minimum of one year's total storage. The storage capacity should be based on assumption that for each part per million of hardness removed there will be two parts per million of dry solids, and the accumulated sludge density being 120 pounds per cubic foot. Distribution channels are required for spreading sludge over the entire area. Provisions must be made for easy access and for paved loading ramps and underdrains. See Section 4.11.1.1 for provisions on flooding and surface water diversion.

c. Disposal to Sanitary Sewer System

1. Approval must be obtained from sewer system officials.

2. Consideration shall be given to the effects the water plant waste will have at the sewer plant including:

i. effect on the sewage treatment process,

ii. additional sludge to be handled.

3. Consideration shall be given to the effects of disposal into the sewage collection system. A schedule for disposal shall be determined in conjunction with sewer system officials.

d. other methods - These include holding tanks, vacuum filters, centrifuging, and recalcining. Detailed studies should be made to justify their use.

4.11.2 Sanitary Waste - The sanitary waste from water treatment plants, pumping stations, etc., must receive treatment. Waste from these facilities must be discharged either directly to a sanitary sewer system or to an individual waste disposal facility providing suitable treatment.

Part 5 - CHEMICAL APPLICATION

5.0 GENERAL - Plans and specifications describing water treatment plants (new, modified or expanded) shall include the chemicals and chemical feed equipment to be used in the treatment process.

5.0.1 These plans and specifications shall include:

a. descriptions of feed equipment, including maximum and minimum feed ranges,

b. location of feeders, piping layout and points of application,

c. storage and handling facilities,

d. specifications for chemicals to be used,

e. operating and control procedures,

f. descriptions of testing equipment and procedures.

5.0.2 Chemical shall be applied to the water at such points and by such means as to:

a. provide maximum flexibility of operation through various points of application, when appropriate, and

b. prevent backflow at all points of feed.

5.1 FEED EQUIPMENT

5.1.1 Number of Feeders

a. Where chemical feed is essential to the production of safe drinking water or necessary for continuous operation

1. a minimum of two feeders shall be provided,

2. a standby unit or combination of units of sufficient capacity should be available to replace the largest unit during shut-downs.

b. Spare parts shall be available for all feeders to replace parts which are subject to wear and damage.

5.1.2 Design and Capacity - Design and capacity shall be such that:

a. feeders will be able to supply, at all times, the necessary amounts of chemical at an accurate rate, throughout the range of feed;

b. feeders are adjustable to handle all plant flow rates;

c positive displacement type solution feed pumps shall be used to feed liquid chemicals, and shall not be used to feed chemical slurries;

d. chemical solutions cannot be siphoned into the water supply;

e. service water supply cannot be contaminated by chemical solutions by:

1. equipping the supply line with backflow prevention devices (see Section 5.l.8.c), or

2. providing an air gap between supply line and solution tank.

f. chemical-contact materials and surfaces are resistant to the aggressiveness of the chemical solution;

g. dry chemical feeders will:

1. measure chemicals volumetrically or gravimetrically,

2. provide effective solution of the chemical in the solution pot,

3. provide gravity feed from solution pots, in open troughs when feasible,

4. completely enclose chemicals to prevent emission of dust to any of the operating areas (see Section 5.2.3d).

h. no direct connection exists between any sewer and a drain or overflow from the feeder or solution chamber or tank.

5.1.3 Location - chemical feed equipment

a. shall be conveniently located near points of application to minimize length of feed lines;

b. shall be readily accessible for

1. servicing, repair and calibration, and

2. observation of operation;

c. shall be located and protective curbing provided, so that chemicals from equipment failure, spillage or accidental drainage shall not enter the water through conduits, treatment or storage basins, or result in hazardous discharge.

5.1.4 Control

a. Feeders may be manually or automatically controlled, with automatic control reverting to manual control as necessary.

b. Process must be manually started following shutdown, unless otherwise approved by the Department.

c. Feed rates proportional to flow must be provided.

d. Automatic chemical dose or residual analyzers may be approved for use and must provide

1. alarms for critical values, and

2. recording charts.

5.1.5 Solution Tanks

a. Means shall be provided in a solution tank to maintain uniform strength of solution, consistent with the nature of the chemical solution; continuous agitation is necessary to maintain slurries in suspension.

b. Two solution tanks may be required for a chemical, of specific capacity, to assure continuity of supply in servicing a solution tank.

c. Each tank shall be provided with a drain;

   1. No direct connection between any tank or drain and a sewer shall be permitted, and

   2. Any drain must terminate at least two pipe diameters above the overflow rim of a receiving sump, conduit or waste receptacle.

d. Means shall be provided to indicate the solution level in the tank.

e. Make-up water shall enter the tank from above the maximum solution level, providing an air gap of two pipe diameters but not less than six inches, or shall be protected with an approved backflow prevention devices (see Section 5.1.8.c).

f. Chemical solutions shall be kept covered. Large tanks with access openings shall have such openings curbed and fitted with tight covers.

g. Subsurface locations for solution tanks shall:

   1. be free from sources of possible contamination.

   2. assure positive drainage for ground waters, accumulated water, chemical spills and overflows.

h. Overflow pipes, when provided, should:

   1. be turned downward, with end screened.

   2. have free discharge, and

   3. be located where noticeable.

5.1.6 Weighing Scales

a. shall be provided for weighing cylinders, at all plants utilizing chlorine gas; for large plants, indicating and recording type are desirable;

b. shall be provided to measure the amount of fluoride fed with the exception of the use of a saturator, which shall have a water meter;

c. should be provided for volumetric dry chemical feeders;

d. should be accurate to measure increments of 0.5% of load;

5.1.7 Feed Lines

a. should be as short as possible in length of run, and

1. of durable, corrosion-resistant material,

2. easily accessible throughout entire length,

3. protected against freezing,

4. easily cleaned,

5. lime feed lines should be designed so they can be readily replaced, and

6. avoiding sharp bends when possible.

b. should slope upward from chemical source to feeder, when conveying gases;

c. should introduce corrosive chemicals in such manner as to minimize potential for corrosion;

d. shall be designed consistent with scale-forming or solids depositing properties of the water, chemical, solution or mixture conveyed;

e. shall not carry chlorine gas beyond chlorine storage and feeder room(s) except under vacuum;

f. should be color coded.

5.1.8 Service Water Supply

a. Water used for dissolving dry chemicals, diluting liquid chemicals or operating chemical feeders shall be:

1. only from a safe, approved source,

2. protected from contamination by appropriate means (see Section 5.1.8c),

3. ample in supply and adequate in pressure,

4. provided with means for measurement when preparing specific solution concentrations by dilution,

5. properly treated for hardness, when necessary.

b. Where a booster pump is required, duplicate equipment should be provided and, when necessary, standby power.

c. Back-flow prevention shall be achieved by appropriate means such as:

1. an air gap between fill pipe and maximum flow line of solution or dissolving tank equivalent to 2 pipe diameters but not less than 6 inches, or

2. an approved reduced pressure backflow preventer, consistent with the degree of hazard, aggressiveness of chemical solution, back pressure sustained, and available means for maintaining and testing the device, or

3. a satisfactory vacuum relief device.

5.2 CHEMICALS

5.2.1 Quality

a. Chemical containers shall be fully labeled to include:

   1. chemical name, purity and concentration,

   2. supplier name and address, and

   3. expiration date where applicable.

b. Chemicals shall be listed under ANSI/NSF Standard 60(or equivalent) and meet American Water Works Association specifications, where applicable.

c. Provisions should be made for assay of chemicals delivered.

d. Chemicals shall not impart any toxic material to the water under recommended dosages.

5.2.2 Storage

a. Space should be provided for:

   1. at least 30 days of chemical supply,

   2. convenient and efficient handling,

   3. dry storage conditions,

   4. a minimum of 1-1/2 truck loads storage volume where purchase is by truck load lots,

   5. protection against excessive, damaging or dangerous extremes in temperature.

b. Cylinders of chlorine shall be:

   1. isolated from operating areas,

   2. restrained in position to prevent upset,

   3. stored inside for sufficient time before being connected to chlorinator that temperature has been approximately equalized,

   4. provided shade from direct sun and given physical security if stored outside of building.

c. Liquid chemical storage tanks must:

   1. have a liquid level indicator,

   2. have an overflow and a receiving basin or drain capable of receiving accidental spills or overflows,

   3. provide for protection against freezing and/or loss from solution due to temperature drop.

d. Special precautions must be taken with:

1. sodium chlorite, to eliminate any danger of explosion;

2. activated carbon, which is a potentially combustible material, requiring isolated, fireproof storage and explosion-proof electrical outlets, lights and motors in areas of dry handling.

3. calcium hypochlorite and potassium permanganate, which may ignite spontaneously on contact with combustible substances;

4. hydrofluosilicic acid, which is extremely corrosive. Fumes or spillage may damage equipment or structures.

5. liquid caustic (50% sodium hydroxide solution) which is hazardous and may be lost from solution at low temperature.

6. gaseous chlorine (see Sections 5.3.4-5.4).

7. on-site generation of sodium hypochlorite. Provisions must be included for dilution and venting of potentially explosive hydrogen gas.

e. Chemicals shall be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved covered storage unit.

f. Solution storage or day tanks supplying feeders directly should have sufficient capacity for one day of operation.

g. Acid storage tanks must be vented to the outside atmosphere, but not through vents in common with day tanks.

5.2.3 Handling

a. Provisions shall be made for

1. measuring quantities of chemicals used to prepare feed solutions, and

2. for easy calibration of solution pumps measured from the suction side.

b. Storage tanks and pipelines for liquid chemicals shall be specific to the chemicals and not for alternates.

c. Chemicals that are incompatible shall not be fed, stored or handled together.

d. Provisions must be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers, in such a way as to minimize the quantity of dust which may enter the room in which the equipment is installed; control should be provided by use of:

1. vacuum pneumatic equipment or closed conveyer systems, or

2. facilities for emptying shipping containers in special enclosures, or

3. exhaust fans and dust filters which put the hoppers or bins under negative pressure.

e. Precautions shall be taken with electrical equipment to prevent explosions, particularly in the use of sodium chlorite and activated carbon.

f. Acids shall:

1. be kept in closed, acid-resistant shipping containers or storage units;

2. not be handled in open vessels, but should be pumped in undiluted form from original containers, through suitable hose, to the point of treatment or to a covered day tank.

g. Carts, elevators and other appropriate means shall be provided for lifting chemical containers to minimize excessive lifting by operators.

h. Provisions shall be made for disposing of empty bags, drums or barrels, by approved procedures which will minimize exposure to dusts.

5.3 <u>HOUSING</u>

5.3.1 Structures, rooms and areas accommodating chemical feed equipment shall provide convenient access for

a. servicing and repair,

b. observation of operation.

5.3.2 Floor surfaces shall be smooth and impervious, slip-proof and well-drained with 2.5% slope, minimum.

5.3.3 open basins, tanks and conduits shall be protected from chemical spills or accidental drainage.

5.3.4 Chlorine gas feed and storage shall be:

a. enclosed and separated from other operating areas in order to prevent injury to personnel and damage to equipment; separate chlorine feed and storage rooms may be required for large installations;

b. provided with an inspection window to permit viewing of the interior of the room and the equipment;

c. provided with doors opening outward with a crash bar, assuring ready means of exit; doors opening to the building exterior only shall be provided.

d. provided with locks to prevent general public access.

5.3.5 Where chlorine gas is used, ventilation for each room shall be provided for one complete air change per minute; and

a. The air outlet from the room shall be near the floor and the point of discharge shall be so located as not to contaminate air inlets to any rooms or structures, or adversely affect the surrounding environment;

b. air inlets shall be through louvers near the ceiling, and temperature controlled to prevent adverse affect on chlorinator;

c. switches for fans and lights shall be outside of the room, at the entrance; signal light indicating fan operation shall be provided at each entrance when fan can be controlled from more than one point;

d. vents from feeders and storage shall discharge to the outside atmosphere, above grade.

5.3.6 Chlorinator rooms should be heated to 60 degrees F, but should be protected from excess heat; cylinders and gas lines should be protected from temperatures above that of the feed equipment.

5.3.7 Gaseous feed chlorine installations shall be equipped with a gas detection device connected to an audible alarm to prevent undetected, potentially dangerous leakage of chlorine gas.

5.4 OPERATOR SAFETY

a. Gases from feeders, storage and equipment exhausts shall be conveyed to the outside atmosphere, above grade and remote from air intakes.

b. Special provisions shall be made for ventilation of chlorine feed and storage rooms (see Section 5.3.5).

c. A M-S-A air mask, Model 401, Catalog No. 01-95066 or equal, complete with storage cabinet and 30 minute air cylinder shall be provided along with a 30 minute backup cylinder to prevent loss of utility while the primary air cylinder is being refilled or tested. The air mask shall be cabinet-mounted close by but not inside the chlorine room, and shall be easily accessible to the operator.

d. A bottle of ammonium hydroxide shall be available for chlorine leak detection during cylinder change.

e. All gaseous feed chlorine installations shall be equipped with appropriate leak repair kits.

f. At least one pair of rubber gloves with long gauntlets, a dust respirator of a type approved by the U.S. Bureau of Mines for toxic dusts, and an apron or other protective clothing shall be provided for each operator in any shift who will handle dry chemicals.

g. Rubber gloves with long gauntlets, rubber roots, goggles, rubber apron or other suitable protective clothing shall be provided for each operator preparing chemical solutions, or cleaning up spills.

h. Facilities shall be provided for washing of face, gloves and protective equipment.

i. A safety shower shall be provided in areas where hazardous chemicals are handled.

j. On-site generation of sodium hypochlorite must include dilution and venting of hydrogen gas.

Part 7 - PUMPING FACILITIES

7.0 GENERAL - Pumping facilities shall be designed to maintain the sanitary quality of pumped water. Subsurface pits or pump rooms and inaccessible installations should be avoided. No pumping station shall be subject to flooding.

7.1 LOCATION - The pumping station shall be so located that the proposed site will meet the requirements of the sanitary protection of the water quality, hydraulics of the system and be protected against interruption of service by fire, flood or any other hazard.

7.1.1 Site Protection - The station shall be:

a. elevated to a minimum of one foot above the 100-year flood elevation, or protected to such elevation;

b. accessible at all times unless permitted to be out of service for period of inaccessibility;

c. graded around station so as to lead surface drainage away from the station;

d. protected to prevent vandalism and entrance by unauthorized persons or animals.

7.2 GROUND WATER FACILITIES - Where pumping facilities are used, wells and springs shall be vented by properly hooded and screened pipe extending at least 12 inches above the pump floor. Where necessary, provision shall be made for lubricating the pump from a point at least 6 inches above the top of the well cover, by means which will prevent contamination of the water supply.

7.2.1 Drilled Wells - Pumping stations located over drilled wells shall;

a. have riser pipe or casing extending at least 6 inches, and preferably 12 inches, above the floor, and be equipped with flange or suitable stuffing box;

b. have riser pipe or casing firmly connected to the pump structure to provide a water tight connection.

c. have base of pump not less than 6 inches above pump room floor;

d. have pump foundation and base designed to prevent water from coming into contact with the joint.

7.2.2 Submersible Pumps - Where a submersible pump is used, the top of the casing shall be effectively sealed against entrance of water under all conditions of vibration or movements of conductors or cables.

7.2.3 Discharge Piping - Discharge piping should be provided with means to pump to waste but shall not be directly connected to a sewer. The discharge line shall:

a. have control valves located above pump floor;

b. be protected against freezing;

c. be valved to permit testing and control of each well;

d. have watertight joints;

e. have all exposed valves protected.

7.3 SURFACE WATER FACILITIES - Pump stations normally associated with surface water sources, either as raw or finished water pump stations, shall:

a. have adequate space for the installation of additional units if needed, and for the safe servicing of all equipment;

b. be of durable character, fire and weather resistant and with outward opening doors;

c. have floor elevation of at least 6 inches above finished grade;

d. have underground structure waterproofed;

e. have all floors drained without impairing the quality of water being handled and if equipment is contained on the floor, the floor shall have sufficient slope to drain adequately.

f. provide suitable outlet for drainage from-pump glands without discharging onto the floor.

7.3.1 Suction Well - Suction wells shall:

a. be watertight;

b. have floors sloped to permit removal of water and entrained solids;

c. be covered or otherwise protected against contamination; including pump lubricant.

7.3.2 Equipment Servicing - Pump facilities shall be provided with;

a. crane-ways, hoist beams, eye bolts, or other adequate facilities for servicing or removal of pumps, meters or heavy equipment;

b. openings in floors, roofs or wherever else needed for removal of heavy or bulky equipment;

c. a convenient tool board or other facilities as needed for proper maintenance of the equipment.

7.3.3 Stairways and Ladders - Stairways or ladder shall

a. be provided between all floors, in pits or compartments which must be entered.

b. have handrails on both sides, and treads of non-slip material.

Stairs are preferred in areas where there is frequent traffic or where supplies are transported by hand. They shall have risers not exceeding 9 inches and treads wide enough for safety.

7.3.4 Heating - Provision shall be made for adequate heating for:

a. comfort of the operator;

b. the safe and efficient operation of the equipment.

In pump houses not occupied by personnel, only enough heat need be provided to prevent freezing of equipment or treatment process.

7.3.5 Ventilation - Adequate ventilation shall be provided for all pumping stations. Forced ventilation of at least 6 changes of air per hour shall be provided for:

a. all rooms, compartments, pits and other enclosures below grade floor;

b. any area where unsafe atmosphere may develop or where excessive heat may be built up.

7.3.6 Dehumidification - In areas where excess moisture could cause hazards to safety or damage to equipment means for dehumidification shall be provided.

7.3.7 Lighting - Pump stations shall be adequately lighted throughout. All electrical work shall conform to the requirements of the American Insurance Association and related agencies and to relevant State and/or local codes.

7.3.8 Sanitary and Other Conveniences - Pumping stations which are manned for extended periods shall be provided with potable water, lavatory and toilet facilities. Plumbing must be so installed as to prevent contamination of a public water supply. Wastes shall be discharged in accordance with Section 4.11 of these standards.

7.3.9 Pumps - At least 2 pumping units shall be provided. Each pumping unit shall be capable of carrying the peak demand. If more than 2 units are installed, they shall have sufficient capacity so that any 1 pump can be taken out of service and the remaining pumps are capable of carrying the peak demand. The pumping units shall:

a. have ample capacity to supply the peak demand without dangerous overloading;

b. be driven by a prime mover able to operate against the maximum head and air temperature which may be encountered;

c. have spare parts and tools readily available.

3600 RPM pumps are not desirable and should be avoided if at all possible.

7.3.10 Suction Lift - Suction lift pumps will be considered on an individual basis based on justification of design engineer.

7.4 <u>BOOSTER PUMPS</u> - Booster pumps shall be located or controlled so that:

a. they will not produce negative pressure anywhere in the distribution system;

b. the pressure in the suction line shall be maintained at or above 20 psi by the use of a pressure sustaining valve or low pressure cutoff device.

c. automatic or remote control devices shall have a range between the start and cutoff pressure which will prevent excessive cycling.

7.4.1 In-line Booster Pumps - In addition to the other requirements of this section, in-line booster pumps shall be accessible for servicing and repairs.

7.4.2 The criteria in this section also apply to fire pumps.

7.4.3 Booster pumps shall not serve more than 50 service connections unless gravity storage is provided or service pressure can be maintained above 20 psi without the pumps running.

7.5 AUTOMATIC AND REMOTE CONTROLLED STATIONS - All automatic stations should be provided with automatic signaling apparatus which will report when the station is out of service. All remote controlled stations shall be electrically operated and controlled and shall have signaling apparatus of proven performance. Installation of electrical equipment shall conform with the National Electrical Code.

7.6 APPURTENANCES

7.6.1 Valves - Pumps shall be adequately valved to permit satisfactory operation, maintenance and repair of the equipment. If foot valves are necessary they shall have a net valve area of at least 2½ times the area of the suction pipe and they shall be screened. Each pump shall have a positive acting check valve on the discharge side between the pump and shutoff valve.

7.6.2 Piping - In general, piping shall:

a. be designed so that the friction head will be minimized;

b. not be subject to contamination;

c. have watertight joints;

d. be protected against surge or water hammer;

e. be such that each pump has an individual suction line or the lines shall be so manifolded that they will insure similar hydraulic and operation conditions.

7.6.3 Gauges and Meters - Each pump shall:

a. shall have a standard pressure gauge on its discharge line;

b. shall have a compound gauge on its suction line;

c. shall have recording gauges in larger stations;

d. should have a means for measuring the discharge.

The larger stations should have indicating, totalizing and recording metering of the total water pumped.

7.6.4 Water Seals - Water seals shall not be supplied with water of a lesser sanitary quality than that of the water being pumped.

7.6.5 Controls - Pumps, their prime movers and accessories, shall be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision shall be made for proper alternation. Provision shall be made to prevent operation of the pump during the backspin cycle. Electrical controls should be located above grade.

7.6.6 Power - When power failure would result in cessation of minimum essential service, power supply shall be provided from at least two independent sources or standby or auxiliary source shall be provided.

7.6.7 Auxiliary Power Supply - When automatic pre-lubrication of pump bearings is necessary, and an auxiliary power supply is provided, the pre-lubrication line shall be provided with a valved by-pass around the automatic control.

Part 8 - FINISHED WATER STORAGE

8.0 GENERAL - The materials and designs used for finished water storage structures shall provide stability and durability as well as protect the quality of the stored water. Steel structures shall follow the current AWWA standards concerning steel tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable. Prestressed concrete tanks shall meet applicable AWWA Standards. Other materials of construction are acceptable when properly designed to meet the requirements of this part.

8.0.1 Location

a. The bottom of ground-level reservoirs should be placed at the normal ground surface and above maximum flood level.

b. Where the bottom must be below normal ground surface, it should be placed above the ground water table. Sewers, drains, standing water, and similar sources of contamination must be kept at least 50 feet from the reservoir. Mechanical-joint water pipe, pressure tested in place to 50 psi without leakage, may be used for gravity sewers at lesser separations.

c. The top of a ground-level reservoir should not be less than 2 feet above normal ground surface and any possible flood level. Clearwells constructed under filters may be excepted from this requirement when the total design gives the same protection.

8.0.2 Protection - All new finished water storage structures shall have suitable watertight roofs or covers which exclude birds, animals, insects, and excessive dust.

8.0.3 Protection from Trespassers - Fencing, locks on access manholes, and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage.

8.0.4 Drains - No drain on a water storage structure may have a direct connection to a sewer or storm drain. Splash pad and drainway shall be provided to prevent erosion.

8.0.5 Overflow - The overflow pipe of a water storage structure should be brought down near the ground surface and discharged over a drainage inlet structure or a splash plate and flow onto a drainway which is rip-rapped or otherwise protected to minimize erosion. No overflow may be connected directly to a sewer or storm drain.

a. When an internal overflow pipe is used, it shall be located in the access tube.

b. The overflow of a ground-level structure shall be high enough above normal or graded ground surface to prevent the entrance of surface water.

c. The overflow shall be protected with a twenty-four mesh non-corrodible screen and a flap valve.

8.0.6 Access - Finished water storage structures shall be designed with reasonably convenient access to the interior for cleaning and maintenance. Manholes on scuttles above waterline:

a. shall be framed at least 4 inches, and preferably 6 inches, above the surface of the roof at the opening; on ground-level structures manholes should be elevated 24 to 36 inches above the top or covering sod;

b. shall be fitted with a solid watertight cover which overlaps the framed opening and extends. down around the frame at least 2 inches;

c. should be hinged at one side;

d. shall have a locking device,

e. shall be a minimum of 20 inches in diameter or equivalent.

8.0.7 Vents - Finished water storage structures shall be vented by special vent structures. Open construction between the side wall and roof is not permissible. These vents:

a. shall prevent the entrance of surface water;

b. shall exclude birds and animals;

c. shall exclude insects and dust, as much as this function can be made compatible with effective venting; for elevated tanks and standpipes, 4-mesh non-corrodible screen may be used;

d. shall, on ground-level structures, terminate in an inverted U construction, the opening of which is 24 to 36 inches above the roof of sod and is covered with 24-mesh non-corrodible screen cloth.

8.0.8 Roof and Sidewall - The roof and sidewalls of all structures must be watertight with no openings except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.

a. Any pipes running through the roof or sidewall of a finished water storage structure must be welded or properly gasketed in metal tanks, or should be connected to standard wall castings which were poured in place during the forming of a concrete structure; these wall castings should have flanges embedded in the concrete.

b. openings in a storage structure roof or top, designed to accommodate control apparatus or pump columns, shall be curbed and sleeved with proper additional shielding to prevent the access of surface or slop water to the structure.

c. Valves and controls should be located outside the storage structure so that valve stems and similar projections will not pass through the roof or top of the reservoir.

8.0.9 Drainage for Roof or Cover - The roof or cover of the storage structure should be well drained, but downspout pipes shall not enter or pass through the reservoir; parapets, or similar construction which would tend to hold water and snow on the roof will not be approved.

8.0.10 Safety - The safety of employees must be considered in the design of the storage structure. As a minimum, such matters shall conform to pertinent laws and regulations.

a. Ladders, ladder guards, balcony railings, and safe location of entrance hatches shall be provided where applicable.

b. Elevated tanks with riser pipes over 8 inches in diameter shall have protective bars over the riser openings inside the tank.

8.0.11 Freezing - All finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents, shall be designed to prevent freezing which will interfere with proper functioning.

8.0.12 Grading - The area surrounding a ground-level structure should be graded in a manner that will prevent surface water from standing within 50 feet of the structure.

8.0.13 Silt stop - The discharge pipe of the reservoir shall be located in a manner that will prevent the flow of sediment into the distribution systems. Either a permanent or removable silt stop shall be provided at least 4 inches above the bottom of the storage structure.

8.0.14 Painting and/or Cathodic Protection - Proper protection should be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both.

a. Paint systems consistent with current American Water Works Association standards, or otherwise acceptable to the Department shall be used. All paints must be acceptable to FDA and EPA for contact with potable water.

b. Cathodic protection should be designed and installed by competent technical personnel.

8.0.15 Turnover of water - If the storage reservoir is sized larger than required for initial demand and there is more than 2 days storage, provisions shall be made for turnover of the water in the tank and/or booster chlorination. Internal piping arrangements to prevent water stratification in ground level standpipes are recommended. For large, ground level tanks/reservoirs, piping and/or check valves can be installed to force water in and out of the tank at different locations in order to minimize dead/stagnant water zones.

8.0.16 Sampling - A suitable sampling tap should be provided on all storage structures and be protected from public access.

8.0.17 Disinfection - Finished water storage structures shall be disinfected in accordance with AWWA Standard C652 before being put in service.

8.1 PLANT STORAGE - The applicable design standards of this part shall be followed for plant storage.

8.1.1 Washwater Tanks - If washwater tanks are used, they shall be sized, in conjunction with available pump units and finished water storage, to give the back wash water required by Section 4.2.1.K.

a. Consideration must be given to the possibility of having to wash more than one filter at a time, or several filters in succession.

8.1.2 Clearwell - Clearwell storage should be sized, in conjunction with distribution system storage, to relieve the filters from having to follow fluctuations in water use to meet peak demands, including filter backwash water. Design shall include features to minimize short circuiting.

a. When finished water storage is used to provide proper contact time for chlorine, (see Section 4.4.2), special attention must be given to size and baffling.

b. An overflow shall be provided and must be protected with a screen and flap valve.

8.1.3 Adjacent Compartments - finished water must not be stored or conveyed in a compartment adjacent to unsafe water when the two compartments are separated by a single wall.

8.1.4 Basins and Wet-Wells - Receiving basins and pump wet-wells for finished water shall be designed as finished water storage structures.

8.2 PRESSURE TANKS - Hydropneumatic (pressure) tanks may be acceptable in some circumstances where the number being served is 50 connections or less. When used, they shall meet ASME code requirements or equal which comply with the requirements of state and local laws and regulations for the construction and installation of unfired pressure vessels.

8.2.1 Location - The tank should be located above normal ground surface and be completely housed, or earth-mounted with one end projecting into an operating house, to prevent freezing.

8.2.2 Bypass - tank should have bypass piping to permit operation of the system while the tank is being repaired or painted.

8.2.3 Appurtenances - Each tank should have an access manhole, a drain, a control equipment consisting of pressure gage, water sight glass, automatic or manual air blow-off, mechanical means for adding air, and pressure-operated start-stop controls for the pumps.

8.2.4 Sizing -

a. The capacity of each well and/or pump in a hydropneumatic system should be at least ten times the average daily consumption rate of the community or the maximum peak demand whichever is greater.

b. The gross volume of the hydropneumatic tank, in gallons, should be at least 20 times the capacity of the largest pump, rated in gallons per minute.

8.2.5 Auxiliary power - Auxiliary power with automatic takeover capability shall be provided when positive pressures are not available from system gravity flow.

8.3 <u>DISTRIBUTION STORAGE</u> - The applicable design standards of this part shall be followed for distribution storage.

8.3.1 The purpose of system storage is to have sufficient water available to provide adequate flow and pressure at peak demand as well as to provide for fire flows when needed. For most water systems a satisfactory rule-of-thumb to meet these needs is to provide at least the average 24-hour demand in elevated storage. In the absence of an acceptable engineering study of the amount of water the system needs to meet customer demand and to provide for fire emergencies, the projected 24-hour demand at the end of the planning period will be the minimum requirement for elevated storage. This requirement may be reduced when the source, treatment facilities and pumps have sufficient capacity with standby power capability to supplement peak demands of the system.

8.3.2 Pressure Variation - System pressure variation on account of changes in level of water in storage structures should be minimized. Elevated storage tanks or large diameter ground tanks located on high ground should be the usual choices. Standpipes will not normally be approved and must be completely justified if proposed.

8.3.3 Drainage - Storage structures which float on the distribution system should be designed to drain for cleaning or maintenance without necessitating loss of pressure in the distribution system. The drains should discharge to the ground surface with no direct connection to a sewer or storm drain. (See Section 8.0.4). A nearby fire hydrant may be considered as a drain as long as service is not interrupted and suitable erosion protection is provided.

8.3.4 Level Controls - Adequate controls shall be provided to maintain levels in distribution system storage structures.

a. Telemeter equipment should be used when pressure-type controls are employed and any appreciable head loss occurs in the distribution system between the source and the storage structure.

b. Altitude valves or equivalent controls may be required for a second and subsequent structures on the system.

c. Overflow and low-level warnings or alarms should be located at places in the community where they will be under responsible surveillance on a 24-hour basis.

Part 9 - DISTRIBUTION SYSTEMS

9.0 SYSTEM DESIGN

9.0.1 Minimum Pipe Size

a. The minimum size of pipe for principal water mains and for water mains where fire hydrants are to be attached shall be 6-inch diameter.

b. Size of water mains shall be justified by hydraulic analysis. 2-inch water mains will only be considered for short cul-de-sacs and permanent dead-ends where future growth is not feasible. The length of 2-inch mains shall be restricted to 3000 feet in any one direction.

c. All water mains including those not designed to provide fire protection shall be sized after a hydraulic analysis based on flow demands and pressure requirements. The system shall be designed to maintain a minimum pressure of 20 psi at ground level at all points in distribution system under all conditions of flow.

d. Wide variations in pressure above the minimum requirement of 20 psi may be inherent in the design of a distribution system but pressures no greater than 100 psi should be delivered to the customer (unless higher pressures are requested.). Main line pressure reducing valves can be used to reduce pressures below 100 psi where feasible. Where water pressures over 100 psi are necessary to the operation of the distribution system, customers must have individual pressure reducing valves.

e. All assumptions and any flow data used must be clearly documented and submitted with the hydraulic analysis. if actual flow data is not available theoretical calculations shall be based on all storage facilities half-full and the Hazen-Williams friction factor appropriate for type of pipe being used but in no case greater than 130.

f. Water distribution lines should be designed and sized for an instantaneous peak demand of 2 gpm per connection for water lines serving up to 100 residential connections. Peak design demands can be reduced to 1.5 gpm per connection for 150 residential connections, 1.0 gpm per connection for 300 residential connections, 0.75 gpm per connection for 500 residential connections, and 0.5 gpm per connection for 1000 or more residential connections.

9.0.2 Fire Protection

a. The minimum pipe size to which a fire hydrant may be connected is 6-inch.

b. Ordinarily fire hydrants shall not be connected to water mains which are not capable of providing a flow of 500 gpm at 20 psi. When a municipality or county enacts a restrictive use ordinance prohibiting pumper trucks from connecting to restricted fire hydrants which are painted a distinctive color and when a copy of this ordinance in on file at this office, we will permit fire hydrants to be connected to 6-inch mains which do not have the required pressure and flow.

c. When fire protection is to be provided, system design should consider the recommendations of the state Insurance Services Organization.

d. Fire hydrants shall meet current AWWA Standard C502.

9.0.3 Dead Ends

a. Dead ends shall be minimized.

b. Where dead-end mains occur they should be provided with a fire hydrant, when fire flows are available, or blow-off for flushing purposes. The blow-off shall be at least 2 inches in diameter, but should provide flushing velocities of 2 feet per second or greater.

c. No flushing device shall be directly connected to any sewer nor be subject to flooding or plugging.

9.1 INSTALLATION OF MAINS

9.1.1 Adequate support shall be provided for all pipes.

9.1.2 A continuous and uniform bedding shall be provided in the trench for all buried pipe.

9.1.3 Rock Excavation - Stones found in the trench shall be removed for a depth of at least six inches below the bottom of the pipe.

9.1.4 Cover - All distribution mains shall be provided with sufficient earth or other suitable cover to prevent freezing. This shall not be less than 30 inches measured above the top of the pipe.

9.1.5 Hydrostatic Tests

a. Pressure and leakage tests shall be performed in accordance with current AWWA Standard C600 and/or manufacturer's installation procedures.

b. The test pressure of the installed pipe shall be a minimum of 150 psi or 1.5 times the working pressure, whichever is greater.

c. Allowable leakage shall be no greater than as calculated in $L = SD /P/133,200$ where L is allowable leakage in gallons/hour, S is the length of pipe tested in feet, D is pipe diameter in inches and P is test pressure in psi.

9.1.6 Disinfection of New Water Mains - The specifications shall include detailed procedures for the adequate flushing, disinfection, and (Total Coliform) bacteriological testing of all new water mains. Disinfection as described in current AWWA Standard C651 will be accepted.

9.1.7 Disinfection When Cutting into or Repairing Existing Mains:

a. Shall be performed when mains are wholly or partially dewatered;

b. Shall follow current AWWA C651 procedures including trench treatment, swabbing with hypochlorite solution, flushing and/or slug chlorination as appropriate;

c. Bacteriological testing should be done after repairs are complete but the water main may be returned to service prior to completion of testing to minimize the time customers are out of water;

d. Leaks or breaks that are repaired with clamping devices while mains remain full of water under pressure require no disinfection.

9.1.8 When non-metallic pipe is installed, detection tape or other acceptable means of detection shall be installed.

9.2 SEPARATION OF WATER MAINS AND SEWERS

9.2.1 General - The following factors should be considered in providing adequate separation:

a. materials and type of joints for water and sewer pipes;

b. soil conditions;

c. service and branch connections into the water main and sewer line;

d. compensating variations in the horizontal and vertical separations;

e. space for repair and alterations of water and sewer pipes;

f. off-setting of pipes around manholes;

g. water mains and sanitary or storm sewers shall not be laid in the same trench.

9.2.2 Parallel Installation

a. Normal conditions - Water mains shall be laid at least 10 feet horizontally from any sanitary sewer, storm sewer or sewer manhole, whenever possible; the distance shall be measured edge-to-edge.

b. Unusual conditions - When local conditions prevent a horizontal separation of 10 feet, a water main may be laid closer to a storm or sanitary sewer provided that:

1. the bottom of the water main is at least 18 inches above the top of the sewer;

2. where this vertical separation cannot be obtained, the sewer shall be constructed of materials and with joints that are equivalent to water main standards of construction and shall be pressure tested to assure water-tightness prior to backfilling.

9.2.3 Crossings

a. Normal conditions - Water mains crossing house sewers, storm sewers or sanitary sewers shall be laid to provide a separation of at least 18 inches between the bottom of the water main and the top of the sewer, whenever possible.

b. Unusual conditions - when local conditions prevent a vertical separation as described in Section 9.2.3a, the following construction shall be used:

1. Sewers passing over or under water mains should be constructed of the materials described in Section 9.2.2b2.

2. Water mains passing under sewers shall, in addition, be protected by providing:

i. a vertical separation of at least 18 inches between the bottom of the sewer and the top of the water main;

ii. adequate structural support for the sewers to prevent excessive deflection of joints and settling on and breaking the water mains;

iii. that the length of water pipe be centered at the point of crossing so that the joints will be equidistant and as far as possible from the sewer.

iv. both the sewer and the water main shall be constructed of water pipe and tested in accordance with Section 9.1.5.

9.2.4 Sewer manholes - No water pipe shall pass through or come into contact with any part of a sewer or sewer manhole.

9.3 SURFACE WATER CROSSINGS - Surface water crossings, both over and under water, present special problems which should be discussed with the Department before final plans are prepared.

9.3.1 Above-water crossings - The pipe shall be:

a. adequately supported;

b. protected from damage and freezing;

c. accessible for repair or replacement.

9.3.2 When crossing water courses which are greater than 15 feet in width:

a. The pipe shall be of special construction, having flexible, watertight joints;

b. Valves shall be provided at both ends of water crossing so that the section can be isolated for test or repair; the valves shall be easily accessible and not subject to flooding;

c. Sampling taps should be available at each end of the crossing;

d. Permanent taps should be made for testing and locating leaks.

9.4 CROSS CONNECTIONS

a. There shall be no physical connection between the distribution system and any pipes, pumps, hydrants, or tanks whereby unsafe water and other contaminating materials may be discharged or drawn into the system.

b. The approval of the Department shall be obtained for interconnections between potable water supplies.

c. Neither steam condensate nor cooling water from engine jackets or other heat exchange devices shall be returned to the potable water supply.

9.5 WATER SERVICES AND PLUMBING - Water services and plumbing shall conform to relevant local and/or state plumbing codes, or to the Standard Plumbing Code.

9.6 MATERIALS - GENERAL

a. Pipe selected shall have been manufactured in conformity with the latest standards issued by the American Water Works Association, if such standards exist, and be acceptable to the Department.

b. in the absence of such standards, pipe meeting applicable ASTM and ANSI criteria and acceptable to the Department may be selected.

c. Used water mains that meet these standards may be used again, after the pipe has been thoroughly cleaned and restored practically to its original condition.

d. Packing and jointing materials used in the joints of pipe shall meet the standards of the American Water Works Association or the Department.

e. Mechanical joints or slip-on joints with rubber gaskets are preferred.

9.7 PIPE

9.7.1 Ductile iron and cast iron pipe shall meet the latest requirements of ANSI/AWWA - C106 or CIO8 for cast iron pipe and C151 for ductile iron pipe.

9.7.2 Concrete pressure pipe shall meet the latest requirements of AWWA C300 or AWWA C301.

9.7.3 PVC pipe - 2 inch through 12 inch

a. PVC pipe meeting the standards set forth in AWWA C-900 (latest edition) will be accepted for those working pressures as designated by class. (Note that C-900 refers only to 4-inch through 12-inch pipe).

b. SDR 21, Class 200 pressure rated pipe may be used where the working pressure does not exceed 135 psi. The pipe must meet all the requirements set forth in ASTM Standard D 2241 for 2-inch through 12-inch pipe designated SDR 21. The pipe must bear the National Sanitation Foundation Testing Laboratories, Inc. seal of approval for potable water, or an approved equal.

c. Provision must be made for contraction and expansion at each joint with flexible ring gaskets made from rubber or other suitable material. Gasket materials shall meet the requirements established in ASTM F477.

d. Joints for PR 200 (pressure rated) pipe (ASTM D2241) shall be manufactured in accordance with ASTM D3139. Section 5.3.1 of this standard refers to 2000-hour tests. If pipe is manufactured in accordance with that section, the testing must be done by an independent laboratory with the results being furnished to this Department. Note also that a separate test is required for each different type of gasket provided.

e. All fittings such as tees, ells, etc. using welded joints shall be factory welded and shall meet the same specifications as the welded bell section.

f. Lubricants shall be non-toxic and shall not promote biological growth.

g. Solvent cemented joints in the field are not permitted.

h. Forty-foot lengths will be permitted when the engineering specifications contain special conditions for handling such pipe lengths. These conditions shall include provisions for transporting pipe from storage areas to the installation area on specially designed racks to prevent the ends of the pipe from dragging.

i. This policy does not apply to plastic service lines.

9.7.4 Fiberglass Composite Pipe shall be composed of an inner core of PVC overwrapped with fiberglass bonded with epoxy. 350 Pressure Rated shall be in accordance with ASTM D-2992 and D-2996.

9.7.5 Polyethylene pipe for water distribution lines shall meet the requirements of AWWA C906.

9.7.6 Molecular oriented PVC pipe shall meet the requirements of AWWA C909.

9.7.7 Any pipe material which is not specifically covered in this section will be considered on an individual basis.

9.8 VALVE, AIR RELIEF, METER AND BLOW-OFF CHAMBERS

a. Sediment accumulations may be removed through a standard fire hydrant, and compressed air and pumping may be used for dewatering mains through hydrants.

b. At high points in water mains where air can accumulate, provisions shall be made to remove the air by means of hydrants or air relief valves. Automatic air relief valves shall not be used in situations where flooding of the manhole or chamber may occur.

c. Chambers of pits containing valves, blow-offs, meters or other such appurtenances to a distribution system, shall not be connected directly to any storm drain or sanitary sewer, nor shall blowoffs or air-relief valves be connected directly to any sewer.

d. Such chambers or pits shall be drained to the surface of the ground where they are not subject to flooding by surface water, or to absorption pits underground.

e. Valves are to be placed at all intersections of water mains but at no time greater than 4000 feet apart.

f. Gate valves shall meet current AWWA standards.

Section 11

Math

Solving for an Unknown Value

For Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Fleming Training Center
Your Partner in Clean Water
TN Department of Environment & Conservation

Difficulties in Math

- A Poor Foundation
  - Mathematics is sequential – concepts build upon concepts
- No Linking or Steps Missing
  - Link new concepts to what you already know
- The "Big Picture" is Missing
  - The skeleton on which all the details can be hung
- "Use It or Lose It" Syndrome
  - The more you practice and use math calculations, the easier they become

Setting Up and Solving Math Problems

- Theoretical Math – concepts such as fractions, decimals, percents, areas, volumes, etc.
  - "Tools" of math - more tools you have, the easier the applied math problems will be
- Applied Math – basic math concepts applied in solving practical problems
  - Applied math calculations have a strategy – a way of approaching every problem that leads them methodically to the answer

Suggested Strategy

- Disregarding all numbers, what type of problem is it?
- What diagram, if any, is associated with the concept identified?
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Solving for an Unknown Value (X)

Solving for X

- Solve for X

$$(4)(1.5)(x) = 1200$$

- X must be by itself on one side of equal sign
  - 4 and 1.5 must be moved away from X

$$x = \frac{1200}{(4)(1.5)}$$

$$x = 200$$

  - How was this accomplished?

Movement of Terms

- To understand how we move the numbers, we will need to consider more closely the math concepts associated with moving the terms.
- An equation is a mathematical statement in which the terms or calculation on one side equals the terms or calculation on the other side.

Introduction to Equations

- Equations are "balanced"
  - It is vital to maintain that balance.

$$25 \times 4 = 20 \times 5 + 15$$
$$100 \neq 115$$

  - To maintain that balance, we whatever we do to one side of the equation, we must do the same to the other side

$$15 + 25 \times 4 = 20 \times 5 + 15$$
$$115 = 115$$

Movement of Terms

$$(3)(x) = 261$$

- We need to get the variable (x) on one side of the equal sign by itself
- We can move the 3 by performing the opposite function

$$(3)(x) \quad = 261$$

What you do to one side of the equation, must be done to the other side.

$$x = \frac{261}{3}$$

$$x = 87$$

Example 1

$$730 = \frac{x}{3847}$$

What you do to one side of the equation, must be done to the other side.

$$730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$\frac{3847}{1} \times 730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$3847 \times 730 = x$$

$$2{,}808{,}310 = x$$

Example 2

$$0.5 = \frac{(165)(3)(8.34)}{x}$$

Simplify

$$0.5 = \frac{4128.3}{x}$$

What you do to one side of the equation, must be done to the other side.

$$0.5 = \frac{4128.3}{x}$$

$$(x)(0.5) = 4128.3$$

$$x = \frac{4128.3}{0.5}$$

$$x = 8256.6$$

Solving for X when squared

- Follow same procedure as solving for X
- Then take the square root

$$x^2 = 15{,}625$$

$$\sqrt{x^2} = \sqrt{15{,}625}$$

$$x = 125$$

Example 3

$$(0.785)(x^2) = 2826$$

$$\frac{\cancel{(0.785)}(x^2)}{\cancel{0.785}} = \frac{2826}{0.785}$$

$$x^2 = \frac{2826}{0.785}$$

$$x^2 = 3600$$

$$\sqrt{x^2} = \sqrt{3600}$$

$$x = 60$$

Do Order of Operations in reverse when solving for X
OR
move the larger font number first.

Solving for X

- When solving for x involving addition and subtraction, the balance of the equation must still remain.
  - What you do to one side you must do to the other

Example 4

Step 1. Simplify

$$115 + 105 + 80 + x = 386$$

$$\cancel{300} + x = 386$$

$$\cancel{-300} \quad - 300$$

$$x = 386 - 300$$

$$x = 86$$

Example 5

Step 1. Simplify

Step 2. Make x positive

$$17 + 23 + 7 - x = 38$$

$$47 - \cancel{x} = 38$$

$$+\cancel{x} \quad + x$$

$$47 = \cancel{38} + x$$

$$-38 \quad - \cancel{38}$$

$$47 - 38 = x$$

$$9 = x$$

Fractions and Percents

Converting Decimals and Fractions

- To convert a fraction to a decimal
  - Simply divide the numerator by the denominator

$$\frac{1}{2} = 1 \div 2 = 0.5$$

$$\frac{10}{13} = 10 \div 13 = 0.7692$$

Percents and Decimals

- To convert from a decimal to a percent
  - Simply move the decimal point two places to the right

$$0.46 \Rightarrow 46.0\%$$

- To convert from a percent to a decimal
  - Simply move the decimal two points to the left

$$79.5\% \Rightarrow 0.795$$

- Remember:

  You CANNOT have a percent in an equation!!

Writing Equations

- Key words
  - **Of** means "multiply"
  - **Is** means "equal to"
  - **Per** means "divide"
- Calculate 25% of 595,000

$$25\% \times 595{,}000$$

$$0.25 \times 595{,}000$$

$$148{,}750$$

Example 5

448 is what percent of 560?

$$448 \quad = \quad x\% \quad \times \quad 560$$

$$\frac{448}{560} = \frac{x\% \times \cancel{560}}{\cancel{560}}$$

$$0.80 = x\%$$

$$80\% = x$$

Basic Math
Solving for the Unknown
Example Problems

1.) $8 + 11 + x + 8 + 10 = 49$

2.) $18.9 - x = 12.7$

3.) $8.1 = (3)(x)(1.5)$

4.) $1203 = \frac{x}{3}$

5.) $\frac{1040}{x} = 40$

6.) $49.3 = \frac{6160.25}{(x)(8.34)}$

7.) $(6)(x^2) = 864$

8.) $x^2 = \frac{107937.5}{(0.785)(55)}$

Basic Math
Solving for the Unknown
Practice Problems

1. $7 + 10 + x + 7 + 9 = 41$

2. $9.5 - x = 8.7$

3. $x - 93 = 165$

4. $10.1 = 9.5 + x$

5. $x + 15 = 19 + 22$

6. $16 = (2)(x)$

7. $8.1 = (3)(x)(1.5)$

8. $(0.785)(0.33)(0.33)(x) = 0.49$

9. $\frac{10}{x} = 50$

10. $\frac{233}{x} = 44$

11. $56.5 = \frac{3800}{(x)(8.34)}$

12. $10 = \frac{x}{4}$

13. $940 = \frac{x}{(0.785)(90)(90)}$

14. $x = \frac{(165)(3)(8.34)}{0.5}$

15. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

16. $2 = \frac{x}{180}$

17. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)(x)}$

18. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

19. $19{,}747 = (20)(12)(x)(7.48)$

20. $\frac{(15)(12)(1.25)(7.48)}{x} = 337$

21. $\frac{x}{(4.5)(8.34)} = 213$

22. $\frac{x}{246} = 2.4$

23. $6 = \frac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

24. $\frac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

25. $109 = \frac{x}{(0.785)(80)(80)}$

26. $(x)(3.7)(8.34) = 3620$

27. $2.5 = \frac{1,270,000}{x}$

28. $0.59 = \frac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

29. $142 = (2)(x) + 13$

30. $(3.5)(x) - 62 = 560$

Solve for the unknown value.

31. $x^2 = 100$

32. $(2)(x^2) = 288$

33. $942 = (0.785)(x^2)(12)$

34. $6358.5 = (0.785)(x^2)$

35. $835 = \frac{4,200,000}{(0.785)(x^2)}$

36. $920 = \frac{3,312,000}{x^2}$

37. $23.9 = \frac{(3650)(3.95)(8.34)}{(0.785)(x^2)}$

38. $(0.785)(D^2) = 5024$

39. $(x^2)(10)(7.48) = 10{,}771.2$

40. $51 = \frac{64{,}000}{(0.785)(x^2)}$

41. $(0.785)(D^2) = 0.54$

42. $2.1 = \frac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

Answers

1. 8
2. 0.8
3. 258
4. 0.6
5. 26
6. 8
7. 1.8
8. 5.73
9. 0.2
10. 5.3
11. 8.06
12. 40
13. 5,976,990
14. 8256.6
15. 0.005
16. 360
17. 1649.42
18. 244.66
19. 10.99
20. 4.99
21. 7993.89
22. 590.4
23. 2816.67
24. 4903.48
25. 547,616
26. 117.31
27. 508,000
28. 0.35
29. 64.5
30. 177.71
31. 10
32. 12
33. 10
34. 90
35. 80
36. 60
37. 80
38. 80
39. 12
40. 39.98
41. 0.83
42. 10.94

Percent Practice Problems

Convert the following fractions to decimals:

1. $\frac{3}{4}$
2. $\frac{5}{8}$
3. $\frac{1}{4}$
4. $\frac{1}{2}$

Convert the following percents to decimals:

5. 35%
6. 99%
7. 0.5%
8. 30.6%

Convert the following decimals to percents:

9. 0.65
10. 0.125
11. 1.0
12. 0.05

Calculate the following:

13. 15% of 125
14. 22% of 450
15. 473 is what % of 2365?
16. 1.3 is what % of 6.5?

Percent Practice Problems

1. 0.75
2. 0.625
3. 0.25
4. 0.5
5. 0.35
6. 0.99
7. 0.005
8. 0.306
9. 65%
10. 12.5%
11. 100%
12. 5%
13. 18.75
14. 99
15. 20%
16. 20%

Dimensional Analysis

Mathematics Manual for Water and Wastewater Treatment plant Operators
by Frank R. Spellman

Dimensional Analysis

- Used to check if a problem is set up correctly
- Work with the units of measure, not the numbers
- Step 1:
  - Express fraction in a vertical format

$$gal/ft^3 \text{ to } \frac{gal}{ft^3}$$

- Step 2:
  - Be able to divide a fraction

$$\frac{\frac{lb}{day}}{\frac{min}{day}} \text{ becomes } \frac{lb}{day} \times \frac{day}{min}$$

Dimensional Analysis

- Step 3:
  - Know how to divide terms in the numerator and denominator
  - Like terms can cancel each other out
    - For every term that is canceled in the numerator, a similar term must be canceled in the denominator

$$\frac{lb}{\cancel{day}} \times \frac{\cancel{day}}{min}$$

- Units with exponents should be written in expanded form

$$ft^3 = (ft)(ft)(ft)$$

Example 1

- Convert 1800 ft^3 into gallons.
- We need the conversion factor that connects the two units
- This is a ratio, so it can be written two different ways
- We want to use the version that allows us to cancel out units

$$\frac{1\ ft^3}{7.48\ gal} \quad \text{OR} \quad \frac{7.48\ gal}{1\ ft^3}$$

Example 1

$$\left(\frac{1800\ ft^3}{1}\right)$$

- Will anything cancel out?

NO

- Let's try the other version
- Will anything cancel out?

YES

Example 2

- Determine the cross-sectional area of a pipe, in ft^2, through which $70\ ft^3/sec$ flows at a velocity of $4.5\ ft/sec$.
- Use units to determine set up
  - Two ways to write the number

$$\frac{4.5\ ft}{1\ sec} \quad OR \quad \frac{1\ sec}{4.5\ ft}$$

  - Which way is the right way?
  - Will anything cancel?

Example 2 Cont'd

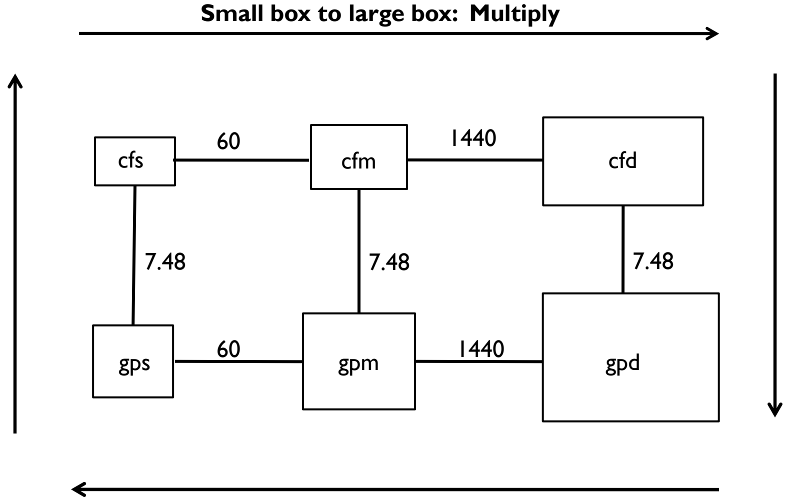
- Remember, units function the same as numbers.

$$ft^3 = (ft)(ft)(ft)$$

- Therefore
- Will anything cancel out?

Flow Conversions – Box Method

Small box to large box: Multiply



Large box to small box: Divide

Metric Units

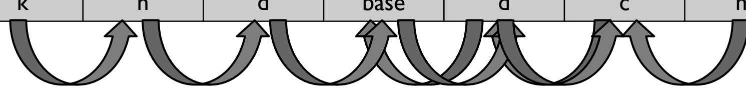
Kilo	Hecto	Deca	Basic Unit	Deci	Centi	Milli
King	Henry	Died	By	Drinking	Chocolate	Milk
1000X larger	100X larger	10X larger	Meter Liter Gram ***1 unit***	10X smaller	100X smaller	1000X smaller

MULTIPLY numbers by 10 if you are getting smaller →

← **DIVIDE** number by 10 if you are getting bigger

Metric Units

King	Henry	Died	by	Drinking	Chocolate	Milk
k	h	d	base	d	c	m



- Convert 2500 milliliters to liters

$$2500\ mL = \square$$

- Convert 0.75 km into cm

$$0.75\ km = \square$$

Dimensional Analysis Example

1. Convert 5 cubic feet to gallons.

2. Convert 56 ft^3/sec to gallons per minute.

3. Convert 3.45 MGD to cubic feet per second.

4. How many mL are in 0.75 L?

Basic Math for Operators
Conversions (1)

Linear Measurement Conversions

1.) ¼ mile = __________ feet

2.) 4200 feet = __________ miles

3.) 17 feet = __________ yds (1 yd : 3 ft)

4.) 122 inches = __________ feet

5.) 30 yds = __________ inches

6.) 0.6 feet = __________ inches

7.) 492 inches = __________ feet

8.) The total weir length for a sedimentation tank is 142 feet 7 inches. Express this length in terms of feet only.

9.) A one-eighth mile section of pipeline is to be replaced. How many feet of pipeline is this?

10.) How many inches is 2.7 miles of pipe?

Metric/English Conversions

11.) 20 feet = ________ meters

12.) 50 L = ___________ gal

13.) 70 cm = _________ inches

14.) 35 yds = _________ feet (1 yd : 3 ft)

15.) 600 mL = ________ gal

16.) 1 lb = ____________ g

17.) 2.7 gal = _________ L

Area Measurement

18.) 1017 in^2 = _________ ft^2 (1 ft^2 : 144 in^2)

19.) 500 yd^2 = _________ ft^2 (1 yd^2 : 9 ft^2)

20.) 4 acres = _________ ft^2

21.) 1 yd^2 = _________ in^2

22.) 9.5 ft^2 = _________ in^2

23.) $78.5\ in^2$ = __________ ft^2

24.) $25,000\ ft^2$ = __________ acres

25.) 0.9 acre = __________ ft^2

26.) For solids treatment, a total of $60,000\ ft^2$ will be required. How many acres is this?

27.) A pipe has a cross-sectional area of $452\ in^2$. How many ft^2 is this?

Volume Measurement

28.) $325\ ft^3$ = __________ yd^3 ($1\ yd^3 : 27\ ft^3$)

29.) $2512\ in^3$ = __________ ft^3 ($1\ ft^3 : 1728\ in^3$)

30.) $25\ yd^3$ = __________ ft^3

31.) $1500\ in^3$ = __________ ft^3

32.) 2.2 ac-ft = __________ yd^3

33.) $21\ ft^3$ = __________ yd^3

34.) $92,600\ ft^3$ = __________ ac-ft

35.) $17{,}260\ ft^3$ = __________ yd^3

36.) $0.6\ yd^3$ = __________ ft^3

37.) $3\ ft^3$ = __________ in^3

38.) A screening pit must have a capacity of 400 ft^3. How many yd^3 is this?

39.) A reservoir contains 50 ac-ft of water. How many ft^3 of water does it contain?

Flow Conversions

40.) 3.6 cfs = __________ gpm

41.) 1820 gpm = __________ gpd

42.) 45 gps = __________ cfs

43.) 8.6 MGD = __________ gpm

44.) 2.92 MGD = __________ gpm

45.) 385 cfm = __________ gpd

46.) 1,662,000 gpd = __________ gpm

47.) 3.77 cfs = __________ MGD

48.) The flow through a pipeline is 8.4 cfs. What is the flow in gpd?

49.) A treatment plant receives a flow of 6.31 MGD. What is the flow in gpm?

Basic Math for Operators

Conversions (1) Answers

1.) 1320 ft
2.) 0.80 miles
3.) 5.67 yds
4.) 10.17 ft
5.) 1080 in
6.) 7.2 in
7.) 41 ft
8.) 142.58 ft
9.) 660 ft
10.) 171,072 in
11.) 6.1 m
12.) 13.21 gal
13.) 27.56 in
14.) 105 ft
15.) 0.16 gal
16.) 454 g
17.) 10.22 L
18.) 7.06 ft^2
19.) 4500 ft^2
20.) 174,240 ft^2
21.) 1296 in^2
22.) 1368 in^2
23.) 0.55 ft^2
24.) 0.57 ac
25.) 39,204 ft^2
26.) 1.38 ac
27.) 3.14 ft^2
28.) 12.04 yd^3
29.) 1.45 ft^3
30.) 675 ft^3
31.) 0.87 ft^3
32.) 3551.2 yd^3
33.) 0.78 yd^3
34.) 2.13 ac-ft
35.) 639.26 yd^3
36.) 16.2 ft^3
37.) 5184 in^3
38.) 14.81 yd^3
39.) 2,178,000 ft^3
40.) 1615.68 gpm
41.) 2,620,800 gpd
42.) 6.02 cfs
43.) 5972.22 gpm
44.) 2027.78 gpm
45.) 4,146,912 gpd
46.) 1154.17 gpm
47.) 2.44 MGD
48.) 5,428,684.8 gpd
49.) 4381.94 gpm

Basic Math for Operators
Conversions (2)

1. How many pounds are there in 1 ft^3 of water?

2. How many pounds does exactly 100 gal of water weigh?

3. Convert 8.2 ft^3/sec to gallons per minute.

4. How many gallons are there in 82 ft^3?

5. Convert 2,445 gal to cubic feet.

6. How much does 725 gal of water weigh in pounds?

7. Convert 5.1 MGD to cfs.

8. Convert 15.0 acre-ft to cubic feet.

9. 4,078,611 ft^3 to acre-feet.

10. Convert 11.9 MGD to cubic feet per second.

11. Convert 5.6 ft^3/sec to gallons per minute.

12. Convert 3.2 ft^3/sec to millions of gallons per day.

13. How many million gallons are there in 22 ac-ft?

14. How many million gallons are there in 43,000 ac-ft?

15. Convert 23 lb/million gallons to milligrams per liter.

16. How many gallons are there in 8,492 ft^3?

17. Convert a solution that has 52,600 ppm to percent.

18. Convert 45 lb/MG to mg/L.

19. The distance between your plant and the nearest customer is 1.535 kilometers. What is this distance in yards?

20. The minimum area required for building a 1 MG storage facility is 900 ft^2. What is this size in acres?

21. Sunny Slope water system daily maximum demand is 556,000 gallons. What is this system demand in ft^3?

22. Based on the dimensions of your storage reservoir, you calculate the total volume to be 210,000ft^3. How many million gallons (MG) of water can you store at this reservoir?

23. During a fire flow test, the gauge shows a flow of 79.3 L/sec. What is the flow at this location in ac-ft/day?

24. Based on your measurements, the maximum flow out of a ¼ inch pipe at your chemical pump effluent is 24.5 gpd. What is the flow rate in mL/min?

25. The length of the pipe between Main St. and Beach Ave. as measured on a map is 0.224 miles. The purchasing department requires you to submit all distances in feet when you place an order for new pipes. What is the distance in feet?

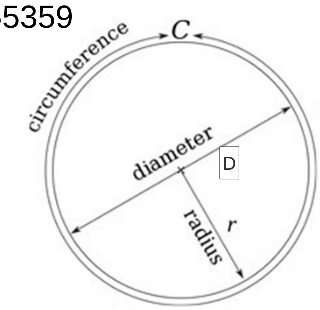
Answers

1. 62.4 lbs
2. 834 lbs
3. 3680.16 gal/min
4. 613.36 gal
5. 326.87 ft^3
6. 6046.5 lbs
7. 7.89 cfs
8. 653,400 ft^3
9. 93.63 ac-ft
10. 18.41 cfs
11. 2513.28 gal/min
12. 2.07 MGD
13. 7.17 MG
14. 14,010.64 MG
15. 2.76 mg/L
16. 63,520.16 gal
17. 5.26%
18. 5.4 mg/L
19. 1678.01 yds
20. 0.02 ac
21. 74331.55 ft^3
22. 1.57 MG
23. 5.56 ac-ft/day
24. 64.4 mL/min
25. 1182.72 ft

CIRCUMFERENCE AND AREA

Parts of a Circle

- Diameter is distance across the center of circle
- Radius is distance from circle's center to the edge
- Circumference is the distance around a circle or a circular object
- Pi (3.14) is a mathematical constant
  - $\pi = 3.14159265359$



Circumference & Perimeter

- Circumference of a Circle

$$Circumference = (3.14)(Diameter)$$

- Perimeter is obtained by adding the lengths of the four sides of a square or rectangle

$$Perimeter = 2(length) + 2(width)$$

Example 1

- Find the circumference of a 6 inch diameter pipe.

$$Circumference = (\pi)(diameter)$$

$$C = (3.14)(6\ inches)$$

$$C = 18.84\ inches$$

- Find the perimeter of a rectangular tank that is 15 ft by 22 ft.

$$Perimeter = 2(length) + 2(width)$$

$$P = 2(15\ ft) + 2(22\ ft)$$

$$P = 30\ ft + 44\ ft$$

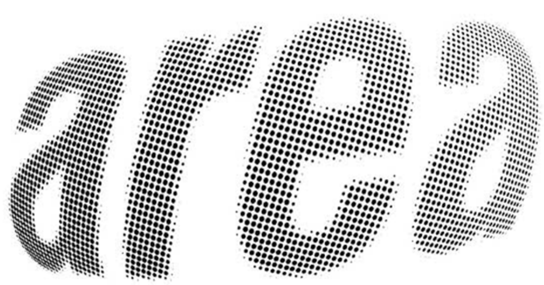
$$P = 74\ ft$$

Suggested Strategy

- Disregarding all numbers, what type of problem is it?
- What diagram, if any, is associated with the concept identified?
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Area

- Area is the measurement of the amount of space on the surface of an object
- Two dimensional measurement
- Measured in: in^2, ft^2, acres, etc.

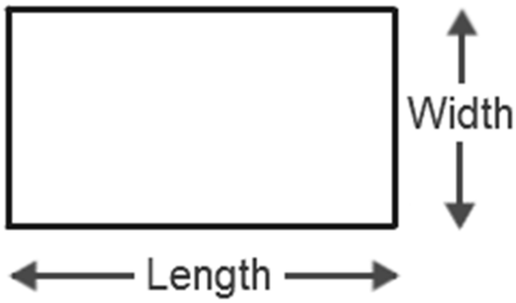


Area

- Area of Rectangle

$$Area = (length)(width)$$

$$A = (L)(W)$$



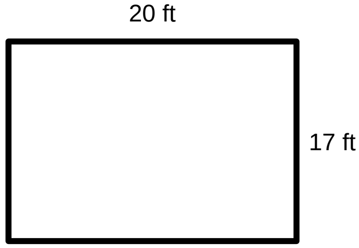
Example 1

- Find the area in ft^2 of a rectangular basin that is 20 feet long and 17 feet wide.

$$A = (L)(W)$$

$$A = (20ft)(17ft)$$

$$A = 340ft^2$$

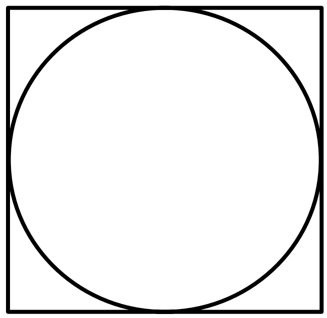


Area

- Area of Circle

$$Area = (0.785)\ (Diameter)^2$$

$$A = (0.785)(D)^2$$



A circle takes up
78.5% of a square.

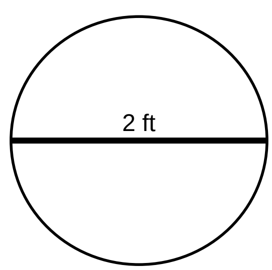
Example 2

- Find the area of the cross section of a pipe in ft^2 that has a diameter of 2 feet.

$$Area = (0.785)(D)^2$$

$$A = (0.785)(2ft)(2ft)$$

$$A = 3.14\ ft^2$$

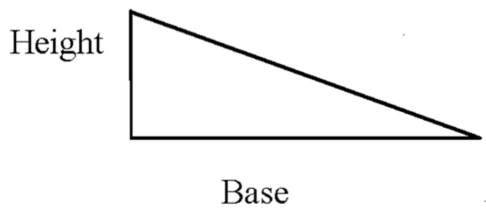


Area

- Area of Right Triangle

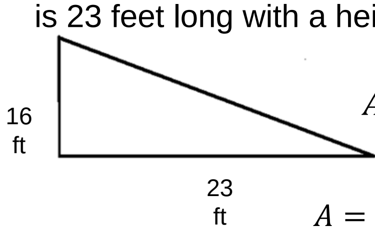
$$Area = \frac{(base)(height)}{2}$$

$$A = \frac{(b)(h)}{2}$$



Example 3

- Determine the area in ft^2 of a right triangle where the base is 23 feet long with a height of 16 feet.



$$A = \frac{(b)(h)}{2}$$

$$A = \frac{(23ft)(16ft)}{2}$$

$$A = \frac{368ft^2}{2}$$

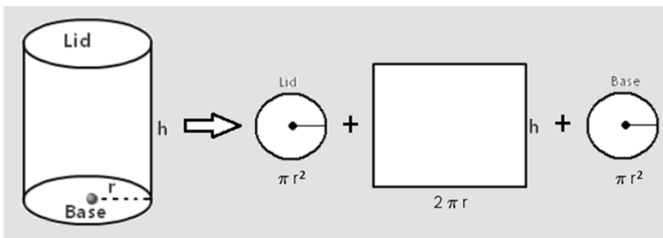
$$A = 184ft^2$$

Area

- Area of Cylinder (total exterior surface area)

$$Area = [surface\ area\ of\ end\ \#1] + [surface\ area\ of\ end\ \#2] + [(3.14)(Diameter)(height)]$$

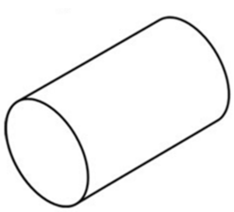
$$A = A_1 + A_2 + [(3.14)(D)(h)]$$



Example 4

- Find the total exterior surface area (in ft[2]) of a pipeline that is 2 ft in diameter and 20 feet long.

$$A = A_1 + A_2 + [(3.14)(D)(h)]$$



$$A_1 = (0.785)(D)^2$$

$$A_1 = (0.785)(2ft)(2ft)$$

$$A_1 = 3.14ft^2$$

$$A_1 = A_2$$

$$A = 3.14ft^2 + 3.14ft^2 + [(3.14)(2ft)(20ft)]$$

$$A = 3.14ft^2 + 3.14ft^2 + 125.6ft^2$$

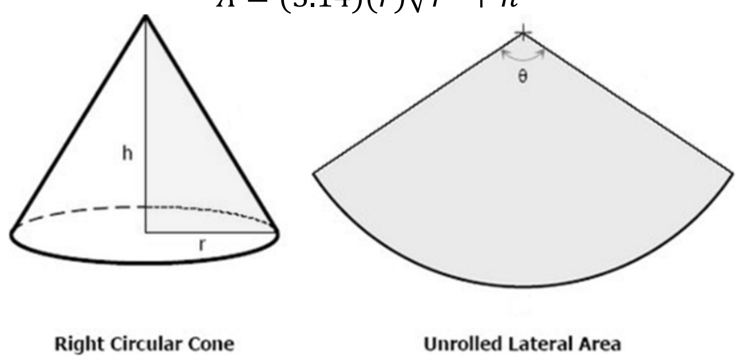
$$A = 131.88\ ft^2$$

Area

- Area of Cone (lateral area)

$$Area = (3.14)(radius)\sqrt{radius^2 + height^2}$$

$$A = (3.14)(r)\sqrt{r^2 + h^2}$$



Example 5

- Find the lateral area (in ft²) of a cone that is 3 feet tall and has a radius of 1.5 feet.

$$A = (3.14)(r)\sqrt{r^2 + h^2}$$

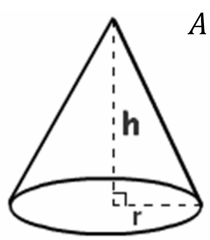
$$A = (3.14)(1.5ft)\sqrt{(1.5ft)(1.5ft) + (3ft)(3ft)}$$

$$A = (3.14)(1.5ft)\sqrt{2.25ft^2 + 9ft^2}$$

$$A = (3.14)(1.5ft)\sqrt{11.25ft^2}$$

$$A = (3.14)(1.5ft)(3.3541ft)$$

$$A = 15.80ft^2$$

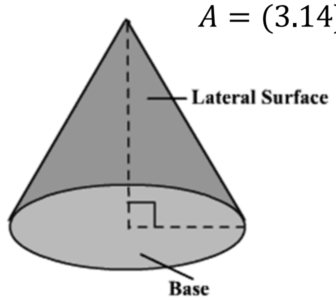


Area

- Area of Cone (total surface area)

$$Area = (3.14)(radius)(radius + \sqrt{radius^2 + height^2}\ )$$

$$A = (3.14)(r)(r + \sqrt{r^2 + h^2}\ )$$



Example 6

- Find the total surface area in ft^2 of a cone that is 4.5 feet deep with a diameter of 6 feet.

$$A = (3.14)(r)(r + \sqrt{r^2 + h^2}\ )$$

$$A = (3.14)(3ft)(3ft + \sqrt{(3ft)(3ft) + (4.5ft)(4.5ft)}\ )$$

$$A = (3.14)(3ft)(3ft + \sqrt{9ft^2 + 20.25ft^2}\ )$$

$$A = (3.14)(3ft)(3ft + \sqrt{29.25ft^2}\ )$$

$$A = (3.14)(3ft)(3ft + 5.4083ft)$$

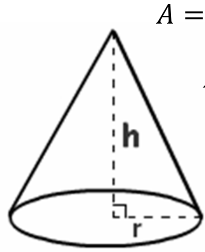
$$A = (3.14)(3ft)(8.4083ft)$$

$$A = 79.21ft^2$$

$$radius = \frac{1}{2}D$$

$$r = \left(\frac{1}{2}\right)6ft$$

$$r = 3\ ft$$



Volume

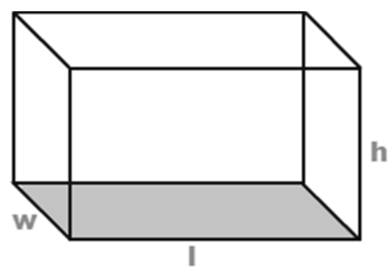
Volume

- Volume is the capacity of a unit or how much it will hold
- Measured in
  - cubic units (ft^3, m^3, yd^3) or
  - liquid volume units (gallons, liters, million gallons)
- The answer will come out in cubic units
  - You must then convert it to liquid volume units

Volume of a Rectangle

$$Volume = (length)(width)(height)$$

$$Vol = (l)(w)(h)$$



Example 1

- Determine the volume in m^3 for a tank that measures 30 meters by 15 meters by 25 meters.

$$Vol = (l)(w)(h)$$

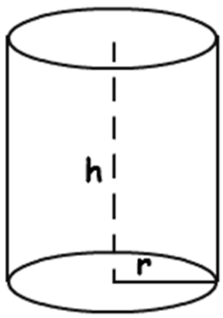
$$Vol = (30m)(15m)(25m)$$

$$Vol = 11250m^3$$

Volume of a Cylinder

$$Volume = (0.785)(Diameter^2)(height)$$

$$Vol = (0.785)(D^2)(h)$$



Example 2

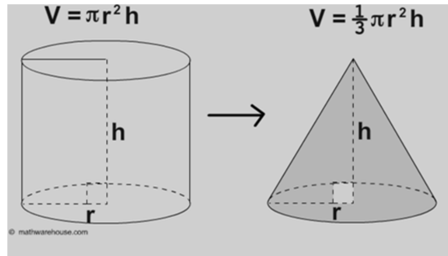
- Determine the volume in ft^3 for a tank that is 20 feet tall with a diameter of 7.5 ft.

$$Vol = (0.785)(D)^2(h)$$

$$Vol = (0.785)(7.5ft)(7.5ft)(20ft)$$

$$Vol = 883.13\ ft^3$$

Volume of a Cone



$$Volume = \left(\frac{1}{3}\right)(0.785)(Diameter^2)(height)$$

$$Vol = \left(\frac{1}{3}\right)(0.785)(D^2)(h)$$

Example 3

- Determine the volume in gallons of a conical tank that is 8 feet wide and 15 feet tall.

$$Vol = \left(\frac{1}{3}\right)(0.785)(D^2)(h)$$

$$Vol = \left(\frac{1}{3}\right)(0.785)(8ft)(8ft)(15ft)$$

$$Vol = (0.3333)(753.6\ ft^3)$$

$$Vol = 251.1749\ ft^3$$

$$Vol, gal = (251.1749\ \cancel{ft^3})\left(7.48\ \frac{gal}{\cancel{ft^3}}\right)$$

$$Vol, gal = 1878.78\ gallons$$

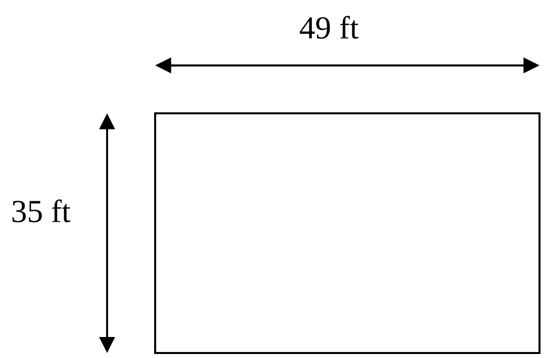
Math Problem Strategies

Strategy for solving word problems:

1) Read the problem, disregard the numbers (What type of problem is it? What am I asked to find?)
2) Refer to the diagram, if provided. If there isn't one, draw your own.
3) What information do I need to solve the problem, and how is it given in the statement of the problem?
4) Work it out.
5) Does it make sense?

It might be helpful to write out everything that is known in one column and the unknown (what am I asked to find?) in another column. Identify the correct formula and write it in the middle, plug in the numbers and solve.

Known		**Unknown**
Length = 35 ft Width = 49 ft		Area = ?
	A = (l)(w)	
	A = (35 ft)(49 ft) A = 1715 ft^2	

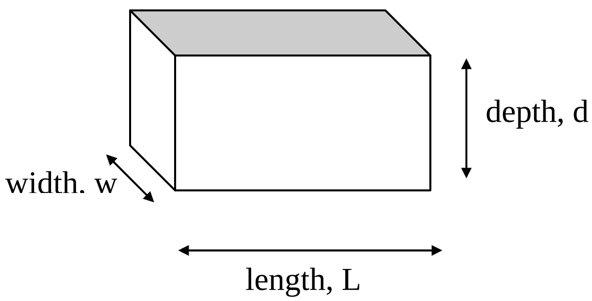


*****Remember: make sure measurements agree; if diameter of pipe is in inches then change to feet; if flow is in MGD and you need feet or feet/sec then change to ft^3/sec before you plug values into formula.***

mega (M)	. .	kilo (k)	hecto (h)	deka (da)	no prefix	deci (d)	centi (c)	milli (m)	. .	micro (μ)
1,000,000		1,000	100	10	1	$^{1}/_{10}$	$^{1}/_{100}$	$^{1}/_{1,000}$		$^{1}/_{1,000,000}$

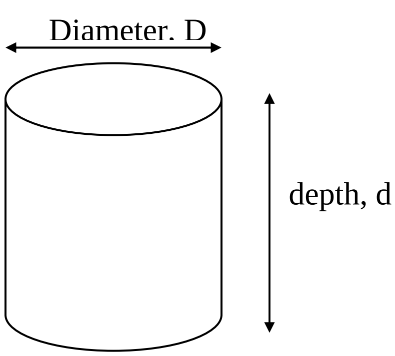
Tank Volume Calculations: Most tank volumes calculations are for tanks that are either rectangular or cylindrical in shape.

Rectangular Tank



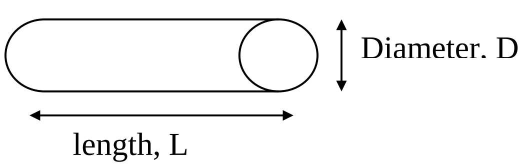
$$\text{Volume} = (L)(W)(d)$$

Cylindrical Tank



$$\text{Volume} = (0.785)(D)^2(d)$$

Portion of a Pipeline



$$\text{Volume} = (0.785)(D)^2(L)$$

Basic Math
Circumference, Area, and Volume
Examples

1. A chemical holding tank has a diameter of 24 feet. What is the circumference of the tank in feet?

2. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

3. Calculate the surface area (in ft^2) of the top of a basin which is 90 feet long, 25 feet wide, and 10 feet deep.

4. Calculate the cross-sectional area (in ft^2) for a 24-inch diameter main that has just been laid.

5. A triangular portion of concrete has just been poured. Calculate the surface area in square feet if the base concrete is 10 feet with a height of 15 ft.

6. Find the lateral surface area (ft^2) of a cone shaped chemical hopper if the hopper is 5 feet deep and 3 feet wide.

7. A conical water storage tank is covered. It has a diameter of 75 feet and a height of 50 feet. Calculate the total surface area of the tank (in ft^2).

8. A cylindrical storage tank is used to hold the day's supply of chemical. If the tank is 3 feet wide and 8 feet deep, what is the total exterior surface area of the cylinder in square feet?

9. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

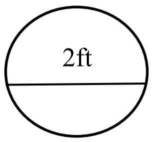
10. Calculate the volume of water in a rectangular tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

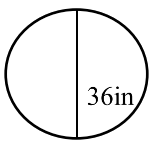
11. A new water main needs to be disinfected. The main is 30" in diameter and has a length of 1320 ft. How many gallons of water will it hold?

12. Calculate the volume (in ft^3) of a cone shaped chemical hopper with a diameter of 12 feet and a depth of 18 feet.

Basic Math for All Certifications
Circumference, Area, and Volume

Circumference (give answers in ft)

1. 

2. 

Area

3. What is the area (in ft^2) of a rectangle 5 ft by 4 ft?

4. A rectangle has a length of 5 feet and a width of 3 feet. What is the area (in ft^2) of the rectangle?

5. The diameter of a circle is 5 feet. What is its area (in ft^2)?

6. What is the cross-sectional area (in ft^2) of a pipe with a diameter of 7 inches?

7. What is the lateral surface area (in ft^2) of a cone with a radius of 12.5 ft and a height of18 ft?

8. Calculate the total surface area (in ft^2) of a cone that has a diameter of 15 feet and a height of 7 feet.

Volume

9. The dimensions of a tank are 60 feet wide, 10 feet deep and 15 feet long. Calculate the volume of the tank in cubic feet.

10. A square tank is 25 ft wide, 75 ft long and can hold water to a depth of 10 ft. What is the volume of the tank, in gallons?

11. The diameter of a tank is 60 ft. When the water depth is 25 ft, what is the volume of the water in the tank, in ft^3?

Miscellaneous Questions

12. Calculate the volume (in gal) of a water tank that is 19 feet in diameter with a height of 25 feet.

13. Calculate the volume of water (in ft^3) in a section of rectangular channel that is 4 feet deep, 5 feet wide, and 50 feet long.

14. A tank is 12 ft wide, 20 ft long and 15 deep. If the depth of the water is 11 ft, how many gallons of water are in the tank?

15. A new section of 12-inch diameter pipe is to be disinfected before it is put into service. If the length of the pipe is 2000 ft, how many gallons of water will be needed to fill the pipeline?

16. A section of 6 inch diameter pipeline is to be filled with chlorinated water for disinfection. If ¼ mile of pipeline is to be disinfected, how many gallons of water will be required?

17. A circular clarifier has a diameter of 40 ft. What is the surface area (in ft^2) of the clarifier?

18. The surface area of a tank is 2000 ft^2. If the width of the tank is 25 feet, what is the length of the tank in feet?

19. What is the cubic yard volume of a trench 500 ft long, 2.25 ft wide and 4 ft deep? (1 yd^3 = 27 ft^3)

20. What is the diameter of a pipe (in feet) that is 750 feet long and holds 1324 ft^3 of water?

21. The top of a tank has a surface area of 3150 ft^2. If the width of the tank is 35 ft, what is the length of the tank?

22. Calculate the volume of water in gallons in a 6 foot deep channel holding 4 feet of water. The channel is 5 feet wide and 120 feet long.

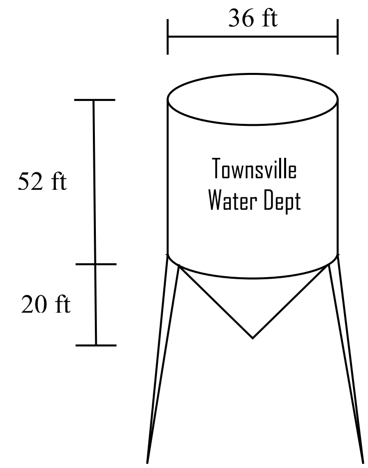
23. A tank is 12 ft wide and 20 feet long. If the depth of water is 11 feet, what is the volume of water in the tank in gallons?

24. Determine the amount of water, in gallons, to be disinfected in a new 36 inch water main that is 2 miles long.

25. A tank will hold 75,000 gallons. What is the volume of water in the tank, in gallons, if the depth is 12.5 feet, width is 20 ft, and length is 25 ft?

26. A 55 gallon steel drum with a diameter of 24 inches and a height of 42 inches needs to be painted. Calculate how many square feet of paint you would need to paint the entire outside of the barrel.

27. A circular water tower that is tapered at the bottom has a diameter of 36 feet and a height of 52 feet from the top to the beginning of the taper. The cone created by the taper has a height of 20 feet. Calculate the total exterior surface area of the water tower.



28. Refer to the water tower in #27. Calculate the total volume (in gallons) when the tower is full.

Answers

1. 6.28 ft
2. 9.42 ft
3. 20 ft^2
4. 15 ft^2
5. 19.63 ft^2
6. 0.27 ft^2
7. 860.15 ft^2
8. 418.23 ft^2
9. 9,000 ft^3
10. 140,250 gal
11. 70,650 ft^3
12. 52,992.99 gal
13. 1,000 ft^3
14. 19,747.2 gal
15. 11,743.6 gal
16. 1,937.69 gal
17. 1,256 ft^2
18. 80 ft
19. 166.67 yd^3
20. 1.5 ft
21. 90 ft
22. 17,952 gal
23. 19,747.2 gal
24. 558,055.87 gal
25. 46,750 gal
26. 28.26 ft^2
27. 8,416.24 ft^2
28. 446,444.70 gal

Velocity & Flow

Velocity

- The speed at which something is moving
- Measured in
  - $^{ft}/_{min}$ $^{ft}/_{sec}$ $^{miles}/_{hr}$ etc

$$\text{Velocity, ft/sec} = \frac{\text{distance, ft}}{\text{time, sec}}$$

Example 1

- Blue dye is placed in a sewer line at a manhole. Three (3) minutes later, the dye appears in a manhole 125 feet down stream. What is the velocity of the flow in ft/min?

$$\text{Velocity} = \frac{\text{distance, ft}}{\text{time, sec}}$$

$$\text{Vel} = \frac{125 \text{ ft}}{3 \text{ min}}$$

$$\text{Vel} = 41.67 \ {}^{\text{ft}}/_{\text{min}}$$

Flow

- The volume of water that flows over a period of time
  - $\frac{\text{volume}}{\text{time}}$
- Measured in
  - ${}^{\text{ft}^3}/_{\text{sec}}$ ${}^{\text{ft}^3}/_{\text{min}}$ ${}^{\text{gal}}/_{\text{day}}$ ${}^{\text{MG}}/_{\text{D}}$

$$\text{Flow} = (\text{Area})(\text{Velocity})$$

$$\text{Q} = \text{AV}$$

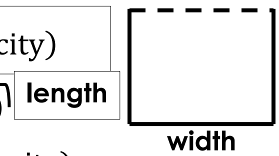
Flow Through a Channel

Water is flowing at velocity 3 ft/sec through a channel that is 2 feet wide and 1.5 feet deep. Calculate the flow in cubic feet per second.

Vel = 3 ft/sec
Width = 2 ft
Depth = 1.5 ft

$$\text{Flow} = (\text{Area})(\text{Velocity})$$

$$\text{Area} = (\text{length})(\text{width})$$



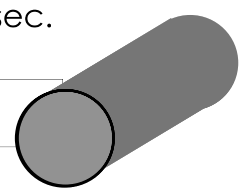
$$\text{Flow} = (\text{length})(\text{width})(\text{velocity})$$

$$\text{Flow} = (1.5\ \text{ft})(2\ \text{ft})(3\ \text{ft/sec})$$

$$\text{Flow} = 9\ \text{ft}^3/\text{sec}$$

Flow Through a Pipeline

- Determine the flow in ft^3/sec through a 5-foot pipe that is flowing full at a velocity of 4.5 ft/sec.



Vel = 4.5 ft/sec
Width = 5 ft

$$\text{Flow} = (\text{Area})(\text{Velocity})$$

$$\text{Area} = (0.785)(\text{Diameter})^2$$

$$\text{Flow} = (0.785)(5\ \text{ft})(5\ \text{ft})(4.5\ \text{ft/sec})$$

$$\text{Flow} = 88.3\ \text{ft}^3/\text{sec}$$

Velocity and Flow
Examples

1. A bobber is placed in a channel and travels 450 feet in 2 ½ minutes. What is the velocity of the water flowing in the channel in ft/min?

2. A channel 30 inches wide has water flowing to a depth of 2 feet. If the velocity of the water is 2.75 ft/sec, what is the flow in the channel in ft^3/sec? And gal/min?

3. The flow through a 24 inch pipe is moving at a velocity of 5.4 ft/sec. What is the flow rate in gal/min?

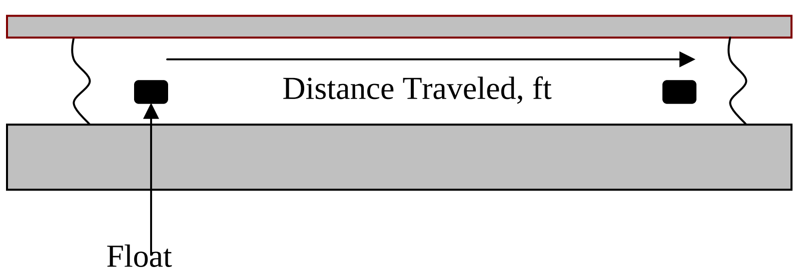
Basic Math for Water and Wastewater
Flow and Velocity

<u>Velocity</u>

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

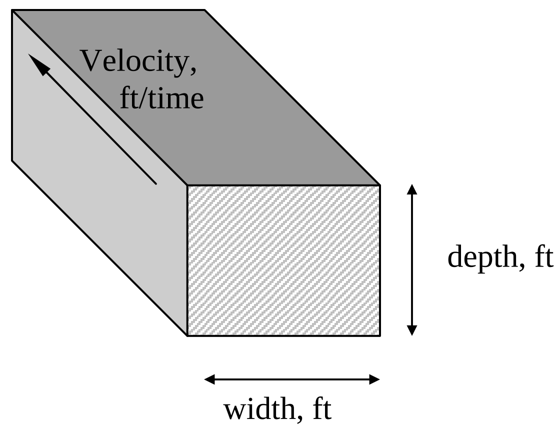
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$

1.) 185 ft/min 2.) 2.2 ft/sec 3.) 210 ft/min



$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \; \underset{(ft/time)}{(V)}$$

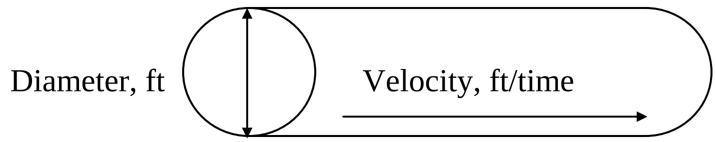
Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?

4.) 16.8 ft^3/sec 5.) 900ft^3/min; 9.7 MGD 6.) 1.8 ft



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \; \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\,\underset{(ft)(ft)}{(D)^2}\,\underset{(ft/time)}{(vel)}$$

<u>Flow through a full pipe</u>

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

9. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

10. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

7.) 10.05 ft3/sec 8.) 0.59 ft3/sec 9.) 6 in 10.) 532.4 gpm

Basic Math for Water and Wastewater
FLOW RATE

Q = AV

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min?

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm?

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe?

5. What would be the gpd flow rate for a 6” line flowing at 2 feet/second?

6. A 36” water main has just been installed. According to the Design Criteria for the State of Tennessee, the minimum flushing velocity is 2 ft/sec. If the main is flushed at 2.5 ft/second, how many gallons/minute should be flushed from the hydrant?

7. A 36” water main has just been installed. If the main is flows at 2 ft/second, how many MGD will the pipe deliver?

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe?

VELOCITY (Open Channel)

9. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

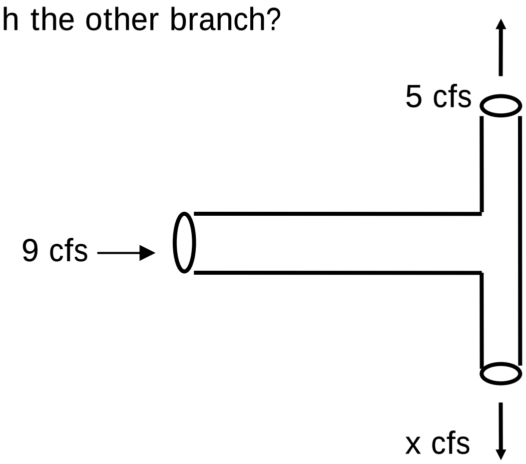
10. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in feet per second?

11. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the cubic-feet-per-minute flow rate in the channel?

FLOW

12. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24" main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that month?

13. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?



ANSWERS:

Flow and Velocity

1. 185 ft/ min
2. 2.24 ft/sec
3. 210 ft/min
4. 16.8 cfs
5. 9.69 MGD
6. 1.8 ft
7. 10.05 cfs
8. 0.59 cfs
9. 6 in
10. 532.4 gpm

Flow Rate

1. 10.8 ft^3/sec
2. 86.35 ft^3/min
3. 2,404.50 gpm
4. 7,170,172.42 gpd
5. 253,661.76 gpd
6. 7,926.93 gpm
7. 9.13 MGD
8. 9.47 MGD
9. 120 ft/min
10. 1.5 ft/sec
11. 1,533.33 ft^3/min
12. 136.83 MG
13. 4 ft^3/sec

Disinfection

Hypochlorite

- 2 types of hypochlorite used for disinfection in typical drinking water systems
  - Sodium hypochlorite
    - $NaOCl$
    - Bleach
    - 5-15% concentration
  - Calcium hypochlorite
    - $Ca(OCl)_2$
    - High test hypochlorite (HTH)
    - 65% concentration

Chlorination

- The pounds formula will be one of the most important formulas to learn this week.

$$\text{feed rate}, \frac{\text{lb}}{\text{day}} = \frac{(\text{dose, mg/L})(\text{flow, MGD})(8.34\frac{\text{lb}}{\text{gal}})}{\%\ \text{purity}}$$

- If no purity provided, assume it is 100%

Example 1

- A water system wants to feed calcium hypochlorite with a purity of 65%. The required dose is 8 mg/L to completely disinfect a flow of 3 MGD. How many pounds per day of disinfectant must be fed?

$$\text{feed rate}, \frac{\text{lb}}{\text{day}} = \frac{(\text{dose, mg/L})(\text{flow, MGD})(8.34\frac{\text{lb}}{\text{gal}})}{\%\ \text{purity}}$$

Chlorination

- When asked to find dose, solve pounds formula for the unknown (dose)

$$\text{dose}, \frac{\text{mg}}{\text{L}} = \frac{(\text{feed rate}, \frac{\text{lb}}{\text{day}})(\%\ \text{purity})}{(\text{flow, MGD})(8.34\frac{\text{lb}}{\text{gal}})}$$

- This formula can also be found on page
  - Make sure to take into account any % chemical purity provided

CT Calculation

Kill = C x T

- Concentration and contact time are two of the most important parameters in chlorination
- They are inversely proportional
  - As one decreases, the other must increase
- CT is simply the concentration of chlorine in your water times the time of contact that the chlorine has with your water
  - Measured in $\frac{\text{mg} \cdot \text{min}}{\text{L}}$

$$\text{CT} = (\text{disinfectant residual}, \frac{\text{mg}}{\text{L}})(\text{time, min})$$

Example 3

- Treated water is dosed with 5 mg/L of chlorine for 30 minutes. What is the CT?

$$\mathrm{CT} = (\text{disinfectant residual}, \tfrac{\mathrm{mg}}{\mathrm{L}})(\text{time}, \mathrm{min})$$

Two Normal equation

- $\mathrm{C} =$concentration
- $\mathrm{V} = \text{volume or flow}$

$$\mathrm{C}_1 \times \mathrm{V}_1 = \mathrm{C}_2 \times \mathrm{V}_2$$
$$\text{want} = \text{have}$$

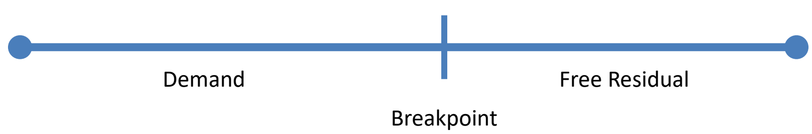
- See also page 6 in FTC formula book

Example 4

- A distribution operator needs to make 10 gallons of a bleach dilution with a concentration 25 mg/L. The bleach on hand has a concentration of 100 mg/L. How many gallons of the concentrate must be used to achieve the dilution?

$$C_1 \times V_1 = C_2 \times V_2$$

Breakpoint Chlorination



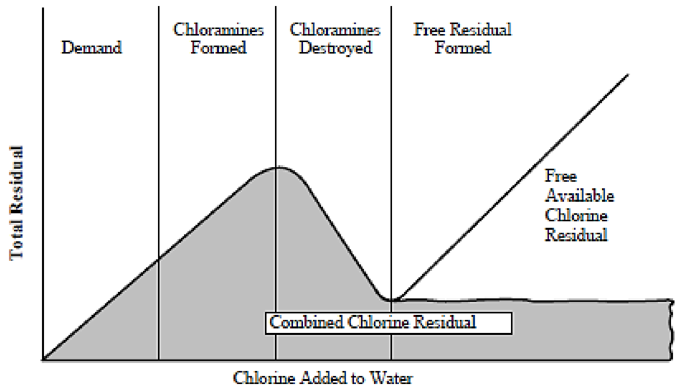
- Total chlorine dose = residual + demand

  -residual - residual

- Dose – residual = demand

Breakpoint Chlorination

- Total chlorine = free residual + combined residual



Disinfection

1. Determine the feed rate in lb/day for a system that wants to dose 2.6 mg/L of 65% HTH. The plant averages 150,000 gallons per day.

2. How many gallons per day of 0.08% sodium hypochlorite would a system need to feed to obtain the required dose of 1.9 mg/L if the system treats 2.0 MGD?

3. Calculate the chlorine dose (mg/L) required if the demand of a water source is 3.7 mg/L and the utility wants to maintain a chlorine residual of 0.8 mg/L in the system.

4. A booster chlorination station feeds 90 lbs/day of chlorine gas to disinfect 900,000 gpd. What is the dose in mg/L?

5. An operator desires 5 gallons of 10 percent bleach. How many gallons of 50% bleach is required to make the dilution?

6. How many pounds of 65% available HTH is needed to make 4 gallons of 12.5% HTH solution?

7. Treated water travels through a water storage tank in 2 hours. When the water is tested at the end of the 2 hours, the free chlorine residual is approximately 2.3 mg/L. What is the CT in mg•min/L?

Distribution Systems

Disinfection Practice Problems

Volume

1. A tank is 60 feet in diameter and has a distance of 90 feet to the overflow. How many million gallons will the tank hold?

2. A tank holds 1.8 million gallons. How many gallons is 5% of the total volume?

3. How many gallons are in a pipe that is 18 inches in diameter and 1,165 feet long?

Pounds

4. If a storage tank holds 1,000,000 gallons filled to the overflow, and the initial chlorine dose needs to be 15 mg/L, how many pounds of HTH 65% available chlorine will it take to get the required dose?

5. The desired chlorine dosage is 10 mg/L. Determine the lb/day setting on a dry chemical feeder if the flow is 3,450,000 gpd.

6. The required dose for a water sample is 12 mg/L. If the flow to be treated is 1,660,000 gpd, what should the dry chemical feed setting be in lb/day?

7. How many pounds of calcium hypochlorite that contains 64.3% available chlorine are needed to disinfect a water main that is 24 inches in diameter, if the pipeline is 781 ft long and the dosage required is 50 mg/L?

Dose

8. A water treatment plant is treating 16.4 MGD. If the chlorine feed rate is 415 lb/day, what is the chlorine dosage in mg/L?

9. What is the chlorine dosage at a water treatment plant, if the chlorinator is set on 320 lb/day and the plant is treating 11.6 MGD?

10. A 2 foot diameter pipe that is 2.45 miles long was disinfected with chlorine. If 126.9 lbs of chlorine were used, what was the initial dosage in mg/L?

Dilutions/Solutions

11. How many gallons of bleach (15% available chlorine) will it take to make a 4% solution when added to enough water to make 50 gallons of hypochlorite?

12. How many pounds of HTH (65% available chlorine) will it take to make a 2% solution when dissolved in enough water to make 15 gallons of hypochlorite?

Practice Problems

13. The 50,000 gallon storage tank is disinfected using AWWA Chlorination Method 3 with 50 mg/L using HTH. How many pounds of HTH 65% available chlorine would be required if the tank is filled to a 10% capacity?

14. What is the dosage in milligrams per liter for a treatment plant that uses 855 lb/day of chlorine and treats 45.25 MGD?

15. How many pounds of 65% available HTH is needed to make 5 gallons of 18% solution?

16. How many pounds of 65% available chlorine HTH is needed to make 1 gallon of 10% solution?

17. The chlorine demand of a water process is 1.6 mg/L. If the desired chlorine residual is 0.5 mg/L, what is the desired chlorine dose?

18. The chlorine dosage for a water process is 2.9 mg/L. If the chlorine residual after 30 minutes of contact time is found to be 0.7 mg/L, what is the chlorine demand expressed in mg/L?

19. You have just laid 5,000 feet of 10 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

20. A section of an old 8" water main has been replaced. The 350-foot section of pipe needs to be disinfected. What is the volume (in gallons) to be disinfected?

21. You have just laid ¾ mile long section of 16 inch line and it needs disinfecting. How many pounds of 65% HTH chlorine will be required to dose the line with 10 mg/L?

22. A flow of 3,880,000 gpd is to be disinfected with chlorine. If the chlorine demand is 2.6 mg/L and a chlorine residual of 0.8 mg/L is desired, what should be the chlorinator setting in lb/day?

23. How many pounds of HTH (65% available chlorine) will it take to make a 2% solution when dissolved in enough water to make 15 gallons of hypochlorite?

24. You have just laid 25,000 feet of 24 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

25. A storage tank that is going to be put back into service requires disinfection at a dosage of 30 mg/L. If the tank has a diameter of 102 ft and is 28.1 ft in height at the overflow, how many gallons of 10.25% sodium hypochlorite solution will be needed if the tank is filled to 10% capacity?

26. How many gal of 5.25% bleach is used to make 1 gallon of 3% solution?

27. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 3 to disinfect the tank. This method requires you to make up a 50 mg/L available chlorine solution that will fill approximately 5% of the tank volume. The tank holds 3 MG. How many gallons of water and lbs of HTH 65% available chlorine will have to be added to meet the above mentioned requirements?

28. You have just laid 200 feet of 8 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

29. How many gallons of bleach (5.25% available chlorine) will it take to make a 2% solution when added to enough water to make 8 gallons of hypochlorite?

30. A water treatment plant is feeding an average of 210 lb/day of chlorine. If the dosage is 3.25 mg/L, what is the number of millions of gallons per day being treated?

31. What should the setting be on a chlorinator in pounds per day if the dosage desired is 2.70 mg/L and the pumping rate from the well is 845 gpm?

32. A well is pumping at a rate of 428 gpm. What should be the setting on a chlorinator in pounds per day, if the residual desired is 1.20 mg/L and the chlorine demand is 3.85 mg/L?

33. What should be the setting on a chlorinator in pounds per day, if the residual desired is 1.75 mg/L, the chlorine demand averages 2.45 mg/L, and the pumping rate from the well is 208 gpm?

34. A 24 inch pipeline, 427 feet long, was disinfected with calcium hypochlorite tablets with 65% available chlorine. Determine the chlorine dosage in mg/L, if 7.0 lb of calcium hypochlorite was used. Assume that the hypochlorite is so diluted that it weighs 8.34 lb/gal.

35. A 1.75 MG storage tank needs to be disinfected with a sodium hypochlorite solution that contains 12% available chlorine and weighs 8.97 lb/gal. If the chlorine dosage is to be 50 mg/L, how many gallons of sodium hypochlorite are required?

Answers

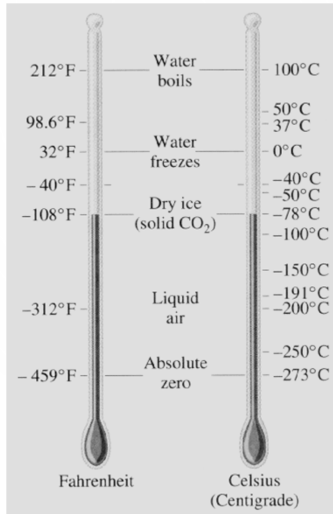
1.)	1.90 MG	19.)	6.54 lb
2.)	90,000 gal	20.)	913.48 gal
3.)	15,391.46 gal	21.)	5.3 lb
4.)	192.46 lb	22.)	110.02 lb/day
5.)	287.73 lb/day	23.)	3.85 lb
6.)	166.13 lb/day	24.)	188.32 lb
7.)	11.87 lb	25.)	50.2 gal
8.)	3.03 mg/L	26.)	0.57 gal
9.)	3.3 mg/L	27.)	96.23 lb
10.)	50.1 mg/L	28.)	0.17 lb
11.)	13.3 gal	29.)	3.05 gal
12.)	3.85 lb	30.)	7,750,000 gpd
13.)	3.21 lb	31.)	27.4 lb/day
14.)	2.27 mg/L	32.)	25.95 lb/day
15.)	11.55 lb	33.)	10.49 lb/day
16.)	1.28 lb	34.)	54.56 mg/L
17.)	2.1 mg/L	35.)	677.95 gal
18.)	2.2 mg/L		

LABORATORY CALCULATIONS

TEMPERATURE CONVERSIONS

TEMPERATURE SCALES

The **Fahrenheit** scale is named for the 18th-century German physicist Daniel Fahrenheit.
His scale is based on 32 for the freezing point of water and 212 for the boiling point of water, the interval between the two being divided into 180 parts.
The scale was in common use in English speaking countries until the 1970's when Europe and Canada adopted the centigrade (Celsius) scale.
The U.S is the only country that still uses the Fahrenheit scale.



The **Celsius** temperature scale is named for the in the Swedish astronomer Anders Celsius who invented the scale in 1742.

The scale is based on 0 for the freezing point of water and 100 for the boiling point of water.

It is sometimes called the centigrade scale because of the 100-degree interval between the defined points.

3

TEMPERATURE FORMULAS

- Degrees Fahrenheit

$$°F = (°C)(1.8) + 32$$

Remember your Order of Operations!!

- Degrees Celsius

$$°C = \frac{(°F - 32)}{1.8}$$

EXAMPLE 1

- Determine the temperature in °F if the temperature is measured as 43°C.

$$°F = (°C)(1.8) + 32$$

EXAMPLE 2

- Water temperature is measured with a pH probe to be 87 °F. What is this in Celsius?

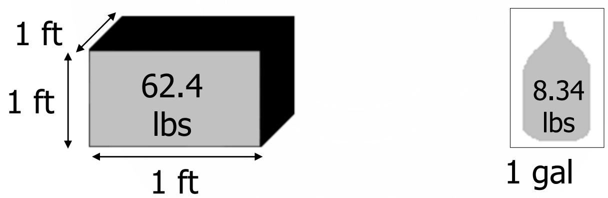
$$°C = \frac{(°F - 32)}{1.8}$$

SPECIFIC GRAVITY AND DENSITY

DENSITY

- weight per unit volume
  - solids and gases expressed in lb/ft^3
  - liquids measured in lb/gal or lb/ft^3
- density of water varies slightly with temperature and pressure
- density of gases changes significantly with changes in temperature and pressure

DENSITY OF WATER



The density of water is

62.4 lbs/ft^3

or

8.34 lbs/gal

SPECIFIC GRAVITY

- compares density of a substance to a standard density
- does not have units
- for solids and liquids
  - compare to standard density of water
    - 62.4 lb/ft^3
    - 8.34 lb/gal

SPECIFIC GRAVITY

$$Specific\ Gravity = \frac{weight\ of\ substance}{weight\ of\ water}$$

- Weights can be measured in $^{lb}/_{gal}$ or $^{lb}/_{ft^3}$
  - Be sure the units are consistent within the equation

EXAMPLE 3

- Determine the specific gravity of a liquid chemical that has a density of 10.5 lb/gal.

$$Specific\ Gravity = \frac{weight\ of\ substance}{weight\ of\ water}$$

Small Water Systems
Laboratory Calculations

1. Mechanical seals should never exceed 160°F. What is this temperature expressed in °C?

2. Convert 170°F to °C.

3. What is the percent removal across a settling basin if the influent turbidity is 8.8 ntu and the effluent turbidity at the settling basin is 0.89 ntu?

4. What is the turbidity removal efficiency through a water plant if the source water turbidity is 18.8 ntu and the treated water entering the distribution system is 0.035 ntu?

5. To determine the average turbidity coming into a plant, an operator collects 5 samples to combine into a 250 mL composite sample. The average flow at the intake is 230,000 gpd. If the flow at the time of the sample collection is 180 gpm. How many mL should the sample portion be at the time of collection?

6. Determine the specific gravity of a gold bar that weighs 521.47 lb and occupies a space of 0.433 ft^3.

7. Find the density (lbs/ft^3) of a certain oil that has a S.G. of 0.92.

8. What is the iron removal efficiency through a water plant if the source water iron content is 4.25 mg/L and the treated water entering the distribution system is 0.030 mg/L?

9. How many pounds of liquid can be pumped per day?

Pump rate desired:	25 gpm
Liquid weight:	74.9 lbs/ft^3

10. Find the density (lbs/gal) of caustic soda that has a S.G. of 1.530.

11. A gallon of solution is weighed. After the weight of the container is subtracted, it is determined that the weight of the solution is 9.1 lb. What is the density of the solution in lb/ft^3?

12. The density of an unknown liquid is 74.1 lb/ft^3. What is the specific gravity of the liquid?

13. The effluent of a treatment plant is 23°C. What is this expressed in degrees Fahrenheit?

14. What is the specific gravity of a polymer solution that weighs 11.1 lb/gal?

15. Convert 17°C to degrees Fahrenheit.

16. What is the density of a substance in pounds per cubic foot if it weighs 29.27 kg and occupies a space of 0.985 ft^3?

17. The magnesium content of a water source averages 0.24 mg/L. What is the percent removal if the treated water averages 0.020 mg/L Mg?

18. A certain pump delivers 14 gallons per minute.
    A. How many lbs of water does the pump deliver in 24 hours?
    B. How many lbs/day will the pump deliver if the liquid weighs 8.1 lbs/gal?

19. A tank holds 1,240 gallons of a certain liquid. The specific gravity is 0.93. How many pounds of liquid are in the tank?

20. Determine the specific gravity of a polymer solution that weighs 1067 lb/gal.

21. Convert 43°C to degrees Fahrenheit.

22. The influent to a treatment plant has a temperature of 75°F. what is the temperature expressed in degrees Celsius?

23. If the influent turbidity for a water plant is 17.5 ntu and the effluent turbidity is 0.03, what is the percent removal?

24. What is the specific gravity for a solution that weighs 9.44 lb/gal?

25. To preserve a bacteriological sample, the sample must be cooled to 4°C. What is this expressed in degrees Fahrenheit?

26. What is the turbidity removal efficiency through a water plant if the source water turbidity is 22.6 ntu and the treated water entering the distribution system is 0.040 ntu?

27. A certain pump delivers 23 gallons per minute.
    A. How many lbs of water does the pump deliver in 1 minute?
    B. How many lbs/min will the pump deliver if the liquid weighs 71.9 lbs/ft^3?

28. Find the density (lbs/gal) of ferric chloride that has a S.G. of 1.140.

29. Find the density (lbs/ft^3) of potassium permanganate that has a S.G. of 1.522.

30. What is the specific gravity of an unknown liquid that has a density of 68.4 lb/ft^3?

Answers

1.) 71.1°C
2.) 388°F
3.) 89.89%
4.) 99.81%
5.) 56.35 mL
6.) 19.3
7.) 57.41 lb/ft^3
8.) 99.29%
9.) 68.07 lb/ft^3
10.) 12.76 lb/gal
11.) 68.07 lb/ft^3
12.) 1.1875
13.) 73.4°F
14.) 1.3309
15.) 62.6°F
16.) 65.51 lb/ft^3
17.) 91.67%
18.) A. 20,160 gal/day
B. 163,296 lb/day
19.) 9,617.69 lb
20.) 127.9376
21.) 109.4°F
22.) 23.9°C
23.) 99.8%
24.) 1.1319
25.) 39.2°F
26.) 99.82%
27.) A. 191.82 lb/min
B. 221.08 lb/min
28.) 9.51 lb/gal
29.) 94.97 lbs/ft^3
30.) 1.0962