Small Water Systems

Course # 2001
Part 1 of 2

TN Department of Environment & Conservation

Fleming Training Center
Your Partner in Clean Water

Updated 12/2/2019

State of Tennessee
Dept. of Environment & Conservation
Bureau of Environment
Fleming Training Center

Fleming Training Center
Your Partner in Clean Water

#2001 Small Water Systems

Instructor: Amanda Carter
Fleming Training Center

Day 1

8:30	Welcome and Roll Call
8:45	Water Sources and Treatment
9:45	Wells
11:00	Lunch
12:15	Small Water Plants
2:00	Disinfection

Day 2

8:30	Safety
9:00	Pumps & Equipment Maintenance
10:00	Cross Connection Control
11:00	Lunch
12:15	Rules and Regulations
2:00	Laboratory

Day 3

8:30	Basic Math
11:00	Lunch
12:15	Applied Math
2:30	Exam and Course Evaluation

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Section 1

Water Treatment 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:

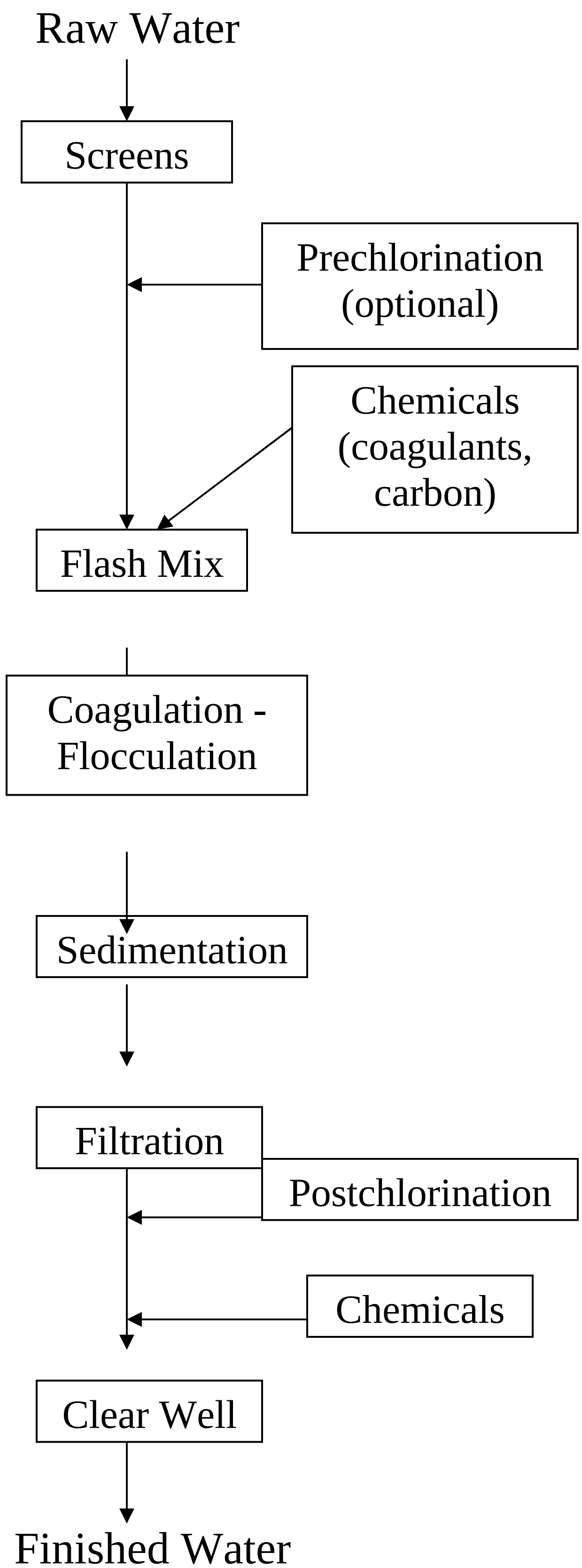
- Water is withdrawn from a lake, reservoir or river at the intake
- It is screened to remove debris
- Water then enters the flash mixing tank where coagulants and other chemicals are added
- Then it is divided into the flocculation basin
- After flocculation, the water enters the settling basins where 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



Removes leaves, sticks, fish and other large debris.

Kills most disease-causing organisms and helps control taste and odor causing substances.

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.

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

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

Settles out larger suspended particles.

Filters out remaining suspended particles.

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

Phosphates control corrosion, fluoride helps prevent dental decay.

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
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
$MgCl_2$	magnesium chloride
$MgCO_3$	magnesium carbonate
$Mg(HCO_3)_2$	magnesium bicarbonate
$Mg(OH)_2$	magnesium hydroxide
$MgSO_4$	magnesium sulfate
Mn	manganese

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
$Na_2O \bullet (SiO_2)_3$	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
SO_4	sulfate
$Zn_3(PO_4)_2$	zinc orthophosphate

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

ABC

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Acknowledgment

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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)

Very Small Water System Operators' Guidebook to Preparing for Certification

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Table of Contents

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
	Ability to demonstrate safe work habits
Organize work activities	Ability to determine what information needs to be recorded
Record information relating to facility performance	Ability to evaluate facility performance
	Ability to follow written procedures
Write reports	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 and Treatment

Small Water System Operation and Maintenance
California State University: Sacramento

Updated 11/20/2019

Water Supply Hydrology and the Hydrologic Cycle

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

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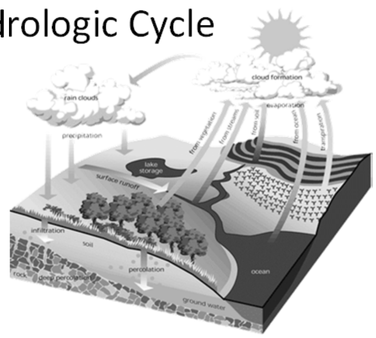
Hydrologic Cycle



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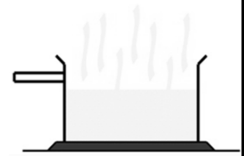
Hydrologic Cycle

- Evaporation and Transpiration
  - Evaporation
    - the changing of liquid to gas (water to water vapor)
  - Water is constantly evaporating from the earth
  - Transpiration
    - the process in which water from the earth is absorbed by plants and transferred to the air through the leaves



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Hydrologic Cycle

- Condensation and Precipitation
  - Condensation
    - occurs when water vapor condenses as it cools and forms tiny droplets of water or clouds
  - Precipitation
    - occurs when the droplets become too heavy to stay airborne
    - these droplets fall back to earth as rain, snow, sleet or hail

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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 (continues downward) to the water table

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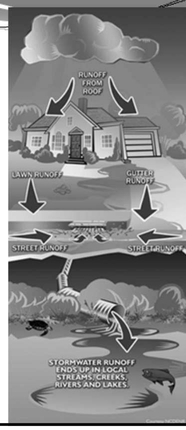
Hydrologic Cycle

- 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



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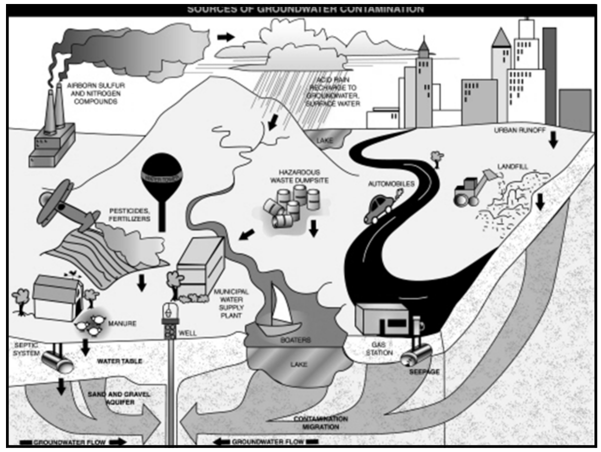

Groundwater

- Water below the surface
- Hidden resource
- Provides 20% of water used in the US
- Has few contaminants
- Resultant of infiltration and percolation
- Relatively free from micro contamination
- Characterized by:
  - high TDS
    - Fe & Mn
  - high dissolved gases
    - radon, CH_4, H_2S
  - low dissolved oxygen
  - low color
  - high hardness
- Can be influenced by natural and human activities

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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

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Aquifers

Unconfined Aquifers

- 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

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Aquifers

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 is usually under pressure
- Flowing artesian well
  - pressure causes water to rise above ground surface
- Non-flowing artesian well
  - water doesn't rise to the surface
- Piezometric surface
  - height that water rises

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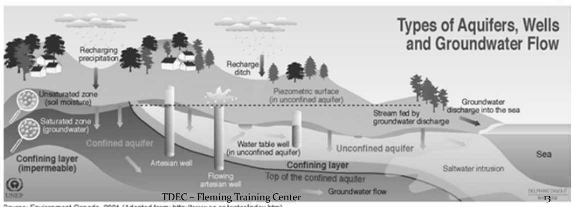
Aquifers

- 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

07



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

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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

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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

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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

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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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Surface Water Supply and Operating Problems

- Contamination
- Loss of water source by evaporation & seepage
- Weather (rain and snowfall)
- Exposure to environmental changes
- Icing
- Rainfall intensity and droughts
- Soil composition
- Human influences
- More and varied treatment processes

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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

<u>Answers</u>

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

SMALL WATER SYSTEM OPERATION AND MAINTENANCE
CALIFORNIA STATE UNIVERSITY: SACRAMENTO

Updated 11/20/2019

Groundwater

Importance of Groundwater

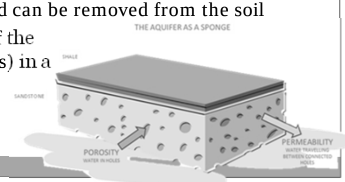
- Function of well is to intercept ground water moving through aquifers and bring water to surface
- Reasons for choosing groundwater source:
  - Generally available in all regions, though quantities may be limited
  - Less costly than surface treatment facilities
  - Less bacterial and viral contamination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

Water Cycle

- 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

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



Overdraft

- 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

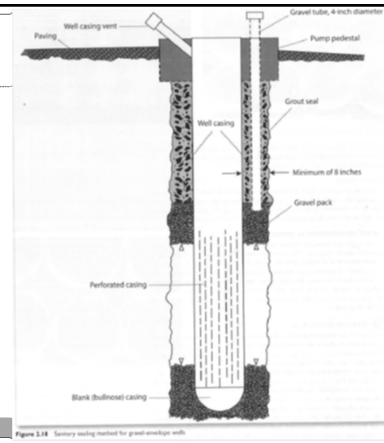
Surface Features of a Well

8

Well Surface Features

9

- 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



Well Surface Features

11

- 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

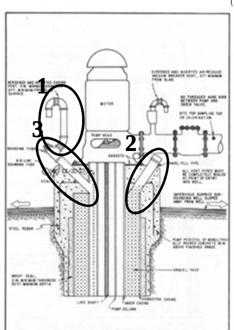


Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

Well Surface Features

12

- 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

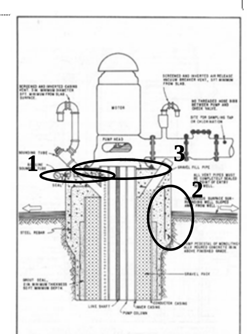


Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

Well Surface Features

13

- 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

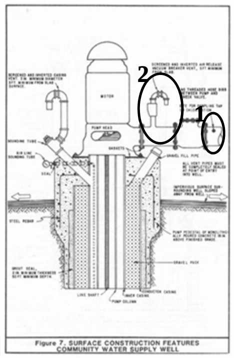


Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

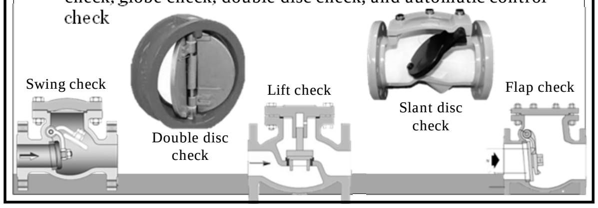
Well Appurtenances

14

Valves

15

- 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

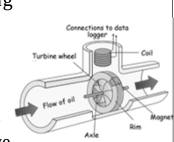
16

- 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

17

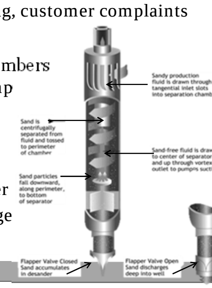
- Used to measure the amount of water being pumped to the system
  - Should be at least 5 pipe diameters distance downstream from any pipe bend, elbow or valve
  - Should be at least 2 pipe diameters distance upstream from any pipe bend, elbow or valve
  - Should be calibrated in place
  - Types:
    - 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

18

- 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

19

- 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

20

- 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

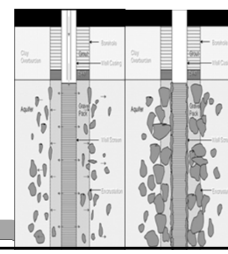
Well Maintenance and Rehabilitation

21

Factors Affecting Maintenance of Well Performance

22

- 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

23

- 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

24

- 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

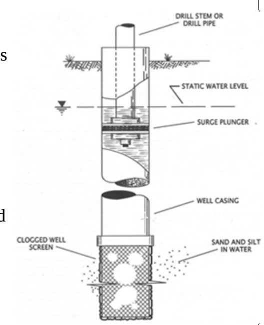
25

- 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

26

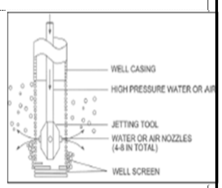
- Surging
  - Procedure used for opening pores in the screen and cleaning gravel pack
  - Common in new well development to purge sand around well screen
  - Effective at combating encrustation when used with acid treatment



Casing and Screen Maintenance

27

- 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

28

- 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

30

- 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

31

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

32

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

33

Well Pumps

34

- 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

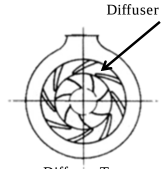
Types of Pumps

35

- 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



Diffuser Type

Types of Pumps

36

- Deep Well Turbine Pumps
  - Standard
    - Driven through rotating lineshaft 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 lineshaft 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

38

- 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

39

New Wells

40

- 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

41

- 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

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- 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

44

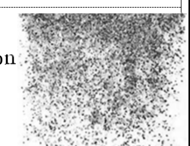
- Wells should be disinfected after repairs and/or parts replacement
  - Swab inside of well casing with non-foaming detergent
  - Add chlorine to provide 100 mg/L in water
    - Based of well diameter and water depth
  - Add chlorine through hose that is raised and lowered to reach all areas of well, 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

45

Sand in Well Systems

46




- 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

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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

Vocabulary

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

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

<u>Answers</u>

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

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

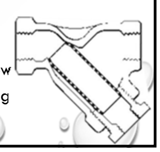
Updated 11/20/2019

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

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)

PACKAGE PLANTS

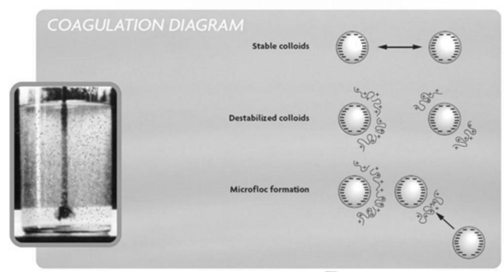
- Most commonly used for filtration of turbid water and removal of dissolved iron and manganese
- Includes all treatment equipment, pumps, chemical feeders, and controls
  - May choose instead to select a custom designed package plant with materials supplied by different manufacturers
- Advantages
  - 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.

COAGULATION & FLOCCULATION

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

COAGULATION



COAGULATION

- 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 alum
  - Mineral content of water
    - Different minerals will affect coagulation differently
  - Water temperature
    - Better coagulation in warmer water

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

COAGULATION OPTIMIZATION

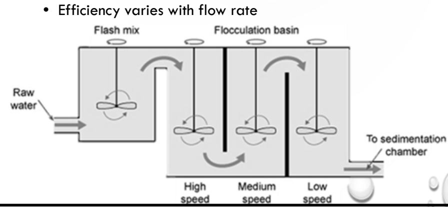
- Does the chemical feeder inject a steady chemical feed into the water?
  - Want consistent pulses vs long interval slug
- Is chemical injector distributing coagulant throughout flow of water?
  - Injectors with multiple-feed orifices better than single orifice
- Is violent rapid mixing provided just 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

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

FLOCCULATION

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



FLOCCULATION

- 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

FLOCCULATION OPTIMIZATION

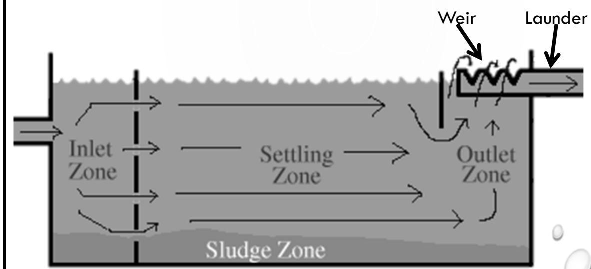
- Correct any deficiencies in the coagulation process
- Check degree of mixing – neither too violent nor too gentle
- Adequate mixing time
  - Do actual flow rates exceed design flows?
- Minimize short circuiting through basin
- Adjust plant to run on a more continuous basis and minimize frequent on/off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

SEDIMENTATION

SEDIMENTATION

- 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

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

SEDIMENTATION

- Factors affecting sedimentation
  - Surface overflow rate – lower rate is better than a higher rate
    - aka surface loading rate (SLR)
    - 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

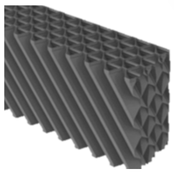
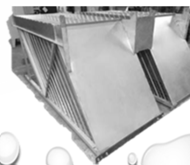


Plate Settler



FILTRATION

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

FILTER MEDIA LAYERS

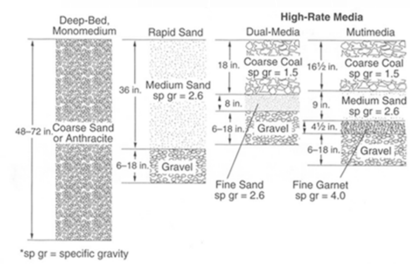


FIGURE 6–8 Comparison of deep-bed, rapid sand, and high-rate filter media

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

FILTRATION MODES

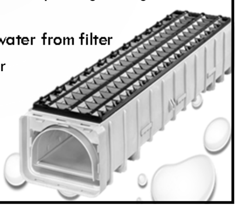
- Diatomaceous earth (precoat) filtration
  - DE is added as a slurry to water being treated and collects on a screening device
  - Water is filtered by passing it through the screening device coated in DE
  - Used where very high particle removal efficiencies required
  - Can be operated as gravity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

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 – 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

- 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
- Corrosion Control
- 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

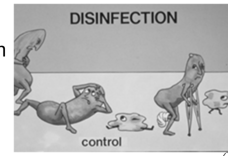
Water Treatment Plant Operation Vol. I

Updated 11/20/2019

TDEC - Fleming Training Center

DISINFECTION VS. STERILIZATION

- Disinfection – the destruction of **pathogenic organisms**
  - To prevent 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
- SWTR (Surface Water Treatment Rule)
  - Requires disinfection for all surface water supply systems to protect against exposure to viruses, bacteria, and *Giardia*

SAFE DRINKING WATER LAWS

- IESWTR (Interim Enhanced Surface Water Treatment Rule)
  - Increase public protection form illness caused by *Cryptosporidium*
- DPBR (Disinfection By-Products Rule)
  - Limits amount of certain potentially harmful disinfection by-products that may remain in drinking water after treatment
- LT2ESWTR (Long Term to Enhanced Surface Water Treatment Rule)
  - Builds upon earlier rules to reduce illness linked with *Cryptosporidium*

FACTORS INFLUENCING DISINFECTION

FACTORS INFLUENCING DISINFECTION

- pH
  - Chlorine disinfects faster at pH of 7 than at pH > 8
  - Hypochlorous acid disassociates at a higher pH
- Temperature
  - Higher temperature means more efficient disinfection
  - Longer contact time required at lower temperatures
  - Chlorine will dissipate faster in warmer waters
- Microorganisms
  - Number and type greatly influence disinfection effectiveness
  - Cysts and viruses can be very resistant to disinfection

FACTORS INFLUENCING DISINFECTION

- Turbidity
  - Excessive turbidity greatly reduces disinfection efficiency
  - Organic Matter
    - Organics can consume great amounts of disinfectants while forming unwanted compounds such as disinfection by-products
    - Reactions with organics and other reducing agents will significantly reduce the amount chemical available for disinfection
  - Inorganic matter
    - Ammonia can combine with disinfectant chemical to form side compounds

FACTORS INFLUENCING DISINFECTION

- Reducing Agents
  - Any substance that will readily donate electrons
  - Demand for chlorine by reducing agents must be met before chlorine becomes available to accomplish disinfection
  - Inorganic reducing agents
    - Hydrogen sulfide gas (H_2S)
    - Ferrous ion (Fe^{2+})
    - Manganous ion (Mn^{2+})
    - Ammonia (NH_3)
    - Nitrite ion (NO_2^-)

PROCESS OF DISINFECTION

PURPOSE OF PROCESS

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

AGENTS OF DISINFECTION

- Physical Means of Disinfection
  - Ultraviolet Rays (UV)
    - Rays must come in contact with each microorganism
    - Lack of measureable residual
  - Heat
    - Rolling boil for 5 minutes
  - Ultrasonic Waves
    - Sonic waves destroy microorganisms by vibration

AGENTS OF DISINFECTION

- Chemical Disinfectants
  - 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 residual, difficult to store, high maintenance requirements

AGENTS OF DISINFECTION

- Chemical Disinfectants
  - Chlorine -- Cl_2
    - 100% pure
    - gas
  - Calcium hypochlorite -- $Ca(Ocl)_2$
    - 65% pure
    - solid
    - HTH – high test hypochlorite
  - Sodium hypochorite -- NaOCl
    - 5-15% pure
    - Liquid
    - Bleach

CHLORINE (Cl_2)

- 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
  - Can support combustion

CHLORINE (Cl_2)

- Reaction with Water

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

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 has a much higher disinfection potential than hypochlorite ion
  - At pH = 7.5, of the chlorine present 50% will be HOCl and 50% will be OCl^-

CHLORINE (Cl_2)

- Hydrogen sulfide and ammonia are inorganic reducing agents
  - Hydrogen sulfide reacts with chlorine to form sulfuric acid and elemental sulfur
    - Causes odor problems
  - Ammonia reacts with chlorine to form chloramines
    - As ammonia concentration increases, the disinfectant power of chlorine decreases
  - Organics react with chlorine to form trihalomethanes (carcinogens)

HYPOCHLORITE (OCl^-)

- Reactions with Water
  - May be applied in the form of calcium hypochlorite ($Ca(OCl)_2$) or sodium hypochlorite (NaOCl)

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

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

  - Raises pH due to OH^- ion
  - If is $Ca(OCl)_2$ injected at the same point of as sodium fluoride, a severe crust can form at injection point

CHLORINE DIOXIDE (ClO_2)

- May be used as a primary disinfectant
  - Not affected by ammonia
  - Very effective disinfectant at higher pH levels
  - Reacts with sulfide compounds to help remove and eliminate their characteristic odors
  - Can control phenolic tastes and odors
  - Effective oxidizing agent with iron and manganese
  - Does not form carcinogenic compounds from treating organics

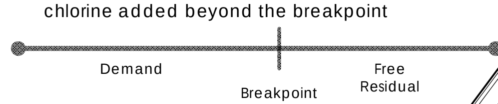
CHLORINATION

- Disinfection Action
  - <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

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



  - Total chlorine dose = residual + demand

BREAKPOINT CHLORINATION

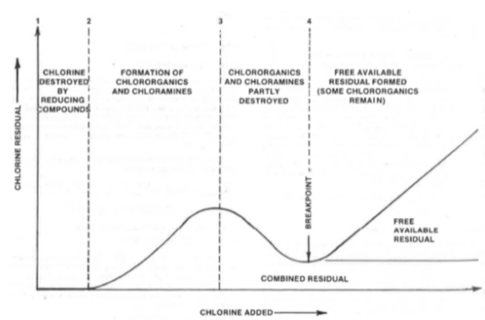


Fig. 7.2 Breakpoint chlorination curve

CHLORAMINATION

- Chloramines have been used as an alternative disinfectant for over 70 years
- An operator's decision to use chloramines depends on several factors
- However, chloramination alone is <u>not an approved method</u> of disinfection in the state of Tennessee

CHLORINE RESIDUAL TESTING

- 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

CHLORINE RESIDUAL TESTING

- Critical Factors
  - Effectiveness of upstream treatment processes
  - Injection point and method of mixing
  - Temperature
    - The higher temp, the more rapid the disinfection
  - Dosage and type of chemical
    - The higher the dose, the faster the disinfection
  - pH
    - The lower the pH, the better the disinfection
  - **Contact time**
    - Longer contact time has better disinfection
  - **Concentration**
    - Chlorine residual

CT VALUES

"kill" is proportional to C x T

- Destruction of organisms depends on the concentration of chlorine added (C) and the amount of time the chlorine is in contact with the organisms (T)
- Inversely proportional
  - If one is decreased, the other must be increased to ensure that "kill" remains the same

POINTS OF CHLORINE APPLICATION

- Prechlorination
  - Application of chlorine ahead of any other treatment processes
  - Benefits
    - Control of algal and slime growths
    - Control of mudball formation
    - Improved coagulation
    - Reduction of tastes and odors
    - Increased chlorine contact time
    - Increased safety factor in disinfection of heavily contaminated waters

POINTS OF CHLORINE APPLICATION

- Postchlorination
  - Application of chlorine after the water has been treated but before it enters the distribution system
  - Primary point of disinfection
- Rechlorination
  - Practice of adding chlorine in the distribution system
  - Common when distribution system is long or complex
- Wells
  - Good practice whenever wells are used for public water supplies

POINTS OF CHLORINE APPLICATION

- Mains
  - After initial installation and any repairs
- Tanks and Reservoirs
  - To resolve specific problems
  - After initial installation, repairs, maintenance, repainting, and cleaning
- Water Supply Systems
  - i.e. Small water systems

OPERATION OF CHLORINATION EQUIPMENT

HYPOCHLORINATORS

- A piece of equipment used to feed liquid chlorine solutions (bleach)
- Consists of chemical solution tank, diaphragm-type pump, power supply, water pump, pressure switch, water storage tank

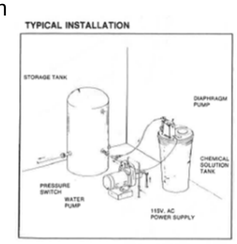
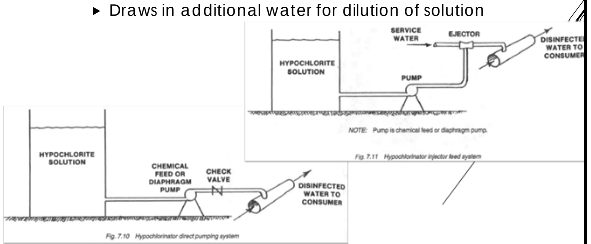


Fig. 7.7 Typical hypochlorinator installation
(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

HYPOCHLORINATORS

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



CHLORINATORS

- Chlorine gas may be removed from chlorine containers by a valve and piping arrangement
- 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

CHLORINATORS PARTS

- Ejector – creates the vacuum that moves the chlorine gas (also called injector or eductor)
  - Fitted with Venturi valve
- Check valve assembly – prevents water from back-feeding as the water moves through ejector
- Rate valve – controls the flow rate at which chlorine gas enters the chlorinator
- Diaphragm assembly – connects directly to the inlet valve of the vacuum regulator

CHLORINE CONTAINERS

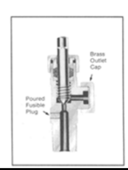
- Plastic
  - Commonly used for storage of hypochlorite solution
  - Should be large enough to hold 2-3 days' supply
    - Fresh solution should be prepared every 2-4 days
    - Sodium hypochlorite will lose 2-4% concentration per month at room temperature
    - Recommended shelf life of 60-90 days

CHLORINE CONTAINERS

- Steel Cylinders
  - 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 CONTAINERS

- 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)

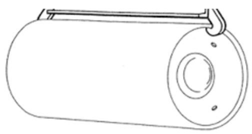


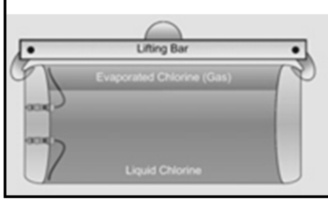
CHLORINE CONTAINERS

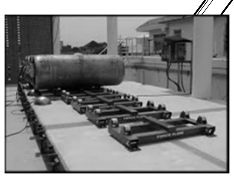
- Ton Tanks
  - Loaded weight of about 3,700 pounds
  - Openings for fusible plugs and valves
    - 2 operating valves
    - 6 fusible plugs (3 on each end)

CHLORINE CONTAINERS

- Ship ton tanks by rail in multiunit cars, truck or semitrailer
- Handle ton tanks with a suitable lift clamp or in conjunction with a hoist or crane
- Lay ton tanks on their sides
- Do not stack
- Separate tanks by 30 inches for access in case of leaks
- Place ton tanks on trunnions that are equipped with rollers
  - In case of a leak, tank can be rolled so that the leaking chlorine escapes as a gas not a liquid
- Use locking devices to prevent ton tanks from rolling while connected





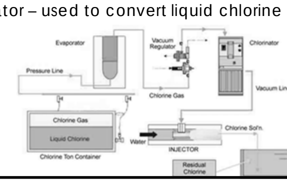


REMOVING CHLORINE FROM CONTAINERS

- 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
  - 50 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

REMOVING CHLORINE FROM CONTAINERS

- Ton Tanks
  - Must be placed on their sides with valves in vertical positions to allow either chlorine gas or liquid to be removed
    - Top valve to remove chlorine gas
    - Bottom valve to remove liquid chlorine
    - Must use an evaporator – used to convert liquid chlorine to gaseous chlorine



MAINTENANCE

CHLORINE LEAKS

- Chlorine leak can be smelled at concentrations as low as 3 ppm
  - Detectors can detect 1ppm or less
- Always work in pairs when looking for and repairing leaks
- If leak is large, all persons in adjacent areas should be warned and evacuated

CHLORINE LEAKS

- Any new or repaired system should be cleaned, dried, and tested for leaks
- Ammonia solution on a piece of cloth held near a chlorine leak will produce a white vapor
  - Use concentrated ammonia solution of 28-30% ammonia
  - A squeeze bottle filled with ammonia water to dispense vapor may also be used
- If leak is in the equipment, close the valves at once

CHLORINE LEAKS

- If leak is in cylinder, use emergency repair kit
  - For 150 lb cylinder, Emergency Repair kit A
  - For ton cylinder, Emergency Repair kit B
  - For railroad car, Emergency Repair kit C

CHLORINE LEAKS

- If chlorine leaking as a liquid, rotate cylinder so leak is on top
  - Chlorine is escaping only as a gas
- If prolonged or unstoppable leak, emergency disposal should be provided
  - Chlorine may be absorbed into solutions of caustic soda, soda ash, or agitated hydrated lime
- Never put water on a chlorine leak
  - By-product (sulfuric acid) will make the leak larger
- Leak around valve stem can be stopped by closing the valve or tightening the packing gland nut

CHLORINE LEAKS

- Leaks at valve discharge outlet can often be stopped by replacing the gasket or adapter connection
- Leaks at fusible plugs and cylinder valves usually require special handling and emergency equipment
- Pinhole leaks in the walls of cylinders can be stopped by using a clamping pressure saddle with a turnbuckle available in repair kits
  - Temporary fix
- A leaking container must not be shipped
- Do not accept delivery of containers showing evidence of leaking, stripped threads, etc.

MEASUREMENT OF CHLORINE RESIDUAL

METHODS OF MEASURING CHLORINE RESIDUAL

- Amperometric titration
- DPD tests
- 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
  - 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

- DPD tests
  - 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

CHLORINE SAFETY PROGRAM

CHLORINE HAZARDS

- Chlorine gas is 2.5 times heavier than air
  - Extremely toxic
  - Corrosive in moist atmospheres
  - Very irritating to mucous membranes of the nose, throat, and lungs

Effect	Cl_2 concentration (ppm)
Slight symptoms after several hours' exposure	1
Detectable odor	0.3-3.5
Noxiousness (harmful)	5
Throat irritation	15
Coughing	30
Dangerous from ½ to 1 hour	40
Death after a few deep breaths	1,000

CHLORINE PPE

- 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 positive pressure breathing equipment must fit and be used properly
- 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

FIRST-AID MEASURES

- Mild chlorine exposure
  - Leave contaminated area
  - Move slowly, breathe lightly without exertion, remain calm, keep warm, and resist coughing
  - If clothing has been contaminated, remove as soon as possible
  - If slight irritation, immediate relief can come from drinking milk

FIRST-AID MEASURES

- Extreme Chlorine Exposure
  - Follow established emergency procedures
  - Always use proper safety equipment; do not enter area without self-contained breathing apparatus
  - Remove patient from affected area immediately
  - First-aid
    - Remove contaminated clothes
    - Keep patient warm and cover with blankets
    - Place patient in comfortable position on back
    - Administer oxygen if breathing is difficult
    - Perform mouth-to-mouth resuscitation if breathing seems to have stopped
    - If chlorine has got in eyes, flush with large amounts of water immediately (at least 15 minutes)

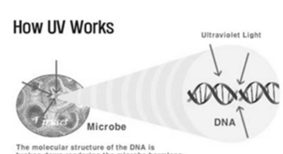
HYPOCHLORITE SAFETY

- Wash spills with large volumes of water
- Hypochlorite can damage eyes and skin upon contact
  - Immediately wash affected are thoroughly with water
- Nonflammable, however can cause a fire when comes in contact with organics

DISINFECTION USING ULTRAVIOLET (UV) SYSTEMS

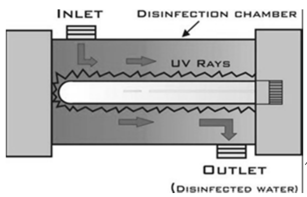
USES OF UV SYSTEMS

- Ultraviolet light – band of electromagnetic radiation just beyond the visible light spectrum
  - UV light absorbed by cells of microorganisms damages the genetic material to cease growth or reproduction



TYPES OF UV LAMPS

- Based on internal operating design
  - Low-pressure, low-intensity
  - Low-pressure, high-intensity
  - Medium-pressure, high-intensity



LOW PRESSURE UV LAMPS

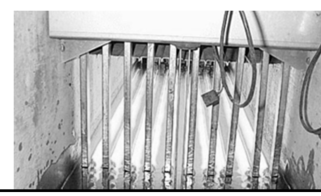
- Source of UV energy in majority of systems
- Last between 8,000 and 10,000 hours
- Operate between 40º and 60ºF
- Generate light by transforming electrical energy into UV radiations
- Emits light at wavelength 253.7 nm
- Each lamp protected by quartz sleeve with watertight electrical connections

LOW PRESSURE UV LAMPS

- Lamp assemblies mounted in a rack(s) that are immersed in flowing water
- Can be enclosed in a vessel or in an open channel
  - Enclosed in vessels in pressure systems
- Placed either horizontal and parallel to flow or vertical and perpendicular to flow
- Number of lamps determines water depth in channel

SAFETY

- UV lamp can burn eyes
- Never look into uncovered parts of the UV chamber without protective glasses
- Lamps contain mercury vapor that will be released of lamp breaks



OPERATION

- Water level over lamps must be maintained to ensure all microorganisms are exposed and to prevent short circuiting
- Water level control device must be regulated by the operator to:
  - Minimize variation of the channel's water level
  - Maintain the channel's water level at a defined level
  - Keep the UV lamps submerged at all times
  - Prevent excessive water layer thickness above the top lamp row

OPERATION

- Light must be intense enough to penetrate pathogens' cell walls
  - Intensity affected by the condition of the UV lamps and the quality of the water
  - An old or dirty lamp has a reduced UV light intensity
  - High turbidity inhibits light transmission, reducing the disinfecting power in proportion to its distance from the light source
  - High TSS inhibits light transmission and shields bacteria protecting them from disinfection
- Low UV light intensity will produce a low level of disinfection

OPERATION

- UV Dose Calculation
  - Intensity of UV radiation and contact time determine the UV dose and, therefore, the effectiveness
  - Expressed as mJ/sq cm (milli-joules per square centimeter)
  - Use worse case intensity for calculation (farthest point from UV)
- Channel Volume Calculation
  - Refers to the irradiated volume of the UV reactor
    - Volume of bacteria exposed to UV radiation
  - Fixed calculation

OPERATION

- Routine Operations Tasks
  - Check UV monitors for UV transmission
  - Routinely clean the UV lamps
- Wiping Systems
  - Should be observed to ensure proper operation of the wiping action of a bank and the proper wiping cycle
- Monitoring Lamp Output Intensity
  - Lamp output declines with use
  - Lamps should be replaced with output no longer meets standards or burn out

OPERATION

- Monitoring Influent and Effluent Characteristics
  - Must maintain velocities and low turbidity levels
    - Suspended particles shield microorganisms from UV light
    - Flows should be somewhat turbulent to ensure exposure to all microorganisms, but controlled so that water is exposed for long enough for disinfection to occur
  - Bacteriological tests must be performed frequently since there is no residual left by UV
- Emergency Alarms
  - UV systems require extensive alarm systems to ensure complete disinfection

MAINTENANCE

- Routine Maintenance
  - Check UV monitor for reduction in lamp output
  - Monitor process for major changes
  - Check for fouling of the quartz sleeves
  - Check that all UV lamps are energized
  - Monitor reports to determine UV lamp replacement interval
  - Check quartz sleeves for discoloration
  - Dewater and hose down UV channel if algae and other attached biological growths form on walls and floor

MAINTENANCE

- Quartz Sleeve Fouling
  - Occurs when cations attach to protein and colloidal matter that crystallizes on the quartz sleeves
  - This will decrease the intensity of the UV light
- Sleeve Cleaning
  - Frequency depends on the quality of water being treated and treatment chemicals used
  - Best done by dipping bulbs an inorganic acid solution for 5 minutes
    - i.e. Nitric acid (50%) or phosphoric acid (5-10%)

MAINTENANCE

- UV lamps
  - Service life ranges from 7,500 – 20,000 hours
  - Depends on
    - Level of suspended solids
    - Frequency of on/off cycles
    - Operating temperature of lamp electrodes
  - Lamp output drops 30-40% in first 7,500 hours
  - Lamp electrode failure is most common cause of lamp failure
  - Do not throw used lamps in garbage can
    - Must be disposed properly due to mercury content

OZONE

Introduction to Water Treatment

OZONE (O_3)

- Bluish toxic gas with pungent odor
- Alternative disinfectant
- Very strong oxidant and virucide (kills viruses)
- Must be generated on site
- Generated by passing an electrical current through pure oxygen

$$O_2 + \text{Energy} \rightarrow O + O$$
$$O + O_2 \rightarrow O_3$$

OZONE (O_3)

- Effectiveness of disinfection depends on
  - Susceptibility of the target organisms
  - Contact time
  - Concentration of the ozone
- Because ozone is consumed quickly, it must be exposed to the water uniformly
- Residual ozone measured by the iodometric method
- Dissolved ozone measured by Indigo test

EQUIPMENT

- Consists of 4 major parts
  - Air preparation unit
  - Electrical power unit
  - Ozone generator
  - Contactor

EQUIPMENT

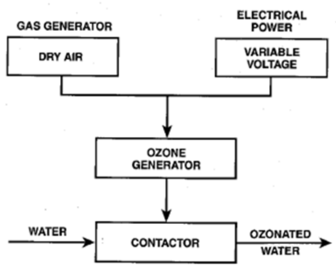


Fig. 7.47 Ozonation equipment

EQUIPMENT

Air preparation

- When air is used as the feed gas for an ozone generator, it must be extremely dry
- The preparation unit usually consists of a commercial air dryer with a dew point monitoring system
  - This is the most critical part of the system
- Air should be clean and dry with a dew point below -51°C (-60°F)

EQUIPMENT

Electrical Power Units

- Usually a very special electrical control system
- Most common unit provides low frequency, variable voltage
- For large installations, medium frequency, variable voltage is used
  - Reduces power costs
  - Allows for higher ozone output

EQUIPMENT

Ozone Generator

- Consists of a pair of electrodes separated by a gas space and a layer of glass insulation
- Air passes through the empty space
- Electrical discharge occurs across the gas space and ozone is formed

Oxygen from air + Electrical voltage → Ionized oxygen + Heat
O_2 + electricity → 2(O)

Ionized oxygen + Non-ionized oxygen → Ozone
2(O) + 2(O_2) → 2 (O_3)

EQUIPMENT

Ozone Contactor

- Mixing chamber for the ozone rich material and the water
- Ozone has a very short life
- Must be evenly and efficiently introduced to the water to be treated
  - Critical to the success of the system

EQUIPMENT

Types of Ozone Contactors

- Turbine mixers
- Injectors
- Packed columns
- Spray chambers
- Fine-bubble diffusion
  - Most common
  - Small bubbles rise through the tank transferring the ozone to the water

OZONE ADVANTAGES

- More effective than chlorine in destroying viruses
- No harmful residuals after ozonation
- No regrowth of microorganisms
- Removes color, tastes, and odors
- Oxidizes iron, manganese, sulfides and organics

OZONE LIMITATIONS

- Low dosage may not effectively inactivate some viruses, spores, and cysts
- Complex technology requiring complicated equipment
- Ozone if very reactive and corrosive require corrosion resistant materials
- Ozone is very irritating and possibly toxic
- The cost of treatment can be relatively high in capital and power costs
- Cannot be used as sole means of disinfectant in Tennessee due to Cl_2 residual requirements
- Can combine with bromide to form bromate
  - A carcinogen

APPLICATIONS OF OZONE

- Ozone may be used for more than just disinfection or viral inactivation
  - When used prior to coagulation
    - Treats Fe and Mn, helps flocculation, and removes algae
  - If applied before filtration
    - Oxidizes organics, removes color, and treats tastes and odors

MAINTENANCE

- Inspect electrical equipment and pressure vessels monthly
- Conduct a yearly preventive maintenance program
  - Should be done by a factory representative or an operator trained by the manufacturer
- Lubricate moving parts according to manufacturer's recommendations

SAFETY

- Ozone is a toxic gas and is a hazard to plants and animals
- When ozone breaks down in the atmosphere, the resulting pollutants can be very harmful
- Ozone contactors must have a system to collect ozone off-gas.
  - Ozone generating installations must include a thermal or catalytic ozone destroyer

Fleming Training Center

Pipe Disinfection Formulas for <u>50 mg/L</u> of HTH

If a pipe is of size not listed below, the following formula will give the calculations needed to find the amount of HTH needed, if the length of line is given:

Calculation Formula = $0.000026007(X)^2(L)$

L= the length of the line in feet,
X = the diameter in inches

Or, Use the following Chart, if Pipe Diameter is listed

DIAMETER (INCHES)	LBS OF HTH
6	0.000935(L)
8	0.00166(L)
10	0.0026(L)
12	0.00374(L)
14	0.00509(L)
16	0.00665(L)
20	0.01038(L)
C24	0.01495(L)

Contact Amanda Carter At Fleming Training Center

(615) 898-6507

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°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

TDEC - Fleming Training Center 2

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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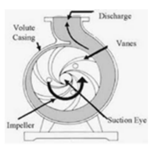
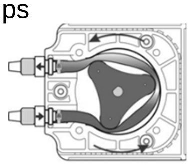
Types of Pumps

- 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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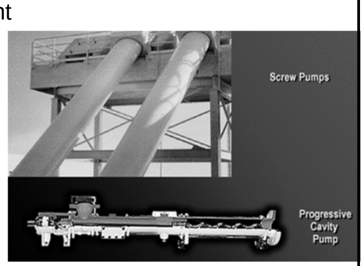
Positive-Displacement Pumps

- 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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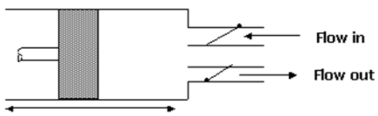
Positive-Displacement Pumps

- 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

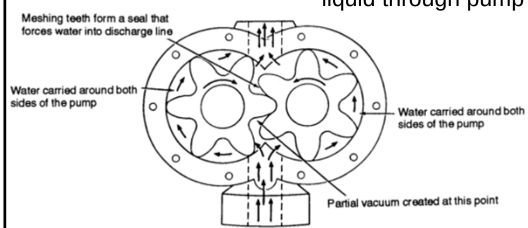
Positive-Displacement Pumps

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



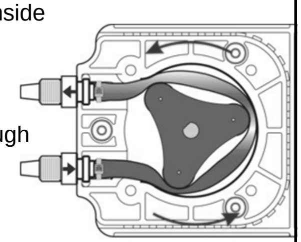
Positive-Displacement Pumps

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



Positive Displacement Pumps

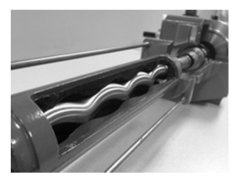
- Peristaltic Pump
  - Fluid to be pumped flows through flexible tube inside a pump casing
  - Rotor inside turns and compresses the tube
  - Rotor forces fluid through tube



Screw Pumps

Incline screw pumps handle large solids without plugging

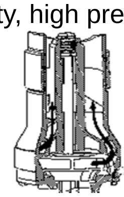
- Aka progressive cavity pumps
- Screw pumps are used to lift wastewater to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge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



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

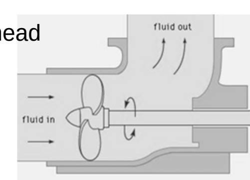
Volute



Diffuser

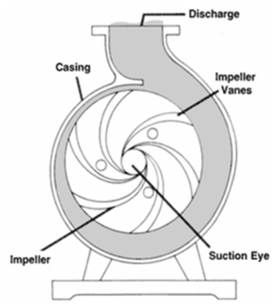
Velocity Pump Design Characteristics

- 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



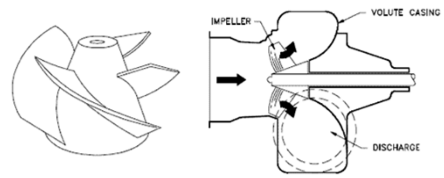
Velocity Pump Design Characteristics

- 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

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

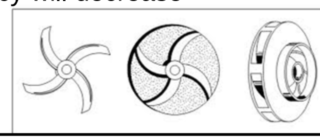
Let's Build a Centrifugal Pump

- 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

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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.

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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

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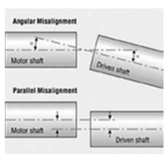
Misalignment of Pump & Motor



- 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.

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Common Pump & Motor Connections

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

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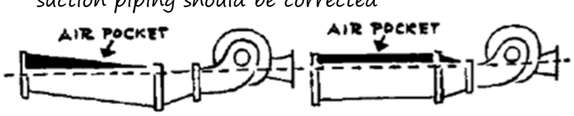
Let's Build a Centrifugal Pump

- 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



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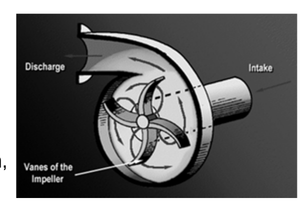
Let's Build a Centrifugal Pump

- 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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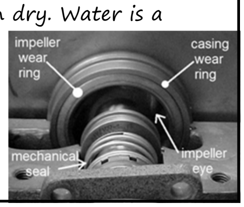
Let's Build a Centrifugal Pump

- 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.

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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.

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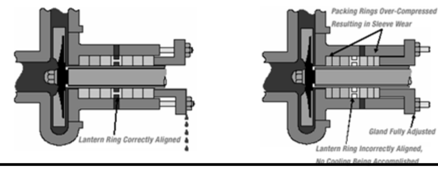
Lantern Rings

- 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



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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

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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**

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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

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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.

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

Packing vs. Mechanical Seals

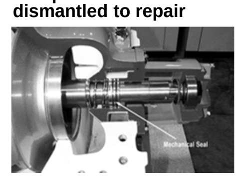
- If a pump has packing, water should drip slowly
- If it has a mechanical seal, no leakage should occur

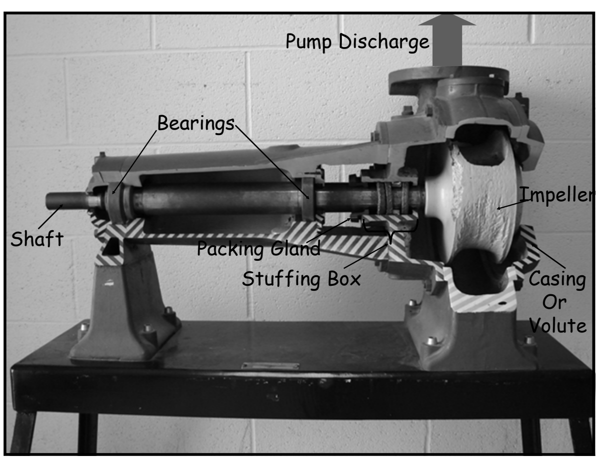
Packing Rings vs. Mechanical Seal

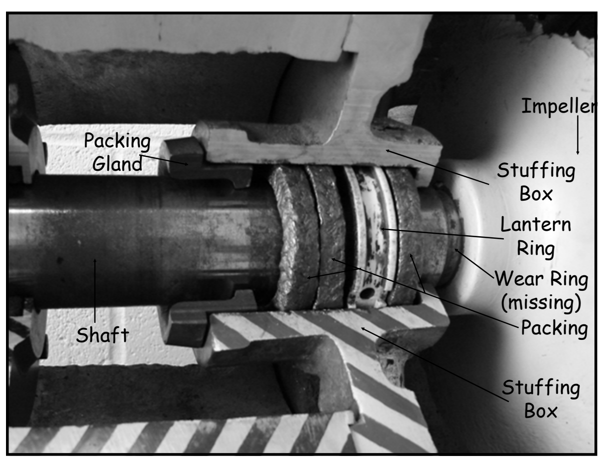
- Advantages
  - Less expensive, short term
  - Can accommodate some looseness
- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and replacement

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**







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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

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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

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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

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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

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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

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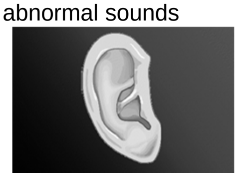
Monitoring Operational Variables

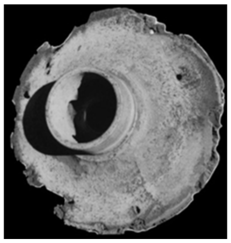
- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds



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

Monitoring Operational Variables

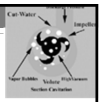


- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

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

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

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

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

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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

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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)

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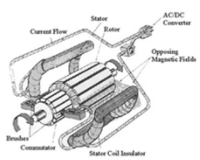
Pump Won't Start?



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

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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.

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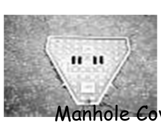
Pump Safety: Wet Wells

- 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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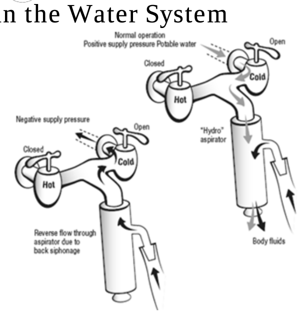
Backflow Case Study

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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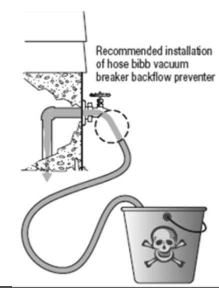
Backflow Case Study

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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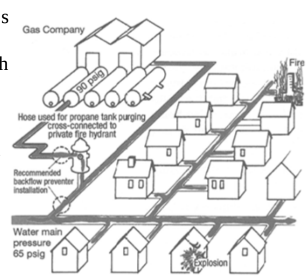
Backflow Case Study

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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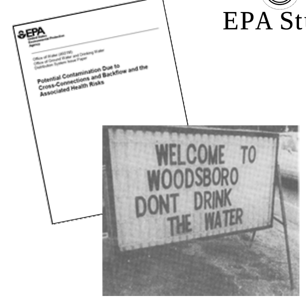
Backflow Case Study

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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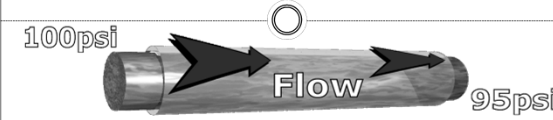
Hydraulics and Pressure



- 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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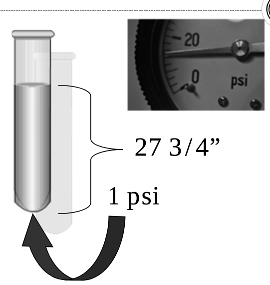
Head Pressure



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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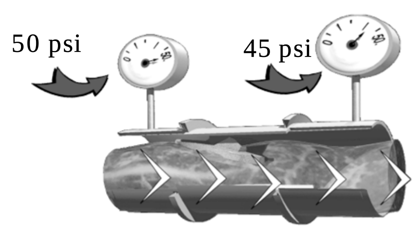
Normal Flow



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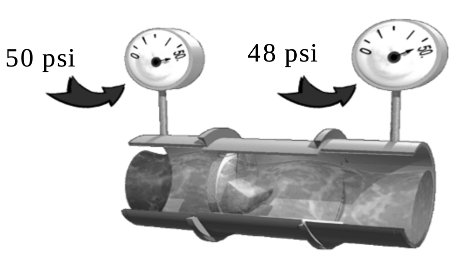
No Flow



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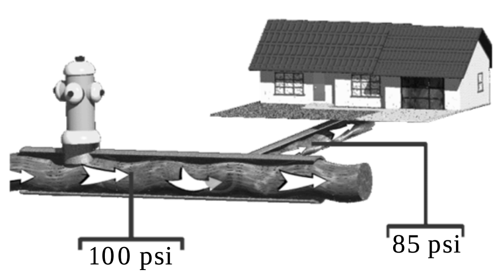
Normal Flow



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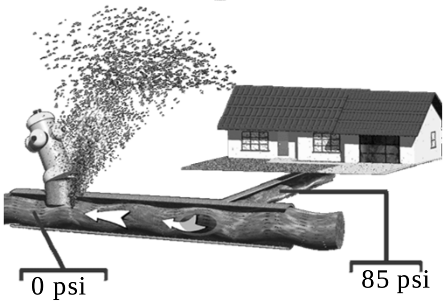
Reverse Flow - Backflow

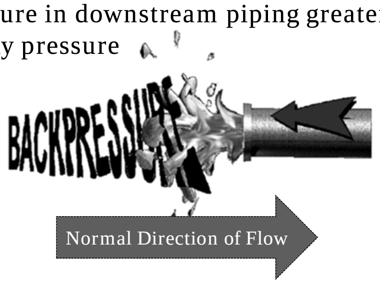


Backflow

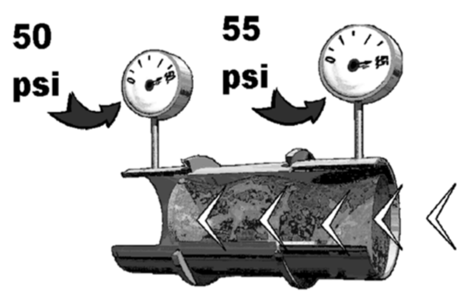
- The undesirable reversal of flow of water or other substances into the potable water distribution supply
- Occurs due to:
  - Backpressure
  - Backsiphonage

Backpressure

- Pressure in downstream piping greater than supply pressure

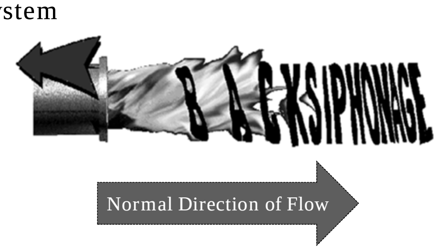


Backpressure



Backsiphonage

- Sub-atmospheric pressure in the water system



Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?

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

Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?

- Whatever is in the barrel…

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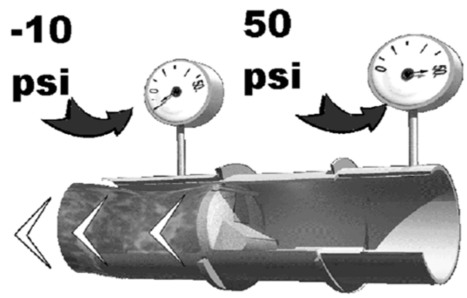
Backsiphonage



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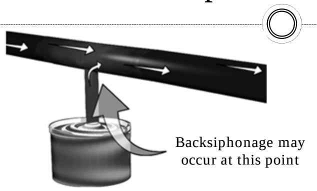
Aspirator Effect



- 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

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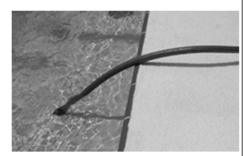
Cross-Connection

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



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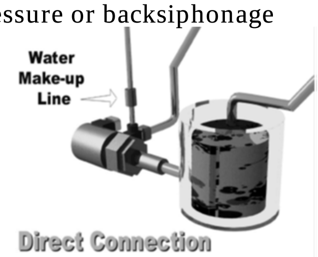
Direct Cross-Connection

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



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Indirect Cross-Connection

- An indirect cross-connection is subject to backsiphonage only

Submerged Inlet

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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)

BEST METHOD OF PROTECTION

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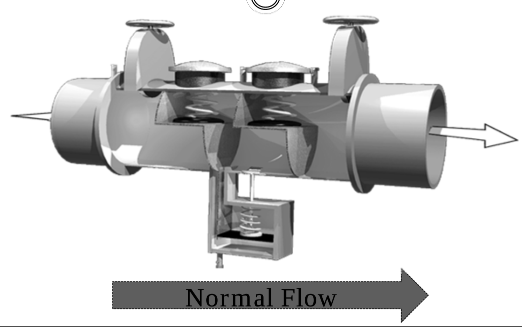
Reduced Pressure Principle Assembly



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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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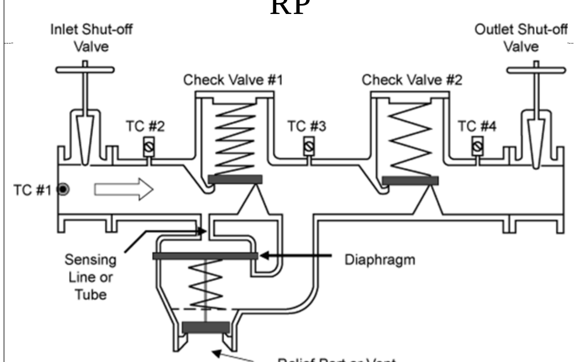
RP



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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

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RP

Backflow Protection Against:

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

BEST DEVICE FOR PROTECTION

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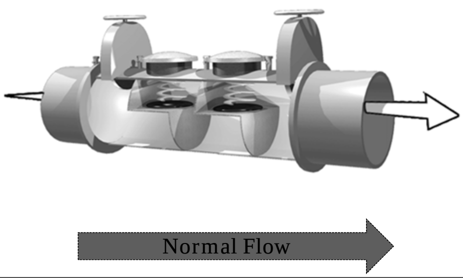
Double Check Valve Assembly (DC)



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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

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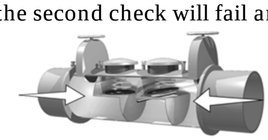
Double Check Valve Assembly (DC)

- 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

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Double Check Valve Assembly (DC)

Backflow Protection Against:

- Backsiphonage
- Backpressure
- Pollutant only

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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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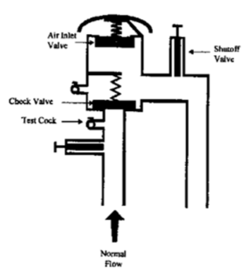
Pressure Vacuum Breaker (PVB)



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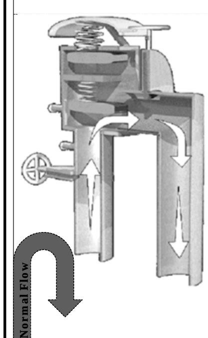
Pressure Vacuum Breaker (PVB)



- 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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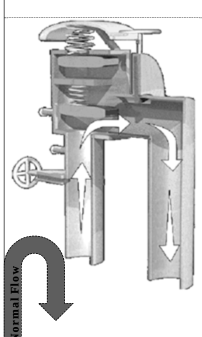
Pressure Vacuum Breaker (PVB)



- 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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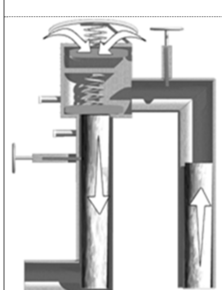
PVB Backsiphonage Condition



- 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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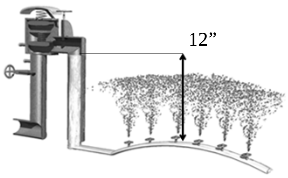
Installation of PVB

- PVB is <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>12 inches</u>** above the highest point downstream



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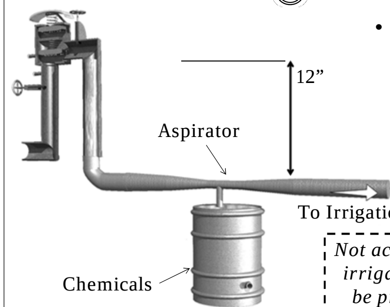
Pressure Vacuum Breaker

- Acceptable installation not subject to backpressure



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

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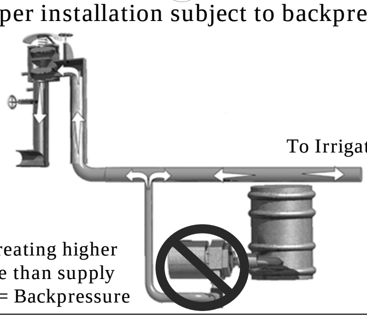
Pressure Vacuum Breaker

- Improper installation subject to backpressure



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Pressure Vacuum Breaker

<u>Backflow Protection Against</u>:

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

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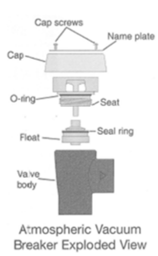
Atmospheric Vacuum Breaker (AVB)



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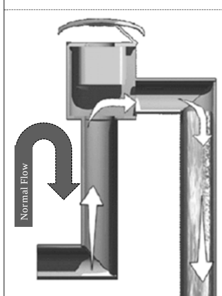
Atmospheric Vacuum Breaker (AVB)



- 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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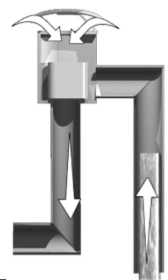
Atmospheric Vacuum Breaker (AVB)

- 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

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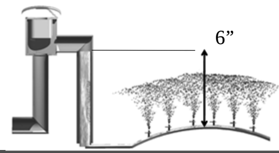
Installation of AVB

- 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



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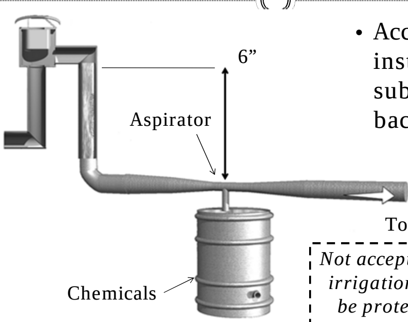
Atmospheric Vacuum Breaker



- Acceptable installation not subject to backpressure

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

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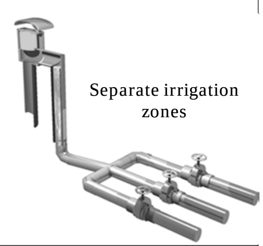
Atmospheric Vacuum Breaker

- 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



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Atmospheric Vacuum Breaker

<u>Backflow Protection Against</u>:

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

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	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	

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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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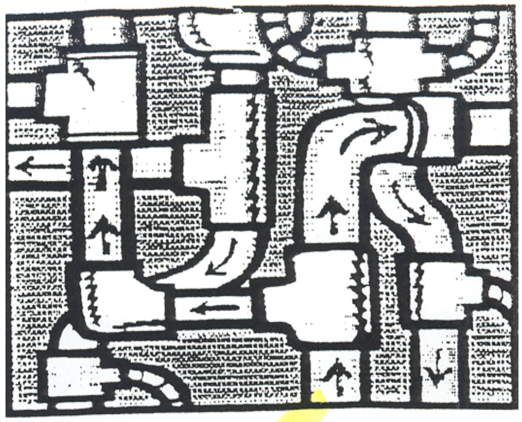


Vocabulary

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

Air Gap – 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.

Atmospheric Pressure – 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.

Backflow – The reversed flow of contaminated water, other liquids or gases into the distribution system of a potable water supply.

Backflow Prevention Device (Backflow Preventer) – Any device, method or construction used to prevent the backward flow of liquids into a potable distribution system.

Back Pressure (Superior Pressure) – (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.

Backsiphonage – (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.

Bypass – 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

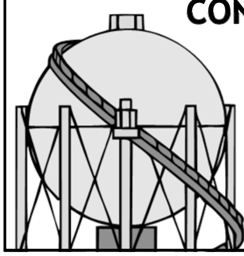
- An accident is caused by either an unsafe act or an unsafe environment

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

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EQUIPMENT NEEDED cont'd

- PPE
- Ladder
- Rope
- Breathing apparatus

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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

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ATMOSPHERIC HAZARDS

- Need to have atmosphere monitored!!!
- Explosive or flammable air
- Toxic air
- Depletion or elimination of breathable oxygen

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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

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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

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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

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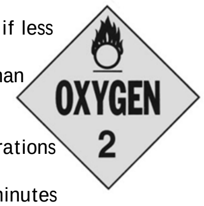
OXYGEN – O_2

- 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

RECORD KEEPING

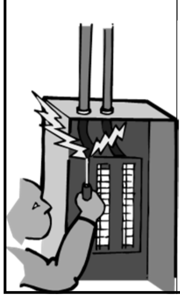
- Identification and evaluation of all hazardous areas in workplace
- Entrance permits filed
- Training certification
- Written confined space program

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)

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

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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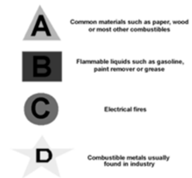
FIRE EXTINGUISHERS

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

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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

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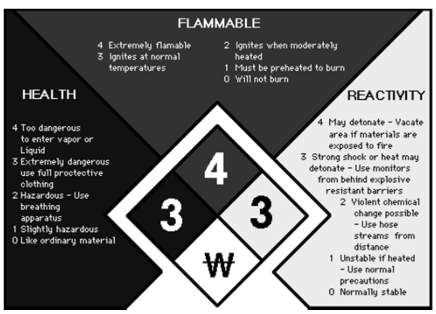
CHEMICAL HAZARD LABEL



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CHEMICAL HAZARD LABEL

Special

- W → water reactive
- Ox → oxidizing agent

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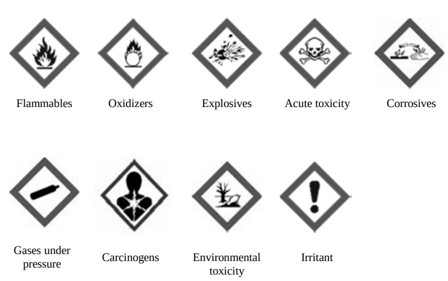
OSHA PICTOGRAMS



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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

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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

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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

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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

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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

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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

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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

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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

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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!!**

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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

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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

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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

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Section 9

Laboratory

Laboratory Practices

Updated 11/20/2019

1

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

2

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

3

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>

4

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

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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

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Sampling

Sample Labeling
- Specific location (address)
- Date and time sampled
- Chlorine residual
- pH and temperature
- Sample type
- Name or initials of person taking sample

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Sampling

Selecting Sampling Points

- Raw-water supply
- Treatment plant
- Distribution system

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Sampling

Raw-water Sampling Points

- Install valve or sample cock on raw-water transmission lines or well discharge pipe

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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

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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

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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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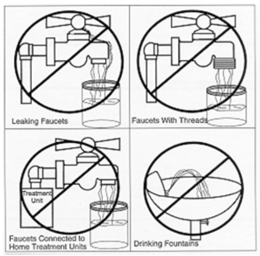
Sampling

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

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EPA Approved Methods

- Multiple-Tube Fermentation
- Presence-Absence Test
- MMO-MUG
- Membrane Filter Method
- Enzyme (chromogenic/fluorogenic) Substrate Tests

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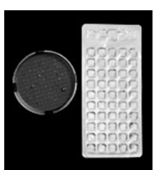
Bacteriological Samples

- The MCL for coliform bacteria is based on presence or absence
- Finished and distributed water should be Zero (absent)



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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

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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*

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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 <u>no fewer than four repeat samples</u> 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.

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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.)

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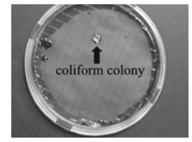
Testing



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

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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

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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

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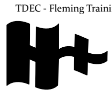
pH



- 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

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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

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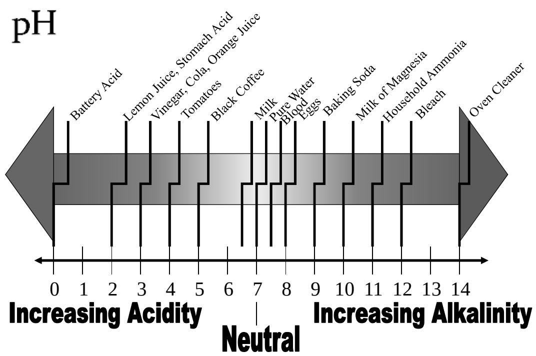
pH



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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

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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

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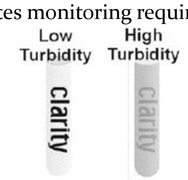
Turbidity

- 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



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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

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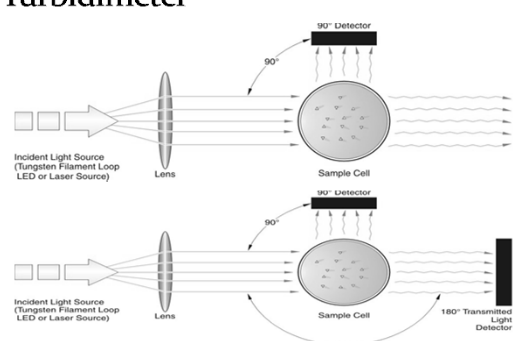
Turbidimeter



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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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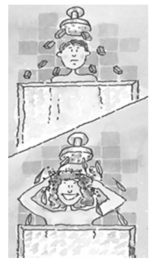
Hardness



- 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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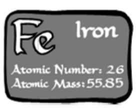
Iron and Manganese

- 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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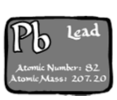
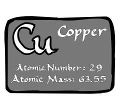
Lead and Copper Rule

- 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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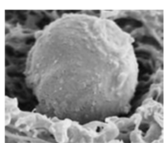
Cryptosporidium (Crypto)

- 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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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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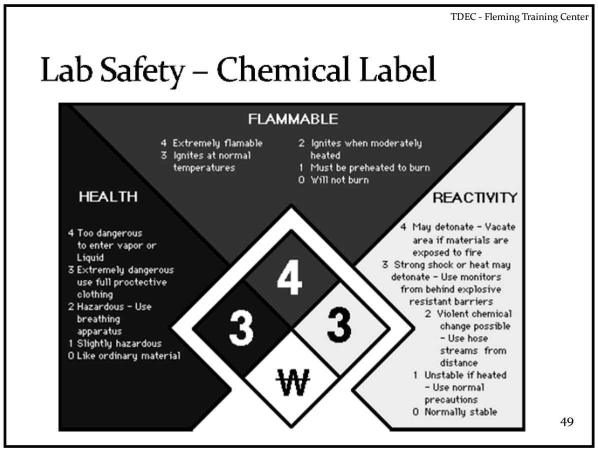
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Lab Safety – Chemical Label
FLAMMABLE
4 Extremely flamable
3 Ignites at normal temperatures
2 Ignites when moderately heated
1 Must be preheated to burn
0 Will not burn
HEALTH
4 Too dangerous to enter vapor or Liquid
3 Extremely dangerous use full proctective clothing
2 Hazardous – Use breathing apparatus
1 Slightly hazardous
0 Like ordinary material
REACTIVITY
4 May detonate – Vacate area if materials are exposed to fire
3 Strong shock or heat may detonate – Use monitors from behind explosive resistant barriers
2 Violent chemical change possible – Use hose streams from distance
1 Unstable if heated – Use normal precautions
0 Normally stable
4
3
3
W
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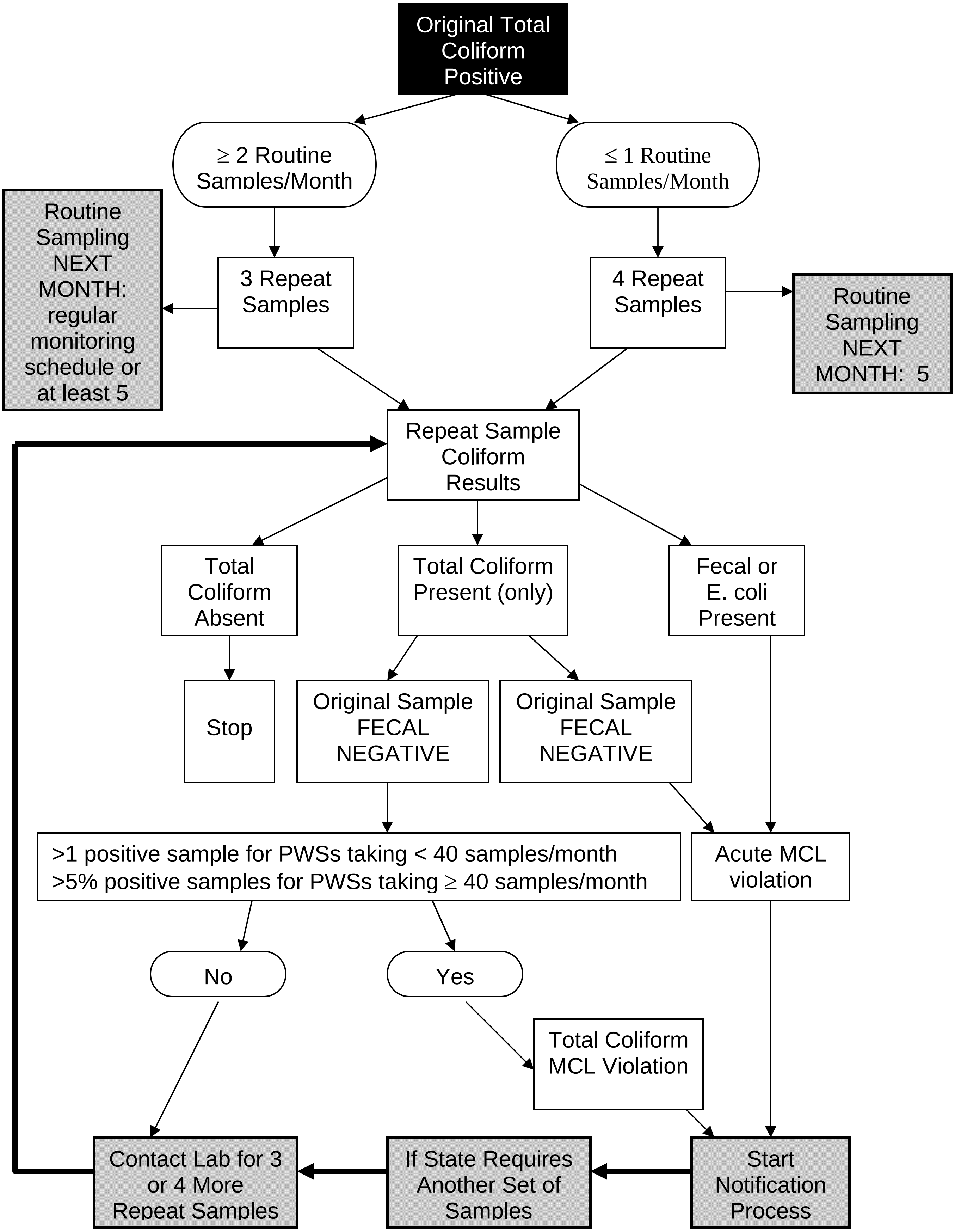
Total Coliform Action Flow Chart



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