Distribution Systems
Course #1103

Fleming Training Center
Jan. 30 – Feb. 3, 2017

Distribution Systems

Course #1103

January 30 - February 3, 2017

Monday, January 30:		
8:30	Registration	Amanda Carter
8:45	Overview of Distribution System	Amanda
10:00	System Design and Materials/Piping	Amanda
11:00	Lunch	
12:00	Distribution Math Review	Amanda
Tuesday, January 31:		
8:30	Distribution Math Review	Amanda
9:00	Valves	Amanda
10:00	Corrosion	Amanda
11:00	Lunch	
12:00	Disinfection	Amanda
1:30	Water Tanks	Amanda
Wednesday, February 1:		
8:30	Cross Connection Control	Ben Rodriquez
9:30	Safety - Confined Space, Trenching, PPE	Ben
11:00	Lunch	
12:00	Pumps and Maintenance	Amanda
Thursday, February 2:		
8:30	Fire Hydrants and Maintenance	Amanda
11:00	Regulations and Design Criteria	Amanda
11:30	Lunch	
12:45	Water Services and Meters	Amanda
1:30	Sampling and Water Analysis	Amanda
Friday, February 3:		
8:30	Exam Review	Amanda
10:00	Exam and Course Evaluation	Amanda

State of Tennessee

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* Instructors are subject to change

Distribution Systems

Section 1

Overview

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
MSDS – material safety data sheets
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 preventer
SCBA – self-contained breathing apparatus
SCD – streaming current detector
SDWA – Safe Drinking Water Act
sMCL – secondary maximum contaminant level
SOC – synthetic organic carbon
SOP – standard operating procedures
TCR – total coliform rule
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

ABC
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ABC

Association of Boards of Certification

Water Distribution Need-to-Know Criteria

A Need-to-Know Guide when preparing for the
ABC Water Distribution Certification Examination.

Acknowledgement
The Association would like to thank the members of the 2010-2011 Water Distribution Validation and Examination Committee for their effort in conducting the job analysis and developing the ABC *Need-to-Know Criteria* for Water Distribution Operators. Committee members included:

- Ray Olson, Colorado (Chair)
- Tom Arnbrister, Washington
- Audrey Burchanan, Nova Scotia
- Brian Kellsey, Alberta
- Martin Nutt, Arkansas
- Kathy Weinsaft, Wyoming
- Mike Wentink, Nebraska
- Chuck Van Der Kolk, Michigan

Introduction

As part of the development of its certification exams, the Association of Boards of Certification (ABC) conducted a job analysis of water distribution operators in 2010. As part of this process, ABC conducted a national survey of distribution operators. This *Need-to-Know Criteria* was developed from the results of ABC's 2010 distribution operator job analysis.

How the *Need-to-Know Criteria* Was Developed

Review of Task Survey
The results of the 2010 task analysis survey were provided to the ABC Distribution V&E Committee. In the task analysis survey, operators rated job tasks and capabilities 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. Of the 617 individuals in the water distribution industry who completed the survey, 122 were class I operators, 151 were class II operators, 124 were class III operators, and 135 were class IV operators.

Analysis of Ratings
The composite criticality ratings and percentage of operators reporting that they performed the tasks were presented to the Distribution V&E Committee in January 2011 to begin development of the new *Need-to-Know Criteria*. V&E committee members were given the opportunity to retain tasks which did not meet decision criteria (a criticality value of at least 10.5 and a percent performing value of at least 50%) if a significant rationale could be provided for their importance on the examination. The V&E committee members were also given the opportunity to remove any tasks which met criteria on the survey but were deemed untestable or inappropriate for the water distribution certification examination. Final examination blueprint weights were calculated by summing the criticality values of all remaining tasks, and dividing the criticality value of each task by the grand total criticality value. Weights of individual tasks were summed for each core competency area to determine the proportion of the water distribution certification examination devoted to each core competency.

Core Competencies

The essential tasks and capabilities that were identified through this process are called the core competencies. The following pages list the core competencies for distribution operators. The core competencies are clustered into the following job duties:

- System Information/Components
- Monitor, Evaluate, and Adjust Disinfection
- Laboratory Analysis
- Install Equipment
- Operate Equipment
- Perform Maintenance
- Perform Security, Safety, and Administrative Procedures

The level of knowledge (i.e., comprehension, application, analysis) required for each task is also identified in the following pages.

- **Comprehension** is the most basic level of understanding and remembering. Items written at the comprehension level require examinees to recognize, remember, or identify important ideas.
- Items written at the **application** level require examinees to interpret, calculate, predict, use or apply information and solve problems.
- Items written at the **analysis** level require examinees to compare, contrast, diagnose, examine, analyze, and relate important concepts.

The level of knowledge is a hierarchy from basic comprehension to analysis. The level of knowledge tested is cumulative. Therefore, tasks identified as application may include questions written at both the application and comprehension levels. Tasks identified as analysis may include questions written at the comprehension, application, and analysis levels.

About the Association of Boards of Certification

Established in 1972, the Association of Boards of Certification (ABC) is a non-profit member-driven organization dedicated to protecting public health and the environment by advancing the quality and integrity of environmental certification programs. ABC membership includes almost 100 certifying authorities, representing more than 40 states, nine Canadian provinces as well as several international programs. Existing solely for its members, ABC is the voice for the profession and serves as the conduit for information in an ever-changing industry.

Over 70 certification programs currently test approximately 35,000 operators and laboratory analysts annually through ABC's industry-leading Certification & Testing Services. Over 400,000 water and wastewater operators, laboratory analysts, and backflow prevention assembly testers have taken an ABC exam since the testing program began in 1982.

ABC Vision
Promote integrity in environmental certification throughout the world.

ABC Mission
ABC is dedicated to advancing the quality and integrity of environmental certification programs.

ABC Objectives
- Promote certification as a means of protecting public health, the infrastructure, and the environment.
- Promote uniformity of standards and best practices in certification.
- Serve as the technical resource for certification entities.
- Facilitate the transfer of certification between certifying authorities.
- Serve the needs of our members.

ABC Distribution Certification Exams

The ABC distribution certification exams evaluate an operator's knowledge of tasks related to the operation of distribution systems. The ABC Distribution V&E Committee determined the content of each exam based on the results of the national task analysis survey. To successfully take an ABC exam, an operator must demonstrate knowledge of the core competencies in this document.

Four levels of certification exams are offered by ABC, with class I being the lowest level and class IV the highest level. 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 example, 18% of the questions on the ABC class I distribution exam relate to the job duty "Operate Equipment." For a list of tasks and capabilities associated with each job duty, please refer to the list of core competencies on the following pages.

ABC Water Distribution Exam Specifications

Blueprint Area	Class I	Class II	Class III	Class IV
System Information/Components	9%	9%	9%	9%
Monitor, Evaluate, and Adjust Disinfection	11%	11%	10%	10%
Laboratory Analysis	21%	21%	21%	20%
Install Equipment	5%	5%	5%	5%
Operate Equipment	18%	18%	18%	18%
Perform Maintenance	20%	20%	20%	21%
Perform Security, Safety, and Administrative Procedures	16%	16%	17%	17%

System Information/Components	Class I	Class II	Class III	Class IV
Assess system demand	Application	Application	Analysis	Analysis
Install joint restraints	Application	Application	Application	Analysis
Install shoring	Application	Application	Application	Analysis
Install thrust blocks	Application	Application	Application	Analysis
Layout system	N/A	N/A	Application	Application
Map system	Comprehension	Comprehension	Comprehension	Comprehension
Perform pressure readings	Application	Application	Application	Analysis
Preparedness contingency/contingency plan	Application	Application	Application	Analysis
Read blueprints, readings, and maps	Application	Application	Application	Analysis
Select materials	Application	Application	Analysis	Analysis
Select type of pipes	Comprehension	Application	Application	Analysis

System Information/Components Continued	Class I	Class II	Class III	Class IV
Size mains	Comprehensive	Comprehensive	Application	Analysis
Write plans	Application	Application	Application	Analysis

Required Capabilities

Knowledge of:
- Approved backflow methods and devices
- Biological science
- Blueprint readings
- Building codes
- Corrosion control process (including cathodic protection)
- Fire flow requirements
- Function of recordkeeping system
- General hydraulic principles
- Hydrology
- Local codes and ordinances
- Measuring instruments
- Mechanical drafting
- Operation and maintenance practices
- Pipe fittings and joining methods
- Piping material, type and size
- Potential causes of disasters in facility
- Potential impact of disasters in facility
- Regulations
- Standards
- Watershed management

Ability to:
- Adjust equipment
- Assess likelihood of disaster occurring
- Generate a written safety program
- Generate capital plans
- Generate long- and short-term plans
- Interpret data
- Organize information
- Perform distribution math
- Perform impact assessments
- Perform physical measurements
- Record information
- Write policies and procedures
- Review reports

Monitor, Evaluate, and Adjust Disinfection	Class I	Class II	Class III	Class IV
Monitor Disinfection				
Calcium hypochlorite disinfection	Application	Application	Application	Application
Chlorine gas disinfection	Application	Application	Application	Analysis
Sodium hypochlorite disinfection	Application	Application	Application	Application
Evaluate Disinfection				
Calcium hypochlorite disinfection	Analysis	Analysis	Analysis	Analysis
Chlorine gas disinfection	Analysis	Analysis	Analysis	Analysis
Sodium hypochlorite disinfection	Analysis	Analysis	Analysis	Analysis

Monitor, Evaluate, and Adjust Disinfection Continued	Class I	Class II	Class III	Class IV
Adjust Disinfection				
Calcium hypochlorite disinfection	Analysis	Analysis	Analysis	Analysis
Chlorine gas disinfection	Analysis	Analysis	Analysis	Analysis
Sodium hypochlorite disinfection	Analysis	Analysis	Analysis	Analysis
Inspect Source Water				
Identify and evaluate potential sources of source water contamination	Analysis	Analysis	Analysis	Analysis
Wells	Application	Application	Application	Application

Required Capabilities

Knowledge of:

- Biological science
- Disinfection concepts
- Disinfection design parameters
- Disinfection process
- General chemistry
- Laboratory equipment
- Measuring instruments
- Physical science
- Proper chemical handling and storing
- Regulations
- Reporting requirements
- Safe Drinking Water Act (SDWA)
- Safety procedures
- Sampling requirements
- Testing instruments
- Watershed management
- 40 CFR 141 Subpart C: Monitoring and Analytical Requirements (turbidity, coliforms, organic contaminants, organic contaminants)
- 40 CFR 141 Subpart D: Reporting and Recordkeeping Requirements
- 40 CFR 141 Subpart F: Maximum Contaminant Level Goals and Maximum Residual Disinfectant Level Goals
- 40 CFR 141 Subpart G: National Primary Drinking Water Regulations: Maximum Contaminant Levels and Maximum Residual Disinfectant Levels
- 40 CFR 141 Subpart H: Filtration and Disinfection

Ability to:

- Adjust equipment
- Adjust flow patterns
- Adjust system units
- Calibrate equipment
- Calibrate instruments
- Interpret data
- Perform distribution math
- Recognize normal and abnormal analytical results

Required Capabilities Continued

Knowledge of:

- 40 CFR 141 Subpart L: Disinfectant Residuals, Disinfection Byproducts, and Disinfection Byproduct Precursors
- 40 CFR 141 Subpart P:Enhanced Filtration and Disinfection Systems Serving 10,000 or More People
- 40 CFR 141 Subpart T: Enhanced Filtration and Disinfection Systems Serving Fewer Than 10,000 People
- 40 CFR 141 Subpart U: Initial Distribution System Evaluations
- 40 CFR 141 Subpart V: Stage 2 Disinfection Byproducts Requirements

Laboratory Analysis	Class I	Class II	Class III	Class IV
Collect and Preserve Samples				
Chlorine demand	Application	Application	Analysis	Analysis
Chlorine residual	Application	Application	Analysis	Analysis
Coliforms	Analysis	Analysis	Analysis	Analysis
Lead/copper	Application	Application	analysis	Analysis
Nitrate	Application	Application	Analysis	Analysis
Nitrite	Application	Application	Analysis	Analysis
pH	Application	Application	Analysis	Analysis
Radionuclides	Application	Application	Analysis	Analysis
Synthetic organic chemicals (SOC)	Application	Application	Analysis	Analysis
Temperature	Application	Application	Analysis	Analysis
Volatile organic chemicals (VOC)	Application	Application	Analysis	Analysis
Perform Laboratory Analysis				
Chlorine demand	Analysis	Analysis	Analysis	Analysis
Chlorine residual	Analysis	Analysis	Analysis	Analysis
pH	Application	Application	Analysis	Analysis
Temperature	Application	Application	Analysis	Analysis

Laboratory Analysis Continued	Class I	Class II	Class III	Class IV
Interpret Laboratory Analysis				
Chlorine demand	Analysis	Analysis	Analysis	Analysis
Chlorine residual	Analysis	Analysis	Analysis	Analysis
Coliforms	Application	Application	Analysis	Analysis
Hardness	Application	Application	Analysis	Analysis
Iron	Application	Application	Analysis	Analysis
Lead/copper	Analysis	Analysis	Analysis	Analysis
Nitrates	Application	Application	Analysis	Analysis
Nitrites	Application	Application	Analysis	Analysis
pH	Application	Application	Application	Analysis
Radionuclides	Application	Application	Analysis	Analysis
Synthetic organic chemicals (SOC)	Application	Application	Analysis	Analysis
Temperature	Application	Application	Application	Analysis
Turbidity	Application	Application	Application	Analysis
Volatile organic chemicals (VOC)	Application	Application	Analysis	Analysis

Required Capabilities

Knowledge of:
- Biological science
- Disinfection concepts
- Disinfection design parameters
- Disinfection process
- General chemistry
- Laboratory equipment
- Monitoring requirements
- Normal characteristics of water
- Physical science
- Proper chemical handling and storing
- Proper sampling procedures
- Quality control/quality assurance practices
- Record keeping policies
- Regulations
- Reporting requirements
- Safe Drinking Water Act (SDWA)
- Safety procedures
- Sampling requirements
- Testing instruments
- 40 CFR 141 Subpart B: Maximum Contaminant Levels (arsenic, nitrate, turbidity)

Ability to:
- Calibrate equipment
- Calibrate instruments
- Determine what information needs to be recorded
- Diagnose/troubleshoot equipment
- Follow written procedures
- Interpret data
- Interpret Material Safety Data Sheets
- Organize information
- Recognize normal and abnormal analytical results
- Record information
- Review reports
- Transcribe data
- Translate technical language into common terminology

Required Capabilities Continued

Knowledge of:
- 40 CFR 141 Subpart C: Monitoring and Analytical Requirements (turbidity, coliforms, organic contaminants, organic contaminants)
- 40 CFR 141 Subpart D: Reporting and Recordkeeping Requirements
- 40 CFR 141 Subpart E: Special Regulations, Including Monitoring Regulations and Prohibition on Lead Use
- 40 CFR 141 Subpart F: Maximum Contaminant Level Goals and Maximum Residual Disinfectant Level Goals
- 40 CFR 141 Subpart G: National Primary Drinking Water Regulations: Maximum Contaminant Levels and Maximum Residual Disinfectant Levels
- 40 CFR 141 Subpart H: Filtration and Disinfection
- 40 CFR 141 Subpart I: Control of Lead and Copper
- 40 CFR 141 Subpart L: Disinfectant Residuals, Disinfection Byproducts, and Disinfection Byproduct Precursors
- 40 CFR 141 Subpart S: Ground Water Rule
- 40 CFR 141 Subpart V: Stage 2 Disinfection Byproducts Requirements

Install Equipment	Class I	Class II	Class III	Class IV
Backflow prevention devices	Comprehension	Application	Analysis	Analysis
Hydrants	Application	Application	Application	Application
Meters	Application	Application	Application	Application
Piping	Application	Application	Application	Application
Service connections	Application	Application	Application	Application
Taps	Application	Application	Application	Analysis
Valves	Application	Application	Application	Analysis
Water mains	Application	Application	Application	Analysis

Required Capabilities

Knowledge of:
- Approved backflow methods and devices
- Blueprint readings
- Building codes
- Corrosion control process (including cathodic protection)
- Dechlorination process
- Different types of cross-connections
- Different types of joints, restraints and thrust blocks
- Function of tools
- Personal protective equipment
- Pipe fittings and joining methods
- Piping material, type and size
- Pneumatics
- Proper lifting techniques
- Protective coatings and paints
- Safety procedures

Ability to:
- Demonstrate safe work habits
- Diagnose/troubleshoot equipment
- Identify potential safety hazards
- Inspect pumps
- Operate safety equipment
- Perform distribution math
- Recognize unsafe work conditions
- Select safety equipment
- Use hand tools
- Use power tools

Operate Equipment	Class I	Class II	Class III	Class IV
Blowers and compressors	Comprehension	Comprehension	Comprehension	Comprehension
Chemical feeders	Application	Application	Application	Analysis
Chlorinators	Analysis	Analysis	Analysis	Analysis
Computers	Comprehension	Application	Application	Application
Drives	Comprehension	Application	Application	Analysis
Electrical motors	Application	Application	Analysis	Analysis
Electronic testing equipment	Comprehension	Comprehension	Application	Analysis
Engines	Comprehension	Application	Application	Application
Generators	Application	Application	Application	Application
Hand tools	Application	Application	Application	Application
Heavy equipment	Comprehension	Comprehension	Application	Analysis
Hydrants	Application	Application	Application	Analysis
Hydraulic equipment	Comprehension	Comprehension	Application	Application
Instrumentation	Application	Application	Application	Analysis
Leak correlators/detectors	Application	Application	Application	Analysis
Pipe locators	Application	Application	Application	Analysis
Power tools	Application	Application	Application	Application
Pumps	Application	Application	Application	Analysis
Samplers	Comprehension	Application	Application	Analysis

Operate Equipment Continued	Class I	Class II	Class III	Class IV
SCADA	Comprehension	Application	Application	Analysis
Tapping equipment	Comprehension	Application	Application	Analysis
Telemetry system	Application	Application	Analysis	Analysis
Valve locators	Application	Application	Application	Analysis
Valves	Application	Application	Analysis	Analysis

Required Capabilities

Knowledge of:
- Facility operation and maintenance
- Function of tools
- General electrical principles
- General hydraulic principles
- General mechanical principles
- Internal combustion engines
- Lubricant and fluid characteristics
- Operation and maintenance practices
- Pipe fittings and joining methods
- Piping material, type and size
- Pneumatics
- Quality control/quality assurance practices
- Start-up and shut down procedures
- Testing instruments

Ability to:
- Adjust equipment
- Adjust flow patterns
- Adjust system units
- Calibrate equipment
- Calibrate instruments
- Demonstrate safe work habits
- Operate safety equipment
- Perform distribution math
- Perform physical measurements
- Recognize unsafe work conditions
- Select safety equipment
- Use hand tools
- Use power tools

Perform Maintenance	Class I	Class II	Class III	Class IV
Blowers and compressors	N/A	N/A	N/A	Application
Chemical feeders	Application	Application	Application	Analysis
Chlorinators	Application	Application	Analysis	Analysis
Corrosion control	Application	Application	Analysis	Analysis
Cross-connection control	Application	Application	Analysis	Analysis
Drives	N/A	N/A	N/A	Analysis
Electric motors	Application	Application	Application	Application
Electrical grounding	Application	Application	Application	Application
Engines	Comprehension	Application	Application	Analysis
Evaluate operation of equipment	Application	Application	Analysis	Analysis
Facility inspection	Application	Application	Analysis	Analysis
Generators	Application	Application	Application	Application
Hydrants	Application	Application	Analysis	Analysis

Perform Maintenance Continued	Class I	Class II	Class III	Class IV
Hydraulic equipment	N/A	N/A	Application	Analysis
Hypochlorinators	Application	Analysis	Analysis	Analysis
Instrumentation	Application	Application	Application	Analysis
Leak detection	Application	Application	Analysis	Analysis
Lock-out/tag-out	Application	Application	Application	Application
Meters	Application	Application	Application	Analysis
Pressure sensors	Application	Application	Analysis	Analysis
Pumps	Application	Application	Analysis	Analysis
Service connection	Application	Application	Application	Analysis
Service pipes	Application	Application	Application	Application
Valves	Application	Application	Application	Analysis
Water mains	Application	Application	Analysis	Analysis
Water storage facility	Application	Application	Analysis	Analysis

Required Capabilities

Knowledge of:

- Approved backflow methods and devices
- Blueprint readings
- Building codes
- Corrosion control process (including cathodic protection)
- Different types of cross-connections
- Different types of joints, restraints and thrust blocks
- Facility operation and maintenance
- Facility security
- Function of tools
- General electrical principles
- General hydraulic principles
- General mechanical principles
- Internal combustion engines
- Laboratory equipment
- Local codes and ordinances
- Lubricant and fluid characteristics
- Measuring instruments
- Operation and maintenance practices
- Personal protective equipment
- Pipe fittings and joining methods
- Piping material, type and size
- Pneumatics
- Potential causes of disasters in facility
- Potential impact of disasters in facility

Ability to:

- Adjust equipment
- Adjust flow patterns
- Adjust system units
- Assess likelihood of disaster occurring
- Assign work to proper trade
- Calibrate equipment
- Calibrate instruments
- Demonstrate safe work habits
- Diagnose/troubleshoot equipment
- Diagnose/troubleshoot system units
- Differentiate between preventative/corrective maintenance
- Discriminate between normal/abnormal conditions
- Evaluate facility performance
- Evaluate operation of equipment
- Evaluate system units
- Identify potential safety hazards
- Inspect pumps
- Interpret data
- Interpret Material Safety Data Sheets
- Maintain inventory control system
- Maintain system in normal operating condition
- Monitor electrical equipment
- Monitor mechanical equipment
- Obtain unbiased data
- Operate safety equipment
- Organize information

Required Capabilities Continued

Knowledge of:

- Proper chemical handling and storing
- Proper lifting techniques
- Protective coatings and paints
- Quality control/quality assurance practices
- Record keeping policies
- Safety procedures
- Sanitary survey processes
- Start-up and shut down procedures
- Testing instruments
- Well-head protection

Ability to:

- Perform distribution math
- Perform general maintenance
- Perform general repairs
- Perform physical measurements
- Recognize normal and abnormal analytical results
- Recognize unsafe work conditions
- Record information
- Review reports
- Select safety equipment
- Translate technical language into common terminology
- Use hand tools
- Use power tools

Perform Security, Safety, and Administrative Procedures	Class I	Class II	Class III	Class IV
Manage System				
Administer safety/compliance program	Comprehension	Application	Application	Analysis
Conduct cross-connection surveys	Application	Application	Analysis	Analysis
Develop budget	N/A	N/A	Analysis	Analysis
Develop operation and maintenance plan	Application	Application	Analysis	Analysis
Develop/maintain sample site plan	Application	Application	Analysis	Analysis
Participate in sanitary surveys	Application	Application	Application	Application
Regulatory reporting	Analysis	Analysis	Analysis	Analysis
Promote Public Relations				
Promote customer service program	N/A	Application	Analysis	Analysis
Respond to complaints	Application	Application	Application	Analysis

Perform Security, Safety, and Administrative Procedures Continued	Class I	Class II	Class III	Class IV
Safety Program				
Chemical safety	Application	Application	Application	Analysis
Confined space entry	Application	Application	Application	Application
Excavation, shoring and trenching	Application	Application	Application	Application
General safety	Application	Application	Application	Application
Personal protective equipment	Application	Application	Application	Application
Public protection	Application	Application	Application	Application
Recordkeeping				
Compliance	Application	Application	Application	Application
Corrective actions to system deficiencies	Application	Application	Application	Application
Equipment repair/replacement	Application	Application	Analysis	Analysis
Laboratory	Application	Application	Analysis	Analysis
Maintenance	Application	Application	Application	Application
System operation	Application	Application	Analysis	Analysis

Required Capabilities

Knowledge of:
- Biological science
- Blueprint readings
- Building codes
- Data acquisition techniques
- Disciplinary procedures
- Emergency plans
- Employment laws
- Facility security
- Function of recordkeeping system
- General chemistry
- General electrical principles
- General hydraulic principles
- General mechanical principles
- Human resource practices
- Hydrology
- Local codes and ordinances
- Memorandums of understanding and agreements
- Monitoring requirements
- Potential causes of disasters in facility

Ability to:
- Assess likelihood of disaster occurring
- Assign work to proper trade
- Communicate in writing
- Communicate verbally
- Conduct meetings
- Conduct training programs
- Coordinate emergency response with other water organizations relative to the distribution system
- Determine what information needs to be recorded
- Develop a staffing plan
- Develop a work unit
- Evaluate facility performance
- Evaluate promotional materials
- Evaluate proposals
- Follow written procedures
- Generate a written safety program
- Generate capital plans
- Generate long- and short-term plans

Required Capabilities Continued

Knowledge of:
- Potential impact of disasters in facility
- Principles of finance
- Principles of general communication
- Principles of management
- Principles of measurement
- Principles of public relations
- Principles of supervision
- Public notification requirements
- Public participation requirements
- Quality control/quality assurance practices
- Record keeping policies
- Regulations
- Reporting requirements
- Risk management
- Safe Drinking Water Act (SDWA)
- Sanitary spring design
- Sanitary survey processes
- Standards
- Water reuse
- Watershed management
- 40 CFR 141 Subpart A: General (definitions, coverage, variances and exemptions, siting requirements, and effective dates)
- 40 CFR 141 Subpart D: Reporting and Recordkeeping Requirements
- 40 CFR 141 Subpart O: Consumer Confidence Reports
- 40 CFR 141 Subpart Q: Public Notification of Drinking Water Violations

Ability to:
- Identify potential safety hazards
- Interpret data
- Negotiate contracts
- Obtain unbiased data
- Organize information
- Perform distribution math
- Perform impact assessments
- Prepare proposals
- Recognize normal and abnormal analytical results
- Recognize unsafe work conditions
- Record information
- Review reports
- Select safety equipment
- Transcribe data
- Translate technical language into common terminology
- Write policies and procedures

References

The following are approved as reference sources for the ABC distribution examinations. 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 Distribution Operator Training Handbook*
- *Basic Science Concepts and Applications*
- *Water System Security, A Field Guide*
- *Water Quality*

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

Association of State Drinking Water Administrators (ASDWA) and National Rural Water Association (NRWA)

- *Security Vulnerability Self Assessment Guide for Small Drinking Water Systems*

To order, contact:
ASDWA
1025 Connecticut Ave NW Ste 903
Washington DC 20036
Available online in PDF format
Web site: www.asdwa.org
Phone: (202) 293-7655
Fax: (202) 293-7656
E-mail: info@asdwa.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

Suggested Distribution System Exam References

The following are approved as reference sources for the distribution examinations. Operators should use the latest edition of these reference sources to prepare for the exam.

Textbooks

American Water Works Association (AWWA) www.awwa.org

- Water Transmission and Distribution
- Water Distribution Operator Training Handbook
- Basic Science Concepts and Applications
- Water System Security, A Field Guide
- Water Quality
- AWWA Standard for Installation of Ductile-Iron Water Mains and Their Appurtenances (ANSI/AWWA C600-93),

Association of State Drinking Water Administrators (ASDWA) and National Rural Water Association (NRWA) www.asdwa.org

- Security Vulnerability Self Assessment Guide for Small Drinking Water Systems

California State University, Sacramento (CSUS) Foundation, Office of Water Programs (www.owp.csus.edu)

- Water Distribution System Operation and Maintenance
- Small Water System Operation and Maintenance
- Manage for Success

Regulations

- Code of Federal Regulations, Labor (CFR 29), Part 1926 (www.gpo.gov)
- Code of Federal Regulations, Title 40 Part 141, www.gpo.gov)
- Community Public Water Systems Design Criteria, State of Tennessee, Department of Environment and Conservation, Division of Water Supply, Nashville, 2008.
- Regulations for Public Water Systems and Drinking Water Quality, State of Tennessee, Department of Environment and Conservation, Division of Water Supply, Nashville. June 2009.
- Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, TN, December 2009, Section 1200-5-3.

Study Guides

American Water Works Association: Operator Certification Study Guide, Fifth Edition: A Guide to Preparing for Water Treatment and Distribution Operator Certification Exams.

Suggested Primary Distribution System Exam References

The following are approved as reference sources for the ABC water treatment examinations. Operators should use the latest edition of these reference sources to prepare for the exam. These reference are not the only reference an operator should use in studying for the exam, however, these are the primary references used in developing the exam.

Distribution 1

- ****CSUS Water Distribution System Operation and Maintenance**
- **AWWA Basic Science Concepts and Applications**
- **AWWA Water Transmission and Distribution**
- **CSUS Small Water System Operation and Maintenance**
- ***Community Public Water Systems Design Criteria State of Tennessee Department of Environment and Conservation Division of Water Supply Nashville, Latest Revision***
- *Regulations for Public Water Systems and Drinking Water Quality State of Tennessee Department of Environment and Conservation Division of Water Supply Nashville, Latest Revision*
- *Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, Latest Revision*

Distribution 2

- ****CSUS Water Distribution System Operation and Maintenance**
- ****AWWA Water Transmission and Distribution**
- **AWWA Basic Science Concepts and Applications**
- ***Regulations for Public Water Systems and Drinking Water Quality State of Tennessee Department of Environment and Conservation Division of Water Supply Nashville, Latest Revision***
- ***Community Public Water Systems Design Criteria State of Tennessee Department of Environment and Conservation Division of Water Supply Nashville, Latest Revision***
- **AWWA Standard for Disinfection of Water Storage Facilities**
- **AWWA Water Distribution Operator Training Handbook**
- **CSUS Small Water System Operation and Maintenance**
- *Rules Governing Water and Wastewater Operator Certification, State of Tennessee, Department of Environment and Conservation, Board of Certification for Water and Wastewater Operators, Nashville, Latest Revision*

There are 2-3 primary references for each of exam. The ** denotes that 20+ of the exam items are linked to the noted reference.

Bold items have at least three items linked to them. Any references that are not in bold, have only 1-2 items linked to them.

The Tennessee State references are included, however, there is a sixth reference if the sixth had at least three items linked to it; in some cases this was a tie of 2-3 references with just a few items each. State of Tennessee references are italicized.

TOSHA Standards Requiring Annual Training

Class	Regulation	Who should attend?
Medical & Exposure Records	1910.20(g)(1)	All employees (inform- existence, person responsible, location, right of access
Emergency Action	1910.38(a)(5) 1910.38(b)(4)	All employees – based upon other standards and requirements
Noise	1910.95(k)	All employees exposed to an 8 hour TWA or greater of 85dBA
Emergency Response	1910.120(q)	Employees who respond to spills of hazardous chemicals
Personal Protective Equipment	1910.132(f)	Employees who wear PPE
Permit-Required Confined Space	1910.146(g)	Employees who enter, attend or supervise P.R. confined spaces
Lock-Out/Tag-Out	1910.147(c)(7)	Employees who work on machinery
First Aid	1910.151(b)	At least one employee on each shift, annual as required by other standards
Fire Brigade	1910.156(c)	All fire brigade members (quarterly and annually)
Portable Fire Extinguishers	1910.157(g)	All employees expected to use fire extinguishers
Fork Lift Trucks	1910.178(1)	Fork lift truck operators
Mechanical Power Presses	1910.217(f)(2)	Operators
Asbestos	1910.1001(j)(1)	All employees exposures at or above PEL or excursion limit
Lead	1910.1025(1)	Anyone with a potential for exposure at any level – copy of appendix A&B. If exposed at or above action level, must be trained
Bloodborne Pathogens	1910.1030(g)(2)	Employees who render first aid
Hazard Communication	1910.1200(h) TDL 800-1-9-.07	Employees exposed or potentially exposed to any type of chemicals
Hazardous Chemicals in Laboratories	1910.1450(f)(2)	Employees exposed to chemicals

Record Category		Time frame required to keep records		Source
Microbiological Records				0400-45-01-.20(1)(a)
Routine distribution		5 years		
Line repair records		5 years		0400-45-01-.17(8)(a)
New line records		5 years		
Bacteriological sampling plan		Keep updated, at least every 3 years		
Chemical Analysis				0400-45-01-.20(1)(a)
Inorganics/ secondaries		10 years		
SOC's		10 years		
VOC's		10 years		
THM's and HAA5's		10 years		
Radionuclides		10 years		
Lead and copper		12 years		0400-45-01-.33(12)
Miscellaneous				
Action regarding violations		3 years		0400-45-01-.20(1)(b)
Certified Letters to Fire Departments regarding Class C hydrants		5 years		0400-45-01-.17(18)
Complaint file		5 years		0400-45-01-.20(1)(h)
Consumer Confidence Reports		3 years		0400-45-01-.35(h)
Cross connection plans and inspection records		5 years		0400-45-01-.20(1)(h)
Daily worksheets, strip charts, shift logs		5 years		0400-45-01-.20(1)(g)
Disinfection Profile		10 years		
Disinfection SOP		Keep updated		
Distribution map		Keep updated, submit copy to DWS every 5 years		0400-45-01-.17(15)
Distribution SOP		Keep updated		
Emergency Operation Plan		Keep updated		0400-45-01-.34(4)(a)
Facility Maintenance Records		5 years		0400-45-01-.20(1)(h)
Flushing records		Survey to survey or 3 years		0400-45-01-.17(10)
MOR's		5 years		
MSDS		At least 30 years		29 CFR 1910.1020
New tap records		Survey to survey or 3 years		0400-45-01-.17(32)
Notice of Construction		Survey to survey or 3 years		
Plant SOP		Keep updated		
Public Notices		3 years		0400-45-01-.20(i)
Sanitary surveys		10 years		
Storage Tank Inspection Records		5 years		0400-45-01-.17(33), 0400-45-01-.20(1)(h)
Tank maintenance records		Life of tank		0400-45-01-.17(33)
Turbidity analysis: daily worksheets, calibration data and strip charts		5 years		0400-45-01-.20(1)(f)
Variances or Exemptions		5 years		0400-45-01-.20(1)(d)

Section 2

System Design & Pipes

Distribution System Design

DISTRIBUTION COURSE

Learning Objectives

- Types of public water systems
- Common configurations used in distribution system design
- Principal considerations involved in sizing water mains
- Considerations made for selecting piping materials

Types of Water Systems

- Surface water supply
- Groundwater
- Purchased water
- Rural Systems
  - Small water systems

Surface Water Systems

- Usually provides water for large communities with a lot of industrial and commercial usage
- Requires more treatment than groundwater
- Water usually enters the distribution system from one side and requires large transmission mains
- Water use on high-use days may be several times the amount on average day

Groundwater Systems

- Usually has limited withdrawal rates
- Requires less treatment than surface water
- Wells are dispersed in some systems, require less transmission mains
- Water may be corrosive or scale-forming
- Rate of water use sometimes exceeds the water source (aquifer)
- If single entry point, distribution system must be furnished with transmission mains as in the case of surface water system

Purchased Water Systems

- 3 principal reasons utilities purchase water
  - Well supply becomes inadequate
  - Water sources found to be contaminated
  - Regulatory compliance makes supply and treatment too difficult
- Operator's job is limited to primarily the distribution system
  - In some cases additional disinfection may be required
- Tight water accountability must be maintained in the distribution system

Factors Affecting Distribution Design

- Water availability and reliability
- Soil conditions and climate
  - How deep to put lines
  - What kind of pipe to use
- Terrain
- Water quality

Factors Affecting Distribution Design

- State and Federal requirements
- Future growth
- Costs: materials, labor, overhead, profit, land acquisition, legal expenses and engineering

Factors Affecting System Layout

- System planning
- Configuration
- Mapping
- Valving

System Planning

- Design should be done by city engineer or consultant
- Operators should be included in the process
- Important to include operators because they will have to make it work

System Configuration

- Usually one of three types
  - Arterial-loop
  - Grid
  - Tree
- Most systems are combination of grid and tree (branching system)

Arterial-Loop System Characteristics

- Attempts to surround the distribution area with large diameter mains
- Mains contribute water supply within the grid from several directions
- All major demand areas should be served by an arterial system
- Minimizes dead ends
- Branch mains project inward
- Fewer service interruptions with line breaks

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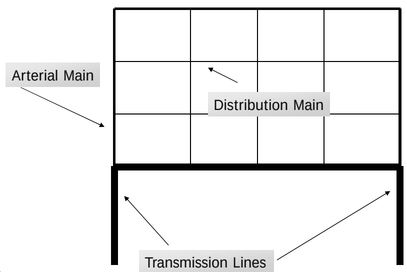
Arterial-Loop System



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Grid System Characteristics

- Depends on the fact that all mains are interconnected
- Water can flow from several different directions
- Mains are usually 6 - 8 inches
- Reinforced with larger arterial mains
- General area is fed by larger transmission mains
- All ends of mains are connected to eliminate dead ends

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Grid System Characteristics

- Minor distribution lines or mains make up secondary system which is the major portion of the grid which supply fire hydrants & domestic and commercial consumers

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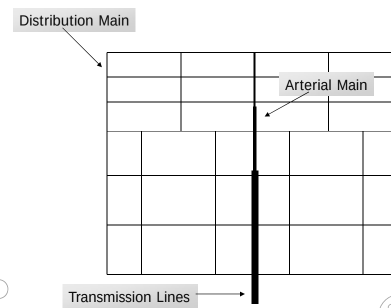
Grid System



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Tree System Characteristics

- Not highly recommended
- Few loops - flows often in one direction
- Difficult to supply a continuous flow of water to all parts of the system
- Customers are without water while repairs made to line breaks

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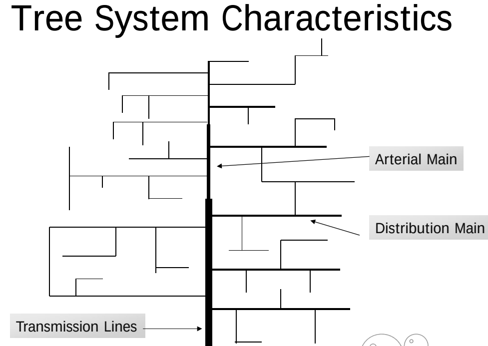
Tree System Characteristics



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Dead Ends

- Water flows in one direction
- Provides limited fire protection flow
- Mains are usually oversized for fire flow
- Domestic use is not enough to prevent stagnation and water degradation
- Customers beyond repair site are without water during work

Dead Ends

- Should have hydrant installed for flushing and fire protection
- Flush with a minimum velocity of
  2 ft/sec
- Should be avoided whenever possible

Types of Water Mains

- Transmission
- Distribution
- Service Lines

Transmission Mains

- Carry water from source of treatment to distribution system
- Generally straight
- No service connections
- Usually made of large pipe
- Size depends upon flow demand and available operational storage facilities
- Concrete with a steel cylinder is suitable because less expensive in larger sizes

Distribution Mains

- Carry water from transmission main
- Main arteries that carry water to neighborhoods
- Tapped for customer connections

Service Lines

- Small diameter pipe
- Connect from distribution main to customer
- Start with a corporation stop (shutoff valve)
- Various material are used commonly plastic pipe, PVC, Polyethylene, and Polybutylene
- Lead service lines no longer acceptable and should be replaced

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Factors for Sizing Water Mains

- Quantity requirements depends on consumption and fire flow requirements
- No main may be less than 6 inches in diameter for fire protection
- High value districts should have minimum pipe size of 8-12 inches

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Factors for Sizing Water Mains

- Residential areas: 6-8 inch lines
- Mains smaller than 6 inches used only when completing a grid
- Varying elevation areas usually require two or more pressure zones
- Higher pressures contribute to more main and service line leaks

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Water Pressure Requirements and Considerations

- Normal working pressure 50 - 75 psi for residential areas
- Minimum: 20 psi (under all flow conditions)
- Maximum: 100 psi
- Pressure reducing valves used if greater pressure exists (some building codes require in newer subdivisions)

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Water Pressure Requirements and Considerations

- High pressure contributes to main and service leak problems
- Booster pumps often required for larger systems
- Ideal system would rely completely on gravity

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Flow Velocity Requirements and Considerations

- Determines pipe capacity and required size
- Normally limited to about 5 ft/sec
- Higher velocities cause excessive friction loss as water flows through pipe
- Large variations of flow can adversely affect water quality

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Flow Velocity Requirements and Considerations

- Sediments can be carried to customer with flow velocity changes
- Low circulation can result in growth of organisms, corrosion products, depletion of oxygen and increased rates of taste and odor
- Turbulence can cause air in system which produces milky water

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Pipe Material Selection Consideration

- What qualities should the pipe have?
- What are the performance ratings of the pipe?
- What pipe material is available?
- What materials are currently used in distribution system?
- Are existing materials compatible?
- COST $$$$$$

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Pipe Qualities Selection Considerations

- Can it handle external load from backfill?
- Can it handle internal pressures within pipe?
- Normally within 40-100 psi range
- Water hammer and surges
- Tensile strength
- Flexible or flexural strength
- Pipe shear breakage when earth shifts
- Beam breakage

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Piping Terms

- **External load** - the pressure exerted on a pipe after it has been buried in a trench
- **Internal pressure** - the hydrostatic pressure from within the pipe
- **Tensile strength** - the resistance of a material to longitudinal (lengthwise) pull
- **Flexural strength** - the ability of a material to bend or flex without breaking

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Piping Terms

- Pipe shear breakage or beam breakage may occur when a force exerted on a pipe causes stresses that exceed the tensile or flexural strength
- **Shear breakage** – occurs when the earth shifts
- **Beam breakage** – occurs when a pipe is unevenly supported along its length

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Pressure Rating of Pipe Material

- Pressure ratings can be calculated using AWWA standards
- Distribution pipe should have pressure rating 2.5 - 4 times normal operating pressure
- Replacement pipe must have a pressure rating greater than or equal to that replaced

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Other Considerations

- Durability & life span
- Corrosion resistance
- Smoothness of inner surface - C Factor
- Ease of installation
- Ease of tapping & repair
- Ability to maintain water quality
- Compatibility
- Local conditions
- Installation COSTS
- All pipe must meet AWWA Standards
- Tennessee Design Criteria for Distribution Systems

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Pipes

Materials, Installation
& Maintenance

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Types of Pipe

- CIP (Cast Iron Pipe)
- DIP (Ductile-Iron)
- Steel Pipe
- Asbestos-cement pipe (AC)
- Plastic
- Concrete

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Gray Cast-Iron Pipe

- Used as early as 1664 in France
- Called sand-cast pipe
- Some systems are over 100 years old in US
- Strong but brittle
- Older pipe can be identified by rough texture on outside wall
- Since 1920, produced by centrifugal process - outside walls smoother and uniform in size
- Beam break most common
- No longer used for manufacturing pipe
- Still used to make some valves and fittings

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Ductile-Iron Pipe (DIP)

- Became popular in 1960's
- More modern, tougher type of cast iron pipe
- Produced in same type mold as CIP
- Has "ductile iron" stenciled to distinguish from CIP
- Graphite distributed in the metal
- Much stronger than CIP
- Polyethylene wrap on pipe commonly used to prevent corrosion

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Advantages of DIP

- Good durability
- Flexural strength
  - Will resist bending and twisting without breaking
- Smooth interior (C140)
- Carrying capacity
- Fracture resistance
- External corrosion good in most type soils
- Withstand high pressure
- Long term economical
- Diversity when combined with different fittings, joints, valves

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Disadvantages of DIP

- External corrosion in aggressive environments if not protected
- Reliant upon special linings to protect against corrosion
- Costly to maintain
- Greater weight increases difficulty of installation

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Ductile-Iron Pipe Joints

- Flanged
- Mechanical
- Ball-and-Socket (Submarine)
- Push-on
- Restrained
- Grooved and Shouldered

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Flanged Joints

- Two machined surfaces tightly bolted together with a gasket between them
- Used in exposed locations
- Should not be used underground
  - Due to lack of flexibility to compensate for ground movement
- Used at treatment plant & pump stations

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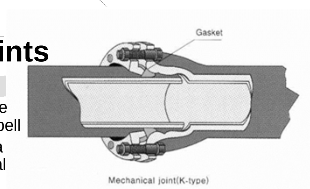
Mechanical Joints



- Movable follower ring on the spigot to the flange on the bell
- Follower ring compresses a rubber gasket to form a seal
- More expensive
- Make a very positive seal and require little technical expertise to install
- Allow for some deflection of the pipe
- Provide flexibility in event of ground settlement after pipe installation

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Ball-Socket Joint

- Special purpose joints used for intakes and river crossings
- Provide large deflection
- Used in rough terrain
- Joint consists of bell with special recess to accept a rubber ring gasket
- Available in several designs
- Deflections up to 15°
- Available in bolted and unbolted

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Ball-Socket Joint

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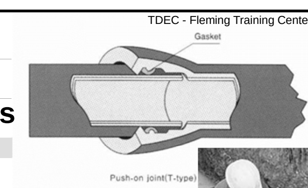
Push-On Joints



- Most popular
- Easier installation
- Lower cost
- Consists of a special bell fitted with a greased gasket
- Spigot end must have beveled edge to prevent tearing the rubber ring gasket
- Available in several designs
- Internal water pressure compresses the gasket making tight seals

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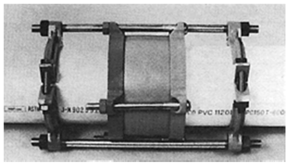
Restrained Joint

- Used to ensure joints do not separate such as elbows
- Used in areas where concrete thrust blocks cannot be used
- Some have special restraining feature



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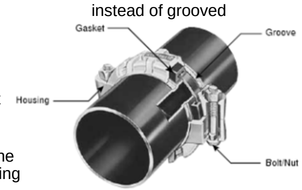
Grooved & Shoulder Joints

- Grooved
  - Utilizes bolted, segmental, clamp-type, mechanical coupling
  - Housing encloses a U-shaped rubber gasket
  - Housing locks the pipe ends together
  - Compresses the gasket against outside of pipe ends
  - Ends of pipe are machine grooved to accept housing
- Shoulder
  - Similar to grooved
  - Pipe ends are shouldered instead of grooved



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Steel Pipe Characteristics

- More often for high-pressure situations
- Relatively light weight
- Competitively priced (i.e. over 16" diameter)
- Will bend without buckling
- High tensile strength
- Is subject to internal and external corrosion

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Steel Pipe Characteristics

- Has cement mortar or epoxy lining
- Partial vacuum can cause pipe distortion or collapse
- Exterior requires corrosion and abrasion protection
- Frequently used for in-plant piping
- May have cathodic protection

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Steel Pipe Joints and Fittings

- Pipe lengths often joined by welding
- Mechanical joints used
- Cast iron or ductile-iron fittings

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Asbestos-Cement Pipe Characteristics

- Often preferred in areas with corrosive soil
- Lightweight, low initial cost
- Made of asbestos fibers, silica sand, and Portland cement
- Asbestos fibers provide much of the strength
- Not subject to metallic corrosion, tuberculation, and C factor usually stays high

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Asbestos-Cement Pipe Characteristics

- Should not be used with very aggressive or soft water, or aggressive soils
- Proper bedding is required to prevent breaks
- Easily punctured during excavations
- Low flexural strength
- Requires safety PPE (personal protective equipment)
- Cannot be located with pipe locators

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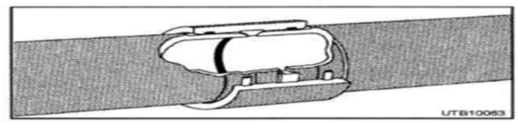
Asbestos-Cement Pipe Joints

- Joined by sleeved couplings, also asbestos cement
- Sleeve has 2 interior rubber rings
- Cast-iron or ductile-iron fittings used, except couplings
- Asbestos in water does not cause health effects
- PVC is replacing AC pipe



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Plastic Pipe Characteristics

- Inert - will not react or corrode
- Widely used in water utility industry
- Will not leach out taste and odor causing substances
- Smooth interior
- Must be NSF International Standard 61 certified and marked on exterior surface
- Organic compounds can permeate (gas, fuel, oil)
- Should not be installed where contamination from organic compounds is probable

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Plastic Pipe Types

- PVC – polyvinyl chloride
  - Most common
- PE – polyethylene
- PB – polybutylene
  - not used for water services

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Plastic Pipe Joints

- PVC
  - Bell and spigot
  - Solvent weld
  - Threading (>schedule 80 pipe)
- PE
  - Heat fusion

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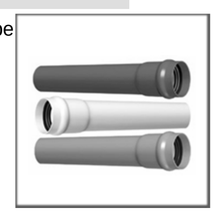
PVC (Polyvinyl Chloride) Pipe Characteristics and Advantages

- Most commonly used plastic pipe
- Generally lower cost
- Cheaper to ship
- Easier to handle
- Cuts easier
- C Factor of at least 150
- Chemically inert
- Moderately flexible and will adapt to ground settling



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PVC Disadvantages

- Susceptible to damage from UV
- Permeable by organics
- Requires careful bedding to prevent damage
- Difficult to locate because nonconductive
- Inability to be thawed electrically
- Susceptible to permeation
- Buckles under a vacuum
- Must adhere to use of proper tools and procedures when service taps are made

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Concrete Pipe Types

- Pre-stressed Cylinder
- Pre-tensioned
- Reinforced
- Reinforced non-cylinder

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Prestressed Concrete Cylinder Pipes

- Two types manufactured
  - Lined-cylinder available in diameters from 16 - 60 inches
  - Embedded-cylinder available in diameters from 24 - 144 inches
- Manufactured with a full length of welded steel cylinder
- Concrete core in the interior

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Pretensioned (Rod-Wrapped) Concrete Cylinder Pipe

- Similar to pre-stressed, but cylinder is wrapped with smooth hot-rolled steel bar
- Core protected with mortar coating
- Normally available in diameters of 10 - 54 inches

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Advantages of Concrete Pipe

- Manufactured inexpensively in large sizes
- Withstands high internal pressure and external load
- Resistant to both internal and external corrosion
- Very long and trouble-free life span, if properly installed
- Minimal bedding requirements

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Disadvantages of Concrete Pipe

- Very heavy weight
- Shipping costs high
- Special handling equipment required
- Exact pipe fittings and lengths required for installation
- Must be carefully planned and laid out in advance

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Installation

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Pipe Shipping and Unloading

- Can be shipped via truck, railroad or barge
- Pipe should be inspected upon arrival
- Handle carefully
- Inspect lining and coating
- Plastic pipe inspected closely if arriving in cold weather
- Use proper equipment to unload

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Stacking Pipe

- If pipe is to be stacked and stored - ensure it is stored off the ground
- Secure pipe to prevent rolling
- Secure the storage area
- Protect plastic pipe from sunlight - but allow air circulation

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Stringing Pipe

- Pipe should be laid as near to the trench as possible to minimize handling
- String pipe on opposite side of spoil pile
- Place bells in direction of installation
- Secure each section to prevent rolling into trench
- String only enough for one days work to prevent vandalism
- May need to cover ends to keep dirt out and prevent contamination

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Excavation

- Plans are prepared by project engineer and submitted for State approval
- Plans should show location and depth of main, valves, hydrants and fittings
- Plans should show location and depth of sewer and gas pipes, buried telephone lines, electric and cable lines
- Ensure selection of proper sized excavation equipment
- Notification to public
- Tennessee One Call

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Excavation

- Water and Sewer lines separation at least ***<u>18 in</u>*** between the bottom of the water main and top of the sewer line
- Water mains should be at least ***<u>10 ft</u>*** horizontally from any sewer line

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Trenching

- Most expensive part of main installation
- Minimize width and depth as much as possible without compromising safety
- Width should be no more than 1-2 ft more than pipe diameter, wider around curves
- Trench depth depends on maximum depth of frost penetration, minimum of 2.5 feet
- Minimum distance from trench to spoil pile is 2 feet

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Trenching

- Must have egress if 4 feet or deeper - stairway, ladders
- Trench must be shored or sloped at 5 feet or deeper
- If 20 feet or deeper, must be designed by an engineer
- Left open as short a time as possible
- Mark with barricades, warning tape, lights, etc to prevent accidents

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Pipe Laying Procedures

- Inspect before laying and placing in trench
- Check for damage to the spigot end and lining
- Tap gently with a hammer (should ring)
- Wash, hose, or swab with hypochlorite if excessively dirty

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Pipe Laying Procedures

- Keep gaskets clean and dry
- Use a sling or pipe tong to place into trench - never roll
- Cover pipe with plug at the end of each work day
- Ensure pipe bedding is level and compacted
- Compact the backfill beneath the pipe curvature (Haunching)

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Pipe Joints

- Ensure gasket and spigot are clean before being attached
- Bell holes or recesses in bedding dug to allow for joint installation
- Spigot end must be inserted to the painted line
- Full-length pipes are beveled at end to facilitate connection
- Level pipe for cutting
- Insert pipe straight

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Connecting to an Existing Main

- Shut off water to existing main and ensure valve will hold
- Must know the size and type of main to get proper fittings and gaskets
- Connecting to main using pressure taps
  - Does not require shutting off water and
  - Less chance of contaminating water
  - Also, fire protection remains in service for the area

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Thrust Restraints in Pipe Installation

- Water under pressure and water in motion exerts tremendous pressure inside a pipe
- All tees, bends, reducers, caps, plugs, valves and hydrants should be restrained or blocked
- 4 general methods
  - thrust blocks
  - thrust anchors
  - restraining joints or fittings
  - batter piles

82

Thrust Restraints in Pipe Installation

- Thrust blocks are made of concrete or other permanent material and are cast in place between fittings and undisturbed soil in the trench
- Thrust anchors can be used when there is no undisturbed solid structure to block against so a thrust block is not usable
  - steel rods hold the pipe and are attached to a block of concrete

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Thrust Restraints in Pipe Installation

- Tie rods are used to restrain mechanical joint fittings that are located close together
  - nuts on either side of each joint take the place of the MJ bolt that they replace
- Restraining fittings use clamps and anchor screws
  - useful where other existing utilities or structures are so numerous that thrust blocks aren't usable

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Piping Air Relief

- Air gets trapped in water mains laid on uneven ground
- Constricts water flow
- In small mains, can be removed by flushing
- Removal possible in corporation stops
- Automatic air-relief can be installed at each high point in pipeline

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Backfilling and Testing

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Purpose of Backfilling

- Provide for pipe and fitting support
- Provides lateral stability between pipe and trench walls
- Prevents pipe movement during water hammer
- Carries and transfers surface loads

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Placing Backfill

- Only clean sand or selected soil should be used for first layer
- Moist enough for compaction
- Should not contain peat, large rocks, debris or frozen material
- First layer placed equally on both sides of pipe, up to center, and compacted
- Do by hand or pneumatic tamper
- Second layer should be good quality backfill material
- Remaining backfill can be excavated spoils

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Compacting

Tamping Soil

- Three methods for compacting soil
  - Tamping
  - Vibration
  - Saturation with water
- Depends upon the type of soil or material used

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Pressure and Leak Testing

- **Leakage** – the volume of water that must be added to the full pipeline to maintain a specific test pressure within a 5 psi range
- Mains tested after trench has been partially filled
- Should be done before trench is completely closed so that any leakage can be observed and repaired easily

90

Leak Testing Procedure

1. Allow at least 5 days for the concrete used for thrust blocks to cure
2. Install pressure pump equipped with a make up reservoir, a pressure gauge, and a method for measuring the amount of water pumped
3. Close all appropriate valves
4. Slowly fill test section with water while expelling air at all high points
5. Start applying partial pressure with positive displacement pump

91

Leak Testing Procedure

6. Once lines full, leave partial pressure on & allow line to stand for 24 hours to stabilize
7. Subject test line to pressure of either 1.5 times the operating pressure or 150 psi, whichever is greater, for at least 30 minutes
8. Examine installed pipe & fittings for visible leaks/pipe movement
9. After test pressure has been maintained for at least 2 hours, conduct leakage test by using the makeup reservoir and measuring the amount of water that has to be used to maintain specified test pressure

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Leak Testing Procedure

10. Compare amount of leakage to allowable leakage given appropriate AWWA standard
    - Swift loss of pressure is likely due to break in the line or an open valve
    - Slow loss of pressure may be due to leaking valve or pipe joint

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Pressure and Leak Testing

- Test pressure and allowable leakage are in AWWA Standards
- Any leaking joints, valves, etc should be adjusted or repaired
- Possible causes for leaks are

Debris lodging a valve	Improperly tightened joints
Partially open corporation stops	Damage to pipe

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Pipe Flushing

- New lines must be flushed, disinfected, and tested for bacteriological quality before placing into service
- Velocity of at least 2.5 ft/sec
- For large diameter mains, more than one hydrant may be used
- A blow off connection may be used if installed
- A pig may be used if water plant capacity not sufficient to provide the quantity of water required for flushing line

95

Disinfection

- Calcium or sodium hypochlorite
- Ensure chlorinated water in pipe for 24 hours
- All valves and hydrants operated to ensure disinfection of all parts
- Should bleed periodically to ensure water movement
- Inject liquid bleach through corporation stop
- When completed, high chlorinated water is flushed out
- Coordinate with waste water plant before discharging highly chlorinated water into sewer
- Contact State if environmental effects occur

96

Methods of Disinfecting

- Tablet Method
- Continuous Feed Method
- Slug Method

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Water Main Cleaning

- Mechanical cleaning may be necessary to clear tuberculation and deposits of older pipes
- Should first try to clean by flushing
- Devices such as swabs or pigs may be needed
- Cleaning operations can increase the flow rates through pipe
- Valves and hydrants should be checked prior to cleaning

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Water Main Cleaning

- Customers notified
- Temporary water service for customers
- Must be able to control pressure surges in system
- Flush until water clear
- Conduct flow test

99

Bacteriological Testing

- State requires two consecutive sets of samples taken 24 hours apart **OR** one set 48 hours after disinfecting new lines
- Samples shall be taken from each 2500 feet of main with samples near the beginning and at the end point
- Requires 24 hour incubation
- Must be absent of coliforms
- If tests positive for coliforms, line must be disinfected again, flushed and retested

State Rules 0400-45-01-.17(8)(b)

100

Site Restoration

- Restored to original condition as soon as possible
- Grass restored, curbs replaced, pavement repaired
- Final inspection should include marked location of valves, hydrants and all in full open position
- Note number of turns to open valves, direction to open
- Check drainage ditches for debris which would facilitate flooding
- Private property must be returned to original condition

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Safety

- Wear hard hats when necessary
- Follow safety guidelines, including sloping and shoring
- Use proper traffic control measures: warning signs, traffic cones, tape off restricted and danger areas, caution lights
- Use proper precautions when unloading pipe
- Get a permit (Tennessee One Call) before excavating
- Use proper Personal Protective Equipment when handling chlorine, etc.

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Pipe Vocabulary

A. Arterial Loop System
B. Backfill
C. Ball & Socket Joint
D. Beam Breakage
E. Bedding
F. C Factor
G. Concrete Pipe
H. Distribution Mains
I. External Load
J. Flanged Joint
K. Flexural Strength
L. Grid System
M. Grooved & Shoulder Joint
N. Haunching
O. Hazen-Williams Formula
P. Internal Pressure
Q. Mechanical Joint
R. Push-on Joint
S. Restrained Joint
T. Service Line
U. Shear Breakage
V. Spoil
W. Surge
X. Tensile Strength
Y. Transmission Line
Z. Tree System

_____ 1. One side of the joint has a bell with a specifically designed recess to accept a rubber ring gasket; the other side has a beveled-end spigot.

_____ 2. This pipe provides a combination of the high tensile strength of steel and the high compressive strength and corrosion resistance of concrete.

_____ 3. A distribution system layout involving a complete loop of arterial mains around the area being served, with branch mains projecting inward.

_____ 4. A distribution system layout that centers around a single arterial main, which decreases in size with length.

_____ 5. The portion of the material placed in an excavation on either side of and under a pipe from the top of the bedding up to the horizontal centerline of the pipe.

_____ 6. A joint that consists of two machined surfaces that are tightly bolted together with a gasket between them.

_____ 7. The soil used to level out an irregularities and ensure uniform support along the length of a pipe in the trench.

_____ 8. A break in a pipe that occurs when the earth shifts.

_____ 9. A distribution system layout in which all ends of the mains are connected to eliminate dead ends.

_____ 10. Any pipe in the distribution system other than a service line.

_____ 11. A sudden repeated increase and decrease in pressure that continues until dissipated by friction loss. Also known as water hammer.

_____12. These joints are special purpose joints, most commonly used for intakes and river crossings because they allow for a high level of deflection.

_____ 13. The pipeline or aqueduct used for water transmission.

_____ 14. The load or force exerted by the water pressure on the inside of a pipe.

_____ 15. The pipe that runs between the utility's water main and the customer's place of use.

_____ 16. A pipe in which each end of the pipe has a groove or shoulder that receives the sides of a trough-shaped metal housing the which there is a similarly shaped rubber gasket.

_____ 17. Any load placed on the outside of the pipe from backfill, traffic, or other sources.

_____ 18. A flexible device that joins pipe or fittings together by the use of lugs or bolts.

_____ 19. Excavated material from the trench of a water main.

_____ 20. A measure of the ability of pipe to resist breakage when it is pulled lengthwise.

_____ 21. A value used to indicate the smoothness of the interior of a pipe.

_____ 22. The material placed over a pipe up to the ground surface.

_____ 23. The ability of a material to bend (flex) without breaking.

_____ 24. A joint that is used where there is a lack of space to lock a joint in place to prevent movement, or where there is a possibility the soil behind a fitting will be disturbed.

_____ 25. A method for calculating pipe size based on flow velocity, hydraulic radius, friction slope, and the Hazen-Williams coefficient (C value).

_____ 26. A break in a pipe that occurs when the pipe is unevenly supported along its length.

Pipe Vocabulary Answers

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

Section 3

Math Review

Basic Math Concepts

For Water and Wastewater Plant Operators
by Joanne Kirkpatrick Price

Suggested Strategy

- Disregarding all numbers, what type of problem is it?
- What diagram, if any, is associated with the concept identified?
- What information is required to solve the problem and how is it expressed in the problem?
- What is the final answer?
- Does the answer make sense?

Solving for the Unknown Value (X)

Solving for X

- Solve for X

$$(4)(1.5)(x) = 1100$$

  - X must be by itself on one side of equal sign
    - 4 and 1.5 must be moved away from X

$$x = \frac{1100}{(4)(1.5)}$$

$$x = 183.3$$

    - How was this accomplished?

Movement of Terms

- To understand how we move the numbers, we will need to consider more closely the math concepts associated with moving the terms.
- An equation is a mathematical statement in which the terms or calculation on one side equals the terms or calculation on the other side.

Movement of Terms

- To preserve this equality, anything done to one side of the equation must be done to the other side as well.

$$3x = 14$$

- Since X is multiplied by 3, you can get rid of the 3 by using the opposite process: division.

Movement of Terms

- To preserve the equation, you must divide the other side of the equation as well.

$$\frac{\cancel{3}x}{\cancel{3}} = \frac{14}{3}$$

$$x = \frac{14}{3}$$

- Since both sides of the equation are divided by the same number, the value of the equation remains unchanged.

Example 1

$$730 = \frac{x}{3847}$$

What you do to one side of the equation, must be done to the other side.

$$730 = \frac{x}{3847} \times \frac{3847}{1}$$

$$\frac{3847}{1} \times 730 = \frac{x}{\cancel{3847}} \times \frac{\cancel{3847}}{1}$$

$$3847 \times 730 = x$$

$$2{,}808{,}310 = x$$

Example 2

$$0.5 = \frac{(165)(3)(8.34)}{x}$$

Simplify

$$0.5 = \frac{4128.3}{x}$$

What you do to one side of the equation, must be done to the other side.

$$0.5 = \frac{4128.3}{x} \times \frac{x}{1}$$

$$\frac{x}{1} \times 0.5 = \frac{4128.3}{\cancel{x}} \times \frac{\cancel{x}}{1}$$

$$(x)(0.5) = 4128.3$$

$$\frac{(x)(\cancel{0.5})}{\cancel{0.5}} = \frac{4128.3}{0.5}$$

$$x = \frac{4128.3}{0.5}$$

$$x = 8256.6$$

Solving for X^2

- Follow same procedure as solving for X
- Then take the square root

$$x^2 = 15{,}625$$

$$\sqrt{x^2} = \sqrt{15{,}625}$$

$$x = 125$$

Example 3

$$(0.785)(x^2) = 2826$$

$$\frac{(\cancel{0.785})(x^2)}{\cancel{0.785}} = \frac{2826}{0.785}$$

$$x^2 = \frac{2826}{0.785}$$

$$x^2 = 3600$$

$$\sqrt{x^2} = \sqrt{3600}$$

$$x = 60$$

DIMENSIONAL ANALYSIS

MATHEMATICS MANUAL FOR WATER AND WASTEWATER TREATMENT PLANT OPERATORS BY FRANK R. SPELLMAN

DIMENSIONAL ANALYSIS

- Used to check if a problem is set up correctly
- Work with the units of measure, not the numbers
- Step 1:
  - Express fraction in a vertical format

$$gal/ft^3 \text{ to } \frac{gal}{ft^3}$$

- Step 2:
  - Be able to divide a fraction

$$\frac{\frac{lb}{day}}{\frac{min}{day}} \text{ becomes } \frac{lb}{day} \times \frac{day}{min}$$

DIMENSIONAL ANALYSIS

- Step 3:
  - Know how to divide terms in the numerator and denominator
  - Like terms can cancel each other out
    - For every term that is canceled in the numerator, a similar term must be canceled in the denominator

$$\frac{lb}{\cancel{day}} \times \frac{\cancel{day}}{min} = \frac{lb}{min}$$

- Units with exponents should be written in expanded form

$$ft^3 = (ft)(ft)(ft)$$

EXAMPLE 4

- Convert 1800 ft^3 into gallons.
- Use the factor 7.48 gal/ft^3
- Would we divide or multiply? Use only the dimensions first to determine the correct setup.
  - Divide

$$\frac{ft^3}{gal/ft^3} = \frac{ft^3}{\frac{gal}{ft^3}}$$

$$ft^3 \times \frac{ft^3}{gal} = \frac{ft^6}{gal}$$

  - Multiply

$$\cancel{ft^3} \times \frac{gal}{\cancel{ft^3}}$$

$$gal$$

EXAMPLE 4 CONT'D

- Convert 1800 ft^3 into gallons.
- Use the factor 7.48 gal/ft^3

$$(1800\ \cancel{ft^3})\left(7.48\ \frac{gal}{\cancel{ft^3}}\right)$$

$$13{,}464\ gal$$

Fractions and Percents

Converting Decimals and Fractions

- To convert a fraction to a decimal
  - Simply divide the numerator by the denominator

$$\frac{1}{2} = 1 \div 2 = 0.5$$

$$\frac{10}{13} = 10 \div 13 = 0.7692$$

Percents and Decimals

- To convert from a decimal to a percent
  - Simply move the decimal point two places to the right

$0.46. \rightarrow 46.0\%$

- To convert from a percent to a decimal
  - Simply move the decimal two points to the left

$.79.5\% \rightarrow 0.795$

- Remember:

  You CANNOT have a percent in an equation!!

Writing Equations

- Key words
  - **Of** means "multiply"
  - **Is** means "equal to"
- Calculate 25% of 595,000

$$25\% \times 595{,}000$$

$$0.25 \times 595{,}000$$

$$148{,}750$$

Example 5

448 is what percent of 560?

$$448 = x\% \times 560$$

$$\frac{448}{560} = \frac{x\% \times \cancel{560}}{\cancel{560}}$$

$$0.80 = x\%$$

$$80\% = x$$

Solving for the Unknown

Basics – finding x

1. $8.1 = (3)(x)(1.5)$

2. $(0.785)(0.33)(0.33)(x) = 0.49$

3. $\frac{233}{x} = 44$

4. $940 = \frac{x}{(0.785)(90)(90)}$

5. $x = \frac{(165)(3)(8.34)}{0.5}$

6. $56.5 = \frac{3800}{(x)(8.34)}$

7. $114 = \frac{(230)(1.15)(8.34)}{(0.785)(70)(70)(x)}$

8. $2 = \frac{x}{180}$

9. $46 = \frac{(105)(x)(8.34)}{(0.785)(100)(100)(4)}$

10. $2.4 = \frac{(0.785)(5)(5)(4)(7.48)}{x}$

11. $19{,}747 = (20)(12)(x)(7.48)$

12. $\dfrac{(15)(12)(1.25)(7.48)}{x} = 337$

13. $\dfrac{x}{(4.5)(8.34)} = 213$

14. $\dfrac{x}{246} = 2.4$

15. $6 = \dfrac{(x)(0.18)(8.34)}{(65)(1.3)(8.34)}$

16. $\dfrac{(3000)(3.6)(8.34)}{(0.785)(x)} = 23.4$

17. $109 = \dfrac{x}{(0.785)(80)(80)}$

18. $(x)(3.7)(8.34) = 3620$

19. $2.5 = \dfrac{1{,}270{,}000}{x}$

20. $0.59 = \dfrac{(170)(2.42)(8.34)}{(1980)(x)(8.34)}$

Finding x^2

21. $x^2 = 100$

22. $(2)(x^2) = 288$

23. $(0.785)(D^2) = 5024$

24. $(x^2)(10)(7.48) = 10{,}771.2$

25. $51 = \frac{64{,}000}{(0.785)(D^2)}$

26. $(0.785)(D^2) = 0.54$

27. $2.1 = \frac{(0.785)(D^2)(15)(7.48)}{(0.785)(80)(80)}$

Basic Math
Dimensional Analysis

Dimensional analysis is not just a way to work math problems. It is an easy way to verify that your formula is set up properly before the calculation is performed.

Rules to follow:

- ✓ Units written in abbreviated or horizontal form should be rewritten in a vertical format. For example:

$$\text{cfs} \Rightarrow \frac{\text{ft}^3}{\text{sec}} \qquad \text{gal/cu ft} \Rightarrow \frac{\text{gal}}{\text{ft}^3}$$

- ✓ Any unit that is a common factor to both the numerator and denominator of a fraction may be divided out. For example:

$$\left(\frac{20\ \text{ft}^3}{\text{sec}}\right)\left(\frac{60\ \text{sec}}{\text{min}}\right) = \frac{(20)(60)\text{ft}^3}{\text{min}}$$

- ✓ An exponent of a unit indicates how many times that unit is to be multiplied together. For example:

$$\text{ft}^3 = (\text{ft})(\text{ft})(\text{ft})$$

  - o Sometimes it is necessary to write terms with exponents in expanded form, while other times it is advantageous to keep the unit in exponent form. This choice depends on which other units are part of the calculation and how these units might divide out.

Remember: Fractions must be multiplied or divided to do any canceling. Fractions that are added and subtracted can't be cancelled.

Basics:
Use dimensional analysis to determine the **units** of the answers:

1. (0.785)(ft)(ft)(ft)

2. (120 ft^3/min)(1440 min/day)

3. $\frac{(8ft)(10ft)(xft)}{sec}$

Verify the mathematical setup for each problem. If the setup is incorrect, correct the setup:

4. (1.6 fpm)(60 sec/min) = fps

5. (70 in)(1 ft/12 in)(0.3048 m/ft) = m

1. ft^3 2. ft^3/day 3. ft^3/sec 4. Incorrect 5. Correct

General Conversions

1. 325 ft^3 = gal

2. 2512 kg = lb

3. 2.5 miles = ft

4. 1500 hp = kW

5. 2.2 ac-ft = gal

6. 2100 ft^2 = ac

7. 92.6 ft^3 = lb

8. 17,260 ft^3 = MG

9. 0.6% = mg/L

10. 30 gal = ft^3

11. A screening pit must have a capacity of 400 ft^3. How many lbs is this?

12. A reservoir contains 50 ac-ft of water. How many gallons of water does it contain?

13. 3.6 cfs = gpm

14. 1820 gpm = gpd

15. 45 gps = cfs

16. 8.6 MGD= gpm

17. 2.92 MGD = lb/min

18. 385 cfm = gpd

19. 1,662 gpm = lb/day

20. 3.77 cfs = MGD

21. The flow through a pipeline is 8.4 cfs. What is the flow in gpd?

22. A treatment plant receives a flow of 6.31 MGD. What is the flow in cfm?

Basic Conversions Extra Problems

1. How many seconds are in a minute?

2. How many minutes are in an hour?

3. How many hours in a day?

4. How many minutes in a day?

5. How many inches in a foot?

6. How many feet in a mile?

7. How many feet in a meter?

8. How many meters in a mile?

9. How much does one gallon of water weigh?

10. How much does one cubic foot of water weigh?

11. Express a flow of 5 cfs in terms of gpm.

12. What is 38 gps expressed as gpd?

13. What is 0.7 cfs expressed as gpd?

14. What is 9164 gpm expressed as cfs?

15. What is 1.2 cfs expressed as MGD?

16. Convert 65 gpm into lbs/day.

17. Convert 345 lbs/day into gpm.

18. Convert 0.9 MGD to cfm.

19. Convert 1.2 MGD to ft^3/hour.

20. Convert a flow of 4,270,000 gpd to cfm.

21. What is 5.6 MGD expressed as cfs?

22. Express 423,690 cfd as gpm.

23. Convert 2730 gpm to gpd.

24. Convert 1440 gpm to MGD.

25. Convert 45 gps to ft^3/day.

Volume and Flow Conversions

1. 2,431 gal
2. 5,533 lb
3. 13,200 ft
4. 1,119 kW
5. 717,200 gal
6. 0.05 ac
7. 5,778.24 lb
8. 0.13 MG
9. 6,000 mg/L
10. 4.01 ft^3
11. 24,960 lb
12. 16,300,000 gal
13. 1,615.68 gal/min
14. 2,620,800 gal/day
15. 6.02 gal/sec
16. 5,968.4 gpm
17. 16,911.67 lb/min
18. 4,416,912 gal/day
19. 19,959,955.2 lb/day
20. 2.43 MGD
21. 5,428,684.8 gal/day
22. 585.82 ft^3/min

Basic Conversions Extra Problems

1. 60 sec/min
2. 60 min/hr
3. 24 hr/day
4. 1440 min/day
5. 12 in/ft
6. 5280 ft/mi
7. 3 ft/yd
8. 1760 yd/mi
9. 8.34 lbs/gal
10. 62.4 lbs/ft^3
11. 2244 gpm
12. 3,283,200 gpd
13. 452,390 gpd
14. 20.42 cfs
15. 0.78 MGD
16. 780,624 lbs/day
17. 0.03 gpm
18. 83.56 ft^3/min
19. 6684.49 ft^3/hr
20. 396.43 ft^3/min
21. 8.67 cfs
22. 2200.83 gpm
23. 3,931,200 gpd
24. 2.07 MGD
25. 519,786.10 ft^3/day

CIRCUMFERENCE AND AREA

Area

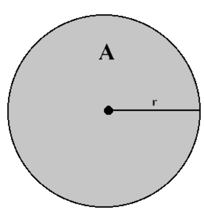
- Area is the measurement of the amount of space on the surface of an object
- Two dimensional measurement
- Measured in: in^2, ft^2, acres, etc.

Area

- Area of Circle

$$Area = \pi(radius^2)$$

$$A = \pi r^2$$



Example 1

- Find the area of the cross section of a pipe in ft^2 that has a diameter of 2 feet.

$$Area = \pi(radius^2)$$

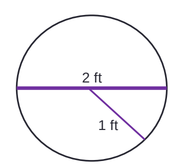
$$r = \frac{1}{2}D$$

$$r = \frac{1}{2}(2ft)$$

$$r = 1ft$$

$$A = \pi(1ft)(1ft)$$

$$A = 3.14\,ft^2$$

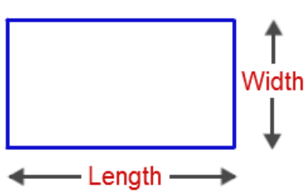


Area

- Area of Rectangle

$$Area = (length)(width)$$

$$A = (L)(W)$$



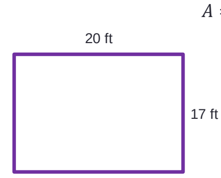
Example 2

- Find the area in ft^2 of a rectangular basin that is 20 feet long and 17 feet wide.

$$A = (L)(W)$$

$$A = (20ft)(17ft)$$

$$A = 340ft^2$$

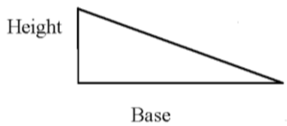


Area

- Area of Right Triangle

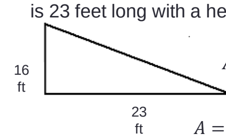
$$Area = \frac{(base)(height)}{2}$$

$$A = \frac{(b)(h)}{2}$$



Example 3

- Determine the area in ft² of a right triangle where the base is 23 feet long with a height of 16 feet.



$$A = \frac{(b)(h)}{2}$$

$$A = \frac{(23ft)(16ft)}{2}$$

$$A = \frac{368ft^2}{2}$$

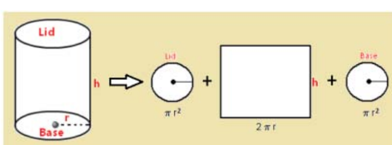
$$A = 184ft^2$$

Area

- Area of Cylinder (total exterior surface area)

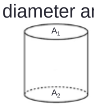
$$\begin{aligned} Area = &[surface\ area\ of\ end\ \#1] \\ &+ [surface\ area\ of\ end\ \#2] \\ &+ [(\pi)(Diameter)(height)] \end{aligned}$$

$$A = A_1 + A_2 + [(\pi)(D)(h)]$$



Example 4

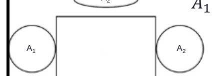
- Find the total surface area in ft² of a pipeline that is 2 ft in diameter and 20 feet long.



$$A = A_1 + A_2 + [(\pi)(D)(h)]$$

$$A_1 = (0.785)(D^2)$$

$$A_1 = (0.785)(2ft)(2ft)$$



$$A_1 = 3.1416ft^2$$

$$A_1 = A_2$$

$$A = 3.1416ft^2 + 3.1416ft^2 + [(\pi)(2ft)(20ft)]$$

$$A = 3.1416ft^2 + 3.1416ft^2 + 125.6637ft^2$$

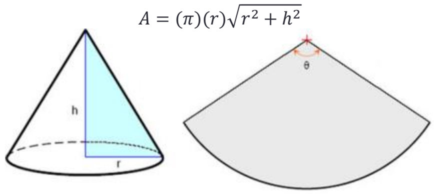
$$A = 1240.26\ ft^2$$

Area

- Area of Cone (lateral area)

$$Area = (\pi)(radius)\sqrt{radius^2 + height^2}$$

$$A = (\pi)(r)\sqrt{r^2 + h^2}$$



Right Circular Cone Unrolled Lateral Area

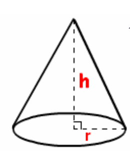
Example 5

- Find the lateral area (in ft²) of a cone that is 3 feet tall and has a radius of 1.5 feet.

$$A = (\pi)(r)\sqrt{r^2 + h^2}$$

$$A = (\pi)(1.5ft)\sqrt{(1.5ft)^2 + (3ft)^2}$$

$$A = (\pi)(1.5ft)\sqrt{2.25ft^2 + 9ft^2}$$



$$A = (\pi)(1.5ft)\sqrt{11.25ft^2}$$

$$A = (\pi)(1.5ft)(3.3541ft)$$

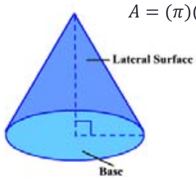
$$A = 15.81ft^2$$

Area

- Area of Cone (total surface area)

$$Area = (\pi)(radius)(radius + \sqrt{radius^2 + height^2}\ )$$

$$A = (\pi)(r)(r + \sqrt{r^2 + h^2}\ )$$



Example 6

- Find the total surface area in ft^2 of a cone that is 4.5 feet deep with a diameter of 6 feet.

$$radius = \frac{1}{2}D$$

$$r = \left(\frac{1}{2}\right)6ft$$

$$r = 3\,ft$$

$$A = (\pi)(r)(r + \sqrt{r^2 + h^2}\ )$$

$$A = (\pi)(3ft)(3ft + \sqrt{(3ft)^2 + (4.5ft)^2}\ )$$

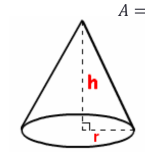
$$A = (\pi)(3ft)(3ft + \sqrt{9ft^2 + 20.25ft^2}\ )$$

$$A = (\pi)(3ft)(3ft + \sqrt{29.25ft^2}\ )$$

$$A = (\pi)(3ft)(3ft + 5.4083ft)$$

$$A = (\pi)(3ft)(8.4083ft)$$

$$A = 79.25ft^2$$



Volume

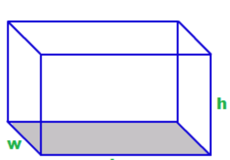
Volume

- Volume is the capacity of a unit or how much it will hold
- Measured in
  - cubic units (ft^3, m^3, yd^3) or
  - liquid volume units (gallons, liters, million gallons)
- The answer will come out in cubic units
  - You must then convert it to liquid volume units

Volume of a Rectangle

$$Volume = (length)(width)(height)$$

$$Vol = (l)(w)(h)$$



Example 1

- Determine the volume in m^3 for a tank that measures 30 meters by 15 meters by 25 meters.

$$Vol = (l)(w)(h)$$

$$Vol = (30m)(15m)(25m)$$

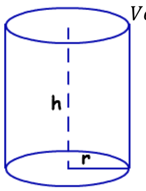
$$Vol = 11250m^3$$

Volume of a Cylinder

$$Volume = (0.785)(Diameter^2)(height)$$

$$Vol = (0.785)(D^2)(h)$$

OR



$$Volume = (\pi)(radius^2)(height)$$

$$Vol = (\pi)(r^2)(h)$$

Example 2

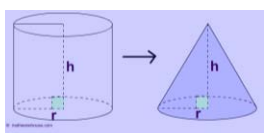
- Determine the volume in ft^3 for a tank that is 20 feet tall with a diameter of 15 ft.

$$Vol = (0.785)(D^2)(height)$$

$$Vol = (0.785)(15\,ft)(15\,ft)(20\,ft)$$

$$Vol = 3532.5\,ft^3$$

Volume of a Cone



$$Volume = (^1/_3)(0.785)(Diameter^2)(height)$$

$$Vol = (^1/_3)(0.785)(D^2)(h)$$

OR

$$Volume = (^1/_3)[(\pi)(radius^2)(height)]$$

$$Vol = (^1/_3)[(\pi)(r^2)(h)]$$

Example 3

- Determine the volume in gallons of a conical tank that is 8 feet wide and 15 feet tall.

$$Volume = (^1/_3)(0.785)(Diameter^2)(height)$$

$$Vol = (^1/_3)(0.785)(8\,ft)(8\,ft)(15\,ft)$$

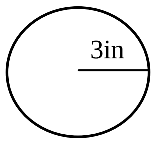
$$Vol = 251.2\,ft^3$$

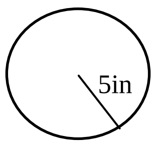
$$Vol, gal = \left(\frac{251.2\,\cancel{ft^3}}{1}\right)\left(\frac{7.48\,gal}{1\,\cancel{ft^3}}\right)$$

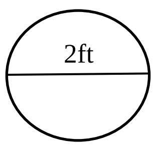
$$Vol, gal = 1878.98\,gal$$

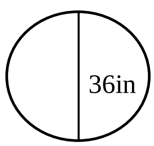
Basic Math for Water and Wastewater
CIRCUMFERENCE, AREA, AND VOLUME

<u>Circumference</u>

1. 

2. 

3. 

4. 

5. A chemical holding tank has a diameter of 24 feet. What is the circumference of the tank in feet?

6. An influent pipe inlet opening has a diameter of 4 feet. What is the circumference of the inlet opening in inches?

7. What is the length (in feet) of the notched weir of a circular clarifier that has a diameter of 32 feet?

Area

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

2. Calculate the lateral surface area (in ft^2) of a cone with a radius of 3 feet and a height of 9 feet.

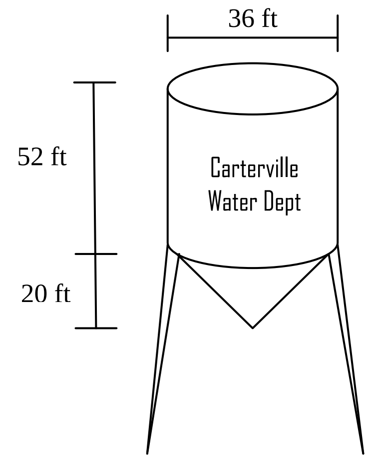
3. Calculate the surface area (in ft^2) of a basin which is 90 feet long, 25 feet wide, and 10 feet deep.

4. Calculate the area (in ft^2) for a 2 ft diameter main that has just been laid.

5. A chemical hopper is cone shaped and covered. It has a diameter of 4 feet and a depth of 7 feet. Calculate the total surface area of the hopper (in ft^2).

6. Calculate the area (in ft^2) for an 18" main that has just been laid.

7. A circular water tower that is tapered at the bottom has a diameter of 36 feet and a height of 52 feet from the top to the beginning of the taper. The cone created by the taper has a height of 20 feet. Calculate the total exterior surface area of the water tower.



Volume

1. Calculate the volume (in ft^3) for a tank that measures 10 feet by 10 feet by 10 feet.

2. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

3. Calculate the volume of water in a tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

4. Calculate the volume (in ft^3) of a cone shaped chemical hopper with a diameter of 12 feet and a depth of 18 feet.

5. A new water main needs to be disinfected. The main is 30” in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

6. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to calculate 5% of the tank volume. How many gallons will this be?

7. Refer back to the water tower in Carterville in problem 7 of the last section. Calculate the total volume (in gallons) when the tower is full.

DON'T THINK TOO HARD ON THIS ONE...

8. If you double the size of a pipe, does it double the volume that can be carried? For example, if you have 1000 feet of 12 inch line and you replace it with a 24 inch line, does your volume double?

ANSWERS:

Circumference

1. 18.85 in
2. 31.42 in
3. 6.28 ft
4. 113.10 in
5. 75.40 ft
6. 150.80 in
7. 100.53 ft

Area

1. 540 ft^2
2. 89.41 ft^2
3. 2250 ft^2
4. 3.14 ft^2
5. 58.31 ft^2
6. 1.77 ft^2
7. 8420.51 ft^2

Volume

1. 1000 ft^3
2. 9050.8 gal
3. 359.04 gal
4. 678.58 ft^3
5. 48442.35 gal
6. 150000 gal
7. 446671.14 gal
8. No, it quadruples it (4X)

Velocity & Flow

Velocity

- The speed at which something is moving
- Measured in
  - $^{ft}/_{min}$ $^{ft}/_{sec}$ $^{miles}/_{hr}$ etc

$$Velocity = \frac{distance}{time}$$

Example 1

- Blue dye is placed in a sewer line at a manhole. Three (3) minutes later, the dye appears in a manhole 125 feet down stream. What is the velocity of the flow in ft/min?

$$Velocity = \frac{distance}{time}$$

$$Vel = \frac{125\,ft}{3\,min}$$

$$Vel = 41.67\ ^{ft}/_{min}$$

Flow

- The volume of water that flows over a period of time
- Measured in
  - $^{ft^3}/_{sec}$ $^{ft^3}/_{min}$ $^{gal}/_{day}$ $^{MG}/_{D}$

$$Flow = (Area)(Velocity)$$

$$Q = AV$$

Example 2

- Water is flowing at velocity 3 ft/sec through a channel that is 2 feet wide and 1.5 feet deep. What is the flow in cubic feet per second?

$$Q = AV$$

$$Q = (l)(w)(velocity)$$

$$Q = (2ft)(1.5ft)\left(3\ ^{ft}/_{sec}\right)$$

$$Q = 9\ ^{ft^3}/_{sec}$$

Example 3

- Determine the flow in ft^3/sec through a 6 inch pipe that is flowing full at a velocity of 4.5 ft/sec.

$D = (6\,in)(\frac{1\,ft}{12\,in})$

$D = 0.5\,ft$

$$Q = AV$$

$$Q = (0.785)(D^2)\,(vel)$$

$$Q = (0.785)(0.5\,ft)(0.5\,ft)\left(4.5\ ^{ft}/_{sec}\right)$$

$$Q = 0.88\ ^{ft^3}/_{sec}$$

Velocity

$$Velocity = \frac{Flow\ rate, {}^{ft^3}/_{sec}}{Area, ft^2}$$

- Use this formula when given the flow and area or dimensions

Example 4

- The flow through a 1.5 foot pipeline is 9.7 gallons per minute. What is the velocity of the water in ft/minute?

$$Velocity = \frac{Flow\ rate, {}^{ft^3}/_{sec}}{Area, ft^2}$$

$$\left(\frac{9.7\ \cancel{gal}}{min}\right)\left(\frac{1\ ft^3}{7.48\ \cancel{gal}}\right)$$

$$= 1.30\ {}^{ft^3}/_{min}$$

$$Vel = \frac{1.30\ {}^{ft^3}/_{min}}{(0.785)(1.5ft)(1.5ft)}$$

$$Vel = \frac{1.30\ {}^{ft^3}/_{min}}{1.7662\ ft^2}$$

$$Vel = 0.74\ {}^{ft}/_{min}$$

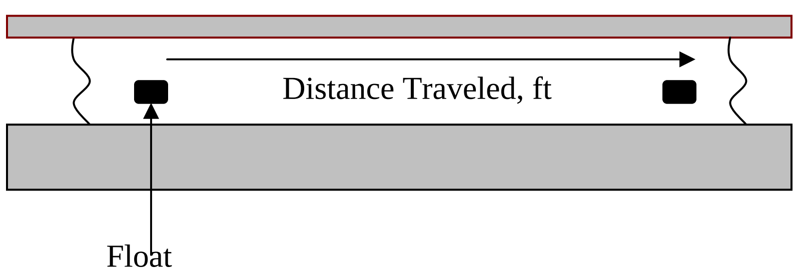
Applied Math for Water Treatment
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

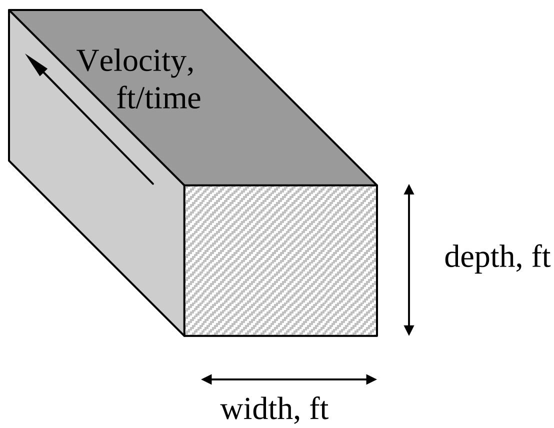
3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$

1.) 185 ft/min 2.) 2.2 ft/sec 3.) 210 ft/min



$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \; \underset{(ft/time)}{(V)}$$

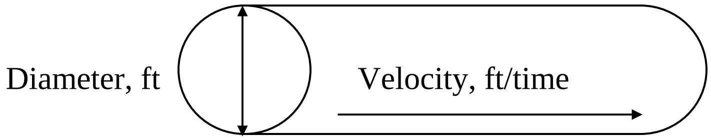
<u>Flow in a channel</u>

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?

4.) 16.8 ft^3/sec 5.) 900ft^3/min; 9.7 MGD 6.) 1.8 ft



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\ \underset{(ft)(ft)}{(D)^2}\ \underset{(ft/time)}{(vel)}$$

Flow through a full pipe

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

9. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

10. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

7.) 10.05 ft3/sec 8.) 0.59 ft3/sec 9.) 6 in 10.) 532.4 gpm

APPLIED MATH FOR WATER
FLOW RATE

Q = AV

1. A channel is 3 feet wide with water flowing to a depth of 2 feet. If the velocity in the channel is found to be 1.8 fps, what is the cubic feet per second flow rate in the channel?

2. A 12-inch diameter pipe is flowing full. What is the cubic feet per minute flow rate in the pipe if the velocity is 110 feet/min?

3. A water main with a diameter of 18 inches is determined to have a velocity of 182 feet per minute. What is the flow rate in gpm?

4. A 24-inch main has a velocity of 212 feet/min. What is the gpd flow rate for the pipe?

5. What would be the gpd flow rate for a 6" line flowing at 2 feet/second?

6. A 36" water main has just been installed. If the main is flushed at 2.5 ft/second, how many gallons/minute of water should be flushed from the hydrant?

7. A 36" water main has just been installed. If the main is flowing at a velocity of 2 ft/second, how many MGD will the pipe deliver?

8. A certain pipe has a diameter of 18 inches. If the pipe is flowing full, and the water is known to flow a distance of 830 yards in 5 minutes, what is the MGD flow rate for the pipe?

9. A water crew is flushing hydrants on a 12-inch diameter main. The pitot gage reads 560 gpm being flushed from the hydrant. What is the flushing velocity (in feet/min) through the pipe?

VELOCITY (OPEN CHANNEL)

10. A float is placed in a channel. It takes 2.5 minutes to travel 300 feet. What is the flow velocity in feet per minute in the channel? (Assume that float is traveling at the average velocity of the water.)

11. A cork placed in a channel travels 30 feet in 20 seconds. What is the velocity of the cork in feet per second?

12. A channel is 4 feet wide with water flowing to a depth of 2.3 feet. If a float placed in the channel takes 3 minutes to travel a distance of 500 feet, what is the cubic-feet-per-minute flow rate in the channel?

AQUIFER FLOW

13. Geologic studies show that the water in an aquifer moves 25 feet in 60 days. What is the average velocity of the water in ft/day?

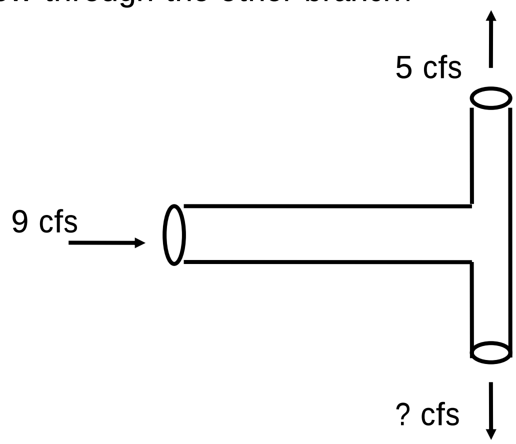
14. If the water in a water table aquifer moves 2 feet per day, how far will the water travel in 13 days?

15. If the water in a water table aquifer moves 2.25 feet per day, how long will it take the water to move 61 feet?

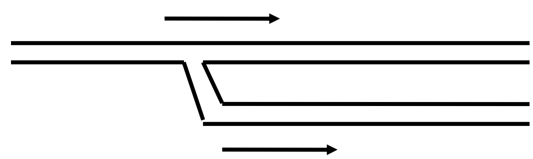
FLOW

16. The average velocity in a full-flowing pipe is measured and known to be 2.9 fps. The pipe is a 24” main. Assuming that the pipe flows 18 hours per day and that the month in question contains 31 days, what is the total flow for the pipe in MG for that one month?

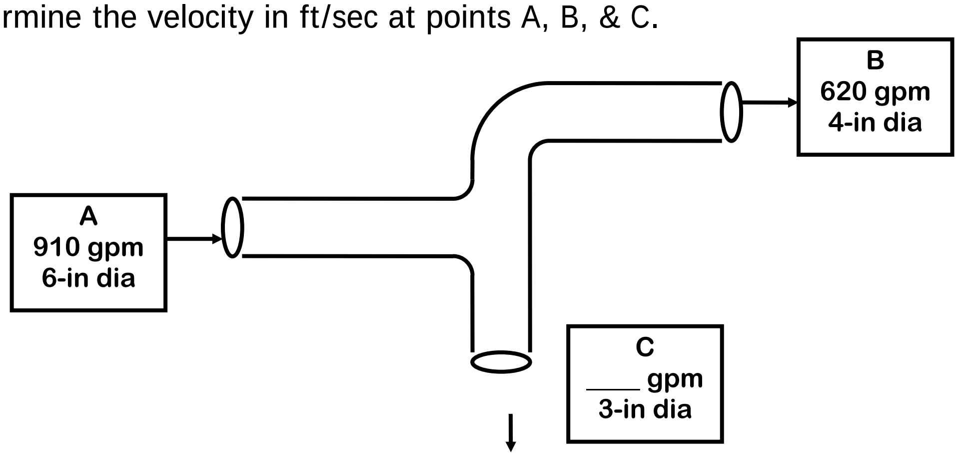
17. The flow entering the leg of a tee connection is 9 cfs. If the flow through one branch of the tee is 5 cfs, what is the flow through the other branch?



18. A water line has been run to a new subdivision. The flow through the main line is 468 gpm. The line splits into two lines (each serving half of the subdivision). If one line flows 210 gpm, what should be the flow from the other line?



19. Determine the velocity in ft/sec at points A, B, & C.



ANSWERS:

1. 10.8 ft^3/sec
2. 86.35 ft^3/min
3. 2,404.50 gpm
4. 7,170,172.42 gpd
5. 253,661.76 gpd
6. 7,926.93 gpm
7. 9.13 MGD
8. 9.47 MGD
9. 95.37 ft/min
10. 120 ft/min
11. 1.5 ft/sec
12. 1,533.3 ft^3/min
13. 0.42 ft/day
14. 26 ft
15. 27.11 days
16. 136.83 MG
17. 4 ft^3/sec
18. 258 gpm
19. A. 10.33 ft/sec
    B. 15.84 ft/sec
    C. 13.17 ft/sec

Section 4

Water Tanks

Storage Tanks

Disinfection

Rules and Regulations

Storage Tanks

- Objectives:
  - Reasons for storing water
  - Operating storage and emergency storage
  - Size and location for storage tanks
  - Operation and maintenance
  - Rules and Regulations

Purpose of Water Storage

- Equalizing supply and demand
- Increasing operating convenience
- Leveling out pumping requirements
- Decreasing power costs

Purpose of Water Storage

- Providing water during power or pump failure
- Providing adequate water for fire fighting
- Providing surge relief
- Increasing detention times
- Blending water sources
- Decrease pumping costs

Capacity Requirements

- Based on maximum water demands in different parts of the system
- Too much storage can cause stagnant water and taste & odor problems
  - 20% turnover rate to prevent it from becoming septic
    - less sediment

Type of Service

- Operating Storage
  - Tank directly connected to distribution piping
  - Fills and empties based on system pressure
- Emergency Storage
  - Used for emergency, e.g. fire protection
  - Not suitable for potable use
  - Subject to freezing due to lack of circulation

TDEC - Fleming Training Center

Configuration of Storage Tanks

- Elevated Tanks
- Ground-Level Reservoirs
- Standpipes
- Hydropneumatic System
- Surge Tanks

7

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Elevated Tanks

- Supported by steel or concrete tower
- Maintains adequate and uniform pressure
- Minimizes variations in pressure due to turning pumps on or off
- May require altitude valve to prevent overflow
- More expensive than ground tanks
- Need altitude valves
  - one way are best

8

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Standpipes

- Tank rests on ground, has greater height than diameter
- Stores volumes at low pressure
- Water must be turned over frequently to avoid stagnation
  - 20% is bare minimum
- Located at high points in land elevation

9

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Ground-Level Reservoirs

- For raw water - lakes, ponds, basins
- For finished water - ground level or underground tanks
  - Lower initial cost than elevated tank, but requires pumps to move water
  - Main disadvantage is cost of booster pump station that must be used with the tank

10

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Ground-Level Reservoirs

This is an old open-topped reservoir that has been converted with a liner-cover

11

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Hydropneumatic System

- Partially filled with water, partially filled with compressed air (2/3 to 1/3)
- Air helps maintain pressure in the tank
- Usually for very small water systems

12

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Surge Tanks

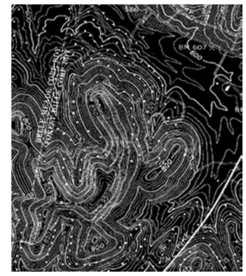
- Not designed for storage
- Used mainly to control water hammer or regulate the flow of water
- Absorbs the sudden surge (pressure of water) to prevent possible breaks in the system

13

TDEC - Fleming Training Center

Selection and Location of Storage

- Determined by hydraulics, water demand, elevation of terrain, purpose of tank, etc
- Type of storage depends on purpose of tank



14

TDEC - Fleming Training Center

Tank Equipment

- Monitoring Devices
  - Pressure sensor at base of tank
    - altitude valve
  - Level sensor inside tank
    - Shuts off flow to tank when water reaches certain level
    - Valve opens when DS pressure is lower than tank pressure
  - Data transmitted to central location - alarms can alert operator of high or low levels

15

TDEC - Fleming Training Center

Tank Equipment

- Air Vents
  - Allow air to enter and escape as water level rises and falls
  - Require screens to keep out birds, other contaminants
  - Mesh should be #24 and stainless steel

16

TDEC - Fleming Training Center

Tank Equipment

- Access Hatches
  - For entry and ventilation during maintenance
  - Hatch on roof requires rim to prevent runoff from entering tank
  - Hatch at bottom of tank must withstand tank pressure
  - Must be secured to prevent vandalism; locks must be in place since 9/11

17

TDEC - Fleming Training Center

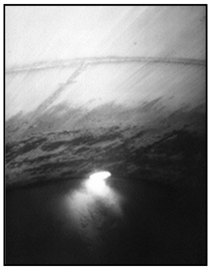
Tank Equipment

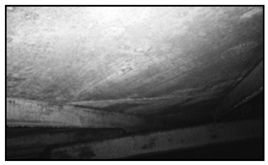
- Ladders
  - Most ladders begin about 8 ft from ground to deter unauthorized use
  - May extend to ground if heavy metal shield is locked in place to prevent unauthorized entry
  - All ladders must meet OSHA regs, including safety cage

18

Tank Equipment

- Coatings
  - Protect interior and exterior of tank from corrosion without causing taste & odor problems
  - Coatings must meet the requirements of NSF (ANSI Standard 61)





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Tank Equipment

- Cathodic Protection
  - Can assist in corrosion control
  - Electrodes placed in tank which corrode instead of tank and appurtenances
  - Inspect annually

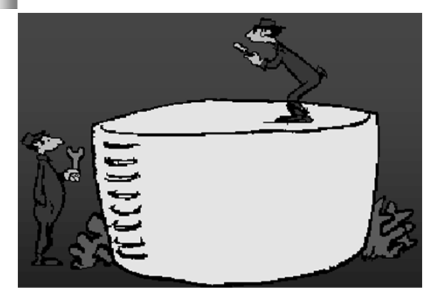
20

Grading

- The dirt around the storage tank needs to be graded away from the tank for 50 feet

21

Maintenance



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Tank Inspections

- Must be professionally inspected every 5 years in accordance with State requirements (Rule 33)
  - inspection by draining or by using a diver
  - inspected by a third party

23

Tank Inspections

- Inspection reports must be on file and available for review by State Sanitary Inspectors
- Visual inspections recommended annually

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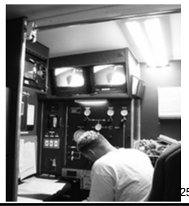
Inspection

- Requires draining the tank or using divers
- Check vents, overflows, paint, altitude valves, etc.
- Check for corrosion inside & outside
- Considered confined space, get permit



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Storage Tank Collapse

- Caused by massive leak in 42 inch water main (50,000 gallon per minute) which quickly drained the tank
- Vacuum formed sucking in the roof

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Vandalism and Security

- Fencing, locks on access to manholes and other necessary precautions shall be provided to prevent trespassing, vadalism and sabotage

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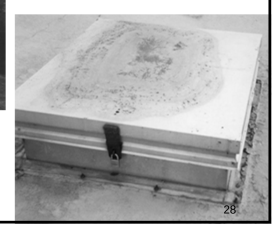
Vandalism and Security



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Records

- Every tank in your system should have a historical record file containing, as a minimum, the most current inspection report
- Location, type of maintenance or repair performed, all contract documents and specifications for repair, paint and equipment submittals, etc

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Safety

- Follow regulations for confined spaces
- Inspect ladders and safety cages for damage
- Use protective equipment
- Provide ventilation inside tank when inspecting
- Provide adequate lighting with proper wiring to prevent shock hazard

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AWWA Standard for Disinfection of Water-Storage Facilities

- Before placing into service, all storage tanks shall be disinfected
- Standards for disinfecting storage tanks covered by ***AWWA C652***
  - including materials, tank preparation, disinfectant application and sampling for coliform bacteria

Forms of Chlorine for Disinfection

- Liquid Chlorine (or gas)
  - 100% available chlorine
- Sodium Hypochlorite
  - 5-15% available chlorine
- Calcium Hypochlorite
  - 65% available chlorine

Methods of Chlorination

- Method 1
  - water-tank shall be filled to overflow level with enough chlorine added to maintain at least 10 ppm residual for 24 hour period

Methods of Chlorination

- Method 2
  - a solution of 200 ppm available chlorine is applied directly to the entire surface of the storage tank that comes in contact with water when it is full for at least 30 minutes
  - applied by brushing on or spraying on
  - tank should be flushed with potable water before put back into service
  - WARNING - experienced operators only; hazardous to attempt

Methods of Chlorination

- Method 3
  - Water and chlorine are added to the storage tank to make a 50 ppm available chlorine that fills about 5% of the total storage volume
  - This is held in the tank for no less than 6 hours
  - The tank is then filled up to the overflow level and held for at least 24 hours
  - There should be a 2 ppm residual chlorine remaining after 24 hour period
  - All highly chlorinated water needs to be drained

Methods of Chlorination

Acceptable sampling station at foot of water tank

- Bacteriological Sampling and Testing
  - storage tanks must be tested for coliform bacteria after chlorination procedure and before it is put back into service
  - if positive sample occurs, must re-disinfect, flush, and resample
    - Per State of TN regulations

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Rules and Regulations

- From Community Public Water Systems Design Criteria Division of Water Supply Tennessee Department of Environment and Conservation, 1997; Part 8

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Rules and Regulations

8.0.2 Protection - All new finished water storage structures shall have suitable watertight roofs or covers which exclude birds, animals, insects, and excessive dust

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Rules and Regulations

8.0.3 Protection from Trespassers - Fencing, locks on access to manholes, and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage

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Rules and Regulations

8.0.4 Drains - No drain on a water storage structure may have a direct connection to sewer or storm drain. Splash pad and drainway shall be provided to prevent erosion.

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Rules and Regulations

8.0.5 Overflow - The overflow pipe of a water storage structure should be brought down near the ground ... No overflow may be connected directly to a sewer or storm drain.

b. The overflow of a ground-level structure shall be high enough above normal or graded ground surface to prevent the entrance of surface water.

c. The overflow shall be protected with a 24 mesh non-corrodible screen with a flap valve.

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Rules and Regulations

8.0.5 – Overflow continued

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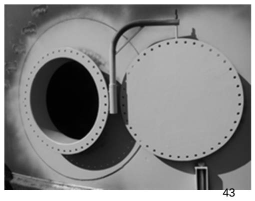
Rules and Regulations

8.0.6 Access - Manholes on scuttles above waterline.

a. … on ground-level structures, manholes should be elevated 24 to 36 inches above the top of covering sod



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Rules and Regulations

8.0.7 Vents - Finished water storage structures shall be vented by special vent structures.

a. shall prevent the entrance of surface water

b. shall exclude birds and animals

d. shall … be covered with 24-mesh non-corrodible screen cloth

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Rules and Regulations

8.0.10 Safety - safety shall be considered …

a. ladders, ladder guards, balcony railings, and safe location of entrance hatches shall be provided where applicable.

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Rules and Regulations

8.0.14 Painting and/or Cathodic Protection - Proper protection should be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both.

a. paint systems consistent with current AWWA standards, or … all paints must be acceptable to FDA and EPA for contact with potable water

b. Cathodic protection should be designed and installed by competent technical personnel

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Rules and Regulations

8.0.15 Turnover of water - If the storage reservoir is sized larger than required for initial demand and there is more than 2 days storage, provisions shall be made for turnover of the water tank and/or booster chlorination.

8.0.17 Disinfection - Finished water storage structures shall be disinfected in accordance with AWWA Standard C652 before being put in service.

8.2.5 (Pressure Tanks) Auxiliary power - Auxiliary power with automatic takeover capability shall be provided when positive pressures are not available from system gravity flow.

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Rules and Regulations

8.0.16 Sampling - A suitable sampling tap should be provided on all storage structures and be protected from public access.

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Rules and Regulations Distribution Storage

8.3.1 The purpose of system storage is to have sufficient water available to provide adequate flow and pressure at peak demand as well as to provide for fire flows when needed. For most water systems a satisfactory rule-of-thumb to meet these needs is to provide at least the average 24-hour demand in elevated storage.

8.3.4 Level Controls - Adequate controls shall be provided to maintain levels in distribution system storage structures.

a. Telemeter equipment should be used when pressure-type controls are employed and any appreciable head loss occurs in the distribution system …

b. Altitude valves or equivalent controls may be required for a second and subsequent structures on the system

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TANK DISINFECTION FORM

Employee Name: ______________________________

Address/Location____

Work Order Number_____________

Project Name: __________________________________ **Project Number**__________

Size of Water Tank: ________gallons (________MG)

Disinfection Procedure: Method 1 Method 2 Method 3 Other: ___________

#s of HTH: ______________________ **Contact Time (hrs):** _________________________

Source of Sample: Fire Hydrant No. __________________ **Blow-off location** ________________

Sample Collected by: _________________ **Sample Transported by:** ______________

Date Collected: __________ **Time Collected:** _____ **AM/PM**

Comments: ____

____

____

Lab Sample Number: __________ **Date Tested:** ___________ **Time Tested:** ________**AM/PM**

ALL UNITS ARE IN mg/L, UNLESS OTHERWISE NOTED

ANALYSIS REQUESTED	RESULTS	x	ANALYSIS REQUESTED	RESULTS	x
Field Measurements			MICROBIOLOGICAL		
Chlorine, Free Res.			Total Coliform		
Temperature F/C			Heterotrophic Plate Count		

Only methodologies as recommended and approved by the United States Environmental Protection Agency and by the most recent Federal Register have been used. The results obtained are true and accurate to the best of my knowledge.

LABORATORY OFFICIAL:_______________________ **DATE:**____________________

Form accepted by TDEC representative ______________________________ **DATE:** ______________

Ground Storage Tank Inspection Report

Job No.: ______________ Date: ________________ Inspector: __________________

Tank owner: ____________________________ Owner's order #: _________________

Owner's representative: _______________________ Title: ______________________

Mailing address: ____

Physical address: ____

City, State: ____ Zip: _________________

County tank is located: __________________ Seismic zone of county: ___________

Telephone: _____________________________ Fax: _____________________________

Location of tank: ____

Original Contractor #: ______________________________ Year built: ___________

Original Manufacturer: _____________________________ Capacity: ____________

Date of last inspection: ____

Diameter: ________________________ Height: _______________________________

Type of construction: Welded: ______________ Riveted: ______________

Who is customer's insurance carrier? ____

Storage Tank Vocabulary

A. Altitude Valve
B. Booster Disinfection
C. Cathodic Protection
D. Elevated Storage
E. Elevated Tank
F. Emergency Storage
G. Fire Demand
H. Ground-level tank
I. Hydropneumatic System
J. Overflow Level
K. Peak Hour Demand
L. Reservoir
M. Riser
N. Silt Stop
O. Standpipe
P. Tank

______1. The required fire flow and the duration for which it is needed, usually expressed as gallons per minute for a certain number of hours. Also used to denote the total quantity of water needed to deliver the required fire flow for a specified number of hours.
______2. The greatest volume of water in an hour that must be supplied by a water system during any particular time period.
______3. A device placed at the outlet of water storage tanks to prevent silt or sediment from reaching the customer.
______4. An electrical system for preventing corrosion to metals, particularly metallic pipes and tanks.
______5. A system using an airtight tank in which air is compressed over water (separated from the air by a flexible diaphragm). The air imparts pressure to water in the tank and the attached distribution pipelines.
______6. A structure used in a water system to contain large volumes of water or other liquids.
______7. The maximum height that water or liquid will rise in a receptacle before it flows over the overflow rim.
______8. A valve that automatically shuts off water flow when the water level in an elevated tank reaches a preset elevation then opens again when the pressure on the system side is less than that on the tank side.
______9. Storage volume reserved for catastrophic situations, such as supply-line break or pump-station failure.
______10. (a) Any tank or basin used for the storage of water. (b) A ground-level storage tank for which the diameter is greater than the height.
______11. A ground-level water storage tank for which the height is greater than the diameter.
______12. In the distribution system, storage of water in a tank whose bottom is at or below the surface of the ground.
______13. In any distribution system, storage of water in a tank supported on a tower above the surface of the ground.
______14. The vertical supply pipe to an elevated tank.
______15. A water distribution storage tank that is raised above the ground and supported by posts or columns.
______16. The practice of adding additional disinfectant in the distribution system.

Storage Tank Review Questions

1. List 9 reasons for providing water storage in a distribution system.
   -
   -
   -
   -
   -
   -
   -
   -
   -

2. List the 4 types of distribution storage tanks and a description of each.
   -
   -
   -
   -

3. What is the difference between operating storage and emergency storage?

4. Why should vent openings on storage tanks be screened?

5. What is the purpose of an altitude valve?

6. How often must storage tanks be inspected according to the Regulations for Public Water Systems and Drinking water Quality for the State of Tennessee?

7. After disinfection, what must be done before a tank is put back in service?

8. Name four things that should be considered when determining the type and the site for a new storage tank.
   -
   -
   -
   -

9. Why should the overflow pipe on a storage tank never be directly connected to a sewer or storm drain?

10. How are storage tanks protected from corrosion?

Storage Tank Vocabulary

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

Storage Tank Review Questions

1.
    - Equalizing pressure and demand
    - Increasing operating convenience
    - Leveling out pumping requirements
    - Decreasing power costs
    - Providing water during source or power failure
    - Providing adequate water for fire fighting
    - Providing surge relief
    - Increasing detention time
    - Blending water sources

2.
    - <u>Elevated</u> – tank on tower, provides pressure, minimizes pressure variations
    - <u>Standpipe</u> – tank on ground, taller than diameter, stores large volumes of water at low pressure, safer than elevated tank, may require pump
    - <u>Ground-level reservoir</u> – diameter greater than height, requires pump
    - <u>Hydro-pneumatic</u> – 2/3 water, 1/3 air; air helps maintain pressure, usually used with wells; small tanks
3. Emergency storage is not considered to be potable water – for emergencies only, e.g. fire protection.
   Operating storage is directly connected to distribution system, fills and empties by distribution pressure.
4. To keep out birds, insects, animals, etc.
5. To keep tank from overflowing
6. Professionally every 5 years
7. Bacteriological samples must be taken and must pass.
8. Water demand; Hydraulics, terrain; Purpose of tank; Public opinion
9. That would be a cross connection
10. Cathodic protection, coatings

Section 5

Disinfection

Distribution Chlorination

Disinfecting Water Mains

AWWA Standards for Disinfecting Water Mains

- AWWA standard C651
- Sec. 1.1
  - All new water mains shall be disinfected before they are placed in service.
  - All water mains taken out of service for inspection, repair, or other activities that might lead to contamination of water shall be disinfected before they are returned to service.

Chlorine

- Most commonly used disinfectant in U.S.
- Maintains residual
- Chlorine gas, Cl_2
- Calcium hypochlorite (HTH), $Ca(OCl)_2$
- Sodium hypochlorite (bleach), NaOCl

Types of Chlorine

- Liquid chlorine (gas): 100% available Cl_2
- Sodium hypochlorite (bleach): 5-15%
- Calcium hypochlorite (HTH): 65%

Chlorine Gas

- Cl_2
- 100% pure
- 2.5 times as dense as air
- Pungent, noxious odor
- Greenish-yellow color
- Highly irritating to eyes, nasal passages, and respiratory tract

Chlorine Liquid

- Created by compressing chlorine gas
- Amber color
- 1.5 times as dense as water
- Expands easily into gas at room temperature 460 times

Hypochlorite (Solid)

- Calcium Hypochlorite $Ca(OCl)_2$
- Solid, granular, or tablet
- White or yellow-white in color
- Most dangerous - fire hazard
- High Test Hypochlorite (HTH)
- 65% pure

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Hypochlorite (Liquid)

- Sodium Hypochlorite NaOCl
- Bleach
- Clear, light-yellow color
- Costs 3 times as much as chlorine gas
- Shelf life 60-90 days
  - 5.25% Chlorine Clorox
    to
  - 12.5% Chlorine Pool bleach

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Chlorination Principles

- Five factors important to success of chlorination:
  - Chlorine concentration (C)
  - Contact time (T)
  - Water temperature
  - Water pH
  - Foreign substances in the water

most important

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Disinfection

"kill" is proportional to C x T

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

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Interferences

- Chlorine is only effective if it comes in direct contact with organisms
- Turbidity protects pathogens from chlorine
- Substances such as ammonia and organic matter reduce effectiveness of chlorine

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Chlorine Safety and Exposure

- Safety
  - Keep head higher than leak
  - Never put water on a chlorine cylinder
  - Fusible plug leaks require special handling or training
- Exposure
  - 1000 ppm fatal
  - 40-60 ppm for 30-60 min may cause serious injury
  - 30 ppm IDLH (immediately dangerous to life or health)
  - 1 ppm is OSHA ceiling
  - 0.5 ppm without adverse effects

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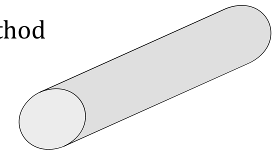
Methods of Line Disinfection

- Tablet Method
- Continuous-Feed Method
- Slug Method



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Tablet Method

- Cl_2 dose of 25 - 50 mg/L (not less than 25)
- This method can only be used if pipes have been kept clean and dry during installation
  - if flushing is required before main can be used, this method is not applicable
- Place HTH granules or tablets in the main as it is being installed and filling with potable water after installation is complete
- Hold chlorinated water for 24 hours

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Tablet Method

- Granules
  - Placement of granules
    - upstream end of first section
    - upstream end of branch main
    - at 500 ft intervals

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Tablet Method

- Tablets
  - number of 5-g tablets shall be $0.0012(D)^2(L)$ rounded to next higher integer; where D=diameter in inches and
    L=length in feet
  - attached with food grade adhesive
  - placement of tablets
    - placed in each section of pipe
    - one in each hydrant, hydrant branch and other auxiliary equipment

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Tablet Method

- Filling and contact
  - filled with water with velocity no greater than
    1 ft/s
  - eliminates air pockets
  - remain in pipe for 24 hours
  - if water temperature is less than 41°F, then hold for 48 hours
  - a detectable chlorine residual should be found at each sampling point after the appropriate holding time and you must report results

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Continuous-Feed Method

- Main is completely filled to remove air pockets
- Flushed to remove particulates at no less than 2.5 fps
- Filled with potable water that shall be chlorinated so that after 24 hours, a free chlorine residual of not less than 10 mg/L is present

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Continuous-Feed Method

- Placement of HTH granules
  - upstream end of first section of pipe
  - upstream end of each branch main
  - every 500 feet intervals
- Chlorinating
  - water supplied from a temporary, backflow-protected connection
  - water shall receive a dose no less than 25 mg/L free chlorine at a point no more than 10 feet downstream from beginning of new main

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Slug Method

- Place HTH granules in the main during construction
- Completely fill main to eliminate all air pockets
- Flush main to remove particulates
- Slowly flow through the main a slug of water dosed at 100 mg/L of chlorine for 3 hours

Textbook says 300 mg/L for 3 hours, but State Rules 0400-5-1-.17 says to use AWWA Standard C-651

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Slug Method

- Chlorinating
  - water shall receive a dose of chlorine at no less than 100 mg/L, beginning at no more than 10 feet downstream from beginning of new main
  - take measurements at regular intervals
  - flow should be slow
  - all interior surfaces of the pipe should come in contact with a concentration of about 100 mg/L for at least 3 hours

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Slug Method

- Chlorinating (continued)
  - if at any time the free chlorine falls below 50 mg/L
    - flow shall be stopped
    - chlorine equipment shall be relocated at head of slug
    - as flow is resumed, chlorine shall be applied to restore free chlorine in the slug to not less than 100 mg/L
  - as slug flows past fittings and valves, related valves and hydrants shall be operated so as to disinfect auxiliary equipment and pipe branches

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Final Flushing of the Main

- Heavily chlorinated water should not remain in contact with the pipe and its auxiliary equipment longer than necessary
- If the highly chlorinated water will endanger the environment, a neutralizing chemical should be used

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Bacteriological Testing

- Bacteriological samples shall be collected prior to placing new lines in service
- 2 options:
  - 1.)Collect 2 sets of samples 24 hours apart after flushing the highly chlorinated water from the line
  - 2.) Collect a single set of samples 48 hours or longer after flushing the highly chlorinated water from the line

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Bacteriological Testing

- At least one set of samples should be taken from each 2500 ft of new water main, plus one set from the end of line and at least one set from each branch
- The samples should be tested according to Standard Methods and should show absence of coliform organisms

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More Disinfection Procedures

- When cutting into or repairing existing mains: (applies to existing mains that are wholly or partially dewatered)
  - after appropriate procedures have been completed, the existing main may be returned to service prior to completion of bacteriological tests
- Leaks or breaks that are repaired with clamping devices while the mains remain full of pressurized water present little danger of contamination and require no disinfection

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More Disinfection Procedures

- Slug Chlorination for existing mains
  - same as previous method but dose may be increased to 300 mg/L with a contact time of 15 minutes
- If you disinfect, you must take bacteriological samples
  - Within **15 minutes** of when the line was returned to service

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Calculations

Dose and demand,
Disinfection of mains,
Solutions and dilutions

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Cl_2 Demand

- Due to a main break, the chlorine residual in the distribution system has dropped from 1.5 mg/L to 0.6 mg/L. What is the chlorine demand?

Demand, mg/L = Dose, mg/L - Residual, mg/L
= 1.5 mg/L - 0.6 mg/L
= 0.9 mg/L

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Water Main Disinfection

- A 300 ft section of a 12” main has been replaced. What is the volume of water in gallons that must be disinfected?

Volume = (0.785)(diameter)^2 (length)
= (0.785)(1 ft)(1 ft)(300 ft)
= 235.5 ft^3
= (235.5 ft^3)(7.48 gal/ft^3)
= 1761.5 gal

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Water Main Disinfection

- If the section of pipe in the previous problem is disinfected with 50 mg/L using 65% HTH, how many pounds of HTH will be required?

$$\text{lb HTH} = \frac{(\text{dosage, mg/L})(\text{volume, MG})(8.34\ \text{lbs/gal})}{\%\ \text{chemical purity, as decimal}}$$

$$= \frac{(50\ \text{mg/L})(0.0017615\ \text{MG})(8.34\ \text{lbs/gal})}{0.65}$$

$$= 1.13\ \text{lbs}$$

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Solutions

- How many pounds of 65% HTH would be needed to make up 10 gallons of a 1% solution?

$$\text{HTH, lbs} = \frac{(\text{desired conc.})(\text{desired vol.,gal})(8.34\ \text{lbs/gal})}{\%\ \text{HTH, as decimal}}$$

$$= \frac{(0.01)(10\ \text{gal})(8.34\ \text{lbs/ gal})}{0\ .65}$$

$$= 1.28\ \text{lbs}$$

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Dilution

- How many gallons of 15% available bleach would be needed to make up 10 gallons of a 1% solution?

$$\text{Bleach, gal} = \frac{(\text{desired conc.})(\text{desired vol.})}{\%\ \text{bleach, as decimal}}$$

$$= \frac{(0.01)(10\ \text{gal})}{0.15}$$

$$= 0.67\ \text{gallons}$$

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Pipe Disinfection Formulas for 50 mg/L 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

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 = $0.000026007(D)^2(L)$

L= the length of the line in feet,
D = 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

Field Data for Newly Constructed or Repaired Water Distribution Lines

Work Order # ______________________ Project # ____________________

Date: ___________________ Time: __________________

Location: ____

Type of Main: ____________ Size: _____________ Footage: __________

Pounds of HTH: _______________

Disinfection procedure utilized: _____________________________________

____

Flushing: ____

Comments: ____

____

____

Signature: _________________________ Date: _____________

Common Waterborne Diseases

Waterborne Disease	Causative Organism	Source of Organism in Water	Symptom
Gastroenteritis	*Salmonella* (bacteria)	Animal of human feces	Acute diarrhea and vomitting
Typhoid	*Salmonella typhosa* (bacteria)	Human feces	Inflamed intestine, enlarged spleen, high temperature - **FATAL**
Dysentary	*Shigella* (bacteria)	Human feces	Diarrhea - rarely fatal
Cholera	*Vibrio comma* (bacteria)	Human feces	Vomitting, severe diarrhea, rapid dehydration, mineral loss – high mortality
Infectious Hepatitis	Virus	Human feces, shellfish grown in polluted waters	Yellow skin, enlarged liver, abdominal pain – low mortality, lasts up to 4 months
Amoebic Dysentery	*Entamoeba* histolytica (protozoan)	Human feces	Mild diarrhea, chronic dysentery
Giardiasis	*Giardia lamblia* (protozoan)	Animal or human feces	Diarrhea, cramps, nausea and general weakness – not fatal, lasts 1-30 weeks
Crytosporidiosis	*Cryptosporidium* (protozoan)	Human and animal feces	Acute diarrhea, abdominal pain, vomiting and low-grade fever
Legionellosis	*Legionella pneomophila* and related bacteria		Acute respiratory illness

Disinfection Vocabulary

A. Bacteria
B. Breakpoint
C. Chlorination
D. Chlorine Demand
E. Combined Residual
F. C x T Value
G. Disinfection Residual
H. Disinfection
I. Disinfection By-Product
J. DPD
K. Free Residual Chlorine
L. HTH
M. Organic Substance
N. Ozone Generator
O. Sterilization
P. Trihalomethane
Q. UV Disinfection
R. Waterborne Disease

_______1. The process of destroying all organisms in water.
_______2. The product of the residual disinfectant concentration C and the corresponding disinfectant contact time T.
_______3. The water treatment process that kills disease-causing organisms in water.
_______4. A device that produces ozone by passing an electrical current through air or oxygen.
_______5. The point at which the chlorine dose has met the demand.
_______6. Living organisms, microscopic in size, which usually consist of a single cell.
_______7. A chemical substance of animal or vegetable origin, having carbon in its molecular structure.
_______8. Disinfection using ultraviolet light.
_______9. The process of adding chlorine to water to kill disease-causing organisms.
_______10. The residual formed after the chlorine demand has been satisfied.
_______11. An excess of chlorine left in water after treatment. Indicates the adequate amount of disinfectant has been added to ensure complete disinfection.
_______12. Compound formed when organic substances such as humic and fulvic acids react with chlorine.
_______13. The difference between the amount of chlorine added to water and the amount of residual chlorine remaining after a given contact time.
_______14. Chemical compounds that are formed by the reaction of disinfectants with organic compounds in water.
_______15. High Test Hypochlorite; calcium hypochlorite or $Ca(OCl)_2$
_______16. The chlorine residual produced by the reaction of chlorine with substances in the water. It is not as effective as free residual.
_______17. A disease caused by waterborne organisms.
_______18. A method of measuring the chlorine residual in water. The residual may be determined by either titrating or comparing a developed color with color standards. Stands for N,N-diethyl-p-phenylene-diamine.

Answers

Vocabulary

1. O
2. F
3. H
4. N
5. B
6. A
7. M
8. Q
9. C
10. K
11. G
12. P
13. D
14. I
15. L
16. E
17. R
18. J

Section 6

Lab Tests and Sampling

Water Quality, Analysis and Sampling in Distribution System

Objectives

- Need for monitoring water quality
- Identify types of samples
- Collect proper samples
  - Preserving and storing techniques
- Perform lab/field tests

Water Quality Monitoring

- Monitored to ensure safety and integrity
- Monitored to meet state and federal requirements
- Water quality can degrade in distribution system due to contamination or growth of organisms

Prevent 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 residual up
  - •Prevent stagnation
  - •Keep excess nutrients out
  - •Prevent cross-connections

Drinking Water Standards

- First established to control waterborne disease outbreaks around 1914
- The 1976 Primary Drinking Water Regulations established MCL's for certain substances
- Safe Drinking Water Act (SDWA) and its amendments require additional testing
  - Originally enacted in 1974 with amendments in 1980, 1986, and 1996
  - States can revise and make more strict
- In 1998, the Interim Enhanced Surface Water Treatment Rule and Disinfection By-products Rule were signed into law.

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 errors in water quality analysis
- All chemical analysis records must be kept for 10 years

Types of Samples

❶ 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

❷ 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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Composite Samples

- Time composite - equal volumes at different times
- Flow-proportional composite - volume varies depending on flow rate

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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 your analysis

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Sample Labeling

- Specific location (address)
- Date and time sampled
- Chlorine residual
- pH and temperature (if needed)
- Sample number or identification
- Name or initials of person taking sample

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Sample Labeling

Site 196 E. Main Street Billieville, TN

Date / Time August 15, 2005 8:15 AM

Code B16089

Sampled by Billy Joe Smith

Comments pH < 2 with H_2SO_4 and stored at 4°C

Free residual chlorine = 2.1 mg/L

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Distribution Sampling Points

- Distribution sampling is best indicator of system water quality
- Water quality changes in distribution system can be caused by:
  - Corrosion - increase in color, turbidity, taste & odor
  - Microbiological growth - slime
  - Cross-connections

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Distribution Samples

- Determine water quality at customers' taps
- Most common tests are chlorine residual and coliform bacteria
- Number of samples depends on size of system and water source

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Bacteriological Samples

- Only approved containers should be used to collect sample
  - should have sodium thiosulfate in them to dechlorinate the water

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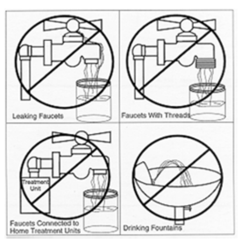
Bacteriological Samples

- Bacteriological 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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Bacteriological Samples

- Do not flame faucet with torch
- Turn on faucet to steady flow and flush service line (2 - 5 min)
  - getting water from main line
- Fill bottle to proper level (100 mL ± 2 mL)
- If container has screw-on lid, do not set it down on ground or put in your pocket
- Label bottle with pertinent information
- Test as soon as possible - within 30 hours

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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
  - Coliform group (total coliforms)

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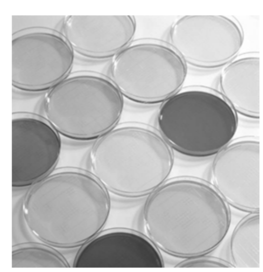
Bacteriological Samples

- The MCL for coliform bacteria is based on presence or absence
- Finished and distributed water should be 0 (absent)
- Must keep results for 5 years



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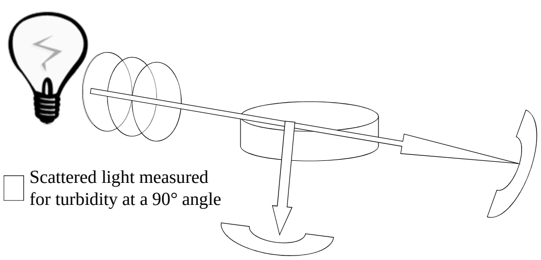
pH

- Measure of the hydrogen ion concentration
- Scale runs from 0 to 14
  - sample is acidic if pH < 7
  - sample is basic if pH >7
- Used to determine whether water is scale forming or corrosive
- pH meter should be calibrated <u>daily</u> with at least 2 standards minimum (3 recommended)
- Samples measured on-site

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 specific monitoring requirements
- Measure samples ASAP; keep sample tubes clean and scratch free inside and out
- Records must be kept for 5 years

Turbidimeter



- Scattered light measured for turbidity at a 90° angle
- Light source from tungsten lamp passing through three precisely aligned lenses, the light is focused in a narrow, collimated beam

Measuring Chlorine Residual

- Free chlorine residual must be tested and recorded when bacteriological samples are collected
- Analysis should be performed as soon as possible, exposure to sunlight or agitation of the sample will cause a reduction in the chlorine residual
  - Sample holding time = 15 minutes
- 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 than 5% of samples each month for any two consecutive months

Measuring Chlorine Residual

- 2 methods:
  - DPD colorimetric
    - method most commonly used
    - Match color of sample to a standard
    - Swirl sample for 20 seconds to mix
    - Within one minute of adding reagent, place it into colorimeter
  - Amperometric titration
    - Titrate sample with phenylarsene oxide solution (PAO) until further additions no longer cause deflection on maicrammeter
    - mL of PAO used is equal to mg/L of free residual
    - **Titration** – process of adding a chemical of known strength drop by drop until a certain endpoint (color change, pH, precipitate, etc) is reached

Fluoride

- Added to drinking water for the reduction of dental caries (cavities)
- Interferences:
  - Phosphate has positive interference
  - Aluminum has negative interference
- Primary MCL = 4.0 mg/L
- Secondary MCL = 2.0 mg/L
- State of Tennessee recommends 0.7 mg/L

Fluoride

- Methods
  - SPADNS (interferences are more common with this test)
    - Can be done either in the field or in the lab
    - Alum or aluminum complexes can interfere
    - There is a 1 minute reaction time
  - Electrode
    - Done in the lab
    - TISAB removes most of the aluminum interferences
    - Store probe in a standard, the higher the better
    - Probes can last 3-5 years
    - Can clean with toothpaste

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Alkalinity

- The ability of a solution to resist a change in pH
- Tested by titrating sample with 0.02 N sulfuric acid
- Two types commonly tested for
  - Phenolphthalein alkalinity
    - Drop pH to endpoint of 8.3 OR
    - Use phenolphthalein color indicator to achieve color change of pink to clear
  - Total alkalinity
    - Drop pH to endpoint of 4.5 OR
    - Use methyl orange or bromcresol green methyl red color indicator to achieve color change of blue/green to pink

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Phosphates

- Test for reactive (ortho-phosphates) phosphates if they are added at the water plant for corrosion control
- Polyphosphates work as sequestering agents - tie up iron and manganese to prevent color and taste complaints
- Orthophosphates work well for lead and copper protection

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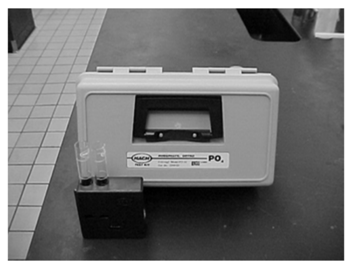
Phosphates



Color comparator method for field testing

Blue color indicates presence of phosphates

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Lead and Copper Rule

- Established in 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 taken 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, must take steps to control corrosion:
  - Corrosion control program
  - Source water treatment
  - Public education
  - And/or lead service line replacement

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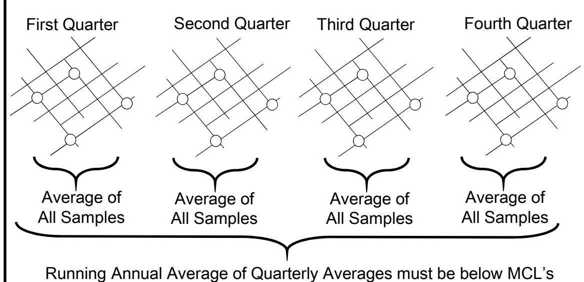
Standard Monitoring Requirements

- What, where, and how often do I monitor?
  - Samples Collected
    - Dual sample set (both TTHM and HAA5) collected at all locations
  - Monitoring Locations
    - High TTHM levels
    - High HAA5 levels
    - Average Residence Time
    - Near Entry Points
  - Number of sites
    - Based on system type
  - Monitoring Frequency
    - 1, 4, or 6 monitoring periods during the year at each location
    - Number based on population served and source type

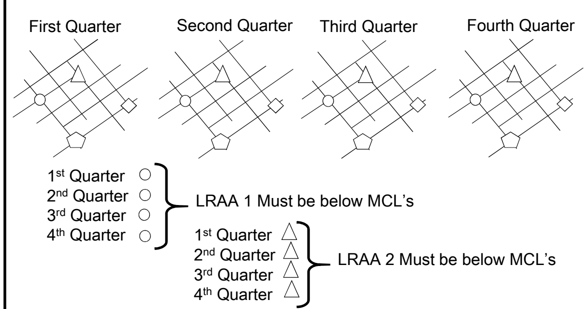
Standard Monitoring Requirements

- When do I sample?
  - Sample months
    - Peak historical month
      - Peak TTHM levels
      - OR
      - Peak HAA5 levels
      - OR
      - Month of warmest water temperature
    - All systems sample during this month
    - Systems sampling more than once will set sample months every 60 days or every 90 days around peak historical month (± 5 days)

Stage 1 DBP Rule



Stage 2 DBP Rule



- **For groundwater systems or systems that purchase groundwater**

THM and HAA5 Standard Monitoring(1)

Population	Frequency	Total	Near EP	ART	High TTHM	High HAA5
< 500 consecutive	1 (during peak historical month)(2)	2	1	-	1	-
< 500 non-consecutive		2	-	-	1	1
500-9,999	4 (every 90 days)	2	-	-	1	1
10,000 – 99,999		6	1	1	2	2
100,000-499,999		8	1	1	3	3
≥ 500,000		12	2	2	4	4

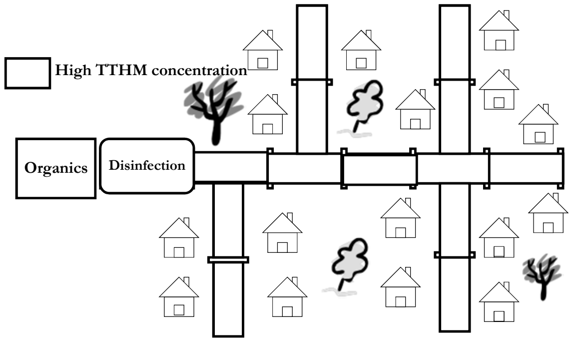
(1) A dual sample set (i.e., a TTHM and an HAA5 sample) must be taken at each monitoring location during each monitoring period.
(2) The peak historical month is the month with the highest TTHM or HAA5 levels or warmest water temperature.

- **For Subpart H systems and systems that purchase Subpart H water**

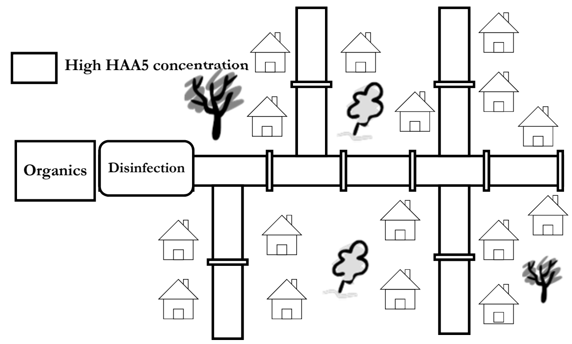
THM and HAA5 Standard Monitoring(1)

Population	Frequency	Total	Near EP	ART	High TTHM	High HAA5
<500 consecutive	1 (during peak historical month)(2)	2	1	-	1	-
<500 non-consecutive		2	-	-	1	1
500-3,300 consecutive	4 (every 90 days)	2	1	-	1	-
500-3,300 non-consecutive		2	-	-	1	1
3,301-9,999		4	-	1	2	1
10,000-49,999	6 (every 60 days)	8	1	2	3	2
50,000- 249,999		16	3	4	5	4
250,000-999,999		24	4	6	8	6
1,000,000-4,999,999		32	6	8	10	8
≥ 5,000,000		40	8	10	12	10

TTHM Formation



HAA5 Formation



Other Factors that Influence DBP Formation

Parameter (Increasing)	TTHM	HAA5
TOC	↑	↑
Time	↑	↔
Temperature	↑	↑
Disinfectant Dose	↑	↑
pH	↑	↓
Bromide	↑	↑

Term Review

- MCL -maximum contaminant level
  - Primary regulation, health hazard
- sMCL - secondary maximum contaminant level
  - Aesthetics
- MCLG - maximum contaminant level goal
  - Level at which no known or anticipated adverse health effect
- Action level - lead & copper
  - Level which requires certain action
- MRDL - maximum residual disinfectant level
  - The highest level of a disinfectant allowed in drinking water without causing an unacceptable possibility of adverse health effects.

Total Coliform Monitoring Frequency for Community Water Systems

Population Served	Minimum Number of Samples Per Month
25 to 1,000	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to33,000	30
33,001 to 41,000	40
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240
780,001 to 970,000	270
970,001 to 1,230,000	300
1,230,001 to 1,520,000	330
1,520,001 to 1,850,000	360
1,850,001 to 2,270,000	390
2,270,001 to 3,020,000	420
3,020,001 to 3,960,000	450
3,960,001 or more	480

Sampling and Analysis Review Questions

1 What is the difference between a grab sample and a composite sample?

2 Why should you never use a composite sample for bacteriological analysis?

3 List and describe the two types of composite samples.

4 What types of faucets should be avoided when selecting sampling points?

5 What is the maximum number of hours a bacteriological sample can be held before testing?

6 How long should a service line be flushed before sampling?

7 What is the easiest method to test for chlorine residual in the field?

8 What information should be recorded on the label of a bacteriological sample?

9 What is the indicator organism used in the bacteriological test?

10 According to the Lead and Copper Rule, what is the action level for lead?

11 According to the Lead and Copper Rule, what is the action level for copper?

12 What determines the MCL for total coliforms in drinking water?

13 Name three causes of water quality degradation in the distribution system.

14 Define the following terms:

- MCL –
- sMCL –
- Action Level –

Answers

1. Grab sample – single volume collected at a specific place and time
   Composite sample – series of grab samples mixed together, determines average concentration, not suitable for all tests.

2. Must be taken in a sterile container, must be tested within 30 hours, cannot determine where the positive occurred.

3. Time composite – equal volumes at different times
   Flow-proportional composite – volume varies depending on flow rate

4. Leaking faucets, Faucets with home treatment units, Drinking fountains, Swivel faucets

5. 30 hours

6. 2-3 minutes (Standard Methods) or to uniform temperature

7. DPD test kit

8. Location, Date, Time, Chlorine residual, Sample # and type, Collector's name or initials

9. Total coliforms (coliform group)

10. 0.015 mg/L

11. 1.3 mg/L

12. Presence / Absence

13. Corrosion, Microbial growth, Cross-connections

14. MCL – Maximum Contaminant Level – maximum permissible level of a contaminant in drinking water as specified in the Safe Drinking Water Act. For primary regulations, health hazards.

    sMCL – Secondary Maximum Contaminant Level – based on aesthetic quality of water, non health hazard

    Action Level – Level of a contaminant which, if exceeded, requires specific action(s) to reduce risk of adverse health effects.

Section 7

Valves

Distribution System Valves

- Uses
- Types
- Operation
- Maintenance

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Why Choose a Certain Valve?

- Location
- Type of liquid
- Pressure
- Average flow
- Frequency of operation
- Cost

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Uses of Valves in Distribution System

- Isolation (gate, butterfly, globe, ball)
- Draining lines (blow-off)
- Throttling flow (butterfly, plug, globe, ball)
- Regulate water storage levels (altitude-control valve)

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Uses of Valves in Distribution System

- Control water hammer (pressure-relief valve)
- Allow air in & out of lines (air-relief valve)
- Control backflow (check valve)

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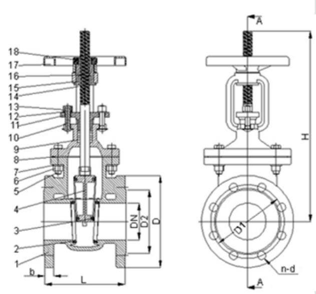
Gate Valves

Gate is raised or lowered by a screw, which is operated by a hand wheel or valve key

- **Rising Stem** - Outside Screw & Yoke (OS&Y) type have exposed screw extending above the valve bonnet



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Gate Valves

- **Non-rising Stem**
- Lower end of the stem is threaded & screws into the disk
- The disk moves up or down while a thrust collar keeps the stem in place

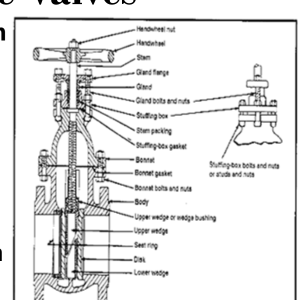

Figure 2-5. Nonrising-stem gate valve

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Gate Valves in the Distribution System

Generally used to isolate sections of the system

- **Hydrant Auxiliary Valve** – direct connection to a fire hydrant
- **Tapping Valves** – connection to a tapping tee & connection to tapping machine
- **Horizontal Gate Valves** – used in large diameter pipe and designed to lie on one side
- **Bypass Valves** – included in large gate valves

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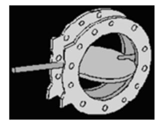
Butterfly Valves

- Has a disk that is rotated on a shaft
  - Pros – operate easily and quickly; ¼ turn can fully open or shut them; less expensive than gate valves
  - Cons – greater head loss; closing too quickly may produce a serious water hammer; can be obstacle if cleaning main with pigs or swabs

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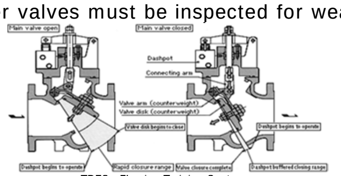
Check Valves

- Allow flow in only one direction
- Commonly used on discharge pumps to prevent backflow
- Could have problems with the valve slamming shut and creating serious water hammer
- Older valves must be inspected for wear



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Pressure Reducing Valves

- Operate automatically to throttle flow and maintain a lower pressure
- Valve has 2 upper operating chambers sealed from each other by a flexible reinforced diaphragm
- The chambers receive pressure from the system and are adjusted to modulate the valve stem up and down to maintain the desired discharge pressure

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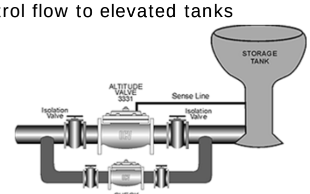
Altitude Valves

- Ground level reservoirs are usually filled through an altitude valve
- Allows water to fill a reservoir at a controlled rate
- Activated by the water pressure from the reservoir to close automatically when the reservoir is full
- Also control flow to elevated tanks



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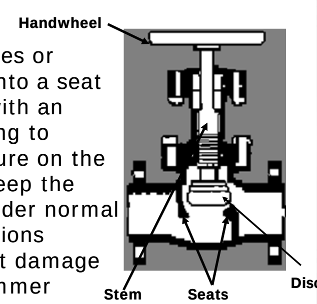
Pressure Relief Valves

- Valve stem raises or lowers a disc onto a seat
- **Globe Valve** with an adjustable spring to maintain pressure on the valve seat to keep the valve closed under normal pressure conditions
- Used to prevent damage from water hammer



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Globe Valves

- Require little maintenance
- Disc and seat can be replaced or restarted quickly and easily
- Relatively high head loss when fully open
- Suitable for service in **small** pipelines only

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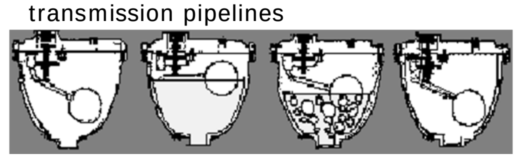
Air and Vacuum Relief Valves

- Float operated valve that allows air to escape when the float is down
- Commonly used on the discharge of a well pump
- Should be installed at high points in transmission pipelines



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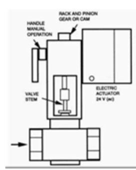
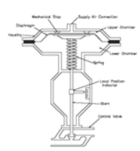
Valve Operation & Installation

- Valve Operators
  - **Electric Actuator** – Small electric motor to rotate the valve stem through a gear box
  - **Hydraulic Actuators** – operated by water pressure or hydraulic fluid
  - **Pneumatic Actuators** – operated with compressed air





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Distribution System Valves

- **Manual Operation** - turning the 2-inch square nut with a valve key
- **Portable Power Operators** – electric or gasoline powered tools for operating valves
- **Valve Boxes** – constructed around the valve after it is installed

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Valve Maintenance Program

- Inspect each valve on a regular basis (annually if possible)
  - more frequently for large valves (16 " or greater)
- Follow Manufacturer's guidelines

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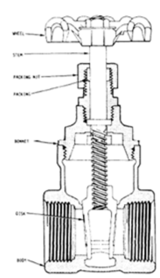
Valve Maintenance Program



- Operate the valve; lubricate as needed
- Check condition of packing, stem, operating nut & gears (if any)
- Check location measurements

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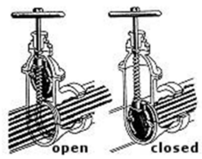
Valve Maintenance Program

- Was valve open or closed
- Number of turns to open or close
- Cycle all gate valves to full open/full close at least every two years
- Make prompt repairs
- Keep complete records of maintenance



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Valve Vocabulary

A. Actuator
B. Air-and-vacuum relief valve
C. Air binding
D. Air-relief valve
E. Altitude-control valve
F. Backflow
G. Ball valve
H. Butterfly valve
I. Bypass valve
J. Check valve
K. Corporation stop
L. Curb box
M. Curb stop
N. Cut-in valve
O. Floorstand
P. Gate valve
Q. Globe valve
R. Inserting valve
S. Isolation valve
T. Nonrising-stem valve
U. Packing
V. Plug valve
W. Pressure-reducing valve
X. Pressure-relief valve
Y. Resilient-seated gate valve
Z. Seat
AA. Service valve
BB. Tapping valve
CC. Valve
DD. Valve box
EE. Valve key
FF. Vault
GG. Water hammer

_______1. A valve for joining a service line to a street water main. It can't be operated from the surface. Also called a corporation cock.

_______2. A valve that automatically shuts off water flow when the water level in an elevated tank reaches a preset elevation then opens again when the pressure on the system side is less than that on the tank side.

_______3. A valve installed in a pipeline to shut off flow in a portion of the pipe, for the purpose of inspection or repair. Such valves are usually installed in the main lines.

_______4. A gate valve with a disc that has a resilient material attached to it, to allow a leak-tight shutoff at high pressures.

_______5. A specially designed valve used with a sleeve that allows it to be placed in an existing main.

_______6. A special shut-off valve used with a tapping sleeve.

_______7. A device, usually electrically or pneumatically powered, that is used to operate valves.

_______8. A metal or concrete box or vault set over a valve stem at ground surface to allow access to the stem so the valve can be opened and closed.

_______9. An underground structure, normally made of concrete, that houses valves and other appurtenances.

_______10. A gate valve in which the valve stem does not move up and down as it is rotated.

_______11. A shutoff valve attached to a water service line from a water main to a customer's premises, usually placed near the customer's property line. Also called a curb cock.

_______12. A valve in which the closing element consists of a disc that slides across an opening to stop the flow of water.
_______13. A hydraulic condition, caused by a difference in pressures, in which nonpotable water or other fluids flow into a potable water system.
_______14. A dual-function air valve that (1) permits entrance of air into a pipe being emptied, to prevent a vacuum, and (2) allows air to escape in a pipe being filled or under pressure.
_______15. The portion of a valve that the disc compresses against to achieve shutoff of the water.
_______16. The potentially damaging slam, bang or shudder that occurs in a pipe when a sudden change in water velocity creates a great increase in water pressure.
_______17. A valve in which the movable element is a cylindrical or conical plug.
_______18. A shutoff valve that can be inserted by special apparatus into a pipeline while the line is in service under pressure.
_______19. The condition in which air has collected in the high points of distribution mains, reducing the capacity of the mains.
_______20. A cylinder placed around the curb stop and extending to the ground surface to allow access to the valve.
_______21. A valve in which the disc rotates on a shaft as it opens or closes. In the full open position, the disc is parallel to the axis of the pipe.
_______22. Any valve that is used to shut off water to individual customers.
_______23. A metal wrench with a socket to fit a valve operating nut.
_______24. A valve that opens automatically when the water pressure reaches a preset limit, to relieve the stress on a pipeline.
_______25. A mechanical device installed in a pipeline to control the amount and direction of water flow.
_______26. A valve designed to open in the direction of normal flow and close with reversal of flow. An approved check valve is of substantial construction and suitable materials, is positive in closing and permits no leakage in a direction opposite to normal flow.
_______27. An air valve placed at a high point in a pipeline to release air automatically, thereby preventing air binding and pressure buildup.
_______28. A small valve installed in parallel with a larger valve; it is used to equalize the pressure on both sides of the disc of the larger valve before the larger valve is opened.
_______29. A device for operating a gate valve (by hand) and indicating the extent of opening.
_______30. Rings of graphite impregnated cotton, flax, or synthetic material, used to control leakage along a valve stem.
_______31. A valve having a round, ball-like shell and horizontal disc.
_______32. A valve with horizontal disc for reducing water pressures in a main automatically to a preset value.
_______33. A valve consisting of a ball resting in a cylindrical seat. A hole is bored through the ball to allow water to flow when the valve is open; when the ball is rotated 90°, the valve is closed.

Review Questions

1. List six uses for valves in a water distribution system.
    -
    -
    -
    -
    -
    -

2. For each valve use listed in question 1, name one valve type suitable for that use.
    -
    -
    -
    -
    -
    -

3. List the three most common types of joints used to install valves.
    -
    -
    -

4. What is the primary purpose of a bypass valve?

5. How often should distribution system isolation valves be operated or inspected?

6. What can happen if a valve is opened or closed to quickly?

7. List at least three items to check during routine inspection of a valve.
   -
   -
   -

Answers

Vocabulary:

1. K
2. E
3. S
4. Y
5. N
6. BB
7. A
8. DD
9. FF
10. T
11. M
12. P
13. F
14. B
15. Z
16. GG
17. V
18. R
19. C
20. L
21. H
22. AA
23. EE
24. X
25. CC
26. J
27. D
28. I
29. O
30. U
31. Q
32. W
33. G

Review Questions:

1. isolation, draining lines, throttling flow, regulating water-storage levels, controlling water hammer, bleeding off air and allowing air into lines, and preventing backflow
2. isolation: gate, butterfly, globe, plug, ball
   drain: blow-off
   throttle: butterfly, plug, globe, ball
   regulate storage levels: altitude-control valve
   control water hammer: pressure-relief valve
   allow air in and out of lines: air-relief valve
   control backflow: check valve
3. flanged, mechanical, push-on
4. To help equalize pressure on a large valve, making it easier to open and close.
5. annually at least; more often for important valves
6. water hammer
7. location measurements; whether found open or closed; condition of packing, stem, operating nut, gears (if any), box or vault, box cover; number of turns to open and close

Section 8

Hydrants

Hydrants

Installation, Field Testing & Maintenance of Fire Hydrants

1

Objectives

- Uses of hydrants in distribution system
- Components of dry-barrel and wet-barrel hydrants
- Installation, operation, inspection, and maintenance procedures
- Record keeping and safety

2

What is a Fire Hydrant?

- State Rules 0400-45-1-.17(18)
  - Must be installed on a 6 inch main
  - Must flow 500 gpm at 20 residual psi
  - If hydrants don't meet these requirements, it's considered a blow-off
    - These hydrants should also have their bonnets pained red
    - Classified as a Class C Hydrant

3

Fire Hydrant Uses

- Fire fighting
  - Main purpose of fire hydrants
  - Fire Dept. is usually responsible for flow testing
  - Utility usually responsible for maintaining hydrants
- Flushing water mains
  - Fully opening a hydrant to remove sediment
  - Recommended twice a year
  - Velocity in excess of 2.5 ft/sec

4

Fire Hydrant Uses

- Flushing sewers
- Filling tank trucks
- Providing temporary water sources for construction work via hydrant meter

5

Fire Hydrant Uses

- All community water systems having more than 50 service connections shall establish and maintain an adequate flushing program
  - State Rule 0400-45-1-.17(10)
- All dead end water mains shall be equipped with a blow off or other suitable flushing mechanism

6

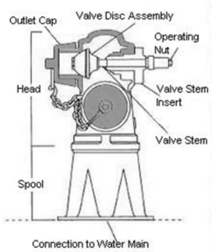
Fire Hydrant Uses

- Unauthorized use of hydrants should be prohibited because:
  - Hydrants can be damaged
  - Water is not paid for
  - User may not shut valve completely, resulting in leakage
  - Cross connection

Design of Wet-Barrel Hydrants

- AWWA Standard C503
  - Completely filled with water at all times
  - Has no main valve; each nozzle equipped with a valve
  - Large amounts of water may flow from broken hydrant

Types of Hydrant



- Wet Barrel C503

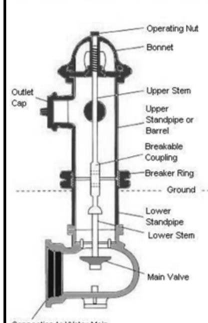
Design of Dry-Barrel Hydrants

- AWWA Standard C502
  - Bonnet shall have “open” cast on or near top to indicate direction to open
  - Must have caps for each outlet nozzle, secured to hydrant with chain
  - Operating nut shall be pentagonal in shape and open counterclockwise

Dry-Barrel Hydrants

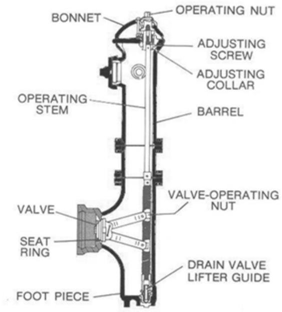
- Valve Types
  - Standard Compression
  - Slide Gate Hydrant
  - Toggle (Corey) Hydrant
  - Flush Hydrant

Types of Hydrant



- Dry Barrel Compression C502

Types of Hydrants



- Corey Toggle Hydrant

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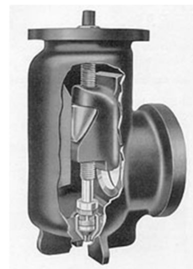
Types of Hydrant



- Dry Barrel Gate Hydrant

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Flush Hydrants

- Entire standpipe and head are below ground
- Operating nut and outlet nozzles are encased in a box with a cover at ground level
- Usually dry-barrel type
- Could also be a fire hydrant on a main less than 6 inches or can not provide 500 gpm with 20 psi

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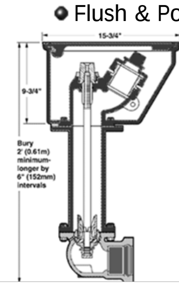
Types of Hydrant

Post

- Flush & Post Hydrants



Flush – Underground in Meter Box

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Traffic Model

- AWWA Standard C502, latest revision
  - The main valve on the hydrant shall remain closed should the hydrant nozzle section be broken off in a traffic accident

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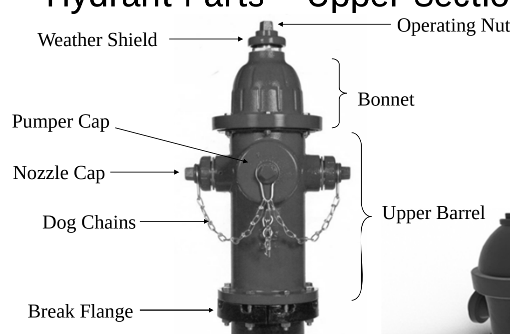
Hydrant Parts – Upper Section



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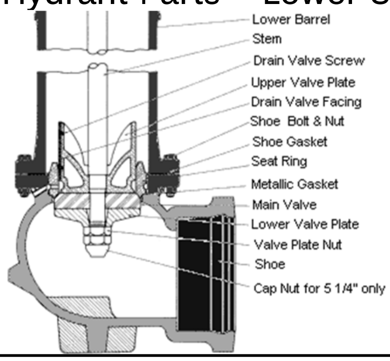
Hydrant Parts – Lower Section



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Operation of Hydrants

- Anyone using a hydrant should be instructed on proper operation of the hydrant

20

Operation of Hydrants

- The main valve should always be opened completely, never throttled
- Hydrants should always be opened and closed slowly to prevent water hammer and damage to valves

21

Inspection of New Hydrants

- Checklist Items:
  - Direction to open operating nut
  - Size and shape of operating nut
  - Depth of bury
  - Size and type of inlet connection
  - Main valve size
  - Outlet nozzle size, configuration, and thread dimensions

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Installation

- Refer to AWWA Manual M17 for procedures
  - Install hydrants plumb
  - Locate to local fire codes
  - Minimum of 16” pumper to ground height
  - Provide thrust restraint for hydrant & valve
  - Always install auxiliary valve
  - Lead & main same material
  - Gravel sump behind hydrant

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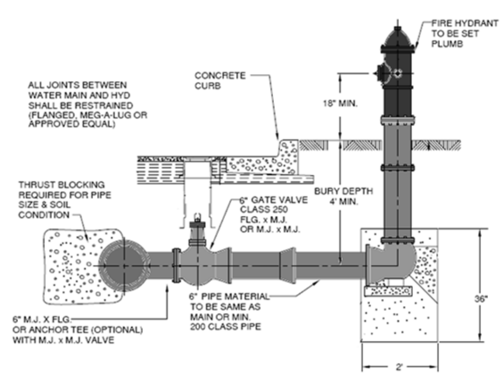

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Installation

- Adoption of color scheme to indicate flow is optional, but if used, it should follow the uniform color coding system:

Class	Flow, gpm	Color
AA	Greater than 1500	**Blue**
A	1000-1499	**Green**
B	500-999	**Orange**
C	Less than 500	**Red**

Per National Fire Code 921:2-1 and 2-2

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Testing

- Hydrants should not be pressure tested at the same time as the main
- When testing the hydrant:
  - Open hydrant fully and fill with water
  - Vent air by loosening one of the caps
  - Apply pressure up to 150 psi
  - Check for leaks at flanges, outlet nozzles, operating stem

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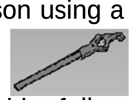
Hydrant Operation

- Hydrants are designed to be operated by one person using a 15-inch long wrench



- Valve should be fully open or fully closed, never throttled
- Hydrants open and close the main valve against water pressure

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Hydrant Maintenance

- All hydrants should be inspected at least annually
- If a hydrant is inoperable and cannot be immediately repaired, the fire department should be notified

28

Hydrant Lubrication

- To insure the readiness for instantaneous use, all fire hydrants should be inspected and tested at six-month intervals
- Oil
  - Follow manufacturers recommendations
  - Mineral oil may be substituted
- Grease
  - No grease containing calcium acetate
  - Food grade preferred
  - No Havoline 10W40

29

Inspection Procedures

- Verify upper barrel connected
- Check ground around hydrant
- Check valves for ease of operation
- Check for leakage at joints
- Flush line to remove foreign material
- Close main valve completely

30

Inspection Procedures

- Check for proper drainage
- Use a hydrant wrench
- Check breakaway mechanism
- Check nozzles for cross threading
- Clean and lubricate threads per hydrant specs
- Lubricate operating nut threads

31

Hydrant Repair

- Notify fire department
- Refer to M17 manual for model cutaway
- Close auxiliary valve
- Repair hydrant to manufacturer recommendations
- Test hydrant and open auxiliary valve

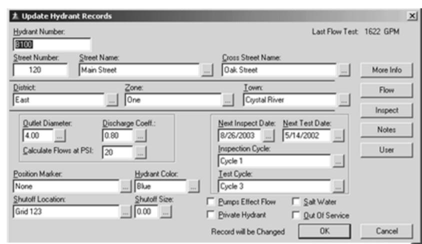
32

Hydrant Records

- Record make, model, location of hydrant at installation
- Record inspection and repair info - proof of condition of hydrant

33

Hydrant Records



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Hydrant Safety

- Force and volume of water from a hydrant can cause injuries
  - Stand behind hydrant
- Provide a non-rigid flow diffuser
  - May cause traffic accidents, hazards
  - Take steps to minimize property damage
- If flow is diverted to a sewer, it must not create a cross-connection

Rigid Diffuser

35

Flushing Safety

- Local regulations may require dechlorination of flushed water
- Devices that are used to control erosion may also be useful to ensure adequate dechlorination

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FIRE HYDRANT MAINTENANCE

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GENERAL

All fire hydrants currently being installed in the south are in compliance with the American Water Works Association (AWWA) C502 standard for dry barrel hydrants, latest addition. Center stem compression hydrants are designed to both minimize maintenance needs as well as facilitate maintenance operations when necessary.

The following general information covers key mechanical components that may apply to all AWWA C502 hydrants. It is suggested to reference the manufacturers maintenance manual that is specific to each hydrant model for further servicing information.

When replacement parts are required, it is essential to provide detailed information specific to the subject hydrant. The following Information for identification will be on the barrel section: 1) name of manufacturer, 2) model number, 3) year of manufacture, and 4) main valve size. Direction to open and depth of trench may also be applicable.

MAIN VALVE

The most common maintenance need relates to obstructions in the seating area and resulting damage to the main valve. This is detectable by continued flow with the hydrant in the closed position.

When obstructions to seating of the main valve occur, it is important to avoid the use of excessive force in attempts to achieve closure. Excessive closure torques can accelerate damage to the main valve or induce damage to other related parts. The suggested procedure is to reopen the hydrant and flush the obstructions clear and attempt to re-close. If this is unsuccessful, the main valve assembly will need to be removed for further analysis.

Since we are going to remove the main valve, we must first <u>turn off the auxiliary valve</u>. Some maintenance functions can be performed under water pressure, however, when using a seat removal wrench we must confirm that the hydrant is not under pressure.

<u>DISASSEMBLY</u> - To access the main valve, the hydrant is disassembled starting from the bonnet. In the case of a grease-lubricated hydrant, we remove the bonnet bolts and thread off the bonnet unit off the stem. Next we remove the seal plate if applicable. In the case of an oil-lubricated hydrant, the manufacturer recommends removal of the operating nut assembly and procedures for retaining the oil in the bonnet.

Next, use the appropriate seat wrench (again with the water off) to remove the seat assembly. For recent production hydrants, this wrench engages on the cast iron break coupling below the break point or to an upper stem drive pin.

Most new model hydrants have bronze to bronze seating (seat ring to sub-seat). Also, the current use of O-ring seals provides servicing advantages verse old gasket seals. This allows for torque applied to the stem assembly to be sufficient drive out the seat ring.

For older models with a seat ring threaded into cast iron shoe, a longer seat wrench that drives directly on seat ring drive lugs is required to deliver disassembly torque. When encountering excessive resistance to seat removal, safety considerations increase in importance - especially when excessive manual force is employed. The wrench can be secured to the seat ring drive lugs by a retention device threaded to the upper stem. This can prevent the wrench from releasing while manual force is employed. Use of gear or power driven wrenches are preferable to the use of manual forces.

Main valve replacement is accomplished after removal of the bottom plate. Match the corresponding tapered seating surfaces of the main valve and the seat ring. At this point, also check the bronze-seating surface for damage. Minimal roughness can generally be buffed out with an emery cloth.

DRAIN VALVE SYSTEM

Function of the drain valve system needs to be checked for proper operation. There are two primary issues that can cause a need for related maintenance.

1) Hydrant barrel fails to drain after use - which subjects it to freeze damage.
2) During full open hydrant operation, continuous discharge of water is taking place which can undermine support for the installation.

To accommodate barrel drainage, a gravel sump is installed around the base of the hydrant to accept water from the drain ports. To check for proper drainage, view the water level drop and/or feel for the suction created at the nozzle outlet. If the <u>hydrant barrel fails to drain</u> there are several possibilities to review:

A) Improper installation of a concrete thrust block over the drain ports is somewhat common with new installations. It is also possible that the poly-wrap used to encase the piping system does not allow for drainage. In either case the need for re-excavation makes the remedy somewhat difficult.

B) There also have been cases where a high water table is the culprit.

C) It is possible the weep holes have become plugged with sand etc over time or during construction. There are two ways to check or remedy this situation.

1) The first option is to attempt to force flush the drain system clear with water pressure. To attempt this, remove a hose cap and open the hydrant slightly and fill hydrant barrel as much as possible. (This step is intended to minimize hazards associated with compressed air inside the hydrant.) Turn off hydrant and tightly secure all hose caps. Open the hydrant approximately 3 turns - standing behind and not over when operating. This allows

line pressure to enter the hydrant while the drain system is open creating an opportunity for line pressure to blow the drain system clear.

2) If problems persist, CLOSE the auxiliary valve and remove the main valve assembly as noted above. Pump the remaining water from the hydrant barrel. Using a long narrow pole with a nail thru the end, locate the drain ports that exit the shoe and attempt to mechanically clear the drain ports.

If the above least difficult remedies are not successful, it is sometimes chosen to designate a hydrant to be pumped out after each use - rather than excavating to address the external drain area. A so designated hydrant should be regularly inspected - since very minor seat leakage may be retained in the barrel section and is subject to freezing.

If <u>during hydrant operation, continuous discharge of water</u> is taking place, note the following possibilities:

A) Hydrant needs to be operated in the full open position only. This assures that the drain valve facing is fully blocking the drain valve port.

B) The drain valve facing is damaged or missing. This is most common with older style hydrants using leather drain valve facings, which are subject to wear, swelling, shrinking & cracking.

The newer pressure activated rubber drain valve facings have been a great improvement to hydrant operations & maintenance. These allow for operational tolerances, which have virtually eliminated wear and resulting, service needs.

C) Inspect the drain valve assembly. This can be subjected to damage from disassembly torques being transmitted thru - and twisting of - the drain ears.

<u>**REASSEMBLY**</u> - To reinstall the main valve assembly, inspect the O-ring seals and replace if necessary. For hydrants with older style gasket type seals, gasket replacement with each servicing is recommended. Clean the threads and apply food grade grease to the O-rings or gaskets and seat ring threads.

Lower the stem and main valve assembly into the barrel - using caution to avoid scrapping or dislodging the O-rings or gaskets. To assure proper starting of the threads, use the wrench to rotate assembly backwards one or two turns to align seat ring threads before threading into place. On models with O-ring seals, only a moderate amount of torque is required to seal the O-rings.

Before applying pressure to the main valve assembly, the bonnet assembly must first be reinstalled. This permits valve closure to be regulated by the operating nut. <u>Do not flush a partially disassembled hydrant without the restraint of the operating nut assembly</u> – since this would allow flow to drive the main valve closed and create a water hammer situation.

STEMS

Bronze upper stem sleeves should be inspected. The stem sleeve is bronze - since bronze is non corrosive and won't cut the bonnet / seal plate O-rings as the stem rises & descends during operation. However, bronze is a relatively soft material and subject to mechanical damage. To inspect, shut off the hydrant lead gate valve – remove the pumper cap - and open the hydrant. At this point the stem sleeve is just about fully visible and any damage should be detectable.

BREAKAWAY SYSTEM

The breakaway system is the weak point designed to fracture upon impact. This minimizes potential damage to the hydrant, the vehicle, and its occupants. Alternately, the break system must have enough structural integrity to facilitate high flow fire fighting operation. Due to potential for minor impact or bump damage, it is very important to perform a visual check of break flanges or break lugs as part of routine maintenance.

Finish grade shall be a minimum of 16 inches from center on pumper nozzle. This is essential for proper performance in the event of a collision. A well supported installation plays a key role in proper break function – in that the impact stress will be more fully focused on the cast iron break away components in a ridged installation rather than transferred to other points in the hydrant assembly.

After a collision - repair can be accomplished as follows:

1) Removing broken coupling and standpipe break rings or break lugs.
2) Unscrew the upper stem from the operating nut
3) Install the new break coupling and replace upper stem.
4) Remove the cap/bonnet assembly.
5) Reassemble upper barrel of hydrant to lower barrel - checking to assure proper gasket/o-ring gasket installation.
6) Install breaker rings or break lugs - tighten evenly to manufacturer's recommended torques.
7) Replace the cap / bonnet assembly by fully threading onto the upper stem and tighten bolts/nuts.
8) Add lubrication as recommended by the manufacturer.

EXTENSIONS

If the break system is not located in the recommended range, an extension should be added to help assure its breakaway function. This also permits the fire department to efficiently use cap wrenches and attach hoses.

Please use original manufacturer extensions to assure proper stem assembly tolerances. Upward thrust (especially at higher pressures) can cause stem deflection. An extended hydrant with two (or more) stem couplings that are too loose or have improper pins will greatly increase the potential for stem deflection and operational failure.

LUBRICATION & OPERATING NUT

The stuffing box area - located between the stem lock nut and the machined bonnet - contains the thrust collar of the operating stem nut. Line pressure provides resistance to initial opening of the main valve - which is transmitted as upward thrust to the op nut thrust collar - forcing it up against the stem lock nut.

Teflon thrust washers have been used over the past 35 +/- years to reduce operating friction. Hydrants with full travel stiff operation are usually older hydrants lacking a thrust washer and/or weather-shield protection of the op nut. Retrofitting a thrust washer is a relatively easy and inexpensive way to greatly improve operation of older hydrants.

Access to the operating nut is achieved after removing the stem lock nut. The stem lock nut is designed with backwards threading (for open left hydrants) - which tends to tighten while absorbing the thrust of opening of the hydrant against water pressure.

Before installing the retrofit washer, clean the stuffing box area. If contacting surfaces have become excessively scored, the bronze parts may need to replaced or refaced. After installation of the washer, be sure enough tolerance exists for operation without binding. Slight machining of the stem lock nut can provide additional tolerance for installation, if required.

After reinstalling the operating nut and stem lock nut, be sure the stem lock nut is fully threaded into the bonnet and retention hardware is engaged. This will prevent the lock nut from backing out while closing the hydrant.

Other possible causes of stiff operating would relate to the remaining operational contact points. These should be limited to:

A) Damaged op nut threads
B) Stem interference through the bonnet or seal plate.
C) Drain valve components that travel within the seat ring.

Hydrant manufactures recommend lubrication of the operating nut either by grease or oil. Regardless of the type of lubricant, use of a NSF food grade lubricant is essential. (Be sure to use a food grade lubricant that *DOES NOT* contain Calcium Acetate.) The need for a food NSF grade lubricant is driven by concerns relating to possible contamination of the water system from the use of an automotive petroleum product. Lubrication access is provided by either an alemite fitting or fill plug.

NOZZLES and CAPS

There are many types of mechanical retention systems used to secure the nozzles to the hydrant upper. Current production models use stainless steel set screws, pins or wedges - in conjunction with 1/4 turn or threaded nozzles.

Caps should be checked to be sure they are not seized to the nozzles. Nozzles (and adaptors) need to be checked to be sure they are properly secured to the hydrant. Also, confirm the nozzle threads match the equipment used by the local fire department.

Removal & replacement of nozzles can be challenging on older hydrants with corrosion and/or dysfunctional retention systems. If all else fails, carefully cut into the bronze only with a saw-saw and collapse the old nozzle with a hammer. Follow the manufacturer's recommendations for nozzle replacement and retention.

O-ring seals are generally used for sealing to the nozzle section. Gaskets are used to provide a seal to the caps.

Hydrant Maintenance Report and Test Data

Hydrant No. ________ MVO ______" Mfgr. ______ Year Cast ______ Installed __/__/__

Location ____

Hose Caps	Missing	______	Replaced	______	Greased	______	Gaskets	______
Pumper Caps	Missing	______	Replaced	______	Greased	______	Gasket	______
Cap Chains	Missing	______	Replaced	______	Freed	______		
Nose Noz Threads	2 1/2" NST	______	Other	______	Recaulk	______	Replaced	______
Pump Noz Threads	4 1/2" NST	______	Other	______	Recaulk	______	Replaced	______
Operating Nut	Condition	______	Greased	______	Replaced	______	No. Turns	______
Valve & Seat	Condition	______	Replaced	______				
Stem Packing/O-Rings	Condition	______	Tightened	______	Replaced	______		
Drainage	Condition	______	Corrected	______				
Paint	Condition	______	Repainted	______				
Branch Valves	Condition	______		______				

Other Defects/Corrections ____

____

____

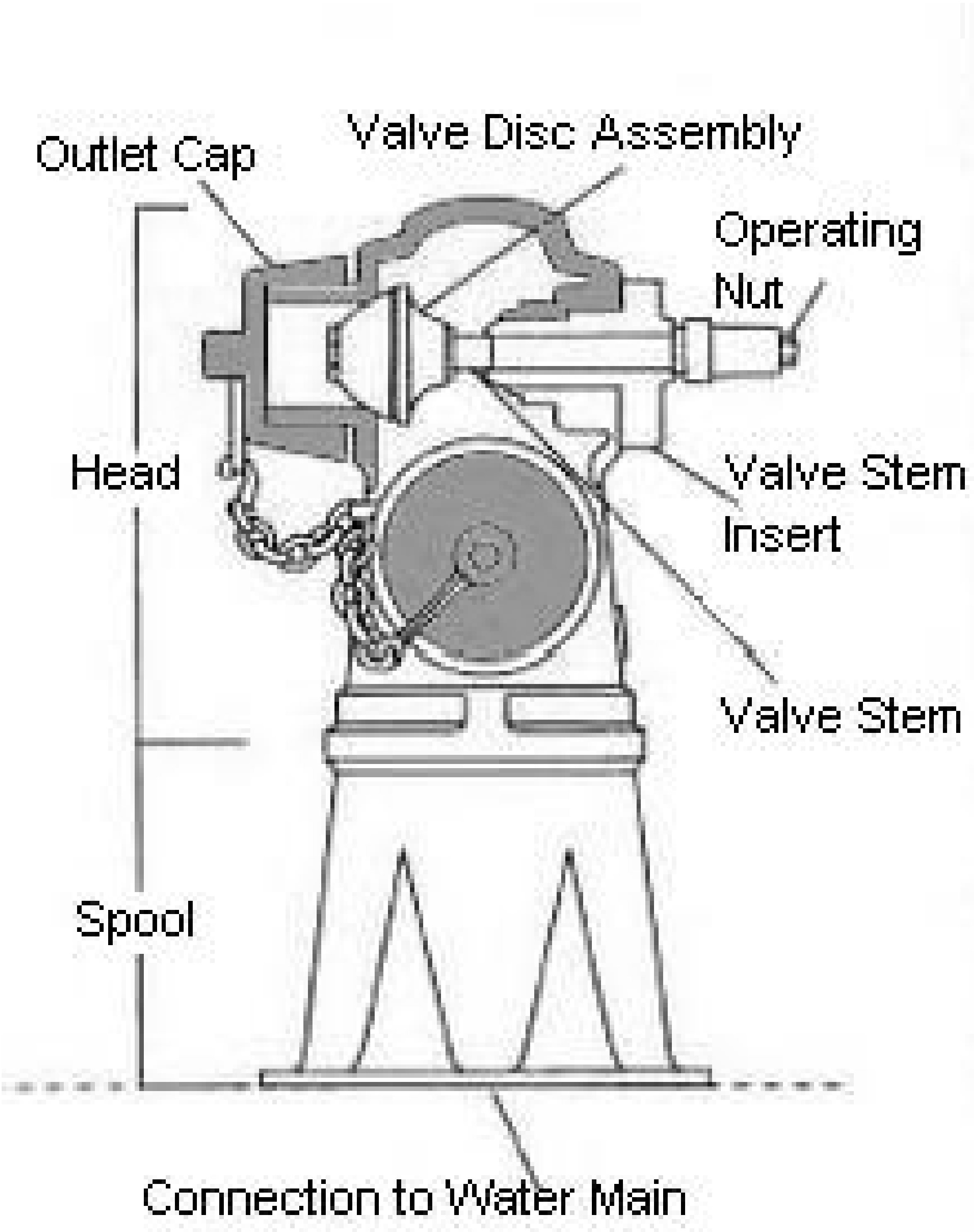
Flushed Minutes ______ Nozzle Open ____________________

Pressure Static ______ psi Residual ______ psi Flow ______ gpm Flow ______ psi

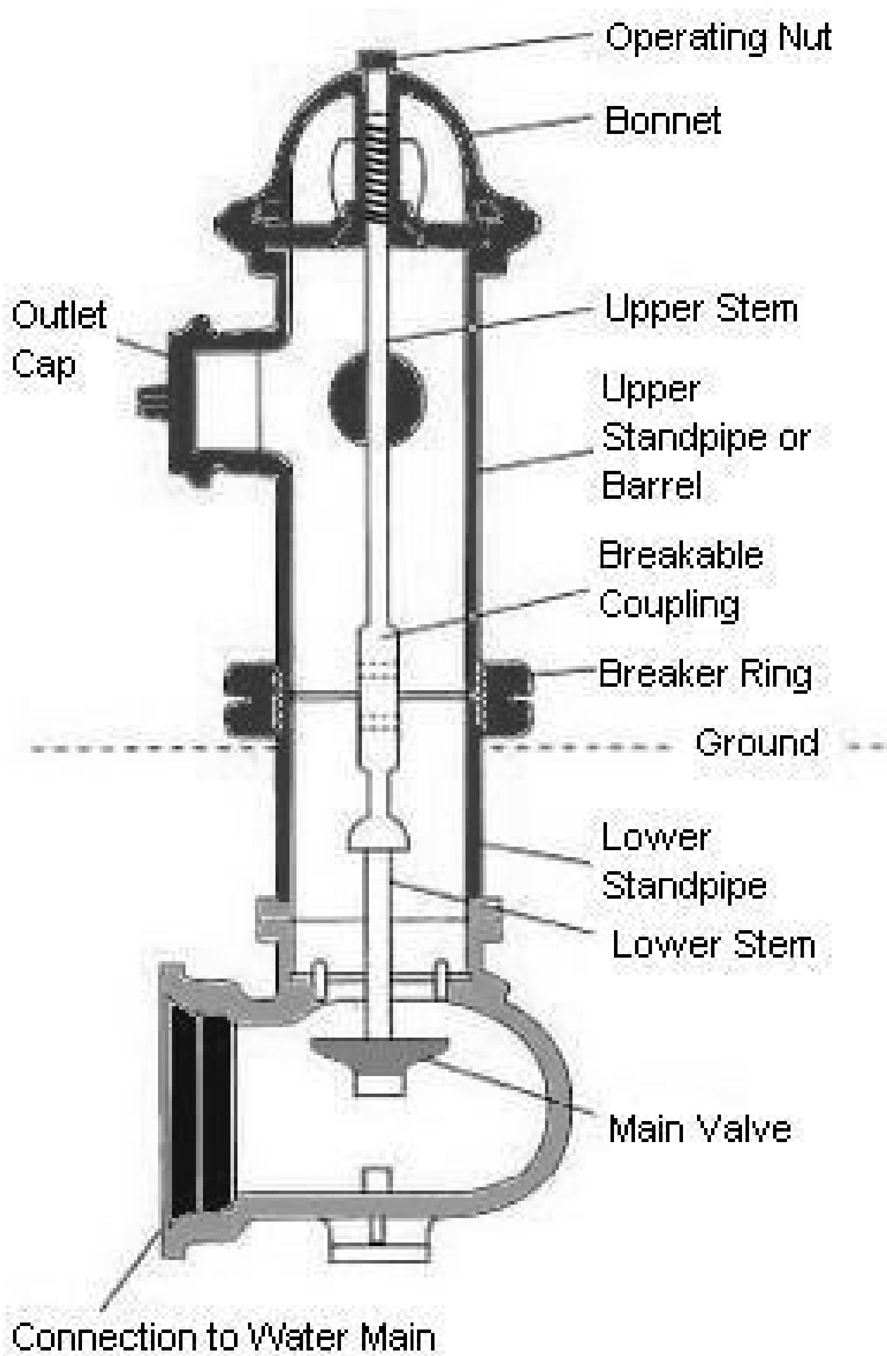
Inspected By: ____________________ Date: ____________

Corrections By: ____________________ Date: ____________

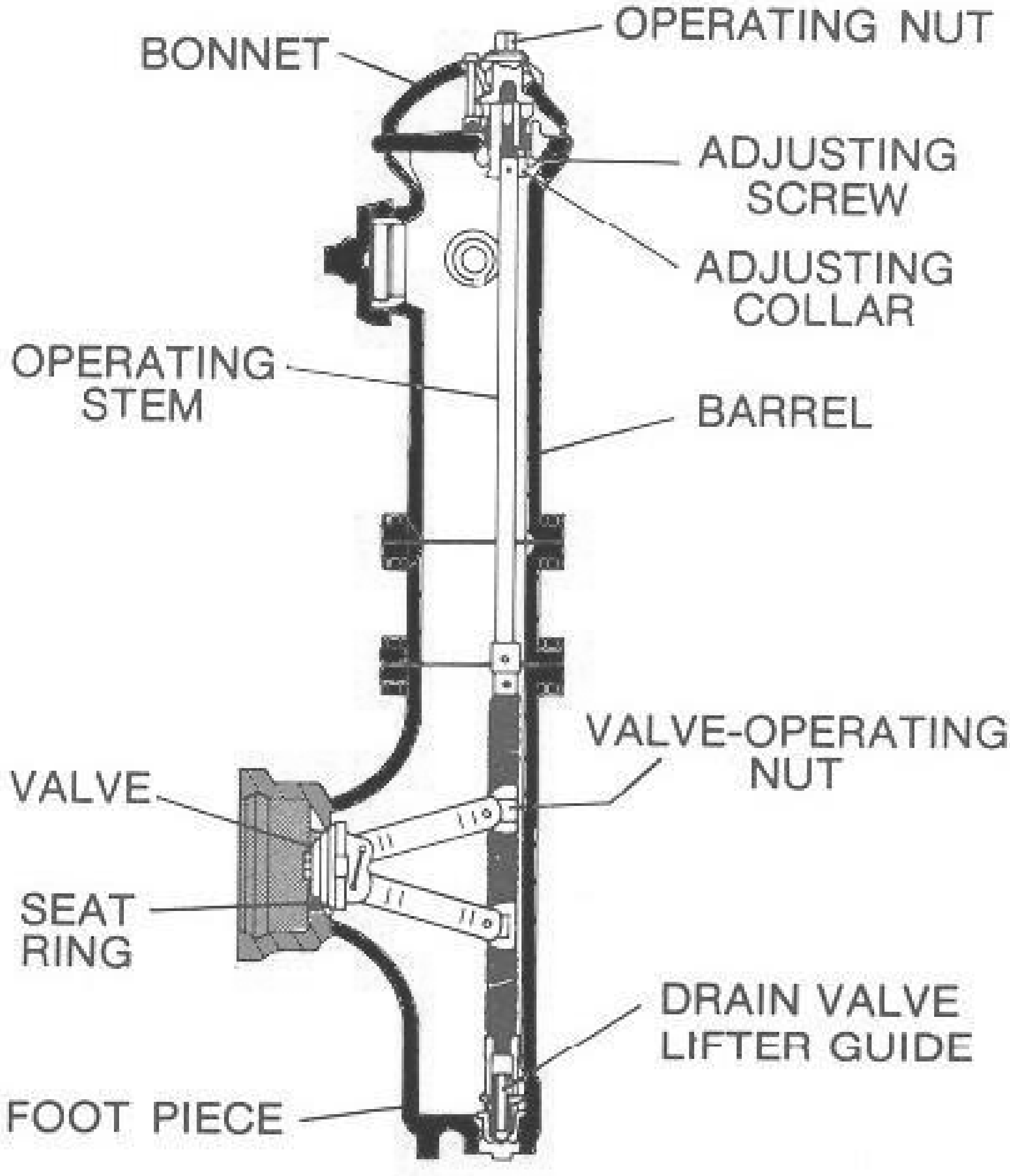
Wet Barrel Hydrant



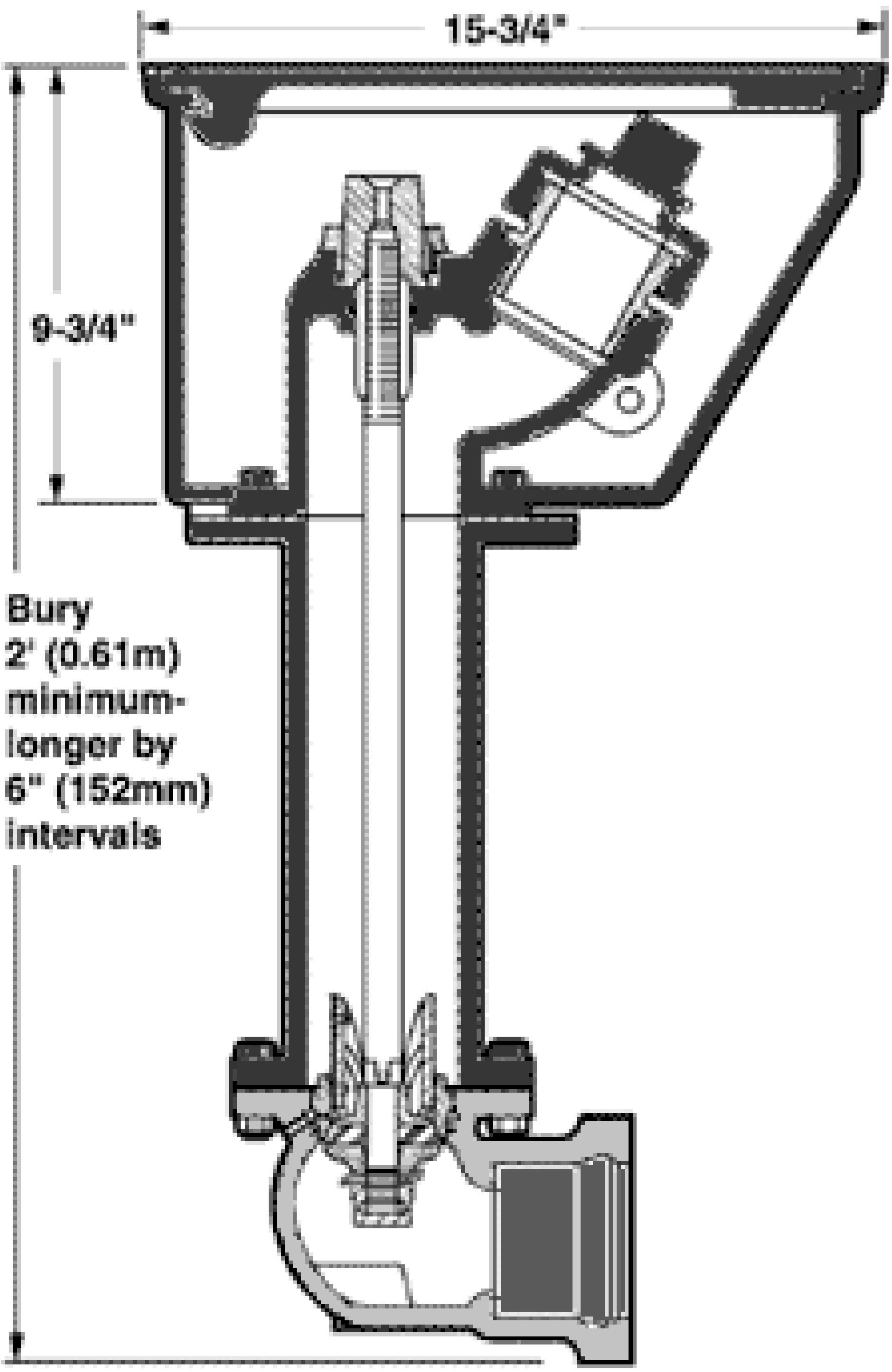
Dry Barrel Hydrant



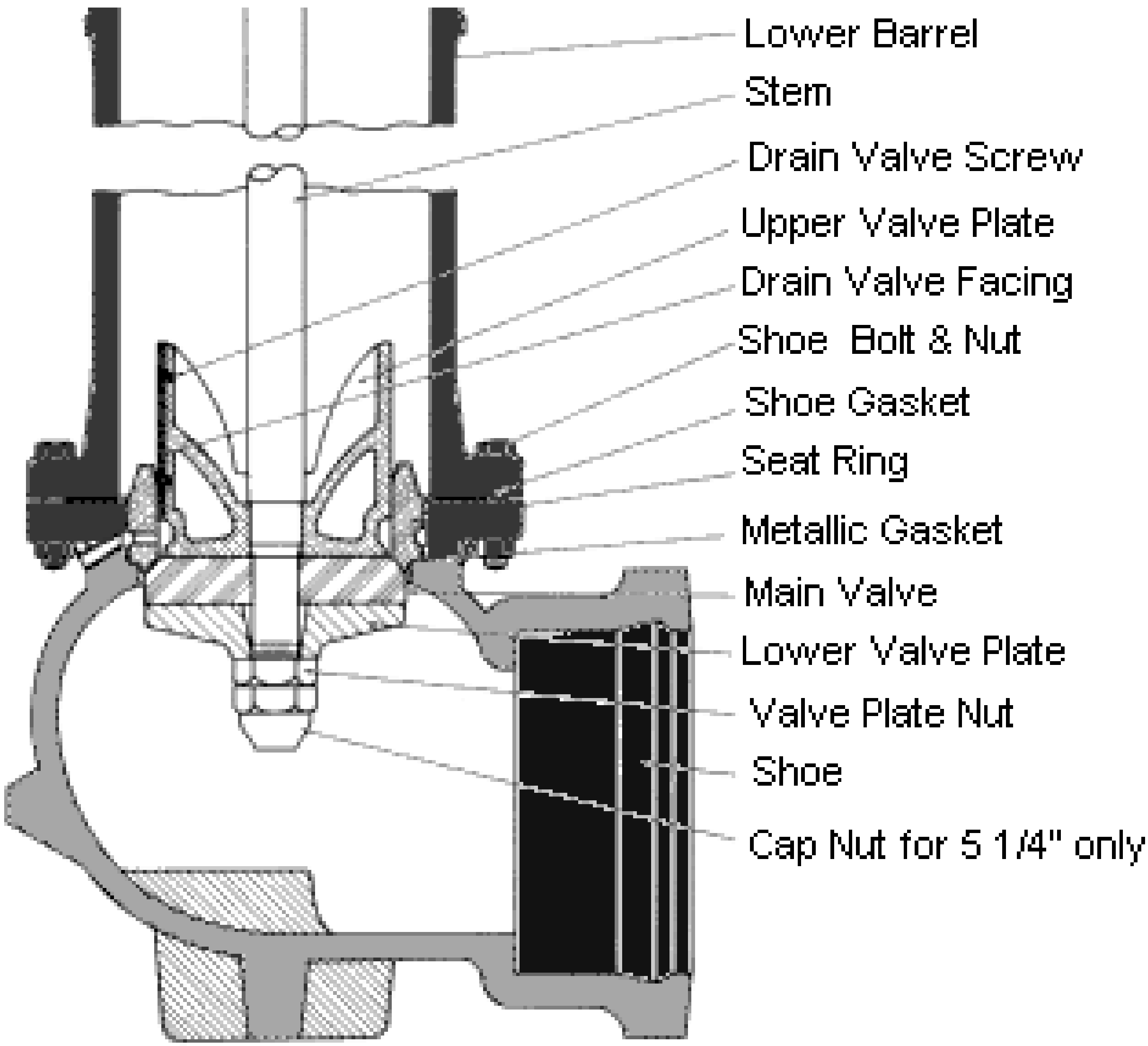
Corey Hydrant



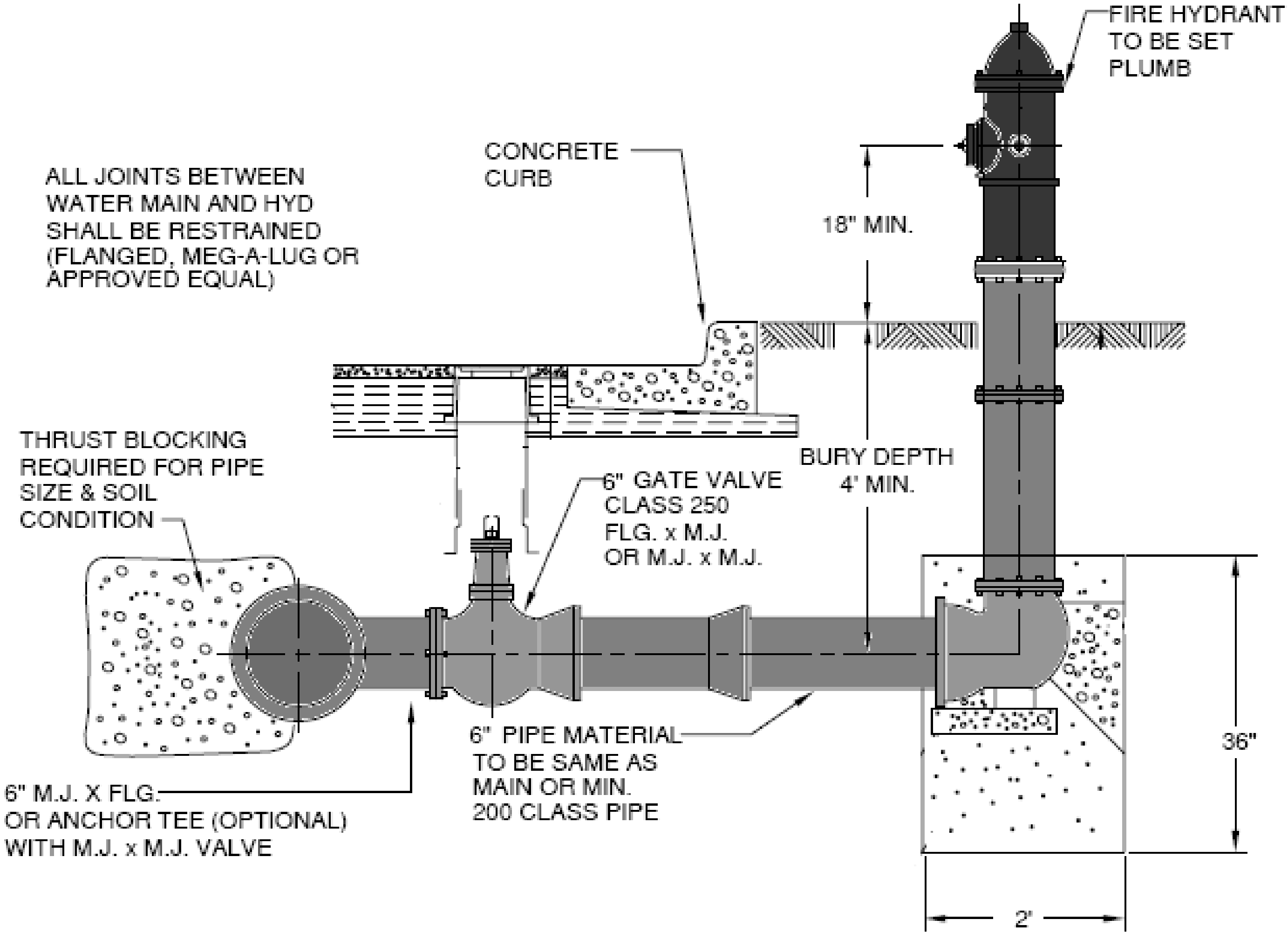
Flush Hydrant



Lower Section



Installation



Fire Hydrant Vocabulary

A. Barrel
B. Base
C. Bonnet
D. Breakaway Hydrant
E. Cap Nut
F. Corey Hydrant
G. Dry Barrel Hydrant
H. Fire Flow
I. Fire Hydrant
J. Operating Nut
K. Outlet Nozzle
L. Pitot Gauge
M. Pumper Outlet Nozzle
N. Residual Pressure
O. Water Hammer
P. Wet Barrel Hydrant

______1. A device connected to a water main and provided with the necessary valves and outlet nozzles to which a fire hose may be attached.
______2. A two-part, dry barrel post hydrant with a coupling or other device joining the upper and lower sections. The hydrant is designed to prevent water loss in the even it is struck by a vehicle.
______3. A type of dry barrel hydrant in which the main valve closes horizontally and the barrel extends well below the connection to the pipe.
______4. The body of a fire hydrant.
______5. A nut, usually pentagonal or square, rotated with a wrench to open or close a valve or fire hydrant valve.
______6. The inlet structure of a fire hydrant; it is an elbow shaped piece that is usually constructed as a gray cast-iron casting.
______7. The potentially damaging slam that occurs in a pipe when a sudden change in water velocity creates a great increase in water pressure.
______8. A hydrant with the main valve located at the base. The barrel is pressurized with water only when the main valve is open.
______9. A threaded bronze outlet on the upper section of a fire hydrant, providing a point of hookup for hose lines or suction hose from hydrant to pumper truck.
______10. A large fire hydrant outlet, usually 4.5 inches in diameter, used to supply the suction hose for fire department pumpers.
______11. The top cover or closure on the hydrant upper section, which is removable for the purpose of repairing or replacing the internal parts of the hydrant.
______12. A device for measuring the velocity of flowing water by using a velocity head of the stream as an index of velocity.
______13. A fire hydrant with no main valve. Under normal, nonemergency conditions the barrel is full and pressurized.
______14. Connects a standard-compression hydrant valve assembly to the hydrant main rod.
______15. The pressure remaining in the mains of a water distribution system when a specified rate of flow, such as needed for fire fighting purposes, is being withdrawn from the system.
______16. The rate of flow, usually measured in gallons per minute, that can be delivered from a water distribution system at a specified residual pressure for fire fighting.

Review Questions

1. List four commonly authorized uses for fire hydrants, other than for fire protection:
   - ➢
   - ➢
   - ➢
   - ➢

2. List four reasons why strict controls should be exercised over hydrant uses:
   - ➢
   - ➢
   - ➢
   - ➢

3. How can operation of a fire hydrant cause water quality problems?

4. Explain the principal difference between a dry barrel and a wet barrel hydrant.

5. In relation to the street, what direction should the pumper nozzle be pointed?

6. List two ways hydrants can be protected from damage by traffic:
   - ➢
   - ➢

7. What is the purpose of a color-coding scheme for hydrant tops or caps?

8. Why is the speed at which hydrant valves are operated important?

9. Name three preventative measures that should be taken in cold climate areas to ensure that hydrants will remain operable during the winter.
   - ➢
   - ➢
   - ➢

10. List three items of information about the distribution system that can be obtained from hydrant flow test.
    - ➢
    - ➢
    - ➢

11. List seven items of information that should be included on a hydrant record form:
    - ➢
    - ➢
    - ➢
    - ➢
    - ➢
    - ➢
    - ➢

12. Name five safety precautions that should be taken during hydrant flushing and testing to prevent injury to personnel and the public and to minimize damage to property.
    - ➢
    - ➢
    - ➢
    - ➢
    - ➢

Answers

Vocabulary

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

Review Questions

1. flushing water mains, flushing sewers, filling tank trucks, providing temporary water source for construction work
2. **(I)** To limit the amount of water that is wasted or not paid for
   (II) To keep a close control on unmetered water to limit the amount of unaccounted-for water
   (III) To minimize damage to hydrants caused by improper operation, such as incomplete valve closing or use of an improper wrench
   (IV) To reduce the possibility of distribution system demand due to such improper hydrant operation as closing a hydrant too quickly and causing water hammer
3. Increased flow in the main can stir up sediment, causing discolored or cloudy water.
4. The dry barrel hydrant has its main valve in the base. The barrel is dry until the valve is opened. When the main valve is closed, the barrel drains to prevent freezing.
   The wet barrel hydrant has no main valve in the hydrant (although there is usually an auxiliary valve). Each outlet nozzle has an independent valve that controls its discharge. The barrel is full of water under pressure at all times when the hydrant is in service.
5. The pumper nozzle should always be pointed toward the street so that the fire department can use a hard suction hose connected to the pumper truck.
6. Set hydrants back from the edge of the pavement and install hydrant guard posts.
7. A color-coding scheme is commonly used to indicate the hydrant flow capacity or the size of the water main. It is not used to indicate main pressure.
8. Hydrants should be opened and closed slowly in order to prevent pressure surges (water hammer) in the mains.
9. (I) Inspect hydrants in the fall to make sure their barrels are drained.
   (II) Inspect hydrants after each use in freezing weather, and pump out the barrel of any hydrant that does not drain properly.
   (III) If any hydrants are found to be inoperable, mark them by putting something over them, and notify the fire department of the locations.
10. (I) The need for additional feeder or looping mains
    (II) The need to clean existing pipes
    (III) Identify system valves that have been inadvertently left closed

11. name of the manufacturer; type or model; date installed; location (street address, plus distance ties to several permanent markers); buried depth; outlet-nozzle sizes and thread types; inlet pipe size
12. (I) Take care that the water force does not injure workers or pedestrians.
    (II) Consider possible traffic hazards.
    (III) Take special precautions if the water may freeze.
    (IV) If flow is diverted with a hose to a sewer, take care not to create a cross-connection.
    (V) If flow is diverted with a hose, the end of the hose must be securely anchored.

Water Main Flushing Program

Fleming Training Center

Flushing Program

- Why do we do this?
  - Important preventative maintenance
    - Removes particulate matter and corrosion from lines
  - Improve water quality
    - Low chlorine residual
    - Brown water
    - Positive bacterial counts
    - Poor taste
    - Bad odor
  - Customer complaints
    - Taste and odor problems
    - Turbid or colored water
    - Reduced pressure
  - Basically it improves overall water quality

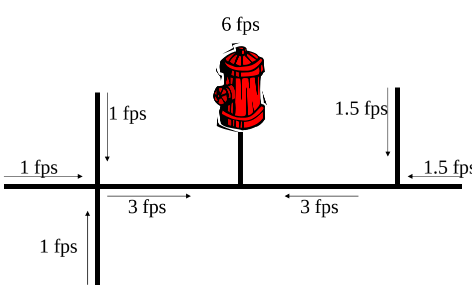
Flushing Programs

- How frequently should you flush?
  - Surface waters systems are usually going to flush more often due to increased nutrients in the water
  - Water quality indicators can be used to increase flushing:
    - Temperature, increase
    - Chlorine residual, decrease
    - Corrosion inhibitor, decrease
    - pH, decrease
    - Taste and odor, increase in complaints

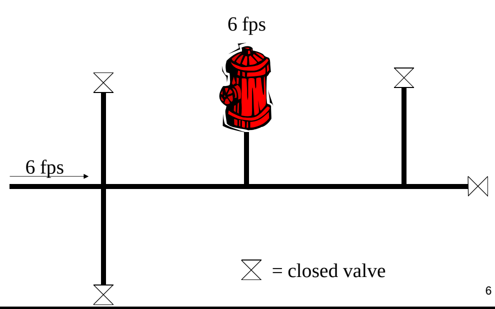
Flushing Program

- 2 types:
  - Unidirectional
    - water system valves are operated to create a one-way flow of the water, this increases the speed and scours the lines removing biofilm and corrosion
  - Conventional
    - the water used to flush the main does not always begin at a clean water source and the speed is low therefore more water is needed to clean mains

Conventional Flushing



Unidirectional Flushing



Unidirectional Flushing

- Needs some engineering
- You control
  - flow
  - direction
    - where the water is coming from and where it is going
- You have to know your system
  - know location of all mains, valves and hydrants

Unidirectional Flushing

- Pros
  - uses 40% less water than conventional flushing
  - scours and cleans pipes up to 2 years
  - more localized
  - tests most valves and hydrants
    - identifies those that need repair or replacement

Unidirectional Flushing

- Requirements:
  - Distribution maps and plans
  - chart flow directions
  - examine depletion and replenishment patterns of storage tanks
  - review components
    - tanks, hydrants, blow off valves, pipe material and pump stations

Unidirectional Flushing

- Divide into sections (manageable loops) that will be flushed in sequence
  - flushing runs
  - set target for flushing velocities 2-5 fps
    - remove biofilm
    - don't stress weak areas
- Develop step-by-step flushing sequence
  - which hydrant or blow off valve to open and which valve to open or close

Unidirectional Flushing

- Start from beginning - treatment plant or storage tank
- Isolate pipes you want to flush - close valves
- Flush from clean to dirty pipes
- Force water from bigger main to smaller main
- Sample water before, during and after

Unidirectional Flushing

- Safety
  - use a diffuser to decrease water velocity
  - dechlorinate if chance of getting into surface water
  - open valves and close them slowly so you don't create water hammer
  - wear appropriate clothing so people will see you
  - watch traffic
  - be careful when flushing hydrant, you don't know what could come out of it

Unidirectional Flushing

- Restored disinfectant residual
- Reduces disinfectant demand
- Reduces bacterial growth
- Dislodges biofilms
- Removes sediments and deposits
- Restores flows and pressures
- Eliminates taste and odor problems

13

TDEC - Fleming Training Center

Documentation

- You should document each time you flush a line
  - location
  - beginning of flush
    - color of water
    - residual chlorine
  - end of flush
    - color of water
    - residual chlorine
  - time flushed
  - rate of flow

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TDEC - Fleming Training Center

Notify Customers

- You should notify your customers that you will be flushing lines in their area
  - bill stuffers
  - media - news papers, new stations
- They should be told that their water may be discolored but to let their cold water run until water is clear
  - they shouldn't use colored water for laundry, cooking or drinking
  - don't use hot water to flush lines, they could end up with colored water getting into their water heaters

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Flushing Program Record

Date	Time	Location or Address	Type of Valve or Hydrant	Time to Clear	Total Time	Flow (gpm)	Free Chlorine Residual	Persons Responsible

Section 9

Corrosion

Stabilization

Corrosion and Scaling Control in the Distribution System

Stabilization

- The process for controlling corrosion and scale deposits on pipelines and plumbing fixtures.
- Corrosion and scale deposits in the distribution system can be very costly for utility.
- Problems range from excessive customer complaints to increased pumping costs, to replacement of mains due to leaks and breaks.
- Corrosion control is also important in protecting consumers from the dangers of excess lead and copper.

Purpose of Stabilization

1 **To protect public health**
  - Corrosive water can leach toxic metals from distribution piping and household plumbing - lead and copper
  - Corrosion of cast-iron mains causes tubercules (iron deposits) that can protect bacteria from chlorine, allowing them to grow and thrive

Purpose of Stabilization

2 **To improve water quality**
  - Corrosive water attacking metal pipes can cause color, taste & odor problems
  - red-water from cast-iron mains
    - the iron will stain a customer's plumbing fixtures and laundry and make the water's appearance unappealing for drinking and bathing
  - corrosion of copper pipes can cause metallic taste and blue-green stains on plumbing fixtures and laundry

Purpose of Stabilization

3 **To extend life of plumbing equipment**
  - Aggressive water reduces life of valves, unprotected metal, asbestos-cement pipe, plumbing fixtures, water heaters
  - Buildup of scale and corrosion products reduces capacity of pipes, which reduces distribution system efficiency and increases pumping costs
  - If scale deposits go unchecked, pipes can become completely plugged

Purpose of Stabilization

4 **To meet federal and state regulations**
  - Lead and Copper Rule - 1991
  - Systems must check if their water is corrosive enough to cause lead and copper to be present
  - Samples taken at high-risk locations; homes with lead pipes, service lines or lead solder

Lead and Copper Rule

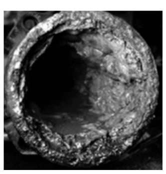
- Samples are to be collected after water has sat in lines for at least 6 hours - first draw
- 1 liter taken from cold water tap in kitchen or bathroom
- Action level for lead is 0.015 mg/L, copper is 1.3 mg/L
- If a system exceeds action level in more than 10% of samples, must take steps to control corrosion

Corrosion

Definition of Corrosion
Factors Affecting Corrosion
Types of Corrosion

Water System Corrosion

- Corrosion - the gradual deterioration or destruction of a substance or material by chemical reaction with the water
- Water that promotes corrosion is called corrosive or aggressive water




Corrosive Water

- Dissolved Oxygen
  - as dissolved oxygen increases, rate of corrosion increases
- Total Dissolved Solids
  - increase electrical conductivity of water
- Alkalinity
  - buffers a change in pH, decreases corrosion
- pH
  - low pH promotes corrosion, high pH can be scale-forming

Corrosive Water

- Hardness
  - a small amount can form protective layer of scale on pipes to prevent corrosion
- Temperature
  - corrosion occurs faster in warmer waters
- Flow Velocity
  - increased velocity can increase rate of corrosion if water is corrosive
  - increased velocity can decrease rate of corrosion if adding corrosion inhibitor

Corrosive Water

- Type of metals
  - galvanic corrosion is corrosion of dissimilar metals
- Electrical Current
  - improperly grounded household electrical systems can accelerate corrosion
  - electric railway systems can be a cause of this also
- Sulfate Reducing Bacteria
  - H_2S gas released - causes rotten egg odor
  - can react with water to form H_2SO_4, which is highly corrosive
  - Produce black sulfide deposits

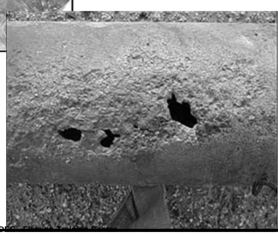
Corrosive Water

- Iron Bacteria
  - Convert dissolved iron into precipitate causing red-water complaints
  - Produce slime which protects against chlorine and prevents accumulation of $CaCO_3$
  - Bacteria can slough off causing tastes & and odors
  - Bacteria can change pH and alkalinity of water as they give off gases, mainly CO_2

Types of Corrosion

- Localized
  - Most common, most serious
  - Attacks surface unevenly, leads to rapid failure of metal
  - two types
    - galvanic corrosion - caused by the connection of dissimilar metals in an electrolyte such as water
    - concentration cell corrosion - forms deep pits or turbercules
- Uniform
  - Occurs evenly over all surface
  - Due to low pH and alkalinity

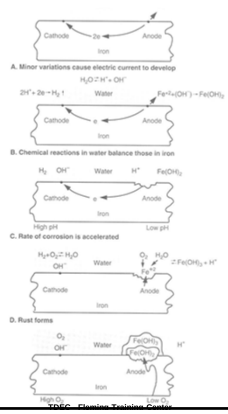
Localized Corrosion



Localized Corrosion

Sink hole caused by 8-in main break

Galvanic Corrosion



Galvanic Corrosion

Corroded End (anode)	Most Active
Magnesium	+
Magnesium alloys	
Zinc	
Aluminum	
Mild Steel	
Wrought (black) Iron	
Cast Iron	Corrosion Potential
Lead-tin Solders	
Lead	
Tin	
Brass	
Copper	
Stainless Steel	-
Protected End (cathode)	**Least Active**

Scale Formation

Definition of Scale Formation
Factors Affecting Scale Formation
Types of Scale Formation

Scale Formation

- Scale formation - the precipitation of certain hardness-causing ions with other minerals to form a coating on pipe walls
- The formation of a small amount of scale can help protect the pipe from corrosion
- Uncontrolled deposits reduce the carrying capacity of the pipe
- Can also decrease the efficiency of boilers, water heaters, etc

Scale-forming Compounds

- $CaCO_3$ – Calcium carbonate
- $MgCO_3$ – Magnesium carbonate
- $CaSO_4$ – Calcium sulfate
- $MgCl_2$ – Magnesium chloride

Scale Formation

- Saturation point - the point at which a solution can no longer dissolve any more of a particular chemical; precipitation of the chemical will occur past this point
- Solubility varies with temp, pH, TDS, etc
- Solubility of $CaCO_3$ in water decreases as temperature increases; the higher temperature in water heaters causes $CaCO_3$ to precipitate out and build up on pipe, tank walls and heating element

Control Methods

1. pH and alkalinity adjustment
2. Formation of $CaCO_3$ coating
3. Use of corrosion inhibitors and sequestering agents

pH and Alkalinity Adjustment

- Soft waters with pH less than 7 and poorly buffered (low alkalinity) will be corrosive to lead and copper
- Water with too much alkalinity can also be corrosive
- A moderate increase in pH and alkalinity can reduce corrosion
- A moderate decrease in pH and alkalinity can prevent scale formation

Stability Scale

Corrosive Water ← Stable water → Scale-Forming

Water is considered stable when it is just saturated with calcium carbonate. It will neither deposit nor dissolve calcium carbonate.

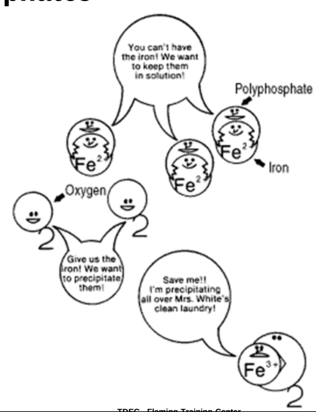
Use of Coatings

- **A protective coating on pipe surfaces can inhibit corrosion.**
  - **Lime, alone or in combo with soda ash or sodium bicarb, can be added to precipitate a $CaCO_3$ scale on the pipe walls**
  - **A coating of cement, epoxy, etc. can be applied to interior pipe surfaces.**
  - **Phosphates and sodium silicate can be used for corrosion control and stabilization.**

Polyphoshates

- **Polyphoshates work as sequestering agents - tie up iron and manganese to prevent color and taste complaints**
  - **They also tie up calcium carbonate to prevent excess scale**
  - **Calcium (from alkalinity) is required as a catalyst**
  - **If low alkalinity, need a blend of polyphosphate and orthophosphate**
  - **Orthophosphate coats pipe, polyphosphate sequesters**
- **Orthophosphates work well for lead and copper protection**

Phosphates



Coupon Testing

- **Measures the effects of the water on a small section of metal (the coupon) inserted in a water line.**
- **After a minimum of 120 days, the inserts are removed, cleaned, weighed and examined.**
- **The weight loss or gain of the coupon can provide an indication of the corrosion or scaling rate.**

Best Stabilization Treatment

- **In the distribution system:**
  - **Evaluate effects of corrosion and scaling**
  - **Records of main breaks and leaks - corrosion**
  - **Info on how well older valves operate - if difficult to operate, may be coated with scale**
  - **Info on reduced flow rates in mains - buildup of scale**
  - **When possible, pieces or sections of pipe removed should be tagged and evaluated.**

Best Stabilization Treatment

- In customers' plumbing:
  - Customer complaints
    - Red water, brown water, loss of pressure
    - Location where problems occur
    - Time of year
- For meeting regulation requirements:
  - Lead and Copper Rule
    - Must take steps to reduce corrosion if action levels are exceeded

Best Stabilization Treatment

- Water quality data:
  - Determine if there is an increase in metals in distribution system (copper, zinc, cadmium)
  - Before initiating a corrosion control program, check with others in the field who can give sound advice.
  - Using the wrong stabilization method can increase problems.

Operational Controls

- Water quality analyses
  - Lab data for calculating Langelier Index
- In-plant monitoring
  - Continuously recording pH meter
- Distribution system monitoring
  - Check for presence of metals indicating corrosion
- Pipe and coupon testing
  - Small section of metal is placed in a pipe, checked for corrosion or scaling

Records

- Amount of chemicals used - state report
- Lab test, Langelier Index calculations
- Maintenance records
- Results of coupon tests, other tests
- Customer complaints related to corrosion or scaling

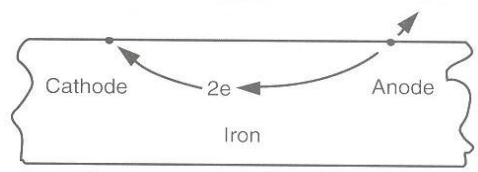
Corrosion Vocabulary

A. Aggressive
B. Anode
C. Cathode
D. Concentration Cell Corrosion
E. Corrosion
F. Corrosive
G. Coupon Test
H. Galvanic Corrosion
I. Galvanic Series
J. Iron Bacteria
K. Langlier Index
L. Localized Corrosion
M. Milk of Lime
N. Red Water
O. Saturation Point
P. Sequestering Agent
Q. Slaker
R. Stabilization
S. Tubercules
T. Uniform Corrosion
U. Unstable

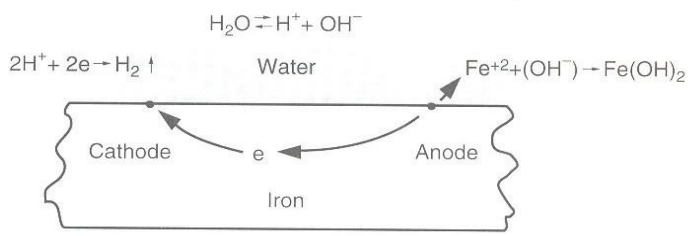
_______ 1. A chemical compound such as EDTA or certain polymers chemically tie up other compounds or ions so they can't be involved in chemical reactions.
_______2. To deteriorate material, such as pipe, through electrochemical processes.
_______3. Bacteria that use dissolved iron as an energy source.
_______4. The lime slurry formed when water is mixed with calcium hydroxide.
_______5. Knobs of rust formed on the interior of cast iron pipes due to corrosion.
_______6. Corrosive.
_______7. A term used to describe rust-colored water due to the formation of ferric hydroxide from iron naturally dissolved in the water or as a result of the action of iron bacteria.
_______8. A listing of metals and alloys according to their corrosion potential.
_______9. To be corrosive or scale-forming.
_______10. Positive end (pole) of an electrolytic system.
_______11. The point at which a solution can dissolve no more of a particular material.
_______12. A numerical index that indicates whether calcium carbonate will be deposited or dissolved in a distribution system.
_______13. The water treatment process intended to reduce the corrosive or scale-forming tendencies of water.
_______14. Negative end (pole) of an electrolytic system.
_______15. A form of localized corrosion that can form deep pits or tubercules.
_______16. A form of corrosion that attacks a small area.
_______17. The part of the quicklime feeder that mixes the quicklime with water to form hydrated lime.
_______18. A form of localized corrosion caused by the connection of dissimilar metals in an electrolyte such as water.
_______19. The gradual deterioration or destruction of a substance or material by chemical reaction. The action proceeds inward from the surface.
_______20. A form of corrosion that attacks material at the same rate over the entire area of its surface.
_______21. A method of determining the rate of corrosion or scale formation by placing metal strips of a known weight in the pipe.

Answers to Corrosion Vocabulary

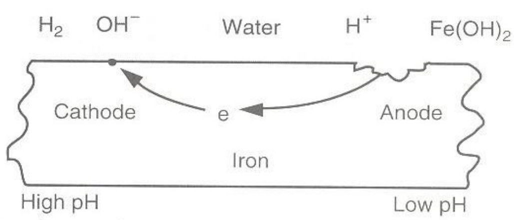
1. P
2. F
3. J
4. M
5. S
6. A
7. N
8. I
9. U
10. B
11. O
12. K
13. R
14. C
15. D
16. L
17. Q
18. H
19. E
20. T
21. G



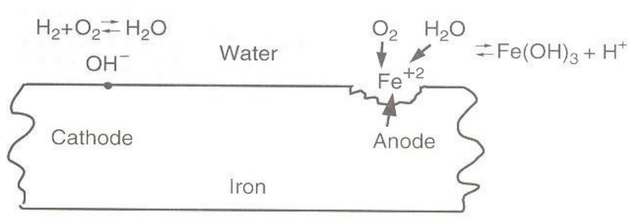
A. Minor variations cause electric current to develop



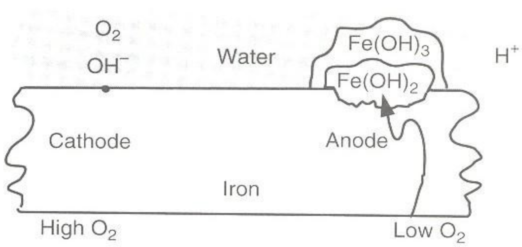
B. Chemical reactions in water balance those in iron



C. Rate of corrosion is accelerated



D. Rust forms



Section 10

Water Meters

Water Services

Water Service Lines

Water service lines are the pipes that lead from a connection on a water main to a connection on a customer's plumbing.

Service Line Sizes

- Depends on:
  - Maximum water demand
  - Main pressure under peak demand conditions
  - Elevation difference between main and the highest portion of the building to be served
  - Distance from main to building plumbing

Service Line Sizes

- Single family residences usually have ¾-inch service line
- Other customers have service line sized for max demand

Types of Service Line Pipe

- Lead pipe
- Galvanized iron pipe
- Copper tubing
- Plastic tubing

Lead Pipe

- Most older systems still have some lead service connections in use
  - Usually replaced, not repaired
  - The principal reason for such a policy is that evidence points to health risks due to lead leached from plumbing materials

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Reduction of Lead in Drinking Water Act of 2011

- Reduced "lead free" from less than 8% content to no more than 0.25% allowed
- Will be effective on January 4, 2014
- Basically, any pipe, plumbing fixture, backflow device, etc. installed as new or replaced during repair must be manufactured and certified to this new lead free standard

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Galvanized Iron

- Connected with gooseneck for flexibility
- Subject to galvanic corrosion, corrosion from soil
  - especially at a pipe connected with brass fittings
- Usually replaced rather than repaired

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Copper Tubing

- Popular replacement for lead and galvanized iron because:
  - It is flexible
  - Easy to install
  - Corrosion resistance in most soils
  - Able to withstand high pressure
- Aggressive water may dissolve copper, to cause green stains on plumbing fixtures

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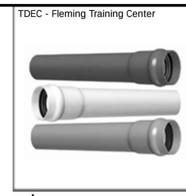
Plastic Tubing



- Three generally used for water services
  - PVC (polyvinyl chloride)
  - PE (polyethylene)
  - PB (polybutylene)
- Low friction, lightweight, corrosion resistant
- Permeable by gasoline, solvents, etc.
- Cannot be located by electronic pipe finder
- Must have NSF approval seal

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Adapters and Connectors

Flare fittings

Compression fittings

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Corporation Stops

- Valve used to connect a small-diameter service line to a water main
- Also known as
  - Corporation cock
  - Corporation tap
  - Corp stop
  - Corporation
  - Corp
  - Stop
- Available with a ball valve or plug valve

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Curb Stops and Boxes

- Curb stop
  - shutoff valve to meter
- Curb box
  - pipe extending from curb stop to surface
  - allows access to curb stop with a key
- Plug or ball valve

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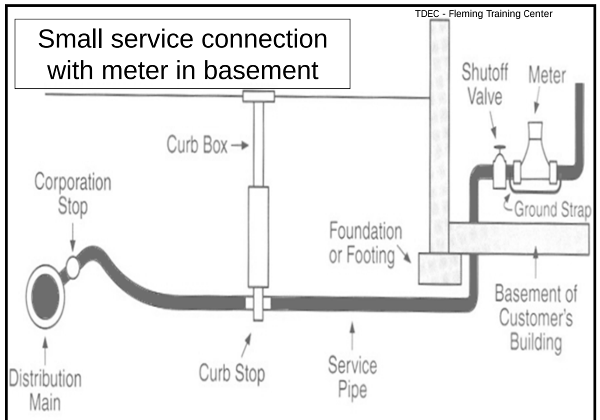
Small service connection with meter in basement



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Water Service Taps

- Dry taps
  - Made during installation of new main
  - Main is empty
- Wet taps
  - Addition to an in-service main
  - Connection made without shutting off water
  - No contamination of line

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Direct Tapping

- Corporation stop is directly screwed into a threaded hole in pipe wall
- For PVC and A-C, carefully follow manufacturer's instructions
- Tapping machine drills, taps (threads), and inserts the corporation stop

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Direct Tapping Process

- Pipe excavated and cleaned, machine clamped into place
- Machine bores hole in pipe wall, tap cuts threads
- Boring bar retracted, flapper valve closes to contain pressurized water

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Direct Tapping Process

- Drill-and-tap tool removed, corporation stop threaded into hole in closed position
- Bar is reinserted into the machine and the corporation stop is screwed into the threaded hole
- Machine is removed; corporation stop is ready for attachment of service line

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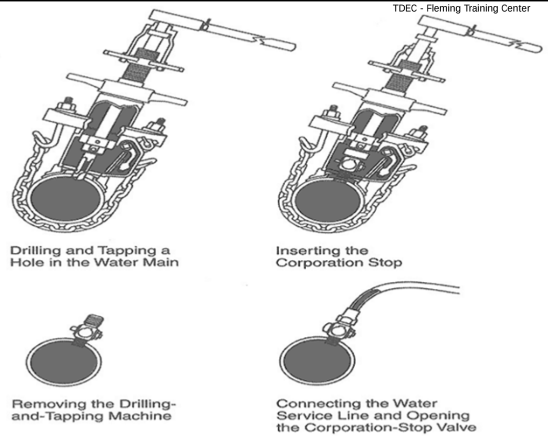

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Service Clamps

- Also known as service saddles
- For taps larger than 1 inch on PVC or A-C, a service clamp should be used instead of a direct tap
- Eliminates chance of pipe splitting

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Tap Location

- 45° angle down from top of main
  - A tap directly on top is more liable to draw air in the service
  - A tap near the bottom could draw in sediment
- On same side of main as building

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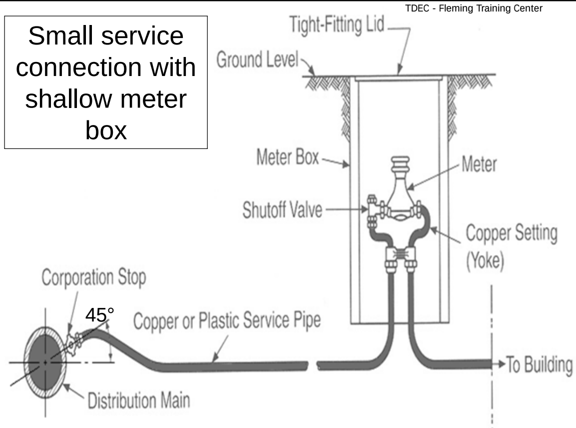
Small service connection with shallow meter box



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Leaks and Breaks

- Lead and galvanized iron pipe likely to leak if disturbed
- Copper and plastic more durable
  - Can break during excavation or settling

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Thawing

- Prevent freezing by burying below frost line
- Metallic pipe can be thawed by electric current
  - By experienced operator
- Hot water can be used for any pipe
- Hair dryer or heat gun will thaw meter or service line in meter box

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Service Line Records

- File by address - card or computer
  - Exact location of tap
  - Type & size of pipe & tap
  - Bury depth
  - Location of curb stop or meter box
  - Location of pipe entry to building
  - Date of installation

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- Good records on plastic pipe are especially important because they cannot be located by electronic equipment

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Water Meters

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Water Meters

- Measure and record the amount of water passing through
- Primary functions are
  - To help water utility account for water pumped to system
  - Charge customers for the water they use

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How do we measure water?

- By volume
  - Filling and emptying a calibrated space
  - Positive displacement meters
    - 2" and smaller meters only
- By velocity
  - Measuring the speed water moves
  - All sizes, residential and commercial

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A Little History

- Modern water measurement did not begin until the late 18th century
- The first practical meter was invented by Reinhold Woltman in 1790

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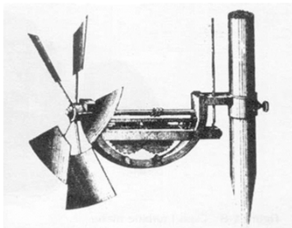

In this form, the Woltman meter could measure flows only in an open stream. The revolutions of the waterwheel were transmitted to a register by a gear train. For a stream of known cross section, the register could be calibrated to give accurate measurements of flow.

Figure 1-7 Original form of the Woltman meter

A Little History

- The Woltman meter could only measure water in an open channel
- It was 1850 before a meter was developed that could be used in a closed pipe
- Class I turbines, developed in the late 1800s are modified Woltman meters that allow a top mounted register by using a vertical axis measuring element

Meter Purpose

- Every water service should have a meter on it
  - Payment purposes
  - Account for water pumped to distribution
  - Help locate water leaks

Incorrect metering accounts for the second greatest loss of water to a utility

AWWA Standards

- C700 - Displacement Meters
- C701 - Turbine Meters
- C702 - Compound Meters
- C703 - Fireline Meters
- C708 - Multi-Jet Meters

Positive-Displacement Meters

- Most commonly used meter for residences and small commercial
- Reliable and accurate for low flow rates
- Measure exact quantity of water passing through it

Positive-Displacement Meters

- Positive displacement meters use a calibrated space that is filled and emptied to measure water
  - Measuring cup
- There are 2 types of positive displacement meters
  - Nutating Disc
  - Oscillating Piston

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Positive-Displacement Meters

- Piston meter - volume of water is measured as water moves the piston
- Nutating disk - sweeps out specific volume for each rotation (wobble)

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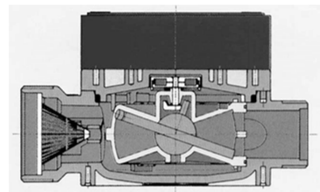
Nutating Disc

- Nutation - n(y)Ü-`tā-shen: Oscillatory movement of a rotating object: wobble



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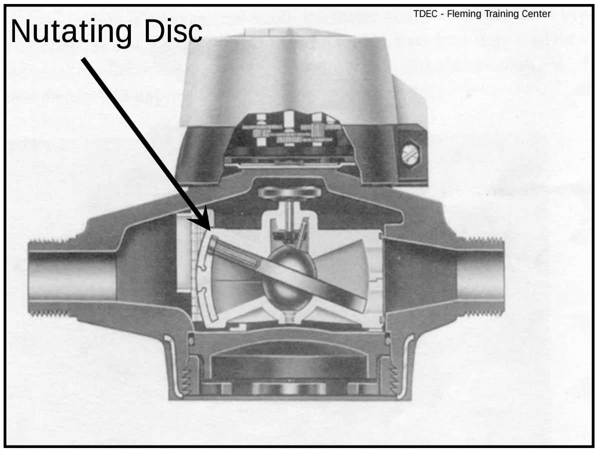
Nutating Disc



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How does it work?

- As water moves into the inlet, it forces the disc to wobble on its axis
- The calibrated space fills and empties with each nutation

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Positive-Displacement Meters

- Advantages
  - Accurate over wide range of flows
  - Easy to repair or replace due to availability
- Disadvantages
  - High head loss at high flow rates
  - Under register when worn; max usage should be half of capacity

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Large Water Meters

- Customers that use large quantities of water
  - Transfer or Utility purchases
  - Industries
    - Great deal of cleaning
    - Incorporate water into manufactured products
  - Businesses
    - Hospitals
    - Large public buildings
    - Apartments
  - Irrigation at golf courses

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Large Water Meters

- Large meters fall into several types
  - Positive Displacement (1-1/2 and 2” only)
  - Multijet (1-1/2 and 2” only)
  - Compound and Fireline Compound (2” - 10”)
  - Turbine (2” - 16”)
  - Propeller (4” - 72”)
  - Magnetic Flow Meters (1/8” - 42”)
  - Ultrasonic Meters (Doppler)

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Compound Meters

- For customers with wide variations in water use
- Turbine meter and a positive-displacement meter in one
- Automatic valve controls water flow through meter
  - High flows go through the turbine side with little restriction
  - Under low flows, the valve shuts and directs water through a small displacement meter
- High maintenance requirement, expensive

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Compound Meters

- As name denotes
  - 2-measuring chambers housed in a single meter body or assembly
- One chamber captures low flows
- One chamber captures high flow

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AWWA Compound Meter Flow Ranges

- 2” - 1/4 gpm to 160 gpm
- 3” - 1/2 gpm to 320 gpm
- 4” - 3/4 gpm to 500 gpm
- 6” - 1-1/2 gpm to 1000 gpm
- 8” - 2 gpm to 1600 gpm

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Where are Compound Meters Used?

For Low to High Continuous Flow Rates

- Apartment Buildings
- Motels
- Hotels
- Condominiums
- Mobile Home Parks
- Hospitals
- Schools
- Restaurants
- Dormitories
- Department Stores
- Shopping Malls
- Public Transportation Centers

Where people live and work!!

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Current Meters

- Also called velocity meters
  - Turbine, multijet, propeller meters
  - Measure velocity of flow past a cross-section of known area
  - Low head loss
  - Inaccurate at low flow rates

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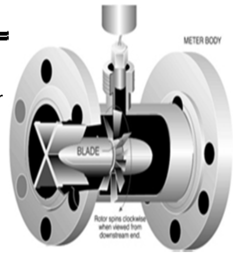
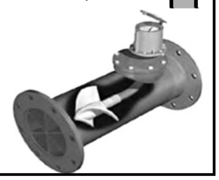
Turbine Meter



Propeller Meter

Venturi Meter



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Multijet Meters

- Multijet meters measure the speed of water passing through the calibrated measuring chamber
  - Velocity Meter

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Multijet Meters

- Multijet meters measure the speed of water passing through the calibrated measuring chamber
  - Velocity Meter
- Multijet meters use a horizontal rotor attached to a vertical spindle
- Water moves through orifices in the measuring chamber wall and causes the rotor to spin

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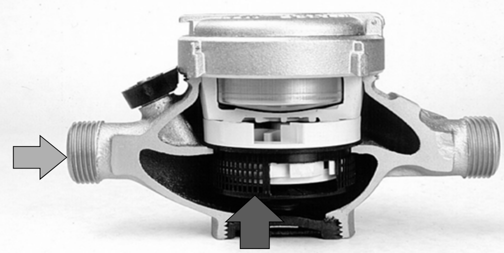
Multijet Meters



From Inlet Water Flows
Thru A 360° Strainer

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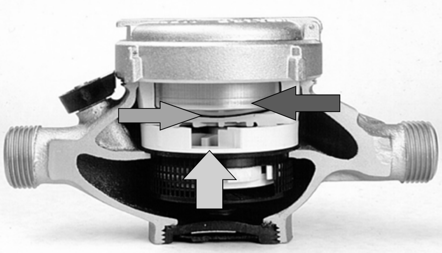
Multijet Meters



The Magnetic Drive links the Measuring Element to the Sealed Register

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Detector-Check Meters

- For emergency high-use services
  - Example: fire sprinkler systems
- Weight-loaded check valve in main line is closed under normal flow, opens for emergency
- Bypass around check valve has displacement meter

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Selecting the Right Meter

- Meter selection is the responsibility of the utility
- First, consider the application
  - Single family residence
  - Small commercial
  - Light industrial
  - Irrigation
- Each application should be considered by it's individual requirements

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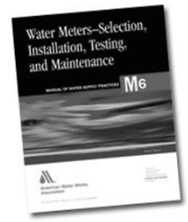
Selecting the Right Meter

- Meter is usually one size smaller than service line
- For residential, start with ⅝ or ¾ inch meter
- AWWA Manual M6 for sizing meters



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Selecting the right meter

- Proper sizing is important for accurate measurement
- Projected water use should be the primary selection criteria
  - Flow rate
    - What is the maximum and minimum expected flow
    - Maximum flow requirement is critical to meter selection
- Total usage should be considered
  - How much water per month is expected to be used

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Selecting the right meter

- Meter manufactures' literature provides flow ranges of their meters

SIZE	SAFE MAXIMUM OPERATING CAPACITY	NORMAL TEST FLOW	REQUIRED ACCURACY	MINIMUM TEST FLOW	REQUIRED ACCURACY
5/8"	20 GPM	1-20 GPM	98.5-101.5%	1/4 GPM	95%
3/4"	30 GPM	2-30 GPM	98.5-101.5%	1/2 GPM	95%
1"	50 GPM	3-50 GPM	98.5-101.5%	3/4 GPM	95%
1-1/2"	100 GPM	5-100 GPM	98.5-101.5%	1-1/2 GPM	95%
2"	160 GPM	8-160 GPM	98.5-101.5%	2 GPM	95%

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Meter Selection

- Determine the customer's actual requirements
  - A restaurant, for example
    - Do they wash dishes?
    - How many restrooms?
    - How many employees?
    - Do they irrigate landscape areas?
    - Will they have fire protection?

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Meter Selection

- Historical data from a business could help
  - If the customer is part of a chain or franchise operation, data from another store should help
  - Similar businesses can be used to help determine potential usage
- Remember, an oversized or misapplied meter will give away water!

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Meter Location

- Climate determines, in part, the location of a meter
  - Non-freezing climates require protection for meters from vandalism, other damage
  - Freezing climates require meter boxes to protect meters

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Meter Location

- Easier to access meter box than entering a building
- Deep meter pits may be subject to flooding
- In buildings - install in basement; make sure the homeowner cannot illegally tap line ahead of meter

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Installation

- Meter should not be subject to flooding
- Upstream and downstream shutoff valves for isolation
- Always install horizontally
- Reasonably accessible for service and inspection
- Location should provide for easy reading
  - Either directly or via a remote reading device

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Installation

- Needs protection against frost, vandalism, tampering
- Large meters should be supported to prevent stress on the pipe
- Large installations require bypass for uninterrupted service during maintenance

64

Installation

- Depth of meter box depends on maximum frost depth
- Requires straight pipe lengths upstream and downstream
- Mountainous regions may require pressure-reducing valve at meter

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Manifold Installation

- For customers requiring high flows
- Allows continuous service during maintenance or replacement
- All meters and valves are same size
- All but one must have spring-loaded check valve
  - When the flow is small, only one meter will operate

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Meter Connections

- Meter sizes up to 1 inch usually have screw-type connections
- Flanged connections for larger meters

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Indoor Installations

- Locate meter immediately after point where service line enters through floor or wall
- Location must be kept clear for easy access

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Outdoor Installations

- Small meters -
  - Meter pit standard size, located near property line
  - Lid flush with ground, tight-fitting, tamper resistant
  - Riser pipes should be 2 inches from walls
  - Location and type of curb stop specified
  - Recommend use of meter yoke to prevent damage over time, and facilitate removal

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Outdoor Installations

- Large meters -
  - No uniform standard
  - Must provide support to prevent service line damage
  - Test valves should be provided to allow for volumetric tests
  - Refer to manufacturer's recommendations

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Meter Reading

- Flow recorded in gallons or cubic feet
- Record all numbers including fixed zeros or multiplier
  - The multiplier such as 10x or 1000x will be noted on the meter register face

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Direct Readout

- Get reading from each meter
  - Inside homes
  - Outside in meter pits

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Remote Reading Devices

- Signal transmitted electrically from meter to a counter outside
- Can plug a reading device into a receptacle on the outside of a building
- Scanning probe picks up signal from meter, transmits readout to handheld device

Testing and Maintenance

- Water meters should be tested:
  - Before installation
  - After maintenance
  - At customer's request

Meter Testing

- Testing new meters allows utilities to limit metering errors
- Over time, meter efficiency decreases; meters begin to under register
- ⅝-inch meters should be tested every 5 to 10 years; test large meters annually

Testing Procedures

- Determine overall efficiency by testing at a variety of flow rates
  - Small meters - test minimum, average, and maximum flow rates
  - Large meters - test at 5 different flow rates

Maintenance and Repair

- Dismantle meter
- Clean all parts
- Inspect parts for damage
- Replace or repair as necessary
- Reassemble and retest

Record Keeping

- Location of meters
- Keep track of meter age and condition
- Should have a card for each meter

Mainline Metering

- Meter at treatment plant discharge allows comparison of water produced and water sold in distribution system
- Keeps track of water bought from or sold to another utility

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Types of Mainline Meters

- Current meters (velocity meters)
  - For lines 3” and larger
  - Turbine meter - rotor is turned by water flow
  - Multijet meter - turbine wheel is spun by jets of water from around circumference
  - Propeller meter - propeller turned by water flow

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Types of Mainline Meters

- Proportional meters
  - A portion of the water is diverted and measured with a turbine or displacement meter
  - Diverted flow is proportional to total flow
  - Accurate except for low flows

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Types of Mainline Meters

- Venturi meters
  - Pressure measured at two points in the flow
  - Translates pressure differential to a flow
  - Accurate over good range of flows

82

Types of Mainline Meters

- Orifice meters
  - Thin plate with a restriction in flow
  - Compares pressure upstream with reduced pressure at restriction
  - Has considerable head loss

83

Types of Mainline Meters

- Magnetic meters
  - Water flowing through magnetic field creates a current proportional to flow
  - No head loss
  - Requires certain distance upstream and downstream with no obstructions (elbows, etc.)

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Types of Mainline Meters

- Ultrasonic meters
  - An electronic transducer sends a beam of ultrasonic sound waves through water
  - Frequency changes with velocity - Doppler Effect
  - Requires certain distance upstream and downstream with no obstructions (elbows, etc.)

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Types of Mainline Meters

- Weirs and Flumes
  - Weirs measure flow in open channels by measuring height of water in weir
  - Flumes measure flow in open channels by measuring width and depth of water upstream and at a constriction

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Meter Change Out Procedures

1. Find out reason for change out
2. Notify customer that their water will be off for short time and ask them to cut it off at house
3. Get the tools that will be needed
4. Cut water off at curb stop
5. Remove meter
6. Spray new meter with chlorine
7. Put new meter in making sure arrow is facing house
8. Instruct customer to turn water on at house but not to draw any water
9. Cut water back on at curb stop
10. Turn outside faucet on and flush line
11. Take chlorine samples
12. Fill out meter job ticket and work order with:
    - New and old meter number
    - New and old reading
    - Chlorine reading
    - Crew and supplies used
    - Address and reason for change out

METERS AND SERVICES
REVIEW QUESTIONS

1. What is the function of a gooseneck in a service line?

2. What is the function of a curb stop?

3. Identify the two most popular materials used for residential water services.

4. Explain why lead and wrought iron are no longer used for residential services.

5. What is a possible problem when iron services are installed with bronze curb stops?

6. What two factors must water suppliers consider when determining the depth and location of a service line.

7. What are three reasons for metering water customers?

8. Identify three meters commonly used in the water distribution system.

9. Name and describe the operation of two major types of positive displacement meters.

10. What is the most common application for a small positive displacement meter?

11. Compound meters are generally used under what conditions?

12. What types of meters might be used for main line or pump station measurements?

13. What are the requirements for acceptable meter installations?

14. What is a meter yoke?

15. Explain the need for maintaining electrical continuity around the meter during removal.

16. When should water meters be tested?

17. List three basic elements in a meter test.

18. What hazards are associated with electrically thawing a frozen service line?

19. What items should be recorded on a service connection record card?

20. What items should be recorded on a meter history card?

Answers

1. A flexible connection that provides for ease of installation and allows for any settlement of the overlying material, or expansion and contraction of the service line due to temperature variations.
2. A meter shut off located in the water service pipe near the curb between the water main and building in which the meter is located.
3. Copper and plastic
4. Lead joints are difficult to install properly and there is some question concerning safety (in terms of the water quality) or lead services. Wrought iron is rigid and requires threading, making it difficult to install. Wrought iron services may also have short lives due to corrosion.
5. Use of dissimilar materials often forms a galvanic cell and causes corrosion of the pipe.
6. Frost penetration and location of other utility lines.
7. Collecting revenues. Encourages customer to use water wisely. Provide indication of water demand.
8. 1. Positive displacement. 2. Compound. 3. Current.
9.
   - Piston-type meter, water flows into the chamber, which houses the piston. As it flows through the chamber, the piston is displaced. The motion of the piston is transmitted to the register, via magnets in newer models or gears in older models. This records the volume of water flowing through the meter.
   - The nutating disc meter uses a measuring chamber containing a hard rubber disc instead of a piston. When water flows through the chamber, the disc wobbles in proportion to the volume. This motion is transmitted to a register that records the volume of water flowing through the meter.
10. Metering residential services.
11. Where water demand varies considerably from high and low flows.
12. Propeller, venturi, proportional and turbine type meters might be used
13.
   - Not be subject to flooding with non-potable water.
   - Provide up and down stream shut-off valve of high quality to isolate the meter for repairs.
   - Position meter in horizontal plane for optimum performance.
   - Reasonably accessible for service and inspection.
   - Provide for easy reading.
   - Protected from frost and mechanical damage.
   - Not an obstacle or hazard to customer or public safety.
   - Meter is sealed to prevent tampering.
   - Proper support for large meters to avoid stress on pipe.
   - There be a by-pass or multiple meters on large installations.

14. A device that holds the stub ends of the pipe in proper alignment and spacing. It cushions the meter against stress and strain in the pipe and provides electrical continuity if metal pipe is used.
15. Reduces the chance of electrical shock during meter removal due to stray current or electrical grounding to the service pipe.
16. Meters should be tested before use, removal from service, after repairs, and upon customer complaint or request.
    Running different rates of flow to determine overall meter efficiency.
17. Passing known quantities of water through the meter at various test rates to provide a reasonable determination of meter registration. Meeting accuracy limits on different rates for acceptable use.
18. Damage to the service line, plumbing, and electrical appliances. Stray current can cause fire or electrical shock.
19. Permanent service number, applicant's name and address, dates of application and installation, size of corporation and curb stop used, size and type pipe used, depth of installation, and detailed measurements of locations.
20. Size, make, type, date of purchase, location, test data, and any repairs on the meter should be included on a meter history card.

Section 11

Pumps

TDEC - Fleming Training Center 1

PUMPS

California State University: Sacramento

TENNESSEE DEPARTMENT OF ENVIRONMENT AND 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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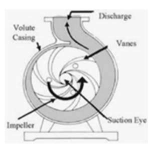
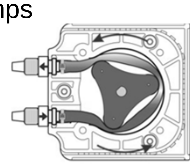
Types of Pumps

- 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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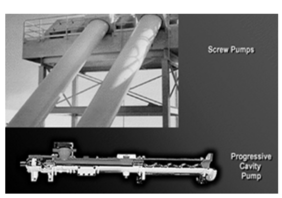
Positive-Displacement Pumps

- 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, or screw pump



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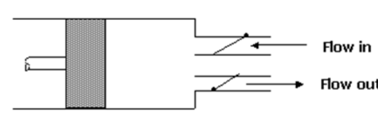
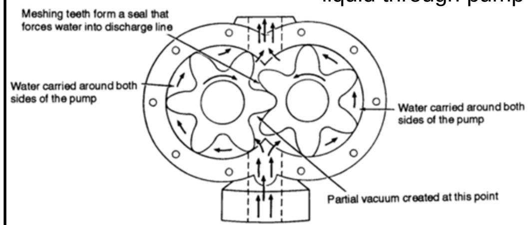
Positive-Displacement Pumps

- 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



Screw Pumps

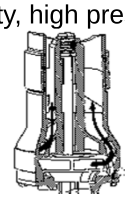
- Aka progressive cavity pumps
- Screw pumps are used to lift wastewater to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge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

Incline screw pumps handle large solids without plugging

Velocity Pumps

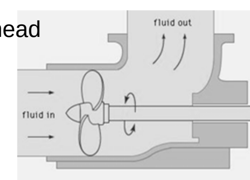
- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)
- High velocity, low pressure water is converted to low velocity, high pressure water


Volute


Diffuser

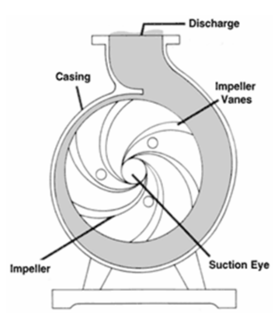
Velocity Pump Design Characteristics

- 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



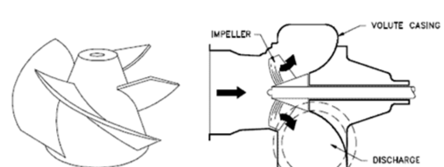
Velocity Pump Design Characteristics

- 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



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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

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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

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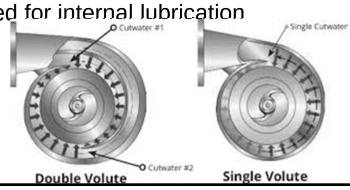
Advantages of Centrifugal Pumps

- 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



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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

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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

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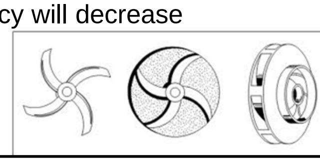
Impeller

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



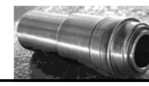
Let's Build a Centrifugal Pump

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

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

Shaft and Sleeves

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



Let's Build a Centrifugal Pump

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

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

Bearings

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

Let's Build a Centrifugal Pump

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

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

Couplings

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

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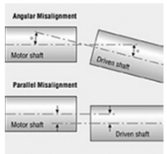
Misalignment of Pump & Motor



- 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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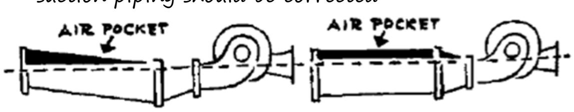
Let's Build a Centrifugal Pump

- 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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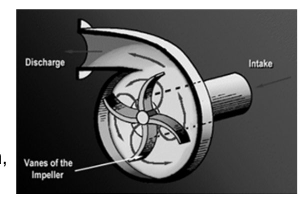
Let's Build a Centrifugal Pump

- 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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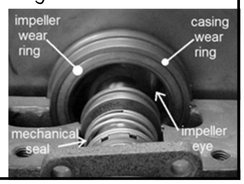
Let's Build a Centrifugal Pump

- 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

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.



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

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

Stuffing Box

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

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

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

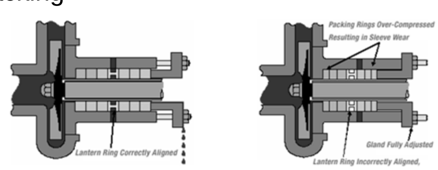
Let's Build a Centrifugal Pump

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

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

Lantern Rings

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



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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.

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Mechanical Seals

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

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Packing vs. Mechanical Seals

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

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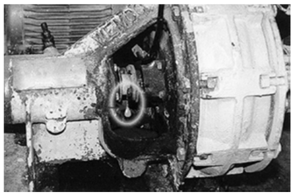
Packing Rings vs. Mechanical Seal

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



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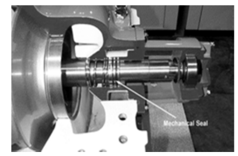
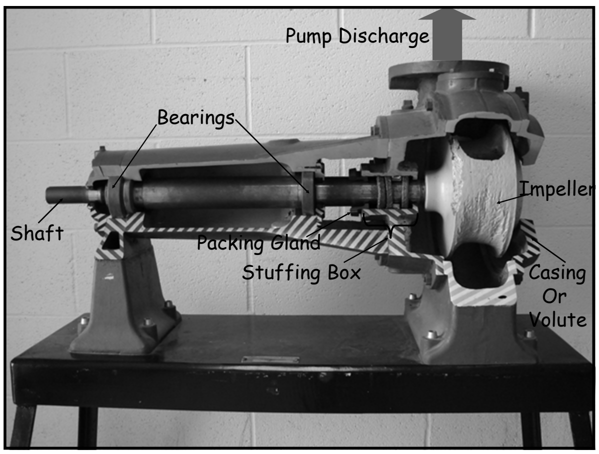
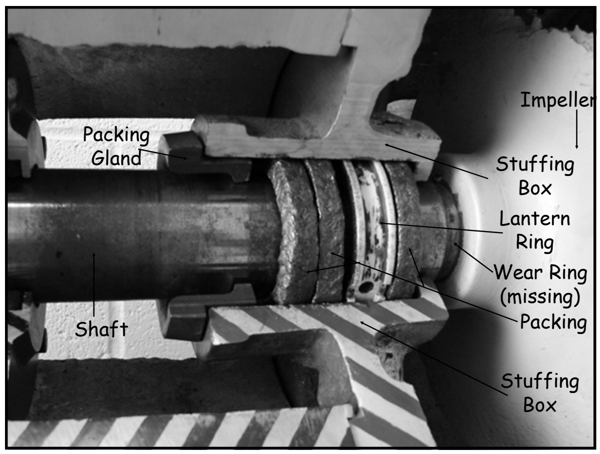
Mechanical Seal vs. Packing Rings

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







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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

Flow Control

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

Monitoring Operational Variables

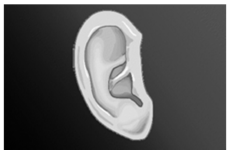
- Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operation

Monitoring Operational Variables

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

Monitoring Operational Variables

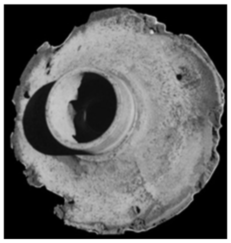
- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds



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

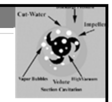


- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

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.

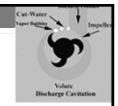
Information from http://www.pumpworld.com/Cavitation_discharge.htm

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

Inspection and Maintenance

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

Inspection: Impellers

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

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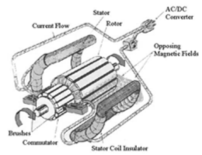
Pump Won't Start?



- 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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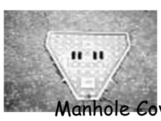
Pump Safety: Wet Wells

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



Manhole Cover, London

Pump Maintenance Record Sheet

Facility ID ____

Equipment ____________________ Manufacturer ____________________

Model No. ____________________ Serial No. ____________________

HP ________ Voltage _________ Amps __________ RPM ___________

Frame ___________ GPM ___________ TDH ___________ft.

Impeller Size ____

Suction Pressure ____________________ Discharge Pressure ____________________

Pump Type ____

Additional Information:

____

____

____

____

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 for cooling.

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 or 71^{o}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 Vocabulary

1. 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.
2. 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.
3. Vertical Turbine Pump – a centrifugal pump, commonly of the multistage, diffuser type, in which the pump shaft is mounted vertically.
4. Submersible Pump – a vertical-turbine pump with the motor placed below the impellers. The motor is designed to be submersed in water.
5. Jet Pump – a device that pumps fluid by converting the energy of a high-pressure fluid into that of a high-velocity fluid.
6. 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.
7. Radial-Flow Pump – a pump that moves water by centrifugal force, spinning the water radially outward from the center of the impeller.
8. Mixed-Flow Pump – a pump that imparts both radial and axial flow to the water.
9. Single-Suction Pump – a centrifugal pump in which the water enters from only one side of the impeller. Also called an end-suction pump.
10. Double-Suction Pump – a centrifugal pump in which the water enters from both sides of the impeller. Also called a split-case pump.
11. Closed-Coupled Pump – a pump assembly where the impeller is mounted on the shaft of the motor that drives the pump.
12. Frame-Mounted Pump – a centrifugal pump in which the pump shaft is connected to the motor shaft with a coupling.
13. Positive Displacement Pump – a pump that delivers a precise volume of liquid for each stroke of the piston or rotation of the shaft.
14. 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.
15. 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.

16. 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.
17. Packing – rings of graphite-impregnated cotton, flax, or synthetic materials, used to control leakage along a valve stem or a pump shaft.
18. Packing Gland – a follower ring that compressed the packing in the stuffing box.
19. 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.
20. 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.
21. 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.
22. 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.
23. Impeller – the rotating set of vanes that forces water through the pump.
24. Casing – the enclosure surrounding a pump impeller, into which the suction and discharge ports are machined.
25. Volute – the expanding section of pump casing (in a volute centrifugal pump), which converts velocity head to pressure head.
26. 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.
27. Bearing – anti-friction device used to support and guide a pump and motor shafts.
28. Diffuser Vanes – vanes installed within a pump casing on diffuser centrifugal pumps to change velocity head to pressure head.
29. 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.
30. Suction Lift – the condition existing when the source of water supply is below the centerline of the pump.
31. 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.

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 semiopen 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) 140°F
   b) 150°F
   c) 160°F
   d) 170°F

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

Answers:

1) B	6) D	11) A
2) C	7) B	12) D
3) C	8) C	13) C
4) A	9) B	14) A
5) C	10) C	

Section 12

Cross-Connections

Cross-Connection Control

Outline

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

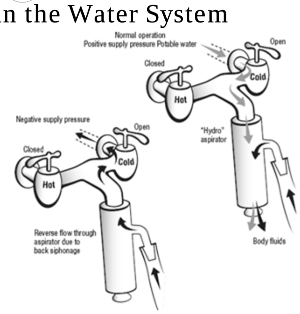
Backflow Case Study

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



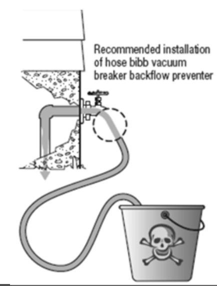
Backflow Case Study

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



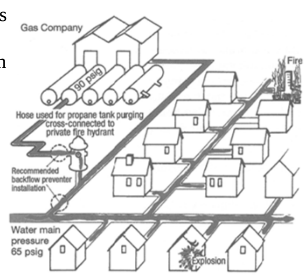
Backflow Case Study

Propane Gas in the Water Mains

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

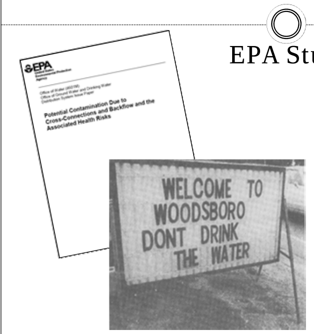
Vapor pressure of propane residual in the tank exceeded water main pressure

Hundreds evacuated, two homes caught fire, water supply contaminated



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

Authority

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

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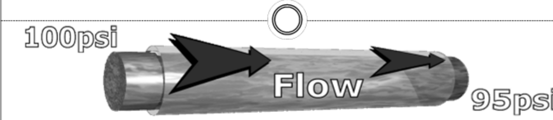
Hydraulics and Pressure



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

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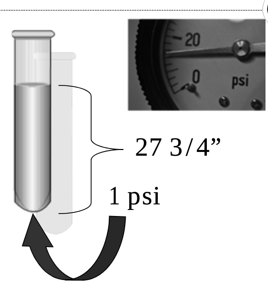
Head Pressure



27 ¾” = 2.31 Feet of Head

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

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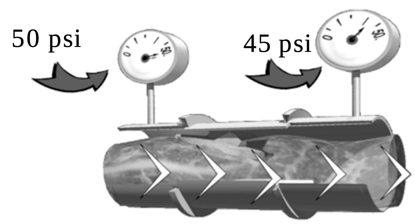
Normal Flow



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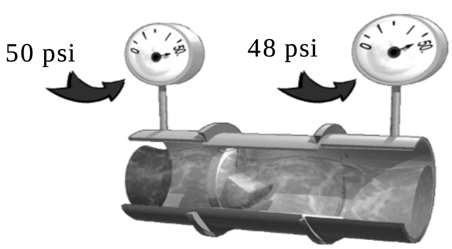
No Flow



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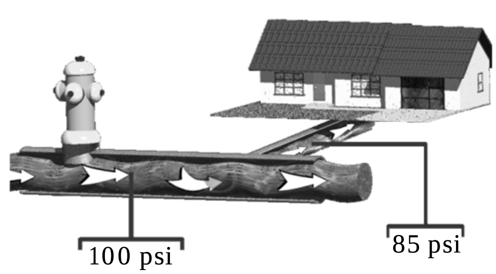
Normal Flow



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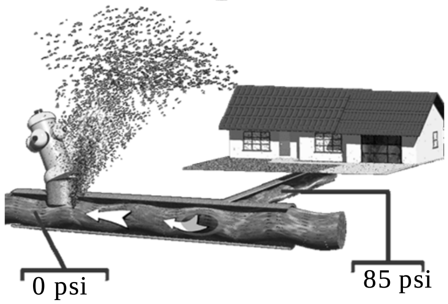
Reverse Flow - Backflow



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Backflow

- The undesirable reversal of flow of water or other substances into the potable water distribution supply

- Occurs due to:
  - Backpressure
  - Backsiphonage

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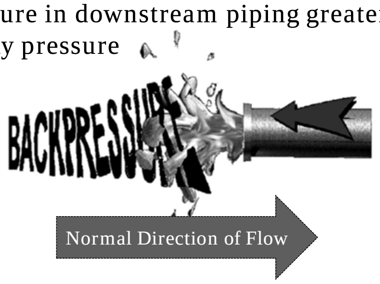
Backpressure

- Pressure in downstream piping greater than supply pressure



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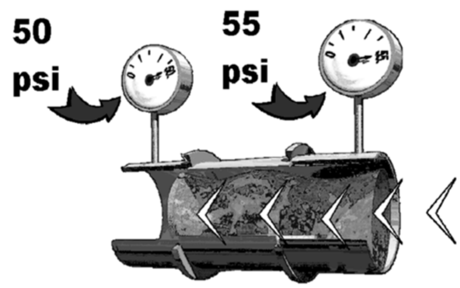
Backpressure



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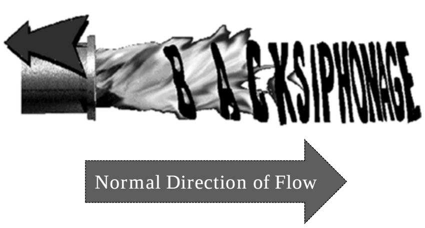
Backsiphonage

- Sub-atmospheric pressure in the water system



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Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?

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

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Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?

- Whatever is in the barrel...

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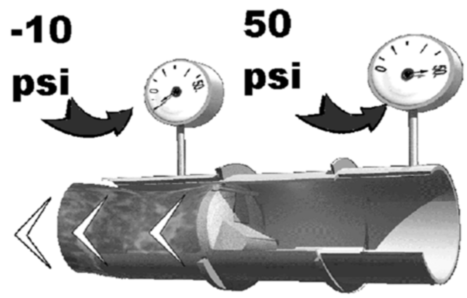
Backsiphonage



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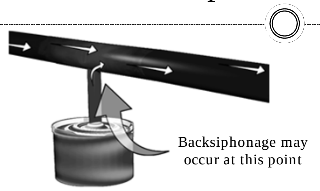
Aspirator Effect



- 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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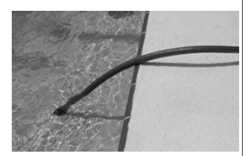
Cross-Connection

- 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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	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
Non – Health Hazard	Air Gap	Air Gap	Air Gap

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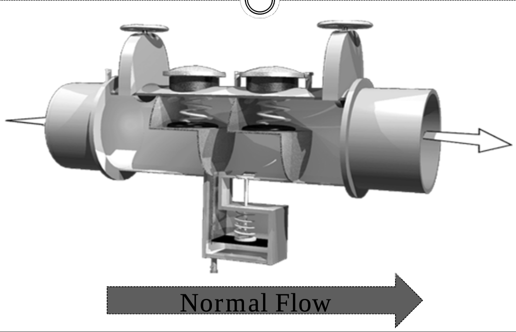
Reduced Pressure Principle Assembly



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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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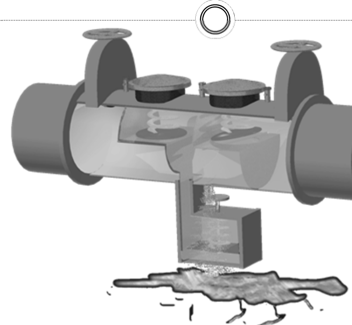
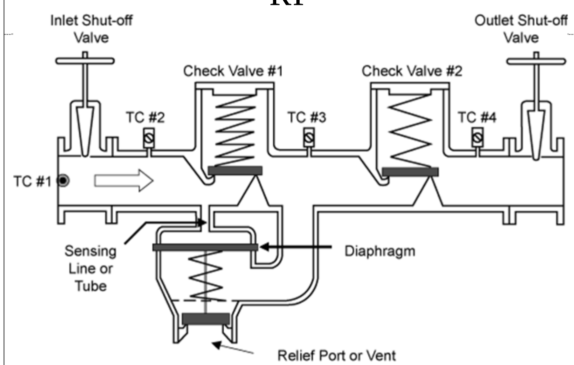
RP



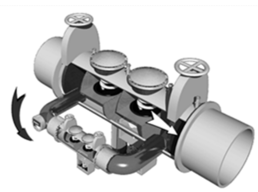
Fouled Second Check with Backpressure

RP



RP Detector Assembly

- Line sized RP
- Smaller detector RP installed on a bypass around large RP
- Water meter before smaller RP
- Purpose is to detect any unauthorized use of water



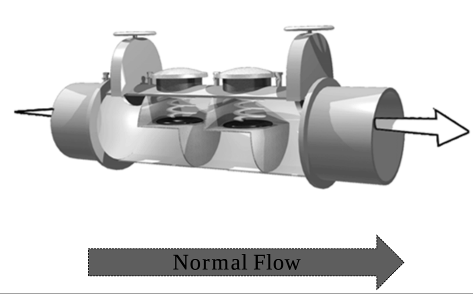
2 GPM and lower travels through bypass only and gets registered on water meter

RP

Backflow Protection Against:
- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

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

Double Check Valve Assembly (DC)



Double Check Valve Assembly (DC)

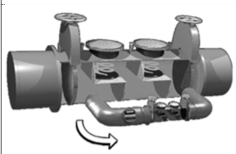
- The double check valve backflow prevention assembly (DC) consists of two independently operating check valves installed between two tightly closing resilient seated shutoff valves and fitted with four properly located test cocks
- Similar to the RP, but has no relief port and no where for the water to go during a backflow incident or failure

Double Check Valve Assembly (DC)

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

Second check fouled during backpressure

DC Detector Assembly



2 GPM and less through bypass only

- Line sized DC
- Smaller detector DC installed on a bypass around large DC
- Water meter before smaller DC registers low flow use
- Purpose is to detect any unauthorized use of water

Double Check Valve Assembly (DC)

Backflow Protection Against:

- Backsiphonage
- Backpressure
- Pollutant only

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

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

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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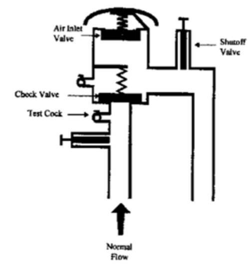
Pressure Vacuum Breaker (PVB)



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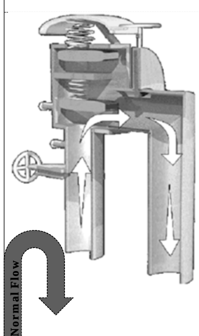
Pressure Vacuum Breaker (PVB)



- The pressure vacuum breaker or spill resistant vacuum breaker consists of an independently operating check valve and an independently operating spring loaded air inlet valve 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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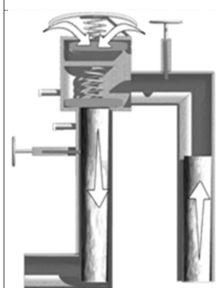
PVB Backsiphonage Condition



- 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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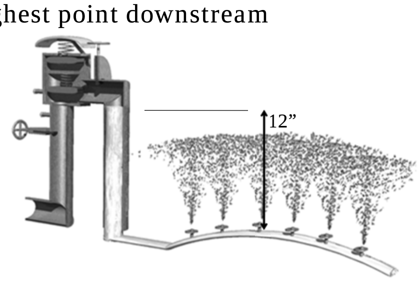
Installation of PVB

- Needs to be installed 12 inches above the highest point downstream



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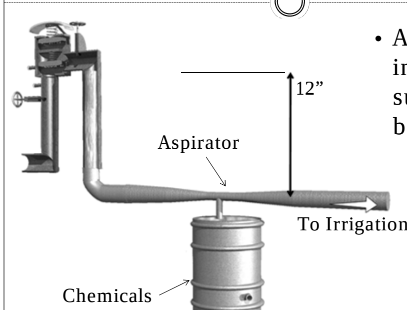
Pressure Vacuum Breaker



- Acceptable installation not subject to backpressure

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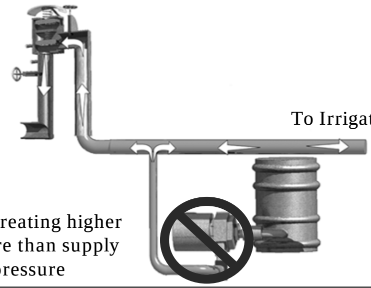
Pressure Vacuum Breaker

- Improper installation subject to backpressure



To Irrigation

Pump creating higher pressure than supply pressure

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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"

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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**	
Non – Health Hazard	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	**PVB**	

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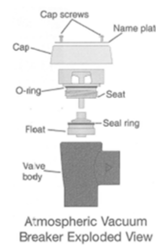
Atmospheric Vacuum Breaker (AVB)



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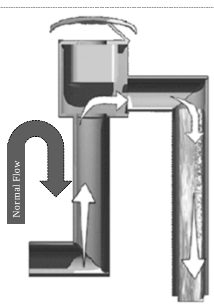
Atmospheric Vacuum Breaker (AVB)



- 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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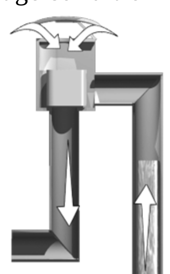
Atmospheric Vacuum Breaker (AVB)

- Backsiphonage condition



Loss of supply pressure

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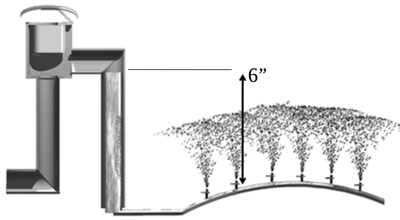
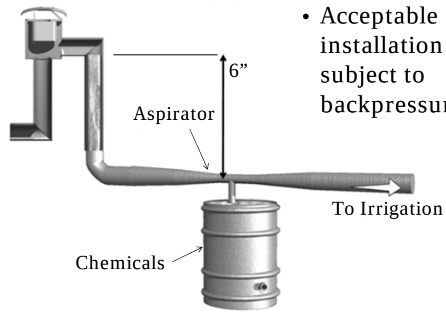
Installation of AVB

- Needs to be installed 6 inches above the highest point downstream



Atmospheric Vacuum Breaker

- Acceptable installation not subject to backpressure



Atmospheric Vacuum Breaker

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

Atmospheric Vacuum Breaker

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

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

Testing of Assemblies

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

Cross-Connection Control Manuals

United States Environmental Protection Agency
Cross-Connection Control Manual
www.epa.gov/ogwdw/pdfs/crossconnection/crossconnection.pdf

Tennessee Department of Environment & Conservation
Cross-Connection Control Manual & Design Criteria
http://www.tn.gov/assets/entities/environment/attachments/crossconnection.pdf

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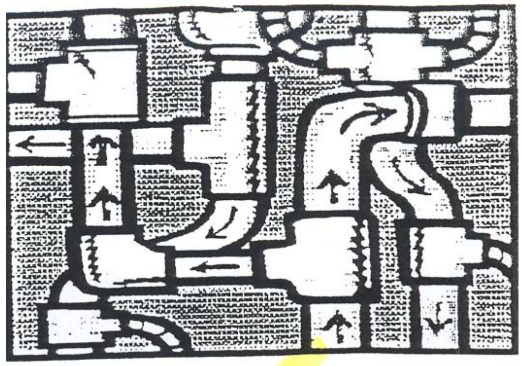


Vocabulary

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 (sub atmospheric) 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.

Some Cross-Connections and Potential Hazards

Connected System	Hazard Level
Sewage pumps	High
Boilers	High
Cooling towers	High
Flush valve toilets	High
Garden hose (sil cocks)	Low to high
Auxiliary water supply	Low to high
Aspirators	High
Dishwashers	Moderate
Car wash	Moderate to high
Photographic developers	Moderate to high
Commercial food processors	Low to moderate
Sinks	High
Chlorinators	High
Solar energy systems	Low to high
Sterilizers	High
Sprinkler systems	High
Water systems	Low to high
Swimming pools	Moderate
Plating vats	High
Laboratory glassware or washing equipment	High
Pump primers	Moderate to high
Baptismal founts	Moderate
Access hole flush	High
Agricultural pesticide mixing tanks	High
Irrigation systems	Low to high
Watering troughs	Moderate
Autopsy tables	High

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.

Cross-Connections Review Questions

1. Define a cross-connection.

2. Explain what is meant by backsiphonage and backpressure.

3. List four situations that can cause negative pressure in a potable water supply.
   -
   -
   -
   -

4. List six waterborne diseases that are known to have occurred as a result of cross-connections.
   -
   -
   -
   -
   -
   -

5. What is the most reliable backflow-prevention method?

6. Is a single check valve position protection against backflow? Why or why not?

7. How often should a reduced-pressure-zone backflow preventer be tested?

8. In what position should an atmospheric vacuum breaker be installed relative to a shutoff valve? Why?

9. How does a vacuum breaker prevent backsiphonage?

10. List seven elements that are essential to implement and operate a cross-connection control program successfully?
    -
    -
    -
    -
    -
    -
    -

Vocabulary 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

Review Question Answers:

1. A cross-connection is any connection or structural arrangement between a potable water system and a nonpotable system through which backflow can occur.

2. Backsiphonage is a condition in which the pressure in the distribution system is less than atmospheric pressure. In more common terms, there is a partial vacuum on the potable system.
   Backpressure is a condition in which a substance is forced into a water system because that substance is under a higher pressure than system pressure.
3.
   - fire demand
   - a broken water main or exceptionally heavy water use at a lower elevation than the cross-connection
   - a booster pump used on a system
   - undersized piping
4.
   - typhoid fever
   - dysentery and gastroenteritis
   - salmonellosis
   - polio
   - hepatitis
   - brucellosis
5. The most reliable backflow prevention method is an air gap.
6. A single check valve is not considered positive protection against backflow. A check valve can easily be held partially open by debris, corrosion products or scale deposits.
7. Reduced-pressure-zone backflow preventers should be tested at least annually.
8. An atmospheric vacuum breaker must be installed downstream from the last shutoff valve. If it is placed where there will be continuing backpressure, the valve will be forced to remain open, even under backflow conditions.
9. When water stops flowing forward, a check valve drops, closing the water inlet and opening an atmospheric vent. This lets water in the breaker body drain out, breaking the partial vacuum in that part of the system.
10.
   - an adequate cross-connection control ordinance
   - an adequate organization with authority
   - a systematic surveillance program
   - follow-up procedures for compliance
   - provisions for backflow-prevention device approvals, inspection and maintenance
   - public awareness and information programs

Section 13

Safety

SAFETY

Distribution Systems

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

General Duty Clause

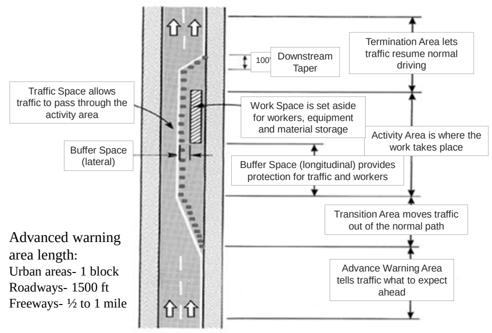
- FEDERAL - 29 CFR 1903.1
- EMPLOYERS MUST: Furnish a place of employment free of recognized hazards that are causing or are likely to cause death or serious physical harm to employees. Employers must comply with occupational safety and health standards promulgated under the Williams-Steiger Occupational Safety and Health Act of 1970.

TRAFFIC SAFETY

Traffic Control Zones

- Advanced warning area
- Transition area
- Buffer space
- Work area
- Termination area

Traffic Control Zones



Advanced warning area length:
Urban areas- 1 block
Roadways- 1500 ft
Freeways- ½ to 1 mile

Advanced Warning Area

- Must be long enough to give motorists adequate time to respond to particular work area conditions
- Typically ½ mile to one mile for highways
- 1500 feet for most other types of roads
- At least one block for urban streets

Transition Area

- Not required if no lane or shoulder closure is involved
- Use of tapers
  - Channeling devices or pavement markings placed at an angle to direct traffic
- Traffic is channeled around the work area

Buffer Space

- Provides margin of safety between transition zone and work area

Work Area

- Ensure closed to traffic
- Shield by barriers
- Post **Road Construction Next ____ Miles** to inform drivers of the length of work area
- Do Not set up sign until work begins

Termination Area

- Provides short distance for traffic to clear work area and return to normal traffic lanes
- Closing tapers are optional

Traffic Signs

- Always use official signs
- Most permanent warning sign are diamond-shaped with black legends on yellow background
- Temporary signs have an orange background
- Best to use picture direction instead of wording
- Place end of construction signs about 500 feet beyond the end of the work site

Channelizing Devices

- Designed to warn and direct traffic away from workers
- Cones are 18-36 inches high and orange in color
- Drums are 2 orange and 2 white stripes

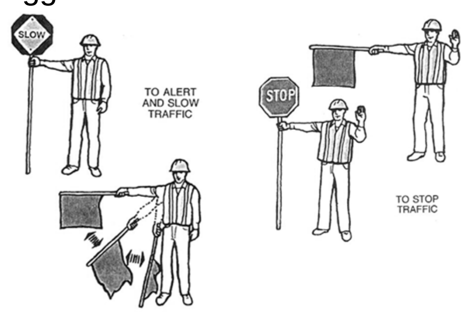
Channelizing Devices

- Barricades are alternating orange and white strips marked with reflectors sloping downward in the direction traffic must turn

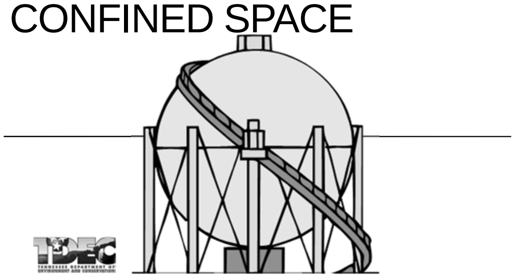
Channelizing Devices

- Flaggers should wear lime green (or orange) and reflectors at night
- Should be positioned at least 100 feet from the work site always facing the oncoming traffic

Flaggers



CONFINED SPACE



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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

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Confined Space Examples

- Vaults
- Silos
- Inside filters
- Basins
- Storage tanks
- Pits
- Hoppers



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Equipment Needed for Confined Spaces

- Safety harness with lifeline, tripod and winch
- Electrochemical sensors
- Ventilation blower with hose



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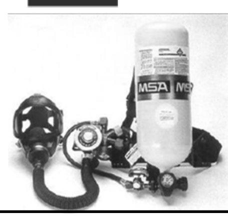
Equipment Needed for Confined Spaces

- PPE
- Ladder
- Rope
- Breathing Apparatus



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Permit-Required Spaces

- Contains or has potential to contain hazardous atmosphere
- Contains material with potential to engulf an entrant
- Entrant could be trapped or asphyxiated

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Atmospheric Hazards

- Need to have atmosphere monitored continuously!!!
  - Depletion or elimination of breathable oxygen
    - Oxygen deficient atmosphere
    - **Minimum oxygen level is 19.5%**
  - Explosive or flammable
    - These can develop in the collection system or sewer plant duel to legal, illegal or accidental sources
  - Toxic
    - Comes from natural breakdown of organic matter in wastewater or toxic discharges

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Hydrogen Sulfide – H_2S

- Detected by the smell of rotten eggs
- Loss of ability to detect short exposures
  - Olfactory fatigue
- Not noticeable at high concentrations
- Poisonous, colorless, flammable, explosive and corrosive
- 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
- S.G. = 1.19 (heavier than air)

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Methane Gas – CH_4

- Product of waste decomposition
- Leaks in natural gas pipelines can saturate the soil
  - Odorless unless natural gas supplied through pipeline, has mercaptans added, but soil can strip the odor
- 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
- Colorless, odorless, tasteless
- Acts as an asphyxiant – displaces oxygen
  - Coal miners used canaries as early alarms; if bird died, it was time to get out
- S.G.= 0.55

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Carbon Monoxide - CO

- Decreases amount oxygen present
- ALWAYS VENTILATE
- 0.15% (1500 ppm) → DEAD
- Will cause headaches at 0.02% in two hour period
- Maximum amount that can be tolerated is 0.04% in 60 minute period
- Colorless, odorless, tasteless, flammable and poisonous
- By-product of fuel gas
  - Can be hazard in home if using gas heat or gas appliances
- S. G. = 0.97

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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
- Early warning signs that an operator is not getting enough oxygen:
  - Shortness of breath
  - Chest heaving
  - Change from usual responses

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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 gases exceeding 10% of the lower explosive limit
  - H_2S exceeds 10 ppm
  - O_2 percentage drops below 19.5%
  - CO alarm set point is 35 ppm
- Calibrate unit before using
- Most desirable units: simultaneously sample, analyze and alarm all three atmospheric conditions

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Atmospheric Alarm Units

- Some physical and environmental conditions that could affect the accuracy of gas detection instruments include:
  - Caustic gases
  - Temperature
  - Dirty air
  - Humidity
  - Air velocity
  - Vibration

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Safety Procedures if Explosive Atmosphere Discovered

- Immediately notify supervisor
- Do not remove manhole cover
- Turn off running engines in area
- Route vehicles around area
- Inspect up and downstream of manhole
- Route traffic off the street
- Notify waste and or pretreatment facility
- Cautiously ventilate
- NO SMOKING IN AREA

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Ventilation

- Blowers need to be placed upwind of manhole and at least 10 feet from opening
- Gas driven engine – exhaust must be downwind of manhole
- Air intake should be 2-5 feet above ground service

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Written Entry System

- Employer shall document entry permits
- Entry supervisor sign permits
- Permit posted
- Shall not exceed time required
- Retain permits for at least 1 year

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Information on Permit Forms

- Space to be entered
- Purpose
- Date and authorized duration
- Attendant ID by name
- Authorized entrants ID by name
- Entry supervisor name and signature
- Hazards of permit space
- Measures to eliminate, isolate, or control the hazards
- Results of tests
- Rescue and emergency services
- Communications

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Information on Equipment

- PPE (personal protective equipment)
- Testing equipment

Duties Of Entrants

- Know signs, symptoms, and consequence of exposure
- Properly use equipment
- Alert attendant of warning signs, symptoms and other possible hazards
- Exit when ordered to evacuate by supervisor or attendant

Duties of Confined Space Attendant

- Know signs, symptoms, and consequences of exposure
- Possible behavioral effects of hazards
- Maintain accurate count of entrants
- Remain outside permit space
- Communicate with entrants
- Summon rescue and emergency units

Duties of Confined Space Attendant

- Warn unauthorized persons to stay away
- Perform non-entry rescue
- Do not perform any duties that may interfere with primary duty: <u>monitoring and protecting entrants</u>

Duties of Supervisors and Managers

- Knowledge of signs, symptoms, and consequences of exposure
- Verify appropriate entries, procedure, tests and equipment
- Terminate entries and cancel permits if warranted
- Verify means for summoning rescue
- Ensure that acceptable conditions are maintained and operations remain consistent with entry permit

Required Training

- Employer shall train all employees on hazards, procedures, and skills to perform their jobs safely
- Employees trained before first assigned duty
- Employer shall certify training of employees
- Maintain individual training records of employees

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Record Keeping

- Identification and Evaluation of all Hazardous areas in workplace
- Entrance permits filed
- Training Certification
- Written Confined Space Program

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General Requirements

- Identify, evaluate, and monitor hazards in permit-required confined spaces
- Post signs "Permit Required"
- Prevent unauthorized entries
- Re-evaluate areas
- Inform contractors
- Have a written program available for employees
- Have proper PPE on hand
- Annual Training (TOSHA requirements)

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Confined Space Requirements

- All electrodes removed and machines disconnected from power sources
- Gas supply shut off
- Gas cylinders outside work area
- All employees entering must undergo confined space training
- Ventilation used to keep toxic fumes, gases, and dusts below max levels

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LOCKOUT / TAGOUT

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General Requirements

- Written program
- Utilize tagout system if energy isolating device not capable of being locked out
- Lockout/tagout hardware provided
- Devices used only for intended purposes
- Tagout shall warn **DO NOT START, DO NOT ENERGIZE, DO NOT OPERATE**
- Only trained employees shall perform lockout/tagout

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Requirements When Lockout of Equipment

- Notify employees
- Before beginning work on any pump, the first thing to be done is to lock it out.
  - The person doing the work should have the ONLY key
- Employees notified after completion of work and equipment re-energized

Recommend Steps for Lockout/Tagout

- Notify employees that device locked and tagged out
- Turn off machine normally
- De-activate energy
- Use appropriate lockout/tagout equipment
- Release any stored energy
- Try to start machine by normal means

Steps for Restoring Equipment

- Check area for equipment or tools
- Notify all employees in the area
- Verify controls are in neutral
- Remove lockout/tagout devices and re-energize device
- Notify employees maintenance and/or repairs are complete and equipment is operational

Training Requirements

- Employer shall train all employees
- All new employees trained
- Recognition of applicable hazardous energy
- Purpose of program
- Procedures
- Consequences
- ANNUAL REQUIREMENT

Inspections

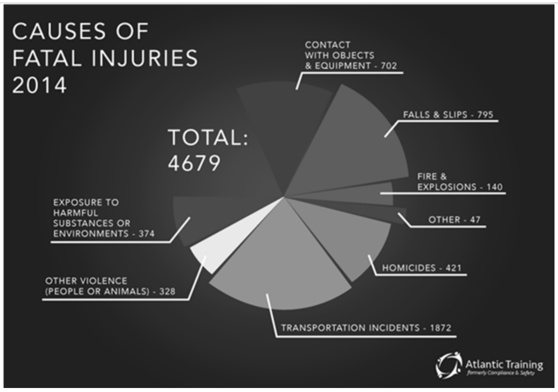
- Conduct periodic inspection at least annually
- Shall include review between the inspector and each authorized employee
- Recommendation: Frequent walk through of work areas and observation of Maintenance and Operation area

Required Record Keeping

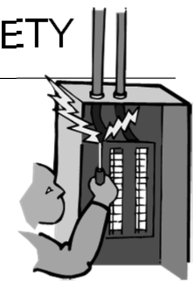
- Written Lockout/Tagout Program
- Training: Annual and New Employees
- Inspections: Annually; including new equipment, inspection of devices, and procedures

Most Frequently Citied Workplace Safety Violations 2015

- Fall protection (1926.501)
- Hazard communication (1910.1200)
- Scaffolding (1926.451)
- Respiratory protection (1910.134)
- Lockout/tagout (1910.14)
- Powered industrial trucks (1910.178)
- Ladders (1926.1053)
- Electrical – wiring methods (1910.305)
- Machine guarding (1910.212)



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

FIRE PROTECTION

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

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
  - Example 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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Types of Fire Extinguishers

Class	Material	Method
A	Wood, paper	Water
B	Flammable liquids (oil, grease, paint)	Carbon dioxide, foam, dry chemical or Halon
C	Live electricity	Carbon dioxide, dry chemical, Halon
D	Metals	Carbon dioxide

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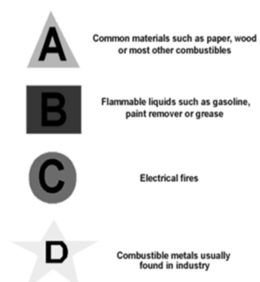
Types of Fire Extinguishers

- Combination ABC are most common
- Have the types of extinguishers available depending upon analyses performed in each area



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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.

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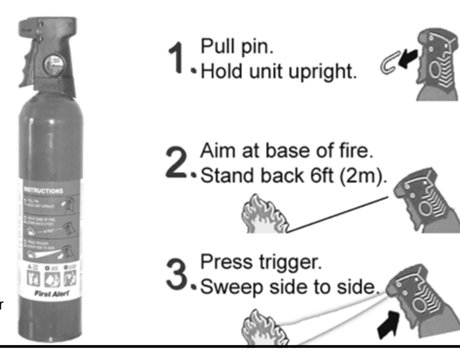
Fire Extinguishers



Combo Extinguisher

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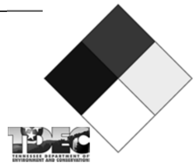
CHEMICAL SAFETY

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Personal Protective Equipment

- Gloves
- Coveralls / Overalls
- Face Shield / Goggles
- Respirator / SCBA
- Boots
- Ear Plugs / Muffs

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Minimum Info for SDS

- Product identification
- Hazard Identification
- Composition/info on ingredients
- First-aid measures
- Fire-fighting measures
- Accidental release measures
- Handling and storage
- Exposure controls
- Physical/chemical properties
- Stability & reactivity
- Toxicological information
- Ecological information*
- Disposal considerations*
- Transport information*
- Regulatory information*
- Other information (including date of SDS or last revision)*

* Non mandatory

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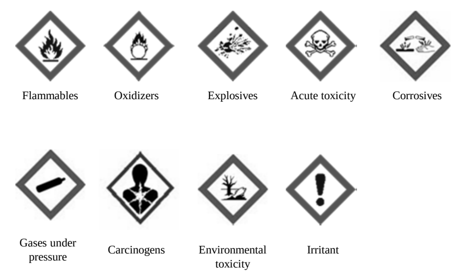
OSHA Pictograms



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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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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.

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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
- This is opposite of GHS
- 1 ◊ highest hazard
- 4 ◊ lowest hazard

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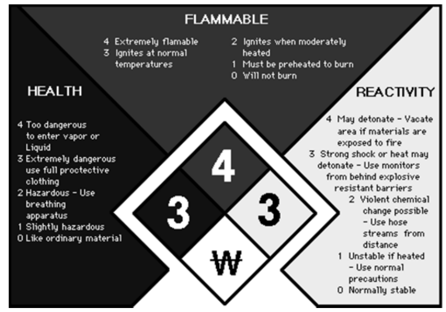
Chemical Label



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Terms

- Lower Explosive Level (LEL) – minimum concentration of flammable gas or vapor in air that supports combustion
- Upper Explosive Limit (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

TOSHA Standards Requiring Annual Training

Class	Regulation	Who should attend?
Medical & Exposure Records	1910.20(g)(1)	All employees (inform-existence, person responsible, location, right of access
Emergency Action	1910.38(a)(5) 1910.38(b)(4)	All employees – based upon other standards and requirements
Noise	1910.95(k)	All employees exposed to an 8 hour TWA or greater of 85dBA
Emergency Response	1910.120(q)	Employees who respond to spills of hazardous chemicals
Personal Protective Equipment	1910.132(f)	Employees who wear PPE
Permit-Required Confined Space	1910.146(g)	Employees who enter, attend or supervise P.R. confined spaces
Lock-Out/Tag-Out	1910.147(c)(7)	Employees who work on machinery
First Aid	1910.151(b)	At least one employee on each shift, annual as required by other standards
Fire Brigade	1910.156(c)	All fire brigade members (quarterly and annually)
Portable Fire Extinguishers	1910.157(g)	All employees expected to use fire extinguishers
Fork Lift Trucks	1910.178(1)	Fork lift truck operators
Mechanical Power Presses	1910.217(f)(2)	Operators
Asbestos	1910.1001(j)(1)	All employees exposures at or above PEL or excursion limit
Lead	1910.1025(1)	Anyone with a potential for exposure at any level – copy of appendix A&B. If exposed at or above action level, must be trained
Bloodborne Pathogens	1910.1030(g)(2)	Employees who render first aid
Hazard Communication	1910.1200(h) TDL 800-1-9-.07	Employees exposed or potentially exposed to any type of chemicals
Hazardous Chemicals in Laboratories	1910.1450(f)(2)	Employees exposed to chemicals

Safety Quiz

Lockout / Tagout

True or False

1. The term “lockout” means to block the flow of energy to equipment and keep it blocked by placing a lock to prevent accidental start-up.

   True False

2. The term “tagout” means to place a tag on the power source to identify yourself and the purpose of the lockout, and to warn others not to turn the power back on.

   True False

3. If someone else has already applied a lock and tag to a piece of machinery you need to work on, you should not add another one.

   True False

4. After locking and tagging out the equipment, you should test the equipment to make sure it won’t start.

   True False

5. You don’t need to use the lockout / tagout procedure if a machine has a built-in safety shut-off.

   True False

Confined Spaces

Fill in the blank:

6. A __________________ is a form designed to make sure workers can safely enter a confined space by establishing procedures that must be followed.

7. The acceptable range for oxygen level in a confined space is ________ %.

8. List some activities that can reduce the level of oxygen in a confined space:

   ____

9. Entry-level permits should be kept on file for at least _________ year(s).

Multiple Choice:

10. Which of these are examples of confined spaces? (Circle all that apply)
    a. Storage tanks
    b. Automobiles
    c. Meter box
    d. Manholes
    e. Meeting rooms

11. When must the atmosphere of a confined space be tested?
    a. Only before a worker enters
    b. Never, if adequate ventilation exists
    c. Continuously
    d. Only if welding or painting is being performed

12. Some gases in a confined space can be:
    a. Colorless
    b. Odorless
    c. Deadly
    d. All of the above

True or False:

13. If dangerous conditions exist, you do not have to wait for trained rescue personnel to perform a rescue.

    True False

14. Carbon monoxide and hydrogen sulfide are two common dangerous gases found in confined spaces.

    True False

Trenching

Multiple Choice:

15. A trench is generally defined by being less than how many feet wide?
    a. Less than 5 feet wide
    b. Less than 15 feet wide
    c. Less than 20 feet wide
    d. More than 20 feet wide

16. How far from the trench must a spoil be placed?
    a. The toe of the spoil must be at least 1 foot from the edge of the excavation
    b. The toe of the spoil must be at least 2 feet from the edge of the excavation
    c. The toe of the spoil must be at least 3 feet from the edge of the excavation
    d. The toe of the spoil must be at least 4 feet from the edge of the excavation

17. One method of classifying soils has to do with texture. Texture is based on soil particle size, name three soil particle size groupings. (Pick three answers)
    a. Clay
    b. Rock
    c. Loam
    d. Silt
    e. Sand
    f. Gravel

18. When must a ladder be installed in a trench?
    a. Any excavation
    b. Any excavation three feet deep or more
    c. Any excavation four feet deep or more
    d. Any excavation five feet deep or more

19. What is the spacing of ladders in longer trenches?
    a. Ladder must be available every 50 feet
    b. Ladder must be available every 25 feet
    c. Ladder must be available every 15 feet
    d. Ladder must be available every 5 feet

20. Methods of cave-in protection at an excavation work site are:
    a. Sloping
    b. Shoring
    c. Shields
    d. All the above

21. Two hazards immediately associated with water and water accumulations are cave-ins and drownings.
    a. True
    b. False

Calcium Hypochlorite

Multiple Choice

22. Calcium hypochlorite:
    a. Is an oxidizer
    b. May cause a fire if contaminated
    c. Can release hazardous chlorine gas if stored improperly
    d. All of the above

23. Which form of calcium hypochlorite is the safest?
    a. Granular
    b. Tablet
    c. Liquid

24. Calcium hypochlorite should be stored away from:
    a. Acids
    b. Paint
    c. Reducing agents
    d. Oils and greases
    e. All of the above

25. What should be used to extinguish a fire involving calcium hypochlorite?
    a. Water
    b. Carbon dioxide
    c. Chemical smothering agents
    d. All of the above

26. When cleaning up a small spill, you should dispose of the calcium hypochlorite by:
    a. Burying it
    b. Placing it in the trash can
    c. Putting it back in the container
    d. Neutralizing it with acid or ammonia
    e. Dissolving it in a large amount of water

Fill in the blank

27. What personal protective equipment should you wear when handling calcium hypochlorite?

    ____

28. Why should smoking be prohibited in calcium hypochlorite storage areas?

    ____

29. Why must you never dispose of calcium hypochlorite in the trashcan?

____

Answers:

1. True
2. True
3. False
4. True
5. False
6. Confined space permit
7. 19.5% - 23.5%
8. Poor ventilation, welding, absorption, chemical consumption
9. One
10. A and D
11. C
12. D
13. False
14. True
15. B
16. B
17. A, D and E
18. C
19. B
20. D
21. A
22. D
23. A
24. E
25. B
26. E
27. Wear self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes (rubber gloves and rubber boots)
28. Fire hazard
29. Can react with organic material and cause a flash fire

Section 14

Trenching

1

Trenching Safety

2

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Trenching Safety

- Reduction of injury and illness rates.
- Daily exposure to job hazards by thousands of workers.
- Efficiency can be greatly improved.
- OSHA safety standards require:
  - Establishment of a “Safety” program
  - Training be conducted
  - Job hazards be assessed
  - Hazards and precautions be explained

3

OSHA Office of Training and Education

Excavation Hazards

- Cave-ins are the greatest risk
- Other hazards include:
  - Asphyxiation due to lack of oxygen
  - Inhalation of toxic materials
  - Fire
  - Moving machinery near the edge of the excavation can cause a collapse
  - Accidental severing of underground utility lines

4

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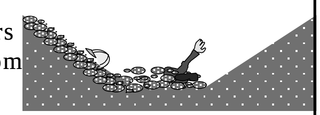
Cave-ins

- Hundreds of workers killed annually from cave-ins
- Thousand of workers injured annually from cave-ins
- Fatality rate for trenching is twice the level for general construction



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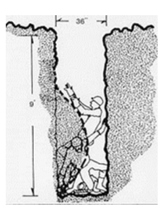
OSHA Office of Training and Education

Injury and Death

- Excavating is one of the most hazardous construction operations
- Most accidents occur in trenches 5-15 feet deep
- There is usually no warning before a cave-in



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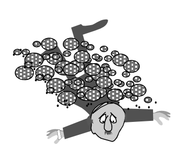
Asphyxiation

- Each time a breath is exhaled the weight of the load restricts inhalation of the next breath.
- Slow suffocation usually follows unless rescue is immediate.



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Cave-ins Result From

- Vibrations
- Adjacent structures
- Freezing and thawing
- Weight of the soil itself
- Addition or removal of water
- Reduction in frictional and cohesive capacities of soil

8

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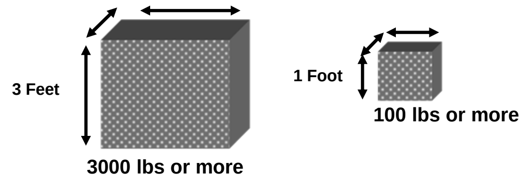
Density and Water Content

- One cubic yard weighs - 3000 lbs or more
- One cubic foot weighs - 100 lbs or more



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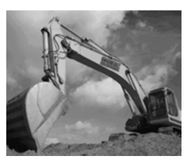
How do most deaths occur?

- Instantaneously
- Trenches 5 to 15 feet deep
- With absolutely no warning
- In seemingly safe conditions
- With workers in a bent or lying position



10

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Before you begin excavation:

- The site must be assessed
- Potential hazards must be determined
- Known hazards reduced or eliminated
- Emergency procedures established
- Periodic inspection intervals determined
- Utility locations must be staked or marked

- Regardless of the equipment used, a main trench must be kept as narrow as possible.

11

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Basic Safety Requirements

- Conduct inspections before each work shift
- Do not travel under elevated loads
- Do not work over unprotected employees
- Wear proper personal protective equipment
- Provide walkways or bridges over trenches

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Basic Safety Requirements

- Provide trench exits within 25 feet of workers in trenches more than four feet deep
  - For every 25 feet of trench there needs to be 1 ladder
- Ensure spoilage is at least 2 ft. from trench edges
- Provide protection for trenches 5 feet or deeper
  - Shores needed
- A registered professional engineer (RPE) must design protective systems for excavations deeper than 20 feet

13

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Emergency Procedures

- Immediately call 911, or the Emergency Response Team
- Report:
  - Exact Location
  - Number of Victims
  - Nature of Emergency
  - Trench Measurements
  - Special Hazards

14

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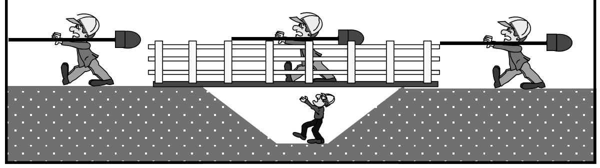
Structural Ramps: Access & Egress

- Used only by people
- Designed by a "competent person"
- Egress required every 25 feet
  - (lateral) ≥ 4ft



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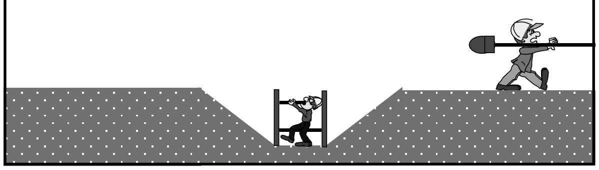
Trench Safety

- Trenches more than 5 feet deep
  - Require shoring
  - Or must have a stabilized slope
- In hazardous soil conditions
  - Trenches under 5 feet need protection



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Hazardous Atmospheres

- Testing and controls
  - Oxygen deficiency
  - Flammable atmospheres
  - testing
- Emergency rescue equipment
  - Availability
  - lifelines

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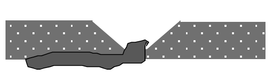
Hazards

- Adequate precautions must be taken when working in accumulated water
- Controlling water and water removal must be monitored by a competent person
- Ditches, dikes or comparable means should be used to prevent surface water from entering excavations



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Weather Factors - Mother Nature

- Don't underestimate the effects weather can have
- Daily (or hourly) site inspections must be made
- Consider protection from:
  - Lightening
  - Flooding
  - Erosion
  - High winds
  - Hot or cold temperatures

19

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Site Inspections

- Daily inspections must be made by a competent person
  - Excavations
  - Adjacent areas
  - Protective systems
- When evidence is found of a hazardous condition, the exposed employees must be immediately removed from the area

20

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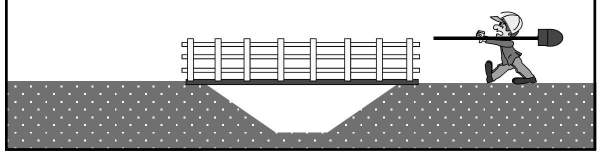
Fall Protection

- Guardrails must be provided for crossing over excavations if the trench is 6 feet or more in depth
- Barriers must be provided for remotely located excavations



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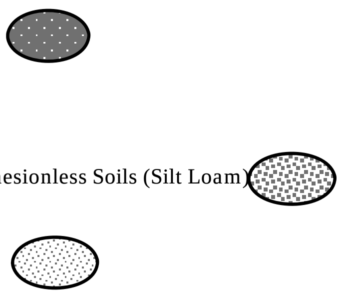
Soil Classification System

- Type A Soils
  - Clay
  - Silty Clay
  - Sandy Clay
  - Clay Loam
- Type B Soils
  - Granular Cohesionless Soils (Silt Loam)
- Type C Soils
  - Gravel
  - Sand
  - Loamy Sand



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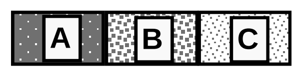
Soil Classification System

- Must be done by a competent person
- Visual test:
  - Check entire worksite
  - Fissured ground
  - Layered soil
  - Disturbed earth
  - Seepage
  - Vibration
  - Poor drainage



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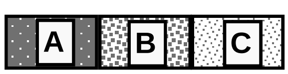
Soil Classification System

- Manual test
  - Plasticity
  - Dry strength
  - Thumb penetration
  - Pocket penetrameter
  - Hand operated shear vane
- Warning:
  - One soil inspection and classification may not be enough.
  - Outside disturbances during excavation may change even the best soil classification.
  - Inspect the soil after any change in conditions.



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Requirements for Protective Systems

- Each employee must be protected from cave-ins by an adequately designed system.
- Exceptions are:
  - Excavation made in stable rock
  - Excavations less than 5 feet
- Protective systems must have the capacity to resist all loads that are expected to be applied to the system

25

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Materials and Equipment

- Must be free from damage or defects that might impair proper function
- Must be used and maintained in a manner that is consistent with the recommendations of the manufacturer
- Must be examined by a competent person if damage occurs

26

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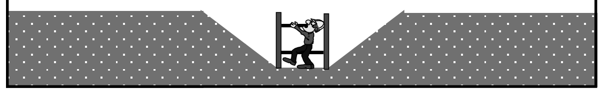
Installation and Removal of Support

- General requirements:
  - Support systems must be securely connected
  - Support systems must be installed and removed in a manner that protects from collapse
  - Support systems must not be subjected to loads exceeding design specifications



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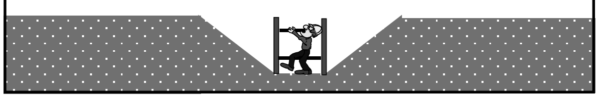
Installation and Removal of Support

- General requirements:
  - Additional precautions must be taken to ensure safety before temporary removal begins
  - Removal must begin at the bottom of the excavation
  - Backfilling must progress together with the removal of support systems from excavations



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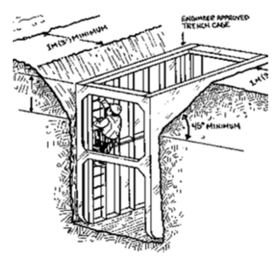
Protect Employees Exposed to Potential Cave-ins

- Slope or bench the sides of the excavation,
- Support the sides of the excavation, or
- Place a shield between the side of the excavation and the work area



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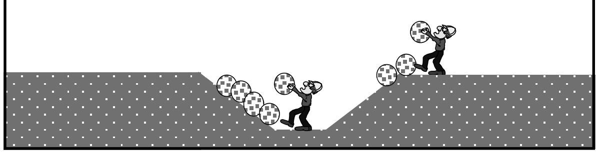
Sloping and Benching Systems

- Employees must not be permitted to work:
  - On the faces of sloped or benched excavations
  - At levels above other employees except when employees at the lower levels are adequately protected from the hazard of falling, rolling or sliding material or equipment



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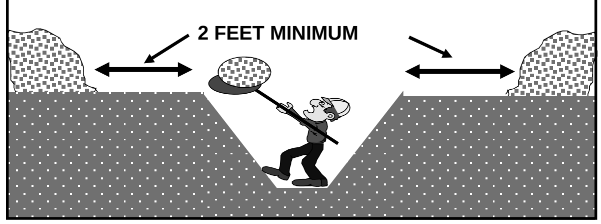
Sloping and Benching Systems

- Temporary spoil piles:



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Spoils

- Don't place spoils within 2 feet from edge of excavation
- Measure from nearest part of the spoil to the excavation edge
- Place spoils so rainwater runs away from the excavation
- Place spoil well away from the excavation

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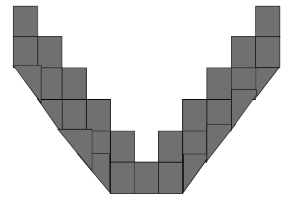
Sloping and Benching Systems

- Benching general requirements
  - Various slope angles are allowed by OSHA
  - Appendix B to 1926 Subpart P must be consulted
  - Evacuate the excavation if walls show signs of distress
  - If soil conditions change, re-inspect



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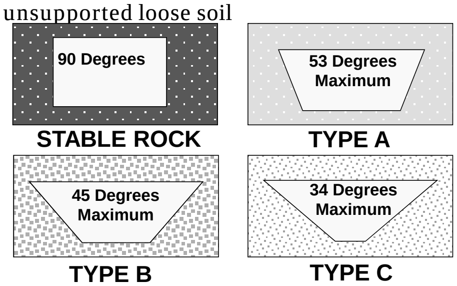
Sloping and Benching Systems

- The angle of repose is the angle of slope of the unsupported loose soil



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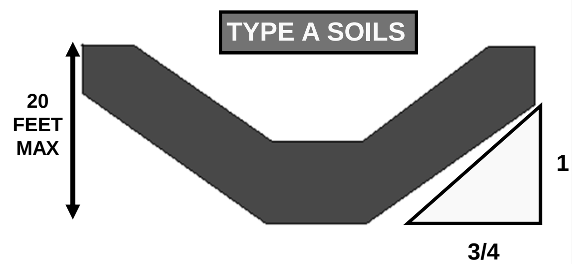
Sloping Example Type A Soils



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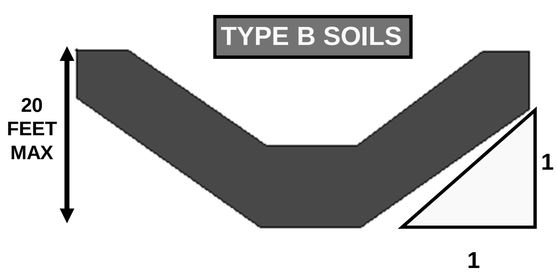
Sloping Example Type B Soils



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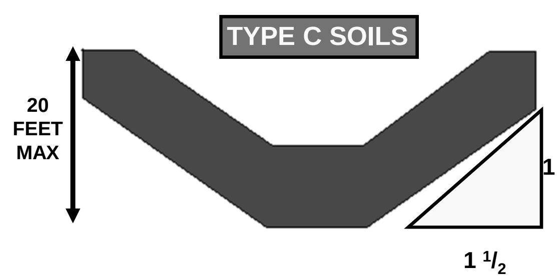
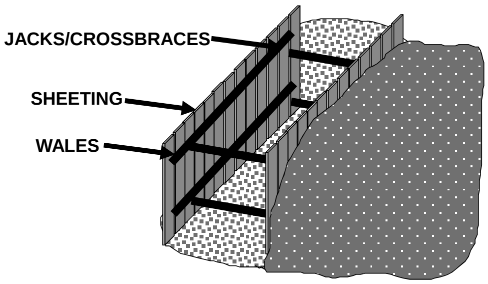
Sloping Example Type C Soils



Shoring Systems

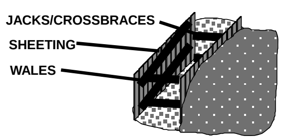


Shoring

- General
  - Provides a framework to work in
  - Uses wales, cross braces and uprights
  - Supports excavation walls
- OSHA tables provide shoring data
  - Must know soil type
  - Must know depth and width of excavation
  - Must be familiar with the OSHA Tables

Shoring Systems

- Removal
  - Remove shoring from the bottom up
  - Pull sheeting out from above
  - Backfill immediately after removal of support system



Hydraulic Trench Support

- Using hydraulic jacks the operator can easily drop the system into the hole
- Once in place, hydraulic pressure is increased to keep the forms in place
- Trench pins are installed in case of hydraulic failure

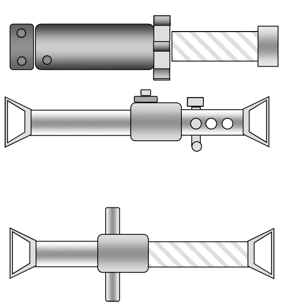
Shoring Systems

PNEUMATIC/ HYDRAULIC JACKS

Often used due to ease of installation and removal

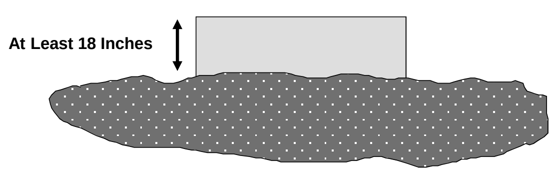
SCREW JACK

Inexpensive; time consuming to install (top to bottom).



Shield Systems

- General
  - Shield systems must project at least 18 inches above the lowest point where the excavation face begins to slope

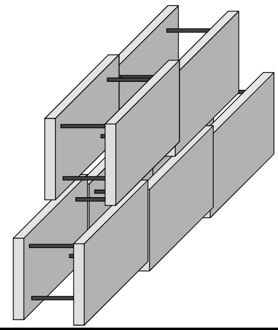


Shield Systems

- General
  - Shield systems must not be subjected to loads exceeding those which the system was designed to withstand
  - Shields must be installed to restrict hazardous movement
  - Employees must be protected from the hazard of cave-ins when entering or exiting the areas protected by shields
  - Employees must not be allowed in shields when shields are being installed, removed, or moved vertically

Shield Systems

- Systems may be connected
- Systems may be stacked
- Configuration must be consistent with the recommendations of the manufacturer
- Must be examined by a competent person if damage occurs



Trench Shield

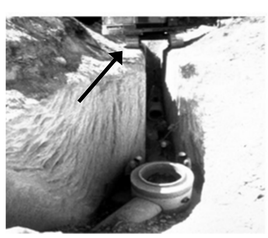
A trench shield was built around this work area

Cave-in Hazard

Inadequate protective system

Hazardous Conditions

- The weight and vibrations of the crane make this a very hazardous condition.
- They should not be working under this crane.



Materials and Equipment

- Equipment used for protective systems must not have damage or defects that impair function.
- If equipment is damaged, the competent person must examine it to see if it is suitable for continued use.
- If not suitable, remove it from service until a professional engineer approves it for use.

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Protection from Vehicles

- Install barricades
- Hand/mechanical signals
- Stop logs
- Grade soil away from excavation
- Fence or barricade trenches left overnight

Trenching Summary

- Provide stairways, ladders, ramps or other safe means of access in all trenches **4 feet** or deeper
  - These devices must be located within **25 feet** of all workers
  - Ladders used in trenches shall protrude at least **3 feet** above the trench edge
  - Minimum diameter of rungs on a fixed steel ladder is **¾-inch**
  - Minimum clear length of rungs on a fixed steel ladder is **16 inches**

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Trenching Summary

- Trenches **5 feet** deep or greater require a protective system, which can be shielding, shoring or sloping
  - A registered engineer must approve all shielding and shoring
- Trenches **20 feet** deep or greater require that the protective system be designed by a registered professional engineer
- Keep excavated soil (spoils) and other materials at least **2 feet** from trench edges.
- The support or shield system must extend at least **18 inches** above the top of the vertical side.

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TRENCH SAFETY™ AND SUPPLY, INC.

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www.trenchsafety.com

Trenching & Excavation Safety Checklist

Site Location ______________________ Date ______________ Time ________ a.m. p.m.

GENERAL INSPECTION

1.	Has the "Competent Person" had specific training in—and is knowledgeable about—soil analysis, use of protective systems, and the requirements of 29CFR1926-Subpart P: Excavations and Trenches?	❑ YES	❑ NO	❑ N/A
2.	Does the "Competent Person" have the authority to remove workers from the excavation immediately?	❑ YES	❑ NO	❑ N/A
3.	Are excavations, adjacent areas, and protective systems inspected by a Competent Person: **A.** Daily prior to the start of work, **B.** As needed throughout the shift, and **C.** After every rainstorm or other occurrence that could increase the hazard?	❑ YES	❑ NO	❑ N/A
4.	Are ALL surface encumbrances removed or supported?	❑ YES	❑ NO	❑ N/A
5.	Are ALL employees protected from loose rock or soil that could pose a hazard by falling or rolling into the excavation?	❑ YES	❑ NO	❑ N/A
6.	Are hard hats worn by ALL employees?	❑ YES	❑ NO	❑ N/A
7.	Are spoils, materials, and equipment set back at least 2 feet from the edge of the excavation?	❑ YES	❑ NO	❑ N/A
8.	Are barriers provided at all remotely located excavations, wells, pits, shafts, etc.?	❑ YES	❑ NO	❑ N/A
9.	Are walkways and bridges over excavations 6 feet or more in depth and 30 inches or more in width equipped with standard guard rails and toe boards?	❑ YES	❑ NO	❑ N/A
10.	Are warning vests or other highly visible clothing provided and worn by all employees exposed to vehicular traffic?	❑ YES	❑ NO	❑ N/A
11.	Are employees required to stand away from vehicles being loaded or unloaded?	❑ YES	❑ NO	❑ N/A
12.	Are warning systems established and used when mobile equipment is operating near the edge of an excavation?	❑ YES	❑ NO	❑ N/A
13.	Are employees prohibited from going under suspended loads?	❑ YES	❑ NO	❑ N/A
14.	Are employees prohibited from working on the faces of sloped or benched excavations above other employees?	❑ YES	❑ NO	❑ N/A

UTILITIES

15.	Are utilities companies contacted and/or utilities located as required by local, state, and federal law?	❑ YES	❑ NO	❑ N/A
16.	Are the exact locations clearly marked?	❑ YES	❑ NO	❑ N/A
17.	Are underground installations protected, supported, or removed when an excavation is open?	❑ YES	❑ NO	❑ N/A

ACCESS & EGRESS

18.	Are ladders or other means of access and egress in place in all trenches 4 feet or more deep?	❑ YES	❑ NO	❑ N/A
19.	Are all workers within 25 feet of a means of access and egress?	❑ YES	❑ NO	❑ N/A
20.	Are the ladders that are used in excavations secured and extended 3 feet above edge of the excavation?	❑ YES	❑ NO	❑ N/A
21.	Are ALL structural ramps used by employees designed by a "Competent Person?"	❑ YES	❑ NO	❑ N/A
22.	Are ALL structural ramps used for equipment designed by a Registered Professional Engineer?	❑ YES	❑ NO	❑ N/A
23.	Are ALL ramps constructed of materials of uniform thickness, cleated together, equipped with no-slip surfaces?	❑ YES	❑ NO	❑ N/A
24.	Are employees protected from cave-ins when entering or exiting excavation?	❑ YES	❑ NO	❑ N/A

WET CONDITIONS

25.	Are precautions taken to protect employees from water accumulation?	❑ YES	❑ NO	❑ N/A
26.	Is water removal equipment monitored by "Competent Person?"	❑ YES	❑ NO	❑ N/A
27.	Is surface water or runoff diverted after every rainstorm or other hazard-increasing occurrence?	❑ YES	❑ NO	❑ N/A

continued on back...

HAZARDOUS ATMOSPHERES

28. Is the atmosphere within ALL excavations tested when there is a reasonable possibility of an oxygen-deficient, oxygen-enriched, combustible, toxic, or other harmful contaminant? ❑ YES ❑ NO ❑ N/A

29. Are adequate precautions taken to protect employees from exposure to an atmosphere containing less than 19.5% oxygen and/or other hazardous atmosphere? ❑ YES ❑ NO ❑ N/A

30. Is verification provided to protect employees from an atmosphere containing flammable gas in excess of 10% of the lower explosive limit of the gas? ❑ YES ❑ NO ❑ N/A

31. Is emergency equipment available when hazardous atmospheres could or do exist? ❑ YES ❑ NO ❑ N/A

32. Are employees trained to use personal protective equipment and other rescue equipment? ❑ YES ❑ NO ❑ N/A

SOILS

33. Has the Competent Person classified the soil using one manual test and one visual test, as specified by the standard? ❑ YES ❑ NO ❑ N/A

Visual Test ______________________ (Type) Manual Test ______________________ (Type)

Soil Classified as: ❑ Solid Rock ❑ Type A ❑ Type B ❑ Type C

SUPPORT SYSTEMS

3 Primary Options are Available:

Note: *If an excavation is deeper than 5 feet (4 feet in some states), a support system is required by federal law, except for excavations entirely in stable rock (very rare!). If an excavation is less than 5 feet deep (4 feet in some states), a support system is required if there is a potential for a cave-in, as determined by the "Competent Person."*

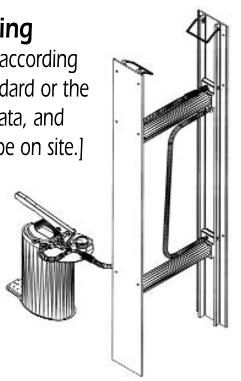
❑ Option #1– Sloping

[For excavations less than 20 feet deep.]

Soil Type	**Maximum Allowable Slope (H:V)**
Stable Rock	Vertical **or** 90˚
Type A	¾:1 **or** 53˚
Type B	1:1 **or** 45˚
Type C	1½ : 1 **or** 34˚

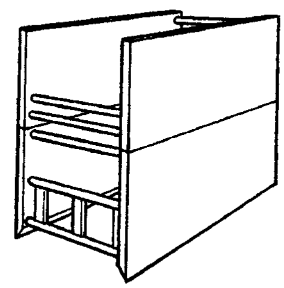
❑ Option #2 – Shoring

[Shoring must be installed according to charts in the OSHA standard or the manufacturer's tabulated data, and these charts or data must be on site.]



❑ Option #3 – Shielding

[Shielding must be installed according to the manufacturer's tabulated data, and this data must be on site.]



Note: A 4th option always available is a system designed by a Registered Professional Engineer

[Designs must be in writing, they must meet OSHA's requirement, and must be on site.]

34. Are materials and/or equipment chosen based upon soils analysis, trench depth and expected loads? ❑ YES ❑ NO ❑ N/A

35. Are materials and equipment that are used for protective systems inspected and in good condition? ❑ YES ❑ NO ❑ N/A

36. Are damaged materials and equipment immediately removed from service? ❑ YES ❑ NO ❑ N/A

37. Are damaged materials and equipment inspected by a Registered Professional Engineer after repairs are made and before being placed back in service? ❑ YES ❑ NO ❑ N/A

38. Are protective systems installed without exposing employees to hazards of cave-ins, collapses, or threat of being struck by materials or equipment? ❑ YES ❑ NO ❑ N/A

39. Are ALL members of support systems securely fastened together to prevent failure? ❑ YES ❑ NO ❑ N/A

40. Are support systems provided to insure stability of adjacent structures, buildings, roadways, sidewalks, etc.? ❑ YES ❑ NO ❑ N/A

41. Are excavations below the level of the base or footing supported, and approved by a Registered Professional Engineer? ❑ YES ❑ NO ❑ N/A

42. Does back-filling progress with the removal of the support system? ❑ YES ❑ NO ❑ N/A

43. Is a shield system installed to prevent lateral movement? ❑ YES ❑ NO ❑ N/A

44. Are employees prohibited from remaining in a shield system during vertical movement? ❑ YES ❑ NO ❑ N/A

Job Notes: ______________________________

Inspected by:

Construction techniques and equipment usage must be in accordance with all governmental regulations and manufacturers' instruction. All orders placed with TrenchSafety are subject to the terms, conditions, and warranty limitations contained in TrenchSafety's Rental and Sales Agreements.

Section 15

Rules and Regs &

Sanitary Survey

The Design Criteria document can be found in its entirety at:

http://www.tn.gov/environment/water/docs/water-supply/design.pdf

The Sanitary Survey document can be found in its entirety at:

http://www.tn.gov/environment/water/docs/water-supply/SSManual.pdf

Part 7 - PUMPING FACILITIES

7.0 GENERAL - Pumping facilities shall be designed to maintain the sanitary quality of pumped water. Subsurface pits or pump rooms and inaccessible installations should be avoided. No pumping station shall be subject to flooding.

7.1 LOCATION - The pumping station shall be so located that the proposed site will meet the requirements of the sanitary protection of the water quality, hydraulics of the system and be protected against interruption of service by fire, flood or any other hazard.

7.1.1 Site Protection - The station shall be:

a. elevated to a minimum of one foot above the 100-year flood elevation, or protected to such elevation;

b. accessible at all times unless permitted to be out of service for period of inaccessibility;

c. graded around station so as to lead surface drainage away from the station;

d. protected to prevent vandalism and entrance by unauthorized persons or animals.

7.2 GROUND WATER FACILITIES - Where pumping facilities are used, wells and springs shall be vented by properly hooded and screened pipe extending at least 12 inches above the pump floor. Where necessary, provision shall be made for lubricating the pump from a point at least 6 inches above the top of the well cover, by means which will prevent contamination of the water supply.

7.2.1 Drilled Wells - Pumping stations located over drilled wells shall;

a. have riser pipe or casing extending at least 6 inches, and preferably 12 inches, above the floor, and be equipped with flange or suitable stuffing box;

b. have riser pipe or casing firmly connected to the pump structure to provide a water tight connection.

c. have base of pump not less than 6 inches above pump room floor;

d. have pump foundation and base designed to prevent water from coming into contact with the joint.

7.2.2 Submersible Pumps - Where a submersible pump is used, the top of the casing shall be effectively sealed against entrance of water under all conditions of vibration or movements of conductors or cables.

7.2.3 Discharge Piping - Discharge piping should be provided with means to pump to waste but shall not be directly connected to a sewer. The discharge line shall:

a. have control valves located above pump floor;

b. be protected against freezing;

c. be valved to permit testing and control of each well;

d. have watertight joints;

e. have all exposed valves protected.

7.3 SURFACE WATER FACILITIES - Pump stations normally associated with surface water sources, either as raw or finished water pump stations, shall:

a. have adequate space for the installation of additional units if needed, and for the safe servicing of all equipment;

b. be of durable character, fire and weather resistant and with outward opening doors;

c. have floor elevation of at least 6 inches above finished grade;

d. have underground structure waterproofed;

e. have all floors drained without impairing the quality of water being handled and if equipment is contained on the floor, the floor shall have sufficient slope to drain adequately.

f. provide suitable outlet for drainage from-pump glands without discharging onto the floor.

7.3.1 Suction Well - Suction wells shall:

a. be watertight;

b. have floors sloped to permit removal of water and entrained solids;

c. be covered or otherwise protected against contamination; including pump lubricant.

7.3.2 Equipment Servicing - Pump facilities shall be provided with;

a. crane-ways, hoist beams, eye bolts, or other adequate facilities for servicing or removal of pumps, meters or heavy equipment;

b. openings in floors, roofs or wherever else needed for removal of heavy or bulky equipment;

c. a convenient tool board or other facilities as needed for proper maintenance of the equipment.

7.3.3 Stairways and Ladders - Stairways or ladder shall

a. be provided between all floors, in pits or compartments which must be entered.

b. have handrails on both sides, and treads of non-slip material.

Stairs are preferred in areas where there is frequent traffic or where supplies are transported by hand. They shall have risers not exceeding 9 inches and treads wide enough for safety.

7.3.4 Heating - Provision shall be made for adequate heating for:

a. comfort of the operator;

b. the safe and efficient operation of the equipment.

In pump houses not occupied by personnel, only enough heat need be provided to prevent freezing of equipment or treatment process.

7.3.5 Ventilation - Adequate ventilation shall be provided for all pumping stations. Forced ventilation of at least 6 changes of air per hour shall be provided for:

a. all rooms, compartments, pits and other enclosures below grade floor;

b. any area where unsafe atmosphere may develop or where excessive heat may be built up.

7.3.6 Dehumidification - In areas where excess moisture could cause hazards to safety or damage to equipment means for dehumidification shall be provided.

7.3.7 Lighting - Pump stations shall be adequately lighted throughout. All electrical work shall conform to the requirements of the American Insurance Association and related agencies and to relevant State and/or local codes.

7.3.8 Sanitary and Other Conveniences - Pumping stations which are manned for extended periods shall be provided with potable water, lavatory and toilet facilities. Plumbing must be so installed as to prevent contamination of a public water supply. Wastes shall be discharged in accordance with Section 4.11 of these standards.

7.3.9 Pumps - At least 2 pumping units shall be provided. Each pumping unit shall be capable of carrying the peak demand. If more than 2 units are installed, they shall have sufficient capacity so that any 1 pump can be taken out of service and the remaining pumps are capable of carrying the peak demand. The pumping units shall:

a. have ample capacity to supply the peak demand without dangerous overloading;

b. be driven by a prime mover able to operate against the maximum head and air temperature which may be encountered;

c. have spare parts and tools readily available.

3600 RPM pumps are not desirable and should be avoided if at all possible.

7.3.10 Suction Lift - Suction lift pumps will be considered on an individual basis based on justification of design engineer.

7.4 BOOSTER PUMPS - Booster pumps shall be located or controlled so that:

a. they will not produce negative pressure anywhere in the distribution system;

b. the pressure in the suction line shall be maintained at or above 20 psi by the use of a pressure sustaining valve or low pressure cutoff device.

c. automatic or remote control devices shall have a range between the start and cutoff pressure which will prevent excessive cycling.

7.4.1 In-line Booster Pumps - In addition to the other requirements of this section, in-line booster pumps shall be accessible for servicing and repairs.

7.4.2 The criteria in this section also apply to fire pumps.

7.4.3 Booster pumps shall not serve more than 50 service connections unless gravity storage is provided or service pressure can be maintained above 20 psi without the pumps running.

7.5 AUTOMATIC AND REMOTE CONTROLLED STATIONS - All automatic stations should be provided with automatic signaling apparatus which will report when the station is out of service. All remote controlled stations shall be electrically operated and controlled and shall have signaling apparatus of proven performance. Installation of electrical equipment shall conform with the National Electrical Code.

7.6 APPURTENANCES

7.6.1 Valves - Pumps shall be adequately valved to permit satisfactory operation, maintenance and repair of the equipment. If foot valves are necessary they shall have a net valve area of at least 2½ times the area of the suction pipe and they shall be screened. Each pump shall have a positive acting check valve on the discharge side between the pump and shutoff valve.

7.6.2 Piping - In general, piping shall:

a. be designed so that the friction head will be minimized;

b. not be subject to contamination;

c. have watertight joints;

d. be protected against surge or water hammer;

e. be such that each pump has an individual suction line or the lines shall be so manifolded that they will insure similar hydraulic and operation conditions.

7.6.3 Gauges and Meters - Each pump shall:

a. shall have a standard pressure gauge on its discharge line;

b. shall have a compound gauge on its suction line;

c. shall have recording gauges in larger stations;

d. should have a means for measuring the discharge.

The larger stations should have indicating, totalizing and recording metering of the total water pumped.

7.6.4 Water Seals - Water seals shall not be supplied with water of a lesser sanitary quality than that of the water being pumped.

7.6.5 Controls - Pumps, their prime movers and accessories, shall be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision shall be made for proper alternation. Provision shall be made to prevent operation of the pump during the backspin cycle. Electrical controls should be located above grade.

7.6.6 Power - When power failure would result in cessation of minimum essential service, power supply shall be provided from at least two independent sources or standby or auxiliary source shall be provided.

7.6.7 Auxiliary Power Supply - When automatic pre-lubrication of pump bearings is necessary, and an auxiliary power supply is provided, the pre-lubrication line shall be provided with a valved by-pass around the automatic control.

Part 8 - FINISHED WATER STORAGE

8.0 GENERAL - The materials and designs used for finished water storage structures shall provide stability and durability as well as protect the quality of the stored water. Steel structures shall follow the current AWWA standards concerning steel tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable. Prestressed concrete tanks shall meet applicable AWWA Standards. Other materials of construction are acceptable when properly designed to meet the requirements of this part.

8.0.1 Location

a. The bottom of ground-level reservoirs should be placed at the normal ground surface and above maximum flood level.

b. Where the bottom must be below normal ground surface, it should be placed above the ground water table. Sewers, drains, standing water, and similar sources of contamination must be kept at least 50 feet from the reservoir. Mechanical-joint water pipe, pressure tested in place to 50 psi without leakage, may be used for gravity sewers at lesser separations.

c. The top of a ground-level reservoir should not be less than 2 feet above normal ground surface and any possible flood level. Clearwells constructed under filters may be excepted from this requirement when the total design gives the same protection.

8.0.2 Protection - All new finished water storage structures shall have suitable watertight roofs or covers which exclude birds, animals, insects, and excessive dust.

8.0.3 Protection from Trespassers - Fencing, locks on access manholes, and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage.

8.0.4 Drains - No drain on a water storage structure may have a direct connection to a sewer or storm drain. Splash pad and drainway shall be provided to prevent erosion.

8.0.5 Overflow - The overflow pipe of a water storage structure should be brought down near the ground surface and discharged over a drainage inlet structure or a splash plate and flow onto a drainway which is rip-rapped or otherwise protected to minimize erosion. No overflow may be connected directly to a sewer or storm drain.

a. When an internal overflow pipe is used, it shall be located in the access tube.

b. The overflow of a ground-level structure shall be high enough above normal or graded ground surface to prevent the entrance of surface water.

c. The overflow shall be protected with a twenty-four mesh non-corrodible screen and a flap valve.

8.0.6 Access - Finished water storage structures shall be designed with reasonably convenient access to the interior for cleaning and maintenance. Manholes on scuttles above waterline:

a. shall be framed at least 4 inches, and preferably 6 inches, above the surface of the roof at the opening; on ground-level structures manholes should be elevated 24 to 36 inches above the top or covering sod;

b. shall be fitted with a solid watertight cover which overlaps the framed opening and extends. down around the frame at least 2 inches;

c. should be hinged at one side;

d. shall have a locking device,

e. shall be a minimum of 20 inches in diameter or equivalent.

8.0.7 Vents - Finished water storage structures shall be vented by special vent structures. Open construction between the side wall and roof is not permissible. These vents:

a. shall prevent the entrance of surface water;

b. shall exclude birds and animals;

c. shall exclude insects and dust, as much as this function can be made compatible with effective venting; for elevated tanks and standpipes, 4-mesh non-corrodible screen may be used;

d. shall, on ground-level structures, terminate in an inverted U construction, the opening of which is 24 to 36 inches above the roof of sod and is covered with 24-mesh non-corrodible screen cloth.

8.0.8 Roof and Sidewall - The roof and sidewalls of all structures must be watertight with no openings except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.

a. Any pipes running through the roof or sidewall of a finished water storage structure must be welded or properly gasketed in metal tanks, or should be connected to standard wall castings which were poured in place during the forming of a concrete structure; these wall castings should have flanges embedded in the concrete.

b. openings in a storage structure roof or top, designed to accommodate control apparatus or pump columns, shall be curbed and sleeved with proper additional shielding to prevent the access of surface or slop water to the structure.

c. Valves and controls should be located outside the storage structure so that valve stems and similar projections will not pass through the roof or top of the reservoir.

8.0.9 Drainage for Roof or Cover - The roof or cover of the storage structure should be well drained, but downspout pipes shall not enter or pass through the reservoir; parapets, or similar construction which would tend to hold water and snow on the roof will not be approved.

8.0.10 Safety - The safety of employees must be considered in the design of the storage structure. As a minimum, such matters shall conform to pertinent laws and regulations.

a. Ladders, ladder guards, balcony railings, and safe location of entrance hatches shall be provided where applicable.

b. Elevated tanks with riser pipes over 8 inches in diameter shall have protective bars over the riser openings inside the tank.

8.0.11 Freezing - All finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents, shall be designed to prevent freezing which will interfere with proper functioning.

8.0.12 Grading - The area surrounding a ground-level structure should be graded in a manner that will prevent surface water from standing within 50 feet of the structure.

8.0.13 Silt stop - The discharge pipe of the reservoir shall be located in a manner that will prevent the flow of sediment into the distribution systems. Either a permanent or removable silt stop shall be provided at least 4 inches above the bottom of the storage structure.

8.0.14 Painting and/or Cathodic Protection - Proper protection should be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both.

a. Paint systems consistent with current American Water Works Association standards, or otherwise acceptable to the Department shall be used. All paints must be acceptable to FDA and EPA for contact with potable water.

b. Cathodic protection should be designed and installed by competent technical personnel.

8.0.15 Turnover of water - If the storage reservoir is sized larger than required for initial demand and there is more than 2 days storage, provisions shall be made for turnover of the water in the tank and/or booster chlorination. Internal piping arrangements to prevent water stratification in ground level standpipes are recommended. For large, ground level tanks/reservoirs, piping and/or check valves can be installed to force water in and out of the tank at different locations in order to minimize dead/stagnant water zones.

8.0.16 Sampling - A suitable sampling tap should be provided on all storage structures and be protected from public access.

8.0.17 Disinfection - Finished water storage structures shall be disinfected in accordance with AWWA Standard C652 before being put in service.

8.1 PLANT STORAGE - The applicable design standards of this part shall be followed for plant storage.

8.1.1 Washwater Tanks - If washwater tanks are used, they shall be sized, in conjunction with available pump units and finished water storage, to give the back wash water required by Section 4.2.1.K.

a. Consideration must be given to the possibility of having to wash more than one filter at a time, or several filters in succession.

8.1.2 Clearwell - Clearwell storage should be sized, in conjunction with distribution system storage, to relieve the filters from having to follow fluctuations in water use to meet peak demands, including filter backwash water. Design shall include features to minimize short circuiting.

a. When finished water storage is used to provide proper contact time for chlorine, (see Section 4.4.2), special attention must be given to size and baffling.

b. An overflow shall be provided and must be protected with a screen and flap valve.

8.1.3 Adjacent Compartments - finished water must not be stored or conveyed in a compartment adjacent to unsafe water when the two compartments are separated by a single wall.

8.1.4 Basins and Wet-Wells - Receiving basins and pump wet-wells for finished water shall be designed as finished water storage structures.

8.2 PRESSURE TANKS - Hydropneumatic (pressure) tanks may be acceptable in some circumstances where the number being served is 50 connections or less. When used, they shall meet ASME code requirements or equal which comply with the requirements of state and local laws and regulations for the construction and installation of unfired pressure vessels.

8.2.1 Location - The tank should be located above normal ground surface and be completely housed, or earth-mounted with one end projecting into an operating house, to prevent freezing.

8.2.2 Bypass - tank should have bypass piping to permit operation of the system while the tank is being repaired or painted.

8.2.3 Appurtenances - Each tank should have an access manhole, a drain, a control equipment consisting of pressure gage, water sight glass, automatic or manual air blow-off, mechanical means for adding air, and pressure-operated start-stop controls for the pumps.

8.2.4 Sizing -

a. The capacity of each well and/or pump in a hydropneumatic system should be at least ten times the average daily consumption rate of the community or the maximum peak demand whichever is greater.

b. The gross volume of the hydropneumatic tank, in gallons, should be at least 20 times the capacity of the largest pump, rated in gallons per minute.

8.2.5 Auxiliary power - Auxiliary power with automatic takeover capability shall be provided when positive pressures are not available from system gravity flow.

8.3 DISTRIBUTION STORAGE - The applicable design standards of this part shall be followed for distribution storage.

8.3.1 The purpose of system storage is to have sufficient water available to provide adequate flow and pressure at peak demand as well as to provide for fire flows when needed. For most water systems a satisfactory rule-of-thumb to meet these needs is to provide at least the average 24-hour demand in elevated storage. In the absence of an acceptable engineering study of the amount of water the system needs to meet customer demand and to provide for fire emergencies, the projected 24-hour demand at the end of the planning period will be the minimum requirement for elevated storage. This requirement may be reduced when the source, treatment facilities and pumps have sufficient capacity with standby power capability to supplement peak demands of the system.

8.3.2 Pressure Variation - System pressure variation on account of changes in level of water in storage structures should be minimized. Elevated storage tanks or large diameter ground tanks located on high ground should be the usual choices. Standpipes will not normally be approved and must be completely justified if proposed.

8.3.3 Drainage - Storage structures which float on the distribution system should be designed to drain for cleaning or maintenance without necessitating loss of pressure in the distribution system. The drains should discharge to the ground surface with no direct connection to a sewer or storm drain. (See Section 8.0.4). A nearby fire hydrant may be considered as a drain as long as service is not interrupted and suitable erosion protection is provided.

8.3.4 Level Controls - Adequate controls shall be provided to maintain levels in distribution system storage structures.

a. Telemeter equipment should be used when pressure-type controls are employed and any appreciable head loss occurs in the distribution system between the source and the storage structure.

b. Altitude valves or equivalent controls may be required for a second and subsequent structures on the system.

c. Overflow and low-level warnings or alarms should be located at places in the community where they will be under responsible surveillance on a 24-hour basis.

Part 9 - DISTRIBUTION SYSTEMS

9.0 SYSTEM DESIGN

9.0.1 Minimum Pipe Size

a. The minimum size of pipe for principal water mains and for water mains where fire hydrants are to be attached shall be 6-inch diameter.

b. Size of water mains shall be justified by hydraulic analysis. 2-inch water mains will only be considered for short cul-de-sacs and permanent dead-ends where future growth is not feasible. The length of 2-inch mains shall be restricted to 3000 feet in any one direction.

c. All water mains including those not designed to provide fire protection shall be sized after a hydraulic analysis based on flow demands and pressure requirements. The system shall be designed to maintain a minimum pressure of 20 psi at ground level at all points in distribution system under all conditions of flow.

d. Wide variations in pressure above the minimum requirement of 20 psi may be inherent in the design of a distribution system but pressures no greater than 100 psi should be delivered to the customer (unless higher pressures are requested.). Main line pressure reducing valves can be used to reduce pressures below 100 psi where feasible. Where water pressures over 100 psi are necessary to the operation of the distribution system, customers must have individual pressure reducing valves.

e. All assumptions and any flow data used must be clearly documented and submitted with the hydraulic analysis. if actual flow data is not available theoretical calculations shall be based on all storage facilities half-full and the Hazen-Williams friction factor appropriate for type of pipe being used but in no case greater than 130.

f. Water distribution lines should be designed and sized for an instantaneous peak demand of 2 gpm per connection for water lines serving up to 100 residential connections. Peak design demands can be reduced to 1.5 gpm per connection for 150 residential connections, 1.0 gpm per connection for 300 residential connections, 0.75 gpm per connection for 500 residential connections, and 0.5 gpm per connection for 1000 or more residential connections.

9.0.2 Fire Protection

a. The minimum pipe size to which a fire hydrant may be connected is 6-inch.

b. Ordinarily fire hydrants shall not be connected to water mains which are not capable of providing a flow of 500 gpm at 20 psi. When a municipality or county enacts a restrictive use ordinance prohibiting pumper trucks from connecting to restricted fire hydrants which are painted a distinctive color and when a copy of this ordinance in on file at this office, we will permit fire hydrants to be connected to 6-inch mains which do not have the required pressure and flow.

c. When fire protection is to be provided, system design should consider the recommendations of the state Insurance Services Organization.

d. Fire hydrants shall meet current AWWA Standard C502.

9.0.3 Dead Ends

a. Dead ends shall be minimized.

b. Where dead-end mains occur they should be provided with a fire hydrant, when fire flows are available, or blow-off for flushing purposes. The blow-off shall be at least 2 inches in diameter, but should provide flushing velocities of 2 feet per second or greater.

c. No flushing device shall be directly connected to any sewer nor be subject to flooding or plugging.

9.1 INSTALLATION OF MAINS

9.1.1 Adequate support shall be provided for all pipes.

9.1.2 A continuous and uniform bedding shall be provided in the trench for all buried pipe.

9.1.3 Rock Excavation - Stones found in the trench shall be removed for a depth of at least six inches below the bottom of the pipe.

9.1.4 Cover - All distribution mains shall be provided with sufficient earth or other suitable cover to prevent freezing. This shall not be less than 30 inches measured above the top of the pipe.

9.1.5 Hydrostatic Tests

a. Pressure and leakage tests shall be performed in accordance with current AWWA Standard C600 and/or manufacturer's installation procedures.

b. The test pressure of the installed pipe shall be a minimum of 150 psi or 1.5 times the working pressure, whichever is greater.

c. Allowable leakage shall be no greater than as calculated in $L = SD /P/133,200$ where L is allowable leakage in gallons/hour, S is the length of pipe tested in feet, D is pipe diameter in inches and P is test pressure in psi.

9.1.6 Disinfection of New Water Mains - The specifications shall include detailed procedures for the adequate flushing, disinfection, and (Total Coliform) bacteriological testing of all new water mains. Disinfection as described in current AWWA Standard C651 will be accepted.

9.1.7 Disinfection When Cutting into or Repairing Existing Mains:

a. Shall be performed when mains are wholly or partially dewatered;

b. Shall follow current AWWA C651 procedures including trench treatment, swabbing with hypochlorite solution, flushing and/or slug chlorination as appropriate;

c. Bacteriological testing should be done after repairs are complete but the water main may be returned to service prior to completion of testing to minimize the time customers are out of water;

d. Leaks or breaks that are repaired with clamping devices while mains remain full of water under pressure require no disinfection.

9.1.8 When non-metallic pipe is installed, detection tape or other acceptable means of detection shall be installed.

9.2 SEPARATION OF WATER MAINS AND SEWERS

9.2.1 General - The following factors should be considered in providing adequate separation:

a. materials and type of joints for water and sewer pipes;

b. soil conditions;

c. service and branch connections into the water main and sewer line;

d. compensating variations in the horizontal and vertical separations;

e. space for repair and alterations of water and sewer pipes;

f. off-setting of pipes around manholes;

g. water mains and sanitary or storm sewers shall not be laid in the same trench.

9.2.2 Parallel Installation

a. Normal conditions - Water mains shall be laid at least 10 feet horizontally from any sanitary sewer, storm sewer or sewer manhole, whenever possible; the distance shall be measured edge-to-edge.

b. Unusual conditions - When local conditions prevent a horizontal separation of 10 feet, a water main may be laid closer to a storm or sanitary sewer provided that:

1. the bottom of the water main is at least 18 inches above the top of the sewer;

2. where this vertical separation cannot be obtained, the sewer shall be constructed of materials and with joints that are equivalent to water main standards of construction and shall be pressure tested to assure water-tightness prior to backfilling.

9.2.3 Crossings

a. Normal conditions - Water mains crossing house sewers, storm sewers or sanitary sewers shall be laid to provide a separation of at least 18 inches between the bottom of the water main and the top of the sewer, whenever possible.

b. Unusual conditions - when local conditions prevent a vertical separation as described in Section 9.2.3a, the following construction shall be used:

1. Sewers passing over or under water mains should be constructed of the materials described in Section 9.2.2b2.

2. Water mains passing under sewers shall, in addition, be protected by providing:

i. a vertical separation of at least 18 inches between the bottom of the sewer and the top of the water main;

ii. adequate structural support for the sewers to prevent excessive deflection of joints and settling on and breaking the water mains;

iii. that the length of water pipe be centered at the point of crossing so that the joints will be equidistant and as far as possible from the sewer.

iv. both the sewer and the water main shall be constructed of water pipe and tested in accordance with Section 9.1.5.

9.2.4 Sewer manholes - No water pipe shall pass through or come into contact with any part of a sewer or sewer manhole.

9.3 SURFACE WATER CROSSINGS - Surface water crossings, both over and under water, present special problems which should be discussed with the Department before final plans are prepared.

9.3.1 Above-water crossings - The pipe shall be:

a. adequately supported;

b. protected from damage and freezing;

c. accessible for repair or replacement.

9.3.2 When crossing water courses which are greater than 15 feet in width:

a. The pipe shall be of special construction, having flexible, watertight joints;

b. Valves shall be provided at both ends of water crossing so that the section can be isolated for test or repair; the valves shall be easily accessible and not subject to flooding;

c. Sampling taps should be available at each end of the crossing;

d. Permanent taps should be made for testing and locating leaks.

9.4 CROSS CONNECTIONS

a. There shall be no physical connection between the distribution system and any pipes, pumps, hydrants, or tanks whereby unsafe water and other contaminating materials may be discharged or drawn into the system.

b. The approval of the Department shall be obtained for interconnections between potable water supplies.

c. Neither steam condensate nor cooling water from engine jackets or other heat exchange devices shall be returned to the potable water supply.

9.5 WATER SERVICES AND PLUMBING - Water services and plumbing shall conform to relevant local and/or state plumbing codes, or to the Standard Plumbing Code.

9.6 MATERIALS - GENERAL

a. Pipe selected shall have been manufactured in conformity with the latest standards issued by the American Water Works Association, if such standards exist, and be acceptable to the Department.

b. in the absence of such standards, pipe meeting applicable ASTM and ANSI criteria and acceptable to the Department may be selected.

c. Used water mains that meet these standards may be used again, after the pipe has been thoroughly cleaned and restored practically to its original condition.

d. Packing and jointing materials used in the joints of pipe shall meet the standards of the American Water Works Association or the Department.

e. Mechanical joints or slip-on joints with rubber gaskets are preferred.

9.7 PIPE

9.7.1 Ductile iron and cast iron pipe shall meet the latest requirements of ANSI/AWWA - C106 or CIO8 for cast iron pipe and C151 for ductile iron pipe.

9.7.2 Concrete pressure pipe shall meet the latest requirements of AWWA C300 or AWWA C301.

9.7.3 PVC pipe - 2 inch through 12 inch

a. PVC pipe meeting the standards set forth in AWWA C-900 (latest edition) will be accepted for those working pressures as designated by class. (Note that C-900 refers only to 4-inch through 12-inch pipe).

b. SDR 21, Class 200 pressure rated pipe may be used where the working pressure does not exceed 135 psi. The pipe must meet all the requirements set forth in ASTM Standard D 2241 for 2-inch through 12-inch pipe designated SDR 21. The pipe must bear the National Sanitation Foundation Testing Laboratories, Inc. seal of approval for potable water, or an approved equal.

c. Provision must be made for contraction and expansion at each joint with flexible ring gaskets made from rubber or other suitable material. Gasket materials shall meet the requirements established in ASTM F477.

d. Joints for PR 200 (pressure rated) pipe (ASTM D2241) shall be manufactured in accordance with ASTM D3139. Section 5.3.1 of this standard refers to 2000-hour tests. If pipe is manufactured in accordance with that section, the testing must be done by an independent laboratory with the results being furnished to this Department. Note also that a separate test is required for each different type of gasket provided.

e. All fittings such as tees, ells, etc. using welded joints shall be factory welded and shall meet the same specifications as the welded bell section.

f. Lubricants shall be non-toxic and shall not promote biological growth.

g. Solvent cemented joints in the field are not permitted.

h. Forty-foot lengths will be permitted when the engineering specifications contain special conditions for handling such pipe lengths. These conditions shall include provisions for transporting pipe from storage areas to the installation area on specially designed racks to prevent the ends of the pipe from dragging.

i. This policy does not apply to plastic service lines.

9.7.4 Fiberglass Composite Pipe shall be composed of an inner core of PVC overwrapped with fiberglass bonded with epoxy. 350 Pressure Rated shall be in accordance with ASTM D-2992 and D-2996.

9.7.5 Polyethylene pipe for water distribution lines shall meet the requirements of AWWA C906.

9.7.6 Molecular oriented PVC pipe shall meet the requirements of AWWA C909.

9.7.7 Any pipe material which is not specifically covered in this section will be considered on an individual basis.

9.8 VALVE, AIR RELIEF, METER AND BLOW-OFF CHAMBERS

a. Sediment accumulations may be removed through a standard fire hydrant, and compressed air and pumping may be used for dewatering mains through hydrants.

b. At high points in water mains where air can accumulate, provisions shall be made to remove the air by means of hydrants or air relief valves. Automatic air relief valves shall not be used in situations where flooding of the manhole or chamber may occur.

c. Chambers of pits containing valves, blow-offs, meters or other such appurtenances to a distribution system, shall not be connected directly to any storm drain or sanitary sewer, nor shall blowoffs or air-relief valves be connected directly to any sewer.

d. Such chambers or pits shall be drained to the surface of the ground where they are not subject to flooding by surface water, or to absorption pits underground.

e. Valves are to be placed at all intersections of water mains but at no time greater than 4000 feet apart.

f. Gate valves shall meet current AWWA standards.

(Rule 0400-45-01-.15, continued)

by the Environmental Protection Agency will have compliance with the MCL determined on the analytical results of its sampling.

(3) Those public water systems which purchase all their water and elect to use the analytical results of the system from which it purchases water shall be deemed to be in compliance with the monitoring and MCL requirements provided the seller of water is in compliance. Any violation of an MCL or monitoring requirement by the seller of water will constitute a violation for all systems which purchase water unless samples are taken as described in paragraph (2) of this rule.

(4) All public notification requirements as contained in Rule 0400-45-01-.19 are the responsibility of the individual public water system regardless of which public water system conducts the analysis.

(5) All public water systems must maintain records as required by Rule 0400-45-01-.20 of all analytical results which pertain to the system regardless of which system actually did the analysis.

Authority: *T.C.A. §§ 68-221-701 et seq. and 4-5-201 et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.16 SITING REQUIREMENTS.

(1) Before a person may enter into a financial commitment for or initiate construction of a new public water system or increase capacity of an existing public water system, he shall notify the Department and, to the extent practicable, avoid locating part or all of the new or expanded facility at a site which:

(a) Is subject to a significant risk from earthquakes, floods, fires, or other disasters which could cause a breakdown of the public water system or a portion thereof; or

(b) Except for intake structures, is within the flood plain of a 100-years flood.

(2) All other siting requirements shall be in accordance with those set forth in “Design Criteria for Public Water Systems” as published by the Department.

Authority: *T.C.A. §§ 68-221-701 et seq. and 4-5-201 et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.17 OPERATION AND MAINTENANCE REQUIREMENTS.

(1) All community water systems which are designated as a surface supply and classified as a filtration system and all iron removal plants which use gravity filters must have an operator in attendance and responsible for the treatment process when the plant is in operation. Gravity iron removal plants which have installed continuous monitoring equipment including equipment for turbidity and chlorine residual with alarms and/or shutdown ability may seek approval from the Department to operate the treatment plant in an automated mode without an operator in attendance. All iron removal plants with pressure filters and using a ground water source from an approved sand and gravel formation will not be required to have an operator in attendance during all periods of operation provided suitable protection, acceptable to the Department, is provided.

Non–community water systems which are classified as a surface supply will be required to have a full time operator in attendance unless certain continuous monitoring equipment is installed.

(Rule 0400-45-01-.17, continued)

Pursuant to T.C.A. § 68-221-904, all operators in direct responsible charge of a water supply system, including the treatment plant and/or distribution system, must be certified by the Department as competent to operate same.

Because the proper operation and maintenance of water systems is critical to a system's ability to provide safe water to the public and to comply with these rules, all water supply systems must comply with the provisions of Chapter 0400-49-01. A violation of those rules is a violation of this rule as well.

(2) All community water systems and those non-community water systems classified as a surface source shall compile and maintain accurate daily operating records of the water works system on forms prepared and furnished by the Department. The daily operating records shall be submitted in a timely manner so they are received by the Department no later than ten days after the end of the reporting month. Any special reports, deemed necessary by the Department to assure continuous satisfactory operation of the water system, shall be submitted to the Department.

Water systems which desire to use their own forms to report the daily operating results to the Department must have prior approval of the form from the Department.

(3) All water quality tests, other than those listed in Rule 0400-45-01-.06 shall be made in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" or alternate methods acceptable to the Department. The schedule of laboratory tests followed in controlling the operation of a waterworks system will vary with the character of the water; therefore, all waterworks systems must have the equipment necessary to perform all laboratory tests pertinent to the control of the plant or system operation, and the equipment shall be maintained in good working order at all times. Laboratory tests pertinent to proper operation shall be prescribed by the Department for each community water system.

(4) Chlorine is the recommended disinfection agent. Other agents will be considered by the Department provided they are effective and testing procedures for their effectiveness are recognized in the latest edition of "Standard Methods for the Examination of Water and Wastewater". All community water systems, using ground water as a raw water source and serving more than 50 connections or 150 persons shall continuously chlorinate (unless other disinfection methods are approved) and shall maintain a free chlorine residual in all parts of the distribution system in the amount of not less than 0.2 mg/l. Public Water Systems using surface water shall continuously chlorinate and maintain a free chlorine residual of 0.2 mg/l in all parts of the distribution system. The residual disinfectant concentration specified by this rule shall not be less than 0.2 mg/l in more than 5 percent of the samples each month, for any two consecutive months the system serves water to the public. All public water systems serving 50 or fewer connections that do not disinfect shall install continuous disinfection if the system fails to comply with the maximum contaminant level for coliform, experiences a disease outbreak or is directed to install disinfection by the department.

(5) All systems submitting samples for microbiological examination to the State laboratory must submit said sample in the bottle(s) provided by the State and return the samples to the proper State laboratory in the shipping carton provided by the State. The cost of postage for shipping the sample to the proper State laboratory shall be paid by the supplier of water. All samples submitted for microbiological examination must be collected and mailed to arrive at the proper State laboratory not later than Thursday noon of any week. Thirty hours is the limit allowed from the time of collection to the time of examination at the proper state laboratory.

(6) Pursuant to T.C.A. § 68-221-711(6) the installation, allowing the installation, or maintenance of any cross–connection, auxiliary intake, or bypass is prohibited unless the source and quality of water from the auxiliary supply, the method of connection, and the use and

(Rule 0400-45-01-.17, continued)

operation of such cross–connection, auxiliary intake, or bypass has been approved by the Department. The arrangement of sewer, soil, or other drain lines or conduits carrying sewage or other wastes in such a manner that the sewage or waste may find its way into any part of the public water system is prohibited.

All community water systems must adopt an ordinance or policy prohibiting all of the above and submit a copy of the executed ordinance or policy to the Department for approval. All community water systems shall develop a written plan for a cross–connection control program to detect and eliminate or protect the system from cross–connections. The written plan must be approved by the Department.

After adoption and approval of the cross–connection ordinance or policy and plan, each community water system must establish an ongoing program for the detection and elimination of hazards associated with cross–connections. Records of the cross–connection control program must be maintained by the water supplier and shall include such items as date of inspection, person contacted, recommendations, follow–up, and testing results.

(a) Public water systems must develop and implement an ongoing cross-connection program. Cross-connection plans and policies shall present all information in conformance with the "Design Criteria for Community Public Water Systems" as published by the Department.

(b) The public water system shall ensure that cross-connections between the distribution system and a consumer's plumbing are surveyed and/or inspected and determined not to exist or contain a significant risk or are eliminated or controlled by the installation of an approved backflow preventer commensurate with the degree of hazard.

(7) Within one year after the effective date of these regulations all community water system shall prepare an emergency operations plan in order to safeguard the water supply and to alert the public of unsafe drinking water in the event of natural or man-made disasters. Emergency operation plans shall be consistent with guidelines established by the Department and shall be reviewed and approved by the Department.

(8) (a) General-Public water systems, construction contractors and engineers shall follow and document sanitary practices used in inspecting, constructing or repairing water lines, finished water storage facilities, filters and wells. In lieu of writing their own disinfection standard operating procedures, public water systems, engineers and contractors may chose to follow the latest edition of the AWWA standards C-651, C-652 or equivalent methods provided the method has been approved in writing by the department and is available during the inspection, construction, maintenance or repair activity. The documentation shall include bacteriological sample results, construction logs, standard operating procedures and may include photographs where appropriate. All pipes, tanks, filters, filter media and other materials shall be properly disinfected prior to being placed in service. Any disinfectant used to disinfect shall be NSF approved or plain household bleach and used in a manner that assures sufficient contact time and concentration to inactivate any pathogens present. Bacteriological results including line repair records indicating adequacy of disinfection shall be maintained on file by the water system for five years. All public water systems, contractors, and engineers shall prepare and follow standard disinfection procedures approved by the Department when inspecting, maintaining, repairing or constructing lines, tanks, filters and wells. Procedures to ensure that water containing excessive concentrations of disinfectant is not supplied to the customers or discharged in such manner as to harm the environment shall be implemented.

All materials used for new or repaired water lines, storage facilities, filters, filter media, and wells will be inspected prior to use for any evidence of gross contamination. Any

(Rule 0400-45-01-.17, continued)

contamination observed shall be removed and the materials protected during installation.

(b) Disinfection of New Facilities-Bacteriological samples will be collected and analyzed to verify the effectiveness of the disinfection practices prior to placing new facilities in service. Bacteriological samples shall be collected to determine the effectiveness of the installation process including protecting the pipe material during storage, installation, and disinfection. This can be demonstrated by collecting two sets of microbiological samples 24 hours apart or collecting a single set of microbiological samples 48 hours or longer after flushing the highly chlorinated water from the lines. In either case microbiological samples in each set will be collected at approximately 2,500-foot intervals with samples near the beginning point and at the end point unless alternate sampling frequency and distance between sampling points approval has been obtained from the Department. Where sanitary conditions were not maintained before, during or after construction, an additional bacteriological sample shall be collected from a location representing the water from the contaminated area. Unsanitary conditions include failure to document the sanitary handling of materials, to conduct construction inspections and to maintain records, and to document sanitary practices during construction and other hazards such trench flooding during construction. If the constructed facility yields positive bacterial samples, additional flushing, disinfection and bacteriological sampling shall be repeated until the water is coliform free.

(c) Disinfection of Existing Facilities-Drinking water mains, storage facilities and filters that have been partially dewatered during inspection or repair shall, after the repair or inspection is completed, be disinfected, and flushed prior to placing it back in service. Bacteriological samples shall be collected immediately or as soon as possible after the repair is completed and from a location representing the water contained in the repaired line, tank or filter. The repaired facility may be returned to service prior to obtaining bacteriological results. If the repaired facility yields positive bacterial samples, additional flushing, disinfection and bacteriological sampling shall be repeated until the water is coliform free.

1. If one-half or more of either the original or repeat bacteriological samples collected from the repaired or renovated facility are total coliform positive, the system shall notify the Department within 30 days that it has reviewed its disinfection and sampling practices in an attempt to identify why the positive samples occurred and revise its disinfection and sampling plans accordingly.

2. If any public water system collects a fecal coliform positive repeat sample or e-coli positive repeat sample or a total coliform positive repeat sample following an initial positive fecal coliform or e-coli sample collected from the repaired or renovated facility, the system shall notify the Department within 24-hours and issue a tier 1 public notice using the language specified in Appendix B of Rule 0400-45-01-.19.

(d) Inspectors, contractors, operators, public water systems or engineers that fail to document and follow adequate disinfection procedures, and fail to collect bacteriological samples during repairs, inspections or maintenance activities that potentially would compromise the microbial quality of the water shall issue a boil water advisory to the customers served by that portion of the public water system prior to returning the facility to service. The boil water advisory shall remain in effect until satisfactory microbial tests results are obtained.

(9) All community water systems shall be operated and maintained to provide minimum positive pressure of twenty (20) psi throughout the distribution system. No person shall install or maintain a water service connection to any premises where a booster pump has been

(Rule 0400-45-01-.17, continued)

installed unless such booster pump is equipped with a low pressure cut-off mechanism designed to cut off the booster pump when the pressure on the suction side of the pump drops to twenty (20) psi gauge.

(10) All community water systems having more than 50 service connections shall establish and maintain an adequate flushing program. The flushing program established shall help ensure that dead end and low usage mains are flushed periodically, drinking water standards are met, sediment and air removal and the free chlorine residual specified under paragraph (4) of this rule is maintained. Records of each flushing are to be maintained by the water system. These records shall include date, time, location, persons responsible and length of flushing. In addition to the above information, the free chlorine residual will have to be measured and recorded on the end of dead end mains after being flushed.

(11) All community public water systems serving more than 50 connections and which have their own source of water shall be required to install, operate and maintain duplicate disinfection equipment. Duplicate disinfection equipment means at least two chlorine cylinders connected to at least two chlorinators. Each set of chlorine cylinders consists of one or more cylinders which may be connected together by an automatic switchover valve. The two sets of chlorine cylinders may tee in to a common feed line leading to the chlorinators, but may not be connected together by an automatic switchover valve. The two sets of chlorine cylinders must be weighed independently and operated simultaneously. At least two chlorinators must be operated at all times with each feeding a part of the required dosage. The chlorinators may discharge to a common manifold piping network to allow multiple injection points. Facilities may be exempt from simultaneously operating duplicate disinfection equipment if the facility has a reliable chlorine residual analyzer with an alarm notifying a manned control center capable of immediately shutting down the treatment facility. Facilities, which are staffed during the time water is treated, can use one set of chlorine cylinders with the automatic switchover device provided the free chlorine residual is checked at the facility every two hours. A reliable free chlorine residual analyzer with an alarm system to a manned control center may be used for unmanned facilities that desire to use one set of chlorine cylinders with the automatic switchover device.

Community public water systems serving more than 50 service connections which use a hypochlorinator shall be required to have two solution pumps, two tanks for bleach solution and operate both units at the same time. Noncommunity systems and community systems serving less than 50 connections which use a hypochlorinator and show deficiencies in the disinfection process shall also be required to have duplicate disinfection units.

(12) All public water systems which utilize a filtration system shall use the following bed specifications and not exceed the following rates of filtration.

(a) Rapid Sand Filtration - 2.0 gallons per minute per square foot for turbidity removal, 3.0 gallons per minute per square foot for iron removal.

There must be 30 inches of sand media with an effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70

(b) High Rate Filtration - 4.0 gallons per minute per square foot for turbidity removal, 4.0 gallons per minute per square foot for iron removal.

There must be 30 inches of dual media with 10 to 12 inches of sand and 18 to 20 inches of anthracite. The sand shall have an effective size of 0.35 mm to 0.55 mm and a uniformity coefficient not greater than 1.70. The anthracite shall have an effective size of 0.8 mm to 1.2 mm with a uniformity coefficient not greater than 1.85.

(Rule 0400-45-01-.17, continued)

(c) Existing water systems with rapid sand filters and approved for higher rates of filtration by the Department will be allowed to continue at that rate provided the drinking water standards are met. The water supplier must be able to document that the Department approved the system for the higher rate.

(d) All mixed media filter beds will be at least 30 inches in depth and approved by the Department.

(e) Filtration rates above 4.0 gallons per minute per square foot will be considered on an individual basis. The Department will take into account the raw water characteristics, the treatment units, operational history, and operating personnel.

(13) All community water systems serving 50 connections or more shall install duplicate pumps for the raw water, finished water, and distribution pumping stations. A water system will not be required to have duplicate pumps in a distribution pumping station under the following conditions: limited number of service connections, availability of replacement pumps, maintaining adequate flows and pressures without the pumping station, and for emergency use only. All community public water systems using ground water supplies and having more than 50 service connections must have duplicate wells and/or duplicate pumps in a spring supply unless fed by gravity flow.

(14) All community water systems serving 50 connections or more are required to have 24 hours of distribution storage based on the average daily demand for the past twelve months. Distribution storage must be located so that the instantaneous demand can be met in all areas at any time.

(a) Systems which purchase water for resale may utilize the storage of the supplier provided the supplier has adequate distribution storage. Water systems that have large ground storage tanks will be given credit for distribution storage provided auxiliary power is available to pump water to the distribution system.

(b) Systems which have more than three (3) treatment facilities, have more than one source of water, and which have special power arrangements so that it is unlikely that all units would be down at the same time are not required to have distribution storage provided the peak demand can be met.

(c) Water systems which have an average daily demand of 10 million gallons or more are not required to have 24 hours of distribution storage provided the system has adopted a contingency plan for emergencies that has been approved by the Department. The contingency plan must demonstrate the water system is able to provide residential service to all customers for a 24 hour period during any emergency involving the shut down of the treatment facility.

(d) Public water systems which utilize wells and provide only disinfection, pH adjustment, corrosion inhibitor and/or fluoridation as treatment, may use the capacity of the wells and the plant as part of the distribution storage under the following conditions:

1. The existing distribution storage tank(s) are adequate to meet the peak demands on the system,

2. The well(s), disinfection equipment and other pumping facilities needed to supply water to the distribution storage tank are equipped with an auxiliary power source with automatic controls, and

3. The well field capacity is determined by removing the largest well from consideration.

(Rule 0400-45-01-.17, continued)

(e) Public water systems may take into account private distribution storage facilities in the following manner:

1. Private distribution storage may be counted as water system storage provided the private storage tank floats on the water utility's system and the water used serves both the private and utility system demand.

2. The water utility may reduce the amount of needed distribution storage by subtracting the average daily volume of any water user that has its own storage tank. This can be done provided the private storage tank is used on a daily basis.

3. Private distribution storage tanks used strictly for fire protection by the private owner cannot be in the water systems distribution storage capacity.

(15) All community water systems serving 50 or more service connections must have and maintain up-to-date maps of the distribution system. These maps must show the locations of the water mains, sizes of mains, valves, blow-offs or flush hydrants, air-release valves, and fire hydrants. One up-to-date copy of the overall system distribution map(s) is to be submitted to the Division of Water Supply every five years.

(16) All vents on wells, springs, storage tanks, overflows and clearwells shall be properly screened. All overflows on springs and tanks shall be screened and protected.

(17) All buildings and equipment used in and for the production and distribution of water (to include chemical and other storage buildings) must be well maintained and be reliable and fit for the purpose for which they are used. This includes, but is not limited to:

(a) When a water treatment plant is not producing water and an operator is not in attendance, plant entrances must be locked.

(b) Equipment such as chemical feeders, pumps, turbidimeters, pumpage meters, alarm systems, and air tanks shall be maintained and in good working condition. Pumps, tanks, hoses, and other equipment used by system personnel shall be disinfected and dedicated to its use if it comes into contact with water that may be consumed by humans.

(c) Duplicate or backup equipment shall be available as necessary to maintain the production of water meeting drinking water standards. Backup equipment or alternate treatment means shall be available for feeding all chemicals critical for adequate water treatment.

(18) All community water systems planning to or having installed hydrants must protect the distribution system from contamination. All water mains designed for fire protection must be six inches or larger and be able to provide 500 gallons per minute with 20 pounds per square inch residual pressure. Fire hydrants shall not be installed on water mains less than six inches in diameter or on water mains that cannot produce 500 gpm at 20 psi residual pressure unless -the tops are painted red. Out of service hydrants shall have tops painted black or covered with a black shroud or tape.

Existing Class C hydrants (hydrants unable to deliver a flow of 500 gallons per minute at a residual pressure of 20 pounds per square inch (psi) shall have their tops painted red by January 1, 2008.

(Rule 0400-45-01-.17, continued)

The water system must provide notification by certified mail at least once every five years beginning January 1, 2008, to each fire department that may have reason to utilize the hydrants, that fire hydrants with tops painted red (Class C hydrants) cannot be connected directly to a pumper fire truck. Fire Departments may be allowed to fill the booster tanks on any fire apparatus from an available hydrant by using the water system's available pressure only (fire pumps shall not be engaged during refill operations from a Class C hydrant).

(19) Before any new or modified community water treatment facility can be placed in service, it must be inspected and approved in writing by the Department.

(20) Each water system adjusting the fluoride content to the finished water must monitor for fluoride quarterly using a certified laboratory and the calculation of the fluoride level will be by running annual average. The recommended level of fluoridation in the finished water is 0.7 mg/l. Any public water system which determines to cease fluoridation treatment of its water supply shall notify the local environmental field office within the department of environment and conservation and the commissioner of the department of health of its decision to discontinue fluoridation within the timeframe as specified by T.C.A. § 68-221-708(c).

(21) New or modified turbidity removal facilities may not be placed into operation until the facility and the operator have been approved by the Department for the turbidity analysis.

(22) All pipe, solder, or flux which is used in the installation or repair of any public water system shall be lead free. This shall not apply to lead joints necessary for the repair of cast iron pipes. The term "lead free" in this paragraph is defined as follows:

(a) When used with respect to solders and flux shall mean solders and flux containing not more than two-tenths of one percent (0.2%) lead and

(b) When used with respect to pipes and pipe fittings shall mean pipes and pipe fittings containing not more than eight percent (8.0%) lead.

(23) All dead end water mains and all low points in water mains shall be equipped with a blow-off or other suitable flushing mechanism capable of producing velocities adequate to flush the main.

(24) All community water systems must establish and maintain a file for customer complaints. This file shall contain the name of the person with the complaint, date, nature of complaint, date of investigation and results or actions taken to correct any problems.

(25) The Department may, upon written notice, require confirmation of any sampling results and also may require sampling and analysis for any contaminant when deemed necessary by the Department to protect the public health or welfare.

(26) Those public water systems required to monitor for turbidity and chlorine residual must have the laboratory approved by the Department before the results of these analyses can be accepted for compliance purposes.

(27) By December 30, 1991, or 18 months after the determination that a ground water system is influenced by surface water, all public water systems classified as a ground water system impacted by surface water shall utilize treatment techniques which achieve:

(a) At least 99.9 percent (3 log) removal and/or inactivation of Giardia lamblia cysts between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer.

(Rule 0400-45-01-.17, continued)

(b) At least 99.99 percent (4 log) removal and/or inactivation of viruses between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer.

(28) All public water systems using surface water shall provide disinfection to control the biological quality of the water. Due consideration shall be given to the contact time of the disinfectant in the water with relation to pH, ammonia, taste producing substances, temperature, presence and type of pathogens, and trihalomethane formation potential. All disinfection basins must be designed to prevent water short-circuiting the system. The disinfectant will be applied in the manner needed to provide adequate contact time.

(29) All community water systems using ground water as the raw water source serving water to more than 50 connections or 150 people will apply the disinfectant in the manner needed for adequate contact time. Contact time for ground water systems shall not be less than 15 minutes prior to the first customer.

(30) Any surface supplied public water system or ground water systems under the direct influence of surface water required to filter shall employ filtration in combination with disinfection that will achieve 99.9% (3 log) and 99.99% (4 log) inactivation of Giardia lamblia and viruses respectively between a point where the raw water is not subject to recontamination by surface water runoff and a point downstream before or at the first customer. For the purposes of determining removal or inactivation efficiencies for Giardia lamblia and viruses Table 0400-45-01-.17(30)1 and 0400-45-01-.17(30)2 shall apply. The free residual disinfectant concentration in the water entering the distribution system cannot be less than 0.2 mg/l for more than four hours.

TABLE 0400-45-01-.17(30)1

Assumed Log Removals by Filtration Method
and Required Levels of Disinfection

Treatment	Assumed Log Removal		Required Minimum Level of Disinfection	
	Giardia	Viruses	Giardia	Viruses
Conventional filtration	2.5	2.0	0.5	2.0
Direct filtration	2.0	1.0	1.0	3.0
Slow Sand filtration	2.0	2.0	1.0	2.0
Diatomaceous Earth filtration	2.0	1.0	1.0	3.0

TABLE 0400-45-01-.17(30)2

CT Values for Achieving 1-Log Inactivation of
Giardia Cysts[1]

	pH	Temperature			
		0.5^oC	5^oC	10^oC	15^oC
Free Chlorine[2,3]	6	55	39	29	19
	7	79	55	41	26
	8	115	81	61	41
	9	167	118	88	59
Ozone		0.97	0.63	0.48	0.32
Chlorine dioxide		1270	735	615	500

1 Values to achieve 0.5 log inactivation are one half those shown in the table.

(Rule 0400-45-01-.17, continued)

[2] CT values are for 2.0 mg/l free chlorine.

[3] CT values for other concentrations of free chlorine may be taken from Appendix E of the guidance manual for Compliance with the “Filtration and Disinfection Requirements For Public Water Systems Using Surface Water Sources,” October, 1989, Edition, Science and Technology Branch Criteria and Standards Division, Office of Drinking Water, USEPA, Washington, D.C.

(31) Each public water system must certify annually in writing to the Department that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified as follows:

Acrylamide = 0.05% dosed at 1 ppm (or equivalent)
Epichlorohydrin = 0.01% dosed at 20 ppm (or equivalent)

Public water systems can rely on manufacturer’s or third parties’ certification for complying with this requirement.

(32) New service taps on existing mains that must be uncovered to make the tap, shall be flushed and the free chlorine residual measured and recorded prior to connecting the service lines. These records shall be retained until the next sanitary survey or for three years.

(33) All public water systems shall properly maintain their distribution system finished water storage tanks. Each community water system shall establish and maintain a maintenance file on each of its finished water and distribution storage tanks. These maintenance files must be available for inspection by Department personnel. These files must include the dates and results of all routine water storage tank inspections by system personnel, any reports of detailed professional inspections of the water storage tanks by contractor personnel, dates and details of routine tank cleanings and surface flushings, and dates and details of all tank maintenance activities. The tank inspection records shall include dates of the inspections; the sanitary, coating and structural conditions of the tank; and all recommendations for needed maintenance activities. Community Water Systems shall have a professional inspection performed and a written report produced on each of their finished water and distribution storage tanks at least once every five years. Non-community water systems shall have a professional inspection and written report performed on each of their atmospheric pressure finished water and distribution storage tanks no less frequently than every five years. Records of these inspections shall be available to the Department personnel for inspection. Persons conducting underwater inspections of finished water storage tanks shall comply with AWWA standard C652-92 or later versions of the standard.

(34) Paints and coatings for the interior of potable water storage facilities must be acceptable to the Department. Paints and coatings accepted by the Environmental Protection Agency (EPA) and/or the National Sanitation Foundation (NSF) for potable water contact are generally acceptable to the Department. Paint systems for steel tanks shall be consistent with AWWA Standard D102-78. Factory coated bolted steel tanks shall be in accordance with AWWA D103-87. Wire-wound circular prestressed concrete tanks shall be in accordance with AWWA D110-86.

(35) By January 1, 1996, public water systems using surface water and ground water systems under the direct influence of surface water that filter shall have rewash capability. Such systems shall perform a rewash cycle, or filter to waste each time a filter is backwashed. The rewash cycle shall be conducted in a way and manner necessary to prevent the introduction of contaminants such as pathogens and turbidity trapped in the filter into the clear well or distribution system.

(Rule 0400-45-01-.17, continued)

Existing filter plants may be approved to operate without rewash (filter-to-waste provisions) if existing operational and backwash practices prevent water of unacceptable quality from entering the clearwell or distribution system. To operate without rewash the water system must demonstrate to the Department that filtered water turbidity after backwashing is reliably and consistently below 0.5 NTU immediately after backwashing each filter. Approval to operate without rewash must be approved in writing and approval must be renewed if any modifications are made to the operation or design of the plant. Each filter that operates without rewash must have a continuous recording turbidimeter and retain the records for a period of five years.

(36) By January 1, 1995, all chemicals, additives, coatings or other materials used in the treatment, conditioning and conveyance of drinking water must have been approved by the National Sanitation Foundation (NSF) or American National Standards Institute (ANSI) certified parties as meeting NSF product standard 60 and 61. Until 1995, products used for treatment, conditioning and conveyance of drinking water shall have been listed as approved by the US EPA or NSF.

(37) Any new Community Water System or Non-Transient Non-Community Water System commencing operation after September 30, 1999 shall have a "Capacity Development Plan" and be a "viable water system."

(38) Public Water Systems identified as not complying or potentially not complying with the requirements of the Safe Drinking Water Act and in accordance with the priorities established in the Department's Capacity Development Strategy shall prepare a "Capacity Development Plan" and demonstrate viability.

(39) Public water systems are not permitted to construct uncovered finished water reservoirs after the effective date of this subparagraph.

(40) Benchtop and continuous turbidimeters used to determine compliance with limits set forth in this rule chapter must be calibrated at least every three months with primary standards and documented. Documentation shall be maintained for a period not less than five years. Primary standards are Formazin, AMCO clear, Stablcal, or alternatives approved in writing by the Department. Dilute Formazin solutions are unstable and must be prepared on the day of calibration. Manufacturers' recommendations on calibration procedure must be followed.

(41) Verifications for benchtop turbidimeters are comparisons to approved reference materials. Verifications for continuous turbidimeters are comparisons to approved reference materials or comparisons to a properly calibrated benchtop turbidimeter. Secondary reference materials are assigned a value immediately after acceptable primary calibration has been completed. Acceptable verifications for turbidity measurements greater than 0.5 NTU must agree within ±10% from the reading assigned to the reference material after primary calibration. Acceptable verifications for measurements 0.5 NTU or less must be within ±0.05 NTU or less from the reading assigned to the reference material after primary calibration. When comparisons are made from a continuous turbidimeter to a benchtop turbidimeter, the continuous measurement must be within ±10% of the benchtop reading for measurements above 0.5 NTU and ±0.05 NTU for reading 0.5 NTU or less. When acceptable verifications are not achieved the instrument must be re-calibrated with primary standards according to paragraph (40) of this rule. Approved reference materials for benchtop turbidimeters are primary standards and materials suggested by the manufacturer such as sealed sample cells filled with metal oxide particles in a polymer gel. The 0.5 NTU ICE-PIC™ from Hach is an approved reference material for secondary turbidity verifications for Hach continuous turbidimeters when utilized as per Manufacturers' recommendations. All other reference materials for turbidimeter verifications must be approved in writing by the Department. Verifications for turbidimeters must be performed according to the following:

(Rule 0400-45-01-.17, continued)

(a) Verification of benchtop turbidimeters must be performed daily and documented. Verifications must include a sample in the expected working range of the instrument or as close to the working range as possible. Documentation must include: assigned reference material value after calibration, recorded daily reading for all reference standards, instrument identification, and date.

(b) Combined filter effluent turbidimeters as required by part (5)(c)1 of Rule 0400-45-01-.31 must be verified daily and documented. When reference material is utilized documentation must include: instrument identification, date, assigned reference material value after calibration, and daily value for reference material. When comparisons to benchtop turbidimeters are utilized documentation must include: instrument identification, date, continuous turbidimeter value, and benchtop turbidimeter value.

(c) Individual filter turbidimeters as required by part (5)(c)4 of Rule 0400-45-01-.31 must be verified weekly.

Authority: *T.C.A. §§ 68-221-701 et seq. and 4-5-201 et seq.* ***Administrative History:*** *Original rule filed August 1, 2012; effective October 30, 2012. Rule was previously numbered 1200-05-01.*

0400-45-01-.18 REPORTING REQUIREMENTS.

(1) Except where a shorter period is specified in this Chapter, the supplier of water shall report to the Department the results of any test measurement or analysis required by this part within (a) the first ten days following the month in which the result is received or (b) the first ten days following the end of the required monitoring period as stipulated by the Department, which ever of these is shortest.

(2) All systems shall report to the Department within forty-eight (48) hours of the failure to comply with Departmental drinking water regulations or other requirements (including failure to comply with monitoring, maximum contaminant level or treatment technique requirements) set forth in these rules and regulations, and in case of any of the following events shall immediately notify the Department and responsible local officials:

(a) any major breakdown or failure of equipment in water treatment process which affects the quality or quantity of the water leaving the treatment plant;

(b) any serious loss of water service due to a failure of transmission or distribution facilities; or

(c) any situation with the water system which presents or may present an imminent and substantial endangerment to health.

(3) Systems are not required to report analytical results to the Department in cases where a State laboratory performs the analysis and reports the results to the Department.

(4) The public water system, within 10 days of completing the public notification requirements under Rule 0400-45-01-.19 for the initial public notice and any repeat notices, must submit to the department a certification that it has fully complied with the public notification regulations. The public water system must include with this certification a representative copy of each type of notice distributed, published, posted and made available to the persons served by the system and to the media.

(5) The water supply system shall submit to the Department, within the time stated in the request, copies of any records required to be maintained under Rule 0400-45-01-.20 hereof

(Rule 0400-45-01-.19, continued)

Table 0400-45-01-.19(1)(a)

Violation Categories and Other Situations
Requiring a Public Notice

1. NPDWR violations:

   (i) Failure to comply with an applicable maximum contaminant level (MCL) or maximum residual disinfectant level (MRDL).
   (ii) Failure to comply with a prescribed treatment technique (TT).
   (iii) Failure to perform water quality monitoring, as required by the drinking water regulations.
   (iv) Failure to comply with testing procedures as prescribed by a drinking water regulation.

2. Variance and exemptions under sections 1415 and 1416 of SDWA:

   (i) Operation under a variance or an exemption.
   (ii) Failure to comply with the requirements of any schedule that has been set under a variance or exemption.

3. Special public notices:

   (i) Occurrence of a waterborne disease outbreak or other waterborne emergency.
   (ii) Exceedance of the alternate MCL for nitrate by non-community water systems (NCWS), where the non-community system has been granted an alternate standard by the department.
   (iii) Exceedance of the secondary maximum contaminant level (SMCL) for fluoride.
   (iv) Availability of unregulated contaminant monitoring data.
   (v) Other violations and situations determined by the department to require a public notice under this rule, not already listed in Appendix A.

(b) Public notice requirements are divided into three tiers to take into account the seriousness of the violation or situation and any potential adverse health effects that may be involved. The public notice requirements for each violation or situation listed in Table 0400-45-01-.19(1)(a) are determined by the tier to which it is assigned. Table 0400-45-01-.19(1)(b) provides the definition of each tier. Appendix A of this rule identifies the tier assignment for each specific violation or situation.

Table 0400-45-01-.19(1)(b)

Definition of Public Notice Tiers

1. Tier 1 public notice-required for NPDWR violations and situations with significant potential to have serious adverse effects on human health as a result of short-term exposure.

2. Tier 2 public notice--required for all other NPDWR violations and situations with potential to have serious adverse effects on human health.

3. Tier 3 public notice--required for all other NPDWR violations and situations not included in Tier 1 and Tier 2.

(c) Who must be notified?

(Rule 0400-45-01-.19, continued)

1. Each public water system must provide public notice to persons served by the water system, in accordance with this rule. Public water systems that sell or otherwise provide drinking water to other public water systems (i.e., to consecutive systems) are required to give public notice to the owner or operator of the consecutive system; the consecutive system is responsible for providing public notice to the persons it serves.

2. If a public water system has a violation in a portion of the distribution system that is physically or hydraulically isolated from other parts of the distribution system, the Department may allow the system to limit distribution of the public notice to only persons served by that portion of the system which is out of compliance. Permission by the department for limiting distribution of the notice must be granted in writing.

3. A representative copy of the each type of the notice distributed, published, posted and/or made available to the persons served by the system and/or to the media must also be sent to the Department within ten days of completion of each public notification.

(2) Tier 1 Public Notice-Form, manner, and frequency of notice.

(a) Which violations or situations require a Tier 1 public notice? Table 0400-45-01-.19(2)(a) of this paragraph lists the violation categories and other situations requiring a Tier 1 public notice. Appendix A to this rule identifies the tier assignment for each specific violation or situation.

Table 0400-45-01-.19(2)(a)

Violation Categories and Other Situations
Requiring a Tier 1 Public Notice

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1. Violation of the MCL for total coliforms when fecal coliform or E. coli are present in the water distribution system as specified in Rule 0400-45-01-.06, or when the water system fails to test for fecal coliforms or E. coli when any repeat sample tests positive for coliform as specified in Rule 0400-45-01-.07;

2. Violation of the MCL for nitrate, nitrite, or total nitrate and nitrite, as defined in Rule 0400-45-01-.06, or when the water system fails to take a confirmation sample within 24 hours of the system's receipt of the first sample showing an exceedance of the nitrate or nitrite MCL, as specified in Rule 0400-45-01-.09;

3. Exceedance of the alternate MCL for nitrate by non-community water systems (NCWS), where the non-community system has been granted an alternate standard by the department;

4. Violation of the MRDL for chlorine dioxide, as defined in Rule 0400-45-01-.36, when one or more samples taken in the distribution system the day following an exceedance of the MRDL at the entrance of the distribution system exceed the MRDL, or when the water system does not take the required samples in the distribution system, as specified in Rule 0400-45-01-.36;

5. Violation of the turbidity MCL under Rule 0400-45-01-.06, where the department determines after consultation that a Tier 1 notice is required or where consultation does not take place within 24 hours after the system learns of the violation;

(Rule 0400-45-01-.19, continued)

6. Violation of the Surface Water Treatment Rule (SWTR) Rule 0400-45-01-.31, Interim Enhanced Surface Water Treatment Rule (IESWTR) or Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) treatment technique requirement resulting from a single exceedance of the maximum allowable turbidity limit (as identified in Appendix A) where the department determines after consultation that a tier 1 notice is required or where consultation does not take place within 24 hours after the system learns of the violation;

7. Occurrence of a waterborne disease outbreak, as defined in Rule 0400-45-01-.04, or other waterborne emergency (such as a failure or significant interruption in key water treatment processes, a natural disaster that disrupts the water supply or distribution system, or a chemical spill or unexpected loading of possible pathogens into the source water that significantly increases the potential for drinking water contamination);

8. Other violations or situations with significant potential to have serious adverse effects on human health as a result of short-term exposure, as determined by the Department either in its regulations or on a case-by-case basis.

9. Detection of E. coli or enterococci in source water samples as specified in paragraph (3) of Rule 0400-45-01-.40.

(b) When is the Tier 1 public notice to be provided? What additional steps are required? Public water systems must:

1. Provide a public notice as soon as practical but no later than 24 hours after the system learns of the violation;

2. Initiate consultation with the Department as soon as practical, but no later than 24 hours after the public water system learns of the violation or situation, to determine additional public notice requirements; and

3. Comply with any additional public notification requirements (including any repeat notices or direction on the duration of the posted notices) that are established as a result of the consultation with the Department. Such requirements may include the timing, form, manner, frequency, and content of repeat notices (if any) and other actions designed to reach all persons served.

(c) What is the form and manner of the public notice? Public water systems must provide the notice within 24 hours in a form and manner reasonably calculated to reach all persons served. The form and manner used by the public water system are to fit the specific situation, but must be designed to reach residential, transient, and non-transient users of the water system. In order to reach all persons served, water systems are to use, at a minimum, one or more of the following forms of delivery:

1. Appropriate broadcast media (such as radio and television);

2. Posting of the notice in conspicuous locations throughout the area served by the water system;

3. Hand delivery of the notice to persons served by the water system; or

4. Another delivery method approved in writing by the department.

(3) Tier 2 Public Notice--Form, manner, and frequency of notice.

(Rule 0400-45-01-.19, continued)

(a) Which violations or situations require a Tier 2 public notice? Table 0400-45-01-.19(3)(a) lists the violation categories and other situations requiring a Tier 2 public notice. Appendix A to this rule identifies the tier assignment for each specific violation or situation.

Table 0400-45-01-.19(3)(a)

Violation Categories and Other Situations
Requiring a Tier 2 Public Notice

1. All violations of the MCL, MRDL, and treatment technique requirements, except where a Tier 1 notice is required under subparagraph (2)(a) of this rule or where the department determines that a Tier 1 notice is required;

2. Violations of the monitoring and testing procedure requirements, where the department determines that a Tier 2 rather than a Tier 3 public notice is required, taking into account potential health impacts and persistence of the violation; and

3. Failure to comply with the terms and conditions of any variance or exemption in place.

4. Failure to take corrective action or failure to maintain at least 4-log treatment of viruses (using inactivation, removal, or a Department-approved combination of 4-log virus inactivation and removal) before or at the first customer under subparagraph (4)(a) of Rule 0400-45-01-.40.

(b) When is the Tier 2 public notice to be provided?

1. Public water systems must provide the public notice as soon as practical, but no later than 30 days after the system learns of the violation. If the public notice is posted, the notice must remain in place for as long as the violation or situation persists, but in no case for less than seven days, even if the violation or situation is resolved. The department may, in appropriate circumstances, allow additional time for the initial notice of up to three months from the date the system learns of the violation. The department will not grant an extension to the 30-day deadline for any unresolved violation or to allow across-the-board extensions by rule or policy for other violations or situations requiring a Tier 2 public notice. Extensions granted by the department must be in writing.

2. The public water system must repeat the notice every three months as long as the violation or situation persists, unless the department determines that appropriate circumstances warrant a different repeat notice frequency. In no circumstance may the repeat notice be given less frequently than once per year. The department will not allow less frequent repeat notice for an MCL violation under the Total Coliform rule or a treatment technique violation under Rule 0400-45-01-.31. The department will not through its rules or policies permit across-the-board reductions in the repeat notice frequency for other ongoing violations requiring a Tier 2 repeat notice. Departmental determinations allowing repeat notices to be given less frequently than once every three months must be in writing.

3. For the turbidity violations specified in this paragraph, public water systems must consult with the Department as soon as practical but no later than 24 hours after the public water system learns of the violation, to determine whether a Tier 1 public notice under subparagraph (2)(a) of this rule is required to protect public health. When consultation does not take place within the 24-hour period, the

(Rule 0400-45-01-.19, continued)

water system must distribute a Tier 1 notice of the violation within the next 24 hours (i.e., no later than 48 hours after the system learns of the violation), following the requirements under subparagraphs (2)(b) and (c) of this rule. Consultation with the department is required for:

(i) Violation of the turbidity MCL under Rule 0400-45-01-.06; or

(ii) Violation of the SWTR, IESWTR or LT1ESWTR treatment technique requirement (Rule 0400-45-01-.31) resulting from a single exceedance of the maximum allowable turbidity limit.

(c) What is the form and manner of the Tier 2 public notice? Public water systems must provide the initial public notice and any repeat notices in a form and manner that is reasonably calculated to reach persons served in the required time period. The form and manner of the public notice may vary based on the specific situation and type of water system, but it must at a minimum meet the following requirements:

1. Unless directed otherwise by the department in writing, community water systems must provide notice by:

(i) Mail or other direct delivery to each customer receiving a bill and to other service connections to which water is delivered by the public water system; and

(ii) Any other method reasonably calculated to reach other persons regularly served by the system, if they would not normally be reached by the notice required in subpart (i) of this part. Such persons may include those who do not pay water bills or do not have service connection addresses (e.g., house renters, apartment dwellers, university students, nursing home patients, prison inmates, etc.). Other methods may include: publication in a local newspaper; delivery of multiple copies for distribution by customers that provide their drinking water to others (e.g., apartment building owners or large private employers); posting in public places served by the system or on the Internet; or delivery to community organizations.

2. Unless directed otherwise by the department in writing, non-community water systems must provide notice by:

(i) Posting the notice in conspicuous locations throughout the distribution system frequented by persons served by the system, or by mail or direct delivery to each customer and service connection (where known); and

(ii) Any other method reasonably calculated to reach other persons served by the system if they would not normally be reached by the notice required in subpart (i) of this part. Such persons may include those served who may not see a posted notice because the posted notice is not in a location they routinely pass by. Other methods may include: publication in a local newspaper or newsletter distributed to customers; use of E-mail to notify employees or students; or, delivery of multiple copies in central locations (e.g., community centers).

(4) Tier 3 Public Notice--Form, manner, and frequency of notice.

(a) Which violations or situations require a Tier 3 public notice? Table 0400-45-01-.19(4)(a) lists the violation categories and other situations requiring a Tier 3 public

(Rule 0400-45-01-.19, continued)

notice. Appendix A to this rule identifies the tier assignment for each specific violation or situation.

Table 0400-45-01-.19(4)(a)

Violation Categories and Other Situations Requiring a Tier 3 Public Notice

1. Monitoring violations for the primary drinking water contaminants, except where a Tier 1 notice is required under subparagraph (2)(a) of this rule or where the department determines that a Tier 2 notice is required;

2. Failure to comply with an approved departmental or EPA testing procedure, except where a Tier 1 notice is required under subparagraph (2)(a) of this rule or where the department determines that a Tier 2 notice is required;

3. Operation under a variance granted under Section 1415 or an exemption granted under Section 1416 of the Safe Drinking Water Act;

4. Availability of unregulated contaminant monitoring results, as required under paragraph (7) of this rule, and

5. Exceedance of the fluoride secondary maximum contaminant level (SMCL), as required under paragraph (8) of this rule.

(b) When is the Tier 3 public notice to be provided?

1. Public water systems must provide the public notice not later than one year after the public water system learns of the violation or situation or begins operating under a variance or exemption. Following the initial notice, the public water system must repeat the notice annually for as long as the violation, variance, exemption, or other situation persists. If the public notice is posted, the notice must remain in place for as long as the violation, variance, exemption, or other situation persists, but in no case less than seven days (even if the violation or situation is resolved).

2. Instead of individual Tier 3 public notices, a public water system may use an annual report detailing all violations and situations that occurred during the previous twelve months, as long as the timing requirements of part 1 of this subparagraph are met.

(c) What is the form and manner of the Tier 3 public notice? Public water systems must provide the initial notice and any repeat notices in a form and manner that is reasonably calculated to reach persons served in the required time period. The form and manner of the public notice may vary based on the specific situation and type of water system, but it must at a minimum meet the following requirements:

1. Unless directed otherwise by the Department in writing, community water systems must provide notice by:

(i) Mail or other direct delivery to each customer receiving a bill and to other service connections to which water is delivered by the public water system; and