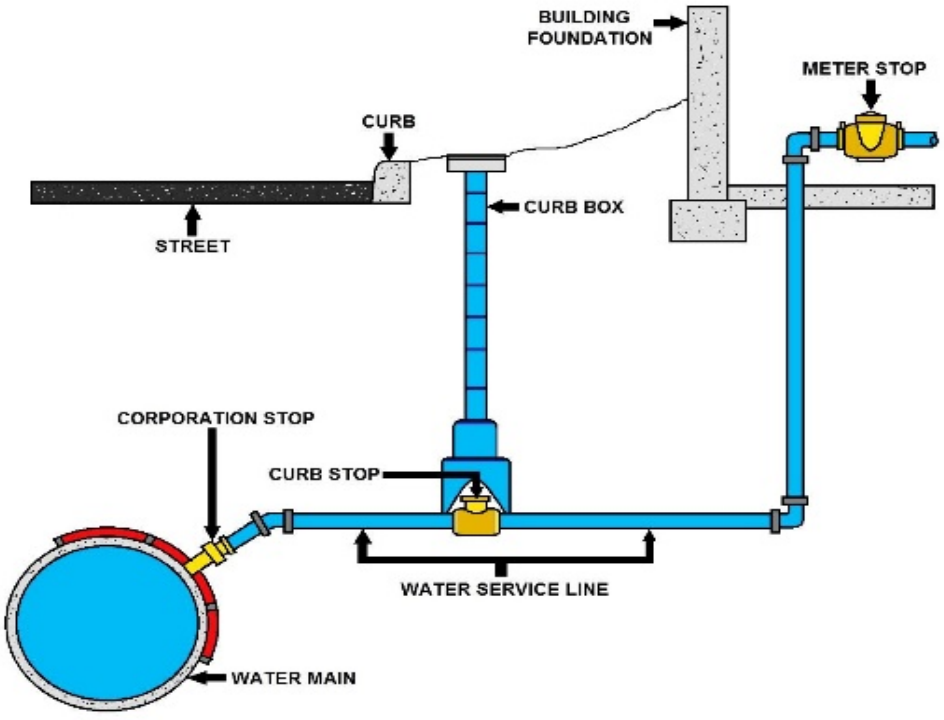
Water Distribution Grade 1 Training
May 22nd – 26th, 2017
Agenda

Water System Use and System Design	**12**
Pipes and Fittings	**20**
Pipe Installation	**31**
Water Services	**41**
Valves	**47**
Hydrants	**53**
Storage Facilities	**59**
Pumps and Motors	**69**
Water Meters	**88**
Disinfection	**96**
Backflow and Cross Connection	**107**
Rules and Regulations	**111**
Math	**123**



ONE VARIATION OF COMMON WATER METER INSTALLATION METHOD

ABC
Association of Boards of Certification

2017

Need-to-Know Criteria

Water Distribution Operator Class I

A Need-to-Know Guide when preparing for the ABC Water Distribution Operator Class I Certification Exam

Before You Dive In...

What is ABC's *Need-to-Know Criteria*?

This *ABC Water Distribution Operator Class I Need-to-Know Criteria* was developed to assist operators in understanding the content that will be covered in ABC's 2017 Standardized Water Distribution Operator Class I exam. During 2014-2016, a methodical and comprehensive international investigation was conducted to determine the most significant job tasks performed by water distribution operators. The content covered on the exam represents the job tasks identified through this research as essential operator competencies, and is not limited to the practices of your system/facility. The following pages organize these job tasks into Content Areas and identify the amount of the test devoted to each area.

Is this *Need-to-Know Criteria* relevant to MY exam?

ABC offers a variety of standardized and customized exam services. This document is reflective only of the 2017 edition of the ABC Standardized Water Distribution Operator Class I exam; older editions of the standardized exam and various customized exams are also administered by various certification programs. Please contact your certifying authority to determine whether they have implemented this exam for your program.

Pre-Test Questions

Your exam may include up to 10 extra questions that have not been used on previous versions of the exam. These are known as "pre-test" questions and allow ABC to gather valuable data about the new questions before they are included in future tests. Pre-test questions are unidentified and scattered throughout the exam so you will answer them with the same care in which you address scored questions. The pre-test questions are not included in your final score.

Exam Preparation Resources

Visit www.abccert.org to access the formula/conversion table administered with this exam, a list of approved references, information on purchasing study guides available from partner organizations, and more.

Copyright Notice

All ABC examination questions are the copyrighted property of ABC. It is forbidden under federal copyright law to copy, reproduce, record, distribute, or display these examination questions by any means, in whole or in part, without written permission from ABC. Doing so may subject violators to severe civil and criminal penalties.

Water Distribution Operator Class I *Need-to-Know Criteria*

Exam Content

The Water Distribution Operator Class I exam will test you on essential job tasks. These job tasks have been categorized into the Content Areas detailed in the following pages. The table below summarizes the areas that are included on the exam, the number of test questions in each of these areas, and the complexity of the test questions in each area.

Just as water distribution operator job duties vary in their complexity, so will the questions you are asked on the exam. Some will be more simple and routine, whereas others will be more complex, or cognitively demanding. The following three levels are used to describe the complexity of the questions you will encounter on this exam:

Recall – tasks at this level typically require the simple recall or recognition of specific facts, concepts, processes, or procedures, with little to no problem-solving involved. You may be asked to identify, illustrate, recall, and/or recognize specific information.

Application – tasks at this level will involve some basic problem solving, calculations, or the interpretation and application of data. You may be asked to calculate, categorize, classify, compare, differentiate, explain, specify, translate, and/or apply knowledge.

Analysis – tasks at this level may involve higher level problem solving, evaluation, or the fitting together of a variety of elements into a meaningful whole; they will usually require many steps in the thought process. You may be asked to analyze, evaluate, formulate, generalize, judge, predict, and/or use inductive or deductive reasoning to arrive at a solution.

Exam Content Outline

Number of Questions	Content Area	Job Task Complexity Levels
25	Distribution System Components	10 15 0
24	Equipment Installation, Operation, & Maintenance	10 14 0
27	Disinfection Monitoring, Evaluation, Adjustment, & Laboratory Analysis/ Interpretation	19 8 0
24	Security, Safety, Administrative Procedures, & Public Interactions	10 14 0
100*	Total	49 51 0

This exam includes 8 calculation questions

*Your exam may contain up to 10 extra unscored pre-test questions (see *Before You Dive In* for more details).

Distribution System Components

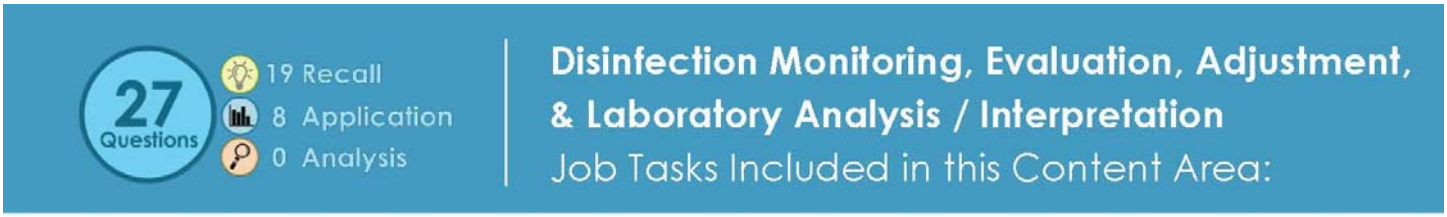
Job Tasks Included in this Content Area:

1. Aid in the design of water distribution projects
2. Assess water production (e.g., water restrictions and demand)
3. Adjust the water production to meet the demand (e.g., start pumps, adjust flow valves)
4. Understand backflow prevention and control devices
5. Implement a cross-connection control program
6. Monitor water distribution system pressure
7. Determine water volume (e.g., tank, main)
8. Determine water flow rate (e.g., mains, pumps, services)
9. Maintain an up-to-date map of the distribution system (e.g., GIS, repairs, replacements)
10. Maintain distribution system components:
    a. Pumps and related equipment (e.g., packing pumps, starters and controls)
    b. Mains and related equipment (e.g., hydrants and valves)
    c. Metering and related equipment (e.g., remote readers, meter replacements)
    d. Finished water storage and related equipment (e.g., tanks, overflow pipe, vents, access hatches)
11. Understand schematic diagrams

Equipment Installation, Operation, & Maintenance

Job Tasks Included in this Content Area:

1. Install water lines:
    a. Service lines (e.g., tapping, curb stops, corporation stops)
    b. Water mains (e.g., valves, hydrants)
2. Inspect new construction
3. Maintain pump stations and related equipment (e.g., check valves, control systems)
4. Monitor pump stations and related equipment (e.g., records, online monitoring equipment)
5. Clean the finished water storage facilities
6. Inspect finished water storage facilities (e.g., drains, screens, corrosion control)
7. Conduct distribution system flushing
8. Repair water line (e.g., install repair clamps and sleeves)
9. Repair distribution components (e.g., mains, services, meters, valves, hydrants, pumps)
10. Disinfect components used during install/repairs
11. Conduct a leak detection program (e.g., survey, testing meters, water loss audit)
12. Operate well and related equipment
13. Maintain well and related equipment
14. Maintain the sanitary condition of the well
15. Measure static water levels and pumping water levels
16. Locate water lines (e.g., valves, hydrants)
17. Perform underground locating, marking, and notification



1. Adjust the disinfection dosage
2. Perform routine maintenance on the disinfection equipment
3. Handle disinfection chemicals
4. Secure the disinfection chemicals (e.g., chain cylinders, lock the disinfection facility)
5. Maintain an adequate supply of the disinfection chemicals
6. Monitor the disinfection equipment
7. Collect samples to determine:
    a. Chlorine residual
    b. Microbiological
    c. Lead/copper
    d. pH
    e. Radionuclides
    f. Organic chemicals
    g. Inorganic chemicals
    h. Temperature
    i. Disinfectant byproducts
8. Perform analyses to determine:
    a. Chlorine residual
    b. pH
    c. Temperature
9. Interpret laboratory analysis for:
    a. Chlorine residual
    b. Chlorine demand
    c. Microbiological
    d. Lead/copper
    e. pH
    f. Organic chemicals
    g. Inorganic chemicals
    h. Temperature
    i. Disinfectant byproducts
    j. Compliance with established water quality standards
    k. Meeting standard operating practices

Security, Safety, Administrative Procedures, & Public Interactions

Job Tasks Included in this Content Area:

1. Participate in safety/compliance program
2. Perform traffic control during maintenance, repairs, and construction
3. Implement a confined space program
4. Communicate observed unsafe workplace conditions
5. Identify opportunities to mitigate risks
6. Work in or around excavation sites:
    a. Implement cave-in protection program
    b. Secure the excavation site
    c. Excavate the site
    d. Restore the excavation site
7. Work in and around confined spaces:
    a. Implement a confined space program
    b. Enter confined spaces
    c. Monitor activities in and around confined spaces
8. Secure all water system facilities in a manner that protects the supply from contamination and prevents unauthorized entry and vandalism
9. Investigate system tampering
10. Maintain an emergency plan of operations
11. Maintain system records (e.g., laboratory, consumption, maintenance)
12. Interpret plans, maps, and system standard specifications
13. Participate in the budget process
14. Address water quality communications (e.g., taste, odor, color)
15. Conduct meter reading
16. Address customer inquiry (e.g., pressure, employee performance, billing)
17. Answer questions from the public
18. Participate in consumer confidence reports
19. Inform customers of planned repairs or changes in the water line

Supporting Knowledge

The chart below outlines several types of knowledge that support the performance of the job tasks on which you may be tested. These types of knowledge are rated at one of three levels to represent the extent of knowledge needed to perform the job tasks assigned to each Content Area:

Basic – A fundamental or lower level of knowledge is required. Operators performing tasks requiring this level of knowledge will be able to do so with some training; this level of knowledge may also be acquired and developed through job experience. Such tasks may be routine, utilizing established procedures, and have a low level of complexity. Not having this level of knowledge will have minimal impact or significance on the performance of the tasks listed in the Content Area, or on public safety and welfare.

Intermediate – A level of knowledge beyond the basic level is required. Operators performing tasks requiring this level of knowledge will be able to do so with training beyond that of the basic level. The operator will not only be able to apply required fundamental concepts, but will be able to understand and discuss the application and implications of changes to processes, policies, and procedures within the Content Area. Not having this level of knowledge will have a significant impact on the performance of the job and on public safety and welfare.

Advanced – A very high level of knowledge/job expertise is required and the operator will be functioning at an expert level. The operator can apply all fundamental, as well as highly developed or complex concepts, and will be able to design, review, and evaluate processes, policies, and procedures within the Content Area. Not having this level of knowledge will have a serious impact on the performance of the job and will be very harmful to public safety and welfare.

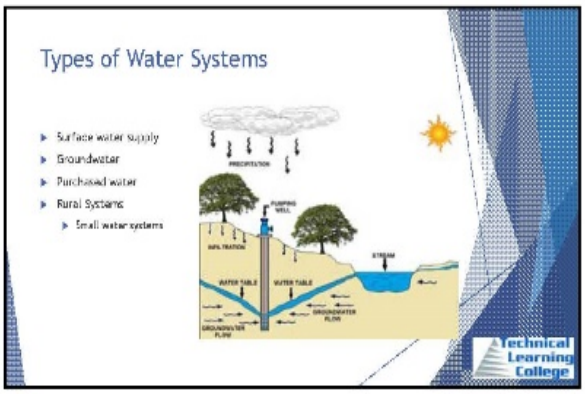
Supporting Knowledge Type	Distribution System Components (25%)*	Equipment Installation, Operation, & Maintenance (24%)*	Disinfection Monitoring, Evaluation, Adjustment, & Laboratory Analysis / Interpretation (27%)*	Security, Safety, Administrative Procedures, & Public Interactions (24%)*
Characteristics of chlorine and chlorine compounds (e.g., gas/liquid)			Intermediate	
Chlorination/dechlorination (e.g., safety, storage, handling, feeding, measurements)		Intermediate	Intermediate	Intermediate
Chlorine demand significance and relationship to dose			Basic	
Coliform group (e.g., monitoring, occurrence, significance)	Basic	Basic	Basic	Basic
Control systems (e.g., SCADA, pumps, valves)	Basic	Intermediate		
Corrosion control process (e.g., cathodic protection)	Intermediate	Intermediate		
Cross-connection control program and principles (e.g., surveys, method, devices)	Intermediate	Intermediate		Basic
Disinfection concepts (e.g., pipes, tanks, repairs, wells)	Intermediate	Intermediate	Intermediate	Intermediate
Emergency/contingency response plans	Basic	Basic	Intermediate	Intermediate

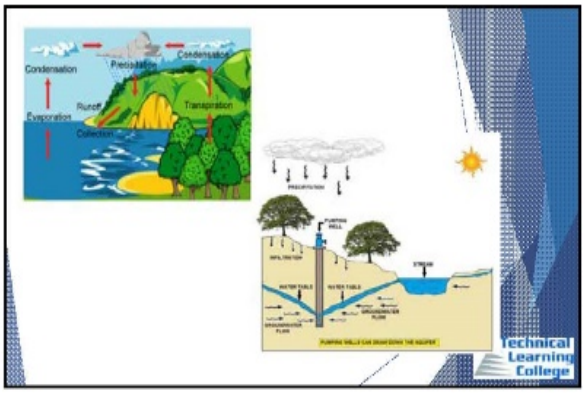
Supporting Knowledge Type	Distribution System Components (25%)*	Equipment Installation, Operation, & Maintenance (24%)*	Disinfection Monitoring, Evaluation, Adjustment, & Laboratory Analysis / Interpretation (27%)*	Security, Safety, Administrative Procedures, & Public Interactions (24%)*
Flow effect of pipe size, type, head loss, and C factor	Basic	Basic		
Groundwater and surface water supplies (e.g., water quality, characteristics)			Basic	
Hazards and safety requirements (e.g., confined space, excavation, trench safety)		Intermediate		Intermediate
Leak detection and repair (e.g., mains, service lines, meters)	Intermediate	Intermediate	Intermediate	Basic
Metering technologies (e.g., AMR, meter types)	Basic	Basic		
Monitoring requirements (e.g., water quality, pressure)		Basic	Intermediate	
Operation of laboratory field equipment (e.g., chlorine monitor, pH monitor)		Intermediate	Intermediate	
Piping materials (e.g., pipes, valves, hydrants, fittings, joints, restraints)	Intermediate	Intermediate		
Potential waterborne diseases (e.g., types, causes, prevention)			Basic	Basic
Proper sampling requirements and procedures		Intermediate	Intermediate	
Public notification requirements (e.g., CCR, advisories, violations)				Intermediate
Quality control/quality assurance practices (e.g., laboratory, field unit)		Intermediate	Intermediate	
Reporting requirements and frequency (e.g., CCR, samples)				Intermediate
Sanitary survey processes (e.g., system responsibilities, preparation)	Basic			Intermediate
Security practices and procedures	Basic			Intermediate
Source water protection (e.g., ground water, surface water)		Intermediate		Advanced
Standard disinfection methods (e.g., new/repaired mains, storage facilities, wells)	Intermediate	Intermediate	Intermediate	
System damage prevention (e.g., water hammer, cavitation)	Basic	Basic		
System documents (e.g., as-builts, blueprint, records, GIS)	Intermediate			Intermediate
Tool selection/use (e.g., safety, efficiency)		Basic		Intermediate
Underground utility identification practices	Basic			Basic
Variable/positive displacement pumps (e.g., centrifugal, diaphragm, peristaltic)	Intermediate	Intermediate	Intermediate	
Water quality standards and compliance procedures (e.g., regional requirements, drinking water legislation)			Intermediate	Intermediate

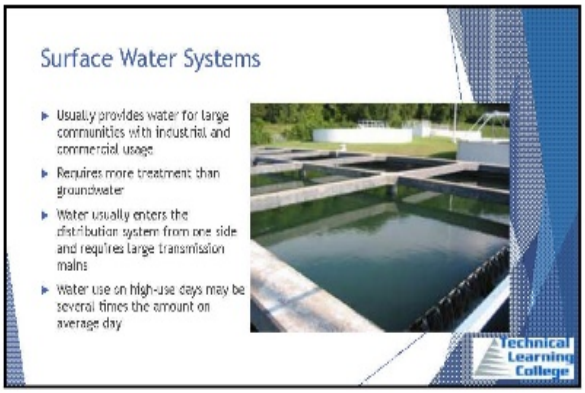
Supporting Knowledge Type	Distribution System Components (25%)*	Equipment Installation, Operation, & Maintenance (24%)*	Disinfection Monitoring, Evaluation, Adjustment, & Laboratory Analysis / Interpretation (27%)*	Security, Safety, Administrative Procedures, & Public Interactions (24%)*
Water storage facilities (e.g., maintenance, security, operation)	Intermediate	Intermediate		Intermediate
Well operation, monitoring, and maintenance	Intermediate	Intermediate	Intermediate	Intermediate
Workplace safety rules, regulations, practices, and procedures		Intermediate		Advanced

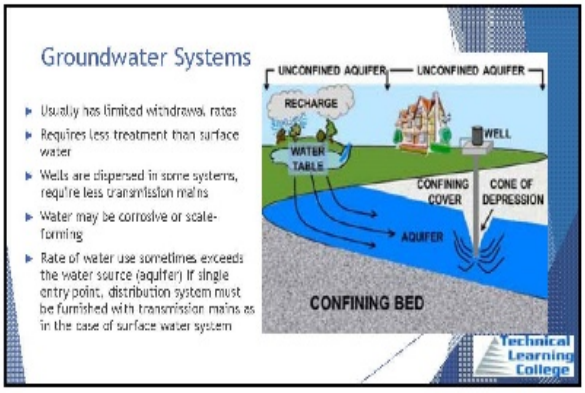
Percent of exam associated with the Content Area

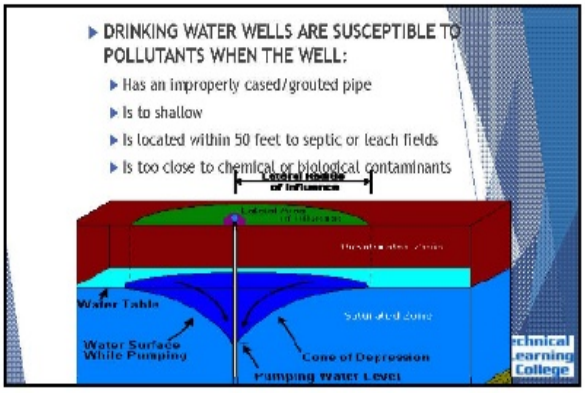
Water System Use and System Design



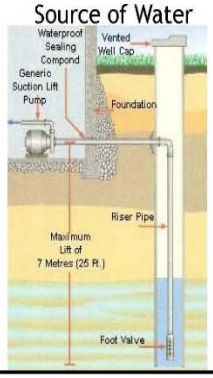








Source of Water



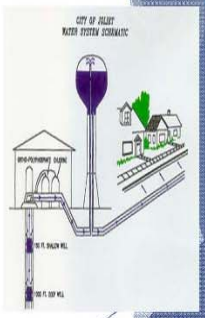
- Groundwater
  - Percolation or Infiltration
  - Springs
  - Reclaimed
- Little Turbidity
  - Generally free of microorganisms
  - May have iron, manganese, H2S, radionuclides, and possibility of contamination
- Surface Water
- Groundwater Under the Influence of Surface Water

Health Related Categories

- Physical relates to how the customers judge the water; smell, taste, temperature, floaters, and color.
- Chemical changes the pH of the water. Some minerals cause hardness or staining.
- Biological are the living things. Some biological conditions can change the physical and chemical characteristics of the water.
- Radiological factors could be produce from some mining operations.

Purchased Water Systems

- Why 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



System Design & Pipes

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

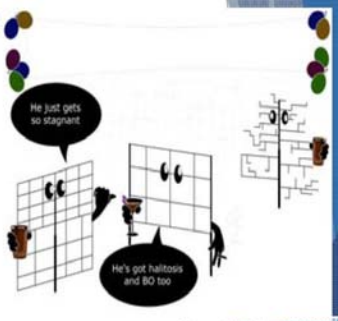
- State and Federal requirements
- Future growth
- Costs: materials, labor, overhead, profit, land acquisition, legal expenses and engineering

Factors Affecting System Layout

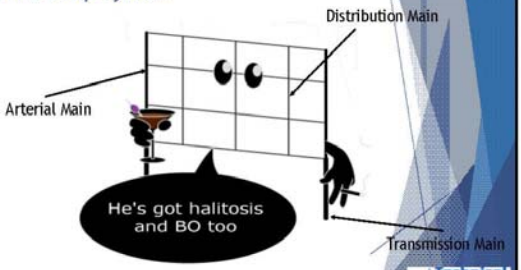
- System planning
- Configuration, Mapping & Valving
- Design should be done by city engineer or consultant
- Operators should be included in the process
- Important to include operators because they make it work

System Configuration

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



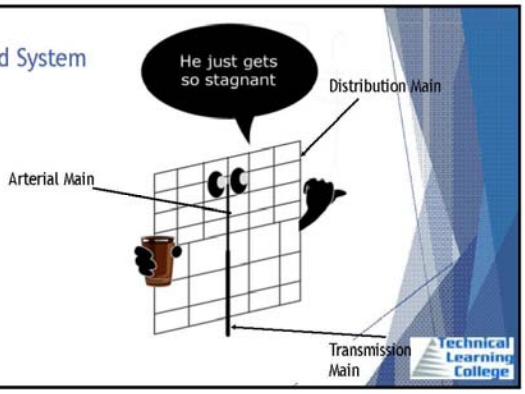
Arterial-Loop System



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

Grid System



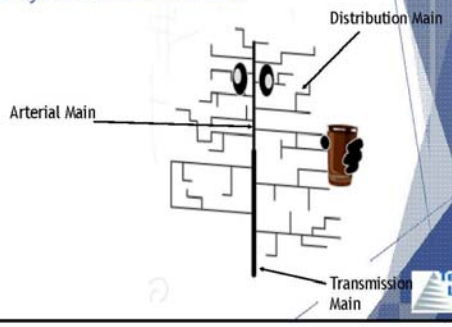
Grid System Characteristics

- 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

Grid System Characteristics

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

Tree System Characteristics



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

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

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 less expensive in larger sizes

Distribution Mains (Arterial)

- 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

Factors for Sizing Water Mains

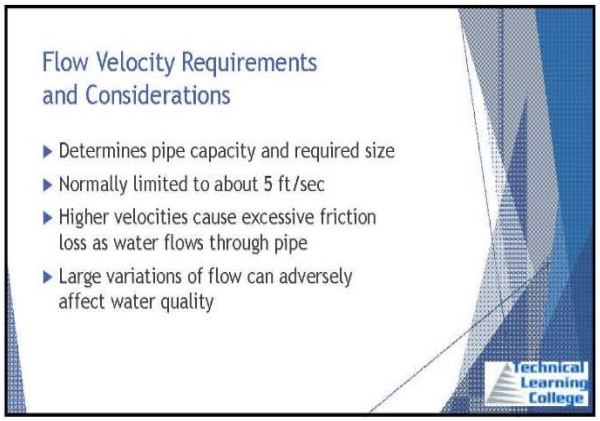
- Quantity depends on consumption and fire flow requirements
- No main may be less than 6 inches in diameter for fire protection
- High value areas should have minimum pipe size of 8-12 inches

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

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


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
Technical Learning College

Assignment

Answer the following questions using the AWWA book, Chapter 3.

Name three water supply categories.

List the time when water usage is at its lowest and highest.

What is a flat rate user?

What % increase of water is used for people not on septic systems?

Define Riparian doctrine:

Define Prior Appropriation Doctrine:

What are the four systems used to determine rights to groundwater.

What are the two primary reasons for drinking water distribution systems?

List the types of Water Systems:

What water quality does groundwater have that surface water could treat?

List the at least three considerations when planning a system.

What components does a conventional layout of a water system have?

What are the 3 layout designs in a distribution system?

What information should be listed in an existing system?

What should be immediately recorded after installation?

Where mains intersect in a grid how many branch lines should be provides with valves?

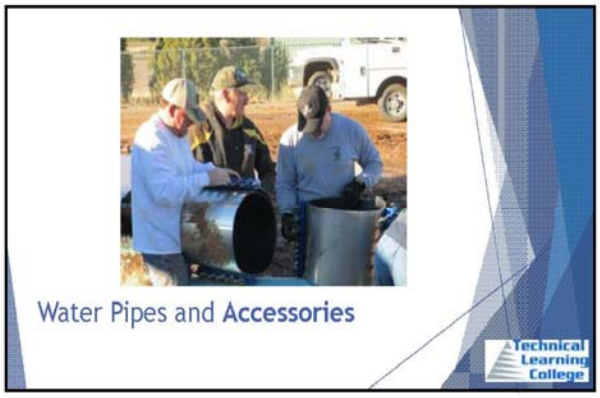
Who sets the fire flow requirements for system less than 50,000?

What are the suggested main sizes for fire insurance?

What is the minimum pressure in the system during high peak flows?

What's the average flow through a pipe?

What is the common formula to calculate pipe size called?



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 $$$$$$

Technical Learning College

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

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
- **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

Technical Learning College

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

Technical Learning College

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

Technical Learning College

Types of Pipe

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

Gray Cast-Iron Pipe (CIP)

- 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

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

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

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

Ductile-Iron Pipe Joints

- Flanged
- Mechanical
- Ball-and-Socket
- Push-on
- Restrained
- Grooved and Shouldered

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

Mechanical Joints

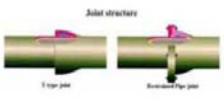
- Movable follower ring on the spigot to the flange on the bell
- Follower ring compresses a rubber gasket to form a seal
- More expensive
- Make a very positive seal and require little technical expertise to install
- Allow for some deflection of the pipe
- Provide flexibility in event of ground settlement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

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

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



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

Grooved & Shoulder Joints

- Grooved
  - Utilizes bolted, segmental, clamp-type, mechanical coupling
  - Housing encloses a Ushaped 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

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

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

Steel Pipe Joints and Fittings

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

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

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

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
- HOWEVER!!!

Plastic Pipe Types

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

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

Plastic Pipe Joints

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

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

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

Concrete Pipe Types

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

Pre-stressed 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

Pretension (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

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

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

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

Assignment

Answer the following questions using the AWWA book, Chapter 5.

What happens to Iron and steel pipe if it is not protected?

List some general factors to consider when selecting pipe.

Define ANSI/NSF Standard 61.

List what should be considered for pipe characteristic.

Define the following:

External load:

Internal pressure:

Water hammer:

Tensile strength:

Flexural strength:

What is the difference between shear and beam break?

What should the pressure rating of a pipe be?

What causes friction head loss, what factors can affect it, and how does it relate to velocity in pipe lines?

What is the C-factor and what does it indicate in a water pipe and what's the term that is caused by buildup of corrosion?

List the types of pipes used (Note C900 is the most typically used):

List the types of joints used for DIP:

Why are steel pipes frequently used?

How do steel pipes connect together?

What is PE and PB?

Define Permeation:

What type of PVS is used for large transmission lines?

Can PVC be thawed electrically?

How are PVC pipes joined together?

Fiberglass Pressure Pipe WOW!!!! What's the pressure ranges?

Typically Concrete pipes are made of what two materials?

What AWWA standard is used for pipes?

How are Concrete joints sealed?

Notice the type of pipe connection device.

This is known as a “Restraining Flange”.

Pipe Vocabulary

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

Pipe Installation

Stringing Pipe

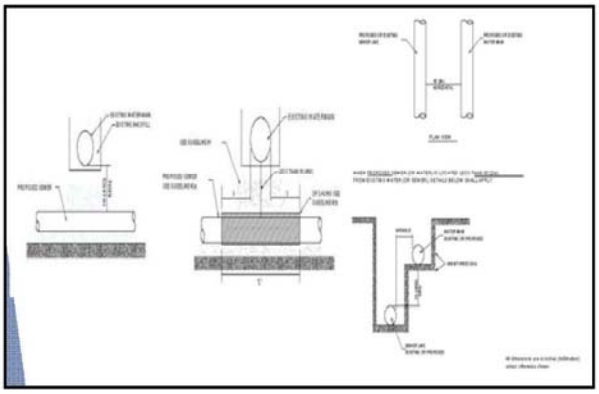
- Pipe should be laid as near to the trench as possible to minimize handling
- String pipe on opposite side of spoil pile
- Place bells in direction of installation
- Secure each section to prevent rolling into trench
- String only enough for one days work to prevent vandalism
- May need to cover ends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

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
- One Call

Excavation

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

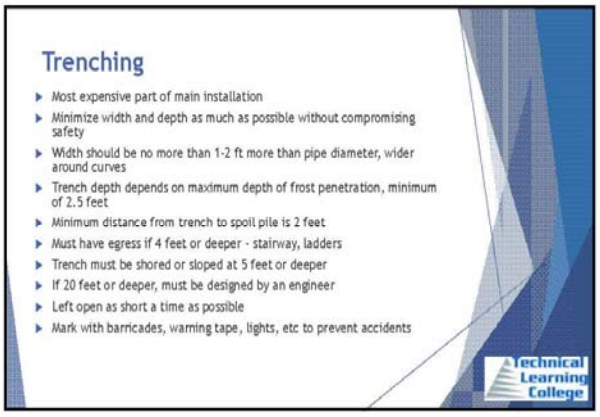


Excavations

- Competent person, is a person capable of indentifing existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate the hazards.

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
- 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



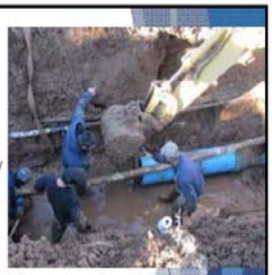
Soil Types

- Type A (most stable)—dense and heavy clay
- Type B-silt, sandy loam, medium clay
- Type C (least stable) —gravel, loamy sand, soft clay

Sloping and Benching

- Sloping: angling of walls at an incline
- Benching: series of steps to angle walls
- Soil type determines angle of slope/bench
  - Type A: 3 feet horizontal to 4 feet vertical (3/4:1)
  - Type B: 4 feet horizontal to 4 feet vertical (1:1)
  - Type C: 6 feet horizontal to 4 feet vertical (1-1/2:1)
  - Benching not permitted for Type C soil

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
- 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 workday
- Ensure pipe bedding is level and compacted
- Compact the backfill beneath the pipe curvature (Haunching)

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

Connecting to an Existing Main

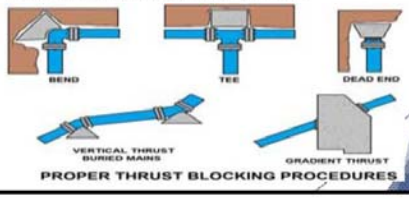
- Shut off water to existing main and ensure valve will hold
- Must know the size and type of main to get proper fittings and gaskets
- Connecting to main using pressure taps
  - Does not require shutting off water and
  - Less chance of contaminating water
  - Also, fire protection remains in service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

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

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



PROPER THRUST BLOCKING PROCEDURES

Technical Learning College

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

Technical Learning College

Piping Air Relief

- Air gets trapped in water mains laid on uneven ground
- Constricts water flow
- Automatic air-relief can be installed at each high point in pipeline

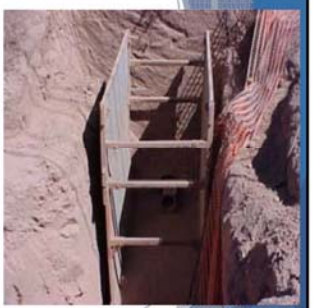
Technical Learning College

Backfilling and Testing

Technical Learning College

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



Technical Learning College

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

Technical Learning College

Compacting

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

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

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 a tall high points
5. Start applying partial pressure with positive displacement pump

Leak Testing Procedure

6. Once lines full, leave partial pressure on & allow line to stand for 24 hours to stabiiize
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 2hours, conduct leakage test by using the make up reservoir and measuring the amount of water that has to be used to maintain specified test pressure
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

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 maybe 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

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

Methods of Disinfecting

- Tablet Method
- Continuous Feed Method
- Slug Method

Bacteriological Testing

- State requires two consecutive sets of samples taken24 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

Site Restoration

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

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 whenhandling chlorine, etc.

Assignment

Answer the following questions using the AWWA book, Chapter 6 & 7.

What are the four general steps to pipe handling?

If using a forklift to remove pipe, what is recommended?

What should gaskets be protected from?

What side of the trench should the pipe be strung?

When preparing for excavation what should the project plans include?

Before making the traffic crazy who and how do you notify? (I said who and how!)

Briefly write down what controls the depth and width of a trench.

What is the typical coverage of a pipe in normal climates?

What should the width of the trench be around the pipes bottom?

Sewer and water, yum! What are the recommended distances in a trench?

Clay expands with water and shrinks when dry, not great for compactions. Figure 6-16 and 6-17 shows the best loading strengths for pipes and bedding. (Just a FYI)

Define Haunching: (Also use this word when someone bugs you)

Describe briefly how to inspect, clean and place pipes prior to installation.

What procedures should be followed for installation of Joints and how should they be dug?

What are the four steps to assemble DIP or PVC push-on pipes?

What group preformed “Push it”?

What are the disadvantages of mechanical joints?

What should be done first before installing tees?

What are the two common methods for inserting tee’s?

Just a heads up, wet taps and dry taps was the terminology used. List a few advantages of “Pressure taps”.

How should the face of the flange be set?

Define “coupon”:

How are mains installed under railroad tracks, highways and other crap in the way?

What is the purpose of thrust restraints?

List three areas of force in a pipe.

List four common thrust restraints.

What is the purpose of air vents?

Chapter 7

What is the purpose of backfill?

List the three types of compacting and how it's done.

What type of dirt is hand-controlled plate tampers used for?

What is the pressure range a pipe should hold during a pressure test?

What type of pump is used in a pressure test?

Sad… pressure test failed, look at the list of causes, crap someone didn't close the corp after tapping!

What is the typical velocity rate for flushing a main?

What are polypigs used for?

What is the free residual concentration in a main that was super chlorinated?

What factors should you know prior to chlorination?

Define the following
Continuous feed method:

Slug method:

Tablet method:

What is the typical contact time for disinfecting?

Remind the instructor about a HPC!

Trenching & Excavation (AWWA book, pages 131-136)

A device which provides adequate protection from falling or collapsing earth loads. The trench box is a common form of:

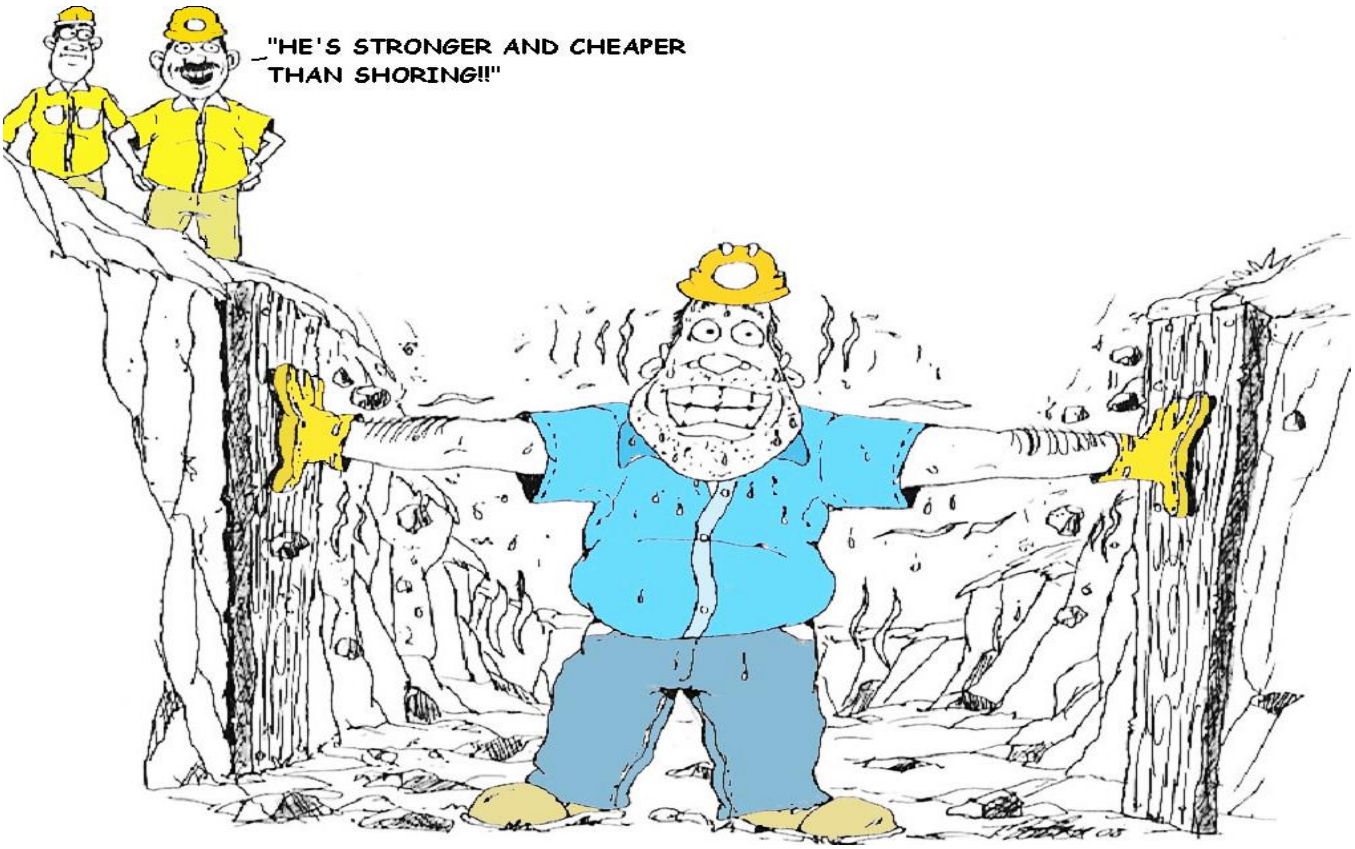
A. Sand
B. Shielding
C. Saturation
D. Shear
E. Sheeting
F. None of the Above

The process of cutting back the sides of a trench to avoid a cave-in.
A. Shoring
B. Shielding
C. Silt
D. Silty Clay
E. Sloping
F. None of the Above

Vertical members of a trench shoring system placed in context with the earth. These members usually are not placed in direct contact with one another.
A. Uprights
B. Vibration
C. Voids
D. Wales
E. Wall Stability
F. None of the Above

What are the three main shoring assembly parts?

What is the recommended procedure to remove shoring?



Water Services

Water Service Lines

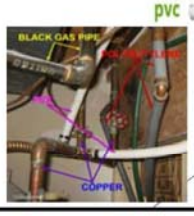
- Water service lines are the pipes that lead from a connection on a water main to a connection on a customer's plumbing.

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
- 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

Reduction of Lead in Drinking Water Act of 2011

- Reduced "lead free" from less than 8% content to no more than 0.25% allowed
- Was 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

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

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

Technical Learning College

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

Technical Learning College

Corporation Stops

- Valve used to connect a small-diameter service line to a water main
- Also known as
  - Corporation cock
  - Corporation tap
  - Corp
- Available with a ball valve or plug valve

Ford Ballcorps and Corporation Stops

Technical Learning College

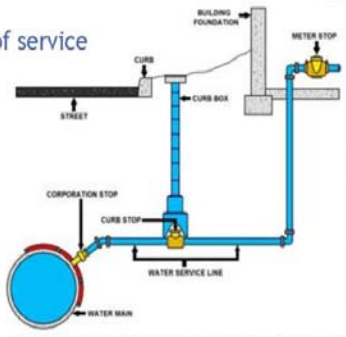
Curb Stops and Boxes

- 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

Ford Curb Stops and Meter Valves

Technical Learning College

Picture of service



ONE VARIATION OF COMMON WATER METER INSTALLATION METHOD

Technical Learning College

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

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

Direct Tapping Process

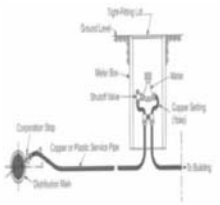
- Pipe excavated and cleaned, machine clamped into place
- Machine bores hole in pipe wall, tap cuts threads
- Boring bar retracted, flapper valve closes to contain pressurized water
- Drill-and-tap tool removed, corporation stop threaded into hole in closed position
- Bar is reinserted into the machine and the corporation stop is screwed into the threaded hole
- Machine is removed; corporation stop is ready for attachment of service line

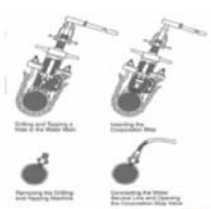
Service Clamps

- 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

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





Leaks and Breaks

- Lead and galvanized iron pipe likely to leak if disturbed
- Copper and plastic more durable
- Can break during excavation or settling

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

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
  - Good records on plastic pipe are especially important because they cannot be located by electronic equipment

Assignment

Answer the following questions using the AWWA book, Chapter 8.

List several names for meter boxes and describe what they are used for.

List what determines the size of a service line.

What are the typical sizes for a residential service line?

List the type of service pipes used and that has the higher potential for corrosion.

What type of pipe is flare fittings used?

What type of coupling prevents corrosion?

List the two types of valves in a “corporation stop” AND list it’s aka’s.

What is the advantage of a Mueller thread?

This device is used to isolate the customer service line:

Which state has a curb box named after it?

List three operations a tapping machine provides.

List the four stops making a service tap.

What is the recommended clamp on an AC pipe?

What is the definition of a service saddle?

Which types of service pipes are considered old?

List ways to handle frozen pipes.

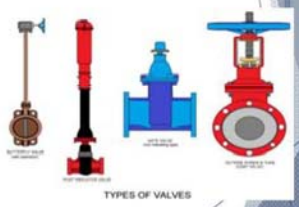
Who is responsible for service lines?

Valves

Valves

Common Valves in the System

- The five most common categories of valves
- Slide (linear) - Gate Valve
- Rotary
- Globe
- Diaphragm valves
- Ball, fully on or fully off.



TYPES OF VALVES

Uses of Valves in Distribution System

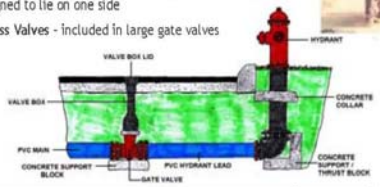
- Isolation (gate, butterfly, globe, ball)
- Draining lines (blow-off)
- Throttling flow (butterfly, plug, globe)
- Regulate water storage levels (altitude-control valve)
- Control water hammer (pressure-relief valve)
- Allow air in & out of lines (air-relief valve)
- Control backflow (check valve)

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
  - 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

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

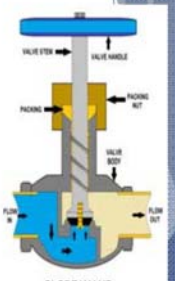


Butterfly Valves

- 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

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



GLOBE VALVE

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

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

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

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

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

Valve Operation & Installation

- **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
- **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

Technical Learning College

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

Technical Learning College

Assignment

Answer the following questions using the AWWA book, Chapter 9.

List the reasons for using valves in the Distribution System.

What position should a valve be normally?

How many valves should a pump have and why?

What type of valves regulate pressure?

Pressure relief valves can be installed to release some of the energy caused by_____.

What type of valve is used for water heaters?

Air relief valves on installed on the_____ of the pump.

What is the most common valve found in a distribution system?

Non-rising and outside screw and yolk are what type of valve?

Why are bypass valves used?

Define the following:
Cutting-in valve:

Inserting valve:

Resilient-seated valve:

Slide valve:

What type of a valve is an altitude?

List the types of Rotary valves.

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

____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.

Hydrants

Hydrants

Hydrant Uses

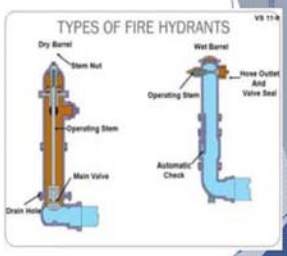
- Fire fighting
- Flushing water mains
  - Fully opening a hydrant to remove sediment
  - Recommended twice a year
  - Velocity in excess of 2.5 ft/sec
  - All dead end water mains shall be equipped with a blow off or other suitable flushing mechanism
- Flushing sewers
- Filling tank trucks
- Providing temporary water sources for construction work via hydrant meter

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

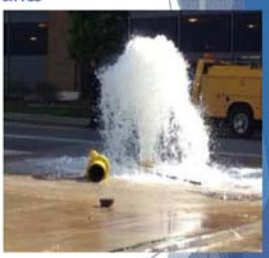
Types of Hydrant

- Wet Barrel AWWA C503
- Dry-Barrel Hydrants AWWA C502



Design of Wet-Barrel Hydrants

- 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



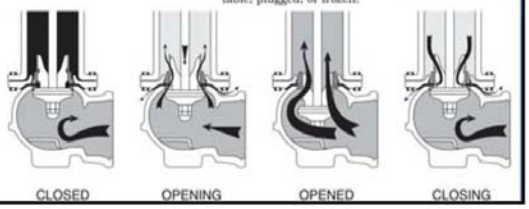
Traffic Model

- 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

Operation of Hydrants

Operating Sequence - Closing

During closing of the hydrant, the drain valve remains closed until the main valve is within 1 to 5 turns of being closed. At this time the drain valve will begin to open, allowing water under pressure to once again clear the drain holes. As the main valve reaches full closure, the drain valve returns to a full open position. All remaining water in the barrel of the hydrant will drain through the drain valves. This assumes that the drain valve is not below the water table, plugged, or frozen.

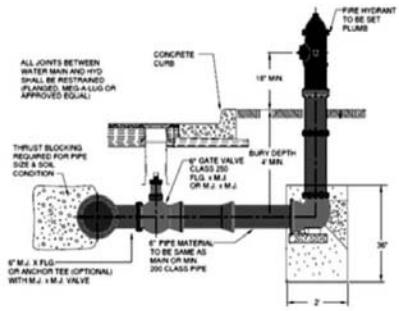


Inspection of New Hydrants

- 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

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



Installation

- Adoption of color scheme to indicate flow is optional, but if used, it should follow the uniform color coding system:
- Per National Fire Code 921:2-1 and 2-2
- Class Flow, gpm Color
  - AA Greater than 1500 **Blue**
  - A 1000-1499 **Green**
  - B 500-999 **Orange**
  - C Less than 500 **Red**

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

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

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

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 10 W40

Inspection Procedures

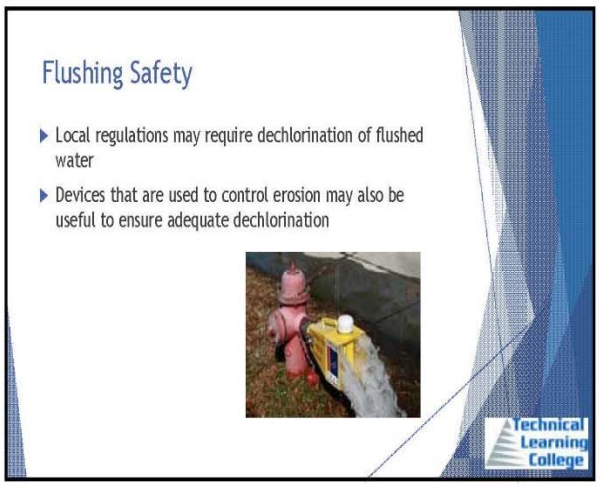
- Verify upper barrel connected
- Check ground around hydrant
- Check valves for ease of operation
- Check for leakage at joints
- Flush line to remove foreign material
- Close main valve completely
- Check for proper drainage
- Use a hydrant wrench
- Check breakaway mechanism
- Check nozzles for cross threading
- Clean and lubricate threads per hydrant specs
- Lubricate operating nut threads

Hydrant Repair

- Notify fire department
- Close auxiliary valve
- Repair hydrant to manufacturer recommendations
- Test hydrant and open auxiliary valve
- Record make, model, location of hydrant at installation
- Record inspection and repair info - proof of condition of hydrant

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


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
Technical Learning College

Assignment

Answer the following questions using the AWWA book, Chapter 10.

List four uses for fire hydrants, other than for fire protection:

List four reasons why strict controls should be exercised over hydrant uses:

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

List four types of Hydrants.

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

What is the typical flow in gpm and psi for fire flow?

List two ways hydrants can be protected from damage by traffic:

What should be checked when receiving a new Hydrant, list all seven:

What should be considered when installing a Hydrant?

What procedures must be taken if the drain holes (weep holes) are below water table?

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

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

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

List seven items of information that should be included on a hydrant record form:

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.

Storage Facilities

Storage Tanks
Disinfection
Rules and Regulations

Technical Learning College

Water Storage "WHY"

- 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

Technical Learning College

Capacity Requirements

- Based on maximum water demands indifferent 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
- Bottom Line:
  - Peak Demand
  - Equalization of Pressure

Technical Learning College

What Determines Storage Capacity?

- The highest single day demand during the year.

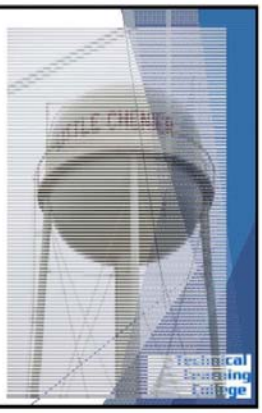
Technical Learning College

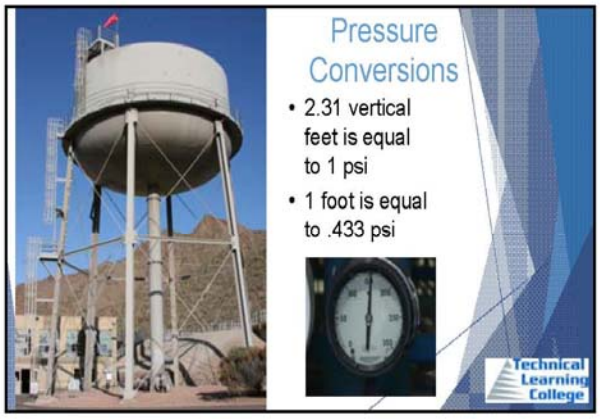
Storage Tanks

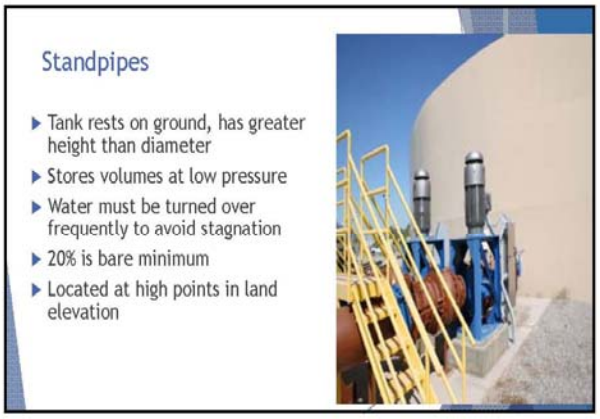
- Elevated Tanks
- Ground-Level
- Reservoirs
- Standpipes
- Hydropneumatic System
- Surge Tanks

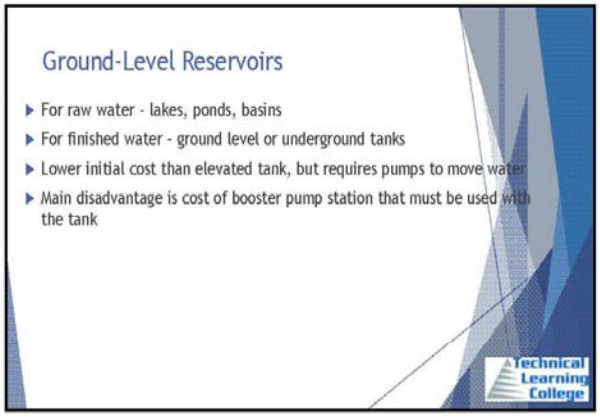
Elevated Tanks

- 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

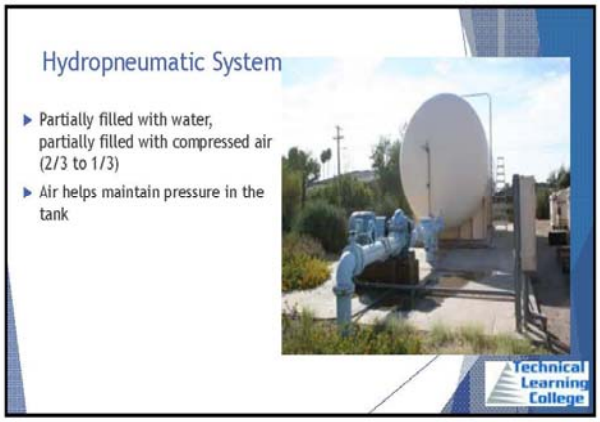


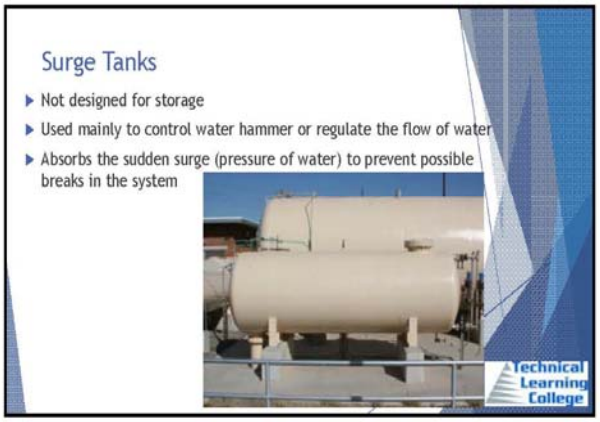

Pressure Conversions
• 2.31 vertical feet is equal to 1 psi
• 1 foot is equal to .433 psi
Technical Learning College


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


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
Technical Learning College


Ground-Level Reservoirs


Hydropneumatic System
Partially filled with water, partially filled with compressed air (2/3 to 1/3)
Air helps maintain pressure in the tank
Technical Learning College


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
Technical Learning College

What is the cause of water hammer?

Selection and Location of Storage

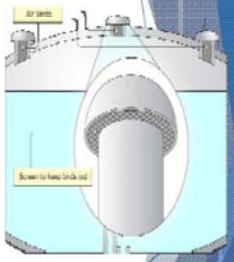
- Determined by hydraulics, water demand, elevation after rain and purpose of tank.
- Type of storage depends on purpose of tank

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 distribution pressure is lower than tank pressure
- Data transmitted to central location - alarms can alert operator of high or low levels

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
- 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



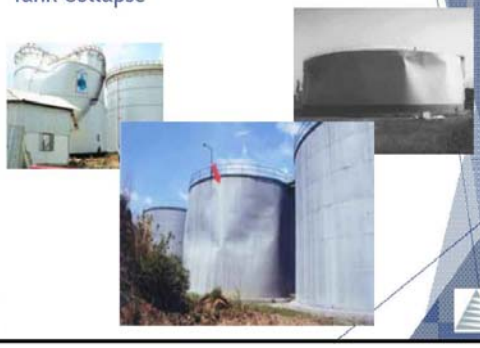
Tank Equipment

- 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
- Coating protect interior and exterior of tank from corrosion without causing taste & odor problems
- Coatings must meet the requirements of NSF (ANSI Standard 61)
- Cathodic Protection assist in corrosion control
- Electrodes placed in tank which corrode instead of tank and appurtenances
- Inspect annually
- The dirt around the storage tank needs to be graded away from the tank for 50 feet

Tank Inspections

- Must be professionally inspected every 5years in accordance with State/Federal requirements inspection by draining or by using a diver inspected by a third party
- Inspection reports must be on file and available for review by Official Inspectors
- Visual inspections recommended annually
- Requires draining the tank or using divers
- Check vents, overflows, paint, altitude valves, etc.
- Check for corrosion inside & outside
- Considered confined space, get permit

Tank Collapse



Vandalism and Security

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

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

Records

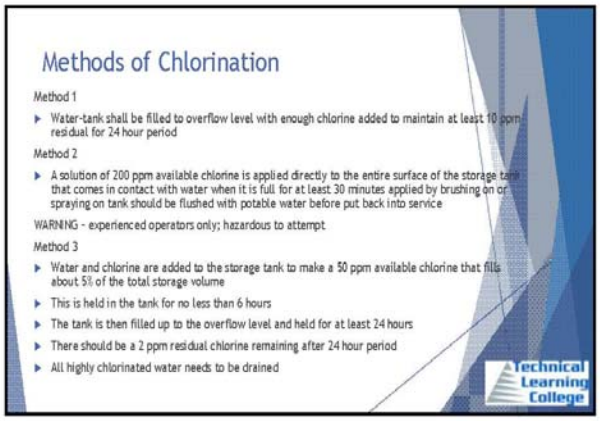
- Every tank in your system should have a historical record file containing, as a minimum, the most current in section report
- Location, type of maintenance or repair performed, all contract documents and specifications for repair, paint and equipment submittals, etc

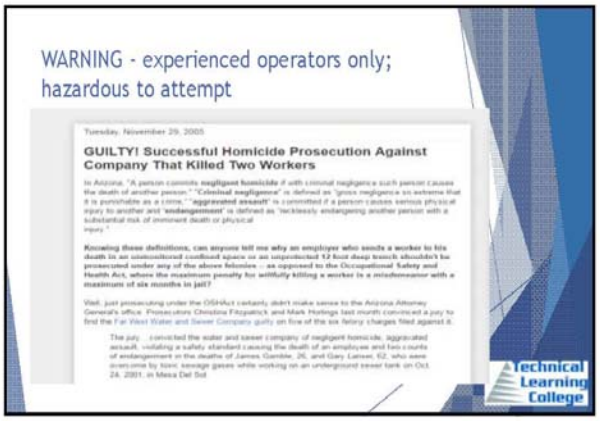
AWWA Standard for Disinfection of Water-Storage Facilities

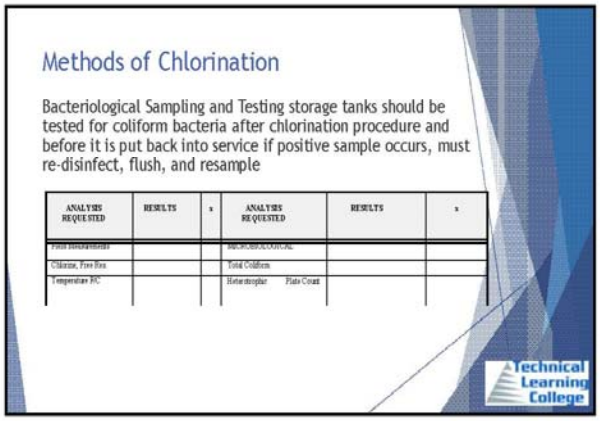
- Before placing into service, all storage tanks shall be disinfected
- Standards for disinfecting storage tanks covered by AWWA C652 including materials, tank preparation, disinfectant application and sampling for coliform bacteria

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
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
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
Technical Learning College


WARNING - experienced operators only; hazardous to attempt
Tuesday, November 29, 2005
GUILTY! Successful Homicide Prosecution Against Company That Killed Two Workers
Technical Learning College


Methods of Chlorination
Bacteriological Sampling and Testing storage tanks should 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
ANALYSIS REQUESTED
RESULTS
x
ANALYSIS REQUESTED
RESULTS
x
Chlorine, Free Res.
Total Coliform
Temperature ºC
Heterotrophic Plate Count
Technical Learning College

Assignment

Answer the following questions using the AWWA book, Chapter 11.

List the four primary storage structures.

List the purpose of the storage facilities.

Define “Peak hour demand” and when it usually occurs.

Define “fire demand”.

Define “Detention Time”

Why would you blend water sources?

What is emergency storage used for? (Do not Duh me!)

Which storage tank is not made of steel?

Which tank uses compressed air?

How are steel tanks assembled and what type of coating is used?

List the three types of concrete tanks and reservoirs.

Where should elevated tanks be located?

What is the pipe name that provides water to an elevated tank?

What type of pipe should be installed in all tanks as a safeguard?

How is air introduced to a tank and how should it be treated?

What is the typical height from the bottom of a tank for a ladder?

List conditions inside a tank that can deteriorate the coating.

Define “cathodic protection”.

Where are inlet and outlet pipes located in a ground level tank?

How do we drain tanks?

Baby its cold outside, list some ways to prevent the water from freezing in a tank.

DISINFECTION
List the methods:

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.

Assignment

Answer the following questions using the AWWA book, Chapter 12.

Define the following
Static electricity:

Direct current (DC):

Alternating current (AC):

What is the charge of an electron?

Which circuit uses transformers, AC or DC?

Compare how water relates to electricity:

Molecule of water =

Flow (gpm) =

Pressure (psi) =

Pressure drop =

Friction =

Pump =

Turbine =

Turbine driven pump =_____=_____

Reservoir =

Flooding =

Instantaneous transmission of pressure =

Describe “Ohm’s law” and what is the formula?

List the main categories of instrumentation control.

List the types of sensors used.

How does a bubbler tube work?

How does thermocouples work?

How does thermistors work?

How is “Power” expressed?

List the different monitors used in a water system.

What is the difference between a Receiver and Indicator?

What are the two types of instrument displays?

Define RTU (Not star wars….):

Define CTU:

List three types of control systems:

What is “SCADA”

Pumps & Motors

Pump Classes

- Centrifugal is most commonly used & is a velocity type pump
- Positive displacement

Frame Mounted Pumps

- Are a horizontal pump
- Pump and Motor bearings are independent of each other
- Motor can be replaced without removing pump piping

Close Coupled Pumps

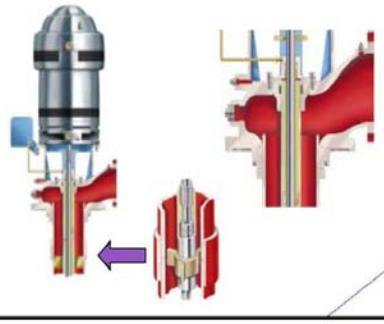
- Are a horizontal pump
- Impellers are supported by the motor bearings
- Piping in most cases needs to be removed to access impeller

Vertical Lineshaft Pumps

- Lineshaft Turbine
- Can Turbine
- Submersible
- Axial Flow

Lineshaft Turbine- Water Lube

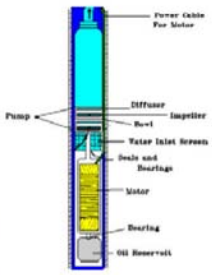
Lineshaft Turbine- Oil Lube



Can Turbine

- Operates in flooded suction or pressure condition

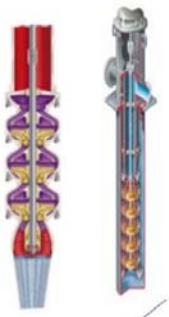
Submersible



Axial Pumps

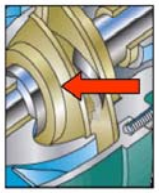
Bowls

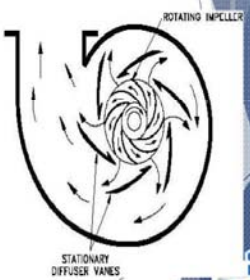
- Impellers Located in Bowls
- Multi-stage - stages/bowls add pressure not volume



Diffuser Vanes

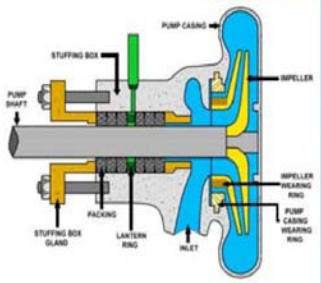
- Diffuser vanes convert velocity to pressure





STUFFING BOX

- Packing or mechanical seal
- Lantern ring
- Packing glands
- Seal water - 5 psi higher than maximum suction pressure



CENTRIFUGAL PUMP PARTS

External Seal Water

- Clean water source
- Used when pumped water has grit in it
- Needs to be turned on several minutes before starting pump
- Should have back flow preventer on clean water source.

Technical Learning College

Impellers

- Vertical Pump Location

Technical Learning College

Impellers

- Horizontal Position

Technical Learning College

Impellers

- 3 types - open, semi-open, & closed
- Heart of the pump
- Made from metal, plastic, rubber
- Impeller eye - low pressure zone
- Suction of water is created at the center of the impeller, then it is pushed away from impeller by centrifugal force

Technical Learning College

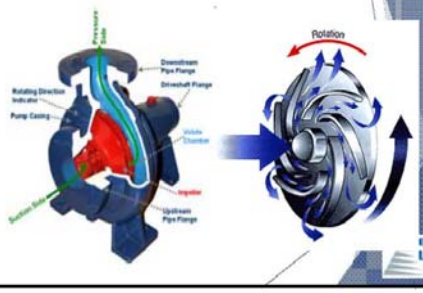
Open Impellers

Closed Impeller

Semi-Open Impeller

Technical Learning College

Pump Rotation



Volute Case

- Houses the impeller
- Curved vanes inside volute case are called volutes & convert velocity energy to pressure energy.
- Should primed full of water on start up

Wear Rings

- Keep water from recirculating from the high pressure zone to the low pressure zone
- Used to protect the volute case and impeller from wear
- Worn rings cause recirculation of water costing more to operate

Wear Ring

- Worn out wear ring

Split Case Pump

- Wear Rings act as a restriction between the impeller discharge and suction areas.

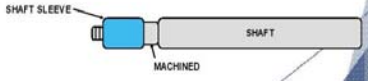
LANTERN RING

- H - shaped cross section
- Made of metal or plastic
- Located inside the stuffing box where seal water enters
- Not used with a mechanical seal
- Allows water to flow evenly through the packing

Seal Water

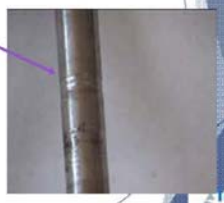
SHAFT

- Driven by motor to turn & support the impeller
- Shaft sleeve - pressed on the shaft, located inside stuffing box
- Shaft sleeve is an expendable part used for wear



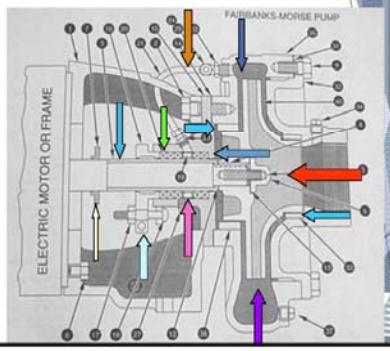
No Shaft Sleeve

- Worn shaft that had no sleeve



Worn Shaft Sleeves

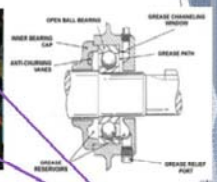
CENTRIFUGAL PUMP COMPONENTS



BEARINGS

- Anti-friction bearings
  - * Roller bearings
  - * Ball bearings
- Manufacturer determines type & frequency of lubrication
- Sleeve bearings

Proper Bearing Lubrication



- Remove plug in grease relief port
- Press new grease into grease fitting displacing old grease
- Allow motor to run and let excess grease exit
- Replace plug in grease relief port

BALL BEARINGS

- Outer Ring
- Inner Ring
- Cage
- Rolling Element

ROLLER BEARINGS

- Supports radial loads and/or thrust loads depending on the design and where the rolling elements are placed

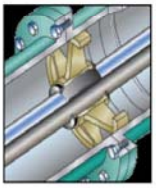
ROLLER TYPE BEARINGS

Roller Bearings

Needle Bearings

Sleeve Bearings

- Located in Spider

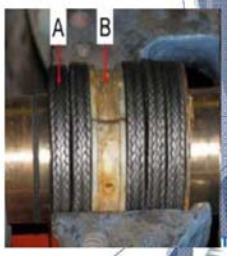


SHAFT SEALS

- Packing
- Mechanical seals
- Separate the wet from dry end of the pump
- Mechanical seals are for high suction head, metal packing can also be used

PACKING

- Should be adjusted to allow a steady drip of water from the packing gland
- Made out of braided animal, flax, plant, mineral or synthetic material
- Impregnated with some type of lubricant
- Comes in contact with shaft sleeve



PACKING CONDITIONS

CONDITIONS	*PACKING*
Less than 100 psi or 1000 FPM	Plant fibers lubed with Teflon, silicon, TFE, or PTFE
	Graphite, acrylics, TFE, kevlar, PTFE, & carbons
100 to 150 psi or 1000 to 2000 FPM	Metal, packing with metal cores or combination of synthetics & metals.
Above 150 psi or 2000 FPM	Asbestos no long used

Stuffing Box

- Packing Location

PACKING PROCEDURE

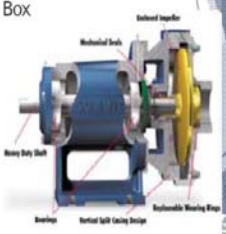
- Remove old packing, never stack new on top of old
- Cut in scarf or butt cuts
- Cut 1/16 - 1/8 shorter than shaft circumference
- Lubricate 1st ring & seat at the bottom of the stuffing box
- Stagger rings 90 degrees
- Line lantern ring with seal water
- Finger tight adjustment nuts

MECHANICAL SEALS

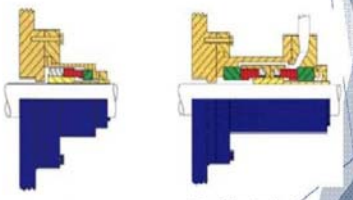
- Two surfaces: one is stationary and the other is rotating
- Stationary surface is made of a harder material than the rotating surface
- Machined to within millionths of an inch enough to allow a water molecule to pass between the two surfaces
- Spring keeps tension on the surfaces
- Seal components must match properly

Mechanical Seals

- Located in Stuffing Box



MECHANICAL SEAL PLACEMENT



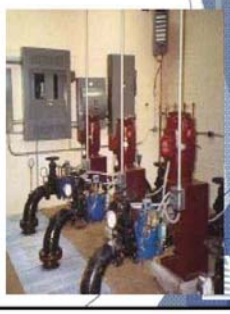
Single Seal Double Seal

START UP

- Rotate shaft by hand
- Run seal water 15 min. prior to start up
- Finger tight adjusting nuts
- Start pump, run 15 min., don't adjust
- Adjust nuts equally, 1/6 turn every 15 min., until desired leakage is reached
- Stuffing box should be cool

START UP

- Check valve positions
- If pump has set for an extended period of time, the shaft should be turned to oil the bearings
- Check oil levels, amp readings, volt readings, flows, well info., Comments

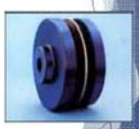


SLINGER RING

- Made of either leather or rubber
- Fits on shaft near the motor
- Prevents water from entering the motor bearings

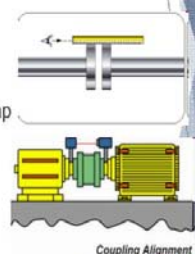
COUPLINGS

- Connect shafts of different diameters
- Transfer energy
- Most allow for slight misalignment
- Absorb starting torque
- Dampen vibrations
- Insulate units from electrical current
- Allow for end movement of shafts



ALIGNMENT TECHNIQUES

- Straight edge and feeler gauge
- Dial indicator
- Severe vibration upon pump start up would indicate misalignment between motor and pump shafts



Coupling Alignment

PUMP OILERS

PUMP MAINTENANCE

- Oil Drip rate = 5 drops per minute
- Use approved food grade mineral oil
- If a pump has been pulled for repair, you must have satisfactory bac-t results before putting back in service
- Drain water from pump piping in the fall if the pump sits during winter

Pump Station Flow

- Each pump in a pump station must be able to deliver the maximum flow of the station
- Make sure the shaft bearings are wet before starting the pump
- Flow increases with decreased pressure head
- Alternating pump operation will help keep windings dry & serviceable
- Booster pumps fill tanks & supply pressure to mains

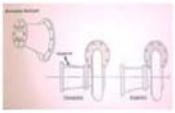
PUMP WEAR AND TEAR

- Pumps condition can be checked by comparing performance when new
- Wear is the main cause of loss in pumping efficiency
- Pump will run longer because of wear, increasing power costs
- Particles from wear can be seen in cooling water from stuffing box

PIPING

- Eccentric reducer - suction side
- Concentric increaser - discharge side
- Eccentric installed with the flat side up, reduces air entering casing & one size larger than suction inlet
- Concentric increases pipe one size, reducing velocity and head loss, for higher pump efficiency
- Should be drained in freezing conditions & pump is not operated for short periods of time

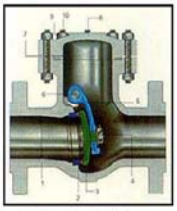
REDUCERS & INCREASERS



VALVING

- A check valve prevents the shaft from spinning backwards and causing damage to the pump
- If no check valve, you can start and stop a pump with the discharge valve closed to prevent water hammer by opening it slowly

CHECK VALVES



Swing Check Valve

Silent Check Valve

Keep pump from spinning backwards

Pump Control Valves

Foot Valves

- Located at the bottom of suction pipe to hold prime

Air Vacuum Release Valves

- Air vacuum release valves - prevent vacuum conditions during shut down, they also release air pockets during start up.
- Placed at high points of the system

RATCHETING DEVICES

Motor Maintenance

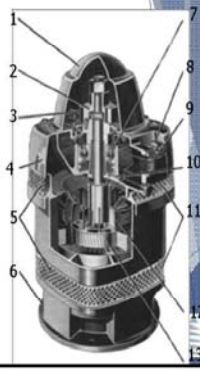
- Follow manufacturer's recommendations
- Over greasing - grease acts like an insulator, holding in heat, causing premature bearing failure
- Two most common speeds are 1800 or 3600 rpm
- Oil seals hold in the lubricant

Pump Motor Operation

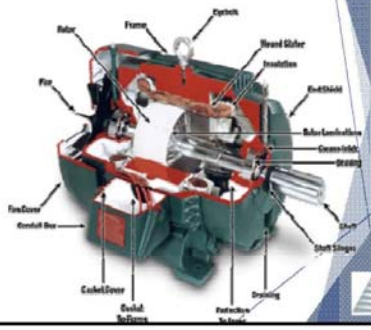
- Motor could overheat with low head pressure
- In a low pressure head situation, throttling the discharge valve would cool the motor cool down due to the increase of pressure head
- Losing a phase on a 3-phase motor would cause the motor to single phase and heat up.
- Voltage imbalance can cause the motor to over heat & burn out windings
- Blow dust off to clean motor housing
- Brake HP is HP supplied by the motor

Vertical Motors

1. Lightweight Top Cover
2. Coupling readily accessible.
3. Lock bar holds shaft during adjustments.
4. Lifting Lugs positioned for stability.
5. Protected Air Openings exceed NEMA Weather Protected Type I requirements.
6. Precision Machined Mounting Base, ample clearance for mounting bolt installation.
7. Rugged Bearing withstands heavy thrust loads.
8. Large Plug simplifies oil fill.
9. Sight Gauge Window for quick oil level reading.
10. Metered Oil Flow minimizes churning.
11. Dual Air Flow system for uniform cooling of motor top and bottom.
12. Windings Protected by new, synthetic materials.
13. Solid Die Cast Rotor with Integral fan blades.



Motor Cutaway



Motor Types

Hollow Shaft Motor

Motor With Shaft

TROUBLESHOOTING

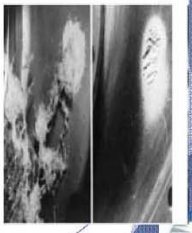
- Losing a phase on a 3-phase pump:
  - *motor would continue to run
  - *motor would overheat
  - *damage could occur

Cavitation

- Main cause of losing pump suction
- Sounds like pumping rocks or pinging
- Vibration & popping noises caused by low pressure in volute
- Generally caused by vapor bubbles
- Vapor bubbles implode causing damage to pump
- Volute case needs to be full of water
- Prevented by having adequate suction pressure and proper bowl depths

Types of Cavitation

- Vaporization of the liquid in volute
- The "vane passing syndrome" from too small an impeller
- Too high suction speed
- Air ingestion on the suction side of the pump
- Turbulence of the fluid



TROUBLESHOOTING

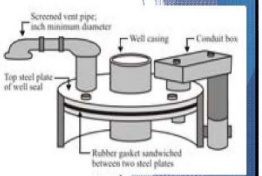
- Bearing failure is first detected by a change in operating sound of the pump and vibration
- Priming a pump not only makes it so the pump will pump, but it also helps prevent pump from cavitating

Accurate Record Keeping

- Shows loss of pumping efficiency along with record of flows & pressures
- Shows drawdown levels to evaluate condition of the well
- Drawdown level is elevation difference between static & pumping levels
- Helps determine proper depths for bowls.
- Shows when preventive maintenance or repairs were last performed

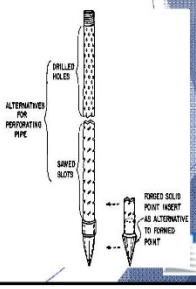
Well Seals

- Well casing maintains an open hole for the well
- Sanitary seal - all openings around well head are sealed off to prevent contamination.



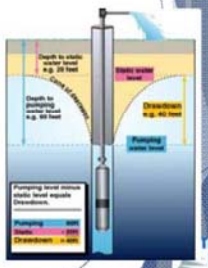
Well Casing

- Well casing perforations provide a way for water to enter pump
- Well casing helps protect the quality of the water.
- Surging a well form of plunging or cleaning the gravel pack around the screen



WELLS

- Well casing size is determined by the amount of water that is safe to yield
- Acidizing a well is a process used to rehabilitate a well for higher flows
- When a well pump is not running, the level of the water is the static level
- After a well pump runs for a period of time, the level is known as the pumping level

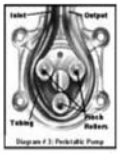


Positive Displacement Pumps

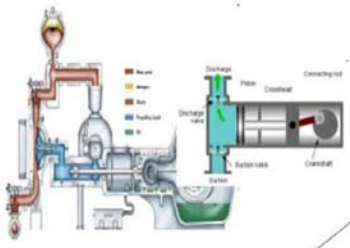
Positive Displacement

- Suction and discharge valves must be open all the way
- Used mainly for chemical dosing
- Not velocity type pumps

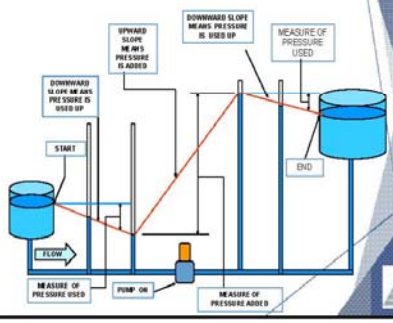
Peristaltic Pumps



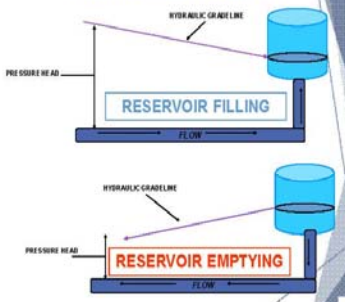
PISTON PUMP



Hydraulic Gradient

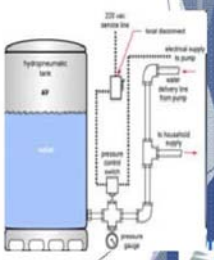


TANK GRADELINES



HYDROPNEUMATIC TANKS

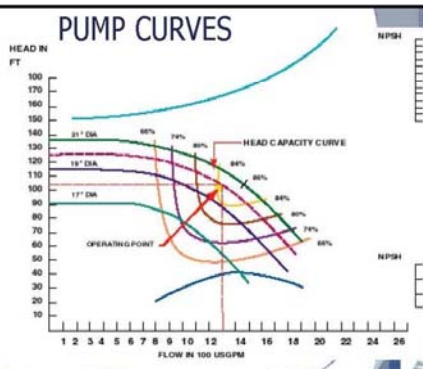
- Operate by applying air pressure to tank
- Tank levels controlled by pressure switches to pumps
- Air leaks can cause pumps to cycle on and off
- 1/3 to 2/3 air to water ratio limiting storage capacity



Pump Curves

- Generally show capacity (flow rate), total head, power (brake horsepower), and efficiency
- The pressure at which a pump operates against is head pressure

PUMP CURVES



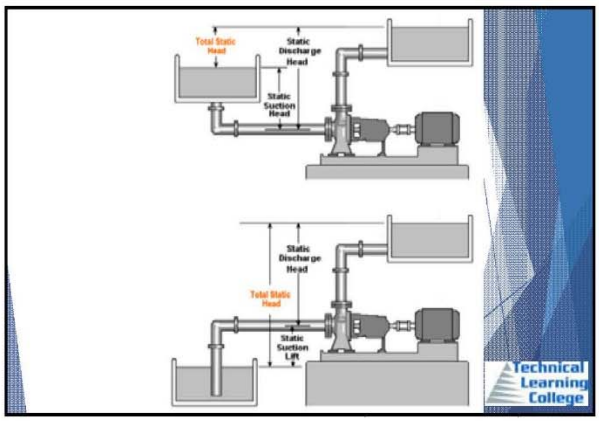
The pressure at which a pump operates against is head pressure

Pressure Head

- Pressure at which a pump operates against expressed as feet of head or head feet
- Total static= static discharge head - the static suction head
- Static suction head is the height of the water above the suction inlet & is pressure created by elevation or depth
- When calculating total dynamic head, static discharge head is part of the equation.
- The total operating head is the vertical distance of pumped water along with all other head losses

Flooded & Lift

- Suction lift is the water level on the inlet side of the pump that is lower than the pump
- Suction lift should be limited to 15 feet
- Flooded means the pump has either an elevation of head feet or water system pressure to operate with


Total Static Head
Static Discharge Head
Static Suction Head
Static Discharge Head
Total Static Head
Static Suction Lift
Technical Learning College

Assignment

Answer the following questions using the AWWA book, Chapter 13 & 14.

What is the typical voltage and horsepower for a single-phase motor?

List three basics types of single-phase motors.

List the three main classification of three-phase motors.

Which three-phrase motor has graphite brushes?

Which motor is variable speed?

What does a typical motor starter include?

Define “reduced-voltage controller”.

What are internal-combustion engines used for?

List the four types of combustion engines.

List basic O&M for combustion engines.

What is the minimum amount of time to run an emergency generator?

What is the typical information needed for pump, motor and engine records?

Chapter 14

What does drawdown refer to when operating a well and why should you keep accurate drawdown records?

What is packing, what does it do.

What is a packing gland, what are the correct procedures to follow in replacing and adjusting the packing in a centrifugal pump?

What would be the probable cause of a severe vibration when a pump is first started?

What is the difference between a velocity pump and a positive displacement pump and what would be the best applications for each?

What valving precautions should be taken with each?

How can ball bearing failure in a pump shaft bearing generally be first detected?

What is the purpose of the curved diffuser vanes on the inside of a pump volute?

What would be the advantage of starting and stopping a centrifugal pump against a closed discharge valve?

What precautions should be taken when opening and closing the discharge valve?

What effect could over-lubrication of grease-packed bearings have on a pump shaft?

What are the three different designs of impellers in relation to shrouds that are used on centrifugal pumps?

Describe the following terms: head loss, friction head loss, static head, dynamic head, total dynamic head, suction head, and suction lift.

What is a hydraulic grade line and how can it be determined?

What advantages does packing have over mechanical seals and vice-versa?

What is the main cause of inefficiency in pumps and motors?

Identify the following parts of a centrifugal pump along with the purpose of each: impeller, wear rings, shaft sleeves, seal water, lantern ring, volute, concentric reducer, and eccentric reducer.

What effect will water running backwards through a centrifugal pump have on the pump and how can it be prevented?

What is the purpose of "priming" a centrifugal pump?

What type of oil should be used for a culinary well pump?

What is a multistage pump and what does addition of stages do to the discharge?

What is cavitation, how is it caused, and how can it be prevented?

What purpose do air and/or vacuum release valves serve on well casings?

What is a sanitary seal and what purpose does it serve on a wellhead?

What are the functions of a well casing and well casing perforations?

What precautions should be taken before starting a water-lubricated pump?

How does the impeller move water from the suction to the discharge side of the pump?

Explain the proper maintenance and alignment techniques for pump couplings.

What maintenance recommendations should one follow when servicing a pump?

After repairs have been done on a pump, what is the last step before putting it back in service?

What is the proper procedure for starting a pump?

What is a pump curve and what are the different things are shown on it?

Water Meters

Water Meters

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

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

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

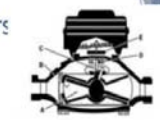
- C700 - Displacement Meters
- C701 - Turbine Meters
- C702 - Compound Meters
- C703 - Fireline Meters
- C708 - Multi-Jet Meters

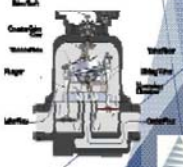
Positive-Displacement Meters

- 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: volume of water is measured as water moves the piston
  - Oscillating Piston: sweeps out specific volume for each rotation (wobble)





Positive-Displacement Meters

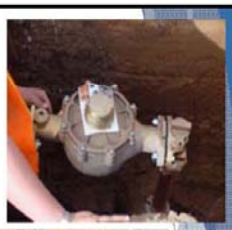
- Advantages
  - Accurate over wide range of flows
  - Easy to repair or replace due to availability
- Disadvantages
  - High head loss at high flow rates
  - Under register when worn; max usage should be half of capacity

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

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)



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 and expensive

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
- For Low to High Continuous Flow Rates
- Apartment Buildings, Motels Hotels, Condominiums, Mobile Home Parks, Hospitals, Schools, Restaurants, Dormitories, Department Stores, Shopping Malls and Public Transportation Centers.....

Current Meters

- Also called velocity meters
  - Turbine Meter: multijet
  - Measure velocity of flow past a cross-section of known area
  - Low head loss
  - Inaccurate at low flow rates
- Venturi Meter
- Propeller Meter

Multijet Meters

- Multijet meters measure the speed of water passing through the calibrated measuring chamber
- 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

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

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

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

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

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

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
- 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

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 deviceNeeds 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
- 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

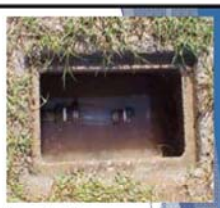
Meter Connections

- Meter sizes up to 1 inch usually have screw-type connections
- Flanged connections for larger meters

Indoor Installations

- Locate meter immediately after point where service line enters through floor or wall
- Location must be kept clear for easy access

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

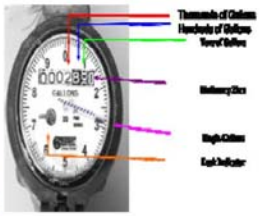
Outdoor Installations

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

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



Direct Readout

- Get reading from each meter
- Inside homes
- Outside in meter pits

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

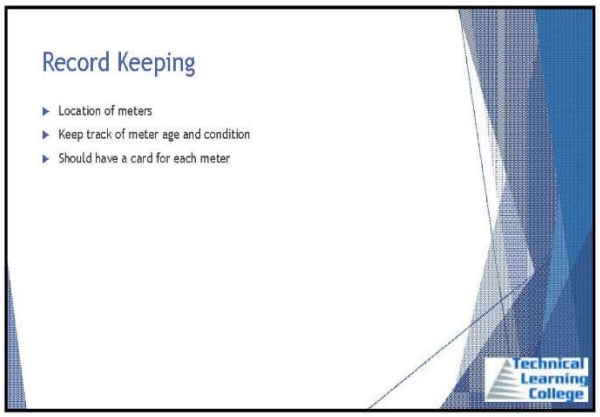
Testing and Maintenance

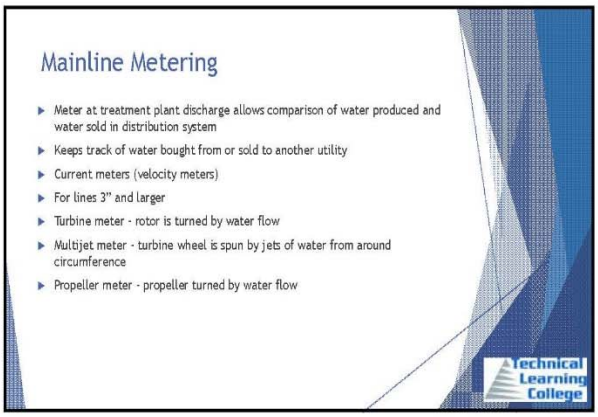
Water meters should be tested:

- Before installation
- After maintenance
- At customer's request
- 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
- 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
Technical Learning College


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
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
Technical Learning College

Assignment

Answer the following questions using the AWWA book, Chapter 15.

What is the function of a gooseneck in a service line?

What is the function of a curb stop?

What is a possible problem when iron services are installed with bronze curb stops?

What two factors must water suppliers consider when determining the depth and location of a service line.

What are three reasons for metering water customers?

Identify three meters commonly used in the water distribution system.

Name and describe the operation of two major types of positive displacement meters.

What is the most common application for a small positive displacement meter?

Compound meters are generally used under what conditions?

What types of meters might be used for main line or pump station measurements?

What are the requirements for acceptable meter installations?

What is a meter yoke?

Explain the need for maintaining electrical continuity around the meter during removal.

When should water meters be tested?

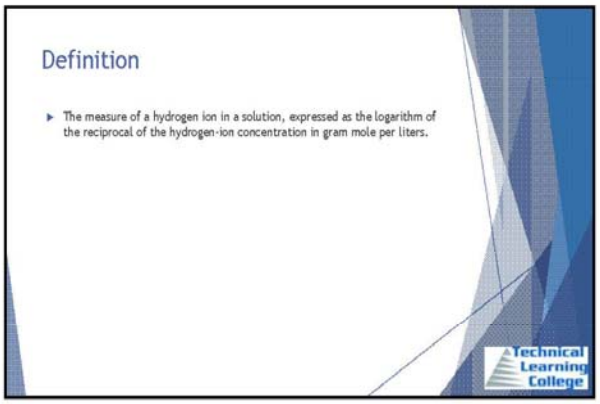
List three basic elements in a meter test.

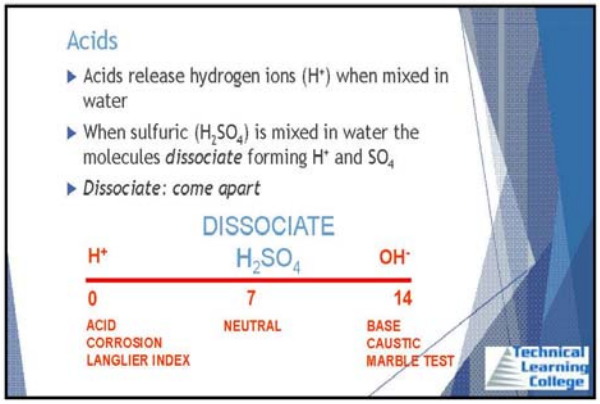
What hazards are associated with electrically thawing a frozen service line?

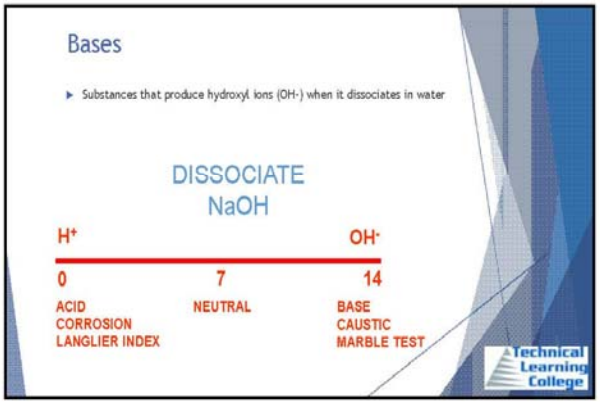
What items should be recorded on a service connection record card?

What items should be recorded on a meter history card?

Disinfection







Alkalinity

- Alkalinity is a measurement of water's capacity to neutralize an acid, whether the neutralization is the result of OH^-, CO_3^{-2}, HCO_3^-, or other negative ions

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.

Types of Chlorine

- Liquid chlorine (gas): 100% available Cl2
- Sodium hypochlorite (bleach): 5-15%
- Calcium hypochlorite (HTH): 65%

NSF ISO 9001

Cl - Chlorine

A green, highly reactive gas, chlorine is the most abundant halogen, comprising nearly two percent of the seas and used in all of our laboratory classes. Karl Scheele discovered chlorine in 1774, but believed it to be an oxide of a ficticous element, murium (which is why hydrochloric acid is also known as muriatic acid.) Murium was never found, but Humphrey Davy recognized it's elemental quality in 1810.

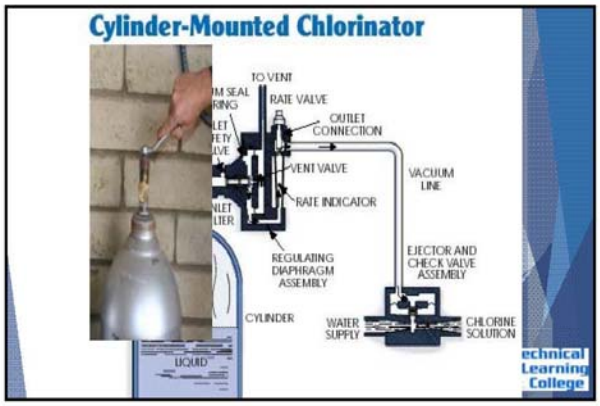
Atomic number-17
Density g/mL 0.000317
Atomic weight 35.453
Melting point K 172.16
Boiling point K 239.1
The oxide is a strong acid.

Chlorine Gas

- Cl2
- 100% pure
- 2.5 times as dense as air
- Pungent, noxious odor
- Greenish-yellow color
- Highly irritating to eyes, nasal passages, and respiratory tract
- Liquid is created by compressing chlorine gas
- Amber color
- 1.5 times as dense as water
- Expands easily into gas at room temperature 460 times

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


Cylinder-Mounted Chlorinator
TO VENT
RATE VALVE
OUTLET CONNECTION
VENT VALVE
VACUUM LINE
RATE INDICATOR
REGULATING DIAPHRAGM ASSEMBLY
EJECTOR AND CHECK VALVE ASSEMBLY
CYLINDER
WATER SUPPLY
CHLORINE SOLUTION
LIQUID


ADVANCE
Series
200
Reset
The Capital Controls Group

Chemistry of Chlorination

Hydrolysis of Chlorine Gas

- When chlorine gas is dissolved in water, it hydrolyzes rapidly according to the following equation:

$$Cl_2 + H_2O \leftrightarrow HOCl + HCl$$

- Temperature influences the reaction rate.

Chemistry of Hypochlorous Acid

- The most ***important reaction*** in the chlorination of an aqueous solution is the formation of **hypochlorous acid**. Hypochlorous acid is a weak acid which means that it tends to undergo partial **dissociation** as follows:

$$HOCl \longleftrightarrow H^+ + OCl^-$$

- In waters of pH between 6.5 and 8.5 the reaction is incomplete and both species are present to some degree.

Calcium Hypochlorite (Solid)

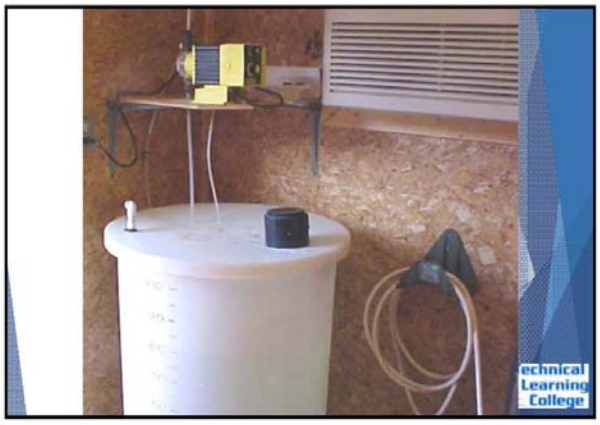
- Calcium Hypochlorite $Ca(OCl)_2$
- Solid, granular, or tablet
- White or yellow-white in color
- Most dangerous - fire hazard
- High Test Hypochlorite (HTH) 65% pure

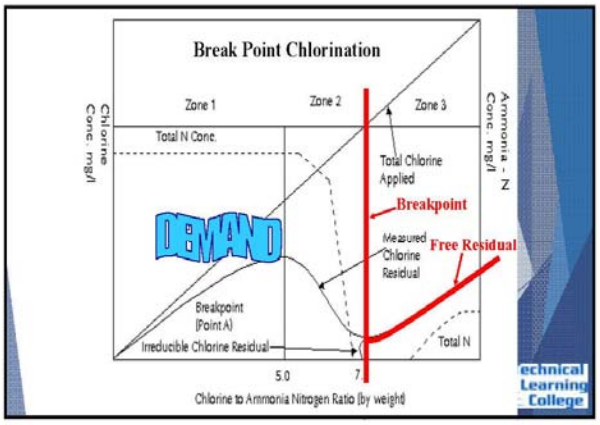
Sodium Hypochlorite (Liquid)

- 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

Chlorination Principles

- Five factors important to success of chlorination:
- CT = Concentration of Chlorine x Time of Contact
  - 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
- Water temperature
- Water pH
- Foreign substances in the water





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

Methods of Line Disinfection

- Tablet Method
- Continuous-Feed Method
- Slug Method

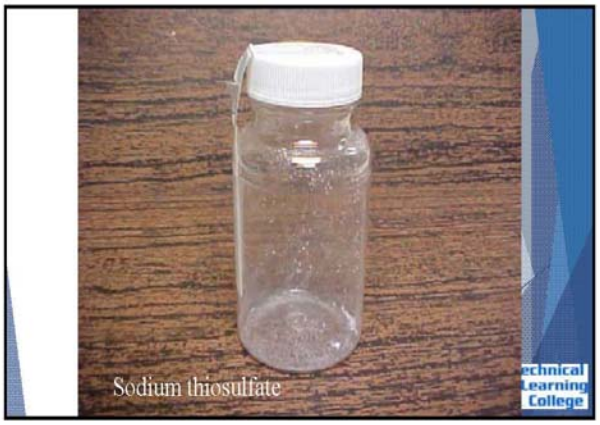
Bacteriological Testing

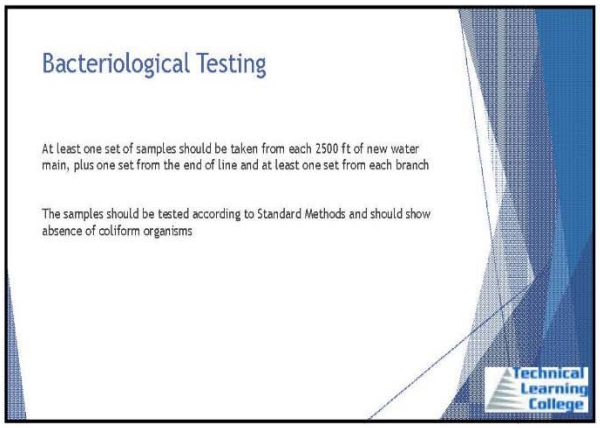
Bacteriological samples shall be collected prior to placing new lines in service

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




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
Technical Learning College

Assignment

Answer the following questions using the AWWA book, Chapter 16 & 17.

1. Explain the following terms and their relationship to each other: free chlorine, total chlorine, demand, residual, pre-chlorination, post-chlorination, and breakpoint chlorination.

2. What is the process of chlorination called as a treatment process and how does it differ from sterilization?

3. What are the physical properties of chlorine, what hazards does it present, what advantages does it have over most other disinfectants, and how does it react with bacteria?

4. What is the purpose of a fusible plug, at what temperature does it melt, and where is it located on 150-lb. and 1-ton cylinders?

5. What is the correct procedure to follow in changing a chlorine cylinder and what item should always be replaced with a new one in doing so?

6. How, when and where should residuals be taken and what information do they provide?

7. What is DPD used for in relation to chlorine and how does it work?

8. What is a SCBA, where should it be stored in relation to the chlorine room, and what special training should be used with it and on what frequency?

9. What are the three available forms of chlorine and what are the most common percentage strengths of each of the three forms?

10. What is HTH and what different forms and strengths is it commonly available in?

11. What effect does the addition of chlorine gas to water have on the water's pH?

12. What chemical is used to detect chlorine leaks and how is it best used?

13. What type of piping should be used for chlorine?

14. How much expansion will take place if one gallon of liquid chlorine is vaporized, and what is the specific gravity of chlorine gas?

15. What type of respiratory protection should be used when working with chlorine?

16. What are the two different types of chlorine residual and what are the advantages and disadvantages of each?

17. What are other types of disinfectants other than chlorine and what are some of the advantages and disadvantages of each?

18. How are hypochlorite solutions generally added to drinking water?

19. How many turns should the valve on a chlorine cylinder be opened and where should the valve wrench be kept?

20. What is a rotameter and what does it do?

21. What is the minimum dosage for disinfecting new water mains using the tablet method as described in AWWA C-651?

22. What effect do the following water quality parameters have on the disinfection process: temperature, pH, turbidity, organic matter, and hardness.

23. Where do most chlorine leaks occur, what type is the most serious and what action is usually taken first to stop a leak?

24. What are chloramines, how are they formed, what problems can result from their presence in a water system, and what advantages does monochloramine have over a free residual?

25. What is a yolk used for in a gas chlorination system?

26. What is a chlorinator that works off of the pressure of a chlorine cylinder called?

27. When chlorinating water, what does an injection check valve do?

28. What is the maximum chlorine feed rate in a 24-hour period for a 150-lb. cylinder?

29. How pure is chlorine gas when calculating dosages?

30. What are the precautions for handling Calcium Hypochlorite?

31. What is slug method disinfection?

32. DBP's are formed when disinfectants react with what?

33. What type of respiratory protection should be used when working with chlorine, where should it be stored, and what routine maintenance should be performed on it?

34. Where should the fan be located in a chlorine room?

35. What types of water systems are required to fill out chlorination reports, where are the reports to be sent and on what frequency?

36. What actions must be completed on a storage reservoir that has been taken out of service before it can be placed back on line?

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.

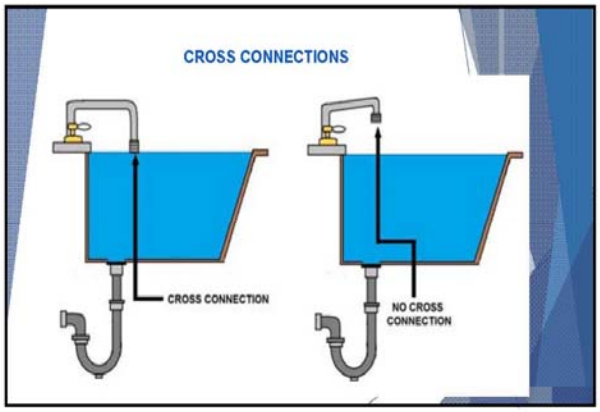
____15. High Test Hypochlorite; calcium hypochlorite or Ca(OCl)2

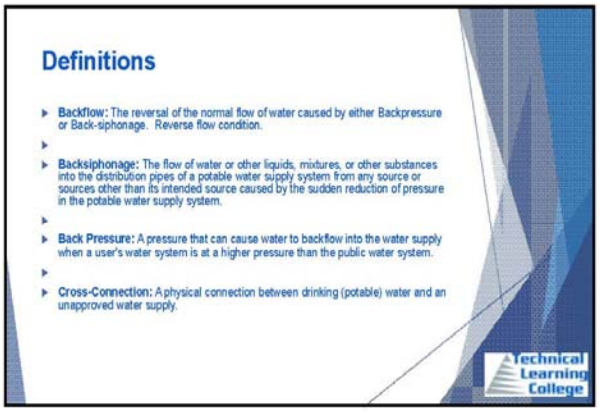
____16. The chlorine residual produced by the reaction of chlorine with substances in the water. It is not as effective as free residual.

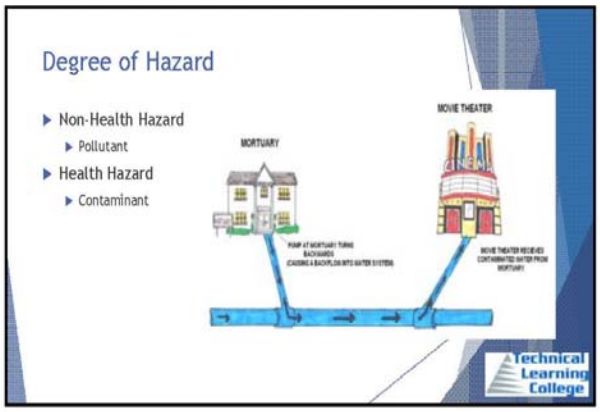
____17. A disease caused by waterborne organisms.

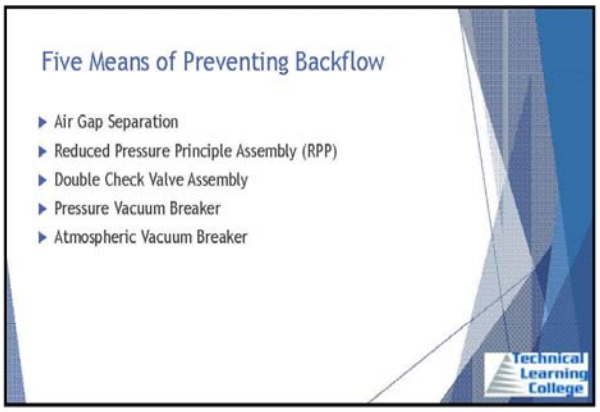
____18. A method of measuring the chlorine residual in water. The residual may be determined by either titrating or comparing a developed color with color standards. Stands for N,N-diethyl-p-phenylene-diamine.

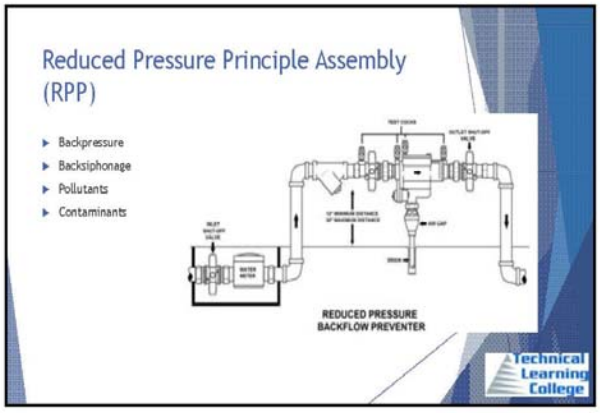
Backflow Prevention

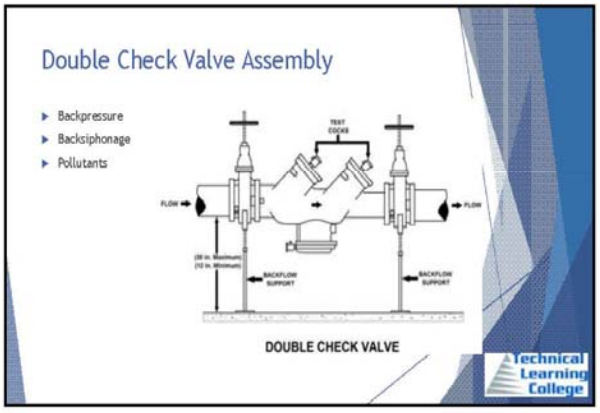










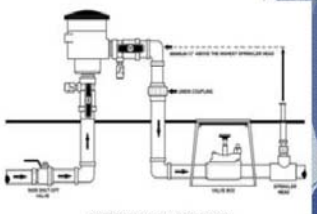


Proper Installation for RPP & DC

- Minimum 12" above grade
- Maximum 36" above grade
- Accessibility for testing and repair
- Weather and vandalism protection (if needed) with adequate drainage

Pressure Vacuum Breaker

- Backsiphonage ONLY
- Pollutants
- Contaminants
- Elevation - at least 12"



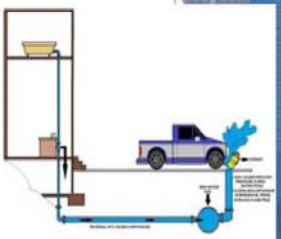
PRESSURE VACUUM BREAKER
BACKFLOW PREVENTER

Atmospheric Vacuum Breaker

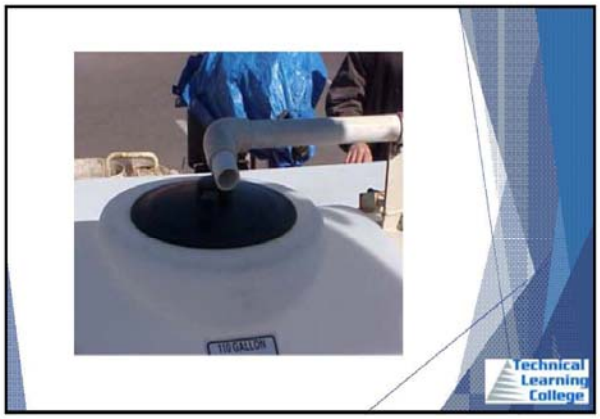
- Backsiphonage ONLY
- Pollutants
- Contaminants
- Elevation - at least 12"
- Non-continues use

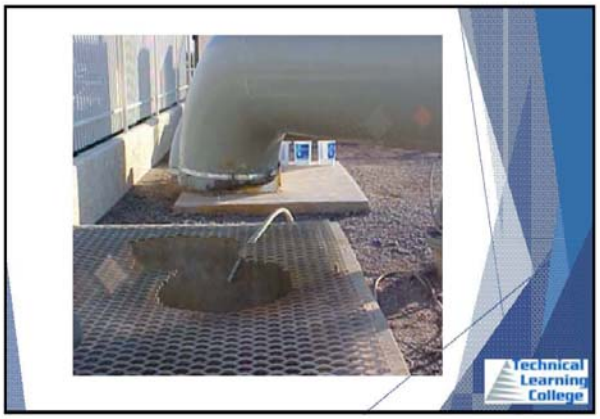
When Choosing

- What type of Cross-connection is it?
  - Indirect - backsiphonage
  - Direct - Both backpressure and backsiphonage
- What is the degree of Hazard
  - Non-health hazard
  - Health hazard
- Is it under continuous use (or pressure)



BACKSIPHONAGE






2795

Assignment

Answer the following questions using the AWWA book, Chapter 19.

Define a cross-connection.

Explain what is meant by backsiphonage and backpressure.

List four situations that can cause negative pressure in a potable water supply.

List six waterborne diseases that are known to have occurred as a result of cross-connections.

What is the most reliable backflow-prevention method?

Is a single check valve position protection against backflow? Why or why not?

How often should a reduced-pressure-zone backflow preventer be tested?

In what position should an atmospheric vacuum breaker be installed relative to a shutoff valve? Why?

How does a vacuum breaker prevent backsiphonage?

List seven elements that are essential to implement and operate a cross-connection control program successfully?

Rules and Regulations

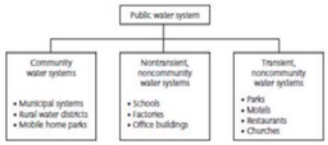
Rules and Regulations

SDWA

- Surface Water Treatment Rule (SWTR)
- Revised Total Coliform Rule (RTCR)
- Interim Enhanced Surface Water Treatment Rule (IESWTR)
- Long-Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)
- Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)
- Ground Water Rule (GWR)
- Stage 1 Disinfectants and Disinfection By-products Rule (Stage 1 DBPR)
- Stage 2 Disinfectants and Disinfection By-products Rule (Stage 2 DBPR)
- Lead and Copper Rule (LCR)
- Public Notification Rule
- Filter Backwash Recycle Rule (FBRR)
- Unregulated Contaminant Monitoring Rule (UCMR)

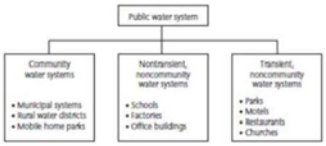
Public Water Systems

- Public Water Systems (PWS):
  - Have 15 services connections AND/OR
  - Serve at least 25 people (or 8 service connections) for 60 days



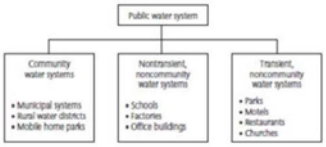
Community Water Systems (CWS)

- Serve year round residents
- Long-term exposure, most stringent sampling requirements
- Municipalities, districts



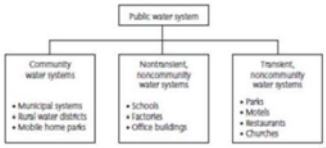
Non-Transient Non-Community Systems (NTNC)

- Serve the same people for at least 6 months out of the year
- Industry, rural schools
- Sampling is less stringent than CWS systems



Transient Non-Community Systems (TNC)

- Serve different people
- Are not active year round
- Short-term exposure
- Least stringent sampling requirements
- Campgrounds, rest stops, churches, restaurants



PWS Requirements

- Construction Standards
- Operational Requirements
- Surface Water Treatment Rule
- Sanitary Surveys/Improvement Priority Rule
- Cross Connection Control
- Source Protection
- Monitoring & Reporting, Water Quality
- Public Notice
- Private systems are NOT regulated

Construction Standards

- Purpose: to provide a safe and reliable supply of drinking water.
- Apply to: source development, water treatment, water quantity, water storage, pump stations, and distribution systems.
- Plans for drinking water projects must be submitted for review.
- Free flowing wells must be controlled by valves.

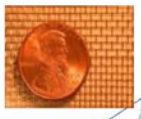
Construction Standards - Example

- Chlorination building. The air intake is at the top and the exhaust is near the floor. The ammonia bottle is required.

Construction Standards - Examples

- Proper sizing of source, storage, transmission and distribution piping to meet demands.
- Water and sewer mains must be separated by 10 feet of horizontal distance and 18 inches above the sewer.
- Flowing wells must be controlled by a valve.
- Storage tank access lids must be locked.
- All vents, overflows and drains must be screened
  - **Air vents** must have a **#14** mesh screen
  - **Water outlets** must have a **#4** mesh screen

#4 mesh



#14 mesh

Construction Standards - Examples

- Finished water storage must be covered.
- Sewer lines must be at least 50 feet from storage reservoirs.
- Sewer lines must be at least **10 feet** from waterlines, and **18 inches** below waterlines.
- Pumping stations must have 2 complete pumps, and each pump must provide the maximum flow of the station.

Construction Standards - Examples

- Access Hatch Lids for Tanks and Springs
  - The access hatch lids must be a shoebox type lid.
  - The lid must overlap 2 inches.
  - There must be a gasket between the lid and the frame.

Construction Standards - Pressure

- Pressure
  - For PWS approved before January 1, 2007:
    - Maintain **20 psi** minimum dynamic pressure at **all locations** during normal operation.
    - Meet the new minimum pressures in new service areas.
  - For new construction after January 1, 2007 at the points of connection:
    - 20 psi with fire flow during peak day demand
    - 30 psi during peak instantaneous demand
    - **40 psi during peak day demand**

Construction - Plan Review

- Required for "construction, addition, and modification" of drinking water facilities.
- Examples
  - Re-coating a water tank interior
  - Change or add a chemical
  - Redevelop a source
  - Add a booster pump, PRV, or chlorinator
  - Construction of tanks, pump stations, pipe lines, sources, treatment plants, etc.
- Plan review is required, there is no construction until Plan Approval is issued.

Operational Requirements

- Contaminated facilities must be disinfected before being placed back into service.
- AWWA disinfection standards (50ppm chlorine)
  - C651 Water mains
  - C652 Storage tanks
  - C653 Water Treatment plants
  - C654 Wells
- Added chemicals must meet National Sanitation Foundation (NSF) Standard 60.
- Deep rooted vegetation in a spring collection area must be mechanically cleaned.

Surface Water Treatment Rule

- Surface Water must be treated. Chlorination alone is not sufficient for treating surface water.
- Package plants must meet the same construction standards as large plants.
- All surface water sources must be monitoring for either cryptosporidium or *E. coli* before all treatment to determine if additional treatment is needed.
- Maximum filter loading rate is 6 gal/min/ft2
- Turbidity
  - Surface Water (SW) systems
    - 0.34 NTU in 95% of samples, never to exceed 1.0 NTU spike
    - Sample turbidity at each individual filter effluent
    - Sample the combined filter turbidity at the clear well
  - (Ground water turbidity = 5.0 NTU)
- SW Treatment systems must submit a monthly report

Surface Water Treatment Rule

- Disinfection:
  - Contact time is required
    - 99% or 2 log inactivation of crypto
    - 99.9% or 3 log inactivation of giardia lamblia cysts
    - 99.99% or 4 log inactivation of enteric viruses
  - CT = Concentration of disinfectant x contact time
  - The chlorine residual leaving the plant must be = or > 0.2 mg/L and measurable throughout the system.
  - Adequate disinfection is mandatory before the first customer.
  - CT with mixing basins & storage tanks is determined by tracer studies or the equivalent.

Surface Water Treatment Rule

- Groundwater may be "under the direct influence" (UDI) of surface water.
- UDI is determined through a filter test called microscopic particulate analysis (MPA) that detects surface origin microorganisms such as algae or observations involving temperature, turbidity, alkalinity and volume, or geologic conditions.
- Surface water treatment is required for UDI sources.

Cross Connection Control

There are 5 required components:

1. Local Authority: identifies a person to administer the program, must require protection for cross connections, must require periodic testing of all backflow prevention assemblies, must require hazard assessments, identifies and authorizes enforcement methods, requires inspection of new construction and existing privately-owned PWS.

Cross Connection Control

5. Ongoing Enforcement: hazard assessment surveys/appropriate protection provided, tracking annual testing of devices, continues public education, assemblies tested annually

Degree of Hazard Protection

- **Sewage: air gap (minimum 1" or twice the diameter of the pipe & best form of CCC)**
- High Hazard: back pressure or back siphonage, requires Reduced Pressure (RP) backflow assembly
- High Hazard: Back siphonage only, requires Pressure Vacuum Breaker (PVB) assembly, spill resistant vacuum (SVB) breaker assembly or atmosphere vacuum breaker device (AVB)
- Low Hazard: back pressure of back siphonage, requires double check valve
- Low Hazard: back siphonage only, requires PVB, SVB, or AVB

Water Quality

- **Primary Drinking Water Standards**
  - Health based, sampling is required
- **Secondary Drinking Water Standards**
  - Aesthetic based, sampling is **not** required
- **Treatment Technique**
  - Only for surface water treatment systems
- **Action Levels**
  - Only for lead/copper

Water Quality - Variances & Exemptions

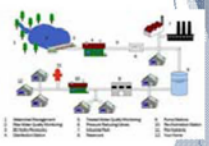
- Variances & Exemptions are not available for total coliform and surface water treatment.
- A variance or exemption must **not** result in an **unreasonable risk** to human health.
- Variances are based on raw water quality.
- Exemptions are based on available of feasible treatment.
- Additional time of given to meet the MCL or BAT (best available technology).

Water Quality - Coliform Bacteria

Community	Sample every month The # of samples depends on population
Non-transient Non-community (NTNC)	1 sample each calendar quarter UNLESS the PWS uses a surface water source (monthly) the population in any month exceeds 1,000 (monthly)
Non-community (NC)	1 sample each calendar quarter UNLESS the PWS uses a surface water source (monthly) the population in any month exceeds 1,000 (monthly)

Water Quality - Coliform Bacteria

- Sampling Site Plan
  - A plan that shows the PWS is rotating its samples throughout representative sites in the system.
  - Must be written & is reviewed during the sanitary survey.
  - A PWS must have at least 5 sites in the plan, or twice the # of samples required.
  - PWS that collect >5 samples/month should not collect them on the same day.
  - The PWS is responsible for taking coliform samples.



Water Quality - Coliform Bacteria

1. You take the routine sample, send it to the lab.
2. The lab will mark the results:
   - Satisfactory (TC -)
   - Unsatisfactory (TC + EC -, or TC + EC +)
   - Indeterminate (interfering bacteria, PWS must take another routine sample within 24 hours.)
3. If the results are satisfactory then no further action is required.
4. If the results are unsatisfactory you must take repeat, triggered and possibly additional samples.

E. coli MCL Violation Occurs With the Following Sample Result Combination

Routine	Repeat
EC+	TC+
TC+	Any missing sample
EC+	EC+
TC+	EC+
TC+	TC+ (but no *E. coli* analysis)

Water Quality - Coliform Bacteria

- **ROUTINE** = the routine samples required monthly or quarterly.
- **REPEAT** = samples taken in the distribution system after an unsatisfactory routine, they must be pulled from within 5 service connections upstream & downstream and one at the original site.
- **TRIGGERED** = for groundwater PWS, these samples are taken at all groundwater sources in use, if a groundwater PWS purchases water then the wholesale system must be notified so they can take these samples at their sources.
- **ADDITIONAL** = for systems taking less than 5 routines per month, these samples are marked routine on the lab form and give a PWS a total of 5 routines the month following an unsatisfactory routine.

Water Quality - Coliform Bacteria

- If the result is Unsatisfactory:
  - The lab analyzes for E.coli (EC) or fecal coliform.
  - PWS takes REPEAT and ground water systems take TRIGGERED samples within 24 hours of notification.
  - The following month the PWS takes a minimum of 5 routine distribution samples (called ADDITIONAL samples.)
- How many repeats do I take?

Population	# routine samples/month	# repeats for each TC +	# Additional samples the next month
25-1000	1	4	4
1001-2500	2	3	3
2501-3300	3	3	2
3301-4100	4	3	1
>4100	5 or more	3	None

Water Quality - Coliform Bacteria

Two Main Types of violations for the Coliform Rule

1. Monitoring Violations = failure to take routines, repeats, and additionals
2. Quality Violations, mandatory health effects language
   - **Non-Acute violations are**
     - PWS that take <40 routines = more than 1 TC+ sample in a month
     - PWS that take >40 routines = more than 5% TC+ samples in a month
   - **Acute violations are confirmed fecal contamination**

Water Quality - Coliform Bacteria

Acute Violations: at two points in time (routine, repeat) a PWS has at least one TC+ and one EC+.

ROUTINE	REPEAT
TC-	
TC+ EC-	TC- EC-
TC+ EC-	TC+ EC-
TC+ EC+	TC- EC-
TC+ EC-	TC+ EC+
TC+ EC+	TC+ EC-
TC+ EC+	TC+ EC+

Water Quality - Groundwater Rule

- Applies to PWS using groundwater, consecutive PWS receiving groundwater, and wholesale PWS using groundwater
- 5 Components
  1. Triggered samples at the source
  2. Assessment samples at the source
  3. Corrective actions
  4. Sanitary Surveys
  5. Compliance monitoring

Water Quality - Groundwater Rule

1. Triggered source samples
   - Required when a routine coliform sample is TC +
   - How many?
     - Take one for each active groundwater source
   - What if the triggered sample is EC +?
     - PWS takes 5 additional source samples.
   - 4 log treated sources are exempt from triggered source samples.

Water Quality - Groundwater Rule

2. Assessment samples
   - Required for sensitive sources such as redeveloped springs, sources with TC + history, sources without plan approval/operating permit
   - A minimum of 12 monthly samples is required per source.
3. Corrective Actions
   - Required when confirmed EC+ at the source
   - Uncorrected significant physical deficiencies
   - Required within 120 days

Water Quality - Groundwater Rule

4. Sanitary Surveys
   - Required 8 elements for surveys
     - operation & maintenance, sources, treatment, finished water storage, pumps, operator certification, monitoring & reporting data verification, distribution system
   - Water system should received the sanitary survey report within 30 days.

Water Quality - Groundwater Rule

5. Compliance Monitoring
   - Required only for sources with the 4 log exemption
   - An engineering reviewed minimum dosage is required for 4 log exempt sources
   - Chlorine residual samples
     - Over 3,300 population continuous monitoring
     - Under 3,300 population daily grab samples
   - Reporting is combined with quarterly DBP

Water Quality - Groundwater Rule

Violations
- Monitoring
  - Failure to collect triggered samples
  - Failure to collect assessment samples
  - Failure to collection additional source samples - default to required corrective action
  - Failure to complete compliance monitoring
- Quality
  - Failure to address confirmed E. coli at the source
  - Failure to correct a significant deficiency or file a corrective action plan

Water Quality - Lead & Copper

- Required for COM, NTNC
- Must have a sampling site plan
- The number of required samples is based on population.
- Samples taken from kitchen/bathroom cold water tap, first draw after sitting undisturbed for 6 hours.

Initial	Reduced	Further Reduced
Every 6 months for 2 rounds	Annually for 3 rounds	Every 3 years forever

Water Quality - Lead & Copper

Sample Sites

- Tier 1
  - Single family homes with copper pipes 1982-1986
- Tier 2
  - Multiple family homes with copper pipes 1982-1986
- Tier 3
  - Homes before 1982 with metal pipes

Compliance

- Based on the 90th percentile result
- Compare the 90th percentiles to the Action Levels
  - Copper = 1300ppb (1.3ppm)
  - Lead = 15ppb (0.015ppm)
- The result can either meet or be less than the AL to be in compliance.

Water Quality - Lead & Copper

90th Percentile

- Arrange the results from lowest to highest.
- Multiply the total number of samples by 0.9.
- Compare that result to the Action Level

A PWS takes 10 samples	A PWS takes 20 samples
10 x 0.9 = 9	20 x 0.9 = 18
Use the 9th highest result to compare against the Action Level.	Use the 18th highest result to compare against the Action Level.

Water Quality - Lead & Copper

- What happens is a PWS exceeds the limit for lead or copper?
  - Corrosion control treatment
  - Public education and notification
  - Water quality parameter testing
  - Possible lead line replacement

Water Quality - Asbestos

- Distribution system sampling
  - Required for CWS, NTNC that contain asbestos piping in their distribution systems
  - Samples are due once every 9 years
- Source sampling
  - Required for CWS, NTNC at the source for sources in naturally occurring asbestos formations
  - Samples are due once every 9 years

Water Quality - Disinfection Byproducts (DBPs)

- Disinfectants (chlorine, chloramines, chlorine dioxide) react with naturally occurring material in the water to create byproducts harmful to human health.
- Disinfection Byproduct (DBP) monitoring
  - Required for CWS, NTNC that disinfect
- Types of byproducts
  - Chlorine forms Total Trihalomethanes and Haloacetic acids
  - Ozone forms Bromate
  - Chlorine Dioxide forms Chlorite

Water Quality - Disinfection Byproducts (DBPs)

- Compliance is based on the average of results at each sampling location.
- Maximum Contaminant Levels (MCLs)
  - Total Trihalomethanes (TTHMs) = 80ppb (0.080mg/L)
  - Haloacetic Acids (HAAs) = 60ppb (0.060mg/L)
- Sampling frequency:
  - Sampling varies from quarterly to annual based on the nature of the PWS's sources and population served.
  - Reduced monitoring is allowed based on sample results, however only very small ground water PWSs (less than 500 population) will be reduced to every 3 years.

Water Quality - Disinfection Byproducts (DBPs)

- A sampling plan is required!
  - The number of samples is based on the population served.
  - Must submit a sampling site plan for PWS that did not do the IDSE (Very Small Systems, 40/30 waiver)
- Consecutive PWSs are on the same sampling frequency and start date as the largest PWS in the group.

Water Quality - Disinfection Byproducts (DBPs)

- Maximum Residual Disinfection Level (MRDL) of 4.0 mg/L
- Groundwater PWS measure residual 3 times/week where coliform samples are taken
- Surface Water plants must continuously monitor disinfectant residuals. Grab samples are allowed for PWS serving less then 3,300 people if approved by DDW.

Water Quality - Disinfection Byproducts (DBPs)

- There is additional monitoring for Coventional Surface Water Treatment Plants:
  - Raw water alkalinity
  - Raw and finished water Total Organic Carbon (TOC)

Water Quality - Treatment Reports

- Chorination, Fluoridation Report Forms
  - Daily readings
  - Volume of water treated
  - Amount of chemical used, residual
- Surface Water Treatment Plant Report Forms
  - Continuous turbidity readings
  - Clearwell is an appropriate place to take turbidity samples
  - Volume of treated water
  - Type and amounts of chemicals used
  - Continuous chlorine residuals

Water Quality - Fluoride

- Maximum Contaminant Level (MCL) = 4.0mg/L
- Secondary MCL = 2.0mg/L (if a PWS is over this level they must notify the public.)
- Plan review & Operating permit
- Monthly reports
- Field test = SPADNS for daily fluoride residual concentrations
- Fluoride chemical addition is currently on a county basis
- Treatment Chemicals
  - Sodium Fluoride
  - Fluorosilicic acid
  - Sodium silicofluoride
  - Sodium fluorosilicate

Water Quality - Standards

- All chemical added to drinking water must be National Sanitation (NSF) Standard 60 approved .
- Turbidity for groundwater source not UDI is 5.0 NTU.
- Turbidity for surface water/UDI treated water is less than or equal to 0.34 NTU in 95% of the results, max 1.0 NTU.
- Chlorine MCL is 4.0mg/L (MRDL)
- Reservoir disinfected to AWWA C 652 Standard

Water Quality - Source Samples

Inorganics & Metals

Systems that must sample	Initial sampling frequency	Reduced sampling frequency
CWS, NTNC	SW = Annual GW = Every 3 yrs	Once every 9 yrs based on all previous rounds <75% of MCL

Sulfate

Systems that must sample	Initial sampling frequency	Reduced sampling frequency
TNC	Every 3 yrs	Once every 9 yrs based on all previous results <75% of MCL

Water Quality - Source Samples

Nitrate

Systems that must sample	Initial sampling frequency	Reduced sampling frequency
CWS, NTNC, TNC	SW = Quarterly GW = Annual	SW = Annual NO OTHER REDUCTIONS ALLOWED

Nitrite

Systems that must sample	Initial sampling frequency	Reduced sampling frequency
CWS, NTNC, TNC	Just one sample If <0.5mg/L = waiver If >0.5mg/L = quarterly	Waiver = no sampling required

Water Quality - Source Samples

Asbestos

Systems that must sample	Initial sampling frequency	Reduced sampling frequency
CWS, NTNC (if the source is vulnerable)	Once every 9 yrs	No sampling required

Radionuclides *Measured in picocuries per liter (pCi/L)

Systems that must sample	Initial sampling frequency	Reduced sampling frequency
CWS	Quarterly for 1 year	Every 3, 6, or 9 yrs depending on initial results

Water Quality - Source Samples

VOCs (Volatile Organics)

Systems that must sample	Initial sampling frequency	Reduced sampling frequency
CWS, NTNC	Quarterly	Annual, Once every 3 yrs (susceptibility waiver), Once every 6 yrs (use waiver)

Pesticides

Systems that must sample	Initial sampling frequency	Reduced sampling frequency
CWS, NTNC	Quarterly	Once or twice every 3 yrs (susceptibility waiver), Not required (use waiver)

Water Quality - Source Samples

- Waivers
  - Reliably & Consistently
    - Based on past data
  - Susceptibility
    - Based on if the source is vulnerable and past data
  - Use
    - Based on if the contaminants are used, transported, manufactured or stored in the source area

Consumer Confidence Reports (CCR)

- Annual water quality report due by July 1st, wholesalers due by April 1st.
- Required for all CWS systems
- EPA must receive:
  - A copy of the CCR by July 1st
  - A certification letter describing how the CCR was delivered to customers by October 1st

Consumer Confidence Reports (CCR)

- The CCR must contain
  - Date prepared, PWS identification number
  - System information (phone, meetings)
  - Source information (names)
  - Definitions (MCL = maximum contaminant level)
  - Table of **detected** contaminants
  - Violations (if any)
  - Additional health information
  - Variances & exemptions (if any)
  - Uncorrected Significant Deficiencies

Public Notification

- Violation Types
  - Tier 1
    - Acute contaminants = confirmed E.coli coliform bacteria acute violation, nitrate, nitrite
    - Mandatory health effects language
    - Notify EPA & customers within 24 hours
  - Tier 2
    - Non-Acute Contaminants = chemical MCLs, treatment technique, non-acute coliform bacteria
    - Mandatory health effects language
    - Notify EPA & customers within 30 days
  - Tier 3
    - Monitoring & reporting violations
    - Notify customers within 1 year
  - Continue notification every 3 months for as long as the violation exists

Record Keeping

Table 1-2 Typical record-keeping requirements

Type of Records	Time Period
Bacteriological and turbidity analyses	5 years
Chemical analyses	10 years
Actions taken to correct violations	3 years
Sanitary survey reports	10 years
Exemptions	5 years following expiration

The questions in this section is a mix of Water Quality, Rules and Backflow

Who has the primary responsibility for drinking water quality and sampling?

What are the different types of public drinking water systems, what are the different ratings, how are they assigned, and what do the ratings represent?

What is an MCL, and what are the MCL's for coliform bacteria, TTHM, HAA, and fluoride?

What would an operator need to do if the results of a routine bacteriological sample indicated that the sample was "coliform positive?" What would the lab need to do?

What is a bacteriological sampling site plan and why is it required?

What effect could an active cross connection control program have on maintaining water quality in a water system?

What is the best method of protection against backflow?

What types of screens are required on air vent and drain lines for water storage tanks?

What is the action level for lead and copper monitoring and how is it determined?

What is the difference between monitoring violations and quality violations in relation to bacteriological sampling?

What is the minimum water pressure that must be maintained in a system?

Where should bacteriological samples be collected from and on what frequency?

What do the following terms represent in reference to water quality:

total coliform
fecal
coliform,presence/absence
acute
non-acute
routine
repeat
action level

What is the definition of a public water system?

What must be done to determine what type of cross connection protection is needed for a water system?

Define Community, Non-Community, Transient and Non-Transient in relation to water systems.

At what level does the public need to be notified for fluoride and what is the MCL?

What information is contained in the Consumer Confidence Report, how often does it need to be provided, and what methods are used to provide it?

What systems using chlorine are not required to sample with regards to the Stage 1 DBP rule?

How often are the Stage 1 DBP reports due?

Chlorine has an MRDL (Maximum Residual Disinfectant Level), what is it?

What are the different requirements for taking chlorine residual and bacteriological samples?

Formula/Conversion Table

Water Treatment, Distribution, & Water Laboratory Exams

Alkalinity, mg/L as $CaCO_3$ = $\dfrac{(\text{Titrant Volume, mL})(\text{Acid Normality})(50{,}000)}{\text{Sample Volume, mL}}$

Amps = $\dfrac{\text{Volts}}{\text{Ohms}}$

Area of Circle* = $(0.785)(\text{Diameter}^2)$

Area of Circle = $(\pi)(\text{Radius}^2)$

Area of Cone (lateral area) = $(\pi)(\text{Radius})\sqrt{\text{Radius}^2 + \text{Height}^2}$

Area of Cone (total surface area) = $(\pi)(\text{Radius})(\text{Radius} + \sqrt{\text{Radius}^2 + \text{Height}^2})$

Area of Cylinder (total exterior surface area) = [End #1 SA] + [End #2 SA] + [(π)(Diameter)(Height or Depth)]
Where SA = surface area

Area of Rectangle* = (Length)(Width)

Area of Right Triangle* = $\dfrac{(\text{Base})(\text{Height})}{2}$

Average (arithmetic mean) = $\dfrac{\text{Sum of All Terms}}{\text{Number of Terms}}$

Average (geometric mean) = $[(X_1)(X_2)(X_3)(X_4)(X_n)]^{1/n}$ *The nth root of the product of* n *numbers*

Blending = $(V_1)(C_1) + (V_2)(C_2) = (V_3)(C_3)$ *Where V = volume or flow, C = concentration or percent solution*

Chemical Feed Pump Setting, % Stroke = $\dfrac{\text{Desired Flow}}{\text{Maximum Flow}} \times 100\%$

Chemical Feed Pump Setting, mL/min = $\dfrac{(\text{Flow, MGD})(\text{Dose, mg/L})(3.785\,\text{L/gal})(1{,}000{,}000\,\text{gal/MG})}{(\text{Liquid, mg/mL})(1{,}440\,\text{min/day})}$

Chemical Feed Pump Setting, mL/min = $\dfrac{(\text{Flow, m}^3\text{/day})(\text{Dose, mg/L})}{(\text{Chemical Feed Density, g/cm}^3)(\text{Active Chemical, \%})(1{,}440\ \text{min/day})}$

Circumference of Circle = (π)(Diameter)

Composite Sample Single Portion = $\dfrac{(\text{Instantaneous Flow})(\text{Total Sample Volume})}{(\text{Number of Portions})(\text{Average Flow})}$

CT Calculation = (Disinfectant Residual Concentration, mg/L)(Time, min)

Degrees Celsius = $\dfrac{(°\text{F} - 32)}{1.8}$

*Pie Wheel Format for this equation is available at the end of this document

Degrees Fahrenheit = (°C)(1.8) + 32

Detention Time = $\frac{\text{Volume}}{\text{Flow}}$ *Units must be compatible*

Electromotive Force, volts* = (Current, amps)(Resistance, ohms)

Feed Rate, lbs/day* = $\frac{\text{(Dosage, mg/L)(Flow, MGD)(8.34 lbs/gal)}}{\text{Purity, \% expressed as a decimal}}$

Feed Rate, kg/day = $\frac{\text{(Dosage, mg/L)(Flow Rate, } m^3\text{/day)}}{\text{(Purity, \% expressed as a decimal)(1,000)}}$

Feed Rate (Fluoride), lbs/day =

$$\frac{\text{(Dosage, mg/L)(Capacity, MGD)(8.34 lbs/gal)}}{\text{(Available Fluoride Ion, \% expressed as a decimal)(Purity, \% expressed as a decimal)}}$$

Feed Rate (Fluoride), kg/day =

$$\frac{\text{(Dosage, mg/L)(Capacity, } m^3\text{/day)}}{\text{(Available Fluoride Ion, \% expressed as a decimal)(Purity, \% expressed as a decimal)(1,000)}}$$

Feed Rate (Fluoride Saturator), gpm = $\frac{\text{(Plant capacity, gpm)(Dosage, mg/L)}}{\text{18,000 mg/L}}$

Feed Rate (Fluoride Saturator), Lpm = $\frac{\text{(Plant capacity, Lpm)(Dosage, mg/L)}}{\text{18,000 mg/L}}$

Filter Backwash Rise Rate, in/min = $\frac{\text{(Backwash Rate, gpm/ft}^2\text{)(12 in/ft)}}{\text{7.48 gal/ft}^3}$

Filter Backwash Rise Rate, cm/min = $\frac{\text{Water Rise, cm}}{\text{Time, min}}$

Filter Drop Test Velocity, ft/min = $\frac{\text{Water Drop, ft}}{\text{Time of Drop, min}}$

Filter Drop Test Velocity, m/min = $\frac{\text{Water Drop, m}}{\text{Time of Drop, min}}$

Filter Loading Rate, gpm/ft² = $\frac{\text{Flow, gpm}}{\text{Filter area, ft}^2}$

Filter Loading Rate, Lps/m² = $\frac{\text{Flow, L/s}}{\text{Filter area, m}^2}$

Filter Yield, lbs/hr/ft² = $\frac{\text{(Solids Loading, lbs/day)(Recovery, \% expressed as a decimal)}}{\text{(Filter Operation, hr/day)(Area, ft}^2\text{)}}$

Filter Yield, kg/hr/m² = $\frac{\text{(Solids Concentration, \% expressed as a decimal)(Sludge Feed Rate, L/hr)(10)}}{\text{(Surface Area of Filter, m}^2\text{)}}$

*Pie Wheel Format for this equation is available at the end of this document

Flow Rate, ft^3/sec* = (Area, ft^2)(Velocity, ft/sec)

Flow Rate, m^3/sec = (Area, m^2)(Velocity, m/sec)

Force, lbs* = (Pressure, psi)(Area, in^2)

Force, newtons = (Pressure, pascals)(Area, m^2)

Hardness, as mg $CaCO_3$/L = $\frac{(\text{Titrant Volume, mL})(1{,}000)}{\text{Sample Volume, mL}}$ *Only when the titration factor is 1.00 of EDTA*

Horsepower, Brake, hp = $\frac{(\text{Flow, gpm})(\text{Head, ft})}{(3{,}960)(\text{Pump Efficiency, \% expressed as a decimal})}$

Horsepower, Brake, kW = $\frac{(9.8)(\text{Flow, } m^3/\text{sec})(\text{Head, m})}{(\text{Pump Efficiency, \% expressed as a decimal})}$

Horsepower, Motor, hp =

$$\frac{(\text{Flow, gpm})(\text{Head, ft})}{(3{,}960)(\text{Pump Efficiency, \% expressed as a decimal})(\text{Motor Efficiency, \% expressed as a decimal})}$$

Horsepower, Motor, kW =

$$\frac{(9.8)(\text{Flow, } m^3/\text{sec})(\text{Head, m})}{(\text{Pump Efficiency, \% expressed as a decimal})(\text{Motor Efficiency, \% expressed as a decimal})}$$

Horsepower, Water, hp = $\frac{(\text{Flow, gpm})(\text{Head, ft})}{3{,}960}$

Hydraulic Loading Rate, gpd/ft^2 = $\frac{\text{Total Flow Applied, gpd}}{\text{Area, } ft^2}$

Hydraulic Loading Rate, $m^3/day/m^2$ = $\frac{\text{Total Flow Applied, } m^3/\text{day}}{\text{Area, } m^2}$

Hypochlorite Strength, % = $\frac{\text{Chlorine Required, lbs}}{(\text{Hypochlorite Solution Needed, gal})(8.34\ \text{lbs/gal})} \times 100\%$

Hypochlorite Strength, % = $\frac{(\text{Chlorine Required, kg})(100)}{(\text{Hypochlorite Solution Needed, kg})}$

Langelier Saturation Index = pH – pHs

Leakage, gpd = $\frac{\text{Volume, gal}}{\text{Time, days}}$

Leakage, Lpd = $\frac{\text{Volume, L}}{\text{Time, days}}$

Loading Rate, lbs/day* = (Flow, MGD)(Concentration, mg/L)(8.34 lbs/gal)

Loading Rate, kg/day = $\frac{(\text{Volume, m}^3\text{/day})(\text{Concentration, mg/L})}{1{,}000}$

Mass, lbs* = (Volume, MG)(Concentration, mg/L)(8.34 lbs/gal)

Mass, kg = $\frac{(\text{Volume, m}^3)(\text{Concentration, mg/L})}{1{,}000}$

Milliequivalent = (mL)(Normality)

Molarity = $\frac{\text{Moles of Solute}}{\text{Liters of Solution}}$

Normality = $\frac{\text{Number of Equivalent Weights of Solute}}{\text{Liters of Solution}}$

Number of Equivalent Weights = $\frac{\text{Total Weight}}{\text{Equivalent Weight}}$

Number of Moles = $\frac{\text{Total Weight}}{\text{Molecular Weight}}$

Power, kW = $\frac{(\text{Flow, L/sec})(\text{Head, m})(9.8)}{1{,}000}$

Reduction in Flow, % = $\frac{(\text{Original Flow - Reduced Flow})(100\%)}{\text{Original Flow}}$

Removal, % = $\frac{\text{In} - \text{Out}}{\text{In}} \times 100\%$

Slope, % = $\frac{\text{Drop or Rise}}{\text{Distance}} \times 100\%$

Solids, mg/L = $\frac{(\text{Dry Solids, g})(1{,}000{,}000)}{\text{Sample Volume, mL}}$

Solids Concentration, mg/L = $\frac{\text{Weight, mg}}{\text{Volume, L}}$

Specific Gravity = $\frac{\text{Specific Weight of Substance, lbs/gal}}{8.34\ \text{lbs/gal}}$

Specific Gravity = $\frac{\text{Specific Weight of Substance, kg/L}}{1.0, \text{kg/L}}$

Surface Loading Rate or **Surface Overflow Rate, gpd/ft²** = $\frac{\text{Flow, gpd}}{\text{Area, ft}^2}$

Surface Loading Rate or **Surface Overflow Rate, Lpd/m²** = $\frac{\text{Flow, Lpd}}{\text{Area, m}^2}$

*Pie Wheel Format for this equation is available at the end of this document

Three Normal Equation = $(C_1 \times V_1) + (C_2 \times V_2) = (C_3 \times V_3)$ *Where $V_1 + V_2 = V_3$; C =concentration, V = volume or flow; Concentration units must match; Volume units must match*

Threshold Odor Number = $\frac{A+B}{A}$ *Where A = volume of odor causing sample, B = volume of odor free water*

Two Normal Equation = $(C_1 \times V_1) = (C_2 \times V_2)$ *Where C = Concentration, V = volume or flow; Concentration units must match; Volume units must match*

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

Velocity, ft/sec = $\frac{\text{Distance, ft}}{\text{Time, sec}}$

Velocity, m/sec = $\frac{\text{Flow Rate, m}^3/\text{sec}}{\text{Area, m}^2}$

Velocity, m/sec = $\frac{\text{Distance, m}}{\text{Time, sec}}$

Volume of Cone* = $(1/3)(0.785)(\text{Diameter}^2)(\text{Height})$

Volume of Cylinder* = $(0.785)(\text{Diameter}^2)(\text{Height})$

Volume of Rectangular Tank* = (Length)(Width)(Height)

Water Use, US Gallons/Capita/Day = $\frac{\text{Volume of Water Produced, gpd}}{\text{Population}}$

Water Use, Liters/Capita/Day = $\frac{\text{Volume of Water Produced, Lpd}}{\text{Population}}$

Watts (AC circuit) = (Volts)(Amps)(Power Factor)

Watts (DC circuit) = (Volts)(Amps)

Weir Overflow Rate, gpd/ft = $\frac{\text{Flow, gpd}}{\text{Weir Length, ft}}$

Weir Overflow Rate, Lpd/m = $\frac{\text{Flow, Lpd}}{\text{Weir Length, m}}$

Wire-to-Water Efficiency, % = $\frac{\text{Water hp}}{\text{Motor hp}} \times 100\%$

Wire-to-Water Efficiency, % = $\frac{(\text{Flow, gpm})(\text{Total Dynamic Head, ft})(0.746\ \text{kW/hp})(100\%)}{(3{,}960)(\text{Electrical Demand, kW})}$

*Pie Wheel Format for this equation is available at the end of this document

Abbreviations

C ..... Celsius
F ..... Fahrenheit
cfs ..... cubic feet per second
cm ..... centimeters
DO ..... dissolved oxygen
EMF ..... electromotive force
ft ..... feet
ft lb ..... foot-pound
g ..... grams
gal ..... US gallons
gfd ..... US gallons flux per day
gpd ..... US gallons per day
gpg ..... grains per US gallon
gpm ..... US gallons per minute
hp ..... horsepower
hr ..... hours
in ..... inches
kg ..... kilograms
kPa ..... kilopascals
kW ..... kilowatts
kWh ..... kilowatt-hours
L ..... liters
lbs ..... pounds
Lpd ..... liters per day
Lpm ..... liters per minute
LSI ..... Langelier Saturation Index
m ..... meters
mg/L ..... milligrams per liter
MGD ..... million US gallons per day
min ..... minutes
mL ..... milliliters
MLD ..... million liters per day
ORP ..... oxidation reduction potential
ppb ..... parts per billion
ppm ..... parts per million
psi ..... pounds per square inch
Q ..... flow
SDI ..... sludge density index
SS ..... settleable solids
TOC ..... total organic carbon
TSS ..... total suspended solids
TTHM ..... total trihalomethanes
VS ..... volatile solids
W ..... watts
yd ..... yards

Conversion Factors

1 acre ..... = 43,560 ft^2
= 4,046.9 m^2
1 acre foot of water ..... = 326,000 gal
1 cubic foot of water ..... = 7.48 gal
= 62.4 lbs
1 cubic foot per second ..... = 0.646 MGD
= 448.8 gpm
1 cubic meter of water ..... = 1,000 Kg
= 1,000 L
= 264 gal
1 foot ..... = 0.305 m
1 foot of water ..... = 0.433 psi
1 gallon (US) ..... = 3.785 L
= 8.34 lbs of water
1 grain per US gallon ..... = 17.1 mg/L
1 hectare ..... = 10,000 m^2
1 horsepower ..... = 0.746 kW
= 746 W
= 33,000 ft lbs/min
1 meter of water ..... = 9.8 kPa
1 metric ton ..... = 2,205 lbs
= 1,000 Kg
1 mile ..... = 5,280 ft
1 million US gallons per day ... = 694 gpm
= 1.55 cfs
1 pound ..... = 0.454 Kg
1 pound per square inch ..... = 2.31 ft of water
= 6.89 kPa
1 square meter ..... = 1.19 yd^2
1 ton ..... = 2,000 lbs
1% ..... = 10,000 mg/L
π or pi ..... = 3.14

Alkalinity Relationships

All Alkalinity expressed as mg/L as $CaCO_3$ • P – phenolphthalein alkalinity • T – total alkalinity

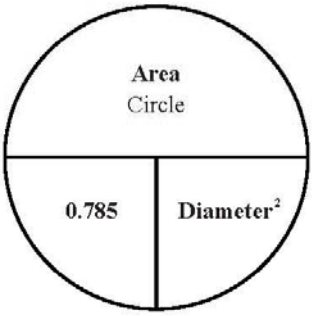
Result of Titration	Hydroxide Alkalinity	Carbonate Alkalinity	Bicarbonate Concentration
P = 0	0	0	T
P < ½T	0	2P	T – 2P
P = ½T	0	2P	0
P > ½T	2P – T	2(T – P)	0
P = T	T	0	0

*Pie Wheel Format for this equation is available at the end of this document

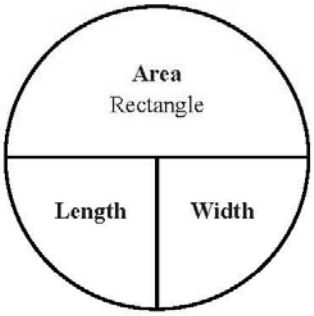
*Pie Wheels

- To find the quantity above the horizontal line: multiply the pie wedges below the line together.
- To solve for one of the pie wedges below the horizontal line: cover that pie wedge, then divide the remaining pie wedge(s) into the quantity above the horizontal line.
- Given units must match the units shown in the pie wheel.
- When US and metric units or values differ, the metric is shown in parentheses, e.g. (m^2).

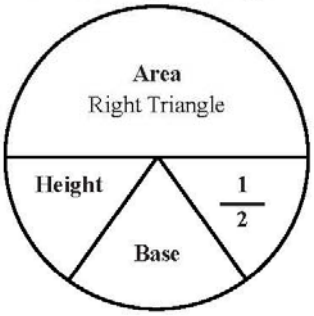
Area of Circle



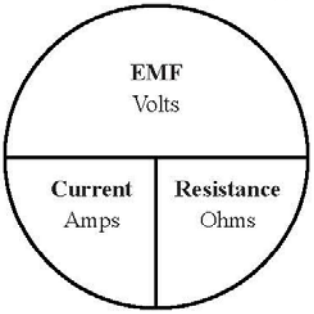
Area of Rectangle



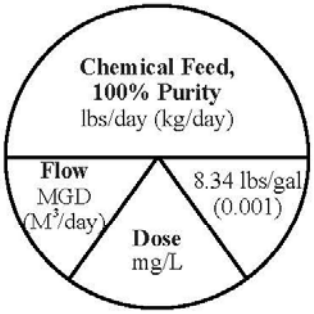
Area of Right Triangle



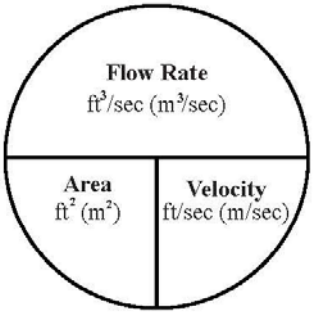
Electromotive Force (EMF), Volts



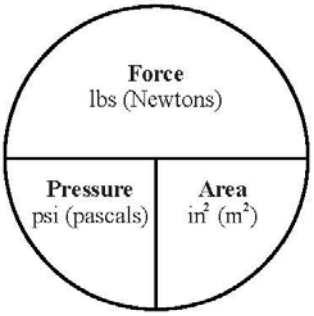
Feed Rate, lbs/day (kg/day)



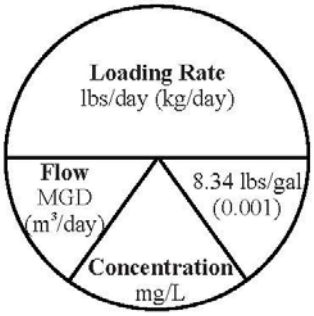
Flow Rate, ft^3/sec (m^3/sec)



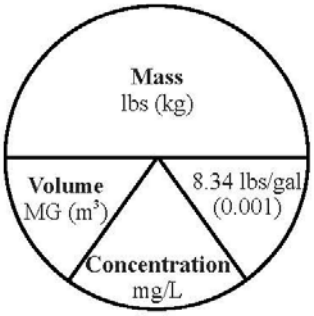
Force, lbs (Newtons)



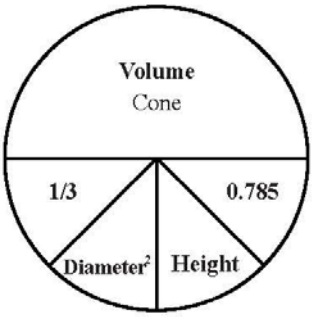
Loading Rate, lbs/day (kg/day)



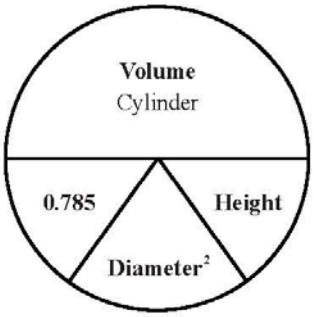
Mass, lbs (kg)



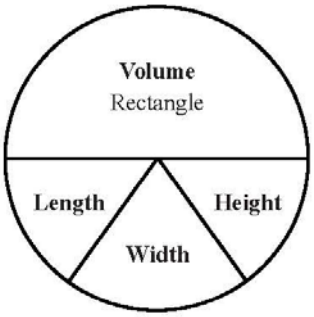
Volume of Cone



Volume of Cylinder



Volume of Rectangular Tank



Math

1. How many minutes are in an hour?
2. How many hours in a day?
3. How many minutes in a day?
4. How many inches in a foot?
5. How many feet in a mile?
6. How many meters are in a foot?
7. How many meters in a mile?
8. How much does one gallon of water weigh?
9. How much does one cubic foot of water weigh?
10. Express a flow of 5 cfs in terms of gpm.
11. What is 38 gps expressed as gpd?
12. What is 0.7 cfs expressed as gpd?
13. What is 9164 gpm expressed as cfs?
14. What is 1.2 cfs expressed as MGD?
15. Convert 65 gpm into lbs/day.
16. Convert 345 lbs/day into gpm.
17. Convert 0.9 MGD to cfm.
18. How many seconds are in a minute?

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.

Answers
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. 0.305 m/ft
8. 1610.4 m/mi
9. 8.34 lbs/gal
10. 62.4 lbs/ft3
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 ft3/min
19. 6684.49 ft3/hr
20. 396.43 ft3/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

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

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

3. 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.

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. 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?

Answers

Circumference:
1. 75.40 ft
2. 150.80 in
3. 100.53 ft

Area:
1. 540 sqft
2. 89.41 sqft
3. 2250 sqft
4.0 3.14 sqft

Volume:
1. 1000 cuft
2. 9050.8 gal
3. 359.04 gal
4. 48442.35 gal

Flow Rates (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?

Answers

1. 10.8 cuft/sec
2. 86.35 cuft/min
3. 2,404.50 gpm
4. 7,170,172.42 gpd

Disinfection

1. You have just laid 25,000 feet of 24 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

2. How many pounds of 65% available HTH is needed to make 5 gallons of 18% solution?

3. What is the dosage in milligrams per liter for a treatment plant that uses 855 lb/day of chlorine and treats 45.25 MGD?

4. A storage tank that is going to be put back into service requires disinfection at a dosage of 30 mg/L. If the tank has a diameter of 102 ft and is 28.1 ft in height at the overflow, how many gallons of 10.25% sodium hypochlorite solution will be needed if the tank is filled to 10% capacity?

5. You have just laid 5,000 feet of 10 inch line and it needs disinfecting. How many lbs of 65% HTH chlorine will be required to dose the line with 25 mg/L?

6. A tank is 60 feet in diameter and has a distance of 90 feet to the overflow. How many million gallons will the tank hold?

7. You need to disinfect a water storage tank that has just been repaired. You have decided to use AWWA Chlorination Method 3 to disinfect the tank. This method requires you to make up a 50 mg/L available chlorine solution that will fill approximately 5% of the tank volume. The tank holds 3 MG. How many gallons of water and lbs of HTH 65% available chlorine will have to be added to meet the above mentioned requirements?

Answers
1. 188.32 lb
2. 11.55
3. 2.27 mg/L
4. 50.2 gal
5. 6.54 lb
6. 1.90 MG
7. 96.23 lb

Pumps Power and Pressure

1. A flow of 555 gpm must be pumped against a head of 40 feet. What is the horsepower required?

2. Based on the gallons per minute to be pumped and the total head the pump must pump against, the water horsepower requirement was calculated to be 18.5 whp. If the motor supplies the pump with 21 hp, what must be the efficiency of the pump?

3. You have calculated that a certain pumping job will require 10.1 whp. If the pump is 84% efficient and the motor is 73% efficient, what motor horsepower will be required?

4. If 20 hp is supplied to a motor (mhp), what is the whp if the motor is 85% efficient and the pump is 80% efficient?

5. Convert a pressure of 26 ft to pounds per square inch.A supply tank is located at an elevation of 118 ft. The discharge point is at an elevation of 215 ft. What is the static head (in feet)?

6. A pump must pump against a total dynamic head of 70 ft at a flow rate of 700 gpm. The liquid to be pumped has a specific gravity of 1.3. What is the water horsepower required for this pumping application?

7. If the pressure at the bottom of the tank is 14.7 psi, what is the height of the water in the tank?

8. The motor nameplate indicated that the output of a certain motor is 35 hp. How much horsepower must be supplied to the motor, if the motor is 90% efficient?

9. What would be the horsepower on a motor that is rated at 16 amps and 440 volts?

Answers

1. 5.6 hp
2. 88.1%
3. 16.5 hp
4. 17 bhp; 13.6 whp
5. 11 psig
6. 97 ft
7. 16.1 hp
8. 34.0 ft
9. 38.9 hp

Vocabulary Answers

Pipe Vocabulary

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

Valve 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

Storage facility 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

Disinfection 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