GROUNDWATER TREATMENT OPERATOR CERTIFICATION MANUAL

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Certification and Licensing Program

Mission
Promote responsible environmental stewardship.

Goal
Provide operators with the basic knowledge required to manage drinking water, wastewater and solid waste systems.

The Division of Compliance Assistance offers free compliance assistance. Our services are available to all individuals, communities and businesses regulated by the Kentucky Department for Environmental Protection. We want to help you succeed!

Hotline and Website for regulatory, technical or operational concerns
800-926-8111
dca.ky.gov

Other programs administered by the Division of Compliance Assistance:

Kentucky Excel Program
Kentucky Brownfield Program
Kentucky Environmental Compliance Assistance Program

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GROUNDWATER TREATMENT OPERATOR CERTIFICATION COURSE

Chapter 1: THE GROUNDWATER OPERATOR

Chapter 1 Objective

1. Explain the three characteristics related to professionalism and groundwater distribution systems operators (*regulations, ethics, and professionalism*).

Why should I become a certified operator?

Wastewater and drinking water system operators are front-line environmental professionals who ensure the quality of Kentucky's water resources and protect the public's health. Only operators that are certified by the Kentucky Certification and Licensing Branch can be in responsible charge of a wastewater or drinking water system.

Working in the water and wastewater industry can be extremely rewarding as you will be providing a critical service to your community. It just might be one of the most important positions in the world since no one can live without water. It takes knowledgeable, conscientious people to deliver clean, potable water and to ensure that wastewater is treated and returned as clean water to the environment.

Certification Process

Certification is obtained by meeting minimum education and experience requirements, submitting the appropriate forms and fee and by passing the certification examination with at least a 70%. Regulations pertaining to the certification of drinking water and wastewater system operators are located in 401 KAR Chapter 11 (see appendix).

System Classifications

Class I-BD	Groundwater system with a design capacity < 50,000 GPD
Class II-BD	Groundwater system with a design capacity ≥ 50,000 but < 500,000 GPD
Class III-B	Groundwater system with a design capacity ≥ 500,000 but < 3 MGD
Class IV-B	Groundwater system with a design capacity ≥ 3 MGD

Regulatory Education and Experience

Class I-BD	High School Diploma or GED and One (1) year of acceptable operation of a Class I-BD or higher public water system shall be required.
Class II-BD	High School Diploma or GED and Two (2) years of acceptable operation of a public water system shall be required with Six (6) months of that experience in a Class 1-AD, II-BD or higher water treatment plant.
Class III-B	High School Diploma or GED and Three (3) years of acceptable operation of a public water system with One (1) year of that experience in a Class II-A, II-BD or higher water treatment plant.
Class IV-B	Baccalaureate degree in engineering, science or equivalent is required and One (1) year of acceptable operation of a public water system in a Class III-A, III-B or higher water treatment plant; or High School Diploma or GED and Five (5) years acceptable operation with One (1) year of acceptable operation of a public water system in a Class III-A, III-B or higher water treatment plant.

Operators in Training (OIT) Certifications

Operators in training certifications are available for each certification type. An individual can apply for an OIT license that is one level higher and of the same type as the certification that the individual currently holds. An individual may also apply for an entry level OIT certification. OITs must pass the appropriate operator certification exam and work under the responsible charge of a mentor. To apply for the exam, individuals must submit the following to the Certification and Licensing Branch:

- Education and Experience Documentation Form;
- Registration Form for Exams and Training;
- The appropriate fee; and
- A letter from the applicant's mentor. The letter from the mentor must include:
  - A commitment to oversee the applicant's work after the applicant becomes an OIT;
  - A commitment to mentor the applicant as long as the applicant is under the mentor's direct responsible charge;

- Verification that the mentor is not currently mentoring any other OITs; and
- Confirmation that the mentor holds a certification license that is equal to or greater than the certification level required to serve in primary responsibility of the facility where the mentor and prospective OIT works.

A Wastewater Treatment Class I-OIT who operates a wastewater treatment plant owned by the operator that serves only one residence may have primary responsibility for that plant. All other OITs may not be in responsible charge of a facility unless they hold an additional certification license that does not have an OIT designation.

Certification Renewal or Maintenance

Drinking water treatment, distribution and bottled water system certifications expire on June 30 of even-numbered years. Certifications shall remain valid until the expiration date, unless suspended, revoked or replaced by a higher classification certificate before that date. Certificates issued between Jan. 1 and June 30 of a renewal year will be issued to include the next two-year renewal period. Failure to renew before July 1 of the renewal year will result in the expiration of certification and a late fee assessment. The certificate shall terminate if not renewed on or before December 31 of the year the certification expired. Certified operators with expired certificates shall not be in responsible charge of a drinking water or wastewater facility.

Certified operators (excluding OIT certificates) may renew their license(s) electronically through the cabinet Web site using the E-Search link or by submitting the Application for Certification Renewal and the appropriate fee to the Division of Compliance Assistance, Certification and Licensing Branch, 300 Fair Oaks Lane, Frankfort, KY 40601.

Certified operators who are designated an Operator in Training may renew a certification without examination if the operator has:

- ✓ Satisfied the continuing education requirements;
- ✓ Earned the required years of operational experience;
- ✓ Submitted an Education and Experience Documentation form verifying his or her experience;
- ✓ Submitted a letter of recommendation from a mentor; and
- ✓ Submitted a completed Application for Certification Renewal form and the renewal fee to the cabinet or has renewed the certification electronically on the cabinet's Web site.

Drinking water treatment, distribution and bottled water certified operators training hours shall be completed for each renewal during the two (2) year period immediately prior to the certificate expiration date. Certified operators holding a treatment, distribution and/or bottled water certificate shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for both certificates.

- ***Reminder*** *-- Continuing education hours earned prior to certification shall not count toward certificate renewal.*

Operator Ethics – Standards of Professional Conduct for Certified Operators

In order to safeguard the life, health, and welfare of the public and the environment and to establish and maintain a high standard of integrity in the certified operator profession, standards of professional conduct apply to persons certified in accordance with 401 KAR Chapter 11. These standards state:

(a) A certified operator shall, during the performance of operational duties, protect the safety, health, and welfare of the public and the environment;
(b) A certified operator shall use reasonable care and judgment in the performance of operational duties;
(c) If a certified operator's judgment is overruled by an employer under circumstances in which the safety, health, and welfare of the public or the environment are endangered, the certified operator shall inform the employer of the possible consequences;
(d) A certified operator shall be objective, truthful, and complete in applications, reports, statements, and testimony provided to the cabinet; and
(e) A certified operator shall ensure the integrity of the samples that the operator collects, prepares, or analyzes so that results shall be a true representation of water quality.

The full set of standards is located in 401 KAR 11:020 (see appendix).

Certified operators who violate the standards in 401 KAR 11:020 are subject to disciplinary actions which include but are not limited to:

(a) Probation of the operator's certification for a specified period of time, not to exceed one (1) year;
(b) Suspension of the operator's certification for a specified period of time, not to exceed four (4) years, during which the certification shall be considered void;
(c) Revocation of the operator's certification;
(d) Civil or criminal penalties; or
(e) A combination of the disciplinary actions listed above.

Disciplinary actions are outlined in 401 KAR 11:050, Section 4.

All regulations related to the certification of wastewater and drinking water operators are located in 401 KAR Chapter 11. A copy of the regulations is located in the appendix of this manual and it is recommended that you become familiar with the regulations that govern your profession.

Key Definitions

Operator means a person involved in the operation of a wastewater treatment plant, wastewater collection system, drinking water treatment plant, or drinking water distribution system. (401 KAR 11:001)

Water Distribution System is defined as the portion of the water supply in which water is conveyed from the water plant or other supply point to the premises of a consumer or a system of piping and ancillary equipment, which is owned or operated by an established water system independent of the water supply system from which the potable water is purchased.

Ethics are defined as a code of morality or a system of moral principles governing the appropriate conduct for a person or group.

System Classifications are used in determining regulatory standards and compliance requirements for each drinking water system.

Public water system is a water system for the provision of water to the public for human consumption and the system has at least 15 service connections or regularly serves an average of at least 25 individuals a year.

Community water system is a public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year–round residents.

Non-community water system is a public water system that serves at least 15 service connections used by persons less than year–round or serves an average of at least 25 individuals at least 60 days per year but less than year–round.

Transient non-community water system is a non-community water system that does not regularly serve at least 25 of the same persons over 6 months per year. (Example – gas stations, parks, resorts, restaurants, etc. with their own water systems.)

Non-transient non-community water system is a non-community water system that does not regularly serve at least 25 of the same persons over 6 months per year. Example – schools, factories, hospitals, etc., with their own water system.

Semi-public water system is a water system made available for drinking or domestic use that serve more than three families but does not qualify as a public water system. Semi-public water systems are commercial facilities that serve food or drink to the public and shall meet the requirements of 401 KAR 8:020. *Semi-public water systems are not required to have certified operators.*

Monthly Operator Report (MOR) is a system's monthly performance report for regulatory compliance. It must be submitted to the Division of Water in Frankfort no later than 10 days after the end of the month for which the report is filed.

KAR – Kentucky Administrative Regulations are the regulations set forth by the Commonwealth of Kentucky, some of which regulate public water systems (Chapter 8, 11).

KRS – Kentucky Revised Statutes are the laws that govern the Commonwealth of Kentucky.

SDWA – Safe Drinking Water Act was passed by the United States Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and again in 1996 and requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and groundwater wells. This act authorizes the United States **E**nvironmental **P**rotection **A**gency (**US EPA**) to set national health-based standards for drinking water to protect against both naturally occurring and manmade contaminants that may be found in drinking water. The federal operator certification requirement was established by this act.

AI # - Agency Interest Number is the number that the Kentucky Environmental Protection Cabinet and the Division of Compliance Assistance (operator certification program) uses to track all activities pertaining to an individual or group involving environmental or regulatory compliance activities.

AWOP – Area Wide Optimization Program is a national program whose goal is to maximize public health protection through optimization of existing conventional surface water treatment utilities. AWOP was developed by the EPA's Technical Support Center as a non-regulatory, voluntary approach to microbial control using optimization tools to focus on operational changes to improve the drinking water quality. Goals are set that go beyond the regulatory requirements for conventional surface water treatment plants for settled water, filtered water and disinfection.

List of Key Acronyms

AOC	Assimilable Organic Carbon – low molecular weight dissolved organic carbon (DOC) that is readily consumed by bacteria leading to growth.
BAC	Biologically Active Carbon
BAT	Best Available Treatment
CPE	Comprehensive Performance Evaluation
C-T	Concentration of disinfectant residual multiplied by contact time
CTAP	Kentucky DOW Comprehensive Technical Assistance Program
CWS	Community Water Supply
D/DBP	Disinfectant and Disinfection By - Product
D/DBPR	Disinfectant and Disinfection By - Product Rule
DBP	Disinfection By- Product
DOC	Dissolved Organic Carbon

DOW	Kentucky Division of Water
EPTDS	Entry Point To Distribution System
GW	Groundwater
GWR	Groundwater Rule
GWUDI	Groundwater Under Direct Influence
HAA_5	Haloacetic Acids (chloroacetic acid, dichloroacetic acid, trichloroacetic acid, bromoacetic acid, dibromoacetic acid)
HPC	Heterotrophic Plate Count (synonymous with Standard Plate Count)
LCR	Lead and Copper Rule
LTESWTR	Long Term Enhanced Surface Water Treatment Rule
LT2	Long Term 2 Enhanced Surface Water Treatment Rule
µg/L	Microgram per Liter
MIEX	Magnetic resin(trademark acronym for a resin specific for DOC removal)
NOM	Natural Organic Matter
ppb	parts per billion
PWS	Public Water System
QA	Quality Assurance
QC	Quality Control
SDWA	Safe Drinking Water Act (as amended in 1996)
SS	Sanitary Survey
TC	Total Coliform
TCR	Total Coliform Rule
THM	Trihalomethane
TNCWS	Transient Non-Community Water System
TOC	Total Organic Carbon
Treated Water	considered no later than the combined filter influent
TTHM	Total Trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform)
USGS	United States Geological Survey
UV	Ultraviolet Light
UV_{254}	Ultraviolet wavelength at 254 nanometers

VA	Vulnerability Assessment
VOC	Volatile Organic Contaminant
WHPA	Wellhead Protection Area
WTP	Water Treatment Plant

Ethics

1. noun – the study of moral standards and how they affect conduct.
2. plural noun – a code of morality, a system of moral principles governing the appropriate conduct for a person or group.

Nationally, more and more certified operators are being prosecuted for unethical or dishonorable behavior in the workplace. Water treatment and distribution in some areas have become a practice of notating the "right" numbers. If the "right" numbers are turned into the regulatory agency, visits from these regulatory agencies would probably not be as frequent or involved as they would be if valid or honest numbers were turned in. Our job is to protect the consuming public and provide potable water to each and every one of them, not satisfy regulatory numbers. Take pride in your work and in your ethical behavior.

Chapter 1 Review

1. Operator certification became federally mandated in ________.

2. A public water system is defined as having ____ service connections or serves at least _______ people year round.

3. Is it possible to obtain a Groundwater Class III – OIT certification if the applicant does not currently hold a valid Groundwater Class II certification?

4. After June 30th of even-numbered years, an operator has _______months to renew before their certification terminates.

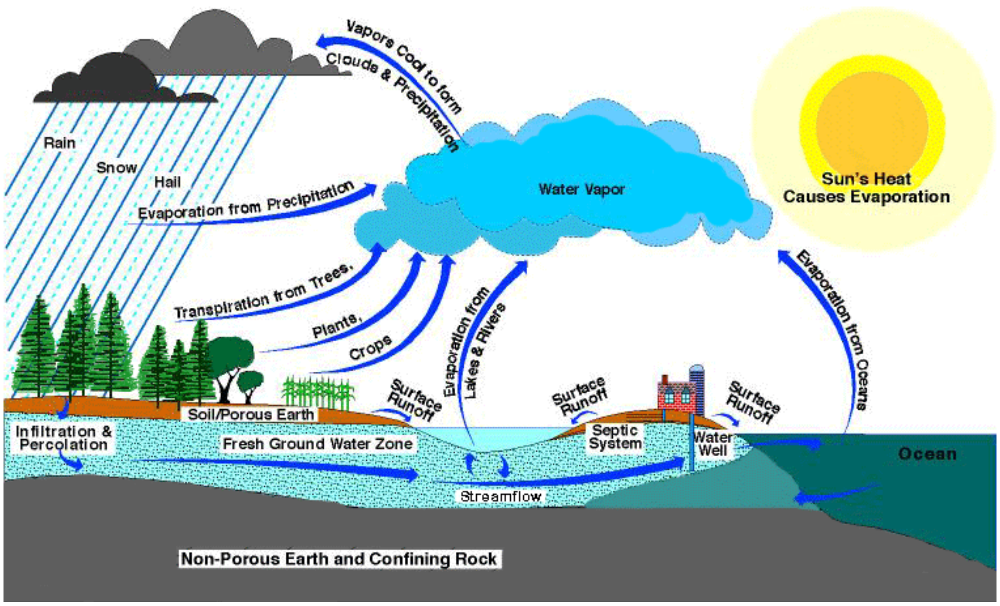
5. Certified operators who violate the standards in 401 KAR 11:020 are subject to disciplinary actions which include but are not limited to _______________; _______________;_______________; _______________; or _______________.

6. The federal law that operator certification falls under is the _______.

Answers for Chapter 1 Review

1. 1996
2. 15, 25
3. No
4. 6
5. Probation of the operator's certification for a specified period of time, not to exceed one (1) year;
   Suspension of the operator's certification for a specified period of time, not to exceed four (4) years, during which the certification shall be considered void;
   Revocation of the operator's certification;
   Civil or criminal penalties; or
   A combination of the disciplinary actions listed above.
6. SDWA

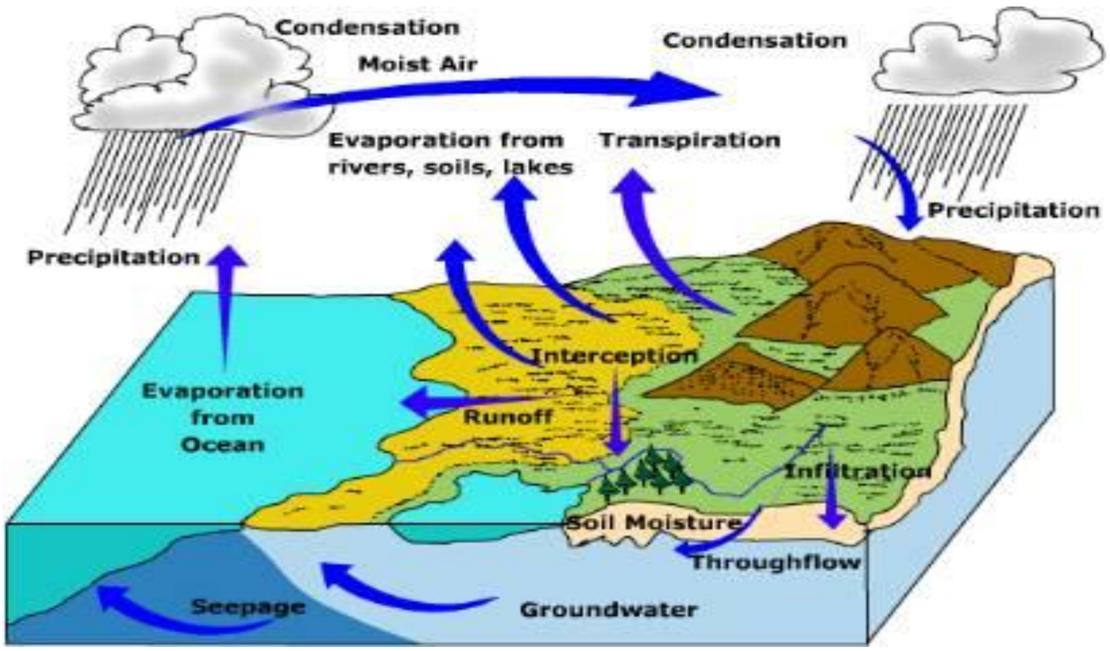
Chapter 2: WATER SOURCES AND CHARACTERISTICS OF GROUNDWATER



<u>Chapter 2 Objectives</u>

1. Identify the sources of drinking water and explain the phases of the hydrological cycle.
2. Explain the types of Aquifers and the movement in the aquifers.
3. List possible contamination sources to aquifers.
4. Describe why subsidence happens.
5. Differentiate between physical, chemical and biological, radiological characteristics of groundwater.
6. Demonstrate the ability to convert temperature conversions.
7. Identify current MCL and MCLG for drinking water systems.

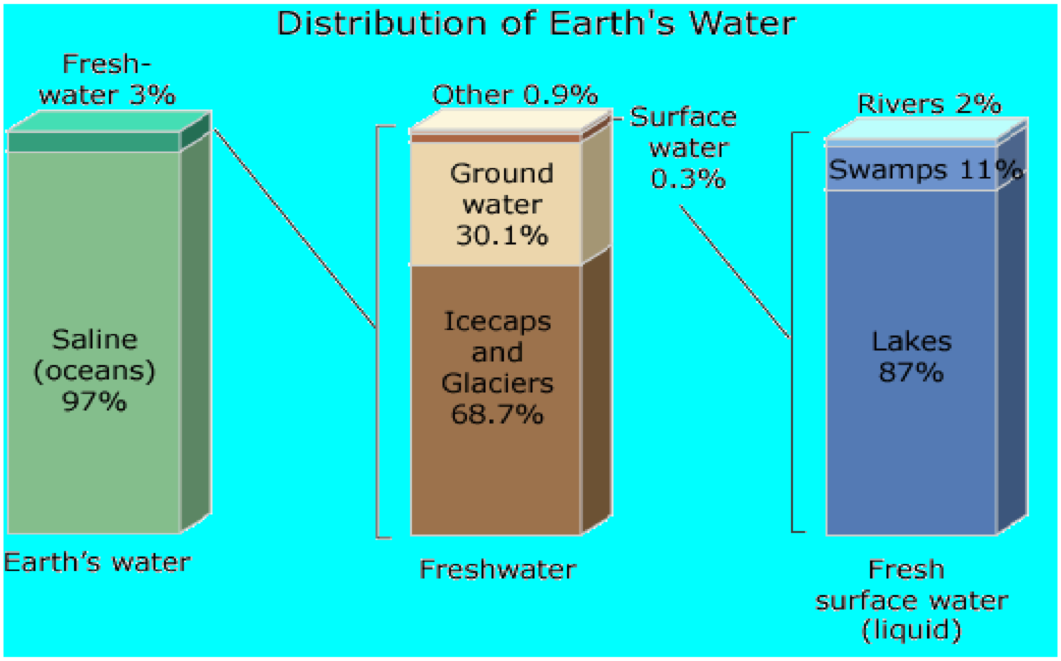
Hydrologic Cycle



The hydrologic cycle begins with the **evaporation** of water from the surface of the ocean. As moist air is lifted, it cools and water vapor condenses to form clouds. Moisture is transported around the globe until it returns to the surface as **precipitation**. Once the water reaches the ground, one of two processes may occur; 1) some of the water may evaporate back into the atmosphere or 2) the water may **Infiltrate** the surface and become **groundwater**. Groundwater either seeps its way to into the oceans, rivers, and streams, or is released back into the atmosphere through **transpiration**. The balance of water that remains on the earth's surface is **runoff**, which empties into lakes, rivers and streams and is carried back to the oceans, where the cycle begins again.

Upon reaching the ground, some water infiltrates into the soil, possibly percolating down to the groundwater zone or it may run across the surface as **runoff**. **Infiltration** refers to water that penetrates into the surface of soil. Infiltration is controlled by soil texture, soil structure, vegetation and soil moisture status. High infiltration rates occur in dry soils, with infiltration slowing as the soil becomes wet. Coarse textured soils with large well-connected pore spaces tend to have higher infiltration rates than fine textured soils. However, coarse textured soils fill more quickly than fine textured soils due to a smaller amount of total pore space in a unit volume of soil. Runoff is generated quicker than one might have with a finer textured soil.

Vegetation also affects infiltration. For instance, infiltration is higher for soils under forest vegetation than bare soils. Tree roots loosen and provide conduits through which water can enter the soil. Foliage and surface litter reduce the impact of falling rain keeping soil passages from becoming sealed.



As you can tell from the image above we are very limited to the amount of water we have to treat for consumption.   We have no new water and what we are treating is the same water your family has been using every generation.

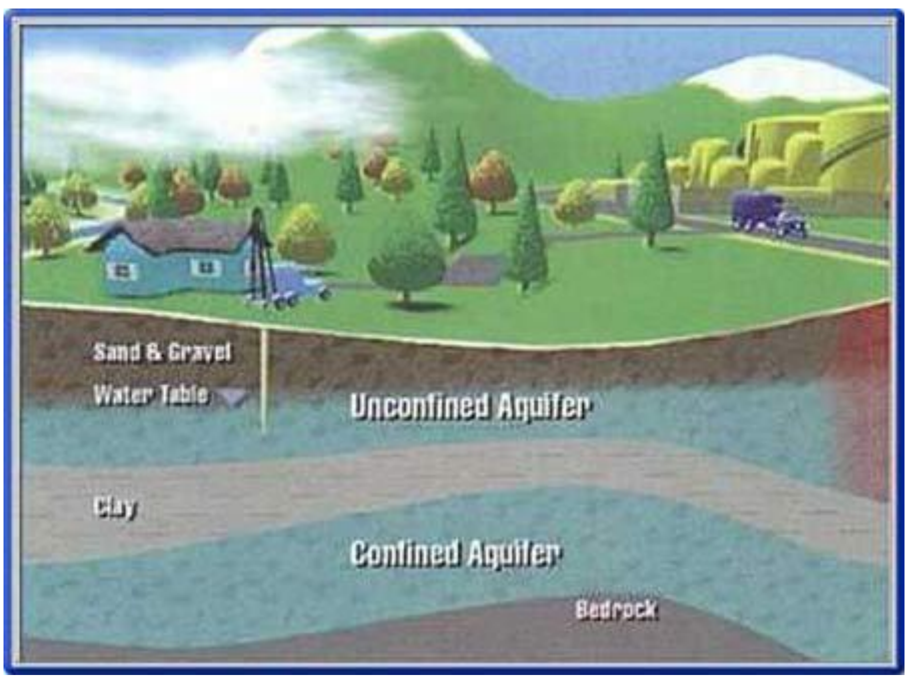
The graph below illustrates the distribution of water usage in the United States.

Our population is growing larger every day. We as a nation are using more and more water. This makes water conservation more important than ever. People need to understand what the operator goes through and to be aware there is just so much water we have to treat for there consumption. **Notifying the public is important**. We must get the word out on what operators have to deal with and the water shortage we will have if we keep consuming water at such a rate.

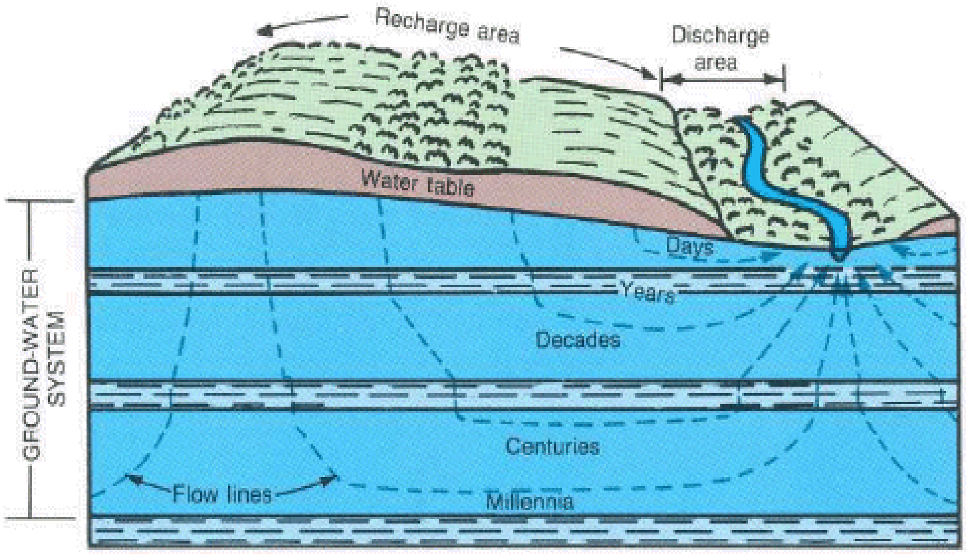
Water Sources

The EPA has categorized the sources of drinking water into three types. Each type has unique treatment methods for the best removal of contamination in each source.

1. **Surface Water** is the water that is found on the surface from our lakes, rivers, and streams. This source is easily contaminated but also easily cleaned. Surface water is naturally replenished by precipitation naturally lost through discharge to evaporation and sub-surface seepage into the groundwater. Although there are other sources of groundwater, such as connate water and magmatic water, precipitation is the major one.
2. **Groundwater under the direct influence of surface water** (GUDI) is groundwater that has surface water characteristics. GUDI is pumped from wells and then treated. GUDI shows signs of a surface water system if the temperature of the water changes with the seasons. A true groundwater system will not change more than a degree or two year around.
3. **Groundwater** is found under ground in unconfined and confined aquifers.

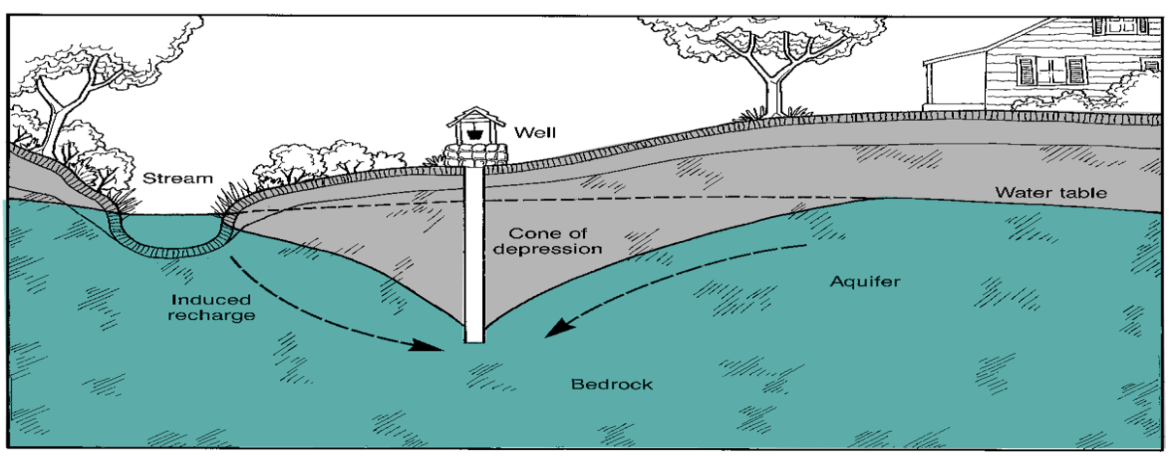


When working with groundwater, water source protection is extremely important. Unlike surface water, once groundwater is contaminated it can take anywhere from days to a millennia before that contaminate can completely be removed and that groundwater has completely recharged.

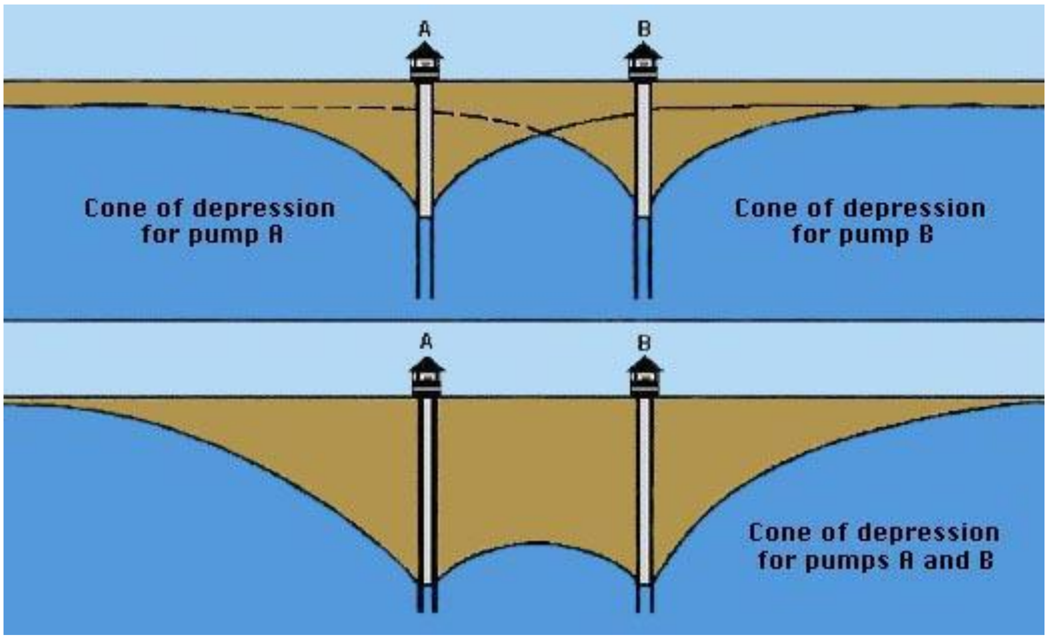


Groundwater is drawn from **aquifers**. There are two types of a aquifers an operator needs to be aware of. An **Unconfined Aquifer** is an aquifer that is restricted by an impervious layer on the bottom but not on top. **Confined Aquifers** are those that are covered (confined) by an impermeable or semi-permeable layer of rock. A confined aquifer is also called a Artesian aquifer.

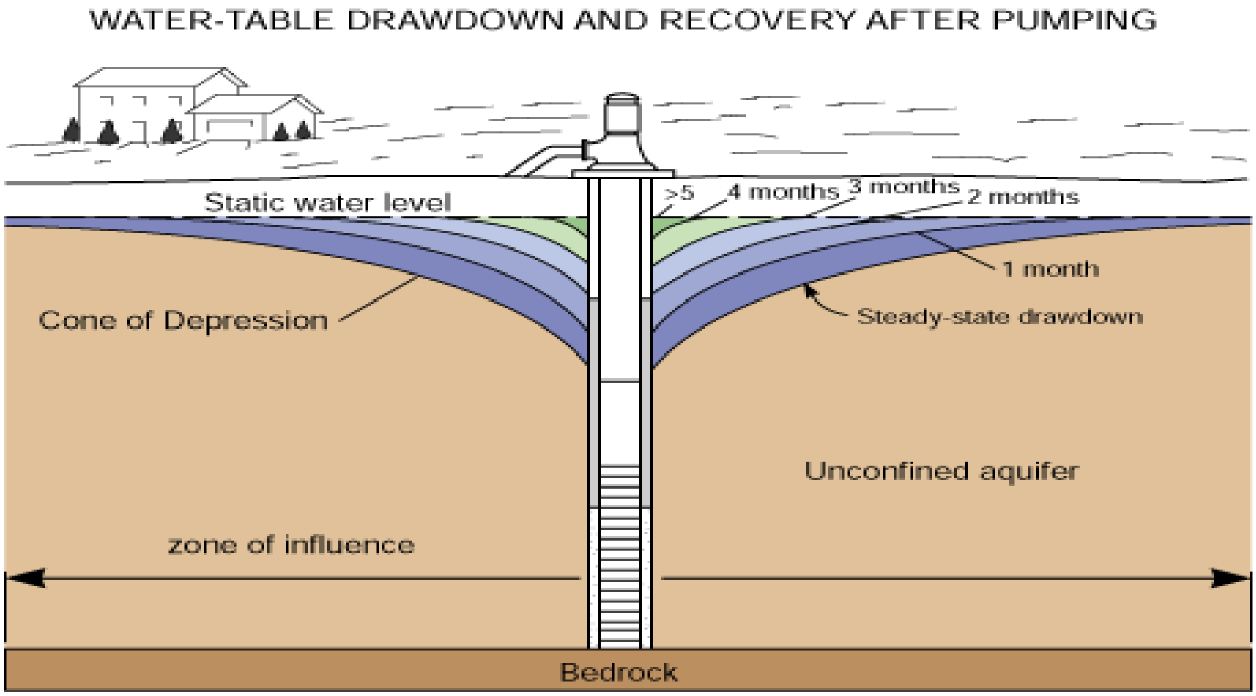
The movement of groundwater can be changed and effected in many ways. When a well is placed in a water-bearing layer of the earth's crust and pumped, water will flow toward the center of the well. In a water table aquifer this movement will create a depression in the water table called the **Cone of Depression**. The shape and size of the cone is dependent on the relationship between the pumping rate and the rate of water movement.



- If the pumping rate is low the cone will be shallow and its growth stabilized.
- If the pumping rate is high, the cone will be sharp and continue to grow in size.



If any contamination is in the area it will be drawn into the cone of depression. This makes the placement of your well even more important than ever. The **water table** is the average depth of groundwater over a selected area. The **zone of influence** reaches from the farthest points of the cone of depression.



<u>Specific Capacity</u> is short term sustainable discharge divided by the drawdown yielding the discharge. (GPM/ft). Drillers measure specific capacity and report it to the state. The math example below illustrates how specific capacity is related to drawdown.

Example:

Well # 25 yields 235 gpm at a drawdown of 90 feet. What is the specific capacity?

235 gpm ÷ 90 feet = ? gpm/ft

2.6 gpm/ft

Potential Contamination of Aquifers

Category	*Contaminant Source*
Agricultural	1. Animal burial areas 2. Drainage fields/wells 3. Animal feedlots 4. Irrigation sites 5. Fertilizer storage/use 6. Manure spreading areas/pits, lagoons 7. Pesticide storage/use
Commercial	• Airports • Jewelry/metal plating • Auto repair shops • Laundromats • Boatyards • Medical institutions • Car washes • Paint shops • Construction areas • Photography establishments • Cemeteries Process waste water drainage • Dry cleaners fields/wells • Gas stations • Railroad tracks and yards • Gulf courses • Research laboratories • Scrap and junkyards • Storage tanks
Residential	• Fuel Oil • Septic systems, cesspools • Furniture stripping/refinishing • Sewer lines • Household hazardous products • Swimming pools (chemicals) • Household lawns

Table continued from previous page.

Category	***Contaminant Source***
Industrial	• Asphalt plants • Petroleum production/storage • Chemical manufacture/storage • Pipelines • Electronic manufacture • Process waste water drainage • Electroplaters fields/wells • Foundries/metal fabricators • Septage lagoons and sludge • Machine/metalworking shops • Storage tanks • Mining and mine drainage • Toxic and hazardous spills 8. Wood preserving facilities
Other	• Hazardous waste landfills • Recycling/reduction facilities • Municipal incinerators • Road deicing operations • Municipal landfills • Road maintenance depots • Municipal sewer lines • Storm water drains/basins/wells • Open burning sites • Transfer stations

*Table information taken from http://www.accuracyinspections.com/water.htm

<u>Subsidence</u> is the sinking down of land resulting from natural shifts or human activity, frequently causing structural damage to buildings. Subsidence occurs over time when the ground that was supported by water from an aquifer has been drained so much over the years nothing is left to hold the ground up.

Water Characteristics and Monitoring Parameters

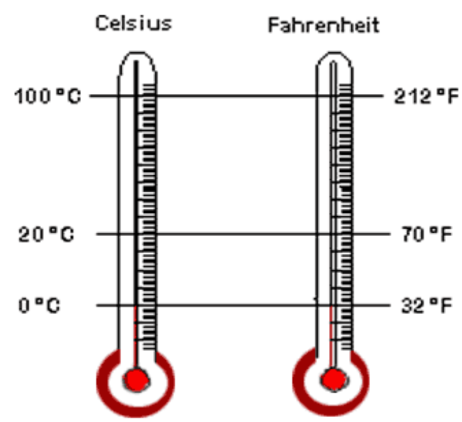
Physical characteristics are characteristics an operator can easily obtain.

Temperature influences all other characteristics and is the only variable the operator has no control of. Temperature normally stays consistent in groundwater systems.

1. Chemical reactions occur faster in warmer water than cold water.
2. Taste and odor are more noticeable in warmer water.
3. Particles will settle out more quickly in warm water.
4. Warmer water will promote the growth of aquatic life such as iron and sulfur reducing bacteria, algae, biofilms and pathogens.
5. Cold water is preferred by consumers and industrial users.
6. Conversion factors for Fahrenheit and Celsius.

Fahrenheit (F°) = (1.8 x C°) + 32

Celsius (C°) = $\frac{(F° - 32)}{1.8}$



1. Convert 40F° to C°?

C° = $\frac{(F° - 32)}{1.8}$ C°= $\frac{(40° - 32)}{1.8}$ C° = $\frac{8}{1.8}$ C° = 4.4

2. Convert 38 C° to F°?

F° = (1.8 x C°) + 32 F°= (1.8 x 38) + 32 F°= 68.4 + 32 F°= 100.4

We use **conversions** every day. Conversions are a change from one measuring or calculating system to another.

Example: If we pull out a measuring tape and determine that a board measures 96 inches and we want to determine how many feet this is, all we have to do is divide 96 inches by 12 inches (1 foot) and we know that this board is 8 feet long.

Sometimes, we must convert certain measurements in order to determine dosages, volumes, velocities, etc.

Conversions	
Multiply (x) if going from left to right →	
1 psi	= 2.31 ft. of head
1 ft. of head	= .433 psi
1 cu ft of water	= 7.48 gallons
1 cu ft of water	= 62.4 lbs.
1 gallon	= 8.34 lbs.
1 gallon	= 3,785 ml
1 Liter	= 1,000 ml
1 Liter	= 1,000 grams
1 mg/L	= 8.34 lbs/MG
1 ppm	= 1 mg/L
1 ml	= 1 gram
1 pound	= 453.6 grams
1 pound	= 7,000 grains
1 kilogram	= 1,000 grams
1 cu ft/sec	= 448.8 gpm
1 MGD	= 1.55 cu ft/sec
1 MGD	= 694.5 gpm
1 HP	= 33,000 ft lbs/min
1 HP	= .746 kilowatt
1 mile	= 5,280 feet
← Divide (÷) if going from right to left	

The key to using this conversion portion of the formula sheet is to find the two entities you need to solve the problem and then decide whether to multiply or divide. For example, if you are given cuft/sec (ft^3/sec) and you need gallons per minute (gpm) there is only one line under the conversions header that gives you both forms of measurement you need. What you know is on the left side and what you don't know is on the right side, so you would multiply to obtain the answer.

Example: Convert 15 cu ft/sec to gpm.
15 cu ft/sec X 448.8 gpm = 6732 gpm

Or, if you are given gpm and need to convert them to MGD there is only one line that has both gpm and MGD. What we are given is on the right side and what we need to know is on the left so we would divide.

Example: Convert 2500 gpm to MGD.
2500 gpm ÷ 694.5 gpm = 3.599 or 3.6 MGD

Turbidity is generally not associated with groundwater supplies; however, its presence can indicate possible pollution to your source water and fluctuating levels can indicate that you have groundwater under the direct influence of surface water.

Turbidity is defined as the cloudy appearance in water caused by suspended and colloidal matter in the water. Its source can be organic (live, dead, and decaying plant and animal matter and their derivatives); or it can be inorganic (sand, silt, clay, minerals, synthetic industrial and domestic waste). It is measured in Nephelometric Turbidity Units (NTU) which is determined by passing a beam of light through a water sample and measuring the amount of reflected light. A NTU of 5.0 is visible to the naked eye. Regulations state that treated groundwater may not exceed 1.0 NTU.

The significance of turbidity is listed below.

1. Turbid water has an objective appearance.
2. Suspended solids interfere with chlorine disinfection.
3. Indicative of potential well contamination of well pumps.
4. May be the result of chemical precipitates (Fe and Mg, $CaCO_3$, corrosion).
5. It may be the result of chemical living organisms.

There are two types of color. *True color* which is contributed by dissolved organics in source water (not a common problem in groundwater) and *apparent color*. Apparent color originates from the precipitation of inorganic solids (such as iron and manganese) in source water. Apparent color is a common problem in groundwater supplies. Some important things to remember about color:

- ✓ Both types of color have an objectionable appearance;
- ✓ Stains plumbing fixtures and laundry;
- ✓ Not a health hazard; but secondary standards apply:

- Iron (Fe) has a secondary MCL of 0.3 mg/l
- Manganese (Mn) has a secondary MCL of 0.05 mg/l

Most taste and odor causing substances in water are organic based, so groundwater generally has very few taste and odor related problems except for dissolved inorganics. Any unusual taste and odor in the water is objectionable to the consumer. Common taste and odor problems associated with groundwater are listed below.

a. Iron-reducing bacteria (*crenothrix*) and sulfur-reducing bacteria can form in the well and on the well screen. Taste and odor comes from the metabolic by-products produced as their populations expand and from their decaying bodies as these populations die off.
b. Dissolved gases such as hydrogen sulfide (rotten egg odor) or methane (metallic taste) may form in the well.
c. Inadequate dosages of chlorine, both high and low can create undesirable taste and odor in the treated water. If phenolic compounds are present in the source water, chlorination will give the water a medicinal taste.
d. Domestic, agricultural, and municipal wastes could get into the aquifer causing a great number of tastes and odors in the source water. This would indicate contamination of the aquifer, therefore all taste and odors should be investigated until the cause is determined.
e. Most taste and odors associated with groundwater systems arise in the treatment facility, storage tanks, or distribution system and are the result of poor operation and maintenance.

Chemical characteristics consist of organic characteristics and how they are formed and found in groundwater. There are over 700 **organic chemicals** have been identified in drinking water and are known to cause cancer or have other adverse health effects. They come from three general sources:

1. The breakdown of naturally occurring organic materials.
   a) Tannins, lignins, fulvic and humic materials (DBP precursors)
   b) Microorganisms and their metabolites (blue-green algae)
   c) Petroleum based aliphatic and aromatic hydrocarbons (MTBE, benzene)

2. Domestic and commercial activities.
   a) Wastewater discharges (fecal coliform bacteria)
   b) Agricultural runoff (fertilizers-nitrates; pesticides-chlordane)
   c) Urban runoff (solvents, degreasers, and other waste products)

d) Lechate from contaminated soils (landfills, septic systems, leaking underground storage tanks, mining and drilling operations, illegal dumps, hazardous chemical spills, etc)

3. Reactions that occur during water treatment and transmission.
   a) Formation of undesirable compounds (disinfection by-products, components of coagulants)
   b) Biological re-growths
   c) Undesirable components of pipes, coatings, linings, and joint adhesives that leach into the water
   d) Backflow of contaminants into the water system

Inorganic characteristics consist of pH, Hardness, Dissolved Oxygen and Dissolved Solids.

1. **pH** is the measurement of the hydrogen ion concentration in water. Its affects all chemical reactions in water and also impacts all treatment processes.

pH<7	pH=7	pH>7
acid	neutral	basic

Operators should know the effect pH has on every treatment process.

2. **Hardness**
   a) Hard water is any water that contains significant amounts of calcium or magnesium. Hard waters tend to precipitate scale in pipes and on plumbing fixtures and make the lathering or soaps difficult.

   b) The degree of hardness is dependent upon the local geology and the amount of time the water contacts these geologic structures. Groundwater has much higher levels than surface water because it is stored in aquifers for many years allowing minerals (Ca & Mg) to more readily dissolve into the water.
   c) Hard water (greater than 120 mg/l) causes scale to form in pipes and meters which reduces pipe carrying capacity and leads to meter malfunction. Soft waters (less than 50 mg/l) contribute to corrosion.
   d) Standard lab tests used to determine hardness express results in mg/l as $CaCO_3$.
   e) Softened water delivered to consumers usually has a hardness level around 80 to 100 mg/l as $CaCO_3$.

3. **Dissolved Oxygen**
   a) Higher concentrations support the growth of aquatic life and contribute to the corrosion f the distribution system.
   b) Colder waters can hold more dissolved oxygen than warmer waters. If supersaturated with dissolved oxygen, water will release oxygen to the atmosphere as it warms. This is important to filtration systems because this release of oxygen could bind filters.
   c) Sources include natural or mechanical aeration of the water; by-product of aquatic plant growth; addition of chemical oxidants to the water
   d) DO is measured chemically or electrically and is expressed as mg/l of DO.

4. **Dissolved Solids**
   Groundwater dissolves minerals from the soil and rock it contacts.

   a) Some dissolved minerals are toxic (arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, and silver).
   b) Waters high in dissolved solids can create problems such as taste, odor, hardness, corrosion, and scaling. Consumption of such water may also cause laxative effects.
   c) Acceptable levels of TDS should be below 500 mg/l.

Biological characteristics are found in either aquatic life or non-aquatic life.

1. **Aquatic Life**
   a) Iron-reducing and sulfur-reducing bacteria are bacteria that feed on iron or sulfur deposits that form on well screens and pipe walls. The reproduction of these organisms clog well screens, reduce pipe carrying capacity, and create taste, odor, and color problems.
   b) Biofilms are large populations of microbiological organisms of various species attach to deposits on pipe walls to form protective slime coatings.

2. **Non-Aquatic Life** consists of insect and insect larva, nematodes, water fleas, and other the small animals that find their way into our water system then die and decompose.

Radiological characteristics consist of two sources: man-made and natural.

1. **Man-made sources**
   a) fallout from nuclear weapons testing
   b) radionuclides from nuclear power systems
   c) from mining of radioactive materials

2. **Natural sources**
   a) radon gas

A **Maximum Contaminant Level (MCL)** is set for each regulated contaminant. The value represents the highest level of a contaminant allowed in water that would still consider the water potable. *Primary MCLs* relate to contaminants having adverse health implications while *Secondary MCLs* relate to aesthetic concerns. Below are examples of each.

PRIMARY MCLs		SECONDARY MCLS	
Nitrate	10.0 mg/l	Sulfate	250 mg/l
Fluoride	4.0 mg/l	Fluoride	2.0 mg/l
Lead	0.05 mg/l (Action Level= 0.015 mg/l)	Iron	0.3 mg/l
Copper	1.3 mg/l (Action Level= 1.3 mg/l)	Manganese	0.05 mg/l
Turbidity	0.3 NTU (As average of monthly samples)		

When MCLs are exceeded, the consuming public must be informed as dictated by the Public Notification Rule and Consumer Confidence Reporting.

Maximum Contaminant Level Goal (MCLG) represents the level of a contaminant that would pose no health effect to humans. It is often less than the MCL for that particular contaminant. As technology improves and/or the costs of complying with these lower levels are reduced, the MCL will gradually be lowered by the EPA until it equals the MCLG.

Chlorine Residuals is a measure of chlorine remaining in the water after allowing adequate contact time following chlorine addition. Chlorine residual, measured by using the DPD test method, exists as Total, Combined, or Free Forms:

Total Residual= Combined Residual + Free Residual

Total residual describes the total amount of chlorine remaining in the water after having ample time to chemically react (as an oxidizer) with the water being treated. This reading, subtracted from the initial dosage of chlorine (in mg/l), describes the chlorine demand for a given water.

Free residual describes the amount of chemically unreacted chlorine remaining in the water. This level shall always remain above 0.2 mg/l. We test our water throughout the distribution system to ensure that this disinfection capability remains in place at all times.

Combined residual (the difference between the total and free readings) is generally not measured, but rather determined mathematically by comparing the total and free measurements. Combined residuals possess the ability to kill pathogens. However, because the chlorine is chemically tied up with other compounds, its killing power is greatly diminished. Chlorine residual measurement, analyzed with the use of the following formula, is used to monitor and control pathogens in the water.

Chlorine Dosage (mg/l) = Chlorine Demand (mg/l) + Chlorine Residual (mg/l)

Operators use chlorine residual readings to determine and locate causes for chlorine demand in the water system. Locating and eliminating chlorine demand in the system will allow the operator to more easily develop and maintain a free residual at lower chlorine dosage.

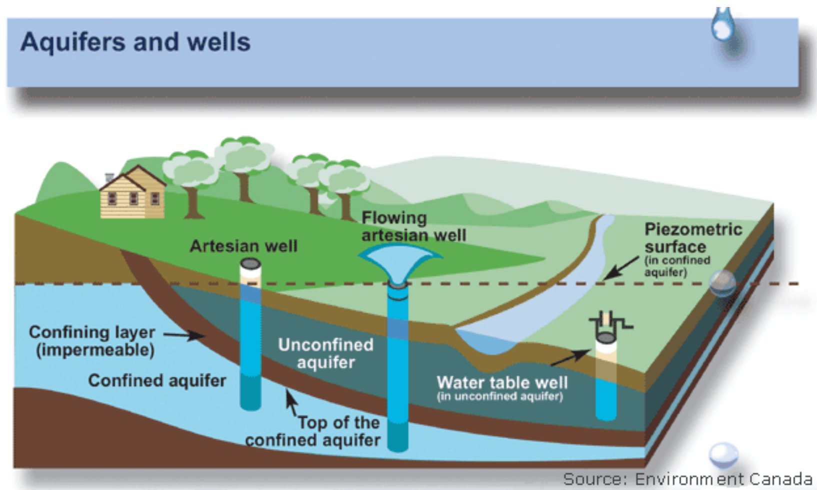
Chapter 2 Review

1. What part of the hydrologic cycle is most critical to groundwater operators?
2. What affects the size of the cone of depression?
3. What is referred to as the farthest points in the cone of depression?
4. Hardness is caused by high concentrations of ________ or__________in the water.
5. Taste and odor issues as well as chemical reactions are exacerbated in _______ water.
6. pH refers to the ___________ ion concentration of water.
7. DBPs are caused by the reaction of _________ and ________.
8. A primary MCL refers to __________ related contaminants.

Answers for Chapter 2 Review

1. Infiltration
2. Pumping rate
3. Zone of Influence
4. Calcium, magnesium ions
5. Warmer
6. Hydrogen
7. Chlorine, organics
8. Health

Chapter 3: WELL SYSTEMS AND APPURTENANCES



Chapter 3 Objectives

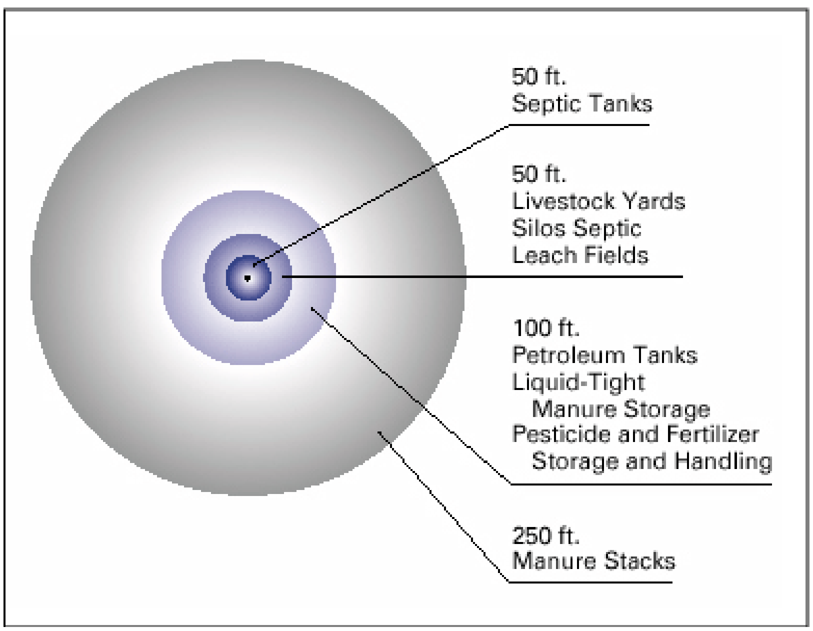
1. Demonstrate the knowledge of well locations and know the proper setbacks and regulations.
2. Describe the meaning of karst topography in KY.
3. Identify the three types of wells (dug, driven, drilled).
4. Differentiate between all well pumps (centrifugal, volute, turbine, submersible, and deep well).
5. Explain the typical components of a well.
6. List the types of cleaning methods for wells (surging, jetting, acid, chlorine, polyphosphates, explosive charges).
7. Describe the five steps of the Wellhead Protection Program for Kentucky.
8. Understand the importance of a wellhead protection plan.
9. Calculate the specific capacity of a well, as well as, flow rates from a well.

Well Development Parameters

Well site selection is very important and the factors below should be taken into consideration when selecting a site.

1. **Adequate supply**- Surveys should take place to determine that the site you are looking at can meet the demands of the population served.
2. **Favorable Quality**- testing of source water to get an overview of the water quality that will be produced if a well was placed there.
3. **Minimal Contamination Potential**- before a well site is selected; a team needs to cover the surrounding area to see what risks of contamination to the well there could be. After the site as been searched for contaminates certain setbacks must be meet before installing a well.

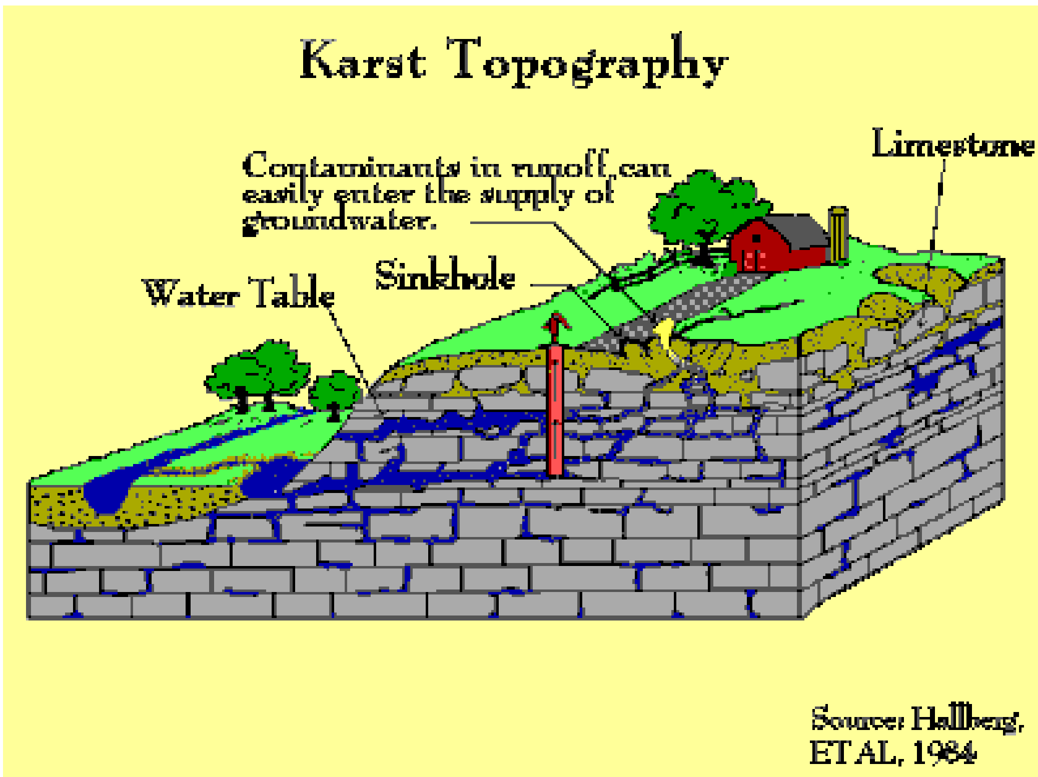
There are **regulatory setbacks** for wells. They are summarized below in the graphic and the points that follow.



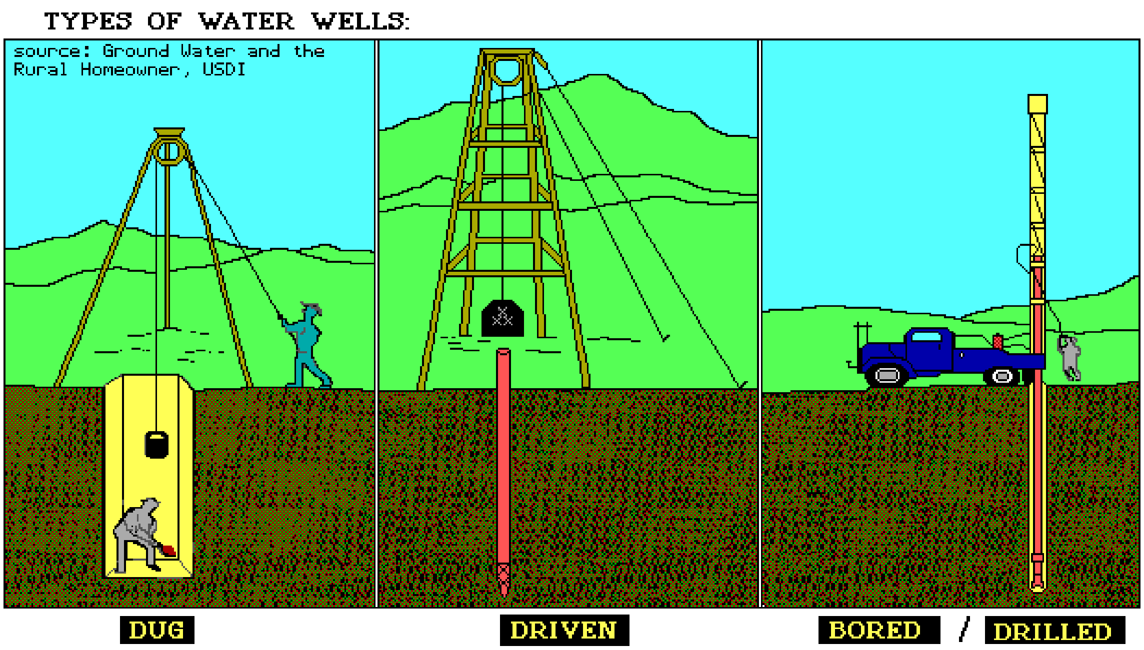
1. No wastewater disposal systems within 200 ft of the well.
2. No sewer lines or holding tanks within 200 ft of the well.
3. Fuel not used on site cannot be stored within 100 feet of the well.
4. Fuel stored on site cannot exceed 500 gallons.
5. Well head must be protected against flooding.
6. Well casing must extend 1 foot above the ground.
7. Top of well casing must extend 12 inches above the well hose floor slab.

8. Ground around well must be sloped away from the well 10 feet in every direction.
9. Well must have a sanitary seal.
10. No well pit.

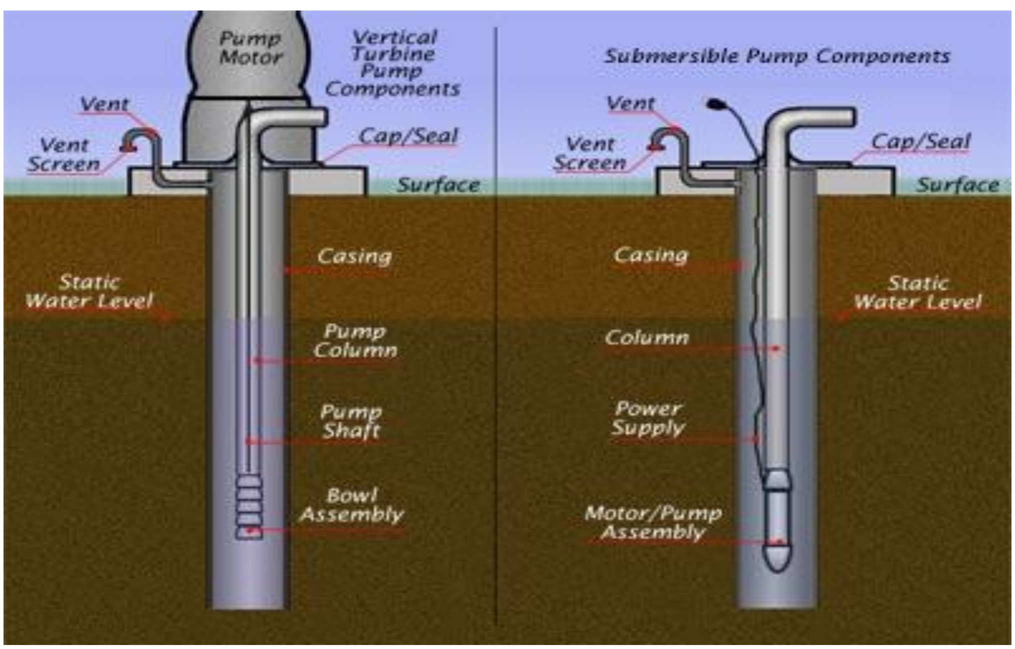
Kentucky has a very Karst topography and must be taken into consideration before selecting a well site.



There are **three types of wells** illustrated below. They are dug, driven and drilled.



Typical Well and Pumping System Features



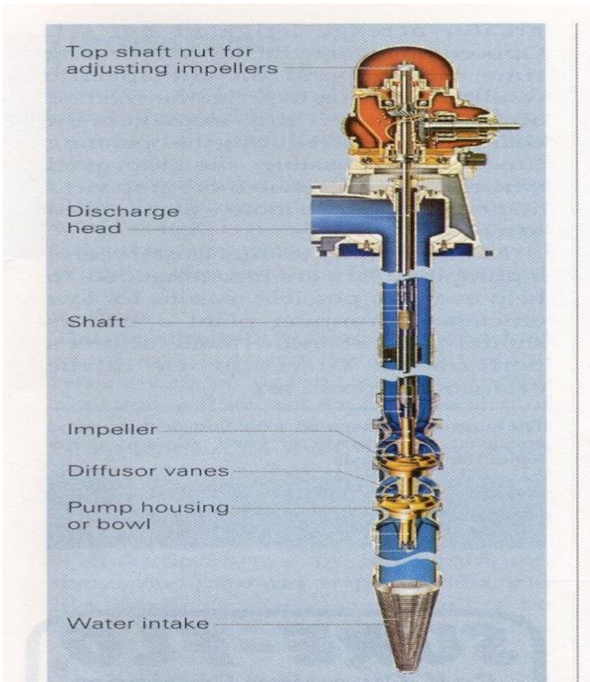
Pump/Motor combinations are important in determining the correct pump for the proper use.

- **Centrifugal pumps** are the most common types of pumps used in water wells today. Centrifugal pumps can be broken down to many categories.

- **Volute pumps** are centrifugal pump with no diffusion vanes. They normally has a single stage design and are used in a large-capacity low head application.

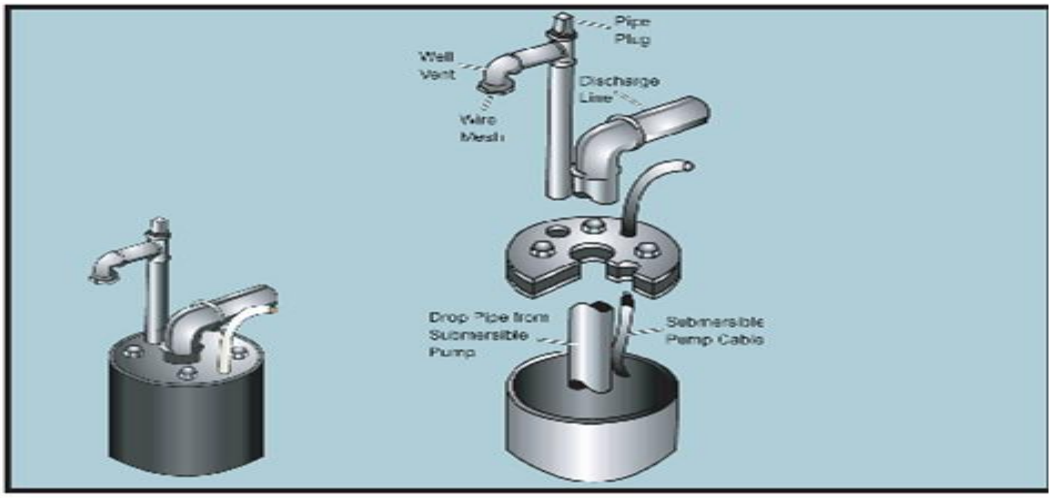
- **Turbine pumps** are most commonly used centrifugal pump for well operations. Turbine pumps have diffusion vanes which help move the water with gradually larger passages which helps lower the velocity of the water leaving the pump, which transforms velocity head to pressure head. Turbine pumps also have two types of deep well pumps. *Standard turbine deep well pumps* which has the motor on top of the well. This well has water lubricated type and oil lubricated. *Submersible deep well turbine pumps* which have the motor is under ground. Both are available in wide rang of flows from five to two thousand gpm.

There are numerous types of pumps that can be used in wells. A few others consist of jet pumps, piston pumps, and rotary pumps. All of these pumps can be used but have limited function for wells.

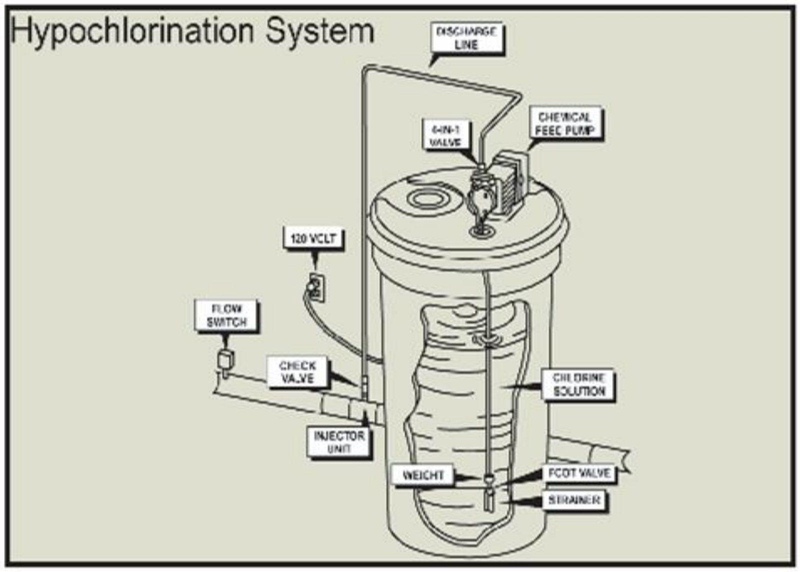


Parts of a deep-well turbine.

<u>Well components</u> are the fundamental parts that are necessary in a typical well.



1. **Sanitary Seal** prevents contamination of the well.
2. **Well Casing Vent** allows air to enter well during drawdown to prevent vacuum conditions and vents excess air during well recovery period.
3. **Sounding Tube** permits insertion of water level measuring device. It is also used to add chlorine or well cleaning agents.
4. **Solution Tank** is used to feed chemical solutions (ie. Chlorine, hypochlorite) with mixer to keep chemical in solution.
5. **Hypochlorinator** is a chemical feed pump which feeds solution into the water supply and must be electronically synchronized with well pump. Common problems with hypochlorinators are clogged lines and injectors. For systems with periods of no water usage, calcium carbonate will come out of solution and clog up the lines. If you have plenty of chlorine in your bucket and the feeder appears to be running, but there is no free or total chlorine in you water, check the lines and injectors to be sure they are not clogged. It is recommended to keep spare lines on hand. *Follow the manufacturer's recommendations for cleaning your chemical feeder.*



6. **Pressure Tanks** are sized to provide at least 30 minutes detention time at a given flow rate, equipped with a pressure switch that is electronically synchronized with well pumps. Drain for pressure relief and they may be mounted vertical or horizontally.

7. **Pressure Relief Valve** is a cross-connection device for relief of backpressure, located on the influent side of pressure tank.

8. **Check Valve** is used to reduce the water hammer and start-up head pressure, located on the effluent side of the pump.

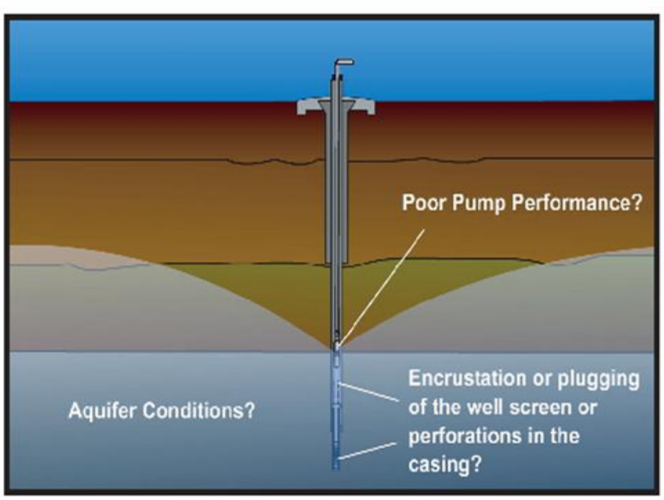
9. **Shutoff Valve** is used for isolation.

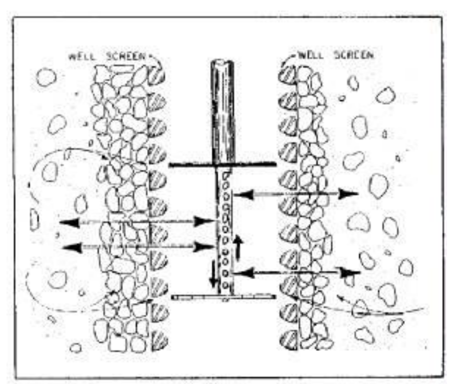
10. **Sampling Tap** is used for collecting water samples on raw and finished water.

11. **Flow Meters** are used for an accurate accounting of pumping volume and flow rate.

Well Operation and Maintenance

There are several reasons for poor performance from a well. Over pumping an aquifer can damage the well by reducing the storage and production of the well. Over pumping can also draw air into the well. Clogging or a collapse of well screen can also affect performance. A decrease in the capacity of a well is most likely from a clogging of the well screen. Corrosion will affect the performance of a well if not monitored or checked and maintained





SURGING ACTION WITHIN THE SCREEN

<u>Casing, screen cleaning and maintenance</u> is important to maintain the quantity and quality of water the well will produce.

<u>Surging</u> is a form of plunging and is mainly used on new well installations. This method can be used in conjunction with acid treatment. Good for cleaning the gravel pack around the well screen.

<u>High –Velocity Jetting</u> sprays water at a high velocity. This can be used as an effective form of backwashing, which can also be used with acid treatment while cleaning the screens of your well. Jetting can also used for re-opening the pores of aquifer and sand forms immediate in the vicinity of well screen.

<u>Acid treatment</u> is the most effective procedure to loosen incrustation so it may be removed from well casing and well lining. The most common acid's used are hydrochloric or sulfamic. Both of these acids easily dissolve calcium and magnesium carbonate. Between the two hydrochloric reacts much faster.

<u>Chlorine</u> treatment is very effective in loosening bacterial growth and slime deposits, which are normally found with a deposition of iron oxide. The method is like a version of shock treatment. A chlorine solution must be pumped in three to four times in order to reach every part of the well that may be affected.

<u>Polyphosphates</u> effectively disperse silts, clays, and the oxides of iron and mangense.

<u>Explosive Charges</u> are small explosive charges can be used to clean plugged well screens. *<u>Experts should be consulted before using this method.</u>*

<u>Recordkeeping</u> is the best possible action for a good maintenance program. Below is a list of items that should be included in your recordkeeping:

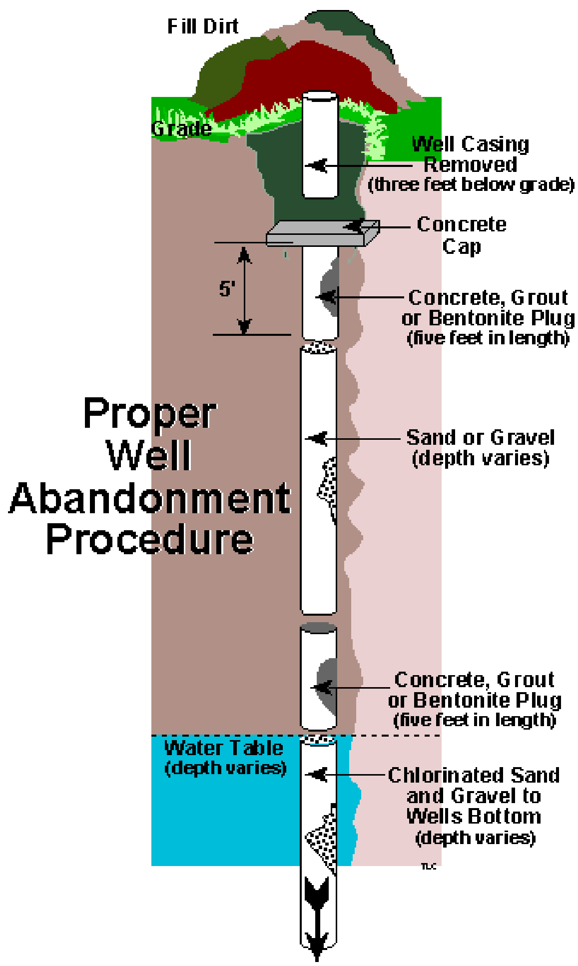
- ❑ Bench sheets
- ❑ MORs
- ❑ Daily pump volume
- ❑ Flow rate
- ❑ Water depth at start and end of pumping
- ❑ Chemical feed rate calibration and adjustment
- ❑ Maintenance schedule
- ❑ Personnel documents

You should complete a walk-through before start-up of the system. You should check the items listed below:

- ✓ Pump/Motor
- ✓ Solution tank/Feeder
- ✓ Valves
- ✓ Pressure Tank

Well Testing and Evaluation is extremely important when installing a new well. Several methods can be used when checking the quantity and quality of the pump: Bailing method, air blow method, variable rate method, constant rate method, and step-continuous method.

Abandoning and plugging wells must be done correctly to prevent contamination to aquifers.



Wellhead Protection Program

Effective wellhead protection programs require control of the sources of contaminants. This brings in land use planning and control of certain developmental activities on private and public lands. Control of land can be very difficult to achieve and requires the support of the public and public officials. Your community must be educated to understand the importance of this program to protect there water supply.

Kentucky's Wellhead Program

Wellhead Protection (WHP) is the prevention of groundwater contamination by management of potential contaminant sources within a designated area around a well or spring. The protected areas are called Wellhead Protection Areas (WHPA'S). The 1986 and 1996 amendments to the safe drinking water act of 1974, source water assessment and Protection Program (SWAP) requires that states adopt a Wellhead Protection Program (WHPP) to protect public water supply wells and springs from contamination. The EPA approved the Kentucky WHPP in September 1993.

Kentucky's Five-Step Program is outlined below.

Step 1: Forming a Planning Team

These teams, composed of representatives of the community, local government, business and industries, are responsible for developing local wellhead protection plans, implementing management strategies and assessing the future needs of the community or public water system (PWS). Each planning team is represented by a local planning team leader who acts as the contact person between the community or PWS and the state. A planning team might include:

- Public organizations such as community organizations, environmental groups, public interest groups, League of Women Voters, retired and senior volunteers.
- Regulatory organizations such as elected officials, local government agencies and public works director.
- Government/public service organizations such as fire departments, public water supplier, local cooperative extension agent and county Natural Resources Conservation Service.
- Private organizations such as business, industry, land developers and farmers.
- Citizens of the community.

Step 2: Delineating the Wellhead or Spring Protection Area

Determining appropriate Wellhead Protection Areas (WHPA) requires the collection of geologic and hydrogeologic data. Because of the technical nature of WHPA delineations, public water systems (PWSs) may need to contract private geologic and engineering firms to perform the necessary work.

The Groundwater Section provides technical assistance to nontransient/noncommunity and smaller community PWSs when requested. The local planning team can contact the Groundwater Section for assistance.

Step 3: Contaminant Source Inventory

Once WHPAs have been delineated, an inventory of potential contaminant sources must be completed for each area. The purpose of this inventory is to locate past, present and proposed activities that may pose a threat to the groundwater. A potential contaminant source may be any activity or substance which, under certain circumstances, may pose a contamination threat to groundwater. Once the potential contaminant sources have been compiled, they are ranked according to their risk to the water supply.

Management strategies should be developed (see Step 4) in accordance with the contaminant source inventory and the risks posed to the groundwater by contaminant sources.

Conducting a Contaminant Source Inventory includes:

- Preparing maps for recording inventory.
- Gathering existing data.
- Conducting field surveys for closing data gaps.
- Ranking potential contaminants.
- Preparing final contaminant source map.

Step 4: Managing Contaminant Sources

Implementation of reasonable and effective management plans within wellhead protection areas is a critical goal of wellhead protection requiring cooperation among federal, state and local governments and the public water systems.

Signage on transportation routes indicating entry into a Source Water Protection Area can be used as a management tool. The signs provide an emergency telephone number for reporting a spill. Spills on Kentucky transportation routes can be reported by dialing 911 or 1-800-928-2380.

The local planning team should adopt management strategies appropriate to the specific needs of the community, bearing in mind the contaminant source inventory prepared in Step 3. Public education and involvement are essential in developing and implementing an effective management plan.

Regulatory Strategies	Non-regulatory Strategies
Zoning	Public Education
Ordinances	Land Transfer and Voluntary Restrictions
Environmental Regulations	Signage

Step 5: Planning for the Future

Contingency planning is a vital aspect of a wellhead protection program. Even with careful planning, unforeseen contamination incidents can occur due to leaks, spills, accidental releases, illegal discharges and other activities in and around the wellhead protection area. A contingency plan helps ensure that the community is prepared to respond to emergency situations and can provide an alternate water supply if necessary.

For communities that rely on groundwater as a water source, wellhead protection should be a vital part of community planning. Development plans should be weighed against the risks to groundwater associated with future land use.

If more information is needed, please contact the Groundwater Section of the Watershed Management Branch or visit the Division of Water's groundwater website: http://water.ky.gov/groundwater/Pages/default.aspx.

Flow Rate

When dealing with wells and pumps we need to look at the rate of flow. The flow rate formula solves flow in cubic feet per second. In water treatment we deal with gpm when wanting our flow from wells. We must remember to use are conversions each time we do a math problem.

Q= A x V

The Crosman water plant is pumping water at 5 fps through a 6 inch pipe. What is the flow through the pipe in cuft/sec and gpm?

What are they asking for?   Flow
Is there a formula?   Yes, Q=A x V

Q= A x V
Q= (.785 x(6/12)x(6/12)) x 5fps
Q= (.785 x.5 x .5) x 5 fps
Q= .196 sqft x 5 fps
Q= .**98 cuft/sec**

One more step
.98 cuft/sec x 448.8 gpm = **439.8 gpm**

Chapter 3 Review

1. Name the three main factors in selecting well sites?
2. What type of well construction is the most effective?
3. What is the most common pump used in groundwater well?
4. What is placed on top of a well to prevent contamination?
5. Kentucky's well head protection program has how many steps?
6. What is the flow rate of a well pumping water at a rate of 4 fps in a 8 inch line?

Chapter 3 Answers

1. Adequate supply, Favorable quality, Minimal contamination potential
2. Drilled
3. Centrifugal
4. Sanitary seal
5. 5
6. 1.36 sec

Chapter 4: DISINFECTION

Chapter 4 Objectives

1. Explain the primary and secondary reasons for disinfection.
2. Differentiate, by describing the strengths and shortcomings, between the types of disinfection.
3. Understand the factors affecting disinfection.
4. Demonstrate competency with several disinfection calculations (lbs, ppm, residual, specific gravity, solution strength).
5. Explain how pipe disinfection and pathogens are removed from groundwater systems.
6. Describe what log removal is.
7. Describe why disinfection by products (DBP's) are formed throughout the treatment process.
8. Explain the regulations as they relate to disinfection.

Purpose of Disinfection

- To kill pathogens
- To provide a residual safeguard

Disinfection is the selective destruction or inactivation of pathogenic organisms. Water, as well as being the universal solvent, also provides a favorable environment for the growth of many biological organisms, some of which are capable of causing disease. The primary purpose of disinfection is to kill or inactivate pathogens in the water.

Pathogens are disease-causing organisms. Many of the largest disease outbreaks in history can be attributed to waterborne pathogens. Because of their propensity to kill large numbers of the population, these and all other pathogens should be controlled in the treatment process. In fact, the processes of coagulation, flocculation, sedimentation and filtration were developed to control pathogenic contamination in drinking water. Pathogens, which are found in either the forms of bacteria, viruses, or protozoa, are not "removed" by disinfection. Some are killed, some are temporarily inactivated, and some are not affected at all by chemical disinfectants or biocides. Because of this fact, it is mandatory to optimize our disinfection processes.

The secondary purpose of disinfection is to provide a residual safeguard. After regulatory standards are met at the treatment process, it will degrade as it moves through the distribution system. The degree of water quality degradation is affected by its chemical and biological composition, as well as the physical condition of the distribution system it travels through. Proper management, which includes flushing, cleaning, pressure maintenance, backflow prevention, monitoring and line replacement programs is necessary to prevent substantial water quality degradation in the distribution system.

We maintain disinfectant residuals to provide a safeguard against pathogenic contamination that could develop in the distribution system. The regulated **minimum disinfectant residual requirements** are **0.2 mg/l for chlorine** and **0.5 mg/l for chloramines**. The maximum residual disinfectant level **(MRDL)** allowable in a distribution system is **4.0 mg/l for chlorine and chloramine** and **0.8 mg/l for chlorine dioxide.**

Water quality degradation can be indirectly determined by calculating the disinfectant demand:

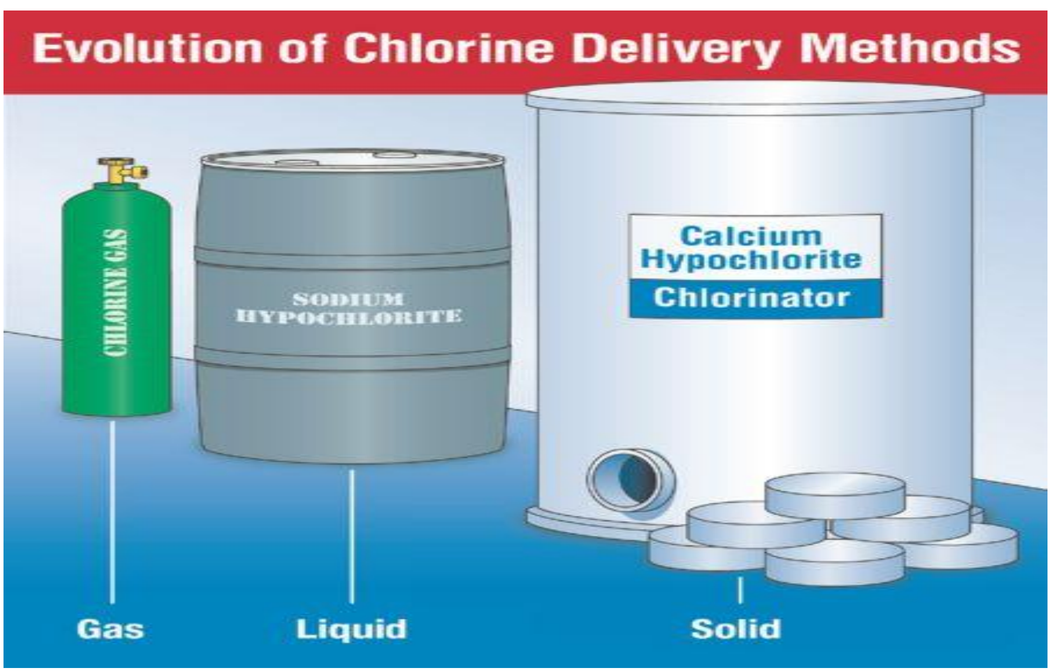
DEMAND = DOSAGE – RESIDUAL

When demand increases in the distribution system, the cause of this increase should be determined and rectified immediately. Increasing the disinfectant feed will only cover up any problems in the system, and it will make the development of halogenated disinfection by products (carcinogens) much more problematic. It can also lead to compromised corrosion control (lead, copper and other metal leaching; red or black water; leaks ;pressure issues), as well as increased operating costs.

Types of Disinfectants

Chlorine

Chlorine is the most widely used disinfectant. Chlorine is effective at pathogenic inactivation as well as providing a residual safeguard in the distribution system. Chlorine is also a viable oxidizer that allows for the precipitation of substances, including iron and manganese prior to settling or filtration. Chlorine volatizes gases, such as hydrogen sulfide, methane and benzene, and will also reduce organic related taste and odor and color causing compounds. When combined with organics for a significant length of time, the formation of trihalomethanes and haloacetic acids can be an issue. THM's and HAA5's are suspected to be carcinogenic, and their levels are federally regulated.



Chlorine Gas

Chlorine is 100 % available gas that is fed out of pressurized tanks or cylinders that actually contain both liquid and gas. The liquid-to-gas concentration is temperature-dependent with higher temperatures yielding a higher concentration of liquid. The atmospheric expansion ratio from liquid to gas is 460:1, and a fusible plug is placed in the bottom of the cylinders and designed to melt between 154º - 165º Fahrenheit in order to exhaust the chlorine as a gas. In the event of a leak on the bottom of a cylinder, it should be rolled over to prevent an escape of the liquid. Chlorine is greenish–yellow in color, and it is 2.5 times heavier than air. It is not flammable, but will readily support combustion. Chlorine gas is corrosive when combined with moisture and usually lowers the pH of water.

Whenever chlorine is fed at a rate of $\geq$ 40 lbs. a day in 150 lb. cylinders, two or more cylinders must be connected together to prevent freezing of the feed system. Though small leaks can be detected with a 10% ammonium hydroxide solution and will show up with the appearance of a white cloud, leak repair kits, as well as SCBA equipment, should be kept just outside of the chlorine room to allow for quick access. The chlorine feed system is contained in a separate room that opens to the outdoors. It must be designed with an exhaust fan and vent located near the floor that activates prior to entry and is capable of exchanging the atmosphere in the chlorine room within one minute. A window for visual inspection and a door equipped with panic hardware are also necessities pertinent to chlorine rooms. Evacuation and emergency plans, as well as up-to-date operator training, are essential for the safe operation of these rooms. Inhalation of chlorine gas can be fatal and repeated brief contact can permanently damage the lungs.

Calcium Hypochlorite

65 – 70 % available chlorine is manufactured as a powder as well as in granular form and a tablet. Calcium hypochlorite has a tendency to elevate the pH of water and is a weaker disinfectant than chlorine gas. It has a maximum shelf life of two years and degrades rapidly at that point, especially at higher temperatures. When in contact with oxidizers or organic compounds, a high flammability factor must be accounted for. Calcium hypochlorite should be stored in a clean, cool, dry areaway from other chemicals. It is used frequently used in distribution systems to disinfect new or repaired pipelines and storage facilities, as well in treatment facilities because of safety concerns about chlorine gas.

Sodium Hypochlorite

More commonly referred to as bleach, this is 5.25 – 12 % available chlorine. Just as with calcium hypochlorite, sodium hypochlorite has a tendency to raise the pH of water and is a weaker disinfectant than both chlorine gas and calcium hypochlorite. Just as with all chlorine products, an acid is produced when in contact with water and is corrosive. The shelf life of sodium hypochlorite is 60 – 90 days and higher concentrations degrade more rapidly, so greater volumes of weaker solutions should be fed. This “bleach” is used for distribution system disinfection, as well as a primary disinfectant in some treatment facilities. Sodium hypochlorite should be stored in a cool, dark location because heat, metals, and time will cause it to degrade.

Chloramines

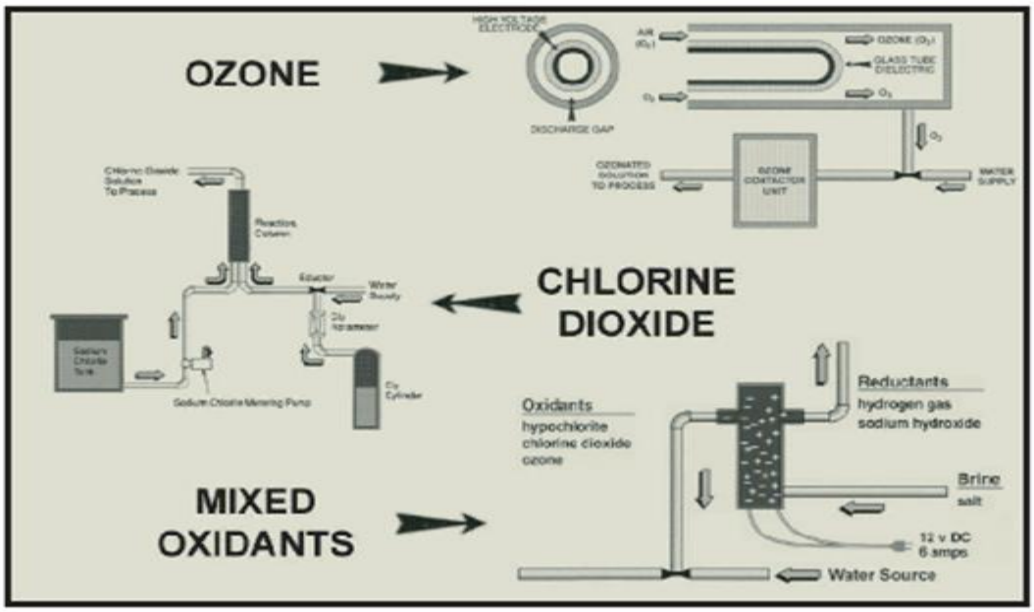
Chloramines are formed when water containing ammonia is chlorinated or when ammonia is added to water containing chlorine. It is an effective bactericide that produces fewer halogenated disinfection by – products, and it is generated on site. Chloramine is a weak disinfectant, and it is much less effective against viruses or protozoa than free chlorine. Chloramine lasts longer in a distribution system than chlorine, by some accounts up to 27 days. Used appropriately as a secondary disinfectant, it prevents bacterial regrowth in a distribution system.

Chlorine Dioxide

This is a pungent, reddish – yellow gas that is an effective disinfectant against waterborne microbes, including Cryptosporidium. It is an effective oxidizer with iron, sulfur compounds and certain taste and odor issues. It dissipates quickly as it reacts as it converts back to chlorine. Chlorine dioxide must be generated on – site and can be formed by combining gaseous chlorine with a 25% dosage of sodium chlorite. A stronger disinfectant than chlorine, it produces fewer halogenated by-products than does chlorine, but a major by-product is chlorite.

Ozone (Ozonation)

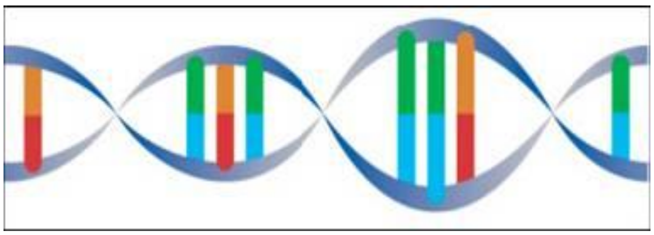
Ozone is formed when a third atom is added to an oxygen molecule. It is produced by passing oxygen through low amperage current. Ozone requires a much shorter contact time than chlorine and does not produce halogenated by-products unless the bromide ion is present. Ozone is a viable disinfectant against Giardia and Cryptosporidium. Ozone gas is unstable and does not maintain an adequate residual in water.

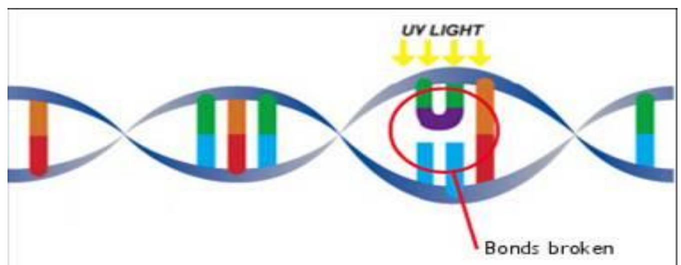


6.4 Figure 1: Alternative disinfectants

Ultraviolet Disinfection (UV)

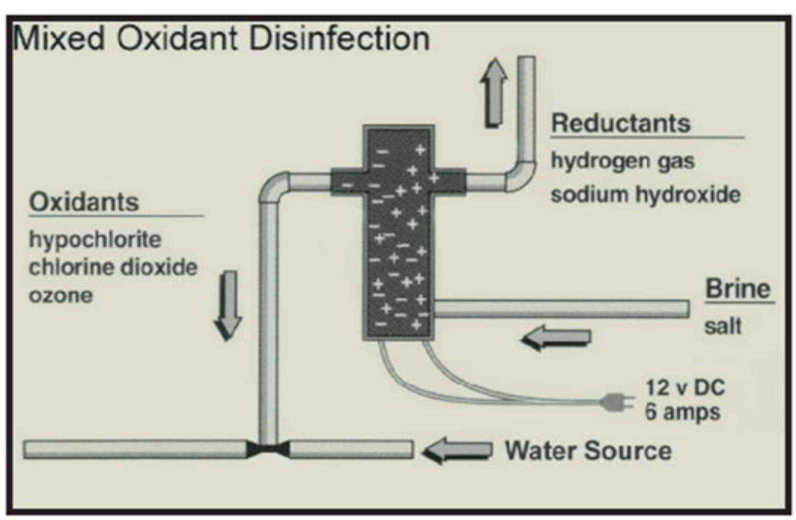
Ultraviolet radiation is generated by a special lamp that, if used correctly, penetrates the cell wall of an organism and disrupts the cell's genetic material and does not allow the cell to reproduce. UV produces no known toxic by-products and requires short contact times to accomplish its task. It does not provide a residual disinfectant.





MIOX (Mixed Oxidants)

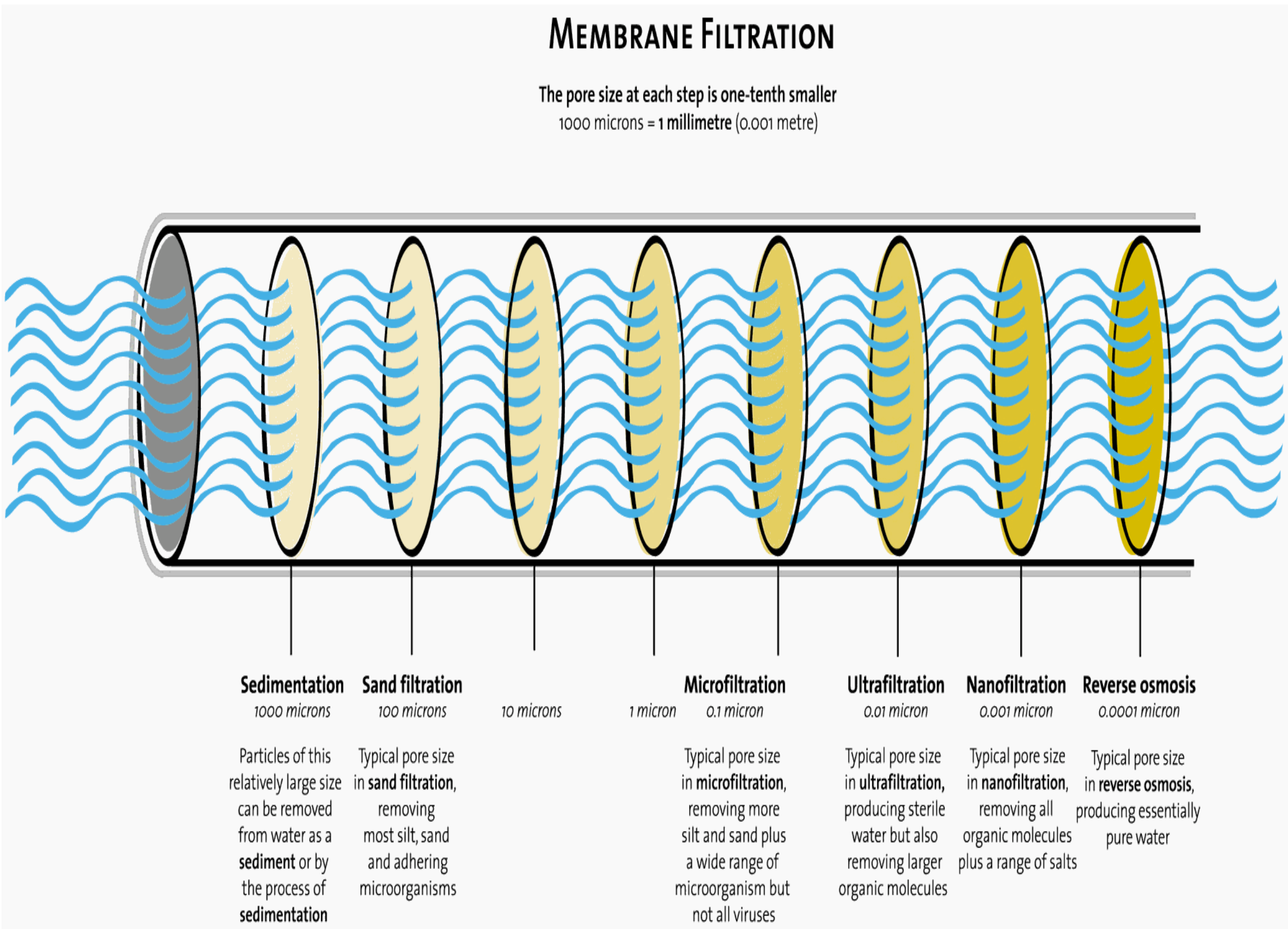
Miox is a dilute chlorine-based liquid disinfectant generated through electrolysis of salt water. It is a weaker, but safer, disinfectant than gaseous chlorine. In some instances, reduced DBP formations have been reported. It is gaining popularity in some facilities because of the cost and the ease of production of MIOX.



6.4.2 Figure 1: Mixed oxidant disinfection

Membranes

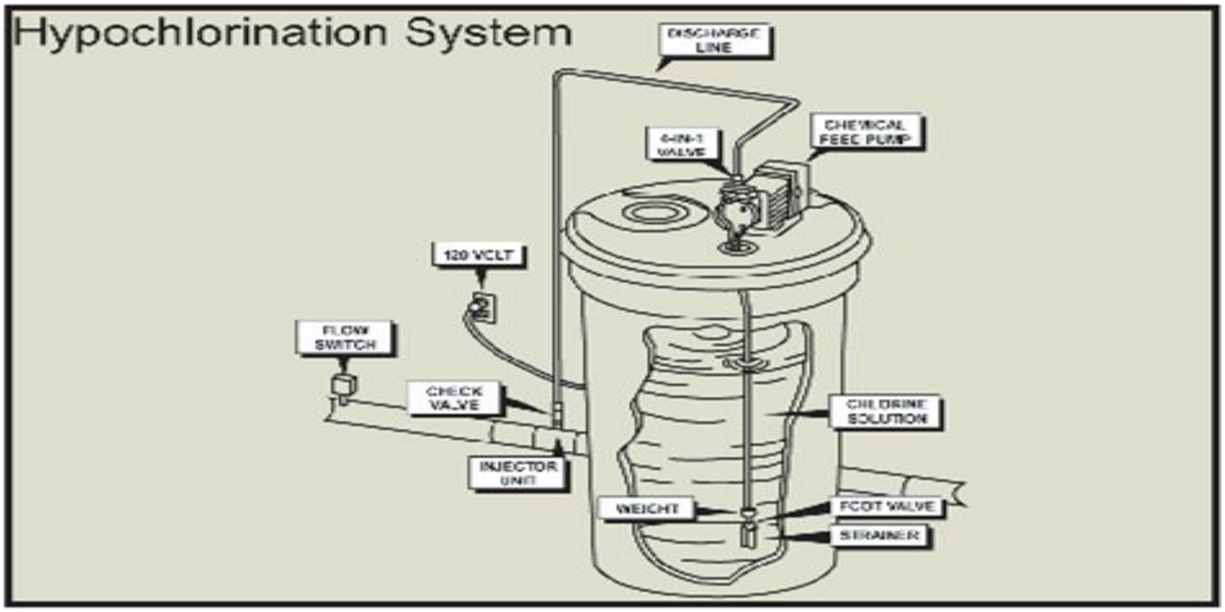
With today's society we are always looking to use fewer chemicals in our treatment process. Membranes are a way of achieving this, using membranes is a actual physical separation of what you want to take out of your water and what you want left over. Below are the four types of membranes and the level of removal of each.



Hypochlorination

The typical hypochlorination system consists of a chemical feed pump, a solution of sodium or calcium hypochlorite, and the appropriate electrical and flow control systems. Hypochlorination systems have become very reliable and safe, however proper techniques should be used in handling these materials to prevent injuries from splashes, spills, or inhaling fumes. This would include the use of protective clothing such as rubber gloves, face or eye shields, and an apron. Many small water systems have hypochlorination over chlorine gas due to safety concerns, as well as new regulations concerning safety, training, and environmental issues. Although hypochlorination systems are safer than gas, OSHA requires hypochlorites be listed in the Hazardous Materials inventory and written procedures for handling, using, and responding to spills.

Sodium hypochlorite provides the least handling hazard to the operator. It may be fed directly from the container that it is delivered in, or can be diluted in a solution tank if desired. It is available in concentrations from 5% to 15% but can lose effectiveness if stored



for periods in excess of 30 days. This chemical should be properly stored in a covered container, out of direct sunlight and away from the electrical control systems associated with the operation of the chemical feed pump.

Calcium hypochlorite is a powder with a chlorine concentration generally in the range of 65%. The powder is mixed with water and fed with the same type of chemical feed pump used for the sodium hypochlorite. Providing a consistent feed rate with calcium hypochlorite can be difficult due to the amount of inert material in this product that can clog chemical feed pump. To prevent chemical feed pump clogging, it may be better to mix the hypochlorite powder with water in one tank, and then transfer the well mixed solution to another tank where it would be pumped into the raw water. By using this approach, the operator could leave the undissolved inert material, which could cause clogging problems, in the bottom of the mixing tank and not exposed to the chemical feed pump. The calcium hypochlorite should be stored in a cool, dry environment. (EPA troubleshooting guide for small ground water systems 1999).

Troubleshooting Guide for Hypochlorination Problems		
Problem	**Possible Cause**	**Possible Solution**
Chemical feed pump won't run.	No power.	Check to see if plug is securely in place. Insure that there is power to the outlet and control systems.
	Electrical problem with signal from well pump or flow sensor.	Check pump motor starter. Bypass flow sensor to determine if pump will operate manually. If you have a liquid level control, check the low-level cut-off switch. Repair or replace if necessary.
	Motor failure.	If the motor is cool and the power is on, the motor may have to be repaired or replaced. Check manufacturer's information.
	Motor overheating.	The motor is over-heated. The overload protection in the motor has opened. The motor will start again when it cools. Make sure that you have a proper voltage supply. Try to turn the motor shaft. If it does not turn, check for a binding pump mechanism.
Motor runs but diaphragm doesn't move.	The stroke adjustment may be set at zero.	Reset stroke adjustment control knob.
	The gear train may be stripped.	Replace any defective parts.
Motor runs, diaphragm moves but no solution is pumped.	Solution tank may be empty.	Check the solution level in the tank. If it is too low refill the tank.
	The pump may not be primed.	If not, prime it.
	Suction line may have an air lock.	Check the suction line for air locks. If there is an air lock, remove the anti-siphon spring from the discharge valve until the air lock is removed.
	The fittings may be loose.	Remove the fittings, clean off the old tape, put on new teflon tape, and replace FINGER tight.
	Leaks from the pump housing.	If there is solution dripping from the pump housing just behind the pump head, replace the diaphragm.

*EPA troubleshooting Guide

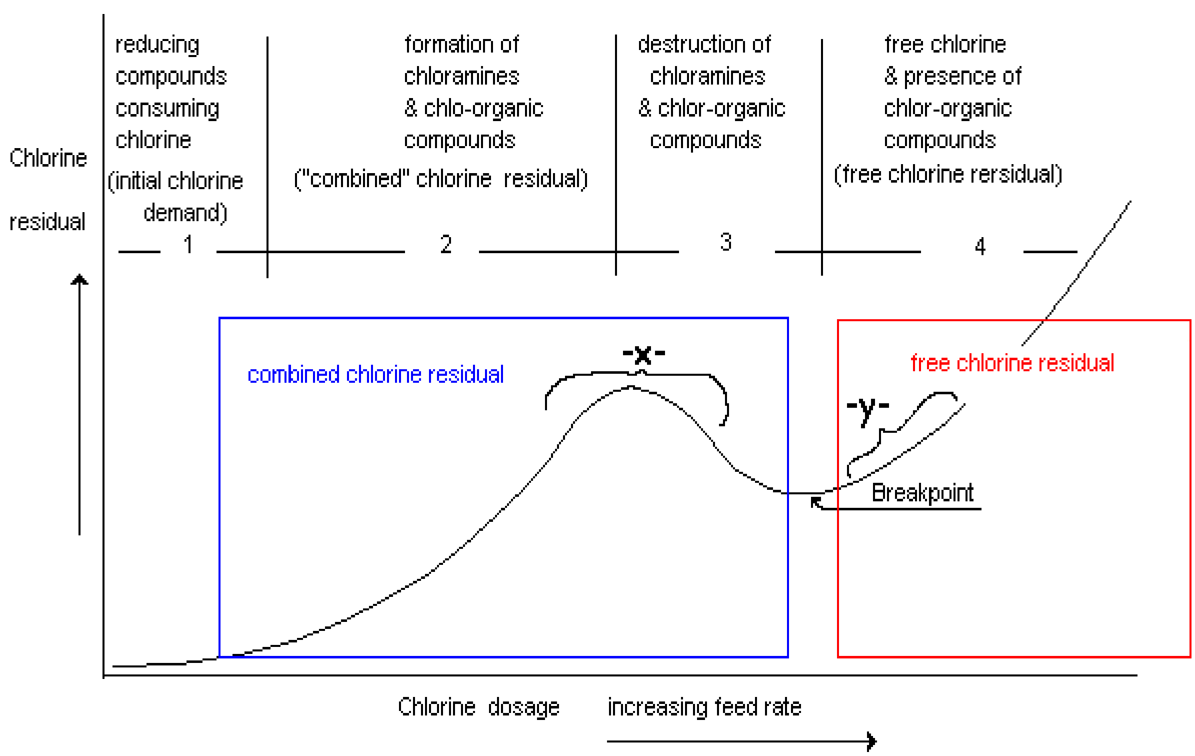
Factors that Affect the Disinfection Process

Dosage (Concentration of Disinfectant)

The more disinfectant added to the water, the more effective the disinfectant process is if all other factors are equal. If longer contact times are used, similar results can be achieved with reduced dosages. If shorter contact times are used, greater dosages are required.

Contact Time

The longer the contact time, the more effective the disinfection process will be. The disinfectant must physically come in contact with the pathogens or contaminants that we desire to disrupt. So the longer the disinfectant is allowed to react with the water, the more effective it will be as a disinfectant. Inadequate contact between chlorine and water will not allow breakpoint chlorination to occur, which will greatly reduce the viability of the disinfection process and the control of pathogens.



Interfering Substances

Chlorine disinfectants must physically contact the pathogens they react with so turbidity and other substances can provide a barrier or shield that may protect the pathogen from effectual disinfection. Some substances are actually food sources for pathogens.

Temperature

The warmer the water, the faster the chemical reactions take place. In the warmer months when the water is warmer, breakpoint chlorination can be more quickly achieved. But, because the dissipation of chlorine is driven by chemical reaction, free residuals will be harder to maintain in the summer months as opposed to the winter months.

When chlorine is added to water, the following chemical reactions take place.

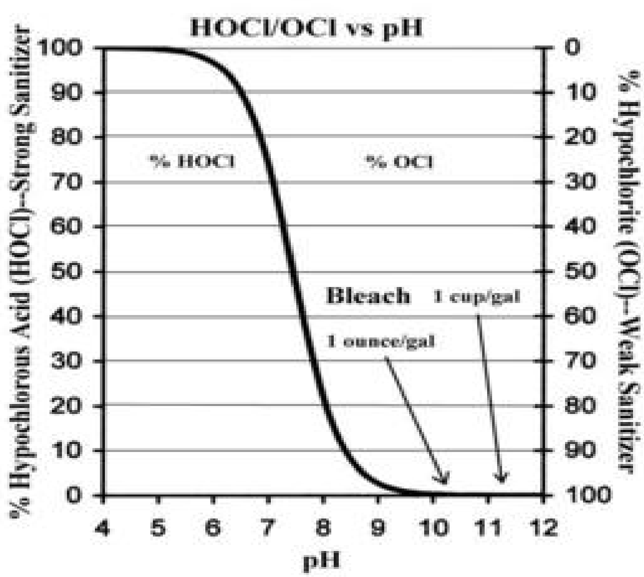
Cl2 + H2O --- HOCl + HCl

(Chlorine + water ---- *Hypochlorous Acid* + Hydrochloric Acid)

HOCL == H+ + OCl

(*Hypochlorous Acid* == Hydrogen Ion + *Hypochlorite Ion*)

The Hypochlorous Acid and the Hypochlorite Ion are the compounds that inactivate or kill pathogens. Hypochlorous Acid is 100 X more effective than the Hypochlorite Ion. Both occur simultaneously in water with the concentrations of each compound being pH dependent.



Point of Application

The more thorough the mixing process, the quicker the chemical reaction will take place and the less contact time needed for effective disinfection. If we apply all of the chlorine in one end of a long pipeline before filling it with water, then when we do fill up the pipe with water all of the disinfectant will wash toward the other end of the pipeline. Adding a proportional amount to each pipe joint just before slowly filling the pipeline will provide a more thorough and effective means of disinfection.

Disinfection Monitoring & Control

Disinfection Feed and Dosage Determination

The amount of disinfectant applied to the water is dependent upon the **demand** and the desired amount of **residual** to be carried into the distribution system. The total of **demand** + **residual** makes up the **dosage** required. Breakpoint chlorination should be practiced at all times to ensure that all demand is met and a free residual is established after adequate contact time.

If using the *slug method* of disinfection, the operator will add an arbitrary amount of disinfectant and then mathematically determine if sufficient amounts of the disinfectant were added to achieve correct dosage requirements. For this type of application, the following formula is used:

$$\text{ppm (or mg/l)} = \frac{\text{lbs. of chemical x \% purity}}{8.34 \text{ x MG}}$$

Although the slug method works, it wastes chemical and therefore, money. A more feasible method is to first determine what dosage is required and then calculate the amount of chemical needed to obtain the desired results. The *continuous flow method*, which feeds the correct dosage of chemical into a flow of water, uses the following formula:

$$\text{lbs of chemical/day} = \frac{\text{ppm (mg/l) X 8.34 X MGD}}{\text{\% purity}}$$

When disinfecting a volume of water (no flow condition), such as when using the *spray or swab method*, the formula used would be:

$$\text{lbs of chemical} = \frac{\text{ppm (mg/l) X 8.34 X MG}}{\text{\% purity}}$$

When mixing a chlorine solution using calcium or sodium hypochlorite, the following formula can be used to determine the strength of solution:

$$\text{strength of solution} = \frac{\text{lbs of chlorine}}{\text{lbs of solution}}$$

To express the strength of solution as a percentage of chlorine in the solution, one would multiply the strength of solution by 100. The strength of solution can be multiplied by the pounds of solution fed to determine the pounds of chlorine fed. The pounds of solution fed can be determined by multiplying the gallons of solution fed by 8.34 (lbs).

For example, if 5 gallons of bleach (5.25% available) is mixed with 45 gallons of water to produce 50 gallons of solution, the strength of solution would be calculated as follows:

$$\frac{\text{5 gal. of bleach X 8.34 lbs/gal X .0525}}{\text{50 gal. of solution X 8.34 lbs/gal}} = \frac{\text{2.189 lbs of chlorine}}{\text{417 lbs of solution}} = .005$$

.005 is the decimal equivalent of .5% (.005 X 100)

If 40 gallons of the solution was fed: 40 gal X 0.005 = 0.2 lbs of chlorine fed

If the chemical being mixed into the solution is a liquid, then the final weight must be multiplied by the specific gravity of the liquid chemical to get the actual weight of the chemical being fed. This is because not all liquids weigh the same as water (8.34 lbs/gal).

If the 0.2 lbs of chlorine were fed into 5,000 gallons of water, the dosage could be calculated as follows:

$$\text{DOSAGE (ppm or mg/l)} = \frac{\text{0.2 lbs of chlorine}}{\text{8.34 X .005 MG}} = \text{4.79 or 4.8 ppm (mg/l)}$$

.

Pipeline Disinfection

Operators should ensure that proper disinfection methods are followed to provide the maximum public health protection when installing and repairing pipelines that are intended for potable water service.

Inspection

Pipes and fittings should be examined for any damage with particular attention to joints. Any damage to the pipe ends or gaskets may result in leakage. The pipe sections should be clean and free of blemishes on the interior. Before placing a pipe in the trench it should be thoroughly inspected for contamination.

Sanitary Construction Methods

Sanitary procedures should be adopted whenever work is to be done to a pipeline. It may seem unnecessary or time prohibitive to perform these sanitary practices, but experience has shown that the steps actually save time because they reduce the bacteriological test failure rates.

Keeping Pipes Clean and Dry

Keeping the pipe clean during installation is the single most important factor that results in successful disinfection. The interior of pipes must be protected during installation. Openings should be sealed with watertight plugs or coverings when the construction is halted and personnel are not present to ensure that contamination does not enter the pipe.

401 KAR 8:150 *(Only the portion related to disinfection of treatment and distribution system facilities is included. The full regulation can be located at www.lrc.ky.gov)*

Section 4. Disinfection of Treatment and Distribution System Facilities, New and Repaired Water Lines.

(1) New construction projects and line extensions.

(a) Disinfection. A water treatment plant or distribution system, including storage distribution tanks, or extensions to existing systems, shall be thoroughly disinfected before being placed in service.

(b) A water distribution system shall disinfect with chlorine or chlorine compounds in amounts that shall produce a concentration of at least fifty (50) ppm and a residual of at least twenty-five (25) ppm at the end of twenty-four (24) hours, and the disinfection shall be followed by a thorough flushing.

(c) Other methods and testing procedures that provide an equivalent level of protection may be used if the cabinet grants prior written approval in accordance with 40 C.F.R. 141.21.

(d) A new water distribution line shall not be placed into service until bacteriological samples taken at the points specified in paragraph (f) of this subsection are examined and are shown to be negative following disinfection.

(e) A water treatment plant or distribution system shall submit to the cabinet results of bacteriological samples for each new construction project, replacement, or extension to existing systems, after the disinfection and flushing.

(f) A sample shall be taken in the newly constructed line at each of the following points:

1. Within 1,200 feet downstream of each connection point between the existing and new lines;

2. One (1) mile intervals; and

3. Each dead end, without omitting any branch.

(g) A new or routine replacement line shall not be placed in service until negative laboratory results are obtained on the bacteriological analyses.

(h) Sample bottles shall be clearly identified as "special" construction tests, and the results submitted to the cabinet shall be clearly marked as "special" samples.

(i)1. Notification of analytical results shall be submitted to the cabinet with the routine monthly compliance bacteriological samples, unless the bacteriological samples are to be used to lift a boil water advisory.

If using tablets of calcium hypochlorite, be sure to use food-grade glue when attaching them to pipes. Attach the tablets to the top of the pipe so the disinfectant can disperse throughout the pipe when it is filled.

Log Removal

When discussing log removal think about a nine. Each log removed is a nine. So a two log removal would be 99% removal, a three log would be 99.9%, and a four log removal would be 99.99%.

Disinfection Byproducts

DBP's are formed when disinfectants used in water treatment and distribution reacts with natural organic matter (NOM).

The reason DBP's are regulated are because of there ability to increase your chances of getting certain cancers. No matter how clean your water is once it leaves your facilities once the water is stored with any organics DBP's will be formed.

DBP's for which regulations have been established include:

- trihalomethanes (THM)
- haloacetic acids (HAA5)
- bromate
- chlorite

Chapter 4 Review

1. Getz water system disinfects their water at 2.5 ppm sodium hypochlorite. Through tests, they have determined that the chlorine demand in Getz is 1.0ppm. What is Getz's disinfectant residual?

2. Petticoat Junction has determined that the chlorine demand in their system is 1.1 mg/l. At the far reaches of their distribution system, the chlorine residual is 0.8 mg/l. What is Petticoat Junction's chlorine dosage?

3. Barkerville treats their water with a 5.25 % available solution of sodium hypochlorite at a rate of 2.0 ppm. The treatment facility treats 2.5 MGD and their distribution system contains four elevated storage facilities. Barkerville has 528 miles of distribution piping and has discovered that the residual at the far reaches of their system is 0.4 ppm. What is Barkerville's chlorine demand?

4. How many pounds of 70 % available calcium hypochlorite would be needed to treat 720,000 gallons at a rate of 500 gpm to the desired dosage of 2.1 mg/l?

5. Would the regulations be met if we dosed a new 10" PVC waterline that is 7,500 feet in length if we glued in 10 (ten) 1 lb. (65% available) HTH tablets?

6. How many gallons of 9% available sodium hypochlorite will be needed to treat 90,000 gallons of water and obtain a dosage of 3.1 mg/l? The sodium hypochlorite has a specific gravity of 1.4.

7. If we add 2 gallons of bleach with a specific gravity of 1.5 to 200 gallons of water, what would be the percent strength of this solution?

8. The second shift treatment operator in Mt. Airy used 8.5 lbs. of chlorine during his 8-hour shift. Mt Airy treats 4.5 MGD. What dosage did the second shift operator obtain during his shift?

9. If Hooterville doses its water at the treatment facility with 12.5 pounds of gaseous chlorine and the residual in the distribution system is 0.8 mg/l. What would the demand be if they treat 1 MGD?

10. If the concentration of the disinfectant is decreased then the ________ must be increased.

11. The strongest disinfectant for potable water disinfection is _______.

12. If your disinfectant residual is at least ___% of the total chlorine, then breakpoint has been achieved.

13. The most common system for disinfecting groundwater is?

Chapter 4 Review Answers

1. ppm (dosage) – 1.0 ppm (demand) = 1.5 ppm residual

2. 1.1 ppm (demand) + 0.8 ppm (residual) = 1.9 ppm (mg/L) dosage

3. 2.0 ppm (dosage) – 0.4 ppm (residual) = 1.6 ppm (mg/L) demand

4. $\text{lbs} = \frac{\text{ppm X 8.34 X MG}}{\text{\% purity}}$ $\quad \text{lbs} = \frac{\text{2.1 ppm X 8.34 X .72MG}}{\text{.70 purity}}$ $\quad \text{lbs} = \frac{\text{12.61 lbs}}{\text{.70}} = 18$

5. The answer is NO.

   $\text{ppm} = \frac{\text{lbs of chemicals}}{\text{8.34 X MG}}$ $\quad \text{ppm} = \frac{\text{10 lbs of chemical}}{\text{8.34 X (.785 X .83 X .83 X 7500 ft X 7.48 gal)}}$

   $\text{ppm} = \frac{\text{10 lbs of HTH}}{\text{8.34 X .03 MG}} \text{ x .65}$ $\quad \text{ppm} = \frac{\text{6.5 lbs}}{\text{.25}}$ $\quad \text{ppm} = 26.00$

6. $\text{lbs} = \frac{\text{ppm X 8.34 X MG}}{\text{\% purity}}$ $\quad \text{lbs} = \frac{\text{3.1 ppm X 8.34 X 0.09 MG}}{\text{0.09}}$ $\quad \text{lbs} = \frac{2.33}{0.09}$ $\quad \text{lbs} = 25.9$

   gallons = 25.9 lbs ÷ 11.7 lbs/gal (8.34 lbs X 1.4 SG)   gallons = 2.2

7. $\text{SOS} = \frac{\text{lbs of chemical}}{\text{lbs of solution}}$ $\quad \text{SOS} = \frac{\text{25 lbs of chemical}}{\text{1693 lbs of solution}}$ $\quad$ SOS = 0.014 SOS = 1.4%

8. ppm = lbs of chemical ÷ (8.34 X MG)   ppm = 8.5 ÷ (8.34 X 1.5 MG)   ppm = .68

9. $\text{ppm} = \frac{\text{lbs of chemical}}{\text{8.34 X 1 MG}}$ $\quad \text{ppm} = \frac{\text{12.5 lbs}}{\text{8.34}}$ $\quad$ ppm = 1.5 (1.4988) dosage

   1.5 ppm (dosage) – 0.8 ppm (residual) = 0.7 ppm DEMAND

10. Contact time
11. Ozone
12. 85
13. Hypochlorination

Chapter 5: BACTERIOLOGICAL SAMPLING

Chapter 5 Objectives

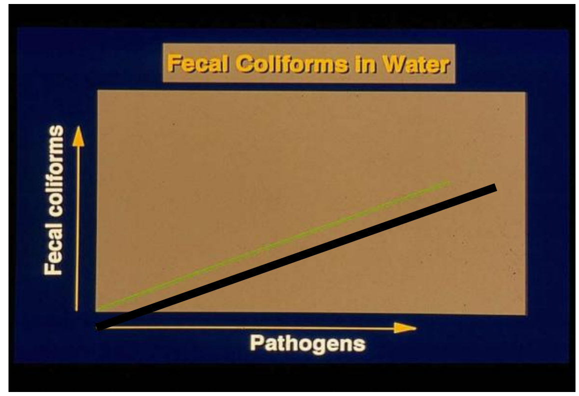
1. Explain the purpose and requirements of sampling.
2. Describe the affect between pathogens and coliforms.
3. Demonstrate the process of sample collection.
4. Describe the importance of representative sampling, check samples and hold time parameters associated with sampling.
5. Describe the methods of analysis.
6. Explain chain of custody along with recordkeeping and differentiate between compliance and special sampling.

Purpose of Bacteriological Monitoring

Bacteriological analysis is used for the detection of pathogens in potable water. Pathogens are disease-causing organisms.

Coliforms, found in the intestinal tract of warm-blooded animals, are used as indicator organisms. They are easy to grow and identify and the presence/absence tests are relatively

inexpensive. If coliforms are present, there is a great likelihood that pathogens are also present.



Fecal or E. coli contamination dictates a regulatory mandated boil water and public notice.

Sample Requirements

All systems require a minimum of 2 samples. The size of the population served determines the required number of samples.

- If < 40 samples taken, all must be negative for compliance.
- If > 40 samples taken, may have 5 % positive without a violation.

Collection

Collect at least 100 milliliters of water in a sterile container. Sample bottles contain sodium thiosulfate that is used to dechlorinate the sample. Compliance samples should NOT be collected from fire hydrants, water fountains, hoses or taps with swivel faucets. Do NOT use leaky faucets or faucets that sputter or do not have a steady flow. Allow the water to run in a pencil-sized stream for 2 – 3 minutes or until temperature is constant. *THE MAJORITY OF SAMPLER ERROR IS THE RESULT OF POOR SAMPLING TECHNIQUE.*

Representative Sampling

Samples should represent the quality of the water throughout the entire system. A negative sample only means that at the time the sample was taken at the location from which it was taken, the water was satisfactory.

Do NOT avoid suspected areas of poor water quality dead ends and low-use areas. Update sampling plans as the distribution system extends or recedes and include residential, commercial, industrial and educational sites.

Check Sampling

Within 24 hours of a positive sample notification, a system must collect 3 check samples: 1 from the original sample location and 1 within 5 service connections upstream and one within 5 service connections downstream.

Check samples are still considered compliance samples. If the system collects fewer than 5 samples a month for compliance, the month after a check sample incident the system MUST submit 5 compliance samples.

Special samples (line extensions, new lines, line breaks, etc) do NOT count toward compliance. BARF's (bacteriological analysis report forms) must still be submitted with special samples even though they are NOT counted toward compliance.

Methods

Multiple Tube Fermentation	ColiBlue 24
Membrane Filtration	Colitag
MMO – MUG Most Probable Number	Colilert 18
MI agar	Colilert
Coliscan	Fluorocult
ONPG-MUG	Colisure

Recordkeeping

Always fill out Chain of Custody documents for samples. BARF's do NOT take the place of a Chain of Custody document. Bacteriological records must be maintained for 5 years.

Sample labels, Chain of Custody documents and BARF's should include the following:

- ✓ Collection date and time
- ✓ Type of disinfection
- ✓ Location code
- ✓ Name, address and PWSID
- ✓ Chlorine residual
- ✓ Signature of sampler

Chapter 5 Review

1. What temperature should the sample achieve?

2. Check samples must number ___ samples and be performed within ___ hours of a positive sample notification.

3. The number of samples taken is dependent upon ____.

4. _____ can be used in place of a compliance sample if minimum residual levels are not satisfied.

5. What needs to be on a chain of custody?
   a. PWSID
   b. Samplers name
   c. Where the sample was taken
   d. All of the above

Answers for Chapter 5 Review

1. The temperature of the water in the main.

2. 3, 24

3. Population

4. HPC's

5. d

Chapter 6: SPECIALIZED TREATMENT

Chapter 6 Objectives

1. Identify all types of specialized treatment (Iron & Manganese, Taste and Odor, Water Softening, etc).
2. Explain the effects of corrosion in the groundwater system (how it happens, how to detect it, and how to stop it).
3. Calculate the LSI pH.

Groundwater requires specialized treatment in order to remove particular contaminates. Below is a description of these contaminants and the most common treatment methods.

Iron and Manganese Control

Iron and manganese in their soluble form, are colorless in water. They react with dissolved oxygen or chemical oxidizers in water to form insoluble compounds. These insoluble compounds give water a **red** or **black** color causing many customers complaints. Higher concentrations are generally associated with deep groundwater wells.

Significance

Iron and manganese can cause staining of laundry and plumbing fixtures, discoloration of water (rust to black), turbidity formation, food source for iron reducing bacteria. Crenthriex and iron reducing bacteria can form thick slime layers on the walls of pipe causing a restriction to flow. When this slime breaks away rust colored water (iron) and/or black particulates (manganese) develop. Iron reducing bacteria can also cause taste and odor as a by-product of their reproduction. Chlorine can control the growth of iron bacteria.

Treatment

There are several ways to treat for Iron & Manganese. Below is a list of the most common with pros and cons.

Chlorination

Chlorine can be added to treat and remove Iron & Manganese. The proper dosage or reaction time is very important, if you dose too little you will not treat the iron & manganese. If you overdose, this creates more DBP's, which you will have to deal with later in the water system.

Polyphosphates

The phosphates chemically tie up the iron & manganese in water by giving them more soluble properties, which delays the oxidation reaction. This is only effective with levels of iron < 1.0 mg/l and manganese <0.3 mg/l. Chemical addition must be added before chlorination.

This treatment is relatively inexpensive and effective if lacking retention. Phosphates do not eliminate the problem, they just disguise it.

Oxidation

The introduction of oxygen atoms, which chemically converts soluble iron and manganese compounds to insoluble compounds. Dissolved oxygen or chemical oxidants may be used to complete the chemical reaction. A retention period and then sedimentation and/or filtration to remove the precipitates must follow process. Higher pH and temperatures reduce retention time period.

Oxidation by Aeration

This brings air and water into physical contact with one another. A higher pH results in a faster reaction; effective manganese precipitation requires a pH>10. No chemicals are required. In addition, this process is expensive to operate. The reaction is too slow for effective manganese and has reduced effectiveness in colder temperatures.

Oxidation with Chlorine

Chlorine, a very strong oxidant, will precipitate Fe and Mn. A higher chlorine residual results in a faster reaction. Superchlorination (5-10 ppm) followed by dechlorination allows quicker precipitation and lesser retention time requirement. This process is effective, inexpensive, and no additional treatment process is needed. This process requires retention time and filters to capture precipitate.

Oxidation with Potassium Permanganate

A strong oxidant, potassium permanganate works like chlorine. An exact dosage is required. Too little results in no precipitation; too much results in a carry over of pink color.

Oxidation with Greensand Filtration

Simultaneously oxidizes and filters out iron and manganese. Greensand requires periodic regeneration with potassium permanganate. Permanganate is generally fed prior to the Greensand filter to aid in oxidation and to provide continuous regeneration. This is an effective alternative to chlorine when high chlorine dosages are a concern. However, it must be carefully monitored to match dosage with demand.

Ion Exchange

This utilizes a filterbed of sulfonated polystyrene resins that remove iron and manganese on contact. To be effective, the water must not contain any dissolved oxygen. DO causes fouling of the exchange resins with iron and manganese precipitates. Groundwater generally has no DO except that which is created when the well pump kicks on. Ion exchange is effective, operates unattended, and no retention or filtration is needed. However, it has a high initial cost, and the regeneration of fouled resins is expensive.

Taste and Odor Control

Water with taste and odor problems must be handled on a case by case basis. Some of the methods for removal of taste an odor include **aeration** which is very effective for the removal of volatile gases like Hydrogen sulfide, and methane gas. Another method includes Oxidation with chlorine or potassium permanganate.

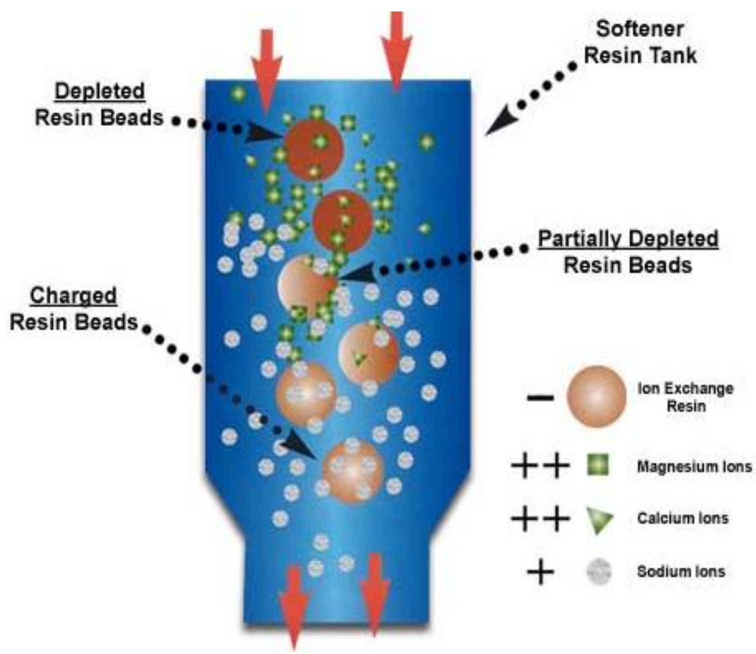
Water Softening

Hard water results from excessive amounts of Calcium and Magnesium. Hardness concentrations are generally greater in groundwater sources.

Significance

Hard water reduces effectiveness of soaps, forms scale (calcium carbonate) on basins, fixtures, dishes, etc; reduces the carrying capacity of pipes, reduces the efficiency of hot water heaters and boiler systems, affects (favorable or unfavorably) many manufacturing processes.

Treatment



Ion Exchange (Zeolite Softening)- exchanges sodium ions (present on the exchange media) with calcium and magnesium ions (in the water). When the ion exchange resins become saturated with calcium and magnesium ions, a brine solution is passed across the resins allowing sodium ions to once again exchange places with the calcium and magnesium ions that were removed during the softening stage.

The zeolite-softened water is very corrosive and will probably need to be blended with unsoftened water to obtain a water with a desired hardness level. A desirable hardness level is 80-90 mg/l as CA CO_3. If the water has a high iron content, fouling of the media will occur and backwashing, regeneration, and possibly media replacement will be necessary.

Lime/Soda Ash Softening- requires a basin to settle out the calcium and magnesium precipitates that chemically form with the addition of lime and/or soda ash. Generally not used in groundwater systems.

Total Dissolved Solids (TDS)

The removal of inorganic minerals or salts such as calcium, sodium, etc., and is generally used for the treatment of brackish waters or high quality waters used in various industrial processes.

Significance

Water high in dissolved solids is highly scale forming, exhibits a highly mineralized taste, or is simply non-potable due to its salinity.

Treatment

Ion exchange, reverse osmosis, electrodialysis, distillation, and freezing.

Fluoride

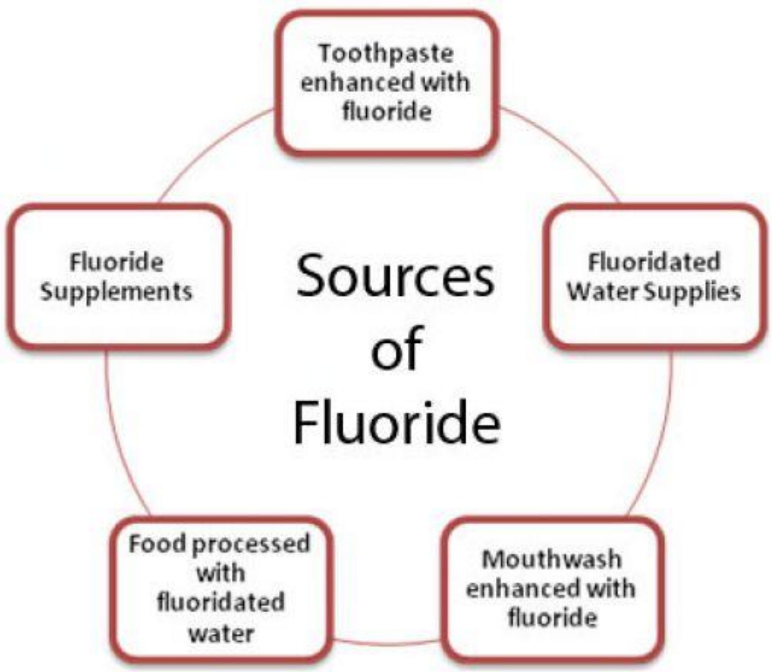
Significance

Fluoride is fed into water as a mineral supplement to aid in the development of strong bones and teeth, particularly in children. Some fluoride ion may be present in source waters and treatment plants add supplemental fluoride to bring the level up to a healthy range. In Kentucky, small well systems are not required to feed fluoride into their treated water supply, but if they voluntarily choose to do so, the State Health Department will supply the system with the necessary equipment and direction necessary to feed it.

Fluoride has both primary and secondary MCLs. The primary MCL (health related) is **4.0 mg/l**. At this level, bones and teeth could become degenerated. The secondary MCL (aesthetic concern) is **2.0 mg/l.** At this level teeth can become discolored. Both MCLs are based on a particular quantify of water consumed over a long time period. The recommended feed level is generally about 1.0 mg/l, however, actual levels are based upon what health officials believe to be the average consumption for a particular population.

Treatment

Fluoride is a corrosive chemical that is manufactured as either a liquid or powder. It is mixed with water to provide a solution and then fed through a liquid chemical metering pump. It is important to know the percent of fluoride ion present in the chemical so that solution strengths can be accurately mixed and fed. Common fluoride chemicals include: hydrofluosilicic acid, sodium silicofluoride, sodium fluoride, and silica fluoride. Because it is an acid, careful storage and handling concerns need to be addressed.



Corrosion Control

Purpose

- Prevent the effects of corrosion or excessive scaling in the distribution system.

Associated Problems

Public Health

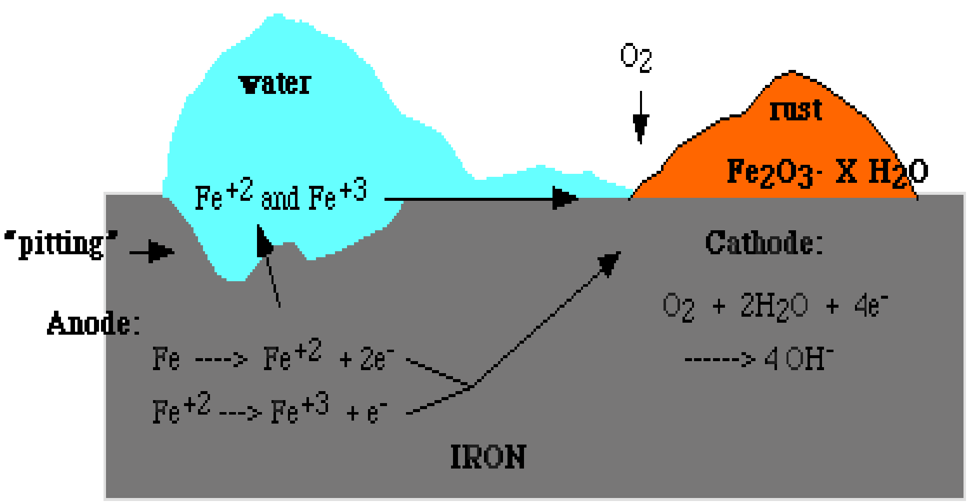
- ✓ Leaching of metals (lead, copper, cadmium, zinc, arsenic, etc.)
- ✓ Shielding of pathogens from disinfection
- ✓ Backflow from pressure loss due to leaks
- ✓ Destruction of fittings, pipelines, etc.

Economic

- ✓ Corrosion costs $37,000,000,000 annually (estimated cost of corrosion in U.S.)
- ✓ Reduced pressure and carrying capacity due to increased friction on pipe walls and reduced inner diameters
- ✓ Higher energy costs because of the necessity of increased pumpage
- ✓ Increased energy costs for boilers and hot water heaters
- ✓ Increased maintenance costs associated with leaks
- ✓ Regulatory compliance

Water Quality and Aesthetics

- ✓ Increases in complaints for color, taste and odor, staining of laundry fixtures
- ✓ Increased turbidity
- ✓ Regulatory compliance



Factors Affecting Corrosion

pH

- Lower pH values increase the rate of corrosion
- Higher pH values promote the precipitation of calcium carbonate (scale), which can offer protection against corrosion

Alkalinity

- Carbonate and bicarbonate forms will form a protective scale coating that can reduce the rate of corrosion

- Helps control pH changes (buffering agent)

Hardness
- Calcium hardness may precipitate as calcium carbonate ($CaCO^3$) to reduce corrosion rate.
- Soft water is extremely corrosive

Dissolved Oxygen
- High levels of DO increases the rate of corrosion

Total Dissolved Solids (TDS)
- High TDS levels increase the conductivity of the water and in turn can accelerate the rate of corrosion

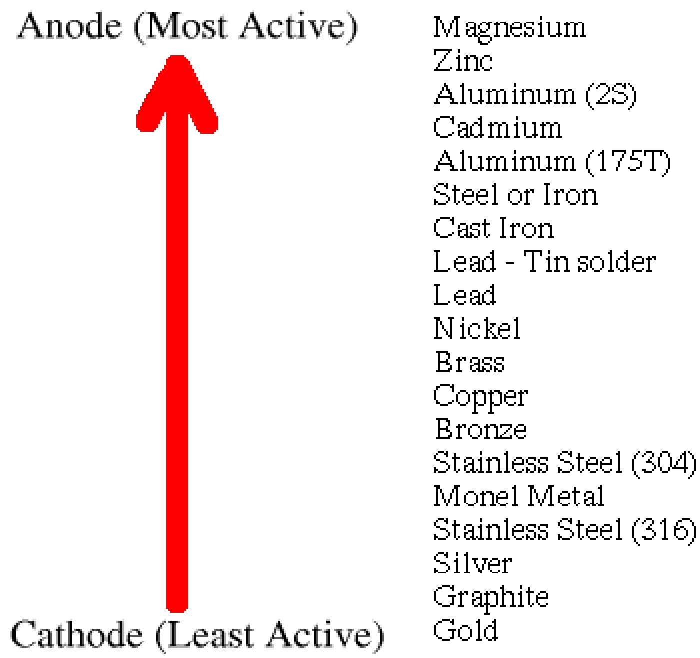
Temperature
- Higher temperatures speed chemical reactions and thereby corrosion rates

Chlorine Residual
- Increases metallic corrosion

Biological Activity
- This can increase or decrease the rate of corrosion dependent upon the type of organism and/or the degree of its activity.

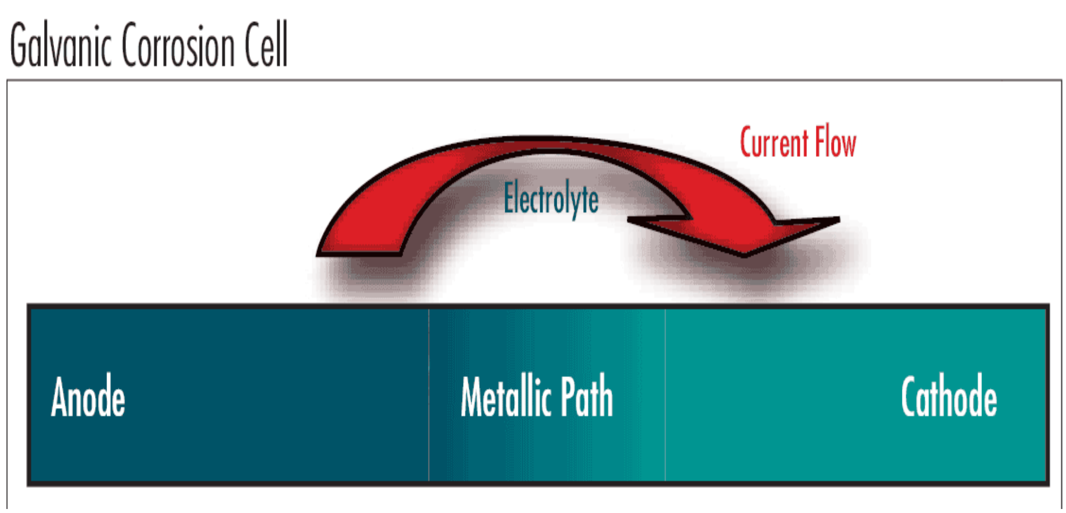
Hydrogen Sulfide, Chloride, Sulfate, Electrical Current
- All of these increase the rate of corrosion.

Dissimilar Metals, Cathodic/Anodic Rate
- Have an effect on the rate of corrosion



Galvanic Corrosion

Galvanic corrosion involves the direct current electricity that is electrochemically generated between dissimilar metals. The further apart metals are on the galvanic series (chart on previous page), the faster the rate of corrosion. For instance, copper and lead would not react together as much as zinc and silver.

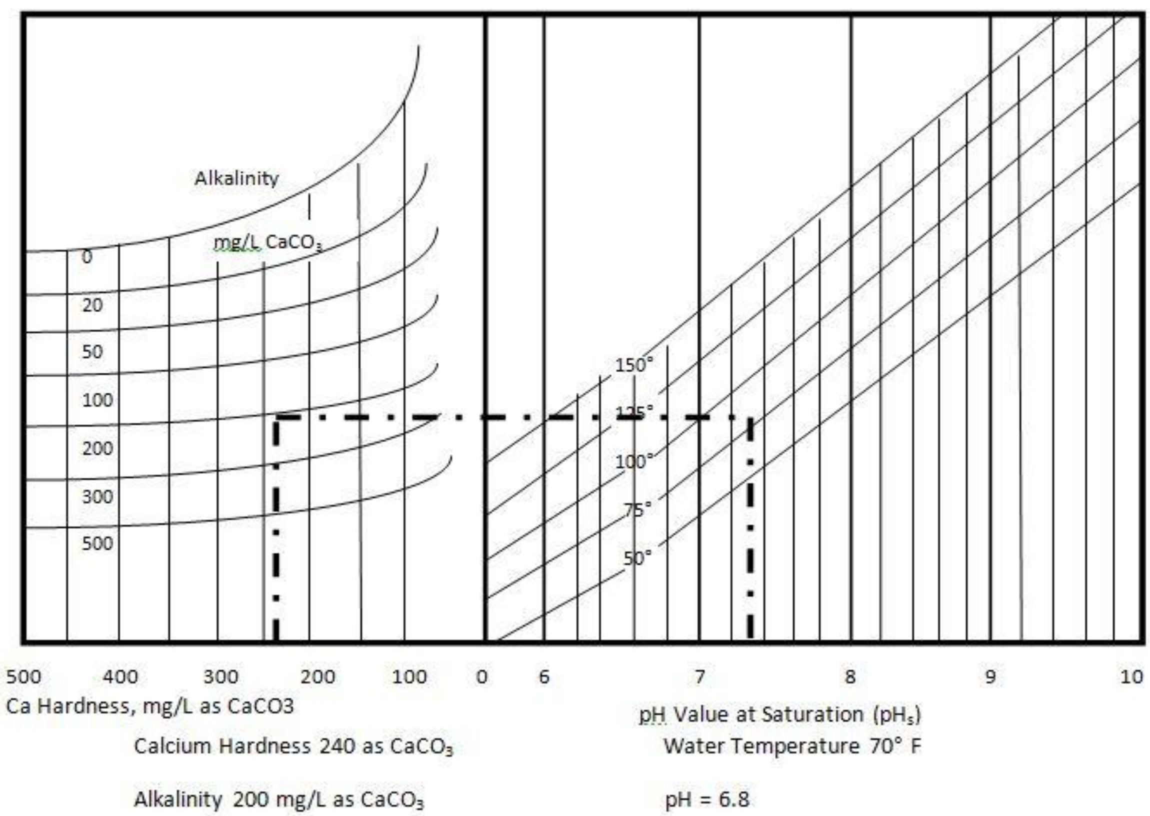


Methods to Determine the Corrosivity of Water

- Coupon testing, distribution and plumbing material inspection.
- Water quality and consumer complaint record evaluation.
- Line change out program.
- Regular flushing and cleaning.

Langeliers Saturation Index

An example of the Langeliers Saturation Index:



Example

- Find the point marking calcium hardness of 240 mg/L as shown (bottom axis of graph between 200-300)
- Draw a line straight up to the 240 mg/L alkalinity curve.
- Draw a line from the 200 mg/L alkalinity curve across the graph to the point indicating a temperature of 70° F. (between the 50 and 75 diagonal lines)
- Draw a line straight down from the temperature point to the bottom of the graph, intersecting the line marked "pH Value"
- Identify the pH value (point at which your line intersects the pH line)
- In the above example, the pH value is 7.3

Calcium hardness	240 mg/L
Water temperature	70º F
Alkalinity	200 mg/L
Actual pH (pHA)	6.8
Saturation pH (pHS)	7.3
pHA	6.8
pHS	7.3 - 0.5

This water has the likelihood of being corrosive.

Three Basic Approaches to Corrosion Control:

1. Modify the water chemistry so that it is less corrosive to pipes and tanks.
2. Place a protective barrier or lining at the interface of the water and metal.
3. Use materials and design system so it is not corroded by a given water.

Common Ways of Achieving Corrosion Control:

1. Properly select system materials and system design
2. Modify water chemistry
3. Use corrosion inhibitors – ortho and polyphosphates.
4. Provide cathodic protection – sacrificial anodes, etc.
5. Use corrosion-resistant linings, coatings, paints, etc.

Chapter 6 Review

1. _____________ is an electrochemical process that can cause leaching and other health related problems.

2. _______________ is added to water to aid in the development of strong bones?

3. You water has a LSI of -0.7 is this water corrosive of scaling forming?

4. ___________ corrosion is the placement of dissimilar metals in contact with each other.

Chapter 6 Review Answers

1. Corrosion
2. Fluoride
3. Corrosive
4. Galvanic

Chapter 7: STORAGE

Chapter 7 Objectives

1. Identify the purpose of storage as it relates to quality and quantity.
2. Describe the three types of storage and associated design features.
3. Identify features located on storage tanks.
4. Understand the operation and maintenance issues associated with storage tanks.
5. Identify the regulations for storage tanks.
6. Explain the operational issues with storage.
7. Explain why excessive water age is the most important factor related to water quality deterioration.
8. Calculate two and three dimensional math computations related to area and volume of wells and groundwater systems.

Traditionally, finished water storage facilities have been designed to equalize water demands, reduce pressure fluctuations in the distribution system and provide reserves for fire fighting, power outages and other emergencies. Some storage facilities have been operated to provide adequate pressure and have been kept full in order to be prepared for emergency conditions. Additionally, some storage facilities have been designed such that the high water level is below thehydraulic grade line of the system, making water turnover extremely difficult. If the hydraulic grade line of the system drops significantly, very old water may enter the system. If tanks are kept full yet are underutilized, the stored water ages and water quality is frequently compromised.

Purpose of Storage: To meet all consumer demands

Storage Quantity: Ensure an adequate supply for fire protection, peak usage periods, distribution maintenance, plant shutdown, major leaks, pressure maintenance, or any other consumer needs.

Quality: Provide pathogen-free water that is also free from inorganic precipitates, biological activity, corrosion byproducts, taste, odor, color, turbidity, disinfection-by-products and any other factor that is detrimental to the health or aesthetic properties of the water.

Under-storage: limits the ability to get the necessary quantity of water to the consumer when needed. Can allow pressure drops during peak usage if sufficient quantities aren't maintained.

Over-storage: can lead to water quality degradation due to the water age or lack of turnover.

Ideally, the operator needs to maintain the minimal amount of water necessary to meet demand on a daily basis in order to prevent water quality degradation and residual chlorine depletion due to a lack of turnover.

Types of Storage

Underground
Ground level
Elevated storage

Design Features

Storage tanks should be:

- ✓ Covered to prevent contamination
- ✓ Vented to relieve vacuum conditions
- ✓ Screened to prevent entry of birds, rodents, etc.
- ✓ Screened and flappered overflows that extend to or below ground level and be directed away from the tank foundation, businesses, homes, etc.
- ✓ Protected against corrosion and its by-products.
- ✓ Built and maintained to ensure structural integrity

Operation and Maintenance

Inspection: coatings (paint), security, safety, corrosion protection, stratification, vents, overflows, telemetry, valve operation, etc. Inspection can be accomplished by draining the facility, diving, remote sensing or float down.

Monitoring: total coliform, disinfectant residuals, pH, temperature, DBP's, bacteria concentration (heterotrophic or standard plate counts), corrosion, scale, nitrification (especially in systems using chloramines), taste, odor, iron, manganese, turbidity, gases, etc.

Cleaning and Disinfection: Draining and cleaning of tanks should be performed when necessary and should be considered on an annual basis. Painting and coatings should be evaluated at least every five to ten years.

Storage Tank Disinfection

Kentucky Administrative Regulations concerning Disinfection of New and Repaired Water Lines:

(1) New Construction Projects and Line Extensions

(a) Disinfection of water lines. A water distribution system, including storage distribution tanks, or all extensions to existing systems, shall be thoroughly disinfected before being placed in service.

(b) A water distribution system shall disinfect with chlorine or chlorine compounds, in amounts as to produce a concentration of at least fifty (50) ppm and a residual of at least twenty-five (25) ppm at the end of twenty-four (24) hours, and the disinfection shall be followed by a thorough flushing.

(c) Other methods and testing procedures that provide an equivalent level of protection may be used if the cabinet grants prior written approval.

(401KAR 8:150, SECTION 4)

Continuous Method

1. Drain and clean tank.
2. As tank is refilling, inject chlorine into the flow to produce 50 ppm.
3. Hold for 24 hours and then measure the free residual (must be > 25 ppm).
4. Drain and dechlorinate the chlorinated water in the tank.
5. Refill with treated water and measure total coliforms and chlorine residual.
6. Return to service *
7. Record and maintain records for a minimum of five (5) years.

Spray/Swab Method

1. Drain and clean tank
2. Fill tank with a measured volume (i.e. 1 ft deep)
3. Dose pre-measured volume at 250 ppm
4. Swab or spray interior walls and ceiling with the chlorine solution.
5. Repeat process no sooner than 1 hour later
6. Allow an additional 30 minutes contact time
7. Drain and dechlorinate the chlorinated water
8. Refill with treated water and measure total coliforms and chlorine residual
9. Return to service *
10. Record and maintain records for a minimum of five years after fulfilling bacteriological sample requirements

** If a new installation is involved, the continuous method must be used and negative coliform results must be obtained before being placed into service.*

Operational Issues

- ✓ Calibrate and maintain the accuracy of the telemetry and valving systems.
- ✓ Drawdown tanks as far as feasible before refilling so water turnover is achieved.
- ✓ Design the tank with a smaller diameter riser to increase velocity and increase mixing.
- ✓ Contemplate retrofitting older designs with separate inlets and outlets to induce water circulation and mixing.

Water Age

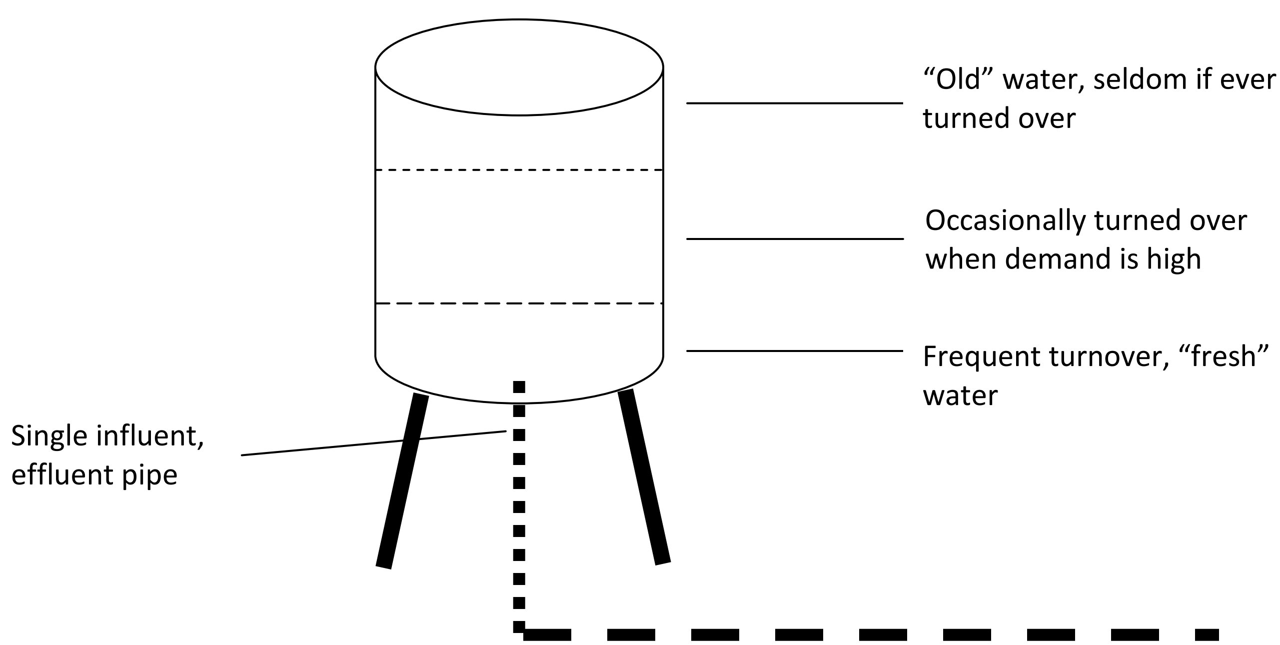
Traditionally many water storage facilities were built with a common inlet and outlet. Water quality problems associated with water storage can be classified as chemical, microbiological or physical.

Excessive water age is probably the most important factor related to water quality deterioration. Long detention times can be conducive to microbial growth and chemical changes. Excessive water age is usually caused by 1) under utilization and 2) short circuiting within the storage facility. Poor mixing (including stratification) can make water quality problems worse by creating zones within the water storage facility where the water age significantly exceeds the average water age throughout your system.

Summary of Water Quality Problems Associated with Finished Water Storage Facilities

CHEMICAL ISSUES	BIOLOGICAL ISSUES	PHYSICAL ISSUES
Disinfectant Decay	Microbial Regrowth*	Corrosion
Chemical Contaminants*	Nitrification*	Temperature/Stratification
DBP Formation*	Pathogen Contamination*	Sediment*
Taste and Odors	Taste and Odors	

** Water quality issues with direct potential health impact*



Guidelines on Water Turnover Rate

SOURCE	GUIDELINE	COMMENTS
Georgia Environmental Protection Division	Daily turnover goal equals 50% of storage facility volume; minimum desired turnover equals 30% of storage facility volume.	As part of this project, state regulators were interviewed by telephone.
Virginia Dept of Health, Water Supply Engineering Division, Richmond, Va	Complete turnover recommended every 72 hours	As part of this project, state regulators were interviewed by telephone.
Ohio EPA	Required daily turnover of 20%; recommended daily turnover of 25%	Code of state regulations; turnover should occur in one continuous period rather than periodic water level drops throughout the day
Baur and Eisenbart 1988	Maximum 5-7 day turnover	German source, cement based internal surface
Braid 1994	50% reduction of water depth during a 24-hour cycle	Scottish source
Houlmann 1992	Maximum 1-3 day turnover	Swiss source

Information taken from Kirmeyer et al. 1999

Summary

- Microbiological, chemical, and physical water quality problems can occur in finished water facilities due to poor mixing or under – utilization.
- Poor mixing can result from poor design and/or operational practices.
- Health-related water quality issues associated with water age or lack of water turnover:
    - DBP formation
    - Nitrification
    - Pathogen contamination
    - Increases VOC/SOC concentrations
    - Loss of disinfectant residua

Troubleshooting Guide for Storage Facilities		
Problem	**Possible Cause**	**Possible Solution**
Growth of algae or other biological organisms.	Exposure to sunlight. Loss of chlorine residual. Long detention time. Sediment or biofilm build-up.	Cover open reservoirs. Check seals on hatches and screens on vents. Install bird wires and fences if necessary. Improve influent water quality. Flush distribution system. Clean and disinfect storage tank.
Contaminant entry.	Uncovered reservoirs or improper design of floating cover. Damaged or missing screens on vents and entry of bats, birds, rodents, or insects. Cross-connection at drain or overflow.	Cover open reservoirs. Check seals on hatches and screens on vents. Install bird wires and fences if necessary. Flush distribution system. Clean and disinfect storage tank.
Increase in pH.	Long detention time in concrete storage.	Provide coating on concrete walls. Increase turnover rate. Fluctuate water levels more frequently.
Biodegradation of internal coatings.	Loss of chlorine residual allowing biological growth. Selection of wrong internal coating.	Prevent loss of chlorine residual. Chlorinate. Clean and disinfect storage tank.
Biofilm growth.	Loss of chlorine residual. Nutrients from coatings or contaminants. Corrosion of surface promoting biological and algae growth. Bacterial seeding.	Prevent loss of chlorine residual. Chlorinate. Clean and disinfect storage tank. Flush distribution system.
Color.	Decaying vegetative material. Algae growth in uncovered reservoirs. Sediment scouring. Iron or manganese.	Improve source water quality. Install treatment for iron and manganese. Increase cleaning frequency.
Red water.	Metals uptake from metal surfaces from lack of or improper cathodic protection. Iron or manganese.	Provide proper corrosion treatment. Install or calibrate cathodic protection. Use sequestering agent. Apply coatings properly.
Build-up of iron and manganese.	Iron and manganese in source water and long detention times. Oxidation and settling of iron or manganese. Improper sequestering agent dose.	Improve source water quality. Install or optimize sequestering system. Increase cleaning frequency.

Area and Volume

Area: a two-dimensional measurement (length X width). Area is a measurement of the amount of space on the surface on an object. Since the square is the basis by which these measurements are made, the units used to express this surface space are in square feet (ft^2).

feet X feet = square feet (ft^2)

Volume: a three-dimensional measurement (length X width X height). Volume is used to measure the holding capacity of an object. The basis of measuring this capacity is the cube expressed as cubic feet (ft^3).

feet X feet X feet = cubic feet (ft^3)

OBJECT	AREA(ft^2)	VOLUME (ft^3)
Rectangle	Length' × Width'	Length' × Width' × Height'
Circle	.785 × D' × D'	
Triangle	½ (Base' × Altitude')	
Cylinder		.785 × D' × D' × Length'
Sphere		.5236 × D' × D' × D'
Diameter (D) = 2 × radius	Circumference = 3.14 × D	Perimeter = Sum of the Sides

Volume Examples

1. The cross-sectional area of a 12 inch pipe is _________?

   $.785 \times 1\ ft \times 1\ ft = .785\ ft^2$

2. The volume of a standpipe that is 20 feet in diameter and 60 feet in height is ______?

   $.785 \times 20ft \times 20ft \times 60\ ft = 18{,}840\ ft^3$

Conversions

In our industry, we don't usually use measurements in cubic feet. In order to convert cubic feet to gallons, we multiply the number of cubic feet by 7.48 gallons. To use the previous problem as an example we would multiply 18, 840 ft^3 by 7.48 gallons.

Multiply (x) if going from left to right	
1 psi	= 2.31 ft. of head
1 ft. of head	= .433 psi
1 cu ft of water	= 7.48 gallons
1 cu ft of water	= 62.4 lbs.
1 gallon	= 8.34 lbs.
1 gallon	= 3,785 ml
1 Liter	= 1,000 ml
1 Liter	= 1,000 grams
1 mg/L	= 8.34 lbs/MG
1 ppm	= 1 mg/L
1 ml	= 1 gram
1 pound	= 453.6 grams
1 pound	= 7,000 grains
1 kilogram	= 1,000 grams
1 cu ft/sec	= 448.8 gpm
1 MGD	= 1.55 cu ft/sec
1 MGD	= 694.5 gpm
1 HP	= 33,000 ft lbs/min
1 HP	= .746 kilowatt
1 mile	= 5,280 feet
Divide (÷) if going from right to left	

18,840 ft^3 X 7.48 gallons = 140,923.2 gallons

The key to using the conversion portion of the formula sheet (above) is to find the two entities you need to solve the problem and then decide whether to multiply or divide.

Conversion Examples

If you are given cuft/sec (ft^3/sec) and you need gallons per minute (gpm), there is only one line under the conversions header that gives you both forms of measurement you need. What you know is on the left side and what you don't know is on the right side, so you would multiply to obtain the answer.

1. Convert 15 cuft/sec to gpm → *15 cuft/sec X 448.8 gpm = 6732 gpm*

If you are given gpm and need to convert them to MGD there is only one line that has both gpm and MGD. What we are given is on the right side and what we need to know is on the left so we would divide.

2. Convert 2500 gpm to MGD → *2500 gpm/694.5 gpm = 3.599 or 3.6 MGD*

STORAGE-RELATED MATH PROBLEMS

1. Calculate the volume of water in a completely filled standpipe that has a diameter of 50 feet and a height of 100 feet.

   a) _______________ cubic feet
   b) _______________ gallons
   c) _______________ MG

2. The Poughkeepsie distribution system has the following:
   Two 350,000-gallon elevated storage tanks
   A 1.3 MG reservoir
   One standpipe that measures 25 feet in diameter and is 70 feet tall.

   What is the storage capacity of the Poughkeepsie system?

   a) ______________ cubic feet
   b) ______________ gallons
   c) ______________ MG

3. A standpipe that is 75 feet in diameter is equipped with a sight glass that is used to monitor the level in the tank. When the tank is full, the water is 60 feet. What is the volume in this tank when the sight glass reads 25 feet?

   a) ______________ cubic feet
   b) _______________ gallons
   c) _______________ MG

4. The community of Stop Gap has a population of 2,700 and an average daily usage of 90 gallons per day per person. What is the average demand for this community?

   a) _______________ gallons/day
   b) _______________ gpm
   c) _______________ MGD

ANSWERS:

1.	***a)***	**196,250 ft^3**	***2.***	***a)***	**301, 723 ft^3**	***3.***	***a)***	**110,390.62 ft^3**	***4.***	***a)***	**243,000 gallons**
	b)	**1,467,950 gallons**		***b)***	**2,256,888 gallons**		***b)***	**825,721.33 gallons**		***b)***	**168.75 gpm**
	c)	**1.47 MG**		***c)***	**2.26 MG**		***c)***	**.825 or .83 MG**		***c)***	**.24 MG**

Chapter 7 Review

1. Chemical reactions occur more quickly in ______ water.

2. Tank ______is an important consideration in reducing water age.

3. A lack of water turnover causes a rapid depletion of ______ residuals.

4. A storage facility should turn the water completely over every ______ hours.

5. Every time a tank is taken out of service for repair or cleaning, it must be disinfected at a dosage of ______ ppm, held for ______ hours and maintain a residual of ______ ppm.

6. Monkeys Eyebrow's 4800 residents use on average 190,000 gallons of water a day. What would the average daily water demand per resident be for the month of June?

    a. 40 gallons
    b. 175 gallons
    c. 1187.5 gallons
    d. 467.6 gallons

Answers for Chapter 7 Review

1. Warmer
2. Turnover
3. Chlorine
4. 72
5. 50, 24, 25
6. a

Chapter 8: PIPES AND SERVICES

Chapter 8 Objectives

1. Differentiate between the different types of pipes and the variables to consider when selecting pipe.
2. Describe the importance of detailed management plans and distribution system maps as they relate to operational concerns and pipe installation.
3. Differentiate between the types of distribution systems (tree, loop, grid and dead end lines) and describe the pros and cons of each type.
4. Describe the process of pipe installation and how it affects pressure.
5. Describe the process of pipe disinfection and repair as it relates to pressure and leak testing.
6. Demonstrate the sanitary practices related to pipe repair.
7. Differentiate between repair and rehabilitation options of water distribution pipes (e.g. pipe busting, slip lining and pigging).
8. Explain the regulations and tests associated with improving water quality.
9. Calculate area and volume.

Types of Pipe and Their Uses

- Pipe material selection along with the appropriate size should match the intended use of the pipe.

Some variables to consider when selecting the correct pipe are:

- Flow requirements
- Pressure requirements
- Corrosive characteristics
- Ease of locating
- Strength
- Effective life span – durability
- Ease of repairs

MATERIAL PROPERTY	DI	PVC	HDPE
Tensile Strength	60,000 psi	7,000 psi	3,200 psi
Compressive strength	48,000 psi	9,000 psi	1,600 psi
Yield strength	42,000 psi	14,500 psi	5,000 psi
Ring bending stress	48,000 psi	None specified	None specified
Impact strength	17.5 ft-lbs/in	0.75 ft-lbs/in	3.5 ft-lbs/in
Density	441 lbs/ft³	88.6 lbs/ft³	59.6 lbs/ft³
Modulus of elasticity	24,000,000 psi	400,000 psi	111,000 psi
Temperature range	< 150º F	< 140º F	-50 to 140º F under pressure
Thermal expansion	0.07" per 10º F per 100'	.33" per 10ºF per 100'	1" per 10ºF per 100'
Corrosion resistance (int)	Good-w/cement lining	Excellent	Excellent
Corrosion resistance (ext)	Good- w/polywrap	Excellent	Excellent
UV resistance	Excellent	Gradual strength decline	Yes – w/carbon black
Abrasion resistance	Excellent	Good	Good
Cyclic resistance	Excellent	Fair	Good
Permeation resistance	Yes	No-solvents & petroleum	No – solvents & petroleum
Scale & growth resistance	Good	Excellent	Excellent

Planning

Detailed plans of the project should be prepared by the project engineer in conjunction with input of the distribution operators. Planning for future growth and development will save money in the future. These plans should include grade, depth, alignment and soil type specifications. Plans must be submitted to the appropriate agencies for approval before construction begins. Right of way and access issues should be resolved before beginning construction. Familiarizing your work plans with other utilities in the area (phone, gas, cable, etc.) will aid in reduced problems once construction begins. Reduce your liability by always having utility lines marked before construction begins. In Kentucky the number to call for line marking is 811.

Data Requirements for a Detailed Management Plan

PHYSICAL	Exist	New	PERFORMANCE	Exist	New	COMMERCIAL/ SERVICE	Exist	New
Installation/yr	Y	Y	Complaint frequency	A	Y	Critical customer	Y	Y
Diameter	Y	Y	Type of complaint	A	Y	Affect on Community	Y	Y
Material	Y	Y	Break frequency	A	Y	No. of People Served	A	A
Length	Y	Y	Type of break	A	Y	Length of shutdown	A	A
Location	Y	Y	Reason for break	A	Y	Coordination w/others	A	A
Interior lining	A	Y	Service (hydraulic) adequacy	Y	Y			
Exterior protection	A	Y	Fire Flow Adequacy	Y	Y			
Joint	A	Y						
Wall thickness	A	Y						
Soil conditions	A	A						
Internal condition	A							
External condition	A							

Y = yes, in all cases   A = as needed, or as available

Distribution system maps

All systems are required by regulation to have *up to date* maps of their distribution systems. Certain items are required to be listed on your map.

Public and semipublic water supplies – general provisions:

(12) Maps
(a) Within twelve months of November 15, 1990, public and semipublic water systems shall have on the premises, or conveniently located to the premises, and an up-to-date map of the distribution system. The map shall, at a minimum, show:

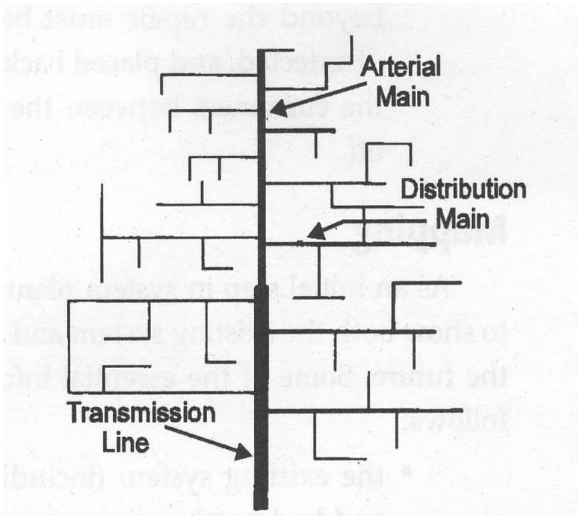
1. Line size
2. Cutoff valves
3. Fire hydrants
4. Flush hydrants
5. Tanks
6. Booster pumps
7. Chlorination stations
8. Connection to emergency or alternative sources
9. Wholesale customer master meters; and
10. Type of piping material in the distribution system and its location

(b) If a public water system, due to age, improper documentation, lost documentation or other valid reason is not able to comply with this requirement, the system may petition the cabinet to modify this requirement to the extent that compliance is not feasible. The petition for modification shall state specifically what portion of this requirement is not practical and why.

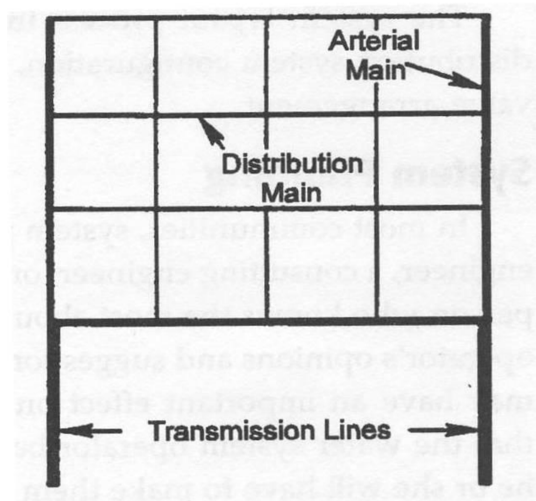
(401 KAR 8:020)

When designing a distribution system, the elimination of dead-end lines is very important. Dead-ends promote the degradation of water quality and reduced or nonexistent chlorine residual.

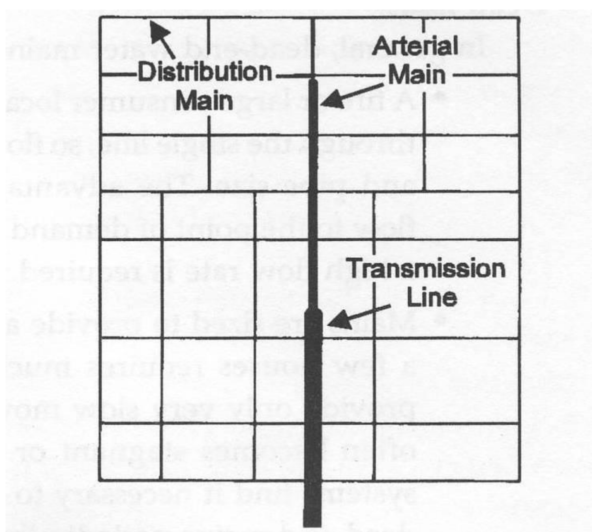
TREE (BRANCHING) SYSTEM with DEAD ENDS



LOOP SYSTEM



GRID SYSTEM



Obviously, the grid system is superior to the tree system as water is always moving and replenishing itself. The elimination of dead end lines or the frequent or routine flushing of them should be a priority. There are many types of flushing devices available for this purpose, from homemade to solar powered.

Pipe Installation

The proper installation of pipe will minimize maintenance problems and aid in desirable water quality and therefore, public health. Improper installation can result in water loss, water quality degradation, and loss of service, loss of consumer confidence, water leaks and increased monetary demands.

Operational/Physical	Applies to	Options	Chemical	Applies to	Options
Manufacturing defects	M,P,C	No	Internal corrosion	M,C	Yes
Improper design/installation	M,P,C	No	External corrosion-soil	M,C	Yes
Geologic instability	M,P,C	No	External corrosion-other	M,C	Yes
Higher operating pressures	M,P,C	Yes	Leadite corrosion	M	Yes
Hydraulic transients	M,P,C	Yes	Leadite expansion	M	Yes
Changes in water temp	M	Yes	Material incompatibilities	M	Yes
Excessive external loads	M,P,C	No	Gasket deterioration	M,P,C	Yes
Damage from digging	M,P,C	No	Material fatigue	P	No

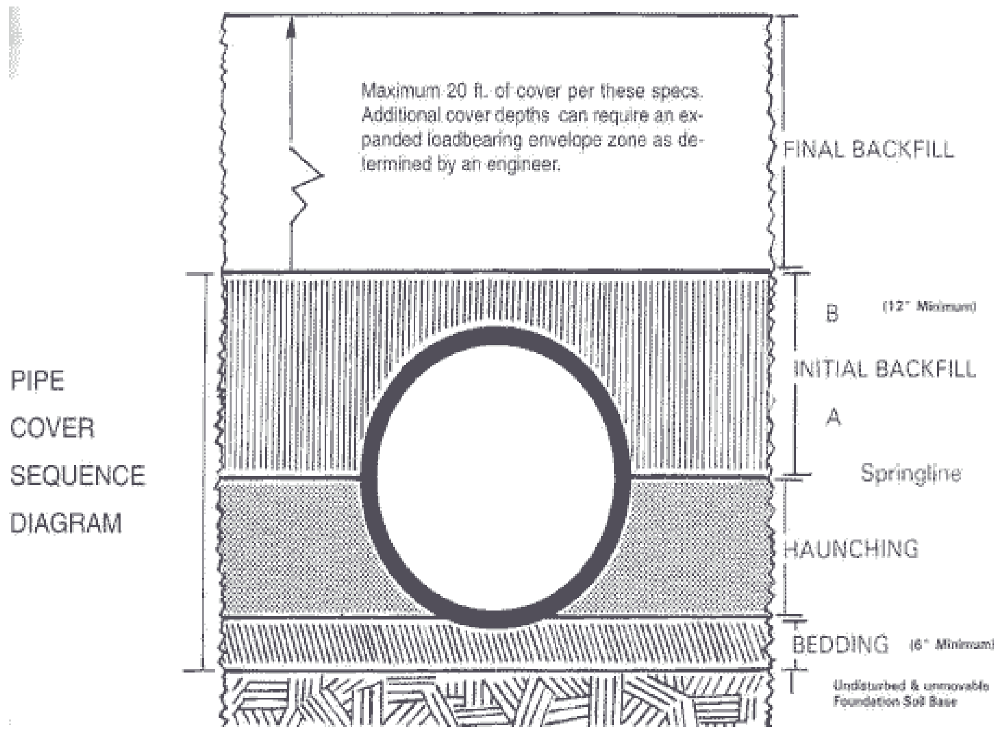
M = Metallic (ductile iron and/or cast iron) P = (PVC or HDPE) C = Concrete (RCP or PCCP)

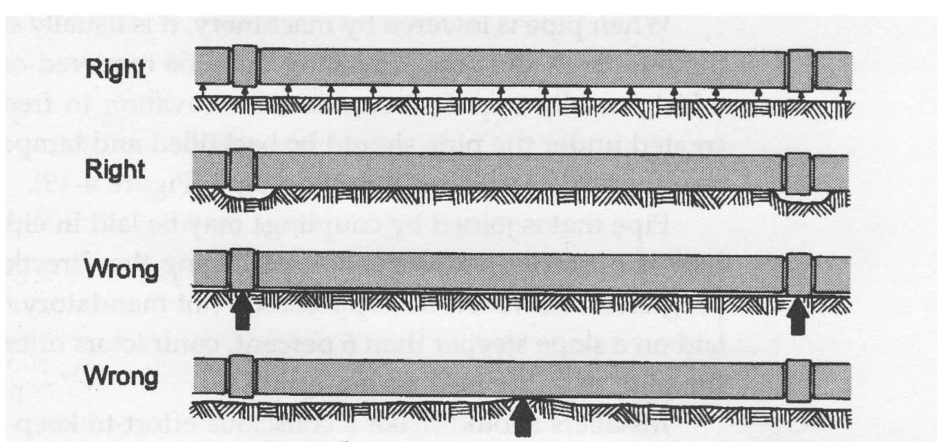
Comparison of Distribution-Size Pipe Materials – Operational Concerns

Operational Concern	DI	PVC	HDPE
Ease of installation	subjective	subjective	subjective
Can be direct tapped	yes	yes	no
Need for special installation equipment	no	no	yes
Need for special bedding for typical installations	no	yes	no
Need for joint restraint	yes	yes	no
Ability to locate underground	excellent	poor – needs tracer wire	poor – needs tracer wire
Applicable for above-ground installations	yes	yes, with UV protection	yes
Applicable for aqueous installations	yes	yes	Yes-potential for flattening is high
Anticipated service life	100 years	50-100 years	50 years

Bedding

This is usually considered to be the material in which the pipe is partially or fully embedded. It increases the load bearing capability of the pipe. The trench bottom should be correctly leveled and compacted to ensure continuous, firm support throughout its length. The bedding material should be well graded material, uniform in size and not containing rocks or other materials that cannot be graded uniformly.

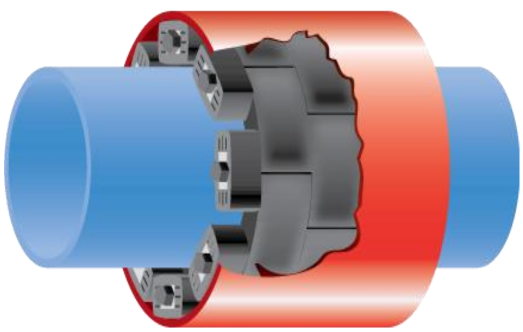




Pipe Laying

Water mains should not be placed in the same trench with sewer lines. If the sewer pipe is leaking, as they often do, a water main could be surrounded by contaminated soil. If a break were to ensue in that water main, a serious health hazard could be in the making. Waterlines should be laid at least 2 feet above and 2 feet laterally from the sewer line. If the water and sewer lines are at the same elevation, they should be at least 10 feet apart. Whenever a water line crosses a sewer line, the water line must be at least 3 feet above the sewer line and should not contain any pipe joints, except pressure joints on either side of the pipe crossing.

When pipelines are installed under roads, railroads, etc., the pipe should be installed in a way that allows for the accessible repair or replacement of that pipe. Casing or casement pipe is required to protect the water line from loads and stress.



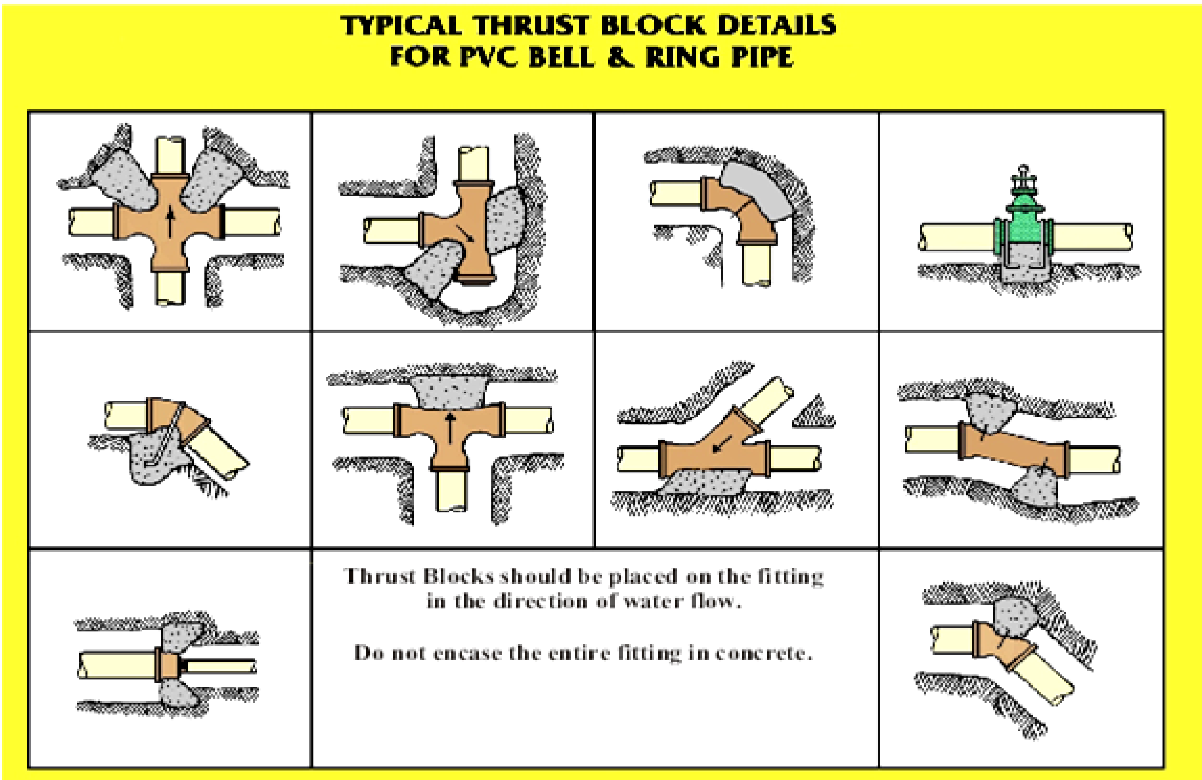
Thrust Blocking

Water under pressure and in motion can exert tremendous forces inside a pipeline. The forces can appear as water hammer, and strains on every fitting and appurtenance associated with the distribution system. A bend, tee, plug, hydrant, valve or any other fitting that changes the direction or velocity of water should be blocked or restrained in some manner. Thrust blocks are masses of concrete that are cast in place between the fitting that needs to be restrained and the undisturbed soil in the trench.

For example: If the water in a completely full 12 inch pipe that is 500 feet in length is required to stop or change direction, there is over 24,485 lbs of water moving in the pipe.
(.785 x 1' x 1' x 500' x 7.48 gallons x 8.34 lbs.)

******Do NOT cover the entire pipe or fitting with concrete as this will lead to extra hours of labor if the fitting requires maintenance.******

Thrust Blocking



Thrust blocking should be used on all gasket joint pipe and fittings since there are great thrusts developed whenever there are changes in direction in the pipeline, dead ends, pipe sizes and valves. These thrusts can blow the joints apart creating big messes.

The thrust block should be placed against undisturbed, fully compacted earth. It should have sufficient area on the soil side to restrain the thrust. The fitting should be placed over a large enough area to keep stresses on the fitting at a minimum.

The thrust block should be designed knowing the intensity of the thrusts developed in the pipe and the load bearing strength of the soil.

Using the tables on the following page you can calculate the size of the thrust block for various pipe sizes.

Example: 4" pipe with a maximum pressure of 100psi at a 90 degree elbow in clay soil.

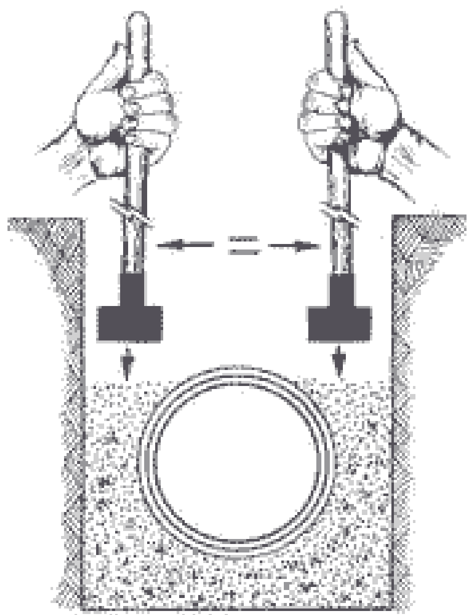
Thrust developed = 1,800 lbs. Load bearing strength of clay = 500 lbs.

1,800 / 500 = 3.6 square feet thrust block

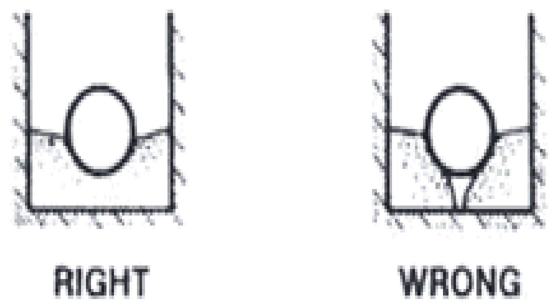
Recent technological developments such as thrust restraints, hydrant restraints, pipe restraint rings, etc., can aid as an addition to thrust blocking or sometimes an alternative, particularly where the soil is disturbed or cannot be tamped at the time of excavation.

Backfilling

The purpose of backfilling is to provide support for the pipe, provide lateral stability between the pipe and the trench walls and to form a cushion around the pipe to protect it from potential damage. The backfill material should be clean and dry and small enough to fill voids and effectively protect the pipe. The material should contain enough material to be compacted properly to viably protect the pipe. Larger rocks, debris and frozen material should not be used to backfill. Fill the trench in stages and compact as each layer is installed. Tamping can be achieved by hand, mechanically or by saturation.



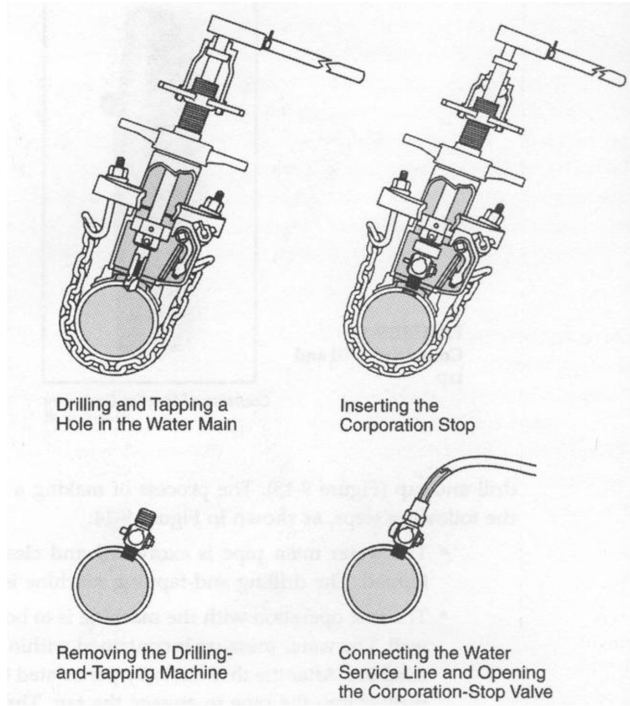
Constructed Ditch Example



Pressure and Leak Testing

Testing for leaks and pressure should be accomplished before finish grading is done. The standard for pressure testing is 1.5 times the pipe's normal working pressure or 150 psi, whichever is greater, and held for a minimum of 24 hours. If your pipe is installed by an outside contractor, this testing before they leave can alleviate a great deal of exasperating and expensive work just to put the pipeline in service.

Tapping



Tapping, by definition, is the cutting in of threads on the inside of a drilled or cut hole. In the water business, tapping is the connecting of one water line to another.

Many utilities now use saddles for tapping because of the widespread use of plastic pipe. Connections can be made either when the main is empty (dry tap) or when the pipe is full and under pressure (wet tap). Fortunately, most tapping done today is wet tapping. This method is preferred because it lessens the risk of contamination and allows the connection to be made to the customer without service interruption to other customers.

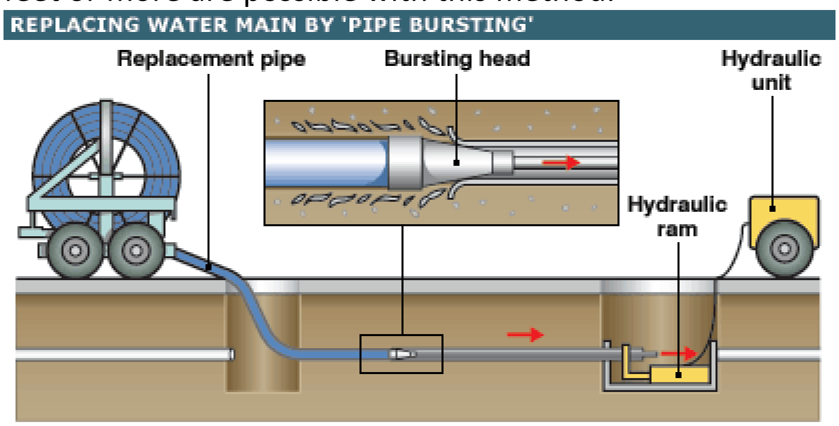
The fitting used to connect small diameter service lines to water mains is called a corporation stop. It is usually a brass ball valve that is threaded on both ends and screwed directly into a water main or a tapping saddle.

Larger taps are made by shutting off the main and installing a tee fitting or by tapping into an existing water main. The larger taps require more expensive tapping machines, as well as operational expertise, and many utilities farm them out to contractors.

TRENCHLESS TECHNOLOGIES

When looking at repairing or installing water mains trenchless technologies is growing trend due to the less public disturbance and cost.

1) Pipe Bursting – a method where the existing pipe is "split apart" and left in the ground and the new pipe is pulled into place right behind the head that splits or bursts the existing pipe. HDPE pipe or a special type of PVC is butt welded or fused together to allow for the long pipe runs. A pipe larger than the original pipe can be pulled into place. Runs of 1500 feet or more are possible with this method.



2) Slip Lining – a method whereby a replacement pipe is pulled into an existing pipe. This method is bound by the size of the existing pipe. Again, runs of 1500 feet are not uncommon.

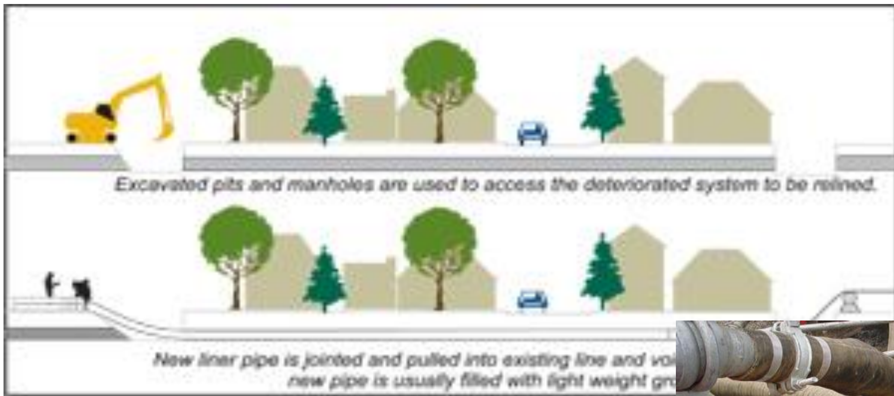
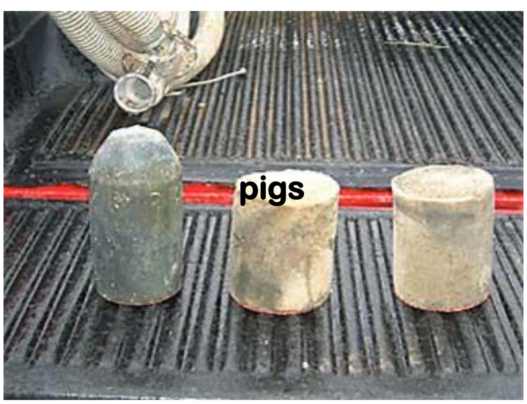
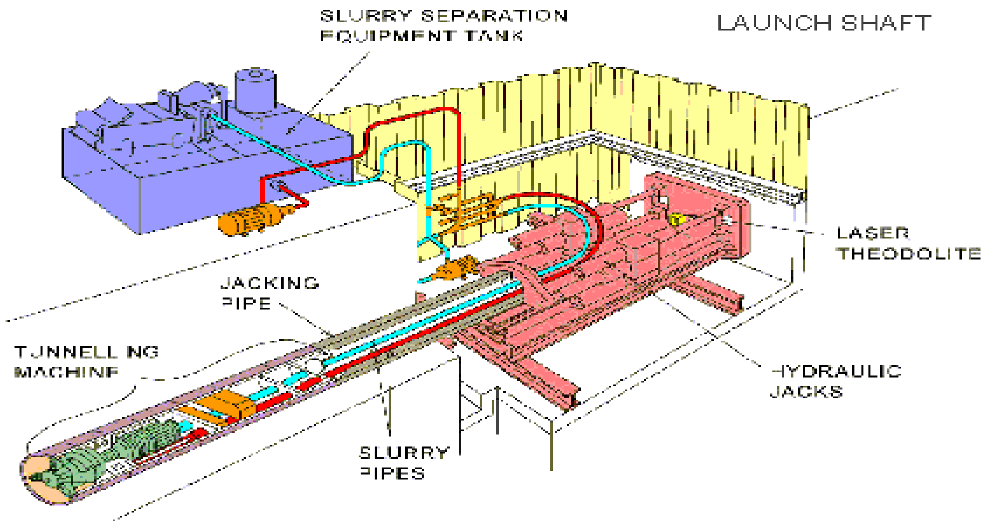


Figure 1:
Generalization of sliplining rehabilitation

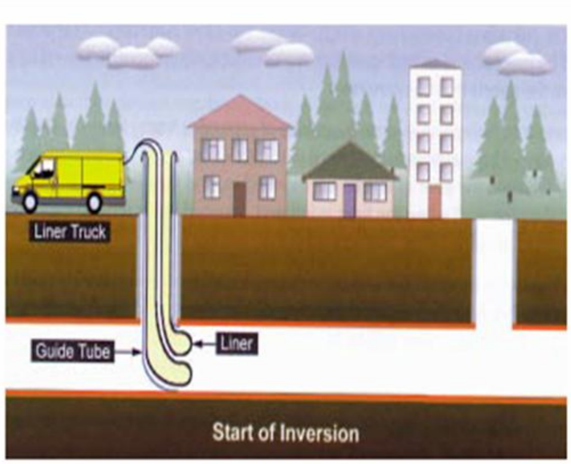
3) Pigging and/or mechanical cleaning – a mechanical means of removing mild tuberculation, scaling or biofilms from an existing pipe. Pigs are run through the existing lines by water pressure or mechanical scraper blades or rods are pulled through the existing pipe to clean it.

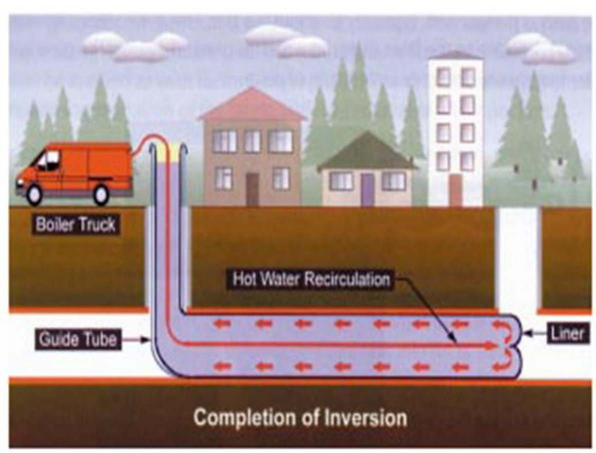


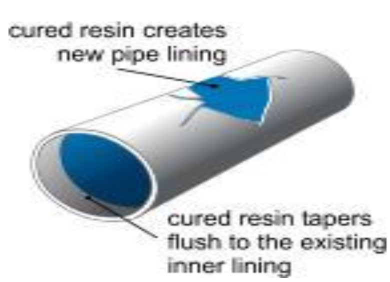
4) Pipe Jacking or microtunneling – a technique for installing underground pipes where hydraulic jacks are used with specially designed pipe behind a shield at the same time as excavation is taking place within the shield. Water is added at the point of excavation to form a “slurry” to soften the ground for the excavating and recycled through lines to be separated in the slurry separation tank and reused for excavating.



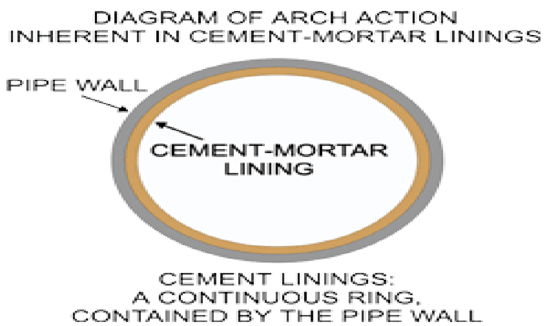
6) Cured in Place Sliplining is a method whereby a liner is pushed or pulled through an existing pipe and “cured” or heated with steam, hot air, hot water, or UV light and relines the existing pipe. The pipe is usually folded and allowed to unfold or sometimes forced to unfold by pumping air through them.

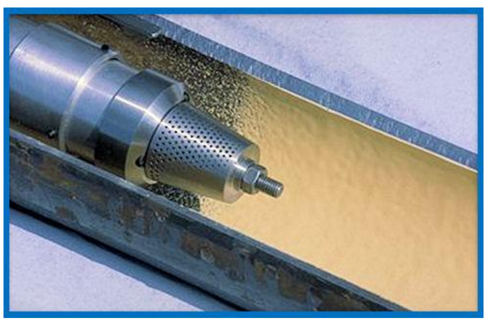




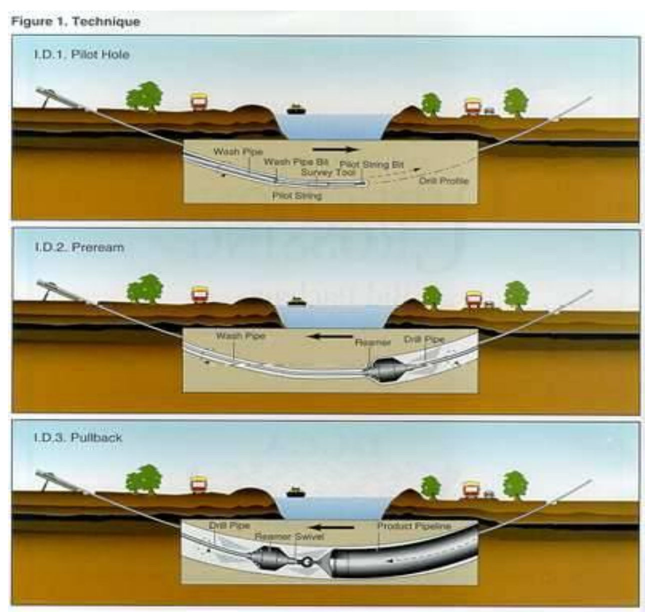


7) Cement lining – A high speed cement lining machine is pulled through an existing pipe followed by a trowel. The existing pipe is now relined with cement and its C- Factor returned to a high level. This method, since it relines an existing pipe, is bound by the size of the original pipe.





8) Horizontal Directional Drilling –
A machine that uses rods of varying lengths and diameters attached to a boring head. These rods can be directed to follow a predetermined route to follow the depth and route desired and not disturb other utilities in the ground. Runs of 3000 feet are not uncommon. The original route is bored and then the product pipe is pulled back to the point of origin.



9) Moles - Pneumatically powered cylindrical tools laid in an excavated pit that bore a hole through rock and dirt toward a second excavated pit. Usually used for service connections.

There are more methods used for “trenchless” excavations, but these are among the most frequently used. With more and more utilities being laid underground, the viability of open cut trenching is getting harder all the time. One of these methods could be a favorable alternative to the traditional open- cut method of laying pipe and are extremely useful when attempting to rehabilitate a pipeline.

401 KAR 8:150 *(Only the portion related to disinfection of treatment and distribution system facilities is included. The full regulation can be located at www.lrc.ky.gov)*

Section 4. Disinfection of Treatment and Distribution System Facilities, New and Repaired Water Lines.

(1) New construction projects and line extensions.

(a) Disinfection. A water treatment plant or distribution system, including storage distribution tanks, or extensions to existing systems, shall be thoroughly disinfected before being placed in service.

(b) A water distribution system shall disinfect with chlorine or chlorine compounds in amounts that shall produce a concentration of at least fifty (50) ppm and a residual of at least twenty-five (25) ppm at the end of twenty-four (24) hours, and the disinfection shall be followed by a thorough flushing.

(c) Other methods and testing procedures that provide an equivalent level of protection may be used if the cabinet grants prior written approval in accordance with 40 C.F.R. 141.21.

(d) A new water distribution line shall not be placed into service until bacteriological samples taken at the points specified in paragraph (f) of this subsection are examined and are shown to be negative following disinfection.

(e) A water treatment plant or distribution system shall submit to the cabinet results of bacteriological samples for each new construction project, replacement, or extension to existing systems, after the disinfection and flushing.

(f) A sample shall be taken in the newly constructed line at each of the following points:

1. Within 1,200 feet downstream of each connection point between the existing and new lines;

2. One (1) mile intervals; and

3. Each dead end, without omitting any branch.

(g) A new or routine replacement line shall not be placed in service until negative laboratory results are obtained on the bacteriological analyses.

(h) Sample bottles shall be clearly identified as "special" construction tests, and the results submitted to the cabinet shall be clearly marked as "special" samples.

(i)1. Notification of analytical results shall be submitted to the cabinet with the routine monthly compliance bacteriological samples, unless the bacteriological samples are to be used to lift a boil water advisory.

CHAPTER 8 MATH REVIEW

If we need to find the area (a two-dimensional measurement) in a rectangle, we simply multiply length x width.

OBJECT	AREA(ft^2)	VOLUME (ft^3)
Rectangle	Length' × Width'	Length' × Width' × Height'
Circle	.785 × D' × D'	
Triangle	½ (Base' × Altitude')	
Cylinder		.785 × D' × D' × Length'
Sphere		.5236 × D' × D' × D'
Diameter (D) = 2 × radius	Circumference = 3.14 × D	Perimeter = Sum of the Sides

If we need the cross–sectional area of a circle, we multiply
.785 x diameter in feet x diameter in feet, which gives us an answer in square feet (ft^2).

Examples:
What would the area be of a basin that measures 6 feet wide by 10 feet long?
Area = Length in feet X Width in feet
Area = 6 ft X 10 ft
Area = 60 suare feet (ft^2)

What would the cross-sectional area of a 24-inch circle be?
Area = .785 X diameter in feet X diameter in feet
Area = .785 X 2 ft X 2 ft
Area = 3.14 ft^2

To find volume (the size of a three–dimensional space enclosed within or occupied by an object) in a rectangle, we account for the third measurement, which would be height or depth.

OBJECT	AREA(ft^2)	VOLUME (ft^3)
Rectangle	Length' × Width'	Length' × Width' × Height'
Circle	.785 × D' × D'	
Triangle	½ (Base' × Altitude')	
Cylinder		.785 × D' × D' × Length'
Sphere		.5236 × D' × D' × D'
Diameter (D) = 2 × radius	Circumference = 3.14 × D	Perimeter = Sum of the Sides

To find the volume of a pipe or cylinder, we
multiply .785 x diameter in feet x diameter in feet x height or depth in feet.

Examples:
A sedimentation basin measures 18 feet wide by 26 feet long by 12 feet in depth. What is the volume of this basin?
Volume = Length (in feet) X Width (in feet) X Depth or Height (in feet)
Volume = 26 ft X 18 ft X 12 ft
Volume = 5,616 cubic feet (ft^3)

How many cubic feet of water would a 24-inch pipeline that measures 1,500 feet in length contain?
Volume = .785 X diameter (in feet) X diameter (in feet) X length (in feet)
Volume = .785 X 2 ft X 2 ft X 1500 ft
Volume = 4,710 cubic feet (ft^3)

CHAPTER 8 PRACTICE PROBLEMS

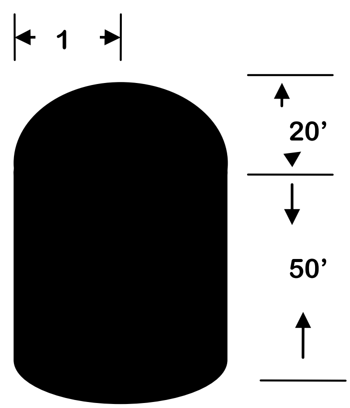
1. What would the area of a circular clarifier that measures 20 feet in diameter?

2. The cross-sectional area of a 10-inch pipe is?

3. A fully filled 8" water line that is 5,280 ft. long will contain how many gallons?

4. An elevated standpipe that measures 40 feet in diameter and stands 60 feet tall would contain ______________ gallons.

5. How many gallons would this structure contain?
   a) 79,276.0 gallons
   b) 369,977.3 gallons
   c) 49,462.2 gallons
   d) 317,104.1 gallons



6. Calculate the volume of water in gallons that a rectangular channel could contain that measures four feet wide, sixty feet in length and has a depth of 36 inches.

7. The radius of a cylindrical tank measures 22 feet and has a depth of nine feet. What is the volume of this tank?

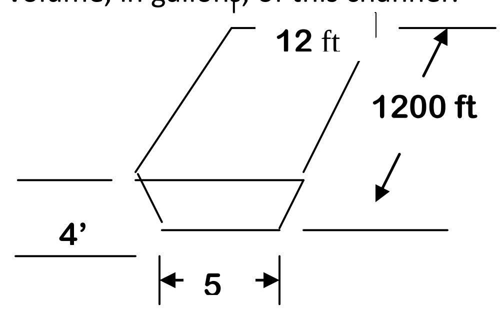
8. A rectangular channel that measures six feet in depth, twenty feet in length and is two feet wide contains one foot of water. How many gallons are in this channel?

9. Tipperary has two storage tanks and 36 miles on line in their system. One storage tank measures 30 feet in diameter and is 70 feet in height. The other storage facility measures 62 feet in diameter and is 50 feet in height. There are 6 miles of 24-inch line, five miles of 12-inch line, seven miles of 8-inch line, twelve miles of 6-inch line, four miles of 4-inch line and two miles of 2-inch line. What is the total volume of Tipperary's distribution system?

a) 260,000 gallons b) 2.6 MG
c) 347,637.8 gallons d) 20,600,000 gallons

BONUS QUESTION

10. A trapezoidal channel measures 12 feet at the top of the channel, 5 feet at the bottom of the channel, 4 foot in depth and is 1200 ft long. What is the volume, in gallons, of this channel?



Answers:

1) .785 X 20 ft X 20 ft = 314 ft^2

2) .785 X (10 inches ÷ 12 inches) X (10 inches ÷ 12 inches) =
.785 X .833 ft X .833 ft =
.544 ft^2

3) .785 X (8 inches ÷ 12 inches) X (8 inches ÷ 12 inches) X 5280 ft X 7.48 gallons =
.785 X.666 ft X .666 ft X 5280 ft X 7.48 gallons =
13751.6 gallons

4) .785 X 40 ft X 40 ft X 60 ft X 7.48 gallons =
563,892.8 gallons

5) .785 X (2 x 15 ft) X (2 x 15 ft) X 50 ft X 7.48 gallons
+
$\frac{.5236 \text{ X } (2 \text{ x } 15 \text{ ft}) \text{ X } (2 \text{ x } 15\text{ft}) \text{ X } (2 \text{ x } 15 \text{ ft}) \text{ x } 7.48 \text{ gallons}}{2}$

.785 X 30 ft X 30 ft X 50 ft X 7.48 gallons + $\frac{.5236 \text{ X } 30 \text{ ft X } 30 \text{ ft X } 30 \text{ ft X } 7.48 \text{ gallons}}{2}$

264,231 gallons + 52873.1 gallons
d) 317,104.1 gallons

6) 4 ft X 60 ft X 3 ft xX7.48 gallons

7) .785 X (2 x 22 ft) X (2 x 22 ft) x 9 ft
5385.6 gallons

.785 X 44 ft X 44 ft X 9 ft
13,677.8 ft^3

8) 6 ft X 20 ft X 1 ft X 7.48 gallons
897.6 gallons

9) .785 X 30 ft X 30 ft X 70 ft X 7.48 gallons + .785 X 62 ft X 62 ft X 50 ft X 7.48 gallons +
.785 X 2 ft X 2 ft X (6 x 5280 ft) X 7.48 gallons + .785 X 1 ft X 1 ft X (5 x 5280 ft) X 7.48 gal +
.785 X .666 ft X .666 ft X (7 x 5280 ft) x 7.48 gal + .785 X .5 ft X .5 ft X (12 x 5280) X 7.48 gal+
.785 X .333 ft X .333 ft X (4 x 5280 ft) x 7.48 gal + .785 X .166 ft X .166 ft X (2 x 5280 ft) X 7.48 =
2,602,303.9 gallons or b) 2.6 MG

Chapter 8 Review

1. What type of distribution system is best for water movement Loop, Tree, or Grid?
2. List three methods of trenchless technologies.
3. Unaccounted for water should be at _________or less.
4. Anytime water changes directions or stops, what should be added to the pipeline?
5. _____________flushing is an engineered, more viable form of flushing.

Answers for Chapter 8 Review

1. Grid

2. Pipe Bursting, CIP, Slip Lining, Epoxy Lining, and Cement Lining

3. 15%

4. Thrust blocks

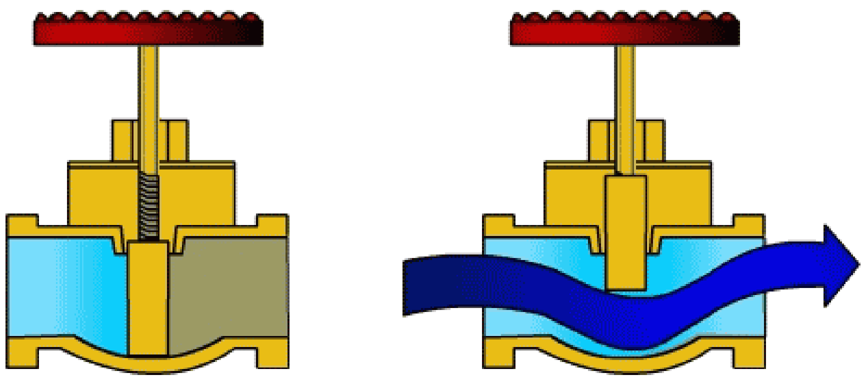
5. Unidirectional

Chapter 9: VALVES

Chapter 9 Objectives

1. Describe the functions as well as the strengths and shortcomings related to the different types of valves (gate, butterfly, globe, plug, ball, air/vacuum release, pressure reducing, altitude, and check).
2. Explain the importance and details associated with valve maintenance.

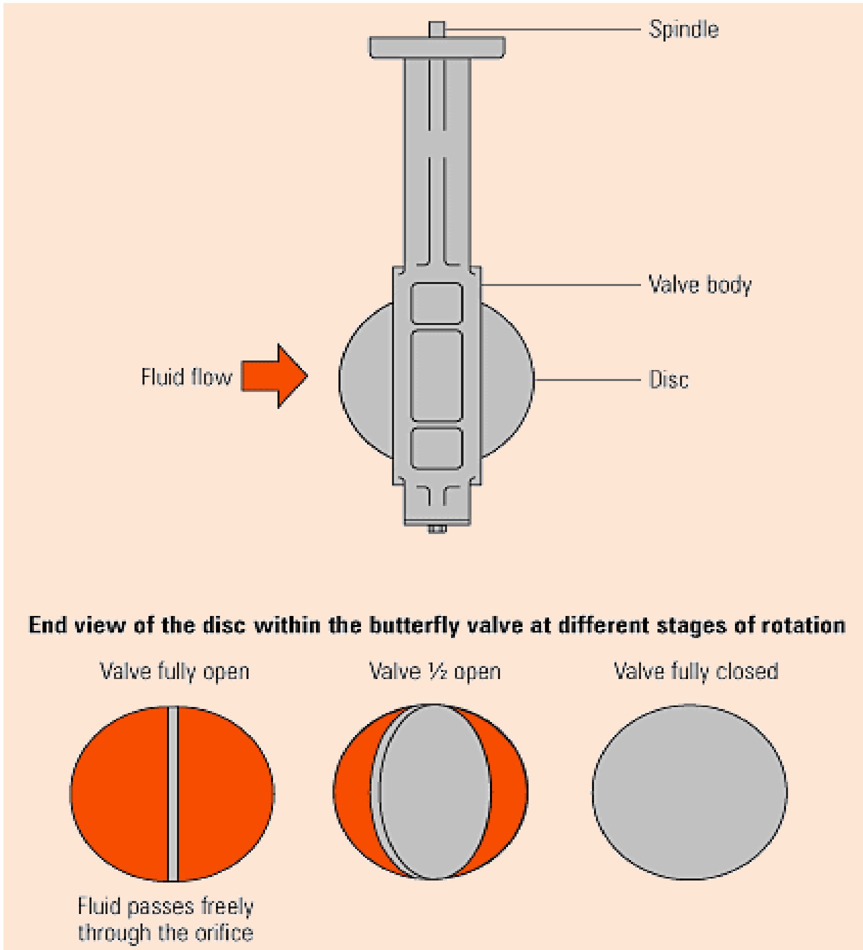
Gate Valves



Gate Valve Closed   Gate Valve Opened

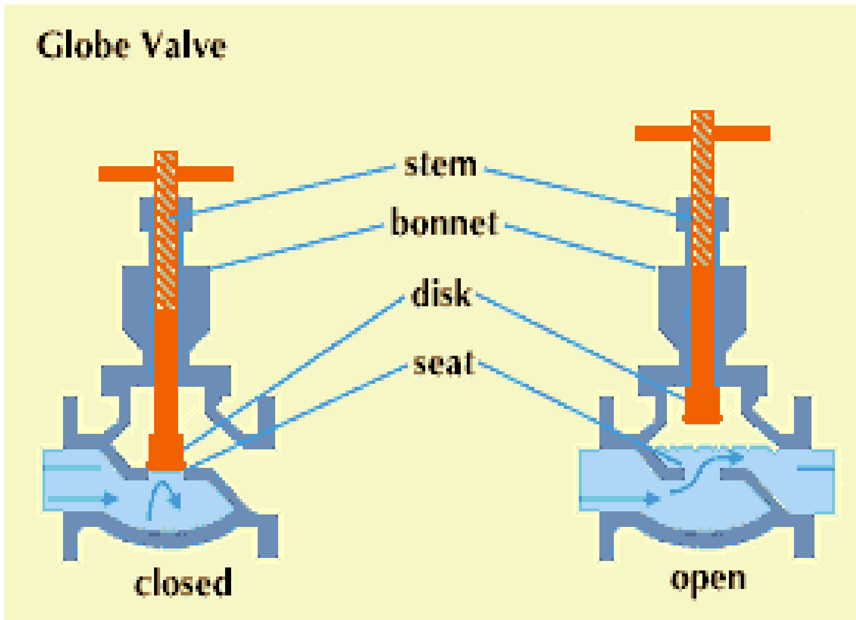
- Operated in a fully open or fully closed position only
- Used for isolating a part of the distribution system or a piece of equipment (i.e. fire hydrant, pump etc.)
- NOT used for throttling
- Very low headloss and turbulence in the fully open position
- Not the best choice if needed to operate frequently
- Thrust blocking and/or mechanical restraint must be used if installed at a dead end or water direction change
- Types – solid wedge, double disk, solid split gate
- Maintained by exercising a full cycle operation on a regular schedule – at least annually
- Valve card notations – number of turns, direction of open, location, type, size, date of installation and maintenance, inspection and/or repair.
- Leakage repair – O-rings, seals, gaskets, or mechanical joint gaskets

Butterfly Valves



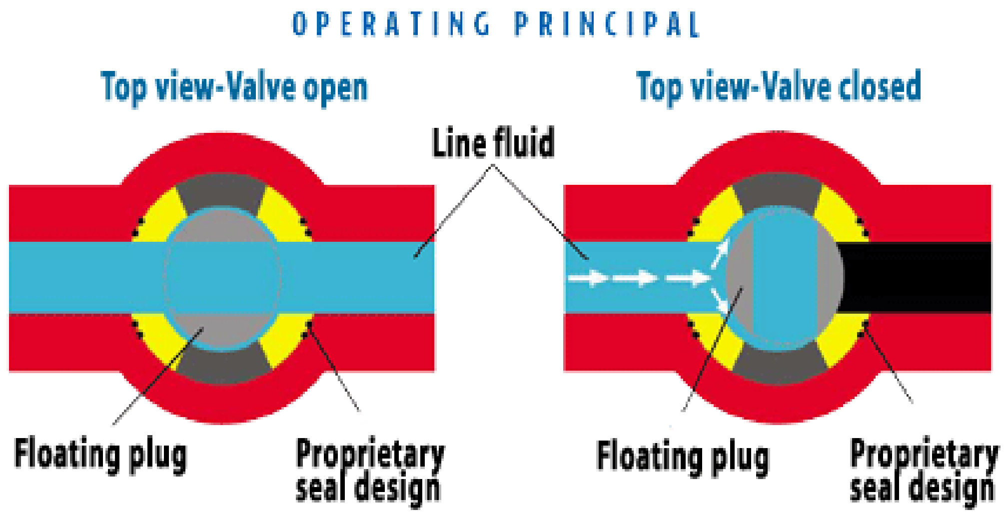
- Primarily used for isolation, but can be used for throttling or even as a check valve.
- Wears better than gate valves
- Shorter, lighter, and cheaper than gate valves in most cases
- Higher headloss than gate valve and prevents the relining or mechanical cleaning of pipes.
- Install in a closed condition
- Minimal maintenance requirements, but removal is necessary for repair

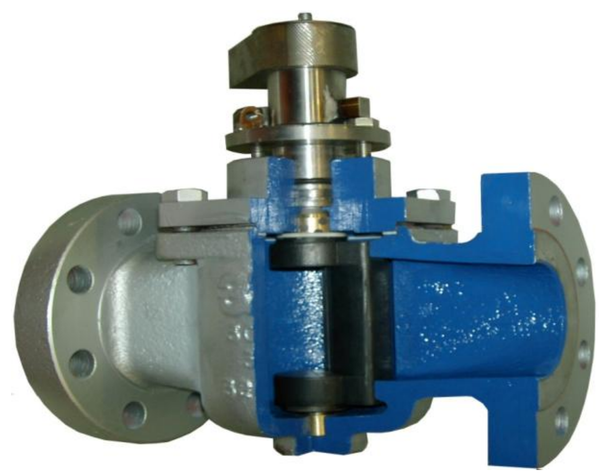
Globe Valves



- An extremely versatile valve
- Used primarily for pressure
- Highest headloss of all valves operating in a fully open position
- Can be used to control pressure, throttling (flow or altitude) and also isolation in small flow or line size applications
- Design aids in disc wear so maintenance is seldom necessary, but removal is compulsory for repair.
- Design also excludes mechanical pipe cleaning or relining without valve removal

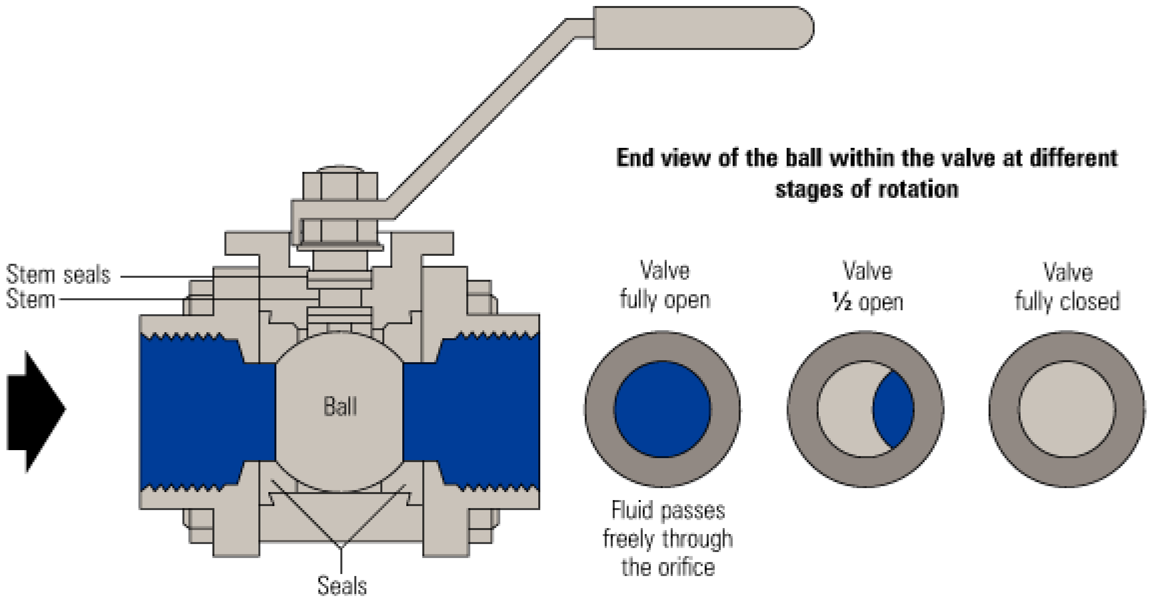
Plug Valves





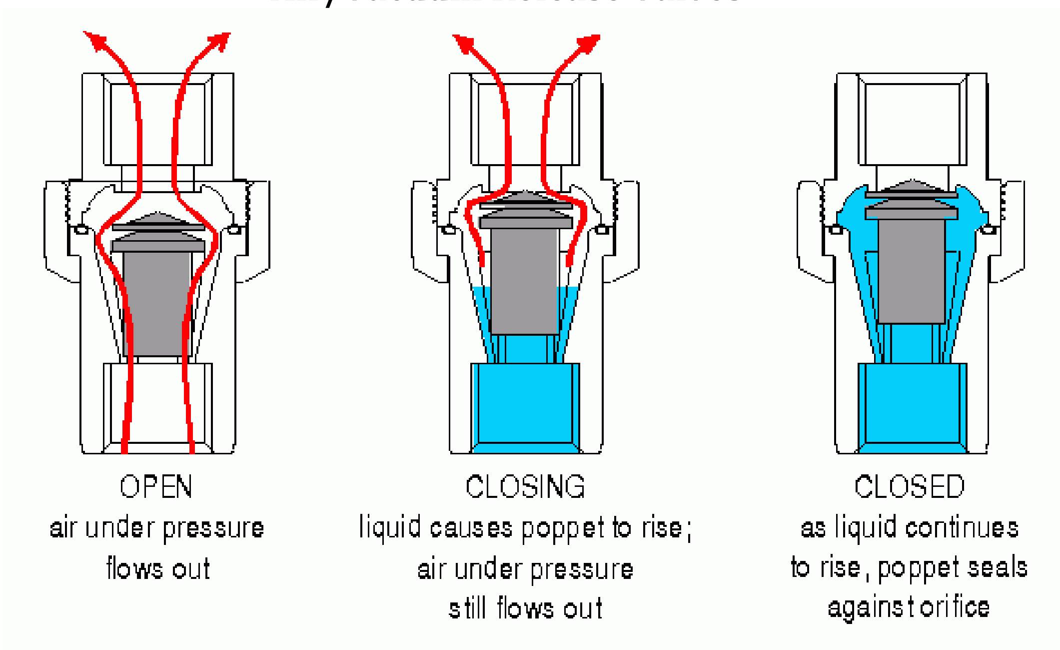
- Used for isolation where frequent operation is required
- Not recommended for throttling unless especially designed as such
- Design minimizes closing surge and allows for longer valve life than a gate valve
- Generally heavier and more expensive than a gate valve
- Low headloss, dependable, easy operation

Ball Valves

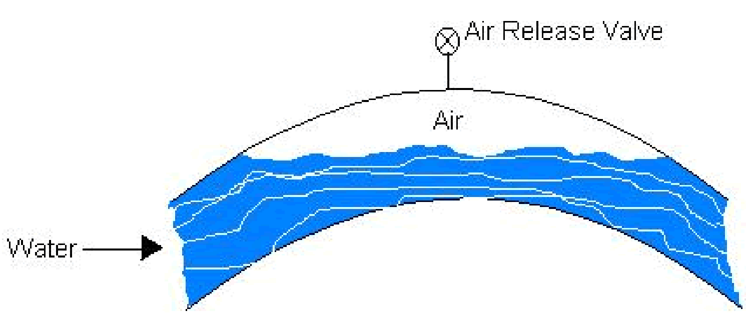


- Really an improved version of the plug valve
- Same characteristics as a plug valve except much lower turning torque required and no metal to metal contact, which extends the life of the valve
- We primarily use these in our service applications (corporation stop)

Air/Vacuum Release Valves

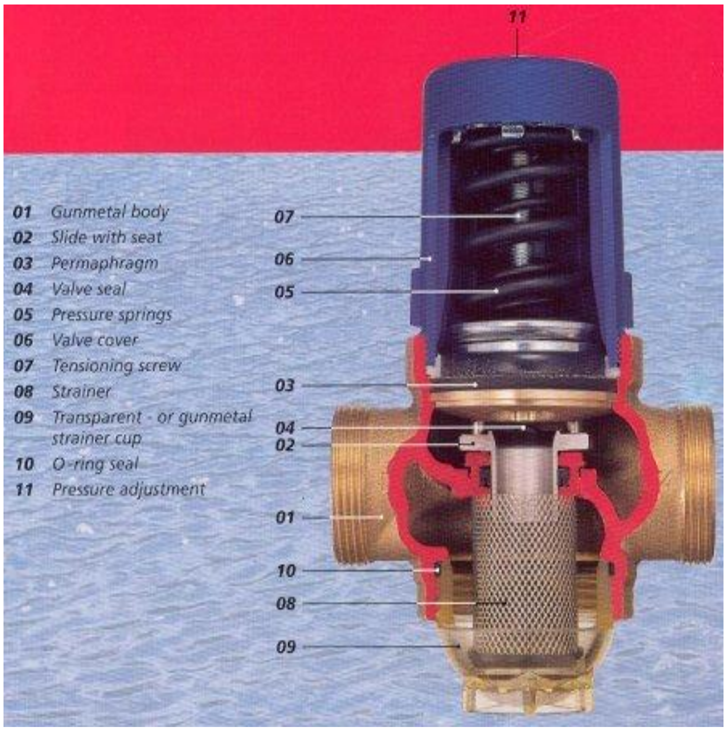


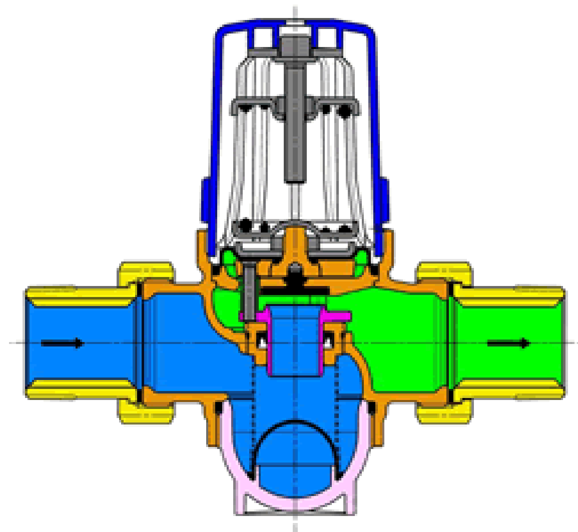
- Air release valves allow the removal of air from water lines due to turbulence or temperature variances which could collect and act as a partially or fully closed valve.
- Vacuum release valves relieve the occurrence of negative pressure due to vacuum conditions that could collapse our pipes.
- Vacuum release valves allow air to enter the pipeline while draining.
- Both air and vacuum relief valves should be installed at high points in the distribution system and atop the mains.



(They may be installed as combination valves or singularly in tandem.)

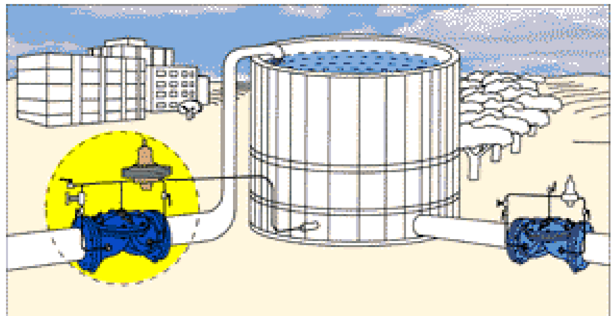
Pressure Reducing Valves





- Usually globe type valves with a spring loaded diaphragm
- PRV's automatically maintain constant outlet pressure regardless of changes in the flow rate or upstream pressure.
- These valves will hold a partially open position in response to the settings of the spring-loaded diaphragm.
- Pressure reducing valves will throttle in this open position relative to the balance of opposing forces.
- The use of two pressure reducing valves in sequence can be used to handle a wide range of flow rates.

Altitude Valves

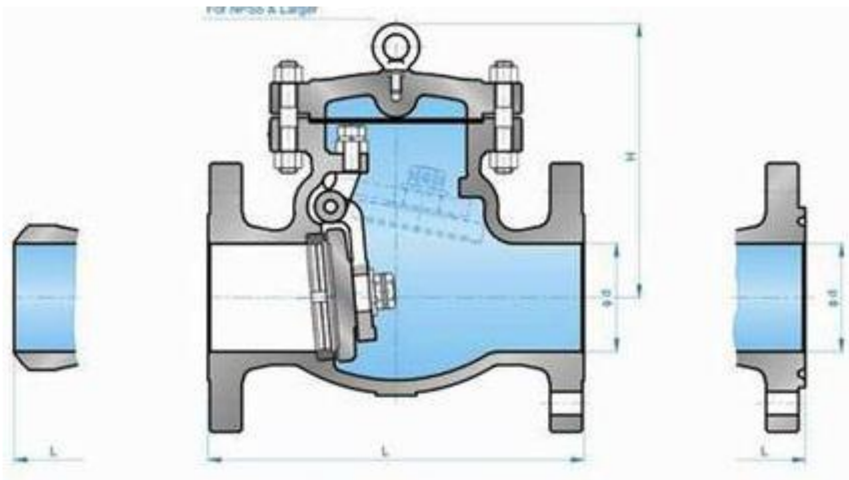


Controls tank levels below the hydraulic grade line

Four types:

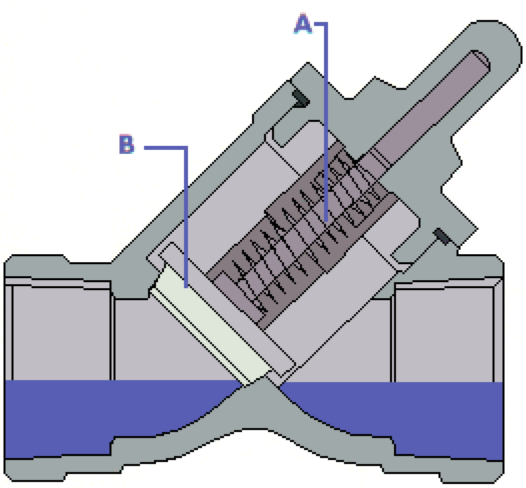
1. Double Acting – closes when the level in the tank reaches high water level; opens for return flow out when line pressure falls below static reservoir head
2. Double Acting with Differential Control – works like double acting valve, except it can be set to activate under preset pressure parameters
3. Single Acting – water discharges from the tank through a separate line. Valve actuates to refill tank when the water level falls 4 – 6 inches below the high water level.
4. Single Acting with Differential Control – works similarly to a single acting, except the valve actuation level can be preset anywhere from 1 – 15 feet.

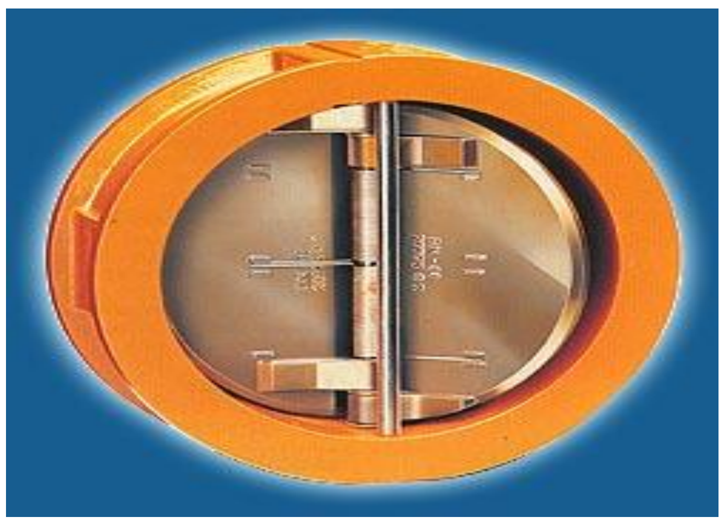
Check Valves



- Prevent the reverse flow of water or prevent the water from traveling in an unintended direction.

- Many controls are available to actuate the valve, such as swing gate (illustrated above) or spring loaded (illustrated below).





- Used to maintain head pressure on the effluent side of a pump or maintain the integrity of some meters.

- ***Valves should be exercised at least annually. Examples are provided below.***

Valve Maintenance Report or Log Examples:

VALVE RECORD

XYZ Waterworks Valve No. _________
Location ____________________________
___ ft ______ of ______ property line of ________
&___ft ______ of ______ property line of ________
Size ______ Make ______________ Type ________
Gearing ______________ By-pass_____________
Opens ______________ Turns to Operate ______
Set in ____________ Depth to nut ____________
Remarks:
____

MAINTENANCE & INSPECTION RECORD

DATE	WORK DONE	OK ?	BY
	(3 X 5 or 5 X 7 card)		

Valve Maintenance Card

VALVE MAINTENANCE REPORT

XYZ Waterworks Valve No. _________
LOCATION
____
MEASUREMENTS: CHECKED OK _________

Measured As Follows
______ FT _______ OF ______ P.L. of
____
______ FT _______ OF ______ P.L. of
____
VALVE TURNS ____________ TO OPEN
VALVE TURNS ____________ TO CLOSE
Packing: OK __Tightened __ Replaced __
Stem: OK ___Bent /Broken __Replaced __
Nut: OK ___ Missing ___ Replaced ___
Gears: Condition ________ Greased ________
Box _____ or Vault _____ OK __ Replaced ___
Buried _______ in. Protruding _____ in.
Riser too close to stem _____ Reset _____
Cover: Missing ___Broken __ Replaced ___
Wedged in _____ Tarred or Grouted In _____
Any Other Defects
____

Inspected ______________ By
____
Defects Corrected ____________ By ________

CHAPTER 9 REVIEW

1. Why would you want to put more than one pressure-reducing valve in a line?

2. Which valve has the highest headloss in the open position?

3. Which type of valve is used in a corporation stop?

4. If the town of Katzenjammer has 2,700 people and each person averages 300 gallons per day of water usage, what is the daily water demand for this city?

5. Altitude valves control the level of storage facilities above or below the hydraulic grade line?

6. Air release valves should be located at what position on the water line?

7. Which valve has the lowest headloss in the fully open position?

8. When a customer complains about water pressure in a looped system, what would be one of the first things to check?

9. Valves should be exercised how often?

10. Valves should be opened and closed _______________ to prevent water hammer.

11. Gate valves should or should not be used for throttling?

12. Advantages butterfly valves possess over gate valves are:

Answers for Chapter 9 Review

1. When velocity needs to lowered twice.
2. Globe
3. Ball
4. 810,000
5. Below
6. On top
7. Gate
8. Checked for a closed valve
9. Every 6 months
10. Slowly
11. No
12. Cheaper

Chapter 10: HYDRANTS

Chapter 10 Objectives

1. Understand dry barrel hydrants and their components.
2. Explain the installation process.
3. Explain the operation of compression hydrants.
4. Explain the advantages of unidirectional flushing over conventional flushing.

Two classifications of hydrants made in the United States are the wet barrel and the dry barrel hydrant. Keep in mind that the MINIMUM SIZE LINE USED FOR A FIRE HYDRANT TO SATISFY FIRE FLOW AND PRESSURE REQUIREMENTS IS 6 INCHES. For purposes of this training we will only address the dry barrel hydrants.

Dry barrel hydrants have the operating valve installed below ground level.

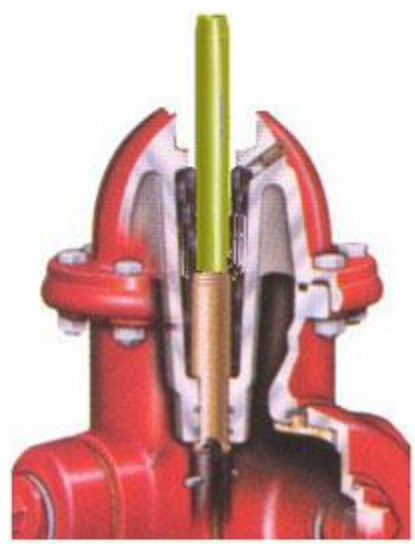
- These hydrants are equipped with special drain valves or weep holes that allow the above ground portion of the hydrant to automatically drain when the hydrant is not in use.
- Used in colder climates where there is a likelihood of freezing temperatures.
- If equipped with a traffic kit, the hydrant will not usually lose water if struck.

FIRE HYDRANTS SHOULD ALWAYS BE OPENED AND CLOSED SLOWLY.******

Hydrant Components

Bonnet

The top of the hydrant contains the bonnet. The bonnet protects the packing and the operating nut mechanism.



Upper Barrel

The upper barrel contains the outlet nozzles and the "O" rings that prevent water from entering the bonnet of the hydrant. Common nozzle sizes include 2½ inch hose nozzles and usually four or six inch pumper nozzles.

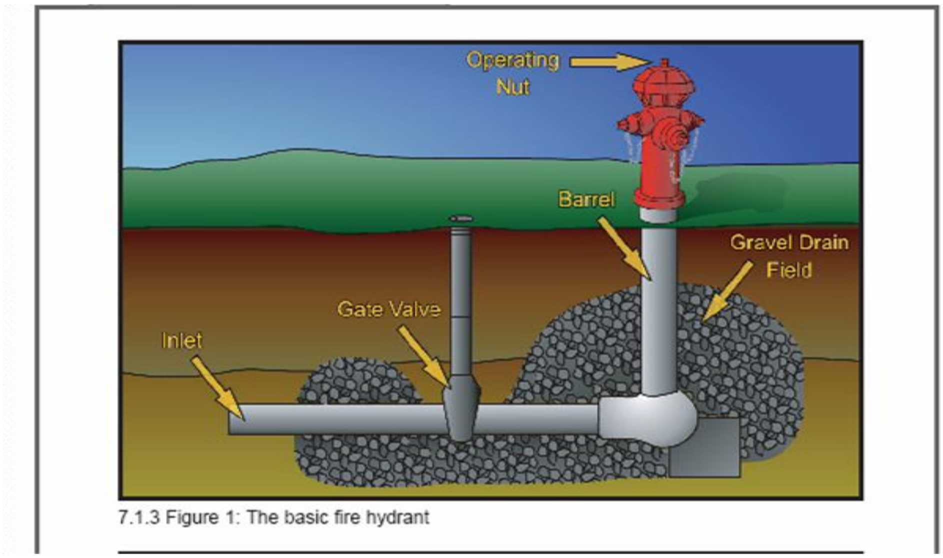
Lower Barrel

These sections determine the height or bury depth of the hydrant. The bury or bury depth is the distance from the bottom of the inlet connection to a point four inches below the flange that connects the lower barrel to the upper barrel.

Shoe

The shoe is where the inlet connection is made. The shoe also changes the direction of the flow from horizontal to vertical. On most compression hydrants, the main valve assembly is located either in the shoe or directly on top of it. The size of the main valve is referred to as the main valve opening (MVO). This is the inside diameter of the valve seat and sizes that range from four through six inches are common.

The shoe also contains the drain valve assembly and/or weep holes, used to drain the hydrant when it is closed.

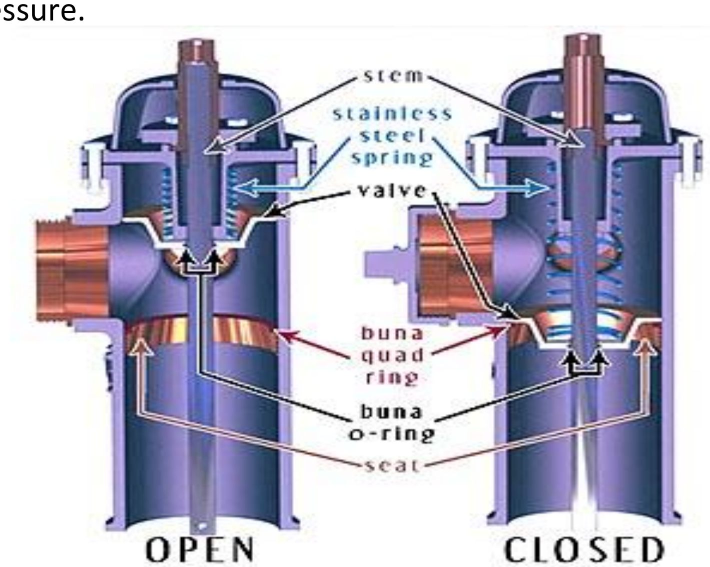


7.1.3 Figure 1: The basic fire hydrant

Proper installation order on a fire hydrant is main, gate valve, pipe, and thrust block. Fire hydrants should be inspected and maintained at least annually.

Compression Type Hydrants

In compression hydrants, the main valve moves jointly on a vertical axis against a seat located in the hydrant base. The valve moves against the seat to close and away from the seat to open. A vertical stem moves up or down when the operating nut is rotated. The valve may be located below the seat and opens against the pressure or above the seat and opens with the pressure.



Hydrant Function

Pitot tubes can be utilized in the distribution system to obtain flow measurements in gallons per minute and pressure (PSI) readings from fire hydrants.


Diffusers redirect the flow from the hydrant and somewhat dissipate the force or intensity of the flow in order to reduce potential property damage and hazards to motorists during flushing. Some diffusers are equipped with pressure and flow gauges and some have dechlorinating capabilities.



Always dechlorinate the water when flushing. Chlorine flowing into streams will damage the ecosystem of that stream. Sodium thiosulfate is commonly used to remove chlorine from water.

Blow Offs

Blow off valves are used to drain lines, remove accumulated sediment via flushing and resolve customer complaints. Blow offs are used at dead ends where fire hydrants are not needed. All blow offs should be flushed regularly to maintain water quality.

Flushing and Cleaning

The flushing of water lines is absolutely necessary to maintain water quality in distribution systems. Flushing will generally occur for one of three purposes:

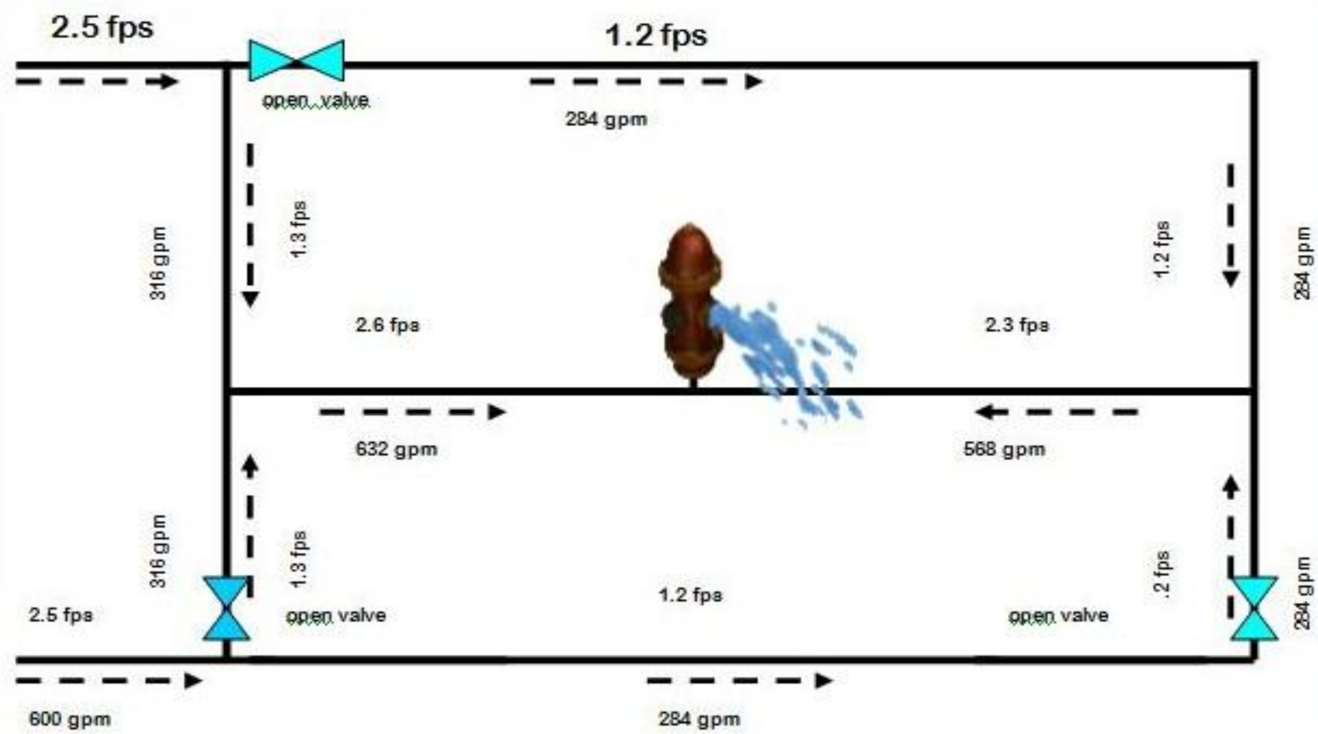
1) *To flush out debris or chlorinated water from newly installed or repaired lines.* After installation or repair of a water line, flush and pressure test, disinfect, dechlorinate and flush again before returning or putting the water line into service.

2) *******To address localized problems such as taste, odor, color or coliform contamination.* When customer complaints or contamination monitoring necessitate a reactive form of flushing. Reactionary flushing means that the problem exists before any corrective actions are taken.

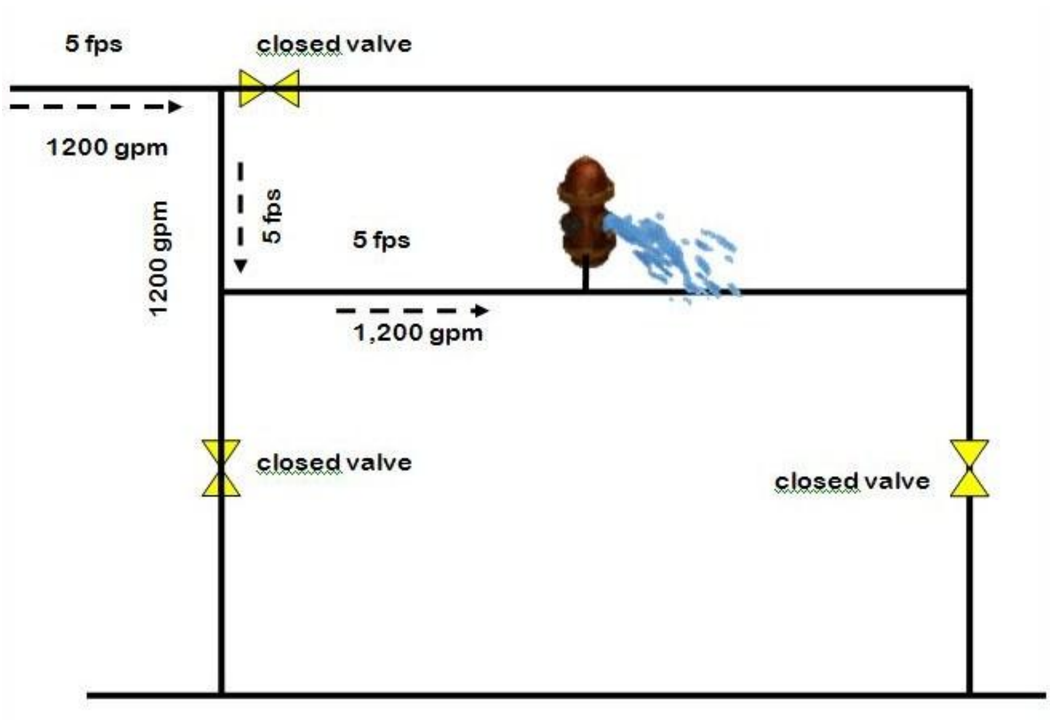
3) *To systematically and routinely clean the distribution system piping.* Planned, engineered, systematic flushing can achieve a degree of cleaning the distribution system dependent upon the condition of the pipes and the viability of your flushing program. This type of flushing is proactive and preventative and can, if done correctly, scour your distribution piping. Velocities must be a minimum of 2 feet per second (fps) with 5-6 fps being the optimum velocities necessary to fully flush your distribution system. Proactive unidirectional flushing will reduce customer complaints, improve water quality and prolong the life of your distribution system.

Always dechlorinate the water when flushing. Chlorine flowing into streams will damage the ecosystem of that stream. Sodium thiosulfate is commonly used to remove chlorine from water.

THE "OLD" WAY



UNIDIRECTIONAL



Mechanical cleaning could be necessary if tuberculation deposits are prolific or if biofilms, iron bacteria, or slime growths abound in large quantities. Try flushing initially, but if this proves inadequate, it may become necessary to use mechanical devices such as pigs or scrapers, to sufficiently clean the line. In addition to cleaning the lines, an increase in the carrying capacity of the lines will reduce pumping and energy costs as well as increase operating pressures close to where they were when the main was installed.

Cleaning can restore lines to close to their original viability but frequently this is a temporary reprieve from the problems associated with old or neglected mains. A change in water chemistry or the additions of corrosion inhibitors are necessary to prevent a reoccurrence of tuberculation problems.

A line replacement program should be considered, planned for and implemented. These programs call for the replacement of a certain percentage or dollar amount of distribution system piping annually. This will also prevent the overall deterioration of the distribution system and spread the cost of replacement over a longer period of time than having to replace a line suddenly due to its failure.

In the United States, the average pipe age ranges from 21 – 91 years. The current replacement rate in the US is only 0.5% annually. Some of the oldest sections of pipe are over 125 years old. Distribution piping will not last indefinitely and water quality is usually adversely affected by the condition of these older pipes.

Pipe Diameter	Cross-Sectional Area (square feet)	GPM @ 2.5 fps	GPM @ 5 fps
2”	0.022	25	50
4”	0.087	98	196
6”	0.196	220	440
8”	0.348	390	780
10”	0.545	612	1224
12”	0.785	881	1762
16”	1.395	1565	3130
18”	1.766	1981	3962
24”	3.14	3523	7046
30”	4.91	5505	11010
36”	7.065	8078	16156

Turn of the 20th century fire pumper

CHAPTER 10 REVIEW QUESTIONS

1. Hydrants should be exercised and lubricated on a ___________ basis at a minimum.

2. One component that can prevent the successful opening or closing of a hydrant is the _______.

3. Water released from hydrants and blow-offs needs to be, by regulation, ___________ before the water hits the ground.

4. What is located in the show of the hydrant that allows water to drain from the hydrant?

Answers for Chapter 10 Review

1. Twice a year (bi-annual or semi-annual)

2. Stem, operating nut

3. 0.01 PPM

4. Weep holes

Chapter 11: METERS

Chapter 11 Objectives

1. Explain the purpose of meters.
2. Describe the types of meters and there applicability, average daily uses and issues related to water loss.
3. Calculate percent water loss and average daily use.

Purpose

1. To measure and display the amount of water passing through it.

2. To prevent wasted water by reducing consumption.

3. To enable accurate billing for the volume of water used by each customer

4. To measure the volume of water produced in relation to the volume of water used so water losses can be estimated and tracked.

When choosing a meter always take into account:

- ✓ The ability to measure and register anticipated flow levels.
- ✓ The ability to meet required capacity with minimal headloss.
- ✓ The durability and ruggedness of the meter.
- ✓ Is that meter supplier a known and reputable manufacturer?
- ✓ Is the meter easy to maintain and repair?
- ✓ Is there a sufficient quantity of spare parts and competent technical services?

TYPES of METERS

Meters can usually be classified as small–flow meters, large-flow meters and combination large- and small-flow meters.

SMALL-FLOW METERS

Displacement Type
Piston: Measures the number of times the chamber (of a known volume) is filled and emptied. A piston or disc goes through a particular cycle of motion, and its movement is transferred to a register either notated in gallons or cubic feet per second.

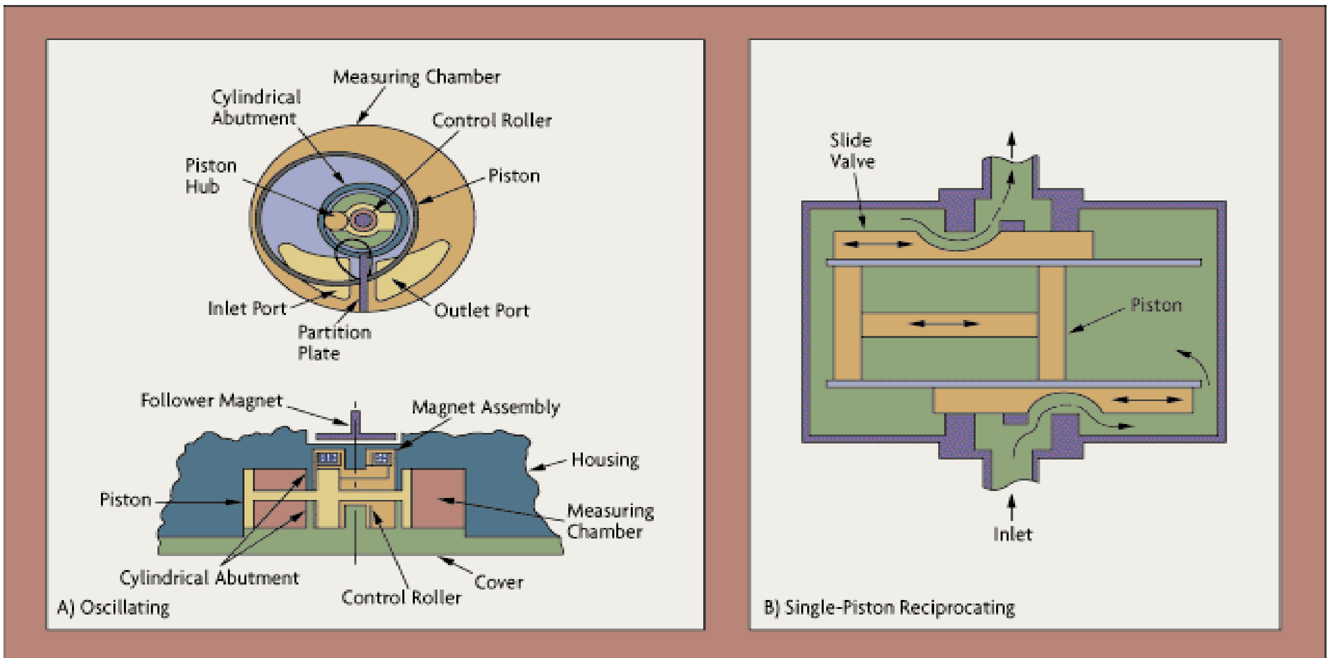


Figure 3-2: Piston Meter Designs

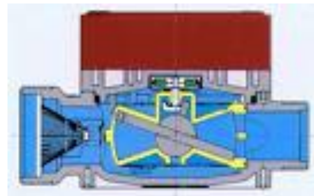
Advantages:

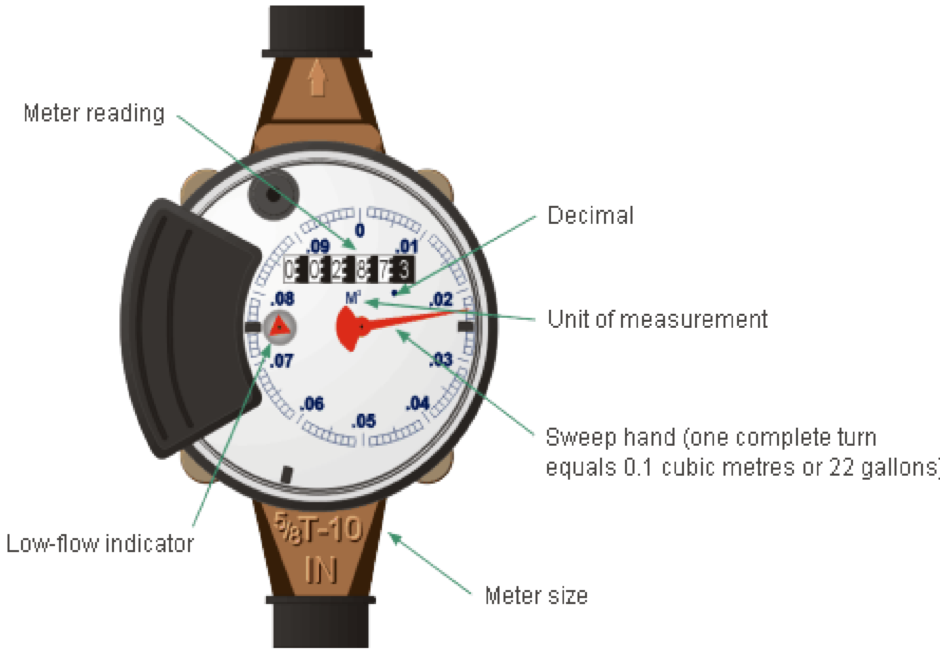
- Measures wide variations of flow rates in preset parameters
- Accurate at measuring low flows

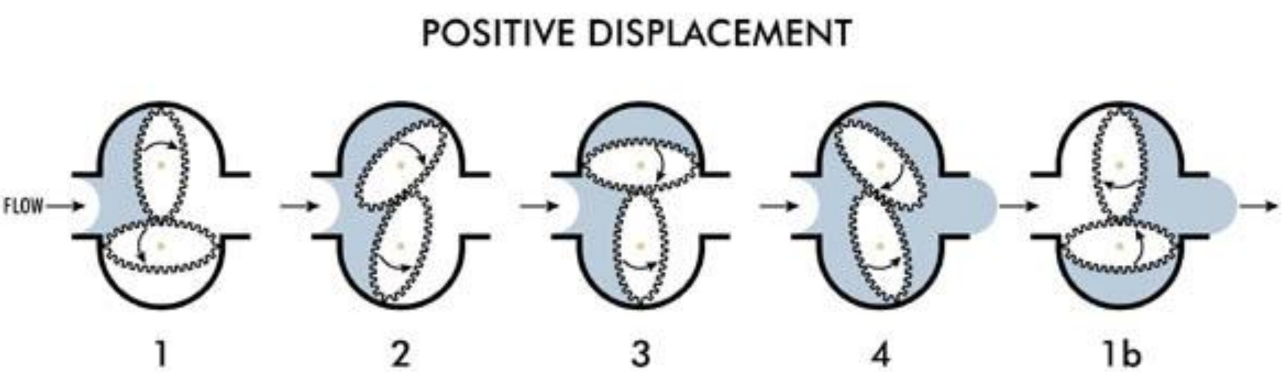
Disadvantages:

- Limited capacity (less accurate at greater sizes)
- Corrosion, scale or other foreign matter will cause meter to under-register or stop

NUTATING DISC



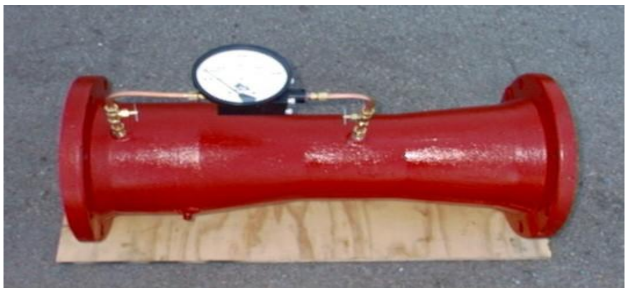




VELOCITY METERS

Normally used for pumps with continuous high-flow rates, main transmission lines, irrigation, industrial and other high-flow applications. Available in sizes anywhere up to 36 inches and above. Most measure the velocity of flow past a known cross-sectional area.

Venturi Meter



Propeller Meter

Turbine Meter

Advantages

- Handles high-flow rates without damage to working parts.
- Rugged and easy to maintain
- Low headloss relative to high-flow rates

Disadvantages

- Unreliable at low flows
- Mainly used for continuous high-flow applications, such as irrigation, industrial, large golf courses and other high-flow applications

COMPOUND METERS

High-flow

Low-flow

- ✓ Used for accurate measurement of widely varied flows
- ✓ Combines both the velocity and displacement meters into one unit
- ✓ The amount of headloss controls which unit is being utilized during a given time

Advantages

- Will measure a wide variance of flows from entities, such as hospitals, distilleries, factories, etc.

Disadvantages

- Friction or headloss is higher than velocity meters
- Accuracy is limited during changeover from one meter to the other
- Large, heavy, cumbersome and expensive

ELECTRONIC METERS

Measures a differential in electrical (magnetic) current passing through a cross-sectional area.

SONIC METERS

Uses sound waves to measure the flow of water

Advantages

- Very accurate
- No headloss

Disadvantages

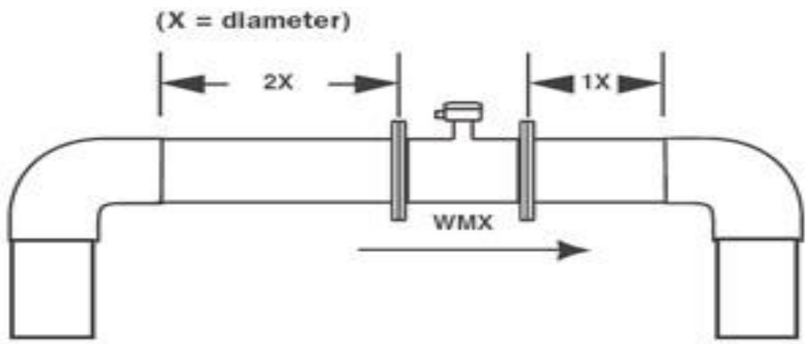
- Accuracy diminishes by anything that changes the velocity of the water. (i.e. pumps, valves, elbows).
- At least ten (10) diameter lengths of unobstructed pipeline upstream are needed from the flow meter to be considered useful and accurate.

PROPORTIONAL METERS

- A certain amount of the total flow is diverted and measured through a second bypass meter
- The register that displays the usage is proportionally geared
- Relatively accurate except for low flows
- Principally used for fire lines

MAG METERS

A magnetic flow meter (mag flowmeter) is a volumetric flow meter that does not have any moving parts. The operation of a magnetic flowmeter is based upon Faraday's Law, which states that the voltage induced across any conductor as it moves at right angles through a magnetic field is proportional to the velocity of that conductor. For obtaining viable measurements, there should be a length of straight pipe 2 times the diameter of the meter in front of the mag meter and a length of pipe equivalent to 1 times the diameter of the meter after the placement of the meter. Elbows within this range will negatively affect the accuracy of the flowmeters.



<u>Faraday's Formula:</u>

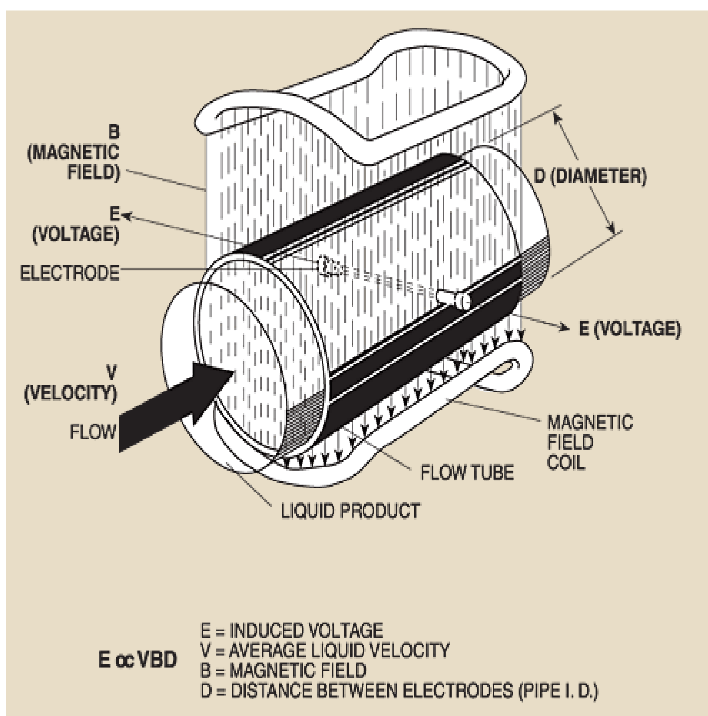
***E** is proportional to **V** X **B** X **D** where:*

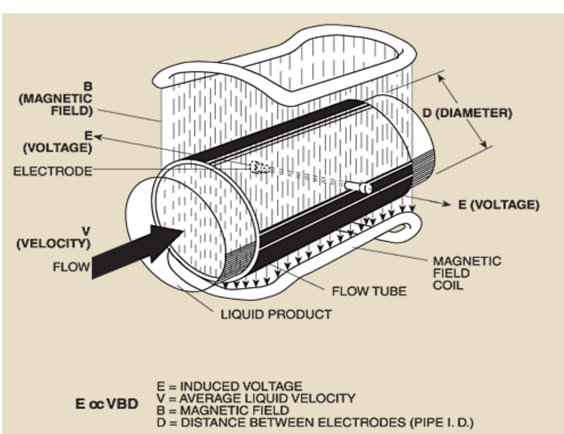
E = voltage generated in a conductor

V = velocity of the conductor

B = magnetic field strength

D = length of the conductor





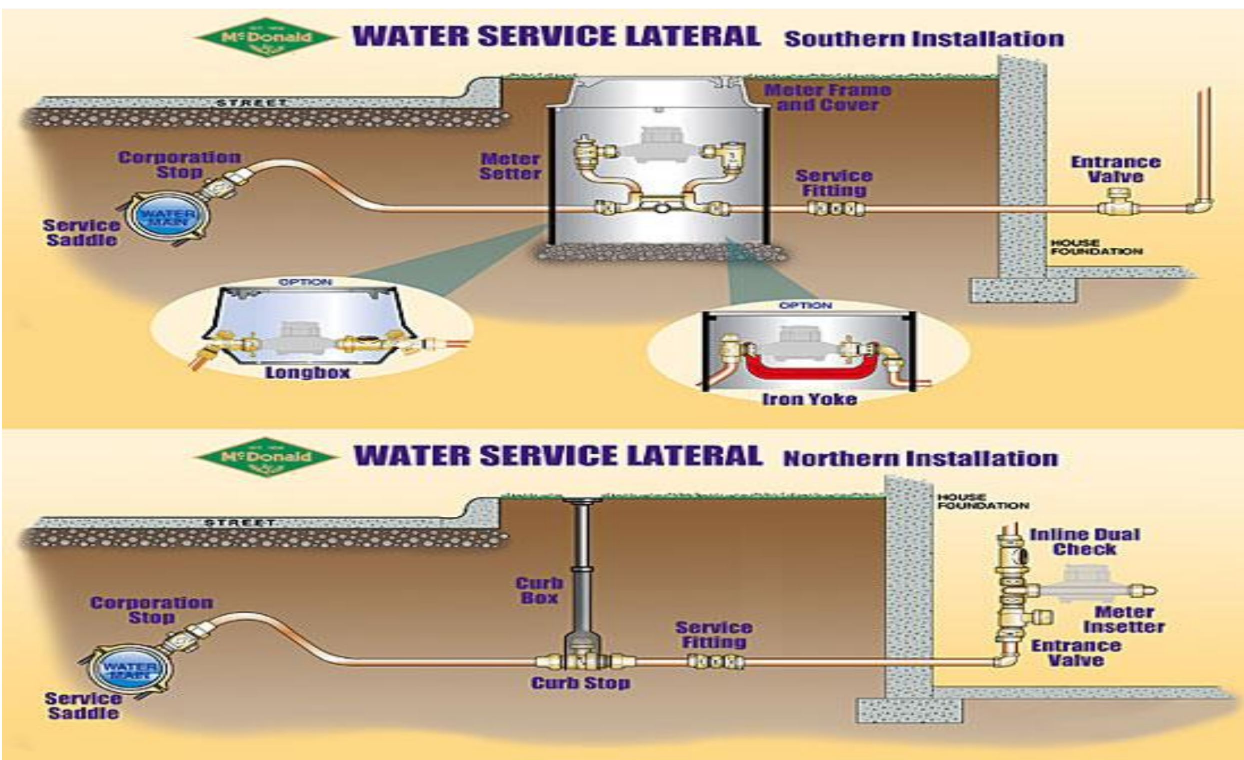
Accuracy Requirements for New Meters[a b]

AWWA Standard Designation and Type of Meter	At Normal Test Flow %	At Minimum Test Flow %
C700 Displacement Type	98.5 – 101.5	95
C701 Turbine Type	98.0 – 102.0	Not Required
C702 Compound Type[c]	97.0 – 103.0	95
C703 Fire Service Type[c]	97.0 – 103.0	95
C704 Propeller Type	98.0 – 102.0	95

a. AWWA Standards

b. There is no standard for the accuracy of repaired meters, but the practice at many utilities is to require the same accuracy as for new meters at the normal test flow and at least 90 percent at the minimum test flow.

c. The accuracy during the "change over period," which is defined in the applicable standards, shall not be less than 85 percent.



*****Water meters should be installed behind the curb and protected in a meter vault.*****

Chapter 11 Math Review

Water Demand

Monkeys Eyebrow's 4800 residents use on average 190,000 gallons of water a day. What would the average daily water demand per resident be for the month of June?

a. 40 gallons
b. 175 gallons
c. 1187.5 gallons
d. 467.6 gallons

Water Loss

- The United States possesses a 34,000,000,000-gallon-a-day supply.
- 6,000,000,000 gallons of water per day is water loss or non-accounted for public use.
- There are approximately 53,000 water systems in the United States.
- The average water loss is 113,207,540 gallons per system.
- At a rate of $3.00 per thousand gallons, the average revenue loss per system equates to $339,621 per system.

Because so many systems have ignored or under-maintained their distribution systems, these figures can only increase.

Water loss, sometimes referred to as non-accounted for or non-revenue water, is something EVERY water system should be aware of and should also be endeavoring to reduce. The Capacity Development Team from the DOW will scrutinize every system's water loss figures. **<u>An acceptable percentage of water loss is < 15%.</u>** There are a number of different formulas to determine the amount of non-revenue water, but two of the simplest are included below.

1. Tucumcari treated 96 MG during December of 2009. Records indicate that Tucumcari billed 88,673,249 gallons for December 2009. What is their percent of water loss?

   a. 10.8 % b. 7.6 % c. 9.2 % d.12.3 %

96,000,000 gallons treated
<u>-88,673,249 gallons billed</u>
7,326,751 gallons “lost”

7,326,751 gallons ÷ 96,000,000 gallons = 0.076
(to get percentage, multiply .076 X 100 = 7.6%)

2. Pigeon Drop billed 31, 928,735 gallons in November of 2009 and treated 37,264,048 gallons. What is the percent water loss if the meter error has been determined to be 2%?
   a. 14% b. 12% c. 10% d. 8%

37,264,048 gallons treated
<u>-31,928,735 gallons billed</u>
5,335,313 gallon difference

5,335,313 gallons non-accounted for water
÷
37,264,048 gallons treated = 0.14 or 14%

14% non-revenue water – 2% meter error = 12% water loss

Meter Installation Chart

Date Purchased_____________ Brand ________________ Type ______________ Cost________

Install Date	Min Flow	Int Flow	Max Flow	% accuracy before repair	% accuracy after repair	Cost of Repair	Tested by

Remarks:

CHAPTER 11 REVIEW QUESTIONS

1. Which meters have no moving parts?

2. What happens when you install an undersized meter in a supply line?

3. The two types of meters commonly used for residential services are the

   ______________________ and the ________________ ____________________.

4. When a meter has excessive wear, what will be the results in relation to registering flow?

5. Which meters have the lowest headloss?

6. If the city of Rays treated 117.8 MG of water during the month of May and their non-accounted water totaled 2,238,200 gallons, what is your water loss percentage?

Answers for Chapter 11 Review

1. Venturi, Mag Meter

2. It under registers

3. Nutating disc and piston

4. Under registers

5. MAG and Sonic Meters

6. $\frac{117,800,000}{2,238,200} = 19\%$

Chapter 12: BASIC HYDRAULICS

Chapter 12 Objectives

1. Identify the major hydraulic concerns for a groundwater system.
2. Demonstrate the ability to calculate flow (velocity and cross-sectional area) in gpm for different sizes of pipes.
3. Differentiate between several concepts related to basic hydraulics (psi versus head; pressure versus velocity) and describe the major hydraulic concerns of water systems.
4. Describe the hydraulic grade line as it relates to pressure and elevation head.
5. Explain and calculate the “C” factor using Williams & Hazen’s formula while describing equivalent flow, the rule of continuity, and pressure loss from undersized piping.
6. Calculate continuity.

The major hydraulic concerns of a water distribution system are

1. Will water flow?
2. In what direction?
3. With sufficient pressure?

In Kentucky, the minimum design pressure is 30 psi and the minimum working pressure is 20 psi. When pressure falls below 20 psi, public notification is mandatory by regulation. Accomplishing these hydraulic goals can be a difficult task, especially in terrain that includes substantial changes in elevation, which are present in our state.

Flow Rate Calculations

Q = A X V

Q = FLOW expressed as ft^3/sec (cubic feet/second)

V = VELOCITY expressed as fps (feet per second)

A = CROSS-SECTIONAL AREA expressed as ft^2

Flow is volume/time. Can be expressed as:

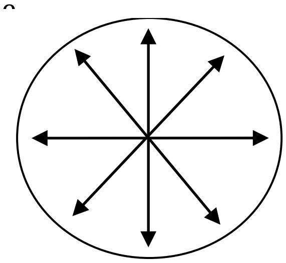
- gallons per minute (gpm)
- million gallons a day (MGD)

Velocity is speed or time/distance. Can be expressed as:

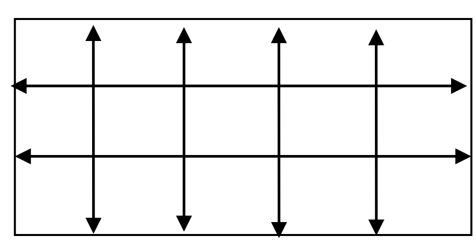
- feet per second (fps)
- yards per hour
- blocks per day

Area is a two-dimensional measurement. In this equation, we calculate the cross-sectional area. All we are concerned with in this equation relative to area is a two-dimensional measurement.

.785 X D (ft) X D (ft) for a circle



Length X Width for a rectangle



Anytime you have a measurement notated in inches, we must convert it to feet in order for us to calculate a correct answer. All that is needed to convert inches to feet is to divide by 12, which is how many inches are contained in a foot. Here are some examples:

8 inches is .666 feet	(8 inches ÷ 12 inches)
2 inches is .166 feet	(2 inches ÷ 12 inches)
42 inches is 3.5 feet	(44 inches ÷ 12 inches)

Area Examples

1. What is the cross-sectional area of a 16 inch pipe?

The formula to obtain this is .785 X D (in feet) X D (in feet)

Area = .785 X (16 inches ÷ 12 inches) X (16 inches ÷ 12 inches)
Area = .785 X 1.33 ft X 1.33 ft
Area = 1.4 ft^2 (actually 1.3885865 rounded up)

So, the cross-sectional area for a 16 inch pipe is 1.4 ft^2

2. Water is flowing through a 4 foot long by 2 feet wide by 3 feet deep trench at 1.9 feet per second. What is the flow?

Q = A X V
Q (flow) expressed as ft^3/sec = (4 ft X 2 ft) X 1.9 fps
Q (flow) expressed as ft^3/sec = 8 ft^2 X 1.9 fps

A = 15.2 ft^3 (cubic feet per second)

Since we are figuring area (a two-dimensional measurement), we do not need to use the depth into the equation for the question above.

3. The flow through a 10 inch water line is 4.4 ft^3/sec. What is the velocity of this water?

$V = Q \div A$

V (velocity) expressed as feet per second (fps) = Q (flow) $ft^3/sec \div$ A (area) ft^2

$V = 4.4\ ft^3/sec\ (flow) \div (.785 \times (10" \div 12") \times (10" \div 12"))$

$V = 4.4\ ft^3/sec \div (.785 \times .83'\ (ft) \times .83'\ (ft))$

$V = 4.4\ ft^3/sec \div .54\ ft^2$

V = 8.1 fps (feet per second)

4. The flow through a 22 inch pipe is 3142 gpm. What is the velocity?

$V = Q \div A$

In order to satisfy the equation, we have to convert 3142 gpm into ft^3/sec

The conversion sheet shows that 1 ft^3/sec = 448.8 gpm

$V = (3142\ gpm \div 448.8\ gpm) \div .785 \times (22" \div 12") \times (22" \div 12")$

$V = 7\ ft^3/sec \div (.785 \times 1.83' \times 1.83')$

$V = 7\ ft^3/sec \div 2.6\ ft^2$

V = 2.69 or 2.7 fps

Practice Examples

1. The flow through the 36 inch main transmission line in the community of Getz is 3.6 MGD. What is the velocity of the water through this pipeline?

2. Water is traveling through a 4 inch pipe at 0.7 fps. What is the flow in this pipe expressed as gpm?

3. You are preparing to attach a line extension to a 12 inch pipe when the track hoe operator punctures the existing line. It took 3 minutes for water to travel through the trench that was 4 feet deep, 3 feet wide and 200 feet long. What is the velocity of this water?

4. Water is flowing through a completely filled 24 inch water main at 75 feet per minute. What is the flow in this pipeline?

5. In order for your new pump to work efficiently it needs a minimum of 700 gpm to be pumped through it. The line attached to the pump is 18 inches, and the water is flowing at 1.1 fps. How many gallons per minute are moving through the new pump?

Solutions

1) $V = Q \div A$
$V = (3.6\ MGD \times 1.55\ ft^3/sec) \div .785 \times (36" \div 12") \times (36" \div 12")$
$V = 5.58\ ft^3 \div (.785 \times 3' \times 3')$
$V = 5.58\ ft^3/sec \div 7.07\ ft^2$
V = 0.8 (actually 0.789) fps

2) $Q = A \times V$
$Q = .785 \times (4" \div 12") \times (4" \div 12") \times 0.7$ fps
$Q = (.785 \times .33' \times .33') \times 0.7$ fps
$Q = 0.085\ ft^2 \times 0.7$ fps
$Q = .0595\ ft^3/sec$ How many gallons per minute would that be? 26.7 gpm

3) If it takes 3 minutes (180 seconds) for the water to travel 200 feet, then we could say that the water was traveling at a rate of 1.1 fps (200 feet ÷ 180 seconds).

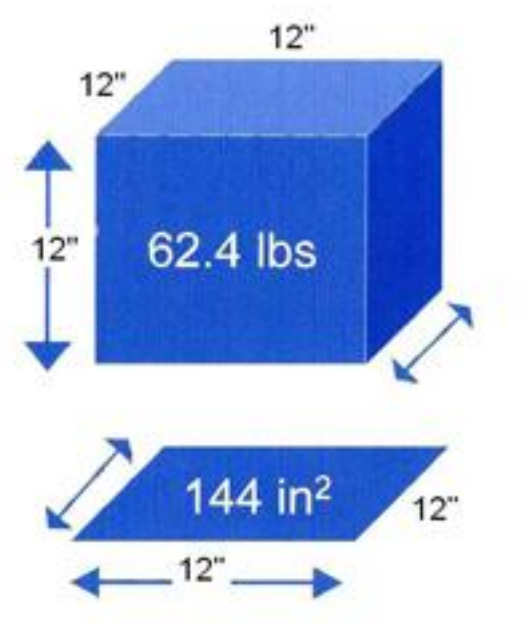
4) $Q = A \times V$
$Q = (.785 \times 2' \times 2') \times 1.25$ fps which has been converted from 75 feet per minute
$Q = 3.14\ ft^2 \times 1.25$ fps
$Q = 3.9\ ft^3/sec$

5) $Q = A \times V$
$Q = (.785 \times (18" \div 12") \times (18" \div 12")) \times 1.1$ fps
$Q = .785 \times 1.5' \times 1.5' \times 1.1$ fps
$Q = 1.94\ ft^3/sec$
Q= Converting to gpm $1.94\ ft^3/sec \times 448.8$ gpm = 870.6 gpm
Q = 870.6 gpm

Hydraulics

Hydraulics is the branch of engineering that focuses on the practical problems of collecting, storing, measuring, transporting, controlling and using water or other liquids. Liquids in motion produce forces and pressure whenever the velocity, flow direction or elevation changes. Knowing pipe pressure and flow along certain points in our distribution systems can help determine the proper pipe size and sufficient capacity. These parameters can also help determine what pipe material would work best in certain situations. In addition, having an understanding of hydraulics can help systems determine if pressure reducers or pumps are necessary to transport water in an efficient manner. Also, a basic understanding of hydraulics can save money, improve water quality, ensure regulatory compliance and help determine the cost and viability of distribution system improvements.

Some of the operational concerns than confront the successful delivery of our water are elevational changes in the topography (elevational head), energy lost through the transmission of the water through the pipelines (frictional head), (velocity head) and pressure requirements that have to be maintained to ensure water quality and regulatory compliance. Understanding that water has a unit weight is important. Water has a unit weight of 8.34 lbs per gallon or 62.4 lbs/ft^3.



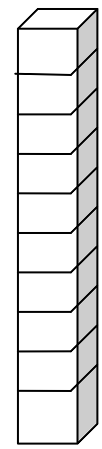
1 cubic foot of water (1 ft X 1 ft X 1 ft) weighs 62.4 lbs.

If it rests on 1 square foot or 144 square inches, then it exerts 0.433 **p**ounds per **s**quare **i**nch. (psi). Pressure is derived by the formula as Force/Area.

$$P = \frac{F}{A} = \frac{62.4 \text{ lbs.}}{144 \text{ sq. in.}} = 0.433 \text{ PSI}$$

Therefore, one square foot of water exerts 0.433 psi.

Now consider 10 feet of water. 10 cubic feet of water weighs 624 lbs if it rests on 1 square foot or 144 square inches.



$$P = \frac{F}{A} = \frac{62.4 \text{ lbs./ft}^3 \text{ x } 10 \text{ ft}^3}{144 \text{ sq. in.}} = 4.33 \text{ PSI}$$

To determine pressure (psi) in relation to a column of water, use "H" (height) in feet of water. If a standpipe held 80 feet of water and the pressure gauge was at the base of the tank, then

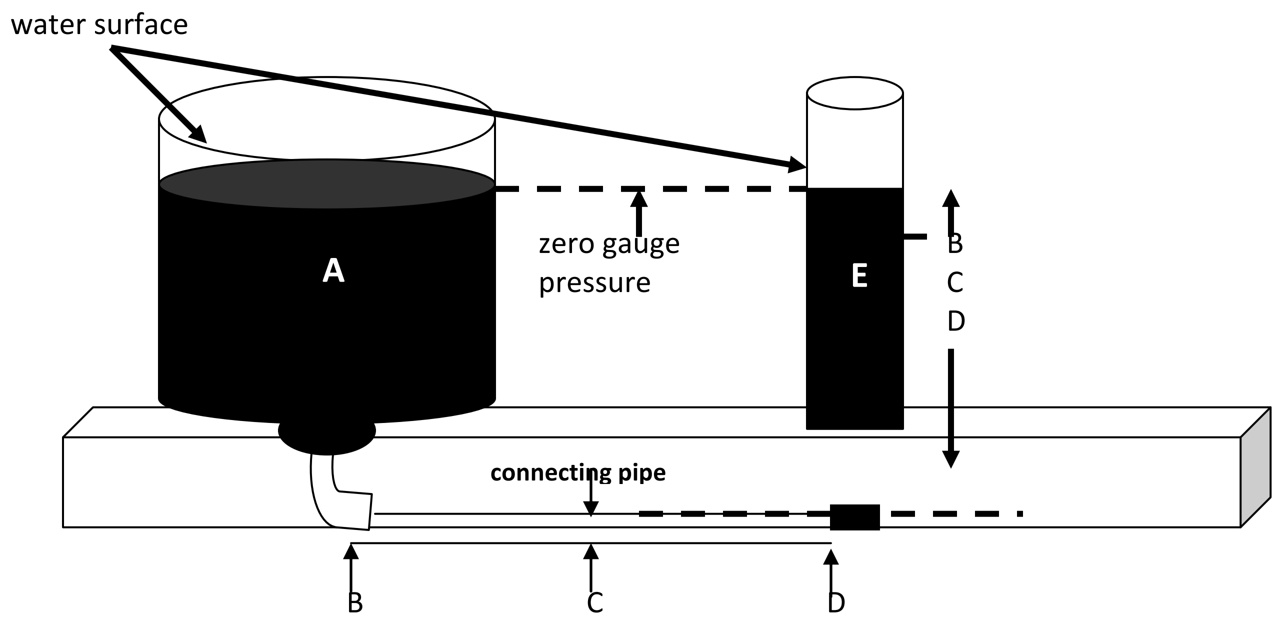
Pressure (psi) = Height of water column X 0.433 psi

Pressure = 80 ft of water X 0.433 psi

Pressure = 34.64 psi

Water exerts force and pressure when it is confined in any type of structure. In our business, the types of structures we commonly use are pipes and tanks.

There is a difference between force and pressure. Pressure is defined as force per unit area, commonly expressed as pounds per square inch (lb/in^2 or psi).



The pressure at point **A** equals the pressure at point **E**, since these points are the depth in the water. Likewise, the hydrostatic pressure at points **B**, **C**, and **D** are equivalent.

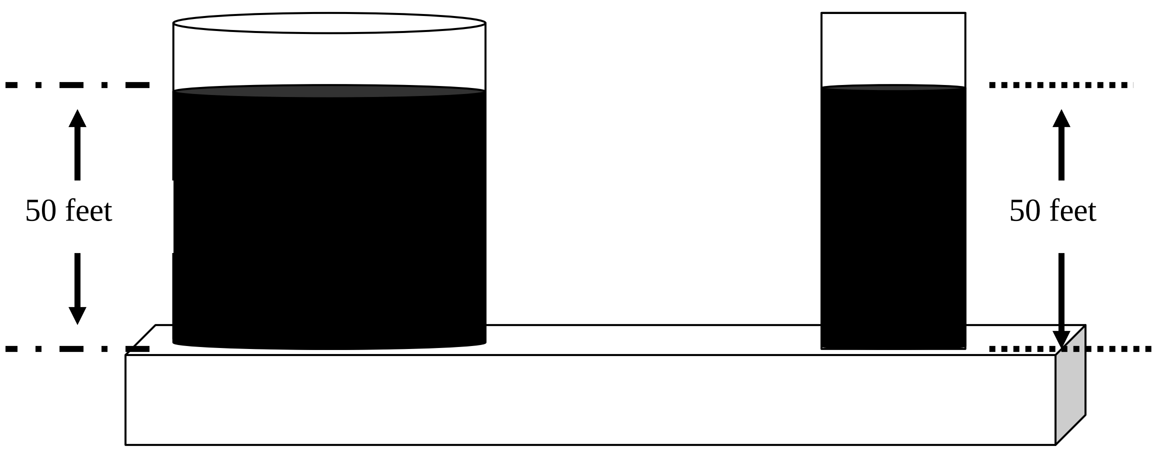
Hydrostatic Pressure

The pressure water exerts is called hydrostatic pressure.

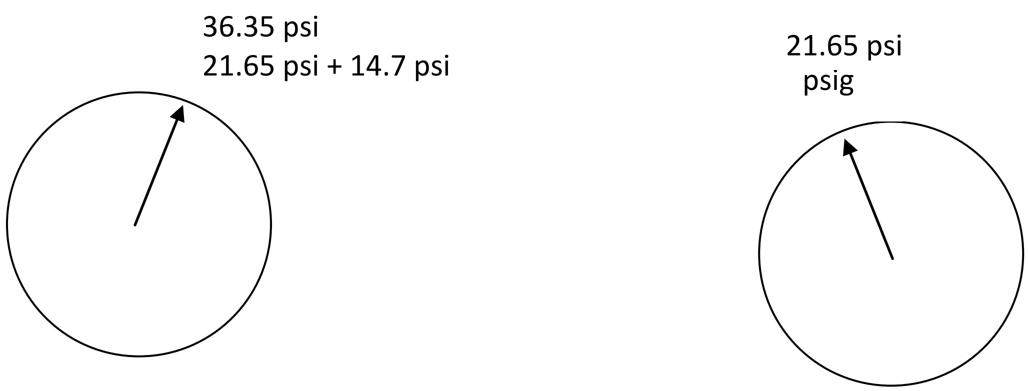
These principles always apply to hydrostatic pressure.

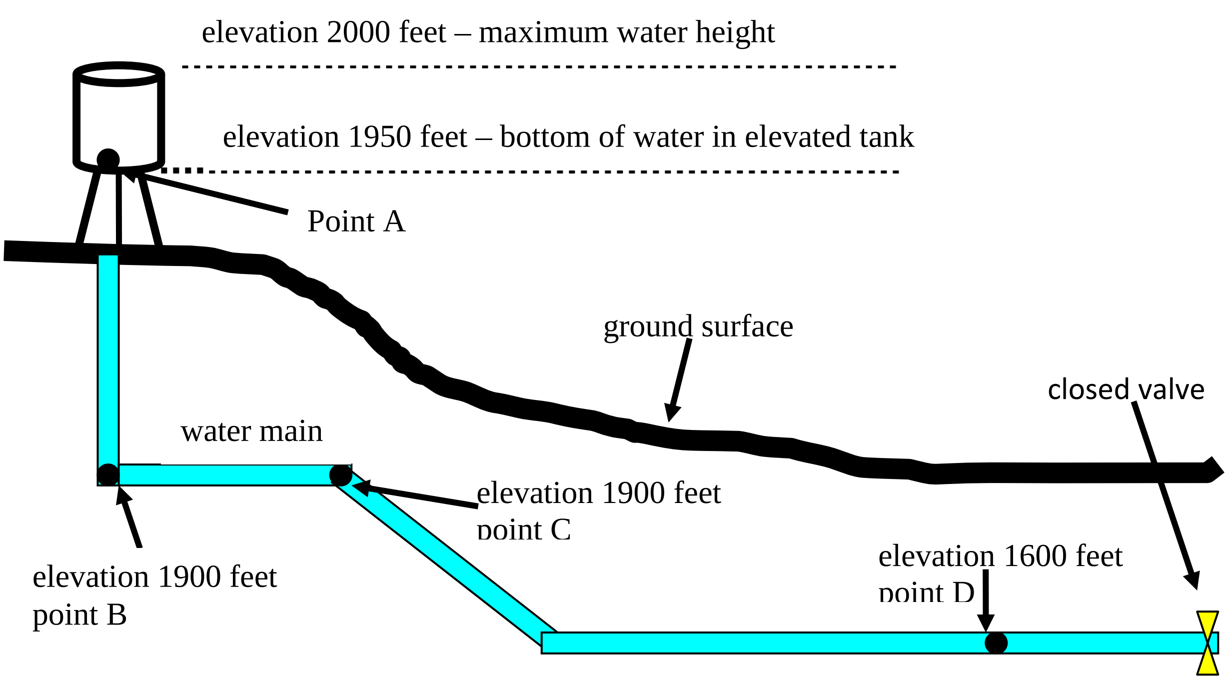
1. Pressure depends only on the depth of water above the point in question (not on the water surface area).
2. Pressure increases in direct proportion to the depth of water.
3. Pressure in a continuous volume of water is the same at all points that are at the same depth or elevation.
4. Pressure at any point in the water acts in all directions at the same magnitude.

Pressure also exists at the surface of the water because of the weight of the air above. This pressure is called atmospheric or barometric pressure. Atmospheric pressure at sea level is 14.7 psi. In practical applications for the distribution operator, atmospheric pressure is NOT used for hydraulic calculations and is considered to be a zero reference or starting point. The application that uses atmospheric pressure is called absolute pressure, as opposed to gauge pressure.



Here we have two storage tanks side by side with different volumes. Even though these tanks have differing volumes, the pressure is the same because the column of water in each tank is the same. Hydrostatic pressure depends solely on the height of water above given points and NOT on the volume of water. In this above illustration, the pressure at the base of each tank is 21.65 psi. (50 feet X .433 psi) If whatever pressure gauge we used included atmospheric pressure, they would NOT read the same.





Example 1

A small water system has an elevated water storage tank and connecting ductile iron pipeline as shown in the illustration above. Calculate the hydrostatic pressure at points A, B, C, D.

A. 2000 feet – 1950 feet = 50 feet elevational difference. 50 ft X 0.433 psi = 21.65 psi

B. The total depth of the water at point B is 2000 feet – 1900 feet = 100 ft
100 feet X 0.433 psi = 43 psi or lbs/in^2

C. The pressure at point C is the same as point B because there is no elevational difference.

D. The total depth of the water above point D is 2000 feet – 1600 feet = 400 feet
400 feet X 0.433 psi = 173.2 psi or lbs/in^2

Example 2

Another issue that is becoming more commonplace is providing a water service for a customer with a house at the top of a hill. In this example, a 6-inch main provides the line to be tapped for the service line. The pressure at the water meter is 51 psi. The house sits on a hill and through topographic maps the meter is at an elevation of 325 feet and the house is at an elevation of 405 feet.

Calculate the pressure drop from the meter to the house.

325 feet – 405 feet = - 80 feet
- 80 feet X 0.433 = - 34.64 psi
51 psi – 34.64 psi = 15.36 psi

Let's take this a step further. This house has a bathroom on the second floor. Estimate another 10 feet of elevation to the second floor. So, there is an additional 10 feet of elevation, which will result in an additional 4.33 psi pressure drop up to the second floor bathroom.

If we add the 4.33 psi to the 34.64 psi pressure drop, our total pressure drop is 34.64 psi + 4.33 psi for a total of 38.97 or 39 psi.

Our starting measurement of 51 psi – 39 psi (pressure drop) means that the water in the second floor bathroom would be measured at approximately 12 psi.

In the above example, it would most likely be wise to inform the customer that the water pressure in their house will be low. ALSO, explain to the customer that THEY can INSTALL and MAINTAIN a small booster pump to increase pressure. This is done at THEIR expense, not the utility's expense.

Example 3

The inverse of this situation could very well arise. A customer has a house in a valley with an elevation 156 feet below the connecting point at the main. The pressure reading at the meter is 94 psi.

What would the pressure be at the service connection entrance to the house?
P (pressure) = 0.433 X Height
P = 0.433 X 156 ft
P = 67.55 psi

Pressure reading at the meter 94 psi + additional pressure gained by elevation gained equals 67.55 psi.

94 psi + 67.55 psi = 161.55 psi at the service entrance to the house.

It is sometimes more convenient to express pressure in terms of the height of a column of water in feet. This is called pressure or elevational head and is the actual or equivalent height of water above the point in question.

For example, when evaluating a water distribution system to determine how high the pressure will push the water up a hill. By turning the equation around, we get:
H = P ÷ 0.433 or by using your conversion sheet, which dictates that every 1 psi is equivalent to 2.31 ft of head. (The 2.31 comes from dividing 1 by 0.433, which gives you 2.309 or 2.31.)

So if we had to overcome a rise in elevation of 65 feet and our starting pressure at the main is 65 psi, then we could take 65 psi ÷ 0.433 psi, which equals 150.1 feet.

OR

Multiply the pressure in psi (65) X 2.31 ft of head, which equals 150.1 ft of head.

So theoretically, the water in the main could rise to a height of 150.1 feet, which is equivalent to 65 psi.

If we had to overcome a 65 rise in elevation and our starting pressure was 65 psi, we could determine what the pressure would be at the crest or apex of the hill.

Starting pressure of 65 psi minus the elevational difference in feet (65 feet) X 0.433 psi means that we would loose 28.1 (65 psi X 0.433 psi) psi, overcoming the 65-foot hill.

If we start at the bottom of the hill with 65 psi and subtract the 28.1 psi, we would loose that energy overcoming the elevational difference and the theoretical pressure at the top of the hill would be 36.9 or 37 psi (65 psi – 28.1 psi = 36.9 or 37 psi).

Hydraulic Grade Line

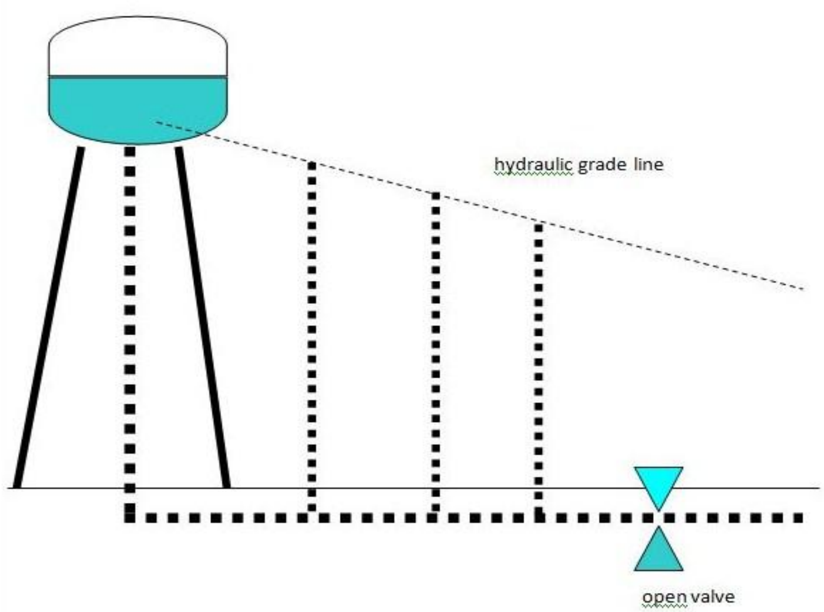
The hydraulic grade line is an imaginary line that displays the sum of the pressure head and the elevational head. The hydraulic head represents the height to which a water column would rise in open standpipes.

A **static** condition means the water in the pipeline is NOT moving, but is stationary.

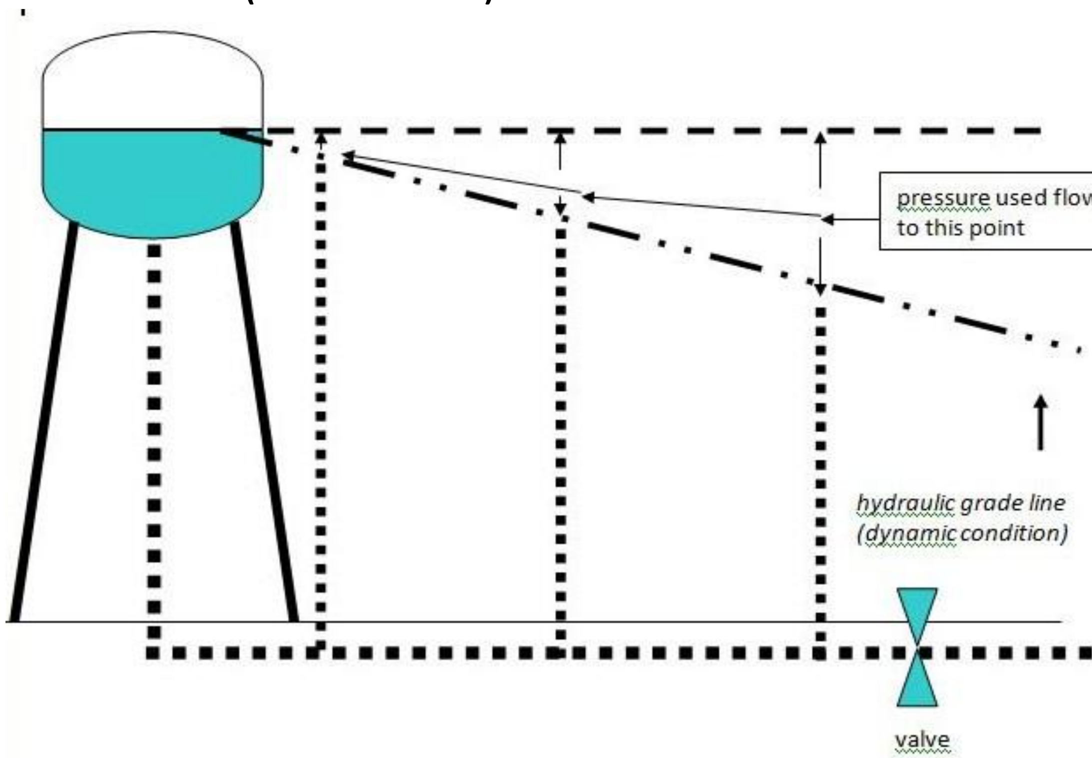
A **dynamic** condition indicates that the water is moving and impacting all the entities that are affected by the movement of water.

Water will flow from the area of higher pressure to areas of lower pressure. This is the principle of how our distribution system works. In the static condition, water is not moving. In the dynamic or kinetic condition, water is moving through the pipelines. Different factors impact the water whether it is in a static or dynamic condition.

Hydraulic Gradeline of Water in Motion (Dynamic or Kinetic Condition)



Hydraulic Grade Line (Static Condition)



C Factor or Values

The "C" Factor or Value denotes the interior smoothness of a pipe. These factors are given a numerical value in order to determine the amount of energy lost in a pipeline due to friction. The energy losses are usually expressed as loss in feet of head, loss in psi, or loss in the velocity of the water in the pipe. The higher the "C Factor," the higher the number associated with it.

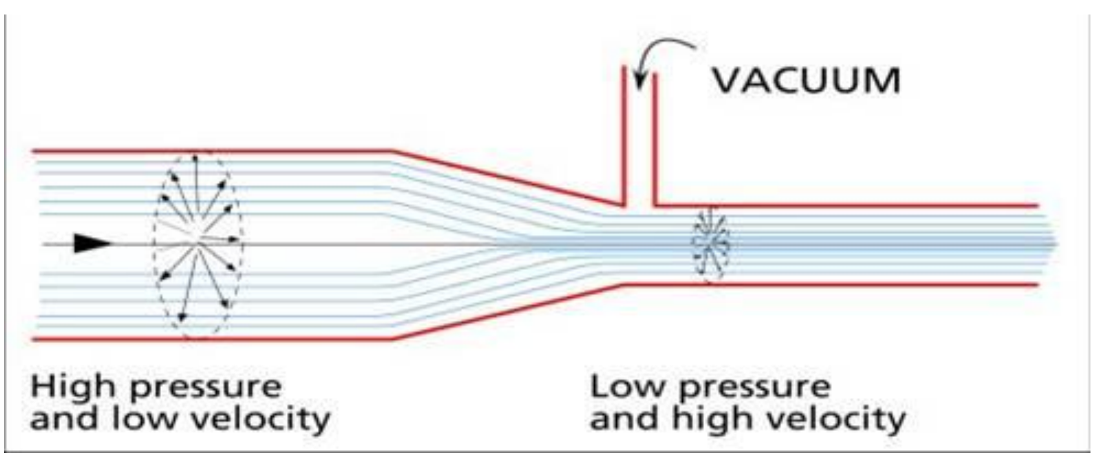
Common Friction Factor Values Used for Design Purposes

Asbestos Cement	140
Cast Iron (new)	130
Cast Iron (40 yr old)	62
Copper Tube	130
PVC Pipe	140
Steel Pipe	120
Ductile Iron Pipe (lined)	140

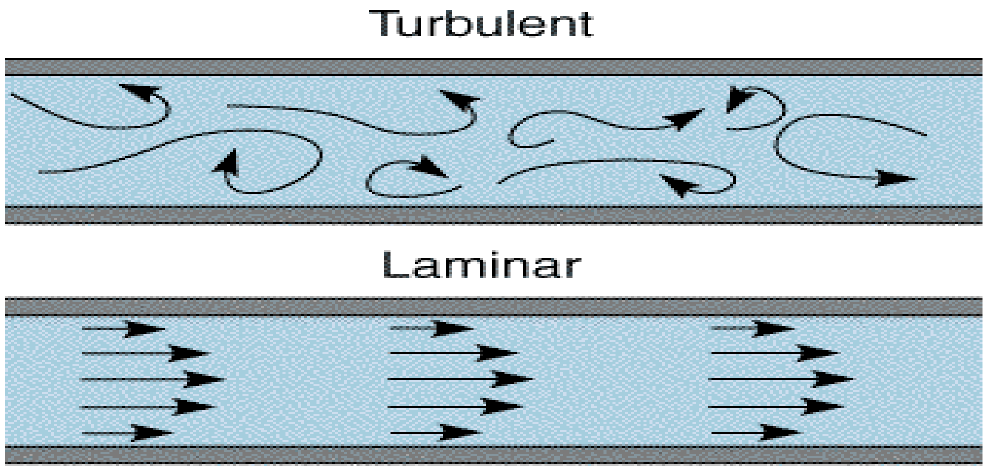
WHICH PIPE WOULD HAVE THE HIGHEST C FACTOR?

A common misconception is that pressure increases when the pipe size decreases. Decreasing pipe diameter will increase the velocity, but will reduce the flow rate of the water – meaning that as the pipe size decreases, the water merely travels faster. The friction created by a liquid flowing in a pipe depends upon its **velocity** and the **diameter of the pipe**.

- Friction increases as velocity increases.
- Velocity and pressure have an inverse relationship. The faster the velocity, the more energy is lost due to friction between the water and the pipe wall.
- When flow is restricted, velocity increases.



When the interior of a pipe has substantial tuberculation, flow in the pipe turns from laminar to turbulent flow. Turbulent flow requires more energy to deliver the same volume of flow.



When connections or additions to pipelines are needed, some calculations of all the factors that will come into play must be accounted for if we want to maintain the water quality as well as deliver the necessary volume of water at sufficient pressures to our customers. Frequently just throwing a pipe in the ground to deliver water without factoring in all the variables will not accomplish what we need and will most likely make conditions worse for anyone hooked to this new line.

Over the years, engineers have developed a number of ways to determine pressure loss relative to flow demand and pipe size. If we install undersized lines, we run the risk of:

a. not delivering enough pressure to the customer
b. not delivering enough volume to the customer
c. creating backflow incidents
d. degrading water quality

Example

You are going to install a new 6" line to supply water to a new subdivision. The distance from the line you are tapping into to supply this new line all the way to the last house in this subdivision is 2000 feet. There is also an elevational incline of 75 feet to overcome when delivering the water. Pressure at the spot that you are tying the new line to has been measured at 100 psi, and the flow rate you want to achieve in the new pipe is 450 gpm. You are going to valve off each intersection so there will be 6 gate valves installed on this line.

Looking at the chart on the following page, we can determine that for each 100 feet of pipe, we will be adding the equivalent of 2.74 ft of head at 450 gpm. We are installing 2000 feet of pipe, so that would be 20, 100 foot sections. We also need to push the water up 75 feet of incline. As well, the six gate valves will be equivalent to 16 feet of head per valve. Now we can factor in all of these parameters and determine if the six inch line is large enough to accomplish what we need.

20 pipe sections X 2.74 ft of head plus 75 feet of elevational head plus 6 valves @ 16 feet apiece.

20 pipe sections X 2.74 ft of head + 75 ft of head + 96 feet of head = 225.8 ft/head.

Starting pressure 100 psi minus (2.74 ft of head X 0.433 psi) = 2.23 psi. You’re in trouble!

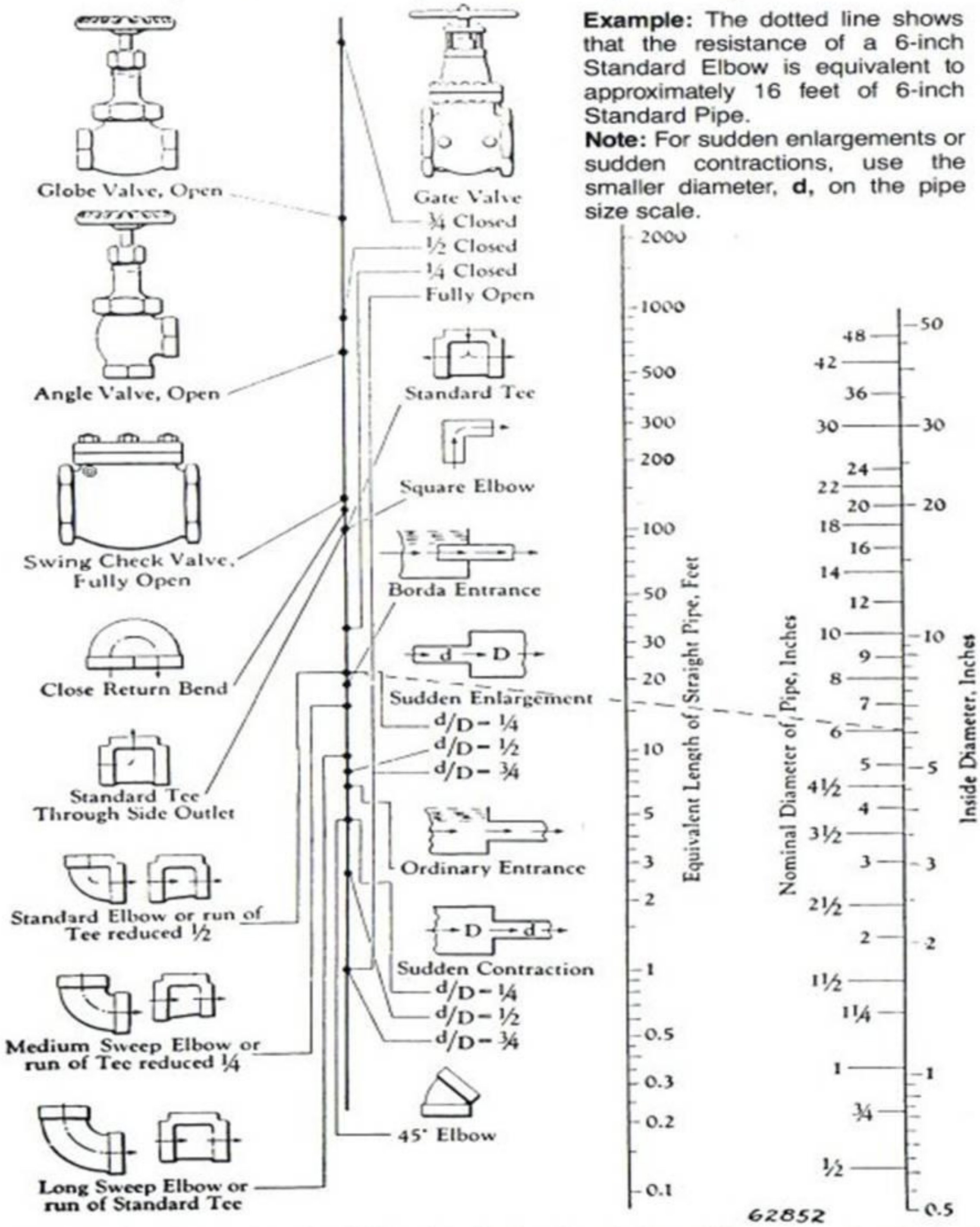
FRICTION LOSS OF WATER IN FEET PER 100 FEET LENGTH OF PIPE. BASED ON WILLIAM & HAZEN FORMULA USING CONSTANT 100. SIZES OF STANDARD PIPE IN INCHES

U.S. Gals. Per Min.	1/2" Pipe		3/4" Pipe		1" Pipe		1 1/4" Pipe		1 1/2" Pipe		2" Pipe		2 1/2" Pipe		3" Pipe		4" Pipe		5" Pipe		6" Pipe		U.S. Gals. Per Min.
	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	Vel. ft. per Sec.	Loss in feet	
2	2.10	7.4	1.20	1.9																			2
4	4.21	27.0	2.41	7.0	1.49	2.14	.86	.57	.63	.26													4
6	6.31	57.0	3.61	14.7	2.23	4.55	1.29	1.20	.94	.56	.61	.20											6
8	8.42	98.0	4.81	25.0	2.98	7.8	1.72	2.03	1.26	.95	.82	.33	.52	.11									9
10	10.52	147.0	6.02	38.0	3.72	11.7	2.14	3.05	1.57	1.43	1.02	.50	.65	.17	.45	.07							10
12			7.22	53.0	4.46	16.4	2.57	4.3	1.89	2.01	1.23	.79	.78	.23	.54	.10							12
15			9.02	80.0	5.60	25.0	3.21	6.5	2.36	3.00	1.53	1.08	.98	.36	.68	.15							15
18			10.84	108.2	6.69	35.0	3.86	9.1	2.83	4.24	1.84	1.49	1.18	.50	.82	.21							18
20			12.03	136.0	7.44	42.0	4.29	11.1	3.15	5.20	2.04	1.82	1.31	.61	.91	.25	.51	.06					20
25					9.30	64.0	5.36	16.6	3.80	7.30	2.55	2.73	1.63	.92	1.13	.38	.64	.09					25
30					11.15	89.0	6.43	23.0	4.72	11.0	3.06	3.84	1.96	1.29	1.36	.54	.77	.13	.49	.04			30
35					13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.10	2.29	1.72	1.59	.71	.89	.17	.57	.06			35
40					14.88	152.0	8.58	40.0	6.30	18.8	4.08	6.6	2.61	2.20	1.82	.91	1.02	.22	.65	.08			40
45							9.65	50.0	7.08	23.2	4.60	8.2	2.94	2.80	2.04	1.15	1.15	.28	.73	.09			45
50							10.72	60.0	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38	1.28	.34	.82	.11	.57	.04	50
55							11.78	72.0	8.66	34.0	5.62	11.8	3.59	4.01	2.45	1.58	1.41	.41	.90	.14	.62	.05	55
60							12.87	85.0	9.44	39.6	6.13	13.9	3.92	4.65	2.72	1.92	1.53	.47	.98	.16	.68	.06	60
65							13.92	99.7	10.23	45.9	6.64	16.1	4.24	5.4	2.89	2.16	1.66	.53	1.06	.19	.74	.076	65
70							15.01	113.0	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57	1.79	.63	1.14	.21	.79	.08	70
75							16.06	129.0	11.80	60.0	7.66	20.9	4.91	7.1	3.33	3.00	1.91	.73	1.22	.24	.85	.10	75
80							17.16	145.0	12.59	68.0	8.17	23.7	5.23	7.9	3.63	3.28	2.04	.81	1.31	.27	.91	.11	80
85							18.21	163.8	13.38	75.0	8.68	26.5	5.56	8.1	3.78	3.54	2.17	.91	1.39	.31	.96	.12	85
90							19.30	180.0	14.71	84.0	9.19	29.4	5.88	9.8	4.09	1.08	2.30	1.00	1.47	.34	1.02	.14	90
95									14.95	93.0	9.70	32.6	6.21	10.8	4.22	4.33	2.42	1.12	1.55	.38	1.08	.15	95
100	8" PIPE								15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96	2.55	1.22	1.63	.41	1.13	.17	100
110									17.31	122.0	11.23	42.9	7.18	14.5	5.00	6.0	2.81	1.46	1.79	.49	1.25	.21	110
120									18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0	3.06	1.17	1.96	.58	1.36	.24	120
130									20.46	166.0	13.28	58.0	8.48	18.7	5.91	8.1	3.31	1.97	2.12	.67	1.47	.27	130
140	.90	.08							22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2	3.57	2.28	2.29	.76	1.59	.32	140
150	.96	.09									15.32	76.0	9.81	25.5	6.82	10.5	3.82	2.62	2.45	.88	1.70	.36	150
160	1.02	.10									16.34	86.0	10.46	29.0	7.26	11.8	4.08	2.91	2.61	.98	1.82	.40	160
170	1.08	.11	10" PIPE								17.36	96.0	11.11	34.1	7.71	13.3	4.33	3.26	2.77	1.08	1.92	.45	170
180	1.15	.13									18.38	107.0	11.76	35.7	8.17	14.0	4.60	3.61	2.94	1.22	2.04	.50	180
190	1.21	.14									19.40	118.0	12.42	39.6	8.63	15.5	4.84	4.01	3.10	1.35	2.16	.55	190
200	1.28	.15									20.42	129.0	13.07	43.1	9.08	17.8	5.11	4.4	3.27	1.48	2.27	.62	200
220	1.40	.18	.90	.06							22.47	154.0	14.38	52.0	9.99	21.3	5.62	5.2	3.59	1.77	2.50	.73	220
240	1.53	.22	.98	.07							24.51	182.0	15.69	61.0	10.89	25.1	6.13	6.2	3.92	2.08	2.72	.87	240
260	1.66	.25	1.06	.08							26.55	211.0	16.99	70.0	11.80	29.1	6.64	7.2	4.25	2.41	2.95	1.00	260
280	1.79	.28	1.15	.09									18.30	81.0	12.71	33.4	7.15	8.2	4.58	2.77	3.18	1.14	280
300	1.91	.32	1.22	.11									19.61	92.0	13.62	38.0	7.66	9.3	4.90	3.14	3.40	1.32	300
320	2.05	.37	1.31	.12	12" PIPE								20.92	103.0	14.52	42.8	8.17	10.5	5.23	3.54	3.64	1.47	320
340	2.18	.41	1.39	.14									22.22	116.0	16.43	47.9	8.68	11.7	5.54	3.97	3.84	1.62	340
360	2.30	.45	1.47	.15			14" PIPE						23.53	128.0	16.34	53.0	9.19	13.1	5.87	4.41	4.08	1.83	360
380	2.43	.50	1.55	.17	1.08	.069							24.84	142.0	17.25	59.0	9.69	14.0	6.19	4.86	4.31	2.00	380
400	2.60	.54	1.63	.19	1.14	.075							26.14	156.0	18.16	65.0	10.21	16.0	6.54	5.4	4.55	2.20	400
450	2.92	.68	1.84	.23	1.28	.95									20.40	78.0	11.49	19.8	7.35	6.7	5.11	2.74	450
500	3.19	.82	2.04	.28	1.42	.113	1.04	.06							22.70	98.0	12.77	24.0	8.17	8.1	5.68	2.90	500
550	3.52	.97	2.24	.33	1.56	.135	1.15	.07							24.96	117.0	14.04	28.7	8.99	9.6	6.25	3.96	550
600	3.84	1.14	2.45	.39	1.70	.159	1.25	.08							27.23	137.0	15.35	33.7	9.80	11.3	6.81	4.65	600
650	4.16	1.34	2.65	.45	1.84	.19	1.37	.09									16.59	39.0	10.62	13.2	7.38	5.40	650
700	4.46	1.54	2.86	.52	1.99	.22	1.46	.10									17.87	44.9	11.44	15.1	7.95	6.21	700
750	4.80	1.74	3.06	.59	2.13	.24	1.58	.11	16" PIPE								19.15	51.0	12.26	17.2	8.5	7.12	750
800	5.10	1.90	3.26	.66	2.27	.27	1.67	.13									20.42	57.0	13.07	19.4	9.08	7.96	800
850	5.48	2.20	3.47	.75	2.41	.31	1.79	.14	1.36	.08							21.70	64.0	13.89	21.7	9.65	8.95	850
900	5.75	2.46	3.67	.83	2.56	.34	1.88	.16	1.44	.084	20" PIPE						22.98	71.0	14.71	24.0	10.20	10.11	900
950	6.06	2.87	3.88	.91	2.70	.38	2.00	.18	1.52	.095									15.52	26.7	10.77	11.20	950
1000	6.38	2.97	4.08	1.03	2.84	.41	2.10	.19	1.60	.10	1.02	.04							16.34	29.2	11.34	12.04	1000
1100	7.03	3.52	4.49	1.19	3.13	.49	2.31	.23	1.76	.12	1.12	.04							17.97	34.9	12.48	14.55	1100
1200	7.66	4.17	4.90	1.40	3.41	.58	2.52	.27	1.92	.14	1.23	.05							19.61	40.9	13.61	17.10	1200
1300	8.30	4.85	5.31	1.62	3.69	.67	2.71	.32	2.08	.17	1.33	.06									14.72	18.4	1300
1400	8.95	5.50	5.71	1.87	3.96	.78	2.92	.36	2.24	.19	1.43	.064	24" PIPE								15.90	22.60	1400
1500	9.58	6.24	6.12	2.13	4.26	.89	3.15	.41	2.39	.21	1.53	.07									17.02	25.60	1500
1600	10.21	7.00	6.53	2.39	4.65	.98	3.34	.47	2.66	.24	1.63	.08			30" PIPE						18.10	26.9	1600
1800	11.50	8.78	7.35	2.96	5.11	1.21	3.75	.58	2.87	.30	1.84	.10	1.28	.04									1800
2000	12.78	10.71	8.16	3.59	5.68	1.49	4.17	.71	3.19	.37	2.04	.12	1.42	.05									2000
2200	14.05	12.78	8.98	4.24	6.25	1.81	4.69	.84	3.61	.44	2.25	.15	1.56	.06									2200
2400	15.32	14.2	9.80	5.04	6.81	2.08	5.00	.99	3.83	.52	2.45	.17	1.70	.07	1.09	.02							2400
2600			10.61	5.81	7.38	2.43	5.47	1.17	4.15	.60	2.66	.20	1.84	.08	1.16	.027							2600
2800			11.41	6.70	7.95	2.75	5.84	1.32	4.47	.68	2.86	.23	1.98	.09	1.27	.03							2800
3000			12.24	7.62	8.52	3.15	6.01	1.49	4.79	.78	3.08	.27	2.13	.10	1.37	.037							3000
3200			13.05	7.8	9.10	3.51	6.68	1.67	6.12	.88	3.27	.30	2.26	.12	1.46	.041							3200
3500			14.30	10.08	9.95	4.16	7.30	1.97	6.59	1.04	3.59	.35	2.49	.14	1.56	.047							3500
3800			15.61	13.4	10.80	4.90	7.98	2.36	60.7	1.20	3.88	.41	2.69	.17	1.73	.05							3800
4200					11.92	5.88	8.76	2.77	6.70	1.44	4.29	.49	2.99	.20	1.91	.07							4200
2500					12.78	6.90	9.45	3.22	7.16	1.64	4.60	.66	3.20	.22	2.04	.08							2500
5000					14.20	8.40	10.50	3.95	8.01	2.03	6.13	.68	3.54	.27	2.26	.09							5000
5500							11.55	4.65	8.78	2.39	5.64	.82	3.90	.33	2.5	.11							5500
6000							12.60	5.50	9.58	2.79	6.13	.94	4.25	.38	2.73	.13							6000
6500							13.65	6.45	10.39	3.32	6.64	1.10	4.61	.45	2.96	.15							6500
7000							14.60	7.08	11.18	3.70	7.15	1.25	4.97	.52	3.18	.17							7000
8000									12.78	4.74	8.17	1.61	5.68	.66	3.64	.23							8000
9000									14.37	5.90	9.20	2.01	6.35	.81	4.08	.28							9000
10000									15.96	7.19	10.20	2.44	7.07	.98	4.54	.33							10000
12000											12.25	3.41	8.60	1.40	5.46	.48							12000
14000											14.30	4.64	9.95	1.87	6.37	.63							14000
16000													11.38	2.40	7.28	.81							16000
18000													12.76	2.97	8.18	1.02							18000
20000													14.20	3.60	9.10	1.23							20000

Friction of Water *(Continued)*
Resistance of Valves and Fittings to Flow of Fluids in Equivalent Length of Pipe

Example: The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Pipe.

Note: For sudden enlargements or sudden contractions, use the smaller diameter, **d**, on the pipe size scale.



From Crane Co. Technical Paper No. 409. Data based on the above chart are satisfactory for most applications; for more detailed data and information refer to pages 3-110 to page 3-120 which are based on Crane Co. Technical Paper No. 410.

3-121

Equivalent Flow Rate Calculation

The Williams and Hazen formula can also be used for C-Values other than 100 by first converting the **actual flow rate** to an **equivalent flow rate** to obtain a C-Factor of 100.

The equation used to find the equivalent flow rate is:

$$\text{Equivalent Flow Rate} = \frac{\text{(Actual Flow Rate) (100)}}{\text{C-Value}}$$

Example

A 10 inch pipeline is 3000 feet long and has a smoothness coefficient (C-Factor) of 130. Water is moving through the pipe at a flow rate of 3900 gpm. Using the Williams and Hazen formula, you can determine the friction head loss.

Since the C-Factor is NOT 100, first use the equation shown above to find the equivalent flow rate.

$$\text{Equivalent Flow Rate} = \frac{\text{(Actual Flow Rate) (100)}}{\text{C-Value}}$$

$$\text{Equivalent Flow Rate} = \frac{\text{(3900 gpm) (100)}}{130}$$

$$\text{Equivalent Flow Rate} = \text{3000 gpm}$$

Now, use the Equivalent Flow Rate to find the friction loss from the Williams and Hazen formula. Find a flow rate of 3000 gpm and then move to the 10 inch column. At that point, the table shows a friction loss of 7.62 feet of head per 100 feet of pipe. The pipeline in the example is 3000 feet long, so now calculate how many 100 foot sections of pipe are contained in 3000 feet. Now multiply this number by the friction loss per 100 foot section of pipe.

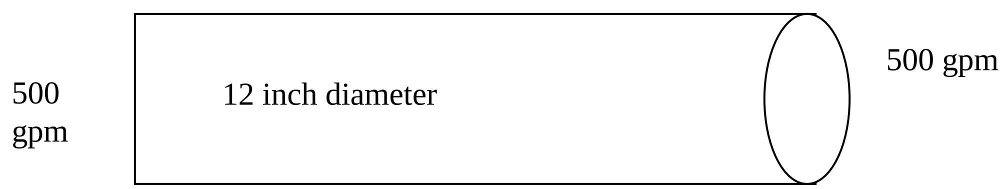
$$(30)\ (7.62) = 228.6 \text{ ft friction loss.}$$

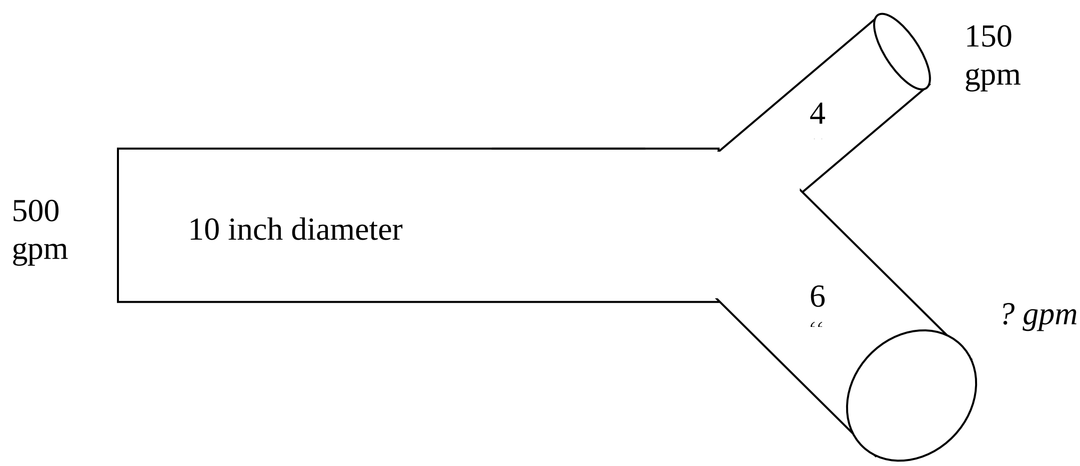
If we wanted to find out how much pressure would be lost through this pipe (assuming it was level and straight with no fittings), we would multiply this figure by 0.433 psi (1 ft of head = .433 psi).

228.6 ft friction loss X .433 psi = 98.98 psi

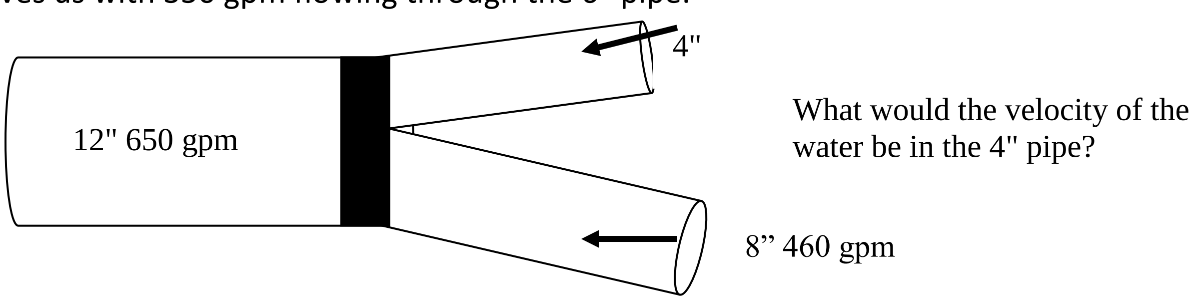
By using the Williams and Hazen formula, we can determine that 98.98 psi would be lost in this 3000 foot pipeline.

Rule of Continuity





What goes in has to come out! What would the flow in the 6 inch pipe be?
If we have 500 gpm coming into the 10" pipe and 150 gpm flowing through the 4" pipe, that leaves us with 350 gpm flowing through the 6" pipe.



V = Q ÷ A
V = 190 gpm (650 gpm – 460 gpm) ÷ (.785 X .33' X .33')
V = .42 ft^3/sec (190 gpm ÷ 448.8 gpm) ÷ .085 ft^2
V = .42 ft^3/sec ÷ .085 ft^2

V = 4.9 fps

Chapter 12 Review

1. The hydraulic grade line is an ___________ line that denotes how high water would rise in a freely vented standpipe.

2. The C-Factor refers to energy lost moving water because of _______ factors.

3. In a pressurized pipeline, when velocity increases _______ decreases.

4. The terms kinetic and dynamic refer to water that is _________.

5. Velocity and pressure have an _______ relationship.

6. Water is flowing through a 10" line at a velocity of 2.5 fps. What is the flow?
    a. 4.8 ft^3/sec
    b. 2.9 ft^3/sec
    c. 610 gpm
    d. 1.36 ft^3/min

Chapter 12 Answers

1. Imaginary

2. Friction

3. Pressure

4. Moving

5. Inverse

6. Q= A x V
   Q= (.785 x .833 x .833) x 2.5 fps
   Q= .544 ft^2 x 2.5 fps
   Q= 1.36 ft^3/sec or 610 gpm

Chapter 13: PUMPS

Chapter 13 Objectives

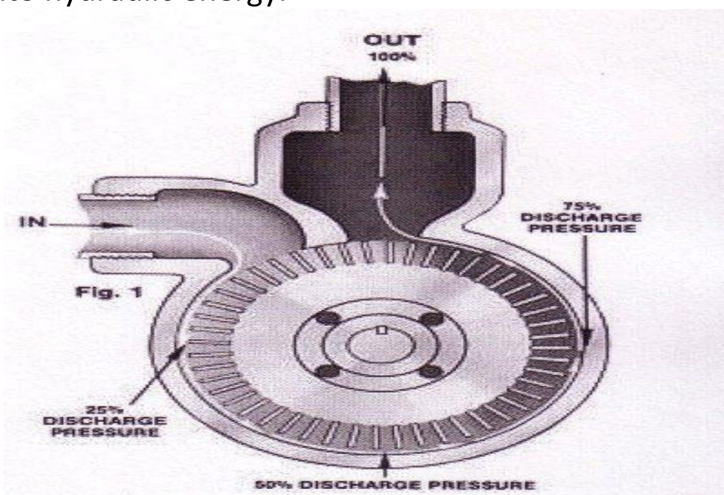
1. Compare and contrast the different types of pumps by describing the functions, advantages and shortcomings of each type of pump.
2. Explain the parts of a centrifugal pump and describe how it works by describing hydraulic efficiency, horsepower, NPSHR, and NPSHA.
3. Describe pump curves and calculate horsepower formulas related to pumps.
4. Explain what cavitation causes.
5. Determine horsepower by using the correct mathematical formulas.

Types Of Pumps and Their Function

APPLICATION	FUNCTION	PUMP TYPE
Low Service	To lift water from the source to the treatment process or from storage to filter backwashing system.	Centrifugal
High Service	To discharge water under pressure to the distribution system.	Centrifugal
Booster	To increase pressure in the distribution system.	Centrifugal
Well	To lift water from shallow or deep wells and discharge it to the treatment plant, storage facility, or distribution system.	Centrifugal Or Jet
Chemical Feed	To add chemical solutions at the desired dosages for treatment or disinfection processes	Positive Displacement
Sampling	To pump water from sampling points to the lab or to automatic analyzers.	Positive Displacement Or Centrifugal
Sludge	To pump sludge from the sedimentation facilities for further treatment or disposal.	Positive Displacement Or Centrifugal

What is a centrifugal pump?

It is a machine that imparts energy to a fluid, causing it to flow, rise to a higher level, or both. It actually uses acceleration (not centrifugal force) to transform mechanical (rotational) energy into hydraulic energy.



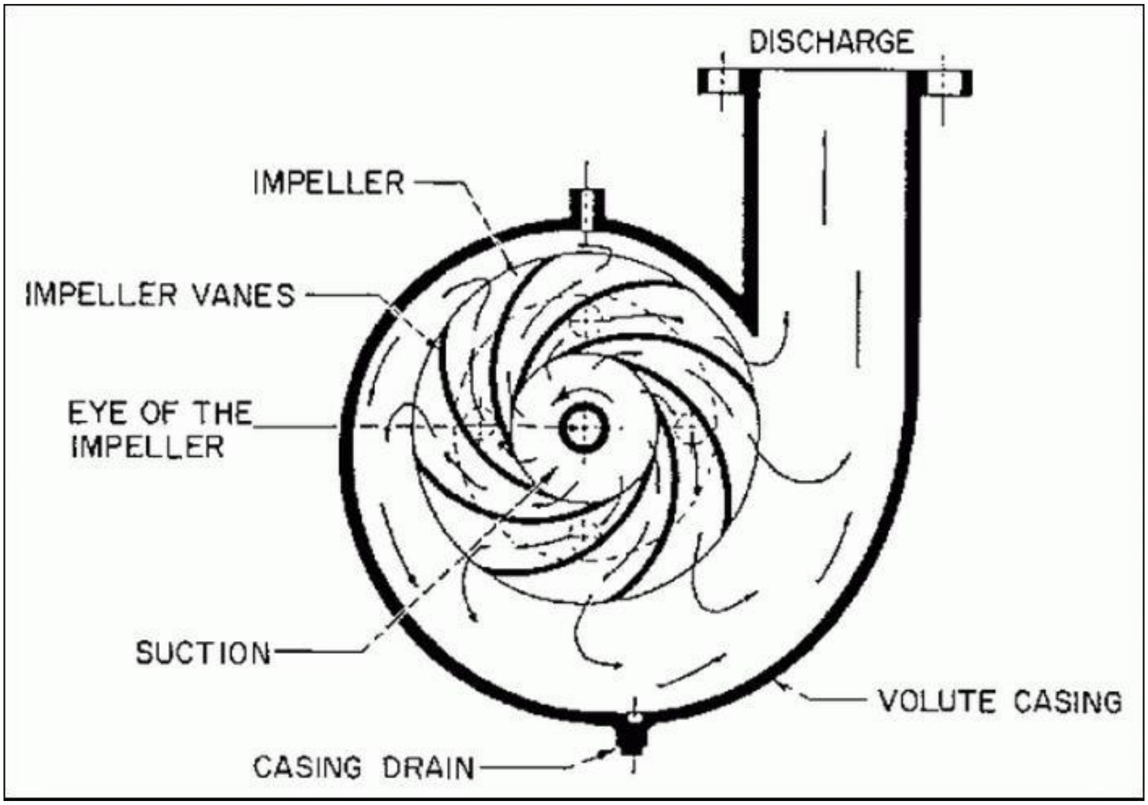
How does it work?

A centrifugal pump consists of an impeller and a volute (most end suction pumps) or a diffuser (submersible turbine pumps).

Rotation of the impeller forces water from its entry point, at the impeller eye, through the impeller's vanes and into the volute or diffuser. As water moves from the center of the circular impeller to its periphery, its velocity increases. When it reaches the volute, velocity is transformed into pressure.

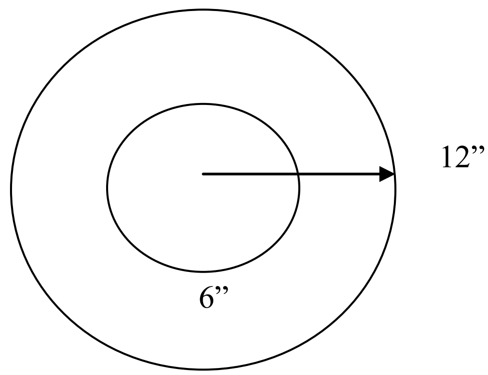
The flow and pressure created by a centrifugal pump depends upon the design of its impeller and its peripheral velocity. An impeller's peripheral velocity is dependent upon its diameter, its rotational speed or both.

A pump cannot pull or "suck" water into its impeller because water has no tensile strength. It lifts water by creating a low pressure area in its impeller eye that allows atmospheric or some other outside pressure to push the water into the eye that causes the suction.

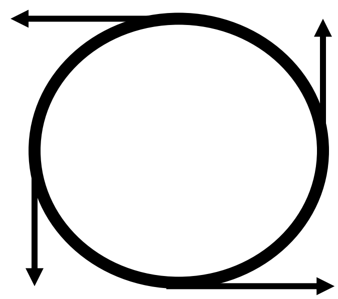

DISCHARGE
IMPELLER
IMPELLER VANES
EYE OF THE
IMPELLER
SUCTION
VOLUTE CASING
CASING DRAIN

Peripheral Velocity

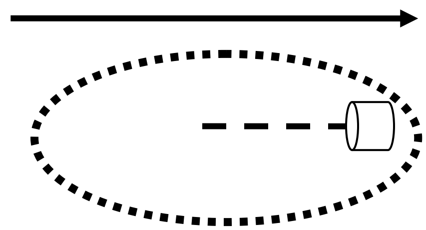
On the disc below, there are two points, one at 6" from its center and one at 12". The circle described at 6" has a circumference of 37.7" and the one at 12" has a circumference of 75.4". At a speed of one rotation per second. a point 12" from the center will travel twice the distance of a point that is 6" from the center. Therefore, its velocity must be ***twice*** as great.



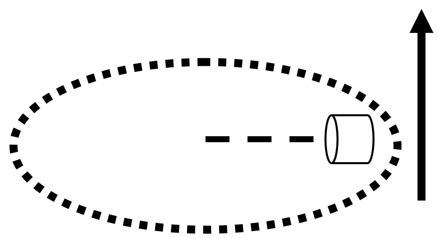
When an object is traveling in a circle, it can actually be moving in a straight line at any given time. The arrows at 12, 3, 6, and 9 o'clock show the direction of travel at that instant in time.



If centrifugal force were a true outward force, the swinging can would move in the direction of the arrow when the string was released.

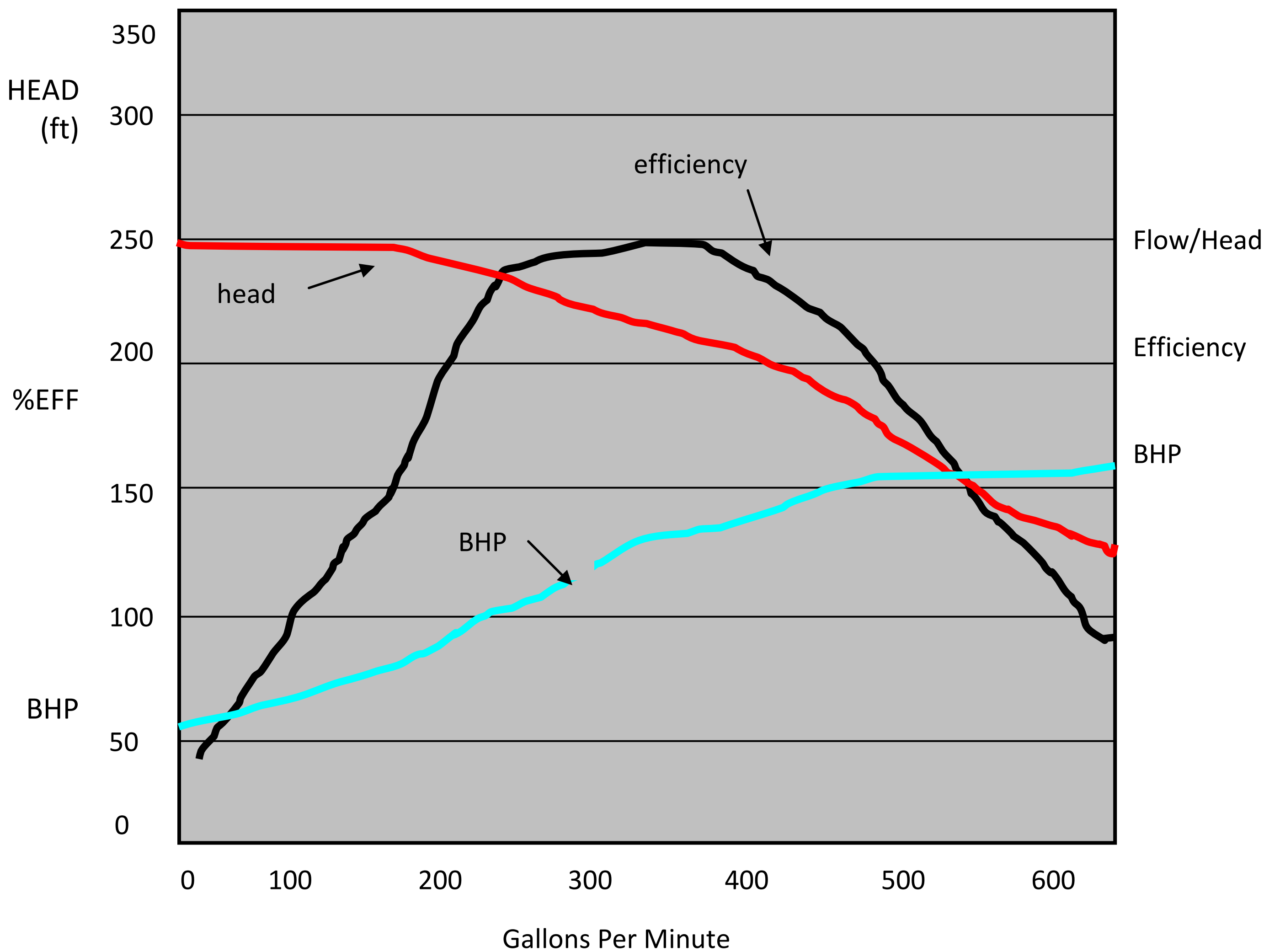


Instead, it actually moves in the same direction it was traveling at the exact moment it was released.

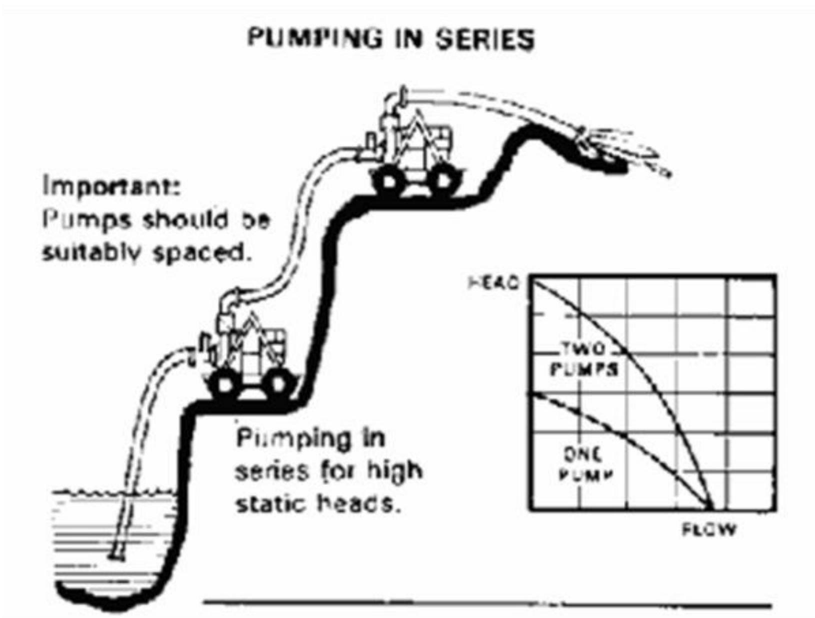


Pump Curves

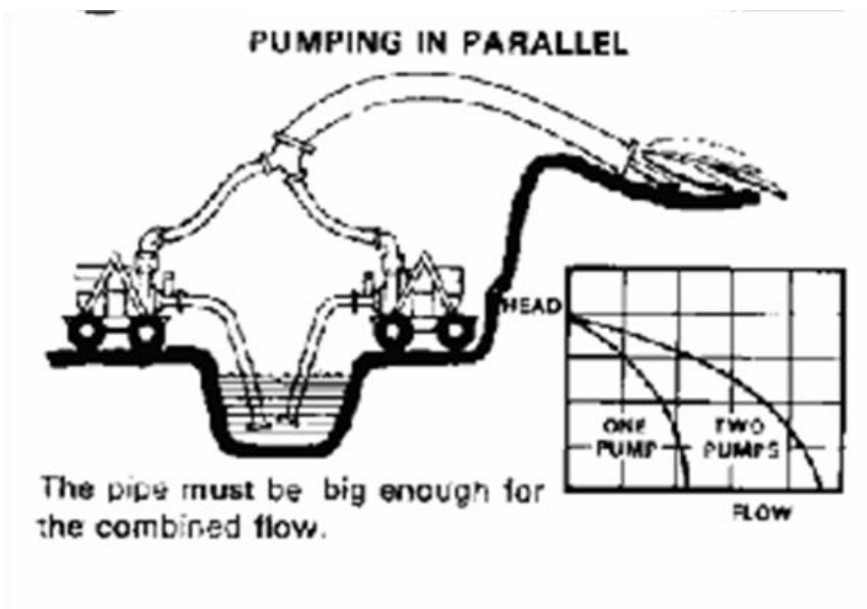
1. Flow and pressure at several points
2. Hydraulic Efficiency
3. Horsepower
4. Net Positive Suction Head Required (NPSHR)



A unique feature of centrifugal pumps is their ability to operate in series (one discharging into another) or parallel (common suction and discharge).

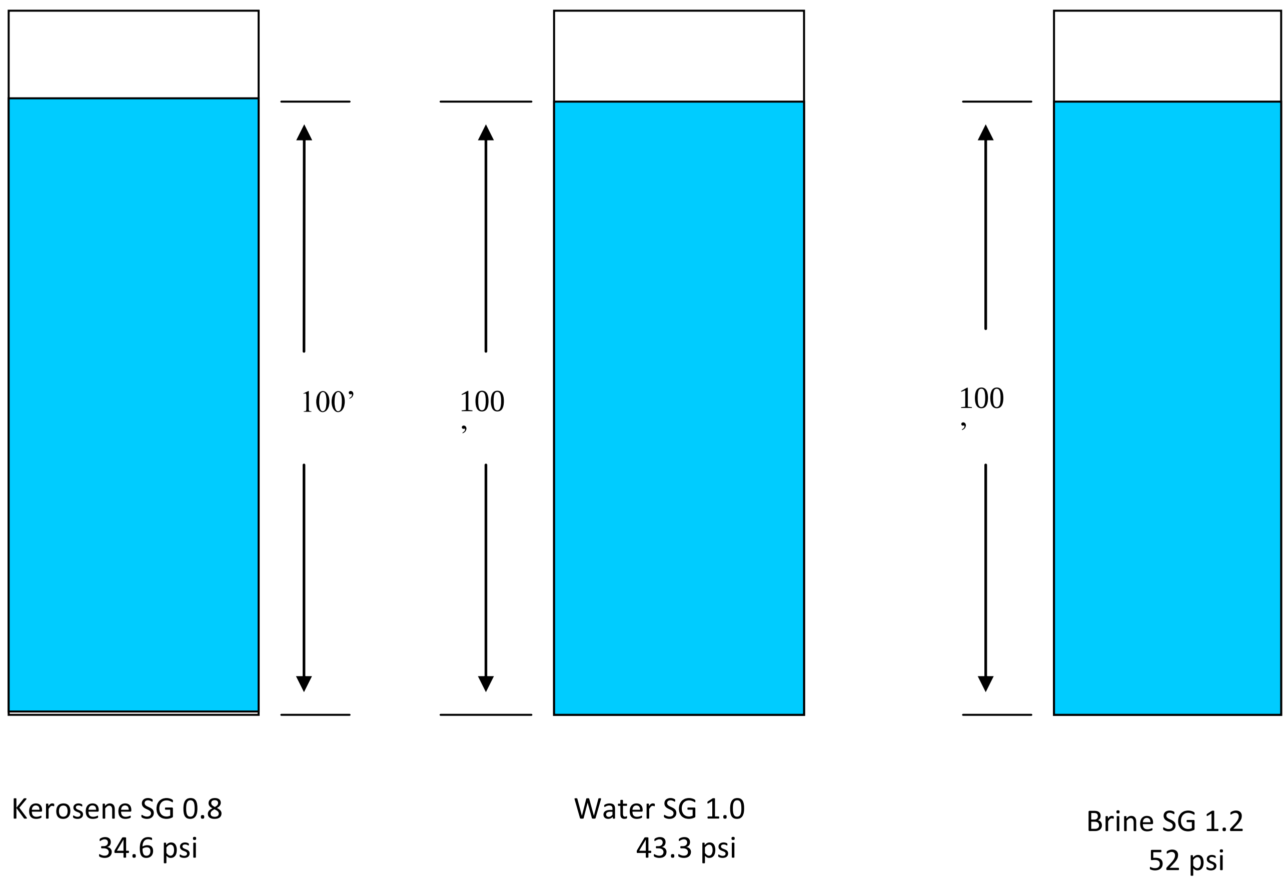


When operated in series, pressure is additive, while flow remains the same. In parallel, flows are additive, while pressure remains the same.



Why is pump pressure frequently stated in feet rather than PSI?

It is all about **specific gravity**. The specific gravity of a liquid is the ratio of its weight of a given volume to that of an equal volume of water. A centrifugal pump will always develop the same head in feet regardless of a liquid's specific gravity (weight). Pressure (psi) varies directly with specific gravity. The brake horsepower (BHP) required to perform a task varies directly with specific gravity.



What would register on the pressure gauge if the liquid had a specific gravity of 1.8 and the column of liquid was also 100' high?

100 ft X .433 psi X 1.8 SG = 77.9 or 78 psi
1 gallon of this liquid weighs 15 lbs.

Affinity Laws

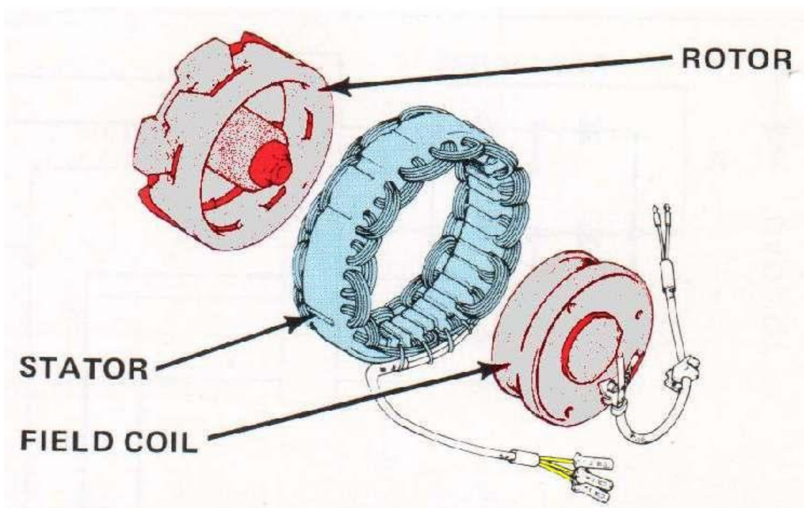
- Capacity (gpm) varies directly with a change in speed or impeller diameter.
- Head (feet or psi) varies as the square of a change in speed or impeller diameter.

- Brake horsepower (BHP) varies as the cube of a change in speed or impeller diameter.

Variable Frequency Operation

The rotational speed of an AC induction motor depends upon the frequency (Hz-hertz) of the current and the number of poles (coils) in its stator. At 60 Hz, a two-pole motor will complete 3600 rotations per minute (RPM).

For each frequency reduction of 1 Hz, a motor's speed will be reduced by 1/60 of its 60 Hz speed (60 RPM in this case).



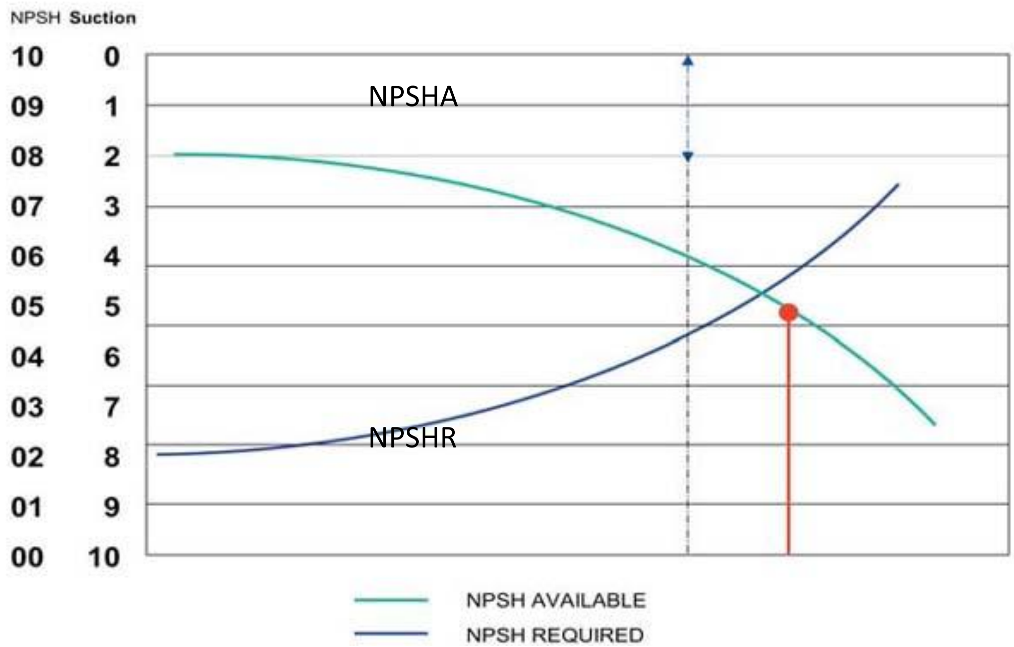
NPSHR & NPSHA

Maximum suction lift depends upon the pump design (NPSHR), the pressure applied to the surface of the water and the vapor pressure of the water under existing conditions (NPSHA). Net Positive Suction Head (NPSH) can be broken down into two components:

- NPSHR – The Net Positive Suction Head Required.
- NPSHA – The Net Positive Suction Head Available.

NPSHR is a function of a specific pump design. Simply stated, it is the pressure, measured at the centerline of the pump's suction, required to satisfactorily function at a given flow.

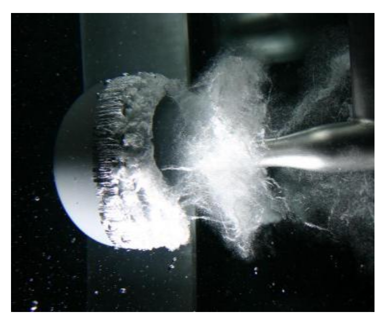
NPSHA is dependent upon the elevation or pressure of the suction supply, friction in the suction line, elevation of the installation (the pump itself in relation to other factors) and the vapor pressure of the liquid being pumped.



When a pump is in a suction lift condition, the only available energy is the atmospheric pressure of 14.7 psia or approximately 34 feet of water(14.7 psi X 2.31 ft of head = 33.957 feet). The amount of energy remaining after the energy consumption conditions have been satisfied is called **available net positive suction head** (NPSHA).

NPSHA = Ha + - Hs –Hvp

Cavitation



This is the rapid formation and collapse of bubbles in a liquid, caused by the movement of something in the liquid, such as an impeller. These bubbles form at the low pressure or suction side of the pump, causing numerous things to happen at once. These bubbles or cavities will collapse when they pass into the higher regions of pressure, causing noise, vibration and damage to many of the pump components (such as a loss in pump capacity and the pump can no longer build the same amount of head).

Horsepower

Horsepower is how we determine the power needed to move the water through the system. *One horsepower equals lifting 33,000 lbs. one foot in one minute.*
When looking at horsepower we must us one of the following formulas to find WHP, BHP, MHP.

$$WHP = \frac{GPM \times \text{Total Head (ft)}}{3960}$$

$$BHP = \frac{GPM \times \text{Total Head (ft)}}{3960 \times EP}$$

$$MHP = \frac{GPM \times \text{Total Head (ft)}}{3960 \times Ep \times Em}$$

A plant treats 1.5 MGD and needs to overcome 24 ft. of head. If the pump efficiency is 94% what is the brake horsepower needed?
What is the question asking?
Brake horsepower?

Find the formula

$$BHP = \frac{GPM \times \text{Total Head (ft)}}{3960 \times Ep}$$

$$BHP = \frac{GPM \times 24 \text{ ft}}{3960 \times 94\%}$$

$$BHP = \frac{(1.5 \times 694.5) \times 24}{3722.4}$$

$$BHP = \frac{1041.75 \times 24}{3722.4}$$

$$BHP = \frac{25002}{3722.4}$$

$$BHP = 6.71 \text{ BHP}$$

Chapter 13 Review

1. What type of pump is the most frequently used pump in the distribution system and why?

2. A single volute centrifugal pump can only push water ______ feet because of _________ pressure.

3. What horsepower is needed to overcome 180 ft of head at a flow of 1100 gpm with a pump efficiency of 85% and a motor efficiency of 71%?

4. Cavitation occurs when water becomes ________ in the volute of a centrifugal pump.

Chapter 13 Answers

1. Centrifugal

2. 33.9 ft, Atmospheric

3. HP = <u>gpm x ft of head</u>

3960 x Ep x Em

$$HP = \frac{1100 \text{ gmp} \times 180 \text{ ft}}{3960 \times .85 \times .75}$$

$$HP = \frac{198{,}000}{2389.86}$$

HP = 82.9

4. Vaporized

Chapter 14: CROSS-CONNECTION CONTROL

Chapter 14 Objectives

1. Explain cross connection.
2. Identify why control is necessary.
3. Explain backflow.
4. Differentiate between backpressure and backsiphonage.
5. Describe incidents related to cross connections and who is responsible.
6. Explain the methods and devices for preventing backflow and backsiphonage.
7. Compare the two types of cross connection programs.
8. Compare the degree of hazards with cross connections.
9. Understand what is needed to implement a cross connection program.
10. Identify the preventative maintenance measures an operator should take on a regular basis.

What is a cross - connection?

A cross - connection is a physical link between a potable water supply and one of unknown or questionable quality.

Why are controls necessary for cross – connections?

A cross connection can link our expensive, well-maintained, safe to drink from, distribution system to a source that contains something that could make people sick or even kill them. This potentially dangerous source can enter our potable water supply by means of **backflow**.

What is backflow?

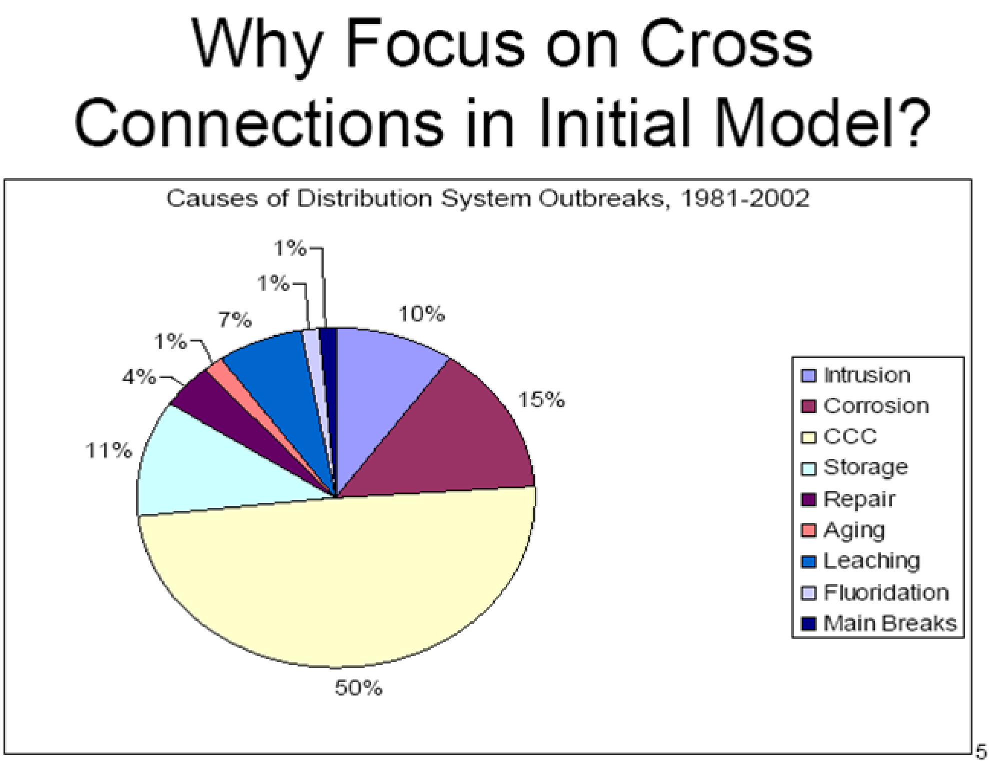
Backflow is the flow in the opposite direction to the normal flow or the flowing back of a substance toward its source. In distribution systems, it is the flowing of water from a service connection into our main lines or in the opposite direction from which it was intended. Backflow can occur in two ways: Backpressure or Back-siphonage

Backpressure occurs when the pressure in the service connection receiving the potable water becomes greater than the pressure in the distribution system. When this occurs, water and other substances in the customer's piping will flow from higher pressure to lower pressure and force this potentially contaminated water back into the distribution system. Potential sources of backpressure include boilers, pumps and elevated tanks on the customer's side of the service connection.

Back-siphonage occurs when the pressure in the distribution system falls below atmospheric pressure (14.7 psia) that creates a partial vacuum or siphon. Siphoning gasoline from a car or even drinking from a straw lowers the air pressure creating a partial vacuum. Liquid flows from an area of higher pressure (the gas tank or soda can) to one of lower pressure (the end of the siphon tube or straw). Some conditions that can cause low pressure in a distribution system at certain times are listed below:

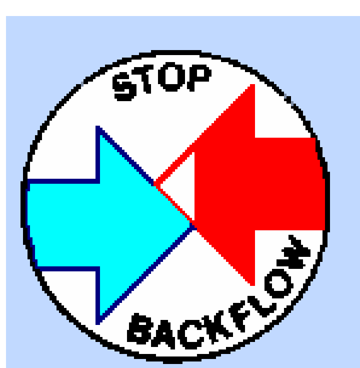
a. Flushing
b. Fire fighting
c. Main breaks
d. Undersized piping (which increases velocity and thereby lowers pressure)

BACKFLOW HAS BEEN IMPLICATED IN MORE WATERBORNE ILLNESS OUTBREAKS THAN ANY OTHER FACTOR. Because most pathogens are microscopic and cannot be detected by the naked eye, experts suspect that the majority of backflow incidents are never detected or recorded.



AWWARF

The American Water Works Research Foundation did a study on backflow incidents. There were between 2800 and 4100 backflow incidents among those who responded to their questionnaire. Of those, there were anywhere from 1100 to 1750 backflow incidents that were substantially documented. Initially, only about half of those utilities questioned responded to their questionnaire. If the numbers given were extrapolated or carried out to include the entire number of those questioned, then the number of backflow incidents could number from 800,000 to 1,000,000 since 1970.



Incident # 1

The services to seventy-five apartments, housing approximately three hundred people, were contaminated with chlordane and heptachlor in a city in Pennsylvania. The insecticides entered the water supply system while an exterminator was applying them as a preventative measure against termites. While the pesticide contractor was mixing the chemicals in a tank truck with water from a garden hose coming from one of the apartments, a workman was cutting into a 6-inch main line to install a gate valve. The end of the garden hose was submerged in the tank containing the pesticides, while at the same time, the water to the area was shut off and the lines drained prior to the installation of the gate valve. When the workman cut the 6-inch line, water started to drain out of the cut, thereby setting up a back-siphonage condition. As a result, the chemicals were siphoned out of the truck, through the garden hose, and into the system, contaminating the seventy-five apartments. Repeated efforts to clean and flush the lines were not satisfactory, and it was finally decided to replace the water main and all the plumbing that was affected.

Incident # 2

When a utility has no backflow prevention program for its town water system, the system can plummet out of control. An emergency intrusion of a foreign substance causes confusion and fear, which is then usually followed by a tremendous expense. Members of the Woodsboro, Maryland Fire Department went door–to–door warning citizens of the danger of using town water, which may have been contaminated with lethal pesticides.

"Yellow gushy stuff" had poured from some of the faucets in town and the State of Maryland had placed a ban on drinking Woodsboro city water. Residents were warned not to use the water for any reason except to flush toilets. The incident drew widespread attention and made the local newspapers, in addition to being the lead story on the ABC news affiliate in Washington, D.C., and virtually all the newspapers in the area. The investigation disclosed that the water pressure in the town water mains was temporarily reduced due to water pump failure in the town's high-service pumps. Coincidentally, a gate valve had been left open. A lethal cross – connection had been created that permitted the herbicide to flow into the potable water supply system. Upon restoration of water pressure, the herbicide flowed into the many faucets and outlets in the town's distribution system.

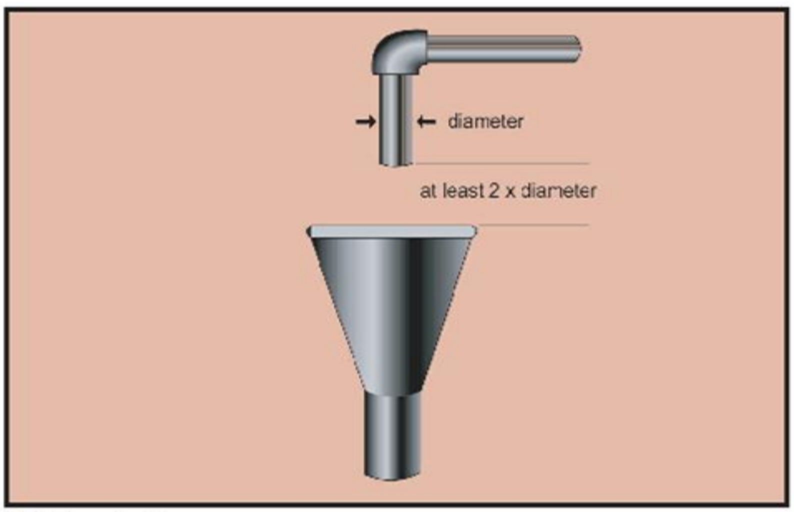
THERE ARE HUNDREDS OF THESE INCIDENTS PUBLISHED, SOME OF WHICH INVOLVE FATALITIES DUE TO THE INGESTION OF WATER THAT HAS BEEN CONTAMINATED.

Who is responsible when a backflow incident occurs? Your entity, as a federally regulated water purveyor or supplier, is bound by the SDWA to supply potable water to your customers. If it is within your power to prevent contaminated water from entering your distribution system and someone gets sick or dies because of contaminated water, then do you think you might get sued?

Methods and Devices for the Prevention of Backflow and Back-Siphonage

Air Gap

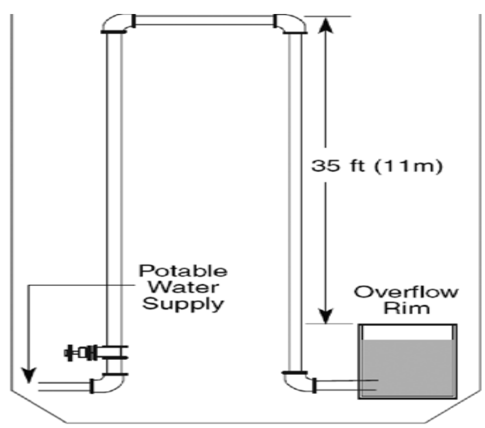
An air gap is a physical separation between the water supply and the intended end point. Air gaps are non-mechanical devices that are very effective against both backpressure and backsiphonage. The air gap must be twice the supply pipe diameter, but never less than one inch.



8.4.1 Figure 1: Air gap

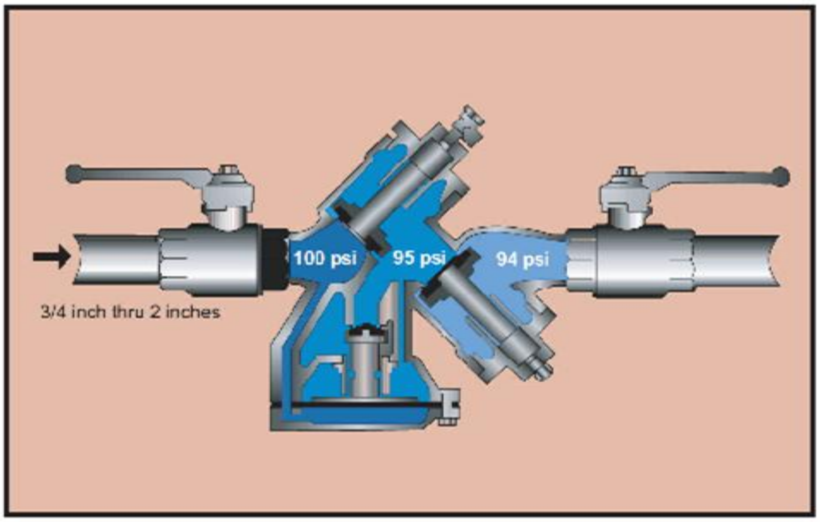
Barometric Loop

The barometric loop consists of a continuous section of supply piping that abruptly rises to a height of approximately 35 feet and then returns down to the originating level. In operation, for protection against backsiphonage, it employs the principle that a water column, at sea level, will not rise above 33.9 feet.



Reduced Pressure Zone

Reduced Pressure Zone (RPZ) assemblies are effective against backpressure and backsiphonage. These devices are essentially modified double-check valves with an atmospheric vent capability placed between the two check valves. This device is designed such that this “zone” between the two checks is always kept at least two pounds less than the supply pressure.

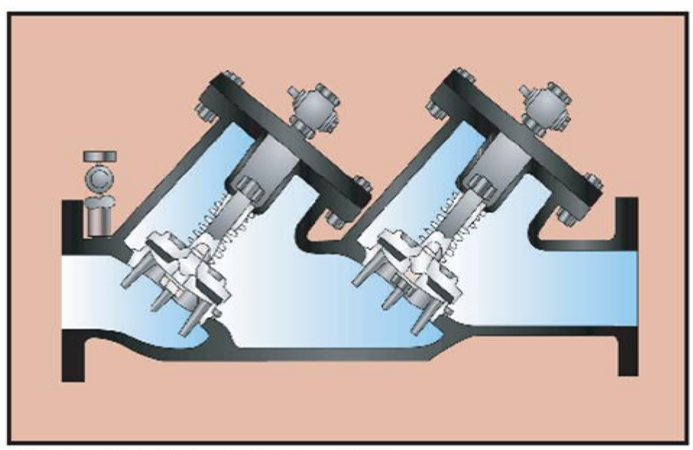


8.4.5 Figure 1: Reduced pressure principle assembly (RP)

In the event of backflow, the RPZ will send the water through the atmospheric vent instead of attempting to send the water back to the main.

Double-Check Valve

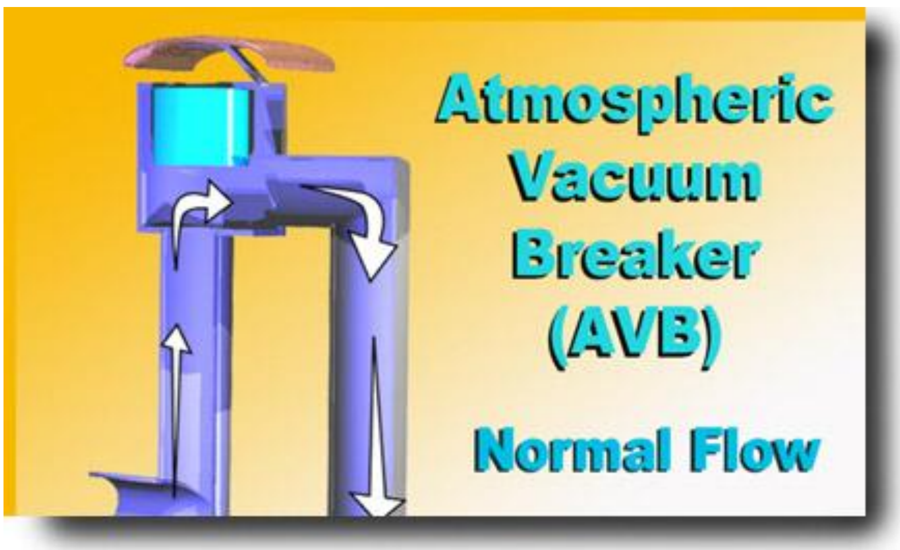
A double-check valve is basically two single-check valves coupled within one body. Each check is spring-loaded closed and requires approximately one pound of pressure to open. This device protects against backsiphonage and backpressure.



8.4.4 Figure 1: Double check valve assembly (DC)

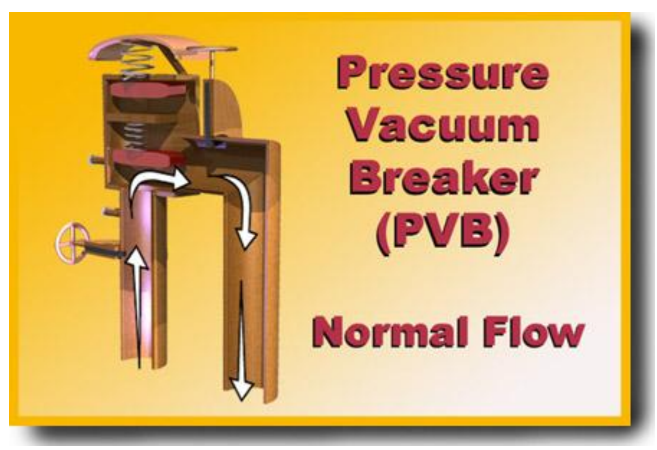
Atmospheric Vacuum Breakers

These devices are among the simplest and least expensive mechanical types of backflow preventers and, when installed properly, can provide excellent protection against backsiphonage. Water flow lifts the float, which then causes the disc to seal. Water pressure keeps the float in the upward sealed position. Termination of the water supply will cause the disc to drop down, thus preventing backsiphonage.



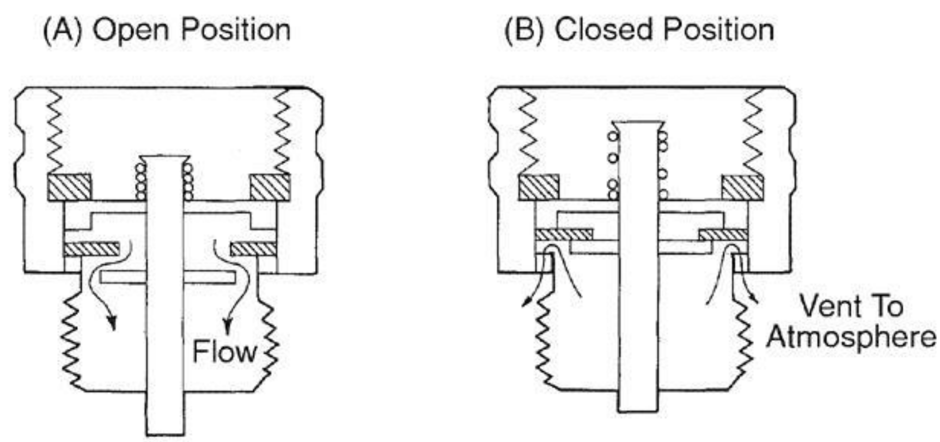
Pressure Vacuum Breaker

This device is an outgrowth of the atmospheric vacuum breaker and evolved in response to a need to have an atmospheric vacuum breaker that could be utilized under constant pressure and that could be tested in line. Just as with an atmospheric vacuum breaker, this device protects against backsiphonage, but not backpressure.



Hose Bibb Vacuum Breakers

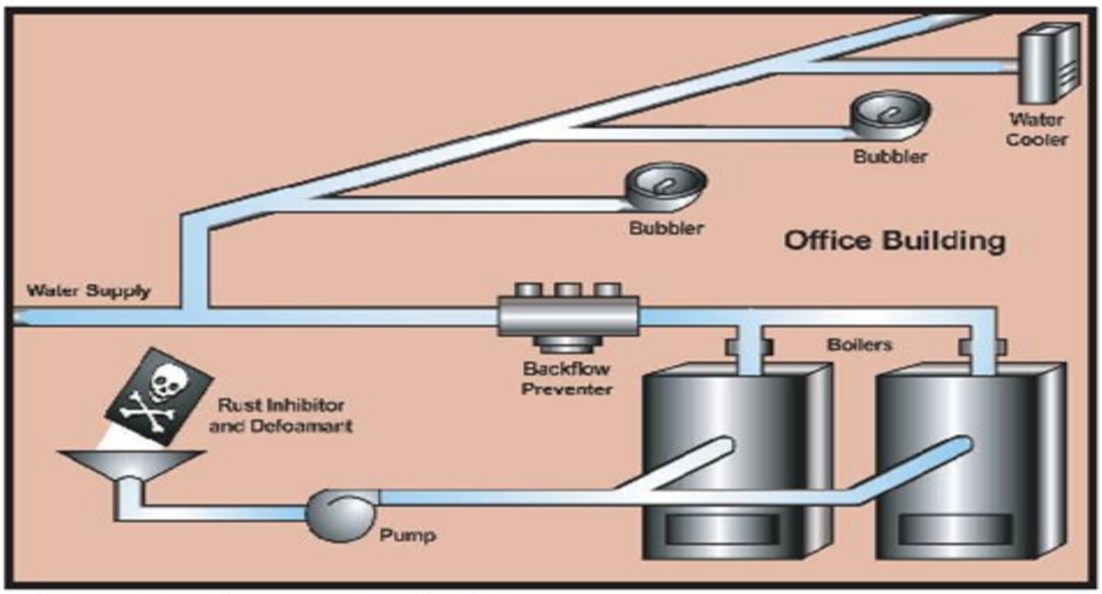
These are a specialized application of the atmospheric vacuum breaker. Generally attached to hose- supplied outlets, such as garden hoses, slop sink hoses, spray outlets, etc. When the water supply is turned off, the device vents to the atmosphere, thus preventing backsiphonage.



Note: Single-check valves are NOT backflow prevention devices.

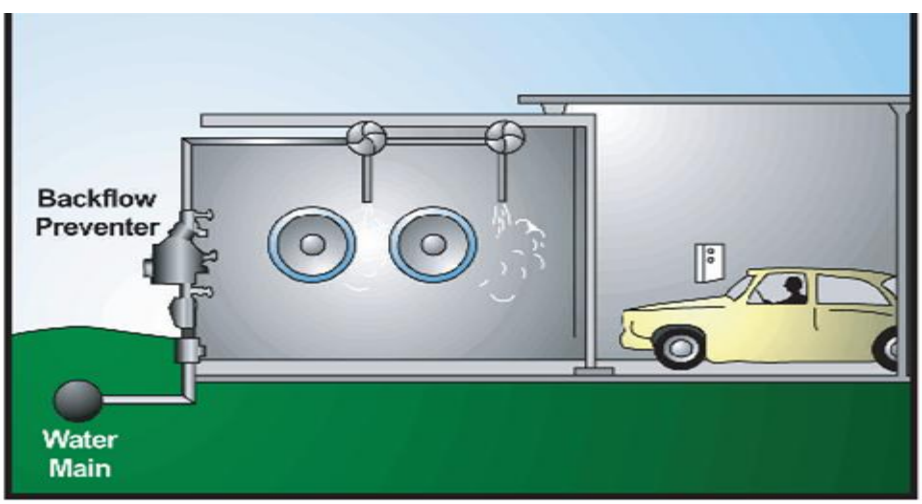
Two Types of Cross–connection Control Programs

1. **Isolation** protects the consumer at their tap.

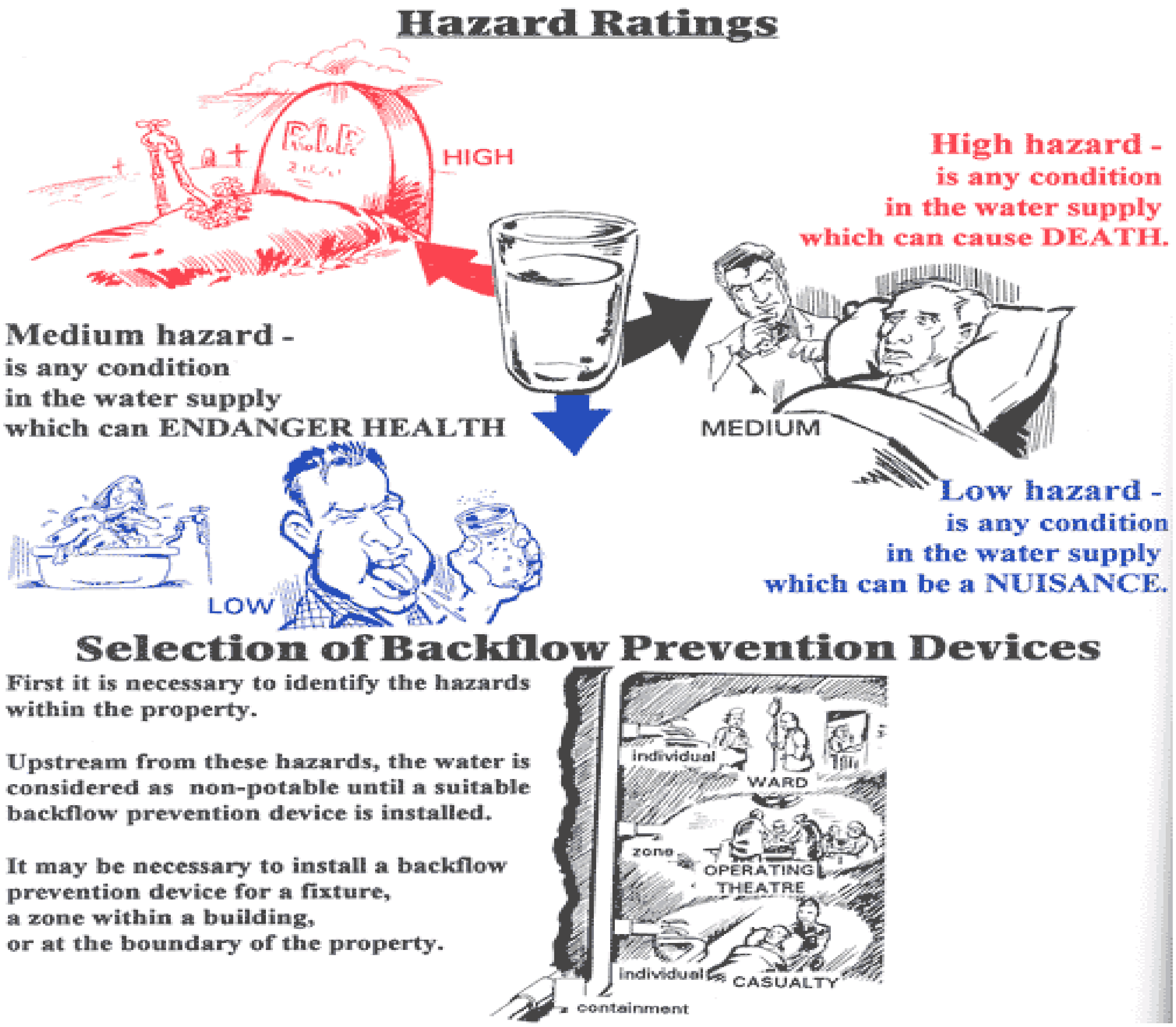


8.3 Figure 2: Isolation protects individual sites

2. **Containment** protects the potable water supply at the service connection.



8.3 Figure 1: Containment protects the public water system



Only the air gap, barometric loop and the reduced pressure zone backflow prevention devices are approved for high hazard applications.

Necessities for Implementing a Cross–connection Control Program

<u>Authority to Implement a Program</u>

- Conduct hazard surveys
- Install approved backflow prevention devices
- Annually test backflow devices
- Make necessary repairs

<u>Certified Personnel</u>

- Backflow assembly testers
- Trained CCC specialists

<u>Defensible Records</u>

- Assesses hazards through surveys and notate findings
- Retain annual test results

<u>Education</u>

- Internal
- Civic movers and shakers
- Public

Keep in mind:

→ Backflow is real and needs to be addressed.

→ Incidents are transient in nature.

→ Hazards are both microbial and chemical.

→ All water systems are susceptible.

→ As a result of inaction by water purveyors, acute or fatal consequences could occur.

Recommended Preventive Maintenance

- Daily
- Weekly
- Monthly
- Quarterly
- Biannually
- Annually

The key to a successful groundwater system is maintaining your equipment and facilities.Below are some recommended preventive maintance procedures for groundwater systems.

Daily

Check water meter readings and record water production. The water system should have a working, properly calibrated master water meter to accurately monitor usage. Take routine source water meter readings and record them in a log. Calculate the amount of water used during a time period, usually daily or weekly, by subtracting the previous meter reading from the current meter reading. Knowing the water use of your water system throughout the year provides information that can be used to evaluate source capacity, water rights, unusually high or low flows, excessive leakage, reduced pump output, unauthorized water use and the adequacy of the treatment system capacity. If your customers have meters, they should be read either on a monthly basis or with your billing cycle, totaled, and compared to your system's master meter.

Record daily chlorine residuals. Public water systems required to chlorinate continuously must monitor the free chlorine residual levels daily and submit a report each month to the Office of Drinking Water (DOW) . Regulations requires a minimum chlorine residual of 0.2 milligrams per Liter (mg/L) prior to the first customer and a trace at all other points in the distribution system. It is important for systems to monitor the free chlorine residual to ensure adequate and consistent levels of chlorine are maintained. Daily monitoring may also identify a failure in the chlorination equipment, which should be addressed immediately.

Check and record chlorine residual at the point of application. Chlorine is added to disinfect the water supplied to your customers. Chlorine also helps control microorganisms that might interfere with treatment plant processes.

Use an EPA approved field test kit to measure free chlorine residuals. If you have not been testing the free chlorine residuals in your system, you will need to start by purchasing a diethyl-p-phenylenediamine (DPD) free chlorine residual test kit. Specifically, you will need a kit that reads from 0-3.5 parts per million (ppm) of free chlorine with a smallest reading increment of 0.1 ppm or mg/L. You may purchase a kit from a water treatment company or from a business that sells lab equipment, such as Hach Company (1-800-525-5940). Digital colorimetric test kits are available that offer greater accuracy if needed. Keep the manufacturer's instructions on proper use of the test kit in your Operations and Maintenance Manual and follow the recommended procedures. Note that high levels of manganese in the source water can interfere with these tests. Oxidized manganese will react directly with the DPD reagent developing a darker red color than the actual reading.

Maintain a minimum contact time as required by DOW Office of Drinking Water. Some water systems with groundwater sources are required to maintain a specific contact time. This requires that a minimum chlorine residual level be maintained at the point of entry, upstream of the first customer. Guidance on how to determine the minimum chlorine residuals for your water system is available for the Office or your water system design engineer.

Complete daily security checks. Source, pumping and storage facilities should be inspected daily to ensure that they provide adequate protection against vandalism and unauthorized entry. Appropriate fencing, locks, and locked well covers should be used to protect the facilities from stray livestock and tampering. Warning signs should be posted to deter trespassing. Warning signs should indicate a building and phone number for reporting incidents. Inspect fencing and gates for damage and needed repairs. Check hatches, locks, doors, windows, and vents for signs of intrusion or vandalism. Check all security lighting and alarms to ensure proper operation. Check that all well caps, seals, and vents are intact and sealed.

Check and record water levels in storage tanks. You should check the water level in each storage tank, as well as system pressure, daily to ensure tank levels are within normal operating conditions. Check for evidence of overflow, erosion under the splash pad, warning lights, wet ground, and so on. If the tank is overflowing, the pump controls may be out of operation. If the tank's level is below normal operating conditions, there may be a problem with system capacity or water level controls. Schedule planned improvements to install a high and low level alarm system, telemetry, and alarms and warning lights with direct notification to system operators.

Inspect well heads. Well head covers or seals prevent contaminated water and other material from entering the well. Visually inspect all well covers and pump platforms. They should be elevated above the adjacent finished ground level, sloped to drain away from the well casing, and free of cracks or excessive wear. Below grade wellheads can become flooded seasonally or after severe weather. Electrical conduits can be damaged, opening a pathway for contaminants to enter the well casing. Wellheads that are potentially vulnerable to vehicles can be severely damaged putting the continued operation of the system at risk. Protect the wellhead from vehicular damage by installing barriers.

Record well pump run times and pump cycle starts. If available, the pump run hour meters and cycle counters on the control panel, should be used to record the running times and number of cycle starts for your well and booster pumps. These readings should be made at about the same time every day. Comparing daily numbers will alert you to potential pump problems. You should develop a daily well pump log. Source pump cycling, turning on and off, more frequently than 20 times an hour may indicate a water-logged pressure tank. The loss of air in a bladder pressure tank or a hydropneumatic tank eliminated the pressure buffer provided by the compressible air causing the pressure switch to open and close when the pump stops and starts. This increased cycling wears out switches, controls and bladder pressure tanks. Many water systems use a pump alternator or a lead/lag pump controllers. The pump run hour meter and pump cycle counter can be used to verify these control systems are working properly.

Weekly

Check and record water levels in hydropneumatic pressure tanks. Pressure tanks come in all shapes and sizes. For small systems, normally a pressure tank will be a small tank of no more than 100 psi and no larger than 400 gallons. Maintaining pressure in these tanks is important for maintaining adequate pressure to the consumers. Hydropneumatic tanks can overfill, or waterlog, at times affecting overall system pressure. Monitoring pressure can assist an operator in identifying leaks, open valves and even well pump problems. Hydropneumatic tanks should have a sight tube installed to visually check the water level in the tank. Often the water level can be obvious from a condensation that forms on the lower portion where the water cools the metal wall. This temperature difference can also be detected by touch.

Record the pumping rate for each well or source water pump. Record the pumping rate from your well or source water pumps. You can do this if your system has a meter that registers flow. A change in pumping rate can indicate that you may have a pump problem. Keep in mind that pumping rates will vary based on water level in the well. For example, the pump produces less when the well has been drawn down from the static water level to the deepest pumping level or if the head the pump is pumping against is high.

Inspect booster pump stations. Check on the condition of the pumps, such as vibration, heat, seal, and controls to ensure that booster pumps are operating properly. Care should be taken when checking how hot a pump or motor may be. Check to make sure the pump operating times are equalized (the pumps automatically switch over). If this is done manually, then make the appropriate switch-over. Check and record meter readings and pressure gauge readings on suction and discharge sides of pumps.

Monthly

Inspect well pumps, motors, and controls. System operators should always be on the lookout for any defects in the system. Look, listen, and feel for unusual sights, sounds, or vibrations. Make sure seals are intact and the system is not running hot. Check all timers to ensure that pump operating times are equalized. Controls should be operated manually to verify that they are working. When you shut down or turn off equipment for repairs, make sure it will not start up accidentally and cause injury.

Take appropriate monthly water quality samples. Water quality samples should be taken routinely in accordance with state requirements. Take samples according to approved procedures and submit them to a certified laboratory or your state, as required, for analysis. Your state drinking water agency can give you an annual schedule for your required sampling. Use state forms and procedures, as required, and use a monthly sampling log to record all water sampling you conduct each month. Though you may only be required to sample for some contaminants quarterly or annually, you should still record the sample in the month it was taken. Keep records of all water quality tests for your own use and to respond to customer inquiries.

Inspect all pumphouse plumbing for leaks. Excess moisture in the pump room can damage motors and other equipment and create unsafe conditions for operators. Leaks also open pathways for contaminants to enter the water supply. Check all sump pumps for proper operation. Check all station alarms. Check your backup power source to ensure it will operate when needed.

Read electric meter at pumphouse and record. Monitor and note any unusual or unexpected changes in electricity use over time. If pumping accounts for a large proportion of your system's energy use, track water production and compare it to energy use. In the winter, you will also need to consider energy use for heating. High meter readings can also be an indicator that your booster or well pumps are working harder to perform their job, which could mean immediately, or at least soon, maintenance will be required.

Check wellhouse and pumphouse water pressures. Check the system pressure in the wellhouse and pumphouse in the distribution system. Accurate gauges are a mandatory requirement to monitor the performance of a pressurized water system. Pressure gauges should be installed on the suction and discharge lines of pumps. Pressure tanks should have pressure gauges on the discharge lines. These should be checked regularly and replace if damaged.

Maintain a 15 to 30 day supply of chlorine in storage. Rotate stock to ensure chlorine supplies are not stored for an excessive length of time. This will reduce the decomposition and formation of unwanted byproducts, such as chlorite/chlorate. Sodium hypochlorite will lose strength over time. It will also lose strength when exposed to high temperatures or sunlight. For example, the rate strength lost doubles with every 5° C rise in temperature. Strong light, especially direct sunlight, causes sodium hypochlorite to break down. Stronger solutions can also lose their strength faster than weak solutions. For example, a 15% solution stored under cool, dark conditions might lose 0.1% strength over a week, while under bad conditions it could drop from 15% to 12-13% in one day. Because of this, you should always store your stock in containers with tight-covers under cool, dark conditions. You should also consider the costs of ordering and storing large amounts of stock versus smaller amounts (1 to 2 months supply). Remember that as your stock loses strength over storage, you will be losing money.

Inspect chlorinators for proper operation. Make sure the feeder is not broken or plugged and that it is adjusted correctly. Check to see if the chlorinator is supplying the correct dosage by measuring how much chlorine solution is being fed and then calculating the dosage. Calculate the dosage using the concentration of the chemical solution, the volume of solution pumped, and the volume of water treated over the same time period. Use a volumetric measuring device such as a graduated cylinder or the calibration cylinder in newer systems to measure the volume of chlorine solution added. Refer to your system's operations manual to determine the correct dosage. Please note that dates on the log are in reverse order to make calculations easier. Use proper personal protective gear when handling chemicals. Chemicals used in water treatment may be harmful to human health if not used properly. Material Safety Data Sheets should be made available to ensure proper usage.

Inspect storage tanks for sanitary deficiencies. Storage tanks should be inspected to ensure they are protected from contamination. Check vent screens for any openings to prevent small animals, bats, birds and insects or debris, dust and organic matter from entering the tank. Check overflows for flap valves or screens. Check the condition of the storage tank and look for cracks, structural damage, leaks, corrosion, and cathodic protection. Check the condition of the access hatch cover seal. This inspection should be documented, including photographs that will be useful for the next routine sanitary survey.

Inspect storage tanks for defects. Both interior and exterior inspections are needed to ensure maintenance of physical integrity, security and high water quality. The type and frequency of the inspection is driven by the type of tank, its susceptibility to vandalism, age, condition, and time since last cleaning or maintenance, history of water quality, plus other local criteria. Exterior inspections for obvious signs of intrusion or vandalism might occur daily or weekly. Periodic inspections of the storage tank for cracks, structural damage, integrity of hatches and vents, leaks, corrosion, and cathodic protection might occur on a monthly or quarterly basis. A comprehensive inspection of the interior is normally conducted when the tank is drained for cleaning. Industry standards recommend tanks be comprehensively inspected, inside and outside, every five years, except for newly constructed tanks, which should be inspected within 10 years of service and every five years thereafter.

Inspect and test standby power generation systems. Emergency power generators and switchover controls should be tested periodically to ensure they are maintained in proper operating condition. Manufacturer's recommendations should be followed. Written records of the checks, operational tests and maintenance performed should be kept.

Quarterly

Make sure fire hydrants are accessible. Fire hydrants provide water for fire fighting and are a means to flush the system. The hydrants should be easy to get to and highly visible. This includes removing snow drifts during the winter, tall grass or weeds during the summer, and painting the hydrants a highly visible color. Hydrants should be color coded according to the available fire flows. During inspection, be sure to check for tampering or vandalism. Record your findings in a log book. You should develop a log book to document your findings and standardize how these checks are made.

Clean pumphouse and grounds. Keeping your pumphouse and grounds clean will help with overall maintenance and operation of your system. The useful life of bearings can be reduced if dirt gets into lubricants. Also, dirt and moisture will form an insulating coating on motor windings and can cause motors to burn out. In addition to cleaning, screen all drain and vent openings in the building to prevent entry by animals and insects, and in the summertime, mow the areas around the pumphouse and storage tanks. Make sure grounds maintenance addresses fire hydrant accessibility. You should develop a weekly cleanliness log card to record your inspections.

Check pressure tank exteriors. Pressure tanks, including hydropneumatic tanks, can become corroded with rust. The exteriors of pressure tanks should be protected from corrosion and any obvious damage repaired. Hypochlorination systems may produce very corrosive vapors when there is inadequate room ventilation, chlorine solution leaks, open solution tanks, and so on. Severe pitting can dangerously weaken the pressure vessel and result in catastrophic failure, risking injury to water system operators. Ultrasonic testing can be done to check the wall thickness if required.

Inspect and clean chlorine solution feed lines and solution tanks. To ensure that your chlorine feed system functions properly, inspect the lines to make sure they're not clogged or kinked and that the solution tanks are clean. Regular cleaning of the chlorine feed systems will help prevent many breakdowns in this equipment. Inert solids will build up sediment on the bottom of the solution tank and can clog the filter or damage the chlorinator.

Calibrate chlorinators after overhaul. At least every three months, and particularly after the chlorinators have been overhauled, the pumps should be re-calibrated to ensure that they deliver the appropriate amount of chlorine solution to the system. Measure the amount of solution withdrawn by the pump over a given time period, record this value and speed/stroke length settings, and compare this rate with the desired feed rate. Refer to the manufacturer's instructions to adjust the feed pump accordingly. Be sure to record any new speed and stroke settings anytime a change is made.

Biannually

Exercise half of all valves. It is important to exercise all valves in the system at least once a year to ensure you can locate them and that they can be opened and closed during emergency shut-down periods. Record the number and direction of turns to closure. Be sure to describe the condition (rusted, new, leaking, failing) of each valve in the appropriate column in a log book. Half of the mainline valves should be exercised in March, and the other half should be exercised in six months. You should develop a map that identifies the valves and their locations. Keep this information in a secure place. It is important to be able to isolate the system or sections of the system. Any failures should be scheduled for repair. You should develop forms to track the valve inspections and repairs or to note any scheduled repairs.

Evaluate water quality monitoring of stored water. Check chlorine residuals, free, total and combined, before and after passage through the storage tank. Disinfectant levels will decline when retention time is increased. Estimate the contact time provided by the storage facility to determine if changes are needed to improve mixing, for example, the baffling coefficient. Storage tanks constructed with a single combined inlet and outlet line or with inlet and outlets located at the bottom can be modified to greatly improve water turnover. Disinfectant byproducts increase in stagnant biologically active water. Heterotrophic plate counts and nitrate and nitrite levels can also increase due to biological action.

Evaluate the water turnover of the stored water. Storage facilities should be operated to provide adequate water turnover and routinely fluctuate the water level in the tank. A variety of factors influence what the water turnover goal should be, including source water quality, disinfection, water use, fire flow, tank design, and so on. Some experts recommend a three to five day water turnover, modified as needed. Water systems with extreme seasonal variations in total water use have additional challenges to adapt operations to maintain good quality water.

Operate all valves inside the wellhouse, treatment plant and pumphouse. All valves in a system should be inspected and exercised routinely. The frequency of inspection depends on the type of valve, but you should inspect the valves at least twice a year. The inspection should include completely closing, reopening, and re-closing the valve until it seats properly. Record the number and direction of turns to closure. Leaking or damaged valves should be scheduled for repair. Use a log book to track inspections. The log card should be routinely updated throughout the year.

Check pressure relief valves. All pressure tanks in public water systems must have an American Society of Mechanical Engineers (ASME) certified pressure relief valve (PRV) to protect them for overpressure conditions. Labor and Industries safety regulations for unfired pressure vessels require ASME PRVs of adequate size to be installed on pressure tanks without intervening shut-off valves. Approved PRVs have tags indicating the ASME status and levels that can be used to verify function. Use caution and follow manufacturer's procedures.

Annually

Flush the distribution system and exercise and check fire hydrant valves. The entire system should be flushed in one direction, outward from plant or storage facility, at least once a year, depending on the quality of your source water. Systems with excessive iron or manganese that do not treat to remove these minerals may need to flush as often as monthly. Flushing clears any sediment in the lines. During the flushing, check the operation of the fire hydrant valves and observe the color of the water. Continue flushing until the

water is clear. When operating a dry-barrel hydrant, you must open it completely so that the drain will become fully closed. Otherwise, water seeping through could result in hydrant damage from freezing. Make sure that any open hydrants are flushing away from private property. After flushing or using a hydrant, check to make sure the drain is working. Use a log book to track when flushing was completed.
Conduct a water audit and leak detection program. Unaccounted-for water should be determined by comparing the records of water production to water use to measure the quantity of water that was produced but not account for by service meter readings. Unaccounted-for water can result from leaks, inaccurate or broken meters, unmetered use, and errors in the billing process. Undetected water main leaks create conditions that put a water system's capacity to supply safe and reliable drinking water at risk. Leak detection can be a continuing challenge that strains the expertise and financial resources of a water system. A system may choose to purchase detection equipment and train staff to check for leaks, or they may hire an outside firm to perform leak detection surveys for them. Some systems use a combination of internal checks and contracting.

Perform storage tank maintenance. Maintenance activities include cleaning, painting, and repair to structures. State drinking water regulations requires adhering to American Water Works Association (AWWA) Standards, National Sanitation Foundation (NSF), and American National Standards (ANSI) for disinfection procedures and approval of coatings. Guidance indicates storage tanks should be drained, cleaned and disinfected annually. Painting is suggested on an as needed basis.

Prepare system for winter operations. This includes checking all exposed facilities such as pumps, valves, and pipes. Make sure all exposed facilities are properly insulated, the heaters in the treatment plant and pumphouse are operable and in good safe working condition, and vents are closed. Also, check all fire hydrants and sprinkler systems to ensure they are drained, check all propane or fuel tanks used for heating the pumphouse are toped off, and lower the water level in the storage tank just slightly. Circulating more of your water in storage facilities helps to prevent freezing. This task may be postponed until October or November based on local weather conditions.

Clean storage tanks. Thoroughly clean tanks after any construction, maintenance or repairs. The surfaces of the walls and floors should be cleaned thoroughly with a high-pressure water jet, sweeping, scrubbing or other methods. All water and dirt should be flushed from the tank. There are several approved methods to clean and disinfect a storage tank. Two commonly used methods are described here. Cleaning and disinfection guidance documents are also available from AWWA.

Method A. Add chlorine to the water used to fill the tank during the disinfection process and mix thoroughly. Use only NSF-approved chlorine for this procedure. Maintain a chlorine residual of at least 50 mg/L for at least 6 hours and preferably for 24 hours. Don't forget to clean the tank above the water line at the same time. When the disinfection procedure is complete, properly dispose of the disinfection water and test the system. You may have to dechlorinate the disinfection water before disposing of it. Improper disposal can lead to contamination of potable water due to backflow or to unlawful surface water pollution. If you use a strong disinfectant solution to the clean the tank, after draining the disinfectant and filling the tank with water, the disinfectant in the tank may be diluted enough for pumping straight to the distribution system for domestic use.

Method B. Cleaning and disinfection procedures for large tanks of more than 1 million gallons may be different. When you are planning to take a tank out of service for cleaning and disinfection, make sure provisions are made to supply adequate water to the distribution system. If you are unsure how to provide service while the tank is off-line, contact your local technical assistance providers or your state drinking water agency for technical assistance. You may also want to consider the use of certified divers trained to do tank inspections and cleanings. This may prevent taking the tank out of service or losing significant amounts of water. After the tanks are cleaned, they will need to be properly tested before returning to service.

Check aesthetic water quality in storage tanks. Identify aesthetic problems that may be associated with inadequate storage facility design, construction or operation. Objectionable taste and odor may indicate poor water turnover promoting growth of taste and odor producing microorganisms. Improperly cured coating materials will result in unpleasant taste and odor in the stored water. Sediment build-up, especially from excessive iron or manganese, will harbor and provide nutrients for biofilm forming bacteria. Regular maintenance and thorough cleaning to reduce sediments will improve water quality. Stagnant water in an above-ground storage tank will tend towards the ambient temperature. Warmer water in the summer and fall months will increase biological growth leading to water quality problems. Water will also stratify in the tank further reducing turnover.

Perform preventive maintenance on wellhouse, treatment plant and pumphouse buildings. Facility piping, buildings, and tanks should be painted regularly to prevent deterioration. Store all pipes, plumbing fittings, chemicals, tools, and other materials in a safe place. Wellhouse ventilation should be checked to ensure there are no blockages and that fans are operable. Inspect for excessive rusting of exposed metal on pressure tanks, pipes, valves, controls, and fans that may be caused by corrosive chlorine vapors and poor ventilation. Deep pitting in pressure tank walls can compromise the structural integrity of the vessel. Wall thickness can be checked with ultrasonic testing devices.

Inspect wellhouse heater operation during winter months. Heaters should be checked throughout the winter on a daily basis to determine that they are working properly. Ensure that wiring and heater are above floor level and not placed where water leakage could cause a safety hazard, an electrical outage, or short any breakers.

Inspect, clean, and repair control panels in wellhouse. The control panels in the pumphouse and treatment plant should be inspected at least once a year for corrosion and other problems that could cause shorts or failures. Control panels should be carefully cleaned with air. Repair the panels if needed.

Contact an electrician to check running amps on well pumps. A change in running amps can indicate a change in the condition of the motors or pumps. When pumps start drawing more amps, it generally means that the motors should be repaired. Checking the amps and voltage on pumps can be a complicated and dangerous task; **do not attempt it yourself**. Contact an electrician to complete this procedure. This task should be performed at least once a year and any time you sense a problem with your pump, such as unusual sounds, vibrations, or the pump is running hot.

Check and record static and pumping levels of each well. This task is important for determining the reliability of the aquifer and for establishing baseline information that can be useful if others tap into the aquifer or take actions that will affect it, such as gravel mining. The static level is the level of the water in a well when the pump is not operating. The pumping level is the distance of the available pool while water is being drawn. You can check these levels by using bubbler lines, electrical sensors, or manual drop lines. The pumping level should be measured at various stages of pumping. You should also measure the recharge time, the amount of time it takes to return to static level. All equipment must be disinfected and handled in a way to prevent contamination of the well. You should develop a monthly static and pumping level log book.

Review Emergency Response Plans. Review all contacts for accuracy, make sure all equipment is working, and ensure all procedures match the plant conditions as they presently exist. Contact your local emergency response agency to update contacts, new processes, or chemical inventories.

Check instrumentation for proper signal input/output. Check to make sure each instrument is working properly. Make a log for each piece of equipment to record readings. Record the manufacturer specifications and notes on the log to make equipment information easily accessible.

Maintain air compressors. Air compressors are often used with water level controls to maintain the proper air/water balance in the larger hydropneumatic tanks. Air intake filters must be kept clean to maintain airflow. Dirty clogged filters must be replaced and cleaned thoroughly. Moisture traps, built into the filter/regulator, are used to catch moisture and dirt particles so they are not introduced into the pressure tank. Follow manufacturer's instructions to do this. Belt driven air compressors need to be covered with safety guards. Operators can become entangled in unprotected belts and seriously injured. Check air compressors and motors for any signs of malfunctions. Unusual noises, vibrations, odors, and heat generation can indicate mechanical problems and should be immediately investigated. Compressors that do not reach preset tank pressure must be evaluated. Bearings on most air compressors need to be lubricated. Special oils and lubricants must be used to prevent contamination of the water in the pressure tank.

Pressure tank supports. Pressure tanks must be supported to prevent tipping or falling. Hydropneumatic tanks tend to be larger and very heavy when filled with water. Supports must be sturdy and maintained in good condition. Stacked blocks or boards can fail during an earthquake. Evaluate the structural condition of the supports and level of the seismic protection provided. Consult a qualified authority if you are unsure. Failure will result in extensive damage to any facilities near the pressure tank. Water leaks will damage more equipment.

Overhaul chlorinators, including O rings, check valves, and diaphragms. Chemical feed pumps should be completely overhauled at least once a year. The overhaul should include cleaning the feeder head, cleaning and checking all valves and O rings for wear, and cleaning and checking the condition of check valves and pump control valves. Replace any worn-out parts, including diaphragms. Spare parts should be kept on hand so breakdowns can be repaired quickly and worn parts can be replaced when the feeder is disassembled for cleaning. A chemical feed pump repair and spare parts kit should be kept in the treatment building. Recalibrate the chlorinator to ensure they deliver the appropriate amount of chlorine solution to the system.

Purchase a backup spare chlorinator. It is highly recommended to have a spare chlorinator on hand for emergencies where repairs are not possible and disruption to service is not acceptable. There may be other approaches that offer a similar level of reliability.

Inspect chemical safety equipment and repair or replace as needed. Review the use of all safety equipment and update safety training. Chemical safety equipment should be checked and tested at least once each year to be certain that it is operable. Follow the manufacturer's instructions on the proper upkeep of all safety equipment, including portable ventilators or respirators, safety harnesses or belts, goggles, gloves, hard hats, and protective clothing. Detection devices for hazardous gases should be calibrated based on the manufacturer's instructions. All equipment should be repaired or replaced as needed. Review all safety procedures. You should develop a safety log book to record routine safety maintenance.

Maintain a log of water line repairs. Water distribution line repairs should be documented, especially when there are repairs/clamps, and so on, placed on the line. These types of repairs are not normally intended for long-term/permanent repairs, but are often performed with that intent. A thorough record of line replacements may help identify areas of the distribution line that are more prone to failure due to age, vibration, or other causes.

Chapter 14 Review

1. The single most important piece of a backflow protection program is a (n) __________.

2. The largest factor when determining the cause of waterborne disease and illness outbreaks is ______.

3. The difference between a RPZ and a double check is _________________.

4. AVBs should be installed _______ the grade line.

5. PVBs protect against __________ only.

Answers for Chapter 14 Review

1. Ordinance
2. Backflow
3. The relief valve that sends the contaminated water to the atmosphere
4. Above
5. Backsiphonage

APPENDIX

401 KAR 11:001. Definitions for 401 KAR Chapter 11.

RELATES TO: KRS 223.160-220, 224.01-010(9), 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.200, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of wastewater operators. KRS 223.200 requires the cabinet to promulgate administrative regulations concerning the certification of water treatment and distribution system operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes definitions applicable to the certification of wastewater and water operators.

Section 1. Definitions.
(1) "Applicant" means a person who has submitted an application to take an examination for certification.
(2) "Board" means:
(a) The Kentucky Board of Certification of Wastewater System Operators; or
(b) The Kentucky Board of Certification of Water Treatment and Distribution System Operators.
(3) "Cabinet" is defined by KRS 224.01-010(9).
(4) "Certificate" means a certificate of competency issued by the cabinet stating that the operator has met the requirements for the specified operator classification as established by 401 KAR Chapter 11.
(5) "Certified operator" means an individual that holds an active certified operator's certificate issued in accordance with 401 KAR 11:050.
(6) "Core content" means the information identified as essential by the board for purposes of certification examination and continuing education training.
(7) "Direct responsible charge" means personal, first-hand responsibility to conduct or actively oversee and direct procedures and practices necessary to ensure that the drinking water treatment plant or distribution system is operated in accordance with accepted practices and with KRS Chapters 223 and 224 and 401 KAR Chapters 8 and 11.
(8) "Operator" means a person involved in the operation of a wastewater treatment plant, wastewater collection system, drinking water treatment plant, or drinking water distribution system.

(9) "Primary responsibility" means personal, first-hand responsibility to conduct or actively oversee and direct procedures and practices necessary to ensure that the wastewater treatment plant or wastewater collection system is operated in accordance with accepted practices and with KRS Chapter 224 and 401 KAR Chapters 5 and 11. (35 Ky.R. 473; Am. 1210; eff. 3-6-2009; 36 Ky.R. 449; 1047; eff. 2-5-2010.)

401 KAR 11:010. Boards of certification.

RELATES TO: KRS 223.160-220, 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.160-200, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the board of certification of wastewater system operators and the certification of wastewater operators. KRS 223.160-220 authorizes the cabinet to promulgate administrative regulations concerning the board of certification for water treatment and distribution operators and the certification of water treatment and distribution system operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes the duties of the Kentucky Board of Certification of Wastewater System Operators and the Kentucky Board of Certification of Water Treatment and Distribution System Operators.

Section 1. Duties of the Board. The board shall:
(1) Evaluate the qualifications of applicants and recommend qualified applicants to the cabinet for certification examination;
(2) Review and provide comments to the cabinet on proposed administrative regulations regarding operator certification;
(3) Review and make recommendations to the cabinet on core content for certification examinations and continuing education training for certification renewal;
(4) Review and make recommendations to the cabinet on training proposed to provide continuing education to certified operators. During the evaluation of training courses and seminars, the board shall consider:
(a) The consistency of training material with the core content;
(b) The ability of the training to provide information that supports effective water conveyance, treatment, and quality; and
(c) The ability of the instructor to properly present the training;
(5) Assist the cabinet in drafting examinations for the certification of operators;
(6) Review and provide comments to the cabinet on proposed fees for the training and certification of operators;

(7) Review applications for reciprocity and recommend to the cabinet the acceptance or denial of the application based on the criteria established in 401 KAR 11:050, Section 1(8); and
(8) Review evidence and advise the cabinet regarding disciplinary actions for certified operators who fail to comply with KRS Chapters 223 and 224 or 401 KAR Chapter 5, 8, or 11. (35 Ky.R. 474; Am. 1211; 1746; eff. 3-6-2009; 36 Ky.R. 450; 1049; eff. 2-5-2010.)

401 KAR 11:020. Standards of professional conduct for certified operators.

RELATES TO: KRS 223.160-220, 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of water and wastewater operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes standards for the performance of certified water and wastewater operator duties.

Section 1. Standards of Professional Conduct.
(1) In order to safeguard the life, health, and welfare of the public and the environment and to establish and maintain a high standard of integrity in the certified operator profession, the following standards of professional conduct apply to persons certified in accordance with 401 KAR Chapter 11:

(a) A certified operator shall, during the performance of operational duties, protect the safety, health, and welfare of the public and the environment;

(b) A certified operator shall use reasonable care and judgment in the performance of operational duties;

(c) If a certified operator's judgment is overruled by an employer under circumstances in which the safety, health, and welfare of the public or the environment are endangered, the certified operator shall inform the employer of the possible consequences;

(d) A certified operator shall be objective, truthful, and complete in applications, reports, statements, and testimony provided to the cabinet; and

(e) A certified operator shall ensure the integrity of the samples that the operator collects, prepares, or analyzes so that results shall be a true representation of water quality.

(2) Proof of certification. While on duty, a certified operator shall carry the cabinet-issued wallet card showing the operator's current certification status.
(3) Maintenance of records. If information related to the operator's employment or mailing address changes from that provided in the application for certification, the certified operator shall provide written notification to the cabinet within thirty (30) days. (35 Ky.R. 475; Am. 1212; 1747; eff. 3-6-2009; 36 Ky.R. 452; 1051; eff. 2-5-2010.)

401 KAR 11:040. Water treatment and distribution system operators; classification and qualifications.

RELATES TO: KRS 223.160-220, 224.10-100, 224.10-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.160-220, 224.10-100, 224.10-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-100 and 224.10-110 authorize the cabinet to promulgate administrative regulations concerning the certification of water operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes classification of water treatment and distribution operator certifications and establishes the qualifications for certification.

Section 1. Classification of Water Operator Certifications.
(1) Water treatment certifications.

(a) Limited certification. As provided in KRS 223.160(2), an operator issued a limited certificate may have primary responsibility for a water treatment facility for a school and for a semipublic water supply.

(b) Class IA-D treatment certification.

1. A Class IA-D treatment operator may be in direct responsible charge for a Class IA-D or Class IB-D water treatment plant as established in 401 KAR 8:030, Section 2.

2. A Class IA-D treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.

(c) Class IB-D treatment certification.

1. A Class IB-D treatment operator may be in direct responsible charge for a Class IB-D water treatment plant, as established in 401 KAR 8:030, Section 2.

2. A Class IB-D treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.

(d) Class IIA treatment certification.

1. A Class IIA treatment operator may be in direct responsible charge for a Class IIA water treatment plant or a Subclass A or B water treatment plant of an equal to or smaller design capacity, as established in 401 KAR 8:030, Section 2.

2. A Class IIA treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.

(e) Class IIB-D treatment certification.

1. A Class IIB-D treatment operator may be in direct responsible charge for a Class IIB-D water treatment plant or a Subclass B water treatment plant of a smaller design capacity, as established in 401 KAR 8:030, Section 2.

2. A Class IIB-D treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.

(f) Class IIIA treatment certification.

1. A Class IIIA treatment operator may be in direct responsible charge for a Class IIIA water treatment plant or a Subclass A or B water treatment plant of an equal to or smaller design capacity, as established in 401 KAR 8:030, Section 2.

2. A Class IIIA treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.

(g) Class IIIB treatment certification.

1. A Class IIIB treatment operator may be in direct responsible charge for a Class IIIB water treatment plant or a Subclass B water treatment plant of a smaller design capacity, as established in 401 KAR 8:030, Section 2.

2. A Class IIIB treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.

(h) Class IVA treatment certification.

1. A Class IVA treatment operator may be in direct responsible charge of any Subclass A or B water treatment plant, as established in 401 KAR 8:030, Section 2.

(i) Class IVB treatment certification.

A Class IVB treatment operator may be in direct responsible charge of any Subclass B water treatment plant, as established in 401 KAR 8:030, Section 2.

(2) Water distribution certifications.

(a) Class ID distribution certification.

1. A Class ID distribution operator may be in direct responsible charge for a Class ID water distribution system, as established in 401 KAR 8:030, Section 2.

2. A Class ID distribution operator shall not be in direct responsible charge for a water distribution system serving a larger population.

(b) Class IID distribution certification.

1. A Class IID distribution operator may be in direct responsible charge for a Class IIID water distribution system, as established in 401 KAR 8:030, Section 2.

2. A Class IID distribution operator shall not be in direct responsible charge for a water distribution system serving a larger population.

(c) Class IIID distribution certification.

1. A Class IIID distribution operator may be in direct responsible charge for a Class IIID water distribution system, as established in 401 KAR 8:030, Section 2.

2. A Class IIID distribution operator shall not be in direct responsible charge for a water distribution system serving a larger population.

(d) Class IVD distribution certification.

1. A Class IVD distribution operator may be in direct responsible charge of any water distribution system.

(3) Bottled water certification. A bottled water operator may be in direct responsible charge for a bottled water system that bottles water for sale.

(4) Operator in Training designations.

(a) Except as provided in paragraph (c) of this subsection, a certified operator with an Operator in Training designation shall not serve in direct responsible charge of a water treatment plant or distribution system.

(b) A certified operator with an Operator in Training designation shall work under the direct supervision of a certified operator who works at the same facility and has obtained a certification level that is equal to or greater than the certification level required to serve in direct responsible charge of the facility.

(c) If a certified operator also has been issued a water treatment, distribution, or bottled water certification without an Operator in Training designation, the operator may serve in direct responsible charge a water treatment plant, distribution system or bottled water system as provided by this Section for the certifications that do not have an Operator in Training designation.

Section 2. Water Operator Qualifications: Experience, Education, and Equivalencies. An individual desiring to become a certified operator shall meet the following minimum qualifications prior to the cabinet approving the individual to take a certification examination as established in 401 KAR 11:050.

(1) The education and experience requirement for each class of water treatment certifications shall be as follows:

(a) Limited certification:

1. Education. A minimum level of education shall not be required.

2. Experience. A minimum level of experience shall not be required.

(b) Class IA-D treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a Subclass A public water system, as established in 401 KAR 8:030, Section 2, with any design capacity

(c) Class IB-D treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a Subclass A or B public water system, as established in 401 KAR 8:030, Section 2, with any design capacity shall be required.

(d) Class IIA treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a water treatment plant, with six (6) months in a Class IIA, IIIA, or IVA water treatment plant, as established in 401 KAR 8:030, Section 2, shall be required.

(e) Class IIB-D treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a public water system with six (6) months in a Class IA-D, II B-D, or higher water treatment plan, as established in 401 KAR 8:030, Section 2, shall be required.

(f) Class IIIA treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a public water treatment plant with one (1) year in a Class IIA, IIIA, or IVA water treatment plant, as established in 401 KAR 8:030, Section 2, shall be required.

(g) Class IIIB treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a public water treatment plant with one (1) year in a Class IIA, IIB-D, IIIA, IIIB, IVA, or IVB water treatment plant, as established in 401 KAR 8:030, Section 2, shall be required.

(h) Class IVA treatment certification:

1. Education. A baccalaureate degree in engineering, science, or equivalent shall be required; and

2. Experience. One (1) year of acceptable operation of a Class IIIA or IVA public water treatment plant, as established in 401 KAR 8:030, Section 2, shall be required.

(i) Class IVB treatment certification:

1. Education. A baccalaureate degree in engineering, science, or equivalent shall be required; and

2. Experience. One (1) year of acceptable operation of a Class IIIA, IIIB, IVA, or IV public water treatment plant shall be required.

(2) The educational and experience qualifications for water distribution certifications shall be as follows:

(a) Class ID distribution certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a water distribution system shall be required.

(b) Class IID distribution certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a water distribution system shall be required. Six (6) months of the required experience shall be in a water distribution system serving a population greater than or equal to 1,500.

(c) Class IIID distribution certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a water distribution system shall be required. One (1) year of the required experience shall be in a water distribution system serving a population greater than or equal to 1,500.

(d) Class IVD distribution certification:

1. Education. A baccalaureate degree in engineering, science, or equivalent shall be required; and

2. Experience. One (1) year of acceptable operation of a water distribution system serving a population greater than or equal to 15,000 shall be required.

(3) Bottled water certification. The educational and experience qualifications for bottled water certifications shall be as follows:

(a) Education. A High school diploma or general education development (GED) certificate shall be required; and

(b) Experience. One (1) year of acceptable operation of a bottled water system shall be required.

(4) The educational and experience qualifications for Operator in Training designations shall be as follows:

(a) Class IA-D Treatment, Class IB-D Treatment, Class ID Distribution, and Bottled Water certifications.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Experience shall not be required.

(b) All other applicants for the classifications identified in subsections 1(1) and 1(2) of this administrative regulation;

1. Shall have successfully qualified for and passed the certification exam of the same type classification at one (1) level lower than the Operator in Training designation being pursued; and

2. Shall not have been subject to disciplinary action as provided by 401 KAR 11:050, Section 4.

(5) Substitutions. The cabinet shall allow the following substitutions for the qualifications established in subsections (1), (2), and (3) of this section:

(a) Education in environmental engineering; environmental technology; and biological, physical, or chemical sciences shall be substituted if the substitution does not exceed fifty (50) percent of the required experience.

1. An associate degree shall be considered equivalent to two (2) years of experience.

2. A baccalaureate degree shall be considered equivalent to four (4) years of experience.

3. Education that did not result in a degree in a related field may be substituted for the required experience as follows:

a. Ten (10) contact hours, one (1) Continuing Education Unit, or one (1) post-secondary education quarter hour with a passing grade shall be considered equivalent to 0.022 years of experience.

b. One (1) postsecondary education semester hour with a passing grade shall be considered equivalent to 0.033 years of experience.

4. Education applied to the experience requirements specified in subsections (1) and (2) of this section shall not be applied to the education requirement.

(b) Experience may be substituted for the educational requirement as follows:

1. One (1) year of operational experience at a water system may substitute for one (1) year of education.

2. The cabinet may allow partial substitution of the education requirement by experience in maintenance, laboratory analysis, or other work related to the collection, treatment, or distribution of drinking water or wastewater. To establish how much experience shall be accepted, the cabinet shall determine the degree of technical knowledge needed to perform the work and the degree of responsibility the applicant had in the operation of the system.

3. Experience applied to the education requirement specified in subsections (1) and (2) of this section shall not be applied to the experience requirement.

(c) Water treatment and distribution experience may be substituted as follows:

1. Two (2) years of distribution system experience shall be considered equivalent to one (1) year of treatment experience.

2. One (1) year of treatment experience shall be considered equivalent to one (1) year of distribution system experience. (36 Ky.R. 1055; 1457; eff. 2-5-2010.)

401 KAR 11:050. Operator certification.

RELATES TO: KRS 223.160-220, 224.10-420(2), 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.160-220, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of water and wastewater operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes application and examination procedures; provisions relating to certificate issuance, renewal, and termination; reciprocity; training; and disciplinary actions.

Section 1. Application and Examination for Certification.

(1) An individual desiring to become a certified operator shall first meet the qualifications established in 401 KAR 11:030 or 11:040 and then pass an examination administered by the cabinet.

(2)(a) An applicant for certification shall complete the Registration Form for Exams and Training and Education and Experience Documentation Form and shall submit them and the certification application fee to the cabinet.

(b) In addition to the requirements of paragraph (a) of this subsection, an applicant desiring to obtain an Operator in Training designation shall submit a signed letter for a certified operator located at the facility where the applicant will work. The letter shall include:

1. A statement from the certified operator indicating that the certified operator shall oversee the work of the applicant seeking an Operator in Training designation;

2. A commitment that the certified operator shall serve as a mentor to the applicant seeking an Operator in Training designation as long as the applicant is under the certified operator's direct responsible charge;

3. Verification that the certified operator is not currently the mentor for any other individuals with an Operator in Training designation; and

4. Confirmation that the certified operator has obtained a certification level that is equal to or greater than the certification level required to serve in primary responsibility of the facility.

(c) An application shall not be submitted to the cabinet unless the applicant has met the qualifications for examination.

(3)(a) After receipt of the application items established in subsection (2) of this section, the cabinet, considering the recommendation of the board, shall determine if the applicant meets the qualifications established in 401 KAR 11:030 or 11:040.

(b) If the applicant meets the qualifications, the cabinet shall approve the application and notify the applicant of the scheduled exam date.

(4)(a) Upon the applicant's completion of the examination, the cabinet shall notify the applicant of the applicant's examination score.

(b) A score of at least seventy (70) percent shall be required to pass the examination.

(5)(a) The cabinet shall issue a certificate and a wallet card to an applicant who successfully passes the certification examination.

(b) The certificate and wallet card shall designate the certification classification for which the operator has demonstrated competency.

(6) An applicant who fails to pass an examination may apply to take the examination again by resubmitting the Registration Form for Exams and Training and the application fee to the cabinet.

(7)(a) An examination shall not be returned to the applicant, but results may be reviewed by the applicant with a member of the cabinet.

(b) A request for a review shall be submitted to the cabinet in writing.

(8) A certificate shall be issued in a comparable classification, without examination, to a person who holds a valid certificate in a state, territory, or possession of the U.S. if:

(a) The requirements for certification under which the certificate was issued are not less stringent than the requirements for certification established in KRS 223.160-220, 224.73-110, and 401 KAR Chapter 11; and

(b) The applicant submits an Application for Reciprocity form and the reciprocity fee to the cabinet.

(9)(a) A certified operator who holds an Operator in Training designation may upgrade the certification by removing the Operator in Training Designation without examination if the operator:

1. Has satisfied the requirements of Section 3(1)(a) and (b) of this administrative regulation;

2. Has acquired the minimum experience required for the certification being pursued as required by 401 KAR 11:030 or 11:040; and

3. Submits a letter from the certified operator who has served as the applicant's mentor during the Operator in Training period that recommends the removal of the Operator in Training designation.

(b) A certified operator with an Operator in Training designation who is unable to comply with the requirements established in paragraph (a) of this subsection shall apply for and retake the certification exam to upgrade the operator's certification.

Section 2. Duration of Certification.

(1)(a) Wastewater certifications shall expire on June 30 of an odd-numbered year unless suspended, revoked, or replaced by a higher classification certificate before that date.

(b) Wastewater certifications issued on or after January 1 and on or before June 30 of an odd-numbered year shall expire on June 30 of the next odd-numbered year.

(2)(a) Water certifications shall expire on June 30 of an even-numbered year unless suspended, revoked, or replaced by a higher classification certificate before that date.

(b) Water certifications issued on or after January 1 and on or before June 30 of an even-numbered year shall expire on June 30 of the next even-numbered year.

(3)(a) An expired certification shall continue in force pending the administrative processing of a renewal if the certified operator has complied with the renewal requirements of Section 3 of this administrative regulation.

(b) A certification continued in accordance with this subsection shall remain fully effective and enforceable.

(4) A certification shall terminate if not renewed on or before December 31 of the year the certification expired.

Section 3. Continuing Education and Certification Renewal.

(1) A certified operator who is not designated an Operator in Training may renew a certification without examination if the operator has:

(a) Accumulated the training hours required in subsection (5) of this section; and

(b) Submitted a completed Application for Certification Renewal form and the renewal fee to the cabinet or has renewed the certification electronically on the cabinet's Web site.

(2)(a) A certified operator seeking to renew a certification with an Operator in Training designation shall apply for and retake the certification exam as provided in Section 1 of this administrative regulation.

(b) The cabinet shall not approve an operator to take an exam to renew a certification with Operator in Training designation unless the applicant has accumulated the training hours required in subsection (5) of this section.

(3) If the Application for Certification Renewal form and the renewal fee are not received by the cabinet or submitted electronically by June 30 of the year the certification expires, a late renewal fee as established in 401 KAR 8:050, Section 3 or 11:060, Section 1 shall be paid.

(4)(a) A terminated certification shall not be renewed.

(b) An operator whose certification is terminated and who wishes to become recertified shall reapply for and pass an examination in accordance with Section 1 of this administrative regulation.

(5)(a) Prior to applying for certification renewal, a certified operator shall complete the required number of cabinet-approved training hours.

(b) A certified operator holding multiple wastewater certifications issued in accordance with this administrative regulation shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for each certificate.

(c) A certified operator holding multiple water certifications issued in accordance with this administrative regulation shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for each certificate.

(d) Hours earned prior to initial certification shall not count toward certification renewal.

(e) Wastewater training hours shall expire two (2) years from the date earned.

(f) Water training hours shall be completed for each renewal during the two (2) year period immediately prior to the certificate expiration date.

1. Certified operators with a Bottled Water, Limited, Class I or II Treatment, Collection, or Distribution certification shall complete twelve (12) hours of approved training; or

2. Certified operators with a Class III or IV Treatment, Collection, or Distribution certification shall complete twenty-four (24) hours of approved training.

(6)(a) A training provider seeking approval of certified operator training shall submit to the cabinet a completed Application for Approval of Courses for Continuing Education Credit form.

(b) Upon completion of the approved training, the provider shall submit to the cabinet a completed Continuing Education Activity Report form.

(c) A certified operator who has attended training that has not been submitted to the cabinet for approval may apply for training approval as established in paragraph (a) of this subsection.

(d) A certified operator who provides approved training shall receive hour-for-hour credit for actual instruction time.

(7)(a) Cabinet approval of training shall expire two (2) years following the date of approval.

(b) The cabinet, in consultation with the board, shall extend the approval expiration date if:

1. The provider requests the extension in writing; and
2. The training has not changed from the previous approval.

Section 4. Disciplinary Action.

(1) A certified operator shall be subject to disciplinary action if the cabinet, in consultation with the board, determines that the certified operator has not satisfactorily performed the operator's duties in accordance with 401 KAR 11:020.

(2)(a) A written complaint received by the board or cabinet regarding a certified operator, unless duplicitous or frivolous, and violations of 401 KAR 11:020 that are identified by the cabinet shall be evaluated by the board.

(b) The certified operator shall appear before the board if requested by the board

(3) The board shall make a recommendation to the cabinet regarding disciplinary action. The board may recommend that disciplinary action not taken or recommend that a disciplinary action be taken if the board determines that the certified operator has not satisfactorily performed operator duties in compliance with 401 KAR 11:020.

(4)(a) Upon receiving a recommendation from the board, the cabinet shall review the available evidence.

(b) After completing the review, the cabinet shall initiate the recommended disciplinary action or notify the board as to why an alternative disciplinary action was taken.

(5) A disciplinary action shall be commensurate with the severity, duration, and number of the violations. Disciplinary actions may include:

(a) Probation of the operator's certification for a specified period of time, not to exceed one (1) year;

(b) Suspension of the operator's certification for a specified period of time, not to exceed four (4) years, during which the certification shall be considered void;

(c) Revocation of the operator's certification;

(d) Civil or criminal penalties; or

(e) A combination of the disciplinary actions established in paragraphs (a) through (d) of this subsection.

(6) If disciplinary action is taken, the cabinet shall notify the certified operator and the operator's employer by certified mail of the action, the reasons outlined for the action, and the length of time for which the disciplinary action shall apply.

(7)(a) A certified operator whose certification has been suspended shall not have primary responsibility during the period that the suspension remains in effect.

(b) Experience gained during a suspension shall not be included toward meeting the requirements of 401 KAR 11:030 or 11:040.

(8) If a certification is revoked, the operator shall be ineligible for future certification.

(9) A certified operator who is aggrieved by a disciplinary action may file a petition for hearing with the cabinet pursuant to KRS 224.10-420(2).

Section 5. Incorporation by Reference.

(1) The following material is incorporated by reference:

(a) "Registration Form for Exams and Training", August 2009;

(b) "Education and Experience Documentation Form", July 2009;

(c) "Application for Certification Renewal", August 2009;

(d) "Application for Approval of Courses for Continuing Education Credit", August 2009;

(e) "Continuing Education Activity Report", August 2009; and

(f) "Application for Reciprocity", July 2009.

(2) This material may be inspected, copied, or obtained, subject to applicable copyright law, at the Division of Compliance Assistance, 300 Fair Oaks Lane, Frankfort, Kentucky 40601, Monday through Friday, 8 a.m. to 4:30 p.m. (35 Ky.R. 479; Am. 1216; eff. 3-6-2009; eff. 2-5-2010.)

401 KAR 8:050. Drinking water program fees. *(Only the portion related to fees for certification of water treatment plant and water distribution system operators is included. The full regulation can be located at www.lrc.ky.gov)*

RELATES TO: KRS 223.220, 224.10-100, 224.10-110, 40 C.F.R. 142.10, Pub. L. 104-182, EO 2008-507, 2008-531

STATUTORY AUTHORITY: KRS 223.220, 224.10-100(20), 224.10-110

NECESSITY, FUNCTION, AND CONFORMITY: KRS Chapter 224.10-100(20) authorizes the cabinet to establish, by administrative regulation, a fee or schedule of fees for the cost of processing applications for permits authorized by KRS Chapter 224. EO 2008-507 and 2008-531, effective June 16, 2008, abolish the Environmental and Public Protection Cabinet and establish the new Energy and Environment Cabinet. This administrative regulation establishes fees for reviewing plans and specifications of public water systems, for operator certification, and for laboratory certification.

Section 3. (1) Fees for certification of water treatment plant and water distribution system operators.
(a) Certification application fee shall be $100.
(b) A renewal application fee shall be:
1. Fifty (50) dollars if renewed through the cabinet Web site; or
2. $100 if not renewed through the cabinet Web site.
(c) A renewal late fee shall be $250.
(d) A reciprocity fee shall be $500.
(2) Each year the cabinet, in consultation with the board, shall establish fees for operator training conducted by the cabinet.
(3)(a) The fees established in subsection (1) of this section shall be nonrefundable.
(b) Fifty (50) percent of the fees established in subsection (2) of this section shall be refundable if registration is canceled at least two (2) business days prior to the beginning of the training event.
(c) The fees in subsection (2) of this section shall be fully refunded if the training event is cancelled by the cabinet. (17 Ky.R. 599; eff. 11-15-1990; 35 Ky.R. 1847; eff. 7-6-2009.)