Waterworks

Operators Manual

Division of Water Supply
Bureau of Environmental Health
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Chapter 1

Safe drinking water

Introduction

Congress passed the original Federal Safe Drinking Water Act (SDWA) in 1974. This law regulates all public water supplies in this country. Congress amended the act in 1986 and again in 1996.

The law establishes a cooperative program between the states and the U. S. Environmental Protection Agency (EPA) for public water supply regulation. States can assume primary enforcement authority (primacy) for the act, and subsequent rules and regulations. To date, only Wyoming has not assumed primacy. The EPA manages the program in that state.

The EPA writes all regulations to implement provisions of the law. These regulations are published in Title 40 of the Code of Federal Regulations, Parts 136 to 149. States use the federal regulations as their guidelines. States that assume primacy must have laws and regulations no **less** stringent than federal requirements.

The Mississippi legislature adopted the SDWA in 1975 with the stipulation that Mississippi's law and regulations would be no **more** stringent than federal requirements. Therefore, Mississippi's regulations are exactly as strict as the federal requirements.

The Mississippi State Department of Health (MSDH) is the primacy agency. The Division of Water Supply (DWS) administers the program for MSDH. The owner or operator of the water system is responsible for meeting the requirements of the SDWA.

Types of water supplies

The law and regulations apply to all publicly or privately owned "public water supplies."
Public water systems are divided into three major types:

Community water systems serve a residential population of year-around residents. The system must have at least 15 service connections or at least 25 residents. Examples: municipal, subdivision, mobile home park, and rural water systems.

Nontransient noncommunity systems provide drinking water to at least 25 of the same people for at least six months per year. Examples: schools, factories, hospitals. These systems must meet the same requirements as community water systems.

Transient noncommunity water systems are those noncommunity systems that do not meet the definition of nontransient noncommunity water system. Examples: highway rest stops, restaurants, motels, golf courses, parks.

Requirements of the Safe Drinking Water Act

The law imposes three major requirements on the water system:

- sampling and reporting
- record keeping
- public notification

Sampling and reporting

The water system is directly responsible for monitoring:

- inorganic chemicals
- microbiological contaminants
- organic chemicals
- radiological contaminants
- turbidity
- unregulated chemicals

The type of analysis, sampling frequency, and location of sampling points vary from system to system and contaminant to contaminant.

In Mississippi, the Mississippi Public Health Laboratory performs the analysis for the required contaminants. MSDH provides the containers, transports samples to the laboratory, completes the analysis, and gives results back to the water system. The Division of Water Supply is available for any assistance or follow-up instructions the water system needs.

Record keeping

The law requires public water systems to keep the following records in the water system or treatment facility:

- copies of laboratory results, including name of person who collected the samples
- dates and locations of sampling points
- records of violations and steps taken to correct violations
- sanitary survey reports
- all other water quality information

These records are public information. Customers of the water system have every right to inspect these records. The public water supply must provide copies on demand. Table 1-1 shows how long these records must be kept.

Table 1-1
Required record keeping and retention

Record	Minimum years retained
Bacteriological analyses	5
Chemical analyses	10
Written reports such as sanitary surveys and engineering reports	10 following completion
Variances and exemptions	5 following expiration
Actions taken to correct violation	3 after last action

Public notification

The water system must notify the public of any regulation violation. Violations are classed by seriousness. Tier 1 violations include failure to comply with a:

- maximum contaminant level (MCL)
- treatment technique
- variance or exemption schedule

Tier 2 violations include failure to comply with:

- monitoring requirements
- a testing procedure
- a variance or exemption.

For example, a violation of an MCL indicates contamination and is more serious than failure to meet a sampling schedule. The MCL violation requires more extensive public notification. Regulations specify that public notification meet certain minimum language and mode of delivery requirements. Table 1-2 lists the methods required for public notification of violations.

Table 1-2
Public notification requirements

Violation or condition	Required notification		
	Mail	Newspaper	Broadcast
Acute violation of an MCL	X	X	X
Nonacute violation of an MCL	X	X	
Failure to monitor	X		
Failure to follow compliance schedule	X		
Failure to use approved testing procedure	X		
System granted a variance or exception	X		

Other regulatory provisions

Variances and exemptions

The SDWA allows variances and exemptions from some of the requirements for systems having technical or financial problems. These exceptions allow a non-compliant system to supply water to the public for a limited time. The supplier must prove that allowing the variance or exemption poses no threat to the public health. Variances and exemptions are difficult to obtain and are extremely rare.

Citizens' lawsuits

The law allows the state to take civil court action against a water system to enforce compliance. Should the state fail to enforce a primary drinking water regulation, the state may ask the EPA to take action or bring civil suit against a water system in federal district court.

For a willful violation, the court may impose a fine of up to $25,000 per violation. Each day in non-compliance is a separate violation.

If these actions fail to force compliance, a citizen may file suit against the water system, the state, and the EPA in U.S. District Court. Class-action suits are not allowed. The court can require a citizen seeking a temporary restraining order or injunction to put up a bond. The court can award litigation costs to either party. The complainant must give 60 days notice before taking civil action against the water system, the state, or the EPA.

Emergency powers

If local and state authorities don't take appropriate corrective action, the EPA may intervene. This applies if the violation poses an "imminent and substantial" danger to public health. The EPA consults with the local and state authorities before taking action.

The action may include orders to protect public health or a restraining order or an injunction. If a water system violates an EPA emergency order, it is subject to a maximum fine of $25,000 per day per violation.

Siting requirements

The law includes siting requirements that prevent facilities from locating in areas subject to disasters such as flooding, fires, and earthquakes. Siting requirements also apply to major improvements. However, the regulations do not apply to minor improvements such as installing one service line. Siting requirements apply in the following situations:

- financial agreement to construct a new public water system
- construction of a new public water system
- major expansion or improvement of an existing water system

The DWS technical assistance branch or DWS regional engineer can supply information about siting requirements for public water systems.

Drinking water standards

The law directs the EPA to issue primary and secondary drinking water standards to ensure safe and acceptable water for the consumer. The National Primary Drinking Water Regulations (NPDWRs) protect the public health. Table 1-3 on the next page shows the health effects associated with regulated contaminants.

The secondary standards are based on aesthetic qualities for drinking water. These are non-enforceable guidelines.

The law and regulations are extensive. What follows is a summary discussion of the requirements.

Primary standards

Primary standards are either maximum contaminant level (MCL) or treatment technique requirements.

The MCL is the enforceable standard. Water samples from public water systems must meet this standard for compliance.

An MCL goal (MCLG) is a value associated with no bad health effects. For chemicals that might cause cancer, the goal is set at zero. The MCLG is a goal, not an enforceable standard.

Treatment technique requirements are set for contaminants that are difficult or costly to measure. The EPA can require specific treatment techniques to prevent possible health risks. Treatment technique requirements are enforceable standards. *The Lead and Copper Rule* and *The Surface Water Treatment Rule* are examples.

Secondary standards

Secondary standards are set for those contaminants that affect aesthetic quality (e.g., taste, odor, or color) of water. Water that exceeds the secondary maximum contaminant levels might not be pleasant to drink but will not cause health problems.

Most complaints that consumers lodge about drinking water are related to secondary standards.

Table 1-3
Health effects of contaminants regulated by the NPDWRs

Contaminant	Health effect
Microbiological organisms	Cause various illnesses such as gastroenteritis, typhoid, bacillary dysentery, infectious hepatitis, amoebic dysentery, and giardiasis. Some illnesses are potentially fatal.
Turbidity	Protects microorganisms from chlorine and other disinfectants, acts as a food source for microorganisms, interferes with maintenance of a chlorine residual in the distribution system, and interferes with coliform testing:
Arsenic	Causes small sores on hands and feet, possibly developing into cancer.
Barium	Causes increased blood pressure and nerve block.
Cadmium	Concentrates in liver, kidneys, pancreas, and thyroid; hypertension is a suspected health effect.
Chromium	Causes skin sensitivity, kidney damage.
Lead	Causes constipation, loss of appetite, anemia, tenderness, pain, gradual paralysis of the muscles, especially the arms, and reduced mental capacity in children.
Mercury	Causes inflammation of the mouth and gums, swelling of the salivary glands, and loosening of the teeth.
Selenium	Causes staining of fingers, teeth and hair, general weakness, depression, irritation of the nose and throat.
Fluoride	Causes stained spots on teeth (mottling) – the amount of discoloration depends on the amount of fluoride ingested.
Nitrate	Causes temporary blood disorder in infants – can be fatal.
Pesticides Endrine Lindane Methoxychlor Toxaphene	Cause symptoms of poisoning which differ in intensity. The severity is related to the concentration of these chemicals in the nervous system, primarily the brain. Mild exposure causes headaches, dizziness, numbness, and weakness of the extremities. Severe exposure leads to spasms involving entire muscle groups, leading in some cases to convulsions. Suspected of being carcinogenic.
Herbicides 2,4-D 2,4,5-TP	Cause liver damage and gastrointestinal irritation.
Trihalomethanes	Suspected as possible carcinogens.

Contaminant groups

The EPA is continuously revising standards for contaminant groups and creating new standards. Refer to 40 CFR, Parts 136 to 149 for the most current regulations.

Microbiological contaminants

This group includes bacteria, viruses, and protozoa — some of which cause diseases. The coliform group of bacteria is the indicator of microbiological contamination. Coliform organisms are not harmful but indicate sewage contamination. Tests to detect coliform bacteria are accurate, easy, and inexpensive. See the *Total Coliform Rule* (Appendix A) for total coliform and *E. coli* standards.

Other types of bacteria regulated under the Surface Water Treatment Rule are *Legionella*, which causes an upper respiratory disease. Tests for heterotrophic bacteria assess the overall bacteriological quality of the water. Enteric viruses, the protozoa *Giardia lamblia* and *Cryptosporidia* are significant threats to public health.

Suspended material in water causes turbidity or cloudiness. The suspended material is not contamination but shields microorganisms from disinfection. Excess turbidity can allow live pathogens to enter the system. New regulations covering these contaminants are included in the *Surface Water Treatment Rule*. This rule is a set of treatment technique requirements for systems using surface water or ground water under the direct influence of surface water.

Inorganic contaminants

Inorganic contaminants are mostly metals. The list includes antimony, arsenic, asbestos, barium, beryllium, cadmium, chromium, cyanide, fluoride, mercury, nickel, nitrate, nitrite, selenium, sulfate, and thallium. *The Lead and Copper Rule* establishes the EPA regulations for lead and copper. Separate rules are being considered for other inorganic contaminants.

Organic contaminants

Organic contaminants are subdivided into three categories: volatile organic contaminants (VOCs), synthetic organic contaminants (SOCs), and pesticides\herbicides\PCBs.

VOCs readily volatilize when exposed to air. Most are industrial chemicals, solvents, or fuel constituents. SOCs are man-made, carbon-containing chemicals and some pesticides and herbicides.

Radiological contaminants

The radionuclides are radioactive chemicals, mostly natural. These include radon, radium-226, radium-228, uranium, beta particle and photon emitters, and alpha emitters.

Unregulated contaminants

Unregulated contaminants are monitored, but there is no enforceable standard. Monitoring helps the EPA decide if regulations are necessary and what the MCL for each contaminant should be.

References

Manual of Instruction for Water Treatment Plant Operators. NY State Dept. of Health, Albany, NY (1975).

National Interim Primary Drinking Water Regulations. Office of Water Supply, USEPA, Washington DC EPA-570/9-76-003 (1976).

National Secondary Drinking Water Regulations. Office of Drinking Water, USEPA, Washington DC EPA-570/9-76-000 (July 1979).

Introduction to Water Quality Analysis. AWWA Denver CO (1982).

A Working Explanation of the Public Notification Rule. AWWA, Denver CO (1990).

A Working Explanation of the Surface Water Treatment Rule. AWWA, Denver CO (1990).

A Working Explanation of the Total Coliform Rule. AWWA, Denver CO (1990).

Sample questions

1. All the following are public water systems except:
   a. community water supplies
   b. noncommunity water supplies
   c. nontransient noncommunity water supplies
   d. private home wells

2. The public is notified of a non-acute MCL violation by all the following except:
   a. TV and radio
   b. newspaper
   c. hand or mail delivery
   d. posting

3. Sanitary survey and chemical analyses reports must be retained for:
   a. 5 years
   b. 3 years
   c. 10 years
   d. 7 years

4. Under the SDWA, water suppliers are responsible for all the following except:
   a. record keeping
   b. sampling
   c. emergency powers
   d. public notification

5. Primary drinking water standards are contaminants with enforceable
   a. MCLs
   b. NPDES
   c. MCLGs
   d. VOCs

6. Contaminants that are monitored but have no enforceable standards are:
   a. radionucleides
   b. organics
   c. unregulated
   d. inorganics

Chapter 2

Operator Certification

Introduction

This chapter explains how water systems are classified and how waterworks operators become certified.

Every community and nontransient noncommunity public water supply in Mississippi must have a certified waterworks operator. An operator is "the person who directly supervises and is personally responsible for the daily operation and maintenance of a community or nontransient noncommunity water system."

The law gives the Mississippi State Department of Health authority to certify waterworks operators. The Mississippi State Board of Health adopts regulations to enforce the law. The Certification, Training and Monitoring Branch, Division of Water Supply, administers the regulations.

Water system classification

Every public water system is classified by the type of water treatment used to assure safe drinking water. Table 2-1 on page 3 shows how water systems are classified. The table summarizes only part of the *Regulation Governing the Certification of Municipal and Domestic Water Systems Operators.* Refer to Appendix B-2 for all of the regulation.

The law

A waterworks operator's certificate must at least equal the system classification. Any system that loses a certified waterworks operator must replace that operator within 180 days. The *Municipal and Domestic Water and Wastewater System Operator's Certification Act of 1986* is in Appendix B-2.

Requirements for certification

An applicant who wants to become certified in Mississippi must meet educational and experience qualifications. The operator must also pass the appropriate waterworks operator certification examination. In some cases, additional experience may substitute for education.

All candidates must have at least one year of supervised experience. The supervisor must hold a certificate that is equal to or higher than the one the candidate seeks. The supervisor must endorse the applicant's application. Two additional MSDH-certified operators must recommend the applicant's certification.

The test is offered three times a year, after the four-day waterworks operators short course. An examination fee is required.

A certification application is sent by mail to those who pass the examination. The Certification Branch reviews applications within two weeks. If the application is approved, the applicant is mailed an invoice for the certification fee. When the agency receives payment, the certificate is sent. The certificate is valid for three years from the first or fifteenth of the month in which the payment is received.

Renewal

Waterworks operator certificates are valid for three years unless revoked for due cause. Causes for revoking a certificate can include:

- Fraud or deception
- Operator is incompetent or unable to properly perform required duties.
- Operator failed to exercise reasonable care or judgment in performing duties.

Re-examination is not required for certificate renewal, provided:

- The application is filed within 30 days after the existing certificate expires.
- The renewal application lists and shows proof that an operator who has been continuously licensed less than 9 years, has attended 48 approved continuing education units within within the three years of the certificate.

or

- The renewal application lists and shows proof that an operator who has been continuously licensed more than 9 years, has attended 24 approved continuing education units within the three years of the certificate. Operators must keep their own education records.

A certified operator must pass the written examination for certification again if:

- The operator files for renewal more than 30 days after the certificate expires.
- The operator fails to get 48 hours of continuing education.

The renewal fee is required. The renewal certificate is valid for three years.

Sample questions:

1. If a public water system loses its certified waterworks operator, how long does the system have to employ another certified water works operator?
   a. 90 days
   b. 365 days
   c. 180 days
   d. 48 days

2. From the time an operator is certified, how long does the operator have to get the 48 or 24 education hours required to renew certification?
   a. Three years plus 60 days
   b. Three years from the date the certificate is dated
   c. 48 months from the date the certificate is dated
   d. Three years from the date the operator takes the exam

3. Who is responsible for keeping up with an operator's continuing education hours?
   a. The certified operator.
   b. The Mississippi Water & Pollution Control Operator's Association
   c. The Mississippi State Department of Health
   d. The Mississippi Rural Water Association

Table 2-1

Classification of public water systems and respective operator qualifications for certification

	Public water system classification	Water operator qualifications for certification
Class A	Systems with surface water treatment, lime softening, or coagulation and filtration for the removal of constituents other than iron or manganese.	**1.** The applicant must have a bachelor's degree in engineering or applied sciences from an accredited college or university, at least one year experience in Class A water plant, and pass the written examination required by the bureau, or **2.** He/She must be a graduate of an accredited high school, or equivalent (GED), have at least six years experience in Class A or B water plant, of which one year must be in a Class A plant, and pass the written examination required by the bureau.
Class B	System with two or more Class C treatment facilities of different types, or with iron or manganese removal facilities breaking pressure or requiring flocculation and/or sedimentation.	The applicant must have graduated from an accredited high school, or equivalent (GED), have at least three years experience in a Class A, B, or C water plant, of which one year must be in a Class A or B plant, and pass the written examination required by the bureau.
Class C	System with aeration, pH adjustment, corrosion control or closed pressure type treatment facilities including zeolite softening or iron removal.	The applicant must have graduated from an accredited high school or equivalent (GED), have at least two years experience in a Class A, B, C or D water plant, of which one year must be in a Class A, B, or C plant and pass the written examination required by the bureau.
Class D	System with one or more wells but no treatment other than chlorination, fluoridation, and phosphate addition.	The applicant must have graduated from an accredited high school or equivalent (GED) and have at least one year experience in the same class facility as being applied for or a higher level. In addition the applicant must pass the written examination required by the bureau.
Class E	Systems that purchase water only. This classification shall also apply to waterworks operators whose only job responsibility is the operation and maintenance of distribution system(s).	The applicant must have graduated from an accredited high school or equivalent (GED) and have at least one year experience in the same class facility as being applied for or a higher level. In addition the applicant must pass the written examination as required by the bureau.

*** At least one year of experience in all classes must be while under the supervision of a certified operator. The supervising operator must have a nonrestricted certificate for the class system being applied for or higher and must endorse the applicant's application.**

Chapter 3

Mathematics

Introduction

This chapter reviews basic calculations that a water system operator uses. Discussions and examples explain how to:

- convert numbers to the same units
- use fractions in calculations
- use decimals and percentages
- understand ratio and proportion
- calculate averages
- calculate area and volume

Numbers

There are two kinds of numbers: pure and concrete. Pure numbers have no units. Here are examples of pure numbers:

1
26
195
⅔
7.48

Concrete numbers have specific units, such as:

1 foot
26 psi
195 gallons
⅔ cup
7.48 gallons per cubic foot

Be sure to convert all concrete numbers to the same units before making calculations.

Units

All water system processes use units, such as:

- pounds per day (ppd)
- gallons per minute (gpm)
- milligrams per liter (mg/l)
- pounds per square inch (psi)

The following units are more common in class A, B, or C treatment processes and in larger plants:

- gallons per square foot (gal/ft^2)
- pounds per gallon (lbs/gal)
- million gallons per day (mgd)

Units used with concrete numbers express filter loading rates, detention times, chemical feed rates, pumping and overflow rates.

To understand and communicate what happens in the treatment plant and distribution system, the operator needs to know mathematics and common units of measurement. The operator must convert units of measurement to make calculations with concrete numbers. Table 3-1 on the next page shows some common conversions.

Table 3-1
Conversion factors used in the water industry

Multiply	by	to convert to
Meters (m)	39.37	Inches (in)
Inches (in)	2.54	Centimeters (cm)
Inches (in)	25.4	Millimeters (mm)
Miles (mi)	1.61	Kilometers (km)
Pounds (lbs)	454	Grams (gms)
Gallons (gals)	3.785	Liters (l)
Head (ft)	0.433	Pounds/in^2 (psi)
Pounds/in^2 (psi)	2.31	Head (ft)
Gallons (gal)	8.34	Pounds (lbs)
Cubic feet (ft^3)	7.48	Gallons (gal)
Cubic feet (ft^3)	62.4	Pounds (lbs)

To convert the right hand column to the left hand column, divide instead of multiply.

Examples:
How long in centimeters is 27 inches?
Inches x 2.54 = centimeters: 27 in x 2.54 (cm/in) = 68.58 cm
How many gallons is 980 liters?
Liters divided by 3.785 = gallons: 980 (l) ÷ 3.785 (l/gal) = 258.92 (gal)

Fractions

A fraction is the ratio between any two numbers. Fractions have two parts, a numerator and a denominator. The numerator is the top number and the denominator is the bottom number:

$$\frac{\text{numerator}}{\text{denominator}}$$

If the numerator is larger than the denominator, it's called an **improper fraction**. Example: $\frac{4}{3}$ A **proper fraction** is when the numerator is smaller than the denominator, such as ¾. A **mixed fraction** or **mixed number** is a whole number and fraction together, such as 3⅞. Here, 3 is the whole number or integer, and ⅞ is the fraction.

Decimals

A decimal is a fraction expressed in tenths (0.1), hundredths (0.01), thousandths (0.001), or to as many decimal places as desired.
Examples: 1/10 is 1 ÷ 10 = 0.1 or one-tenth; ¾ is 3 ÷ 4 = 0.75 or seventy-five hundredths.

Decimal place states the number of places or numbers to the right of a decimal. The number 000.0036200 is carried to the seventh decimal place.

The number of decimal places reflects accuracy. The number .00362 has the same value as 000.0036200, but the larger number expresses greater significance or accuracy.

To report 000.0036200 to three decimal places, we would write the number 0.004, rounding the 3 to 4. The rule is to round up (3 to 4) if the dropped number is 5 or greater, round down if the dropped number is less than 5. Common sense dictates how many places express reasonable results.

Example: 0.45271 is 0.45 or 0.453; 0.123721 is 0.1 or 0.12

To simplify calculations with fractions, use a calculator. Convert the fraction to a decimal. It is much easier to multiply 7.33 x 4.38 than it is to multiply 7⅓ x 4⅜.

Adding and subtracting fractions

To add and subtract fractions, first find a common denominator; that is, the lowest number by which denominators of the fractions can be evenly divided. Examples: the common denominator of ⅓ and ½ is 6; the common denominator of ⅔ and ⅜ is 24.

Find a common denominator by multiplying together all denominators, then check for a lower number by dividing in half. Examples: To find the common denominator of ⅝, ⅓, and ¾: 8 x 3 x 4 = 96 ÷ 2 = 48 (that works) ÷ 2 = 24 (that works) ÷ 2 = 12 (won't work; 8 won't go evenly into 12). However, when using a calculator, it's quicker to use the larger common denominator than to take time to find a smaller number.

Example: $\frac{5}{8} + \frac{1}{3} + \frac{3}{4} =$

$$\frac{3x5}{3x8} + \frac{8x1}{8x3} + \frac{6x3}{6x4} = \frac{15}{24} + \frac{8}{24} + \frac{18}{24} = \frac{41}{24} = 1\frac{17}{24}$$

Adding and subtracting decimals

To add and subtract decimals, line up the decimal points of all the numbers. The decimal place for a number with no decimal point is to the right of the number (2 is 2.0).
Example: add 11.2, 5, and .45:

11.20
5.00
0.45
16.65

Multiplying fractions

To multiply fractions, separately multiply the numerators together and the denominators together. A mixed number must first be expressed as a fraction ($1\frac{3}{4} = \frac{7}{4}$). To multiply a fraction by a whole number, express the integer as a fraction ($5 \times \frac{3}{4} = \frac{5}{1} \times \frac{3}{4}$).

Example: $\frac{2}{3} \times \frac{3}{8} = \frac{2x3}{3x8} = \frac{6}{24}$ or $\frac{1}{4}$

Multiplying decimals

To multiply two numbers with decimals, multiply as if there were no decimals in the numbers. Then count decimal places in both numbers and point off that many places from the right end in the product. Always check to see if the product is reasonable!
Example: 2.15 x 3.2: 215 x 32 = 6880, point off three decimal places from the right end = 6.88. Seem reasonable?

Dividing fractions

To divide fractions, invert the divisor ($\frac{3}{4} - \frac{4}{3}$) and multiply the fractions together.
Example: $\frac{1}{2} \div \frac{2}{3} = \frac{1}{2} \times \frac{3}{2} = \frac{1x3}{2x2} = \frac{3}{4}$

Dividing decimals

To divide by a number with a decimal, move the decimal point of the divisor to the right of the last numeral. Move the decimal point of the number being divided by the same number of spaces.
Example: 325 ÷ 5.25 – 32500 ÷ 525 = 61.905

Exponentiation

Exponentiation means multiplying a number by itself. The simplest example is squaring a number, or multiplying the number by itself one time. The superscript 2 means to square the number. Example: $2^2 = 2 \times 2 = 4$. Cubing a number means raising a number to the third power. Indicated by a superscript 3, it means to multiply the number by itself two times. Example: $2^3 = 2 \times 2 \times 2 = 8$.

Advanced hydraulic modeling formulas, such as Hazen-Williams or Darcy-Weisbach, raise variables to decimal powers ($D^{4.87}$). These calculations are complicated to solve without advanced mathematical techniques, such as logarithms. Operators doing these calculations can rely on scientific calculators and computers for their solutions.

Example: 5^3

On a standard calculator: $\boxed{5}$ $\boxed{x^y}$ $\boxed{3}$ $\boxed{=}$ 125

Reverse Polish notation: $\boxed{5}$ enter $\boxed{3}$ $\boxed{y^x}$ 125

Ratio and proportion

A ratio, normally expressed as X:Y or as a fraction $\frac{X}{Y}$, implies a comparison of two numbers or the division of one number by another. The fraction $\frac{7}{8}$ is the ratio of 7 to 8. A proportion, indicated by an equal sign (=) is a statement of equality between ratios. Products of cross multiplication of numerators and denominators are also equal.
Example: $\frac{a}{b} = \frac{c}{d}$ can be cross multiplied and still maintain equality - ad = bc.
Ratio and proportion operations are fundamental to calculating dosage rates.

Example: The value of x in the following equation:

$$\frac{325}{x} = \frac{4}{6}$$

Cross multiplying: $4x = 6 \times 325$

$x = \frac{6x325}{4}$ $\quad x = 487.5$

Percentage

Percentage is a ratio in which the denominator is always 100. To express a decimal as a percentage, move the decimal two places to the right:

0.50 = 50%. To express a percent as a decimal, move the decimal two places to the left: 50% = 0.50.

Convert mixed numbers and fractions to decimal numbers before they can be expressed as a percentage. ***Example***: 1¼ = 1.25 = 125%.

To calculate the percentage of a number, multiply the number by the percentage expressed as a decimal. ***Example***: 20% of 50 = 0.20 x 50 = 10.

Averages

An average is the calculated middle point in a set of numbers. An average is one way to describe data. For example, average daily demand is an important number for a water system to know. Average daily demand can characterize such operational parameters as average pump run times, storage turnover rates, and expected water consumption. To compute averages, add all the numbers in a data set and divide by the number of data in the set.

Example: the average of the numbers 6, 10, 32, 5, and 7 is the sum of the five numbers divided by five. 6 + 10 + 32 + 5 + 7 = 60 ÷ 5 = 12 is the average or mean.

Area

Area is the product of measurements in two dimensions: length multiplied by width, width multiplied by height, or length multiplied by height. The units of measurement must be the same (see table 3-1 for conversion factors).

Example: To find the area of a rectangle 2 ft long by 18 in wide, convert 18 inches to 1.5 feet. 2 x 1.5 = 3 sq ft.

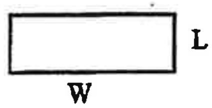
English units for lengths are inches, feet, yards, and miles. Metric units are centimeters, meters, and kilometers. It follows that areas are most commonly reported in square inches (in^2), square feet (ft^2), square yards (yd^2), and square miles (mi^2); square centimeters (cm^2), square meters (m^2), and square kilometers (km^2). The term "square feet" or "ft^2" means length in feet times width in feet equals area.

The formula for the area of a circle is Area = $\frac{\pi \times D^2}{4}$, where π is a universal constant equal to 3.14, and D is the diameter.

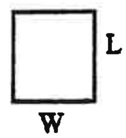
Volume

Volume is the product of measurements in three dimensions — length times width times height. Volume is the surface area times the third dimension. As in area calculations, be sure to use consistent units when calculating volume. The units are the same as those for area calculations. Express volume in cubic feet (ft^3), cubic yards (yd^3), cubic meters (m^3), gallons (gal) and million gallons (MG). Example: a box 3 feet tall, 2 feet wide, and 5 feet long has a volume of 3 x 2 x 5 = 30 cubic feet.

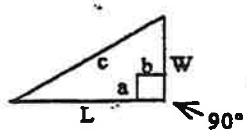
Table 3-2
Formulae for calculating area, perimeter, and volume of various shapes



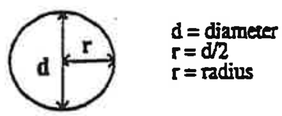
Rectangle
Area = W x L
Perimeter = W + W + L + L = 2w + 2L



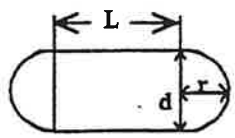
Square
Area = W x L = W x W = W^2 = L^2
Perimeter = 2W + 2L = 4W



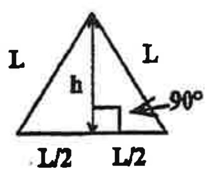
Right angle (90°) triangle
Area = ½ x L x W $c^2 = a^2 + b^2$
Perimeter = c + a + b



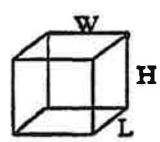
Circle
Area = π x $d^2/4$ = π x r^2
Perimeter = π x d
Note: π or pi = 3.14 (approximate)



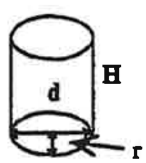
Combined shapes
Area = 3.14 x r^2 + L x d
Perimeter = 3.14 x d + 2 x L



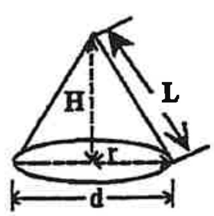
Triangle
Area = ½ x (L ÷ 2) x h + ½ x (L ÷ 2) x h = ½Lh
Perimeter = L + L + (L ÷ 2) + (L ÷ 2) = 3L



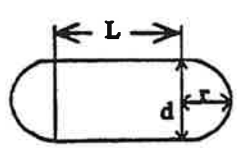
Cube, rectangular tank
Volume = W x L x H
Area = number of sides closed x area of each side



Cylinder. circular tank or length of pipe
Volume = 3.14 r^2H
Area = (3.14 x d x H) + (2 x 3.14 x r^2)



Cone
Volume = (3.14 ÷ 3) x r^2H = 1.05 x r^2H
Area = ½ x 3.14 x d x L



Tank
Volume = (3.14 ÷ 6) d^3 + (3.14d^2L) ÷ 4
Area = (3.14 x d x L) + (4 x 3.14 x r^2)

Sample questions

1. How many miles is 5 kilometers?
   a. 31.1
   b. 3.11
   c. 311
   d. .311

2. How many pounds does 1 million gallons (MG) of water weigh?
   a. 1,000,000
   b. 748,000
   c. 8,340,000
   d. 62,400,000

3. Round the number 0.456 to one significant decimal place.
   a. 00.46
   b. 0.460
   c. 0.5
   d. 0.4

4. What is the lowest common denominator of the fractions ⅔ and ¾?
   a. 12
   b. 24
   c. 6
   d. 4

5. What is ⅔ + ¾ expressed as a mixed number?
   a. $\frac{17}{12}$
   b. $1\frac{5}{3}$
   c. $\frac{5}{7}$
   d. $1\frac{5}{12}$

6. What is 1⅝ - ¼ expressed as a mixed number?
   a. $\frac{11}{16}$
   b. 1⅜
   c. 1⅛
   d. 1 ½

7. What is the sum of 11 + 15.3 expressed to two decimal places?
   a. 16.4
   b. 26.3
   c. 26.30
   d. 26

8. What is 15.3 - 3.14, expressed to one decimal place?
   a. 12.2
   b. 12.16
   c. 73.9
   d. 12

9. What is the product of 3.14 x 15?
   a. 45
   b. 47.10
   c. 4.71
   d. .4710

10. What is 1⅝ divided by ⅔?
    a. $\frac{39}{16}$
    b. $\frac{15}{11}$
    c. $\frac{7}{16}$
    d. $1\frac{1}{12}$

11. What is the product of ⅓ x $\frac{3}{5}$
    a. $\frac{4}{15}$
    b. $\frac{3}{15}$
    c. $\frac{14}{15}$
    d. $\frac{4}{8}$

12. What is 15 divided by 3.1, expressed to two decimal places?
    a. 4.84
    b. 48.4
    c. .484
    c. 484

13. What is 4.1 raised to the third power (4.1^3)?
    a. 68.92
    b. 12.39
    c. 7.13
    d. 8.26

14. What is $(500)^{1.85}$?
    a. 925
    b. 92.5
    c. 98422.5
    d. 270.3

15. What is unknown quantity X in the following equation: $\frac{4}{5} = \frac{X}{10}$?
a. 8
b. 14
c. .8
d. 12.5

16. How many pounds of chlorine are contained in 100 pounds of HTH if HTH has 70% chlorine by weight?
a. 7
b. 70
c. 700
d. 7000

17. If 80% of the customers of a water system are metered, and the water system has 500 connections, how many customers are **not** metered?
a. 40
b. 400
c. 100
d. 10

18. What is the average of the following monthly water bills: $24.00, $35.36, $18.45?
a. $77.81
b. $60.00
c. $25.94
d. $29.54

19. Daily meter readings from a well for five days were 180,000 gals, 145,000 gals, 200,000 gals, 225,000 gals and 155,000 gals. What is the average daily production of the well for the five-day period?
a. 180,000 gals
b. 200,000 gals
c. 179,000 gals
d. 181,000 gals

20. The surface dimensions of a filter are given by length = 20 feet and width = 10 feet. What is the surface area of the filter in square feet?
a. 2.0
b. 20.0
c. 200.0
d. 50.0

21. What is the surface area of a circular filter that has a diameter of 20 feet?
a. 31.4
b. 314.0
c. 15.7
d. 1256.0

22. What is the volume in cubic feet of a circular standpipe that has a diameter of 10 feet and a height of 50 feet?
a. 39.25
b. 392.5
c. 3925.0
d. 39250.0

23. What is the volume in gallons of a 50-foot x 100-foot x 10-foot rectangular settling basin?
a. 5000.0
b. 50000.0
c. 3120000.0
d. 374000.0

Chapter 4

Hydraulics

Introduction

Hydraulics is a branch of science that deals with practical applications (such as the transmission of energy or the effects of flow) of liquid at rest and in motion. It includes the flow of water through pipes, channels, filters, basins and pumps and includes the pressure exerted by the water under static and dynamic conditions. Discussions of static and dynamic hydraulic principles, pumps and flow measurement are included in this chapter. A basic understanding by the water system operator of the hydraulics involved in a water system is essential to the proper operation and control of the system.

Static Hydraulics

Water under pressure, whether at rest or in motion, has energy. The higher the pressure, the more energy that is associated with it. Static hydraulics is the study of liquids (in our case water) at rest. **Static head**, or **elevation head**, refers to the level of water above a reference elevation, measured in feet. Static head represents the amount of potential energy of the water.

Water levels will equalize in a water distribution system at rest. With no water moving, water levels rise in the system to the water level of the highest elevated tank or standpipe. That water level at a point is the static head of the point.

When talking about head, it is necessary to specify the reference or datum elevation to be used in calculations. The most commonly used reference elevation is mean sea level (msl) -- the average water level between low and high tides. Throughout the United States, permanent surveying reference markers have been established by the U.S. Coast and Geodetic Survey. These **benchmarks** are points of known location and elevation and are used by engineers and surveyors as the beginning and ending points for extremely accurate land surveys. For practical purposes, it is not always convenient or necessary to reference these benchmarks. Points of assumed location and elevation can be used. The main floor of the water treatment plant, for example, may arbitrarily be assigned an assumed elevation and all elevations in a water system referenced to it. It is always necessary, however, to understand and record what datum is being used.

To determine the actual static head at a point in a distribution system, subtract the point's elevation from the system's highest water elevation.

Example

The water surface elevation of a full standpipe is found to be +150 feet in reference to an assumed elevation point. The ground elevation at the house nearest the standpipe is +50 feet higher than the assumed reference point. What is the static head at the house?

Solution

Static head (ft) = 150 ft - 50 ft = 100 ft

Answer

a. 200 ft
b. 150 ft
c. 100 ft
d. 50 ft

Example

An elevated tank is 120 feet from the ground to the overflow of the tank. The water treatment plant is 20 feet below the ground elevation of the tank. What is the static head at the treatment plant?

Solution

Static head (ft) = 120 ft + 20 ft = 140 ft

Answer

a. 140
b. 120
c. 100
d. 80

Another term commonly used to express static head is static pressure. Water pressure is directly dependent on the specific weight of water -- 62.4 lbs/ft^3 at 4 degrees centigrade. Where static head implies the units of feet, pressure is usually expressed in pounds per square inch or psi. To determine the pressure in psi exerted by a cubic foot of water one foot square by one foot high:

$$\frac{1\ ft \times 62.4\ lbs/ft^3}{144\ in^2/ft^2} = 0.433\ lbs/in^2\ (psi)$$

Therefore, the column of water one foot square by one foot high exerts a pressure of 0.433 psi at its base.

Consider a one foot square column of water 50 feet high:

$$Area\ (ft^2) = 1\ ft^2$$

$$Area\ (in^2) = 1\ ft^2 \times 144\ \frac{in^2}{ft^2} = 144\ in^2$$

$$Volume\ (ft^3) = 1\ ft^2 \times 50\ ft = 50\ ft^3$$

$$Weight\ (lbs) = 62.4\ \frac{lbs}{ft^3} \times 50\ ft^3 = 3120.0\ lbs$$

The pressure exerted on the bottom of the 50-foot column is:

$$\frac{3120.0\ lbs}{144\ in^2} = 21.67\ \frac{lbs}{in^2}\ or\ 21.7\ psi$$

If the column was a cylinder instead of rectangular, the pressure exerted at the bottom of the cylinder is found in a similar manner (assume the diameter of the cylinder is 1 foot):

$$Area\ (ft^2) = \frac{\pi D^2}{4} = \frac{3.14 \times (1\ ft)^2}{4} = 0.785\ ft^2$$

$$Area\ (in^2) = 0.785\ ft^2 \times 144\ \frac{in^2}{ft^2} = 113.04\ in^2$$

$$Volume\ (ft^3) = 0.785\ ft^2 \times 50\ ft = 39.25\ ft^3$$

$$Weight\ (lbs) = 62.4\ \frac{lbs}{ft^3} \times 39.25\ ft^3 = 2449.2\ lbs$$

The pressure exerted on the bottom of the cylinder of water is determined to be:

$$Pressure\ (psi) = \frac{2449.2\ lbs}{113.04\ in^2} = 21.67\ \frac{lbs}{in^2}\ or\ 21.7\ psi$$

Note that the 50-foot high square column of water exerts the same pressure at the bottom of the column as the 50-foot high cylinder - 21.67 psi. Calculations involving containers of different shape yield the same result. We can conclude that pressure is dependent only on the height of water above our point of measurement, not on the shape of the container.

Example

What is the static pressure at the base of an elevated tank 120 feet (from the ground to the tank's overflow) tall?

Solution on the next page

$$Static\ Pressure\ (psi) = 120\ ft \times 0.433\ \frac{psi}{ft} = 52\ psi$$

Answer

a. 120 psi b. 120 feet c. **52 psi** d. 52 feet

Example

An elevation reading is taken at the end of a distribution system and found to be 225 ft (msl). It's known that the overflow elevation of the system's elevated tank is 400 ft (msl). What is the static pressure at the end of the distribution system?

Solution

$$Static\ Pressure\ (psi) = (400\ ft - 225\ ft) \times 0.433\ \frac{psi}{ft} = 75.78\ psi$$

Answer

a. 175 ft b. 175 psi c. 7.58 psi **d. 75.78 psi**

Another way of thinking about pressure is how many feet of water exert a pressure of 1 psi? Knowing that:

$$1\ ft = 0.433\ psi \quad or \quad \frac{1\ ft}{0.433\ psi}$$

We take the reciprocal:

$$1\ psi = \frac{1\ psi}{0.433\ \frac{psi}{ft}} = \frac{ft \cdot psi}{0.433\ psi} = 2.31\ ft$$

Knowing the pressure at a point, we can calculate the head.

Example

A pressure gage is attached to the bottom of an overflowing elevated tank and a pressure reading of 50 psi is recorded. What is the height of the water (head) above the gage?

Solution

$$Static\ Head\ (ft) = 50\ psi \times 2.31\ \frac{ft}{psi} = 115.5\ ft$$

Answer

a. 21.65 ft

b. 115.5 ft

c. 115.5 psi

d. 11.5 ft

Example

The ground elevation of the above elevated tank is 200 ft mean sea level (msl). What is the overflow elevation (msl) of the tank?

$$Overflow\ Elevation\ (ft) = 200\ ft + 115.5\ ft = 315.5\ ft$$

Solution

Answer

a. 315.5 ft

b. 250.0 ft

c. 211.5 ft

d. 221.7 ft

Dynamic Hydraulics

Flow occurs when there is energy to make the water move. This energy includes the pressure head on the water. The total head or energy causing flow in a hydraulic system is the sum of the elevation (static) head, the velocity head, and the pressure head. According to the Bernoulli equation, the total head at Point A in a system is equal to the total head at Point B in the system plus head losses from Point A to Point B.

Energy @ A (ft) =
Energy @ B (ft) + Energy losses (ft) from A to B

Elevation head is head resulting from the height of the water surface above some reference point. The higher the water's surface, the greater the elevation head. A reference datum is normally chosen below the lowest point in the system to avoid having to use negative values for vertical distances. Mean sea level (msl) is an ideal reference datum.

Velocity head results from water moving through the distribution system. The higher the velocity of the water, the higher the velocity head. Velocity can be found by knowing the pipe diameter and the flowrate:

$$Velocity = \frac{Q\ (Flowrate)}{A\ (Area)}$$

$$Q\ (\frac{ft^3}{sec}) = 200\ \frac{gal}{\text{min}} \times \frac{\text{min}}{60\ \text{sec}} \times \frac{ft^3}{7.48\ gal} = 0.45\ \frac{ft^3}{\text{sec}}$$

where	Velocity	=	ft/sec
	Flowrate	=	ft^3/sec
	Area	=	ft^2

Example

What is the velocity of water in a 6-inch pipe flowing at a rate of 200 gpm?

Solution

$$Area = \frac{\pi D^2}{4} = \frac{3.14 \times (0.5\ ft)^2}{4} = 0.20\ ft^2$$

$$Velocity\ (\frac{ft}{\text{sec}}) = \frac{Q}{A} = \frac{0.45\ \frac{ft^3}{\text{sec}}}{0.20\ ft^2} = 2.25\ \frac{ft}{\text{sec}}$$

Answer

A. .20 ft/sec
B. 2.25 ft/sec
C. 22.5 ft/sec
D. 25.2 ft/sec

Velocity head can be found by the equation:

$$Velocity\ Head\ (ft) = \frac{\ }{\ }$$

where V = velocity (ft/sec)
g = 32.2 ft/sec^2
g = acceleration due to gravity

Velocity heads are normally low since velocities in a distribution system are routinely designed to be less than five ft/sec to minimize friction loss.

Example

What is the velocity head in feet of water moving at a rate of five ft/sec?

Solution:

Answer: A. .08 ft

$$Velocity\ Head\ (ft) = \frac{V^2}{2g} = \frac{(5\ \frac{ft}{\text{sec}})^2}{2 \times 32.2\ \frac{ft}{\text{sec}^2}} = \frac{25\ \frac{ft^2}{\text{sec}^2}}{64.4\ \frac{ft}{\text{sec}^2}} = 0.39\ ft$$

B. .039 ft/sec
C. .39 ft
D. 3.9 ft/sec

The pressure head in a water system is a measure of the height to which water theoretically will rise in a tube open to the atmosphere which is inserted perpendicular to the direction of flow (Figure 4-1).

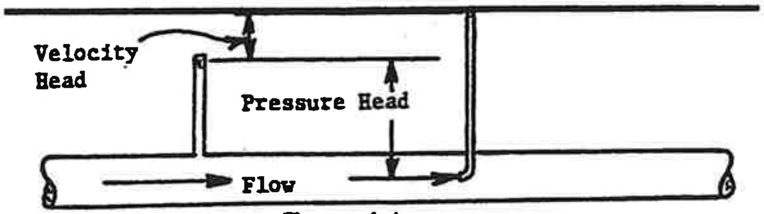
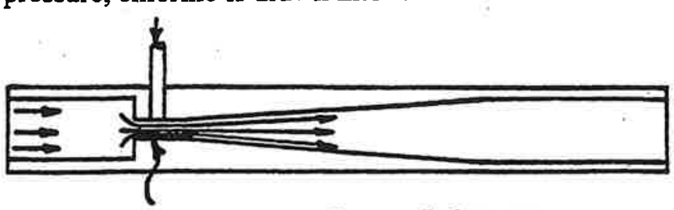


Figure 4-1
Illustration of velocity head

As noted above, the velocity in most distribution systems is low and therefore the velocity head is low. Neglecting the velocity head and assuming elevations at Point A and Point B are equal, it can be seen that the total head is very nearly equal to the pressure head.

It should be noted that as water velocity increases, pressure head decreases. Again, this is not significant in distribution systems since velocities high enough to reduce the pressure head do not normally occur. However, a venturi orifice is designed to translate pressure head to velocity head. If the venturi's constriction is small enough, it is possible to cause a very high velocity which results in an extremely high velocity head. This velocity head may be so great that the pressure head may become negative, that is, a partial vacuum is formed. An example of negative pressure head is the chlorinator ejector illustrated in Figure 4-2. Under negative pressure, chlorine is drawn into the water stream.



Very High Velocity With a Correspondingly Low Pressure

Figure 4-2
Chlorinator ejector

In dynamic hydraulics, two important additional forms of head must be considered: pump head (the energy or head imparted to the system by a pump) and friction head (the energy or head lost due to the friction within the liquid and against the pipe walls).

As water flows through a distribution system, some energy losses or 'head losses' occur. These losses are mainly due to: (1) losses from friction caused by the water molecules slipping against other water molecules and the pipe wall; (2) losses due to bends, enlargements, valves, reducers, restrictions and obstructions. Figure 4-3 Illustrates the effects of friction on the pressure head.

Friction losses in a pipe depend upon the rate of flow (or velocity), the diameter and length of the pipe, and the roughness of the pipe's interior surface.

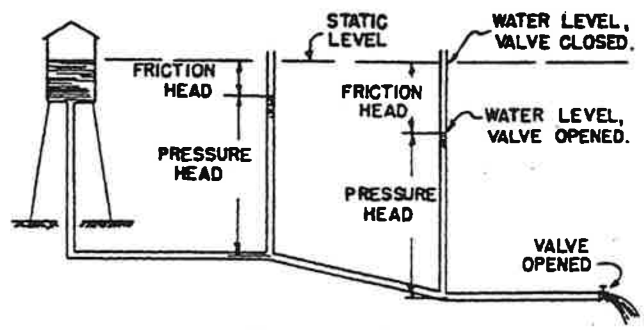


Figure 4-3
Effects of friction on pressure head (1)

It should be obvious from this discussion that pressure head in a dynamic system will always be less than static head. This reduction of head is called the "friction head loss" and represents the energy lost by friction of the water flowing through the pipe. Tables to determine head losses through various pipes and pipe diameters and fittings are given on page 4-11. These losses are mainly derived from use of the Hazen-Williams equation, an empirical formula describing head loss:

$$\textit{Head Loss} = \frac{10.4842}{D^{4.87}} \times \left(\frac{Q}{C}\right)^{1.85} \times L$$

where Head loss = (ft)
D = Pipe diameter (inches)
Q = Flowrate (gpm)
C = Pipe roughness coefficient ()
L = Pipe length (ft)

The pipe roughness coefficient 'C' describes the type and condition of the pipe: the rougher the interior of a pipe, the higher the turbulence and friction, the ***lower*** the coefficient. Thus, new PVC pipe may have a 'C' value of 150. New ductile iron pipe may have a 'C' value of 130. Old tuberculated cast iron pipe may have a 'C' value of 50 or lower.

Example

What is the head loss in 3000 feet of newly installed PVC pipe having a diameter of 6 inches and maintaining a flowrate of 500 gpm? Assume that the roughness coefficient of the pipe is 150.

$$Headloss\ (ft) = \frac{10.4842}{(6)^{4.87}} \times \left(\frac{500}{150}\right)^{1.85} \times 3000\ ft = 47.4\ ft$$

Solution

Answer

A. 4.74 ft
B. 47.4 ft
C. 474 ft
D. 61.7 ft

Example

What is the dynamic pressure at an open hydrant in the distribution system with a ground elevation of 100 feet? The hydrant is served from an elevated storage tank by 5000 feet of 12-inch ductile iron pipe (C=110). The overflow elevation of the tank is 250 feet. A fireflow of 1000 gpm must be provided.

Solution

$$Headloss\ (ft) = \frac{10.4842}{12^{4.87}} \times \left(\frac{1000}{110}\right)^{1.85} \times 5000\ ft = 17.3\ ft$$

$$Pressure\ (psi) = (250\ ft - 100\ ft - 17.3\ ft) \times 0.433\ \frac{psi}{ft} = 57.5\ psi$$

Answer

A. 17.3 psi
B. 100.8 psi
C. 79.1 psi
D. 57.5 psi

Flow measurement

Flow measurement is important to water systems, since the quantities of water pumped or treated must be monitored. The amount of water metered as being purchased by consumers determines the income to the utility to pay for maintenance and repairs, new equipment, expansion, and employee salaries. The amount of water measured as being pumped by the system, when compared with the amount being sold, determines the lost or **unaccounted-for** water. This is an important figure since it suggests the existence of leaks and water usage which is unmetered. In some instances, unaccounted-for water may include flushing of hydrants and that furnished to churches, schools, hospitals or city-owned and operated facilities which are not metered. It is recommended that all service connections and water usage be metered.

There are a variety of devices available for measuring the flow of water. The most common is the residential water meter. This meter contains a rotor or vane which moves or is displaced when water passes through it. These types of meters are satisfactory for measuring flow volumes on a monthly basis for houses, but are not practical for use generally within a water plant or in distribution and transmission mains because of the high flow rates and resulting pressure losses through the meter.

The operator is more often interested in **rate** of flow for some period of time. Common units for expressing rate of flow are cubic feet per second (cfs), million gallons per day (mgd), and cubic meters per second (cms). Most flow measurement devices directly indicate the flow rate, and some can be equipped to record the different flow rates continuously or over periods of special interest.

One type of meter, the venturi meter, operates on the Venturi principle. The chlorinator ejector in Figure 4-2 is an example of this type of meter. An orifice, another type of meter, is simply a metal plate with a chamfered circular hole of known diameter in the center.

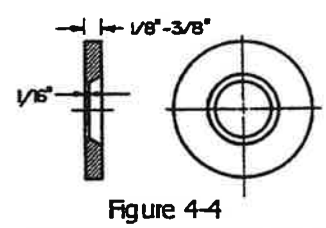


Figure 4-4
Circular orifice weir plate (2

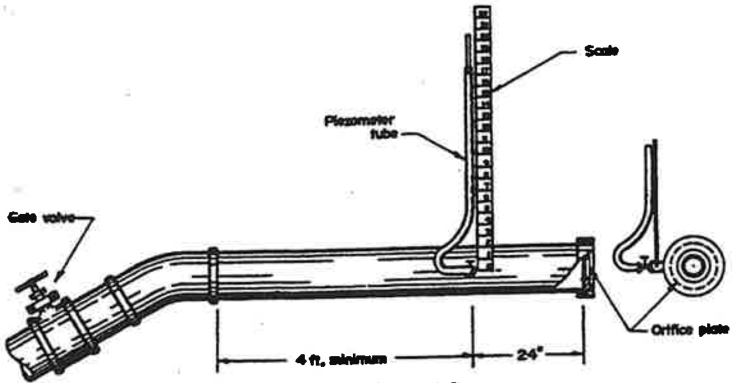


Figure 4-5
Circular orifice weir plate application for measuring pumping rate (2)

It can be installed between the flanges of a pipe as shown in Figure 4-4. It is referred to as a circular orifice weir and is most commonly used to measure the flow from turbine and centrifugal pumps. The use of a weir plate for conducting a pumping test on a well is illustrated in Figure 4-5.

The venturi meter is normally installed in a straight length of pipe as a single unit. It consists of a converging section which tapers from the pipe diameter to the throat and back out to the pipe diameter (Figure 4-6). Taps into the pipe and pressure

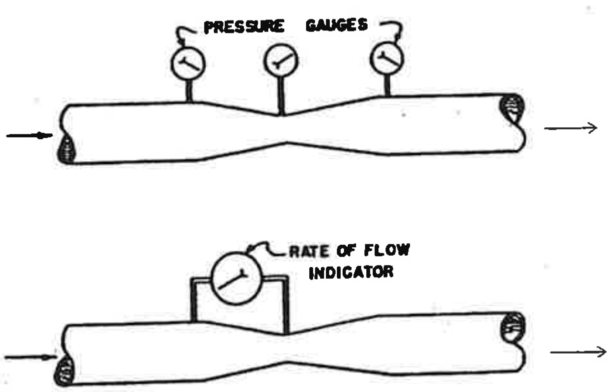


Figure 4-6
Venturi used to measure rate of flow (1)

gages are installed as shown. Assuming that the meter is horizontal, flow is computed from the difference in pressure head between the two gages. A calibrated rate-of-flow indicator or an orifice table may be used to determine flowrate.

A newer type of measuring device being used consists of a non-magnetic tube of the same internal diameter as the pipe diameter across which a magnetic field is established. Water flowing through the magnetic field produces an electric field proportional to the velocity of the water through the meter. Voltage from this electric field is used to indicate flowrate.

For some hydraulic operations such as filtration, it is necessary to control the rate of flow. This can be accomplished with special valves called rate-of-flow controllers (Figure 4-7).

Valve operation is based on the Venturi

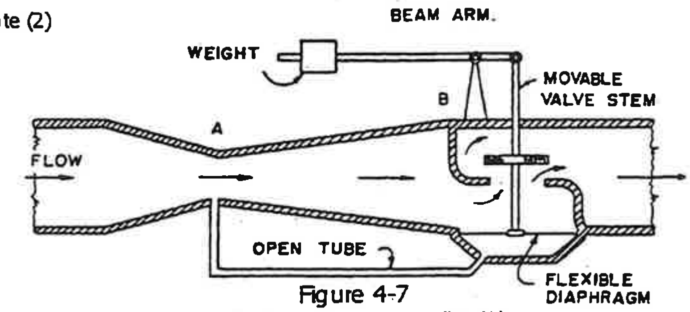
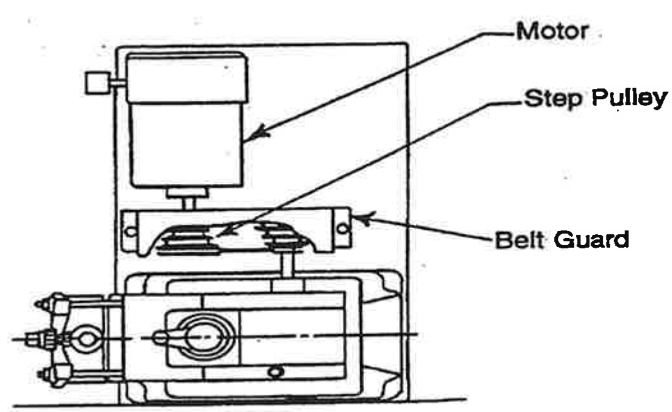


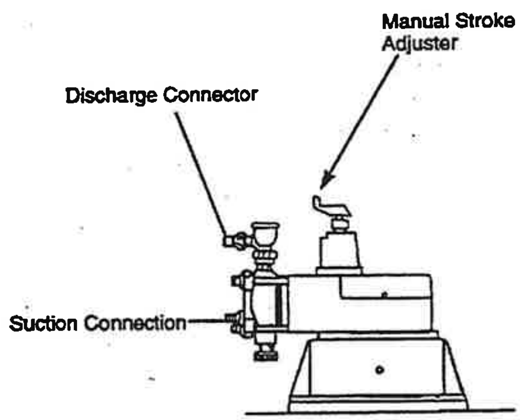
Figure 4-7
Rate of flow controller (1)

principle to control the size of the valve's opening and to regulate the flow of water.

Pumps

Pumps used in water systems are usually classified into two categories, positive displacement and centrifugal. Positive displacement pumps are either piston or rotary. The primary application of positive displacement pumps in small water systems is for feeding chemical solutions of soda ash, potassium permanganate, and/or sodium fluoride. They are simple to operate, reliable, and easy to maintain. Two models are in Figures 4-8 and 4-9.





Positive displacement pumps deliver a constant volume of solution at specific speeds with a pulsating

Figure 4-8
Figure 4-9

flow regardless of conditions downstream of the pump's discharge. The volume produced is small which makes it ideal in small plants. One disadvantage is that the pump will continue to try to operate at the same rate, even if the solution line is restricted or blocked. This can result in extremely high pressures causing the discharge line or the pump's diaphragm to rupture.

Centrifugal pumps develop pressure by centrifugal force. Water enters the center of the impeller and is forced or thrown out by centrifugal force when the impeller rotates (Figure 4-10).

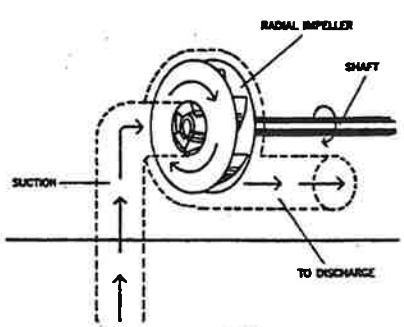


Figure 4-10
Radial-flow impeller for a centrifugal pump (4)

As water moves to the outside of the impeller, low pressure is created at the center of the pump which provides the condition to lift or move the water. A specially shaped casing around the impeller allows the pump to continuously draw water toward the point of lower pressure and at the same time discharge water into the discharge line.

Centrifugal pumps give water a high velocity and hence, a high velocity head. The pump design allows most of the velocity head to be converted to pressure head in the pump's casing or volute and the water leaves under pressure through the discharge line.

Impeller velocity determines the water's velocity, volume pumped and pressure head. As the impeller's velocity increases, the volume of water pumped increases and pressure head decreases.

Most centrifugal pumps are categorized as to service application or type of impeller used and number of impellers. Three basic types of impellers are radial flow, mixed flow, and Francis. Pump classifications based on the number and type of impellers include turbine, mixed flow, axially split case, and close coupled. Service application classifications include low lift, high lift, well, booster, and standby. Some advantages and disadvantages of centrifugal pumps are presented in Table 4-1.

Table 4-1
Advantages and disadvantages of centrifugal pumps

Advantages

- They are simple; no internal valves or reciprocating parts.
- Internal lubrication is not required because there are no close tolerances or rubbing surfaces except for wear rings that can be replaced when they indicate excessive wear.
- There are no vacuum or air chambers on the suction or discharge.
- The initial cost is generally low.
- They do not require a large amount of space for operation.
- They produce nonpulsating flow.

Disadvantages

- The pump must be primed because if the casing is filled with air or vapor, the impeller will not pump out such gases and produce the lower pressure required to move water into the pump.
- There is an optimum efficiency operating point at a particular value of head and discharge, and normally as the head on the pump decreases, the pump output and efficiency decrease.

Because centrifugal pumps operate without close tolerances, water slippage occurs within the pump. If a valve is closed on the discharge side of the pump, the impeller will continue to rotate without pumping any water. As the valve closes, the discharge will

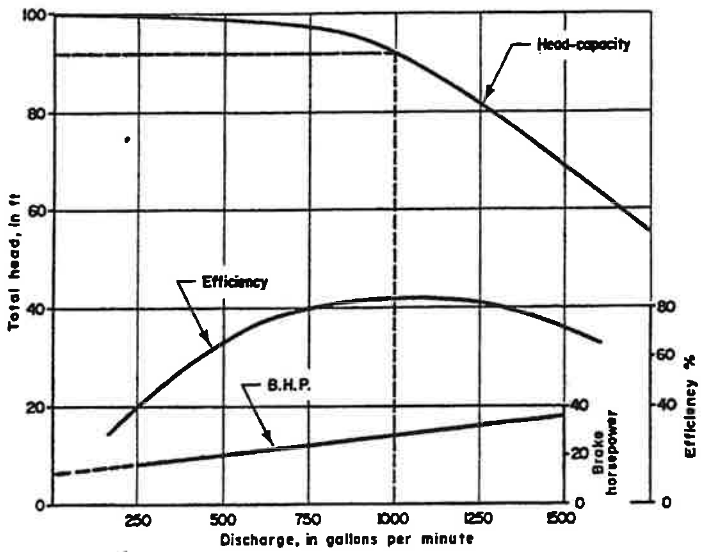


Figure 4-11
Radial-flow impeller for a centrifugal pump (2)

decrease to zero and the pumping head will normally increase to a maximum. The head at which this occurs (zero discharge) is known as **shut-off head**. The varying heads for a corresponding head can be plotted on a graph as shown in Figure 4-11. This curve is known as the head-discharge curve for the pump. Curves for pump efficiency and brake horsepower (the power applied to the pump by the motor or drive mechanism) are also included for most pumps. The combination of these three curves is known as the characteristic curves for the pump.
Advantages and disadvantages of centrifugal pumps are essential for selecting a pump for a particular application.

There is a maximum or high point on the efficiency curve which indicates a head and flow rate which is most efficient for the pump. This is the area of the curve where the pump should be operated most of the time. As the discharge varies from the optimum discharge-head relationship, the efficiency decreases, increasing the cost of operating the pump.

Some of the factors influencing pump selection have been discussed in this section. Table 4-2 includes these and other factors which must be considered prior to selecting a pump.

Table 4-2
General information and conditions that affect pump selection

- Estimation or measurement of peak water usage.
- Determination of pH, dissolved chemicals, temperature, solids, gases, and other characteristics of liquid being pumped.
- Consideration of maximum, minimum, and average discharge heads under operating conditions.
- Determination of the number and size of pumps required to meet minimum, average, and maximum flow and discharge head requirements.
- Consideration of pipe sizes and system layout.
- Determination of average pressure or suction lift and suction line diameter.
- Determination of type of service – continuous or intermittent.
- Determination of type of electrical power available
- Determination of space required to house equipment.
- Investigation of availability of parts and service.
- Requests for pump and motor service guarantees.

References

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John K. Vennard, *Elementary Fluid Mechanics*, 4th ed. (New York: John Wiley and Sons, 1961).

NY State Dept. Health, Office of Environmental Manpower, *Manual of Instruction for Water Treatment Plant Operators* (Albany: Health Education Service).

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Chapter 5

Ground water and wells

Introduction

About 88 percent of water used by public water systems in Mississippi is ground water. All of this state's public water systems use some ground water as primary or backup sources. The first part of this chapter covers use, occurrence, availability, and quality of ground-water sources in Mississippi. The rest of the chapter describes well types, construction, development, and production testing.

Ground-water use

Mississippi withdrew about 3,600 mgd (million gallons per day) from ground- and surface-water sources during 1990. Ninety-one percent came from fresh-water sources. Ground-water sources provided withdrawals. Figures 5-1 and 5-2 show total water withdrawals in Mississippi in 1990.

Figure 5-1

Total water withdrawals, 1990

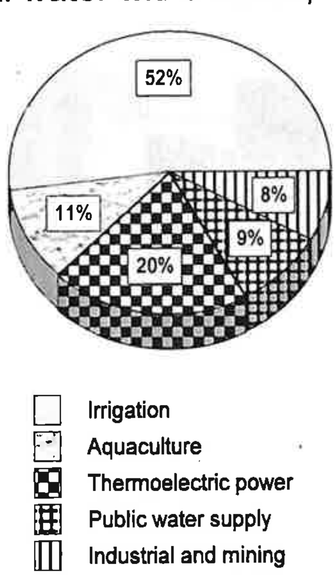
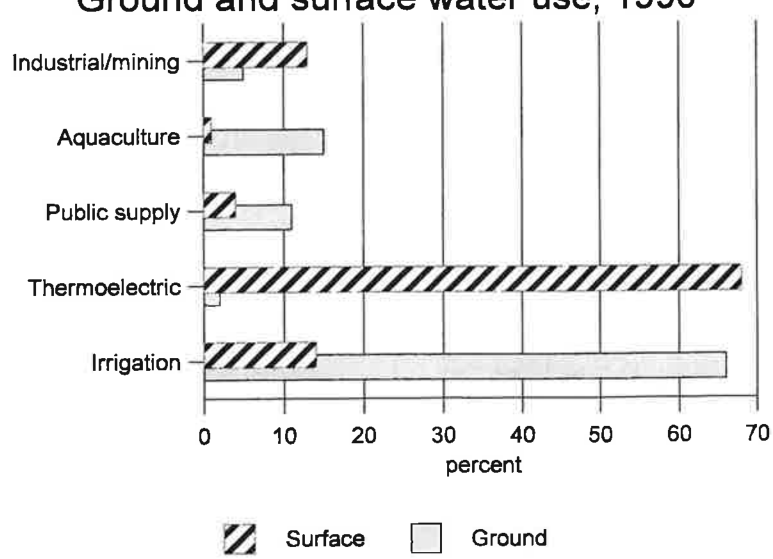


Figure 5-2

Ground and surface water use, 1990



82 percent or 2,700 mgd of total fresh-water

Livestock, domestic and commercial uses were too small to show (one percent or less). Public water supply accounted for only about nine percent of total water withdrawals.

From 1960 to 1990, total ground- and surface-water withdrawals in Mississippi increased 204 percent. Ground-water withdrawals went up 327 percent. Surface-water withdrawals rose 70 percent. Figure 5-3 graphically illustrates these increases.

The biggest increase in water withdrawal was for irrigation (269 percent). Public water supply was second during this period, but slowed to a three percent increase from 1985 to 1990. Figure 5-4 shows total withdrawals for major categories of use. Surface-water accounted for only about 12 percent of public water supply in 1990. Ground water for public water supply has increased at a much higher rate than surface water since 1960.

Figures 5-3 and 5-4 demonstrate rising demands placed on the state's ground-water resources. In areas where competing users place heavy local demand on resources, a potential for shortfalls exists.

Figure 5-3

Withdrawals by source

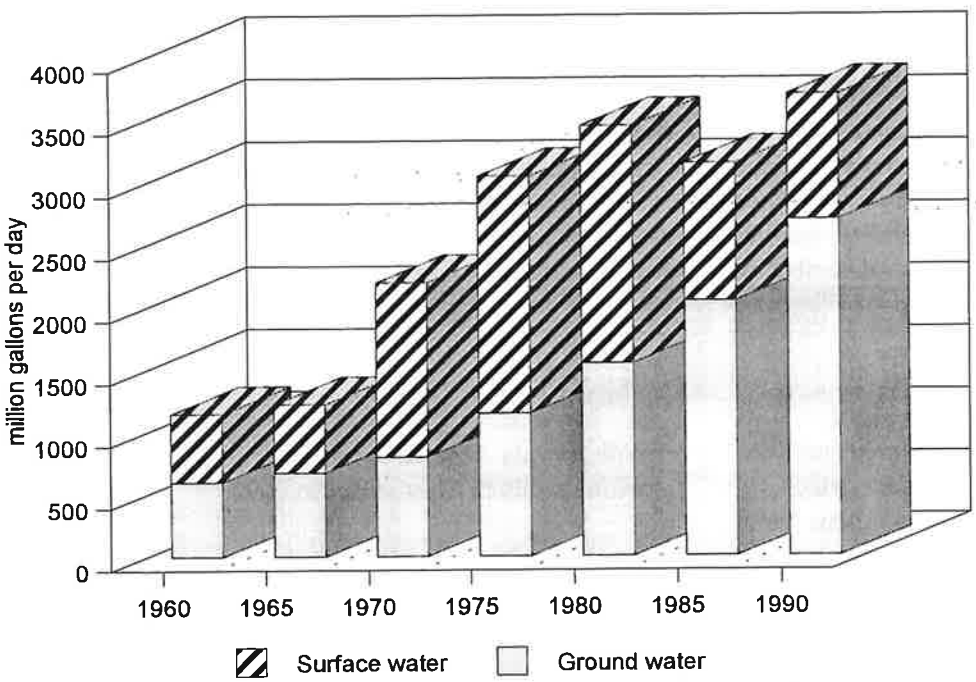


Figure 5-4

Total withdrawals by categories

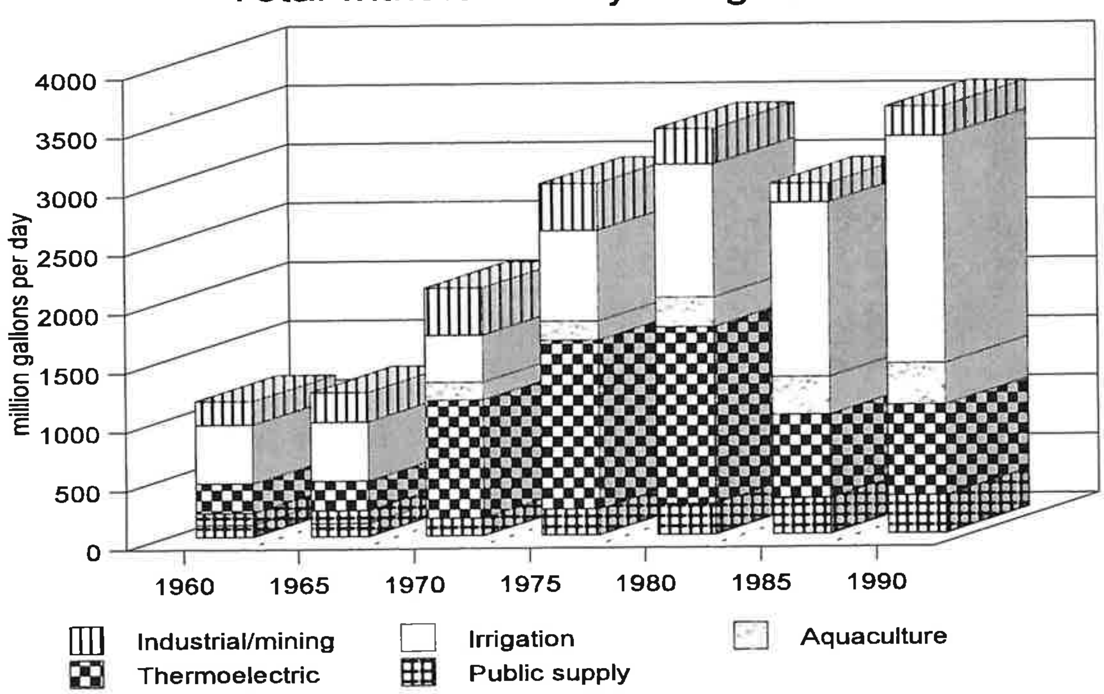


Figure 5-6 shows that in some areas the state has substantially lower ground-water levels than in the past. Most of the state still has one or more aquifers available for public water supply, including areas where water levels have been declining.

Ground water is the main source for public water supplies. Seventy-five percent of the state has one or more excellent aquifers. The cost to develop and treat ground water is less than treating surface water for most uses. Table 5-1 shows advantages and disadvantages of ground-water supplies.

Table 5 - 1
Advantages and disadvantages of ground-water supplies

Advantages
• Less restricted choice of location
• Generally good quality water free from contamination
• Lower initial cost
• Lower operating cost
• Relatively simple operation
• Relatively stable temperature and quality
Disadvantages
• Some locations have high mineral and/or color content
• High carbon dioxide content and low pH cause corrosive water
• Adequate supplies not locally available
• Occasionally high temperatures make water undesirable for cooling
• High hydrogen sulfide gas content gives water a disagreeable odor

The Hydrologic Cycle

Figure 5-5 illustrates the hydrologic cycle. Surface and ground waters start mainly from rain. Snow and sleet add a little water in the northern half of the state. When a rain shower starts, rain water collects in low places. When the low places fill, water overflows and forms creeks, streams, ponds, lakes, and reservoirs.

Some of the rainfall percolates — seeps into the ground. The water collects in a saturated soil layer to form the ground-water table. Ground water might appear as a spring where the ground-water table meets the ground surface, or it might seep out of a river bank.

Ground-water occurrence and availability

Water passing an upper layer of soil or root zone moves down until it reaches a level where all the spaces between soil particles are filled with water. This is the **zone of saturation** or **free ground-water reservoir**. This zone is also called a **water table aquifer** or **unconfined aquifer**. The upper surface is a free water table unless an overlying impervious material restricts it. The material might be clay or rock that will not transmit water.

The free **ground-water reservoir** is similar to a surface reservoir or lake. A well completed in the zone of saturation is called a **water table well**. Water table wells have some disadvantages:

- They can become polluted by industrial discharges, improper use of agricultural chemicals, or effluent from septic tanks.
- Local geology and weather conditions could create variations in the water table level. Changing water tables makes it difficult to maintain water levels above pump intakes.

A water-bearing formation with an impervious formation above and below is called a **confined aquifer**. The water in a confined aquifer has a head or pressure like water in a distribution main.

When ground water tapped by a well rises above the top of the aquifer, it is an **artesian aquifer**. When water rises to the top of the well casing and overflows, it is a **flowing artesian well**. The height to which water will rise in an artesian well depends on:

- the elevation at which water enters the aquifer
- the elevation of the well
- the head loss caused by friction as the water moves through the aquifer to the well

Figure 5-5 illustrates a water table well, an artesian well, and a flowing artesian well.

Figure 5-5

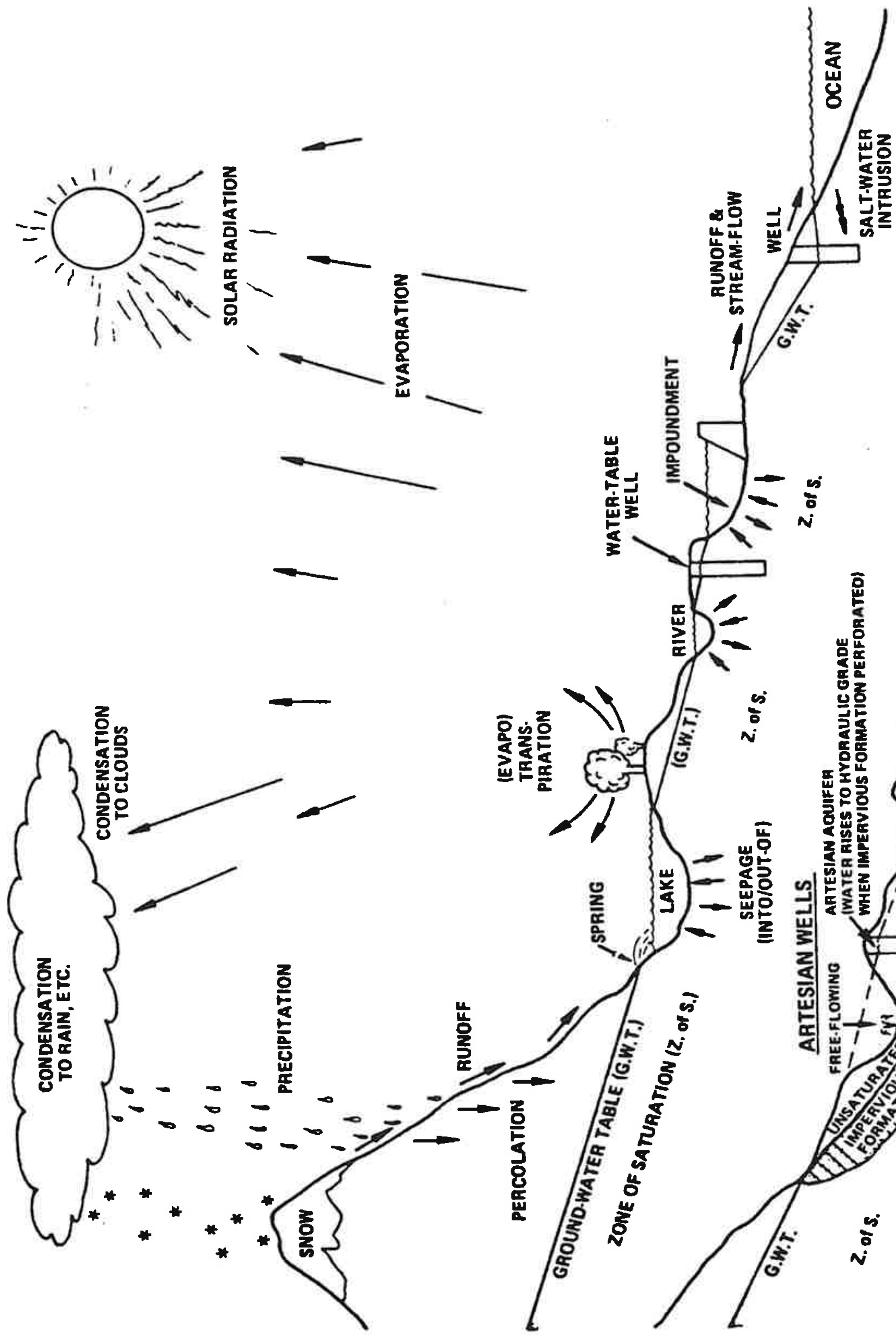

SOLAR RADIATION
EVAPORATION
CONDENSATION TO CLOUDS
CONDENSATION TO RAIN, ETC.
PRECIPITATION
SNOW
RUNOFF
PERCOLATION
GROUND-WATER TABLE (G.W.T.)
ZONE OF SATURATION (Z. of S.)
SPRING
LAKE
SEEPAGE (INTO/OUT-OF)
(EVAPO) TRANS-PIRATION
(G.W.T.)
Z. of S.
RIVER
WATER-TABLE WELL
IMPOUNDMENT
Z. of S.
RUNOFF & STREAM-FLOW
G.W.T.
WELL
SALT-WATER INTRUSION
OCEAN
ARTESIAN WELLS
FREE-FLOWING
ARTESIAN AQUIFER (WATER RISES TO HYDRAULIC GRADE WHEN IMPERVIOUS FORMATION PERFORATED)
UNSATURATED
IMPERVIOUS FORMATION
Z. of S.
G.W.T.
Z. of S.

Figure 5-6

Areas in Mississippi with Water-supply Problems in One or More Major Aquifers

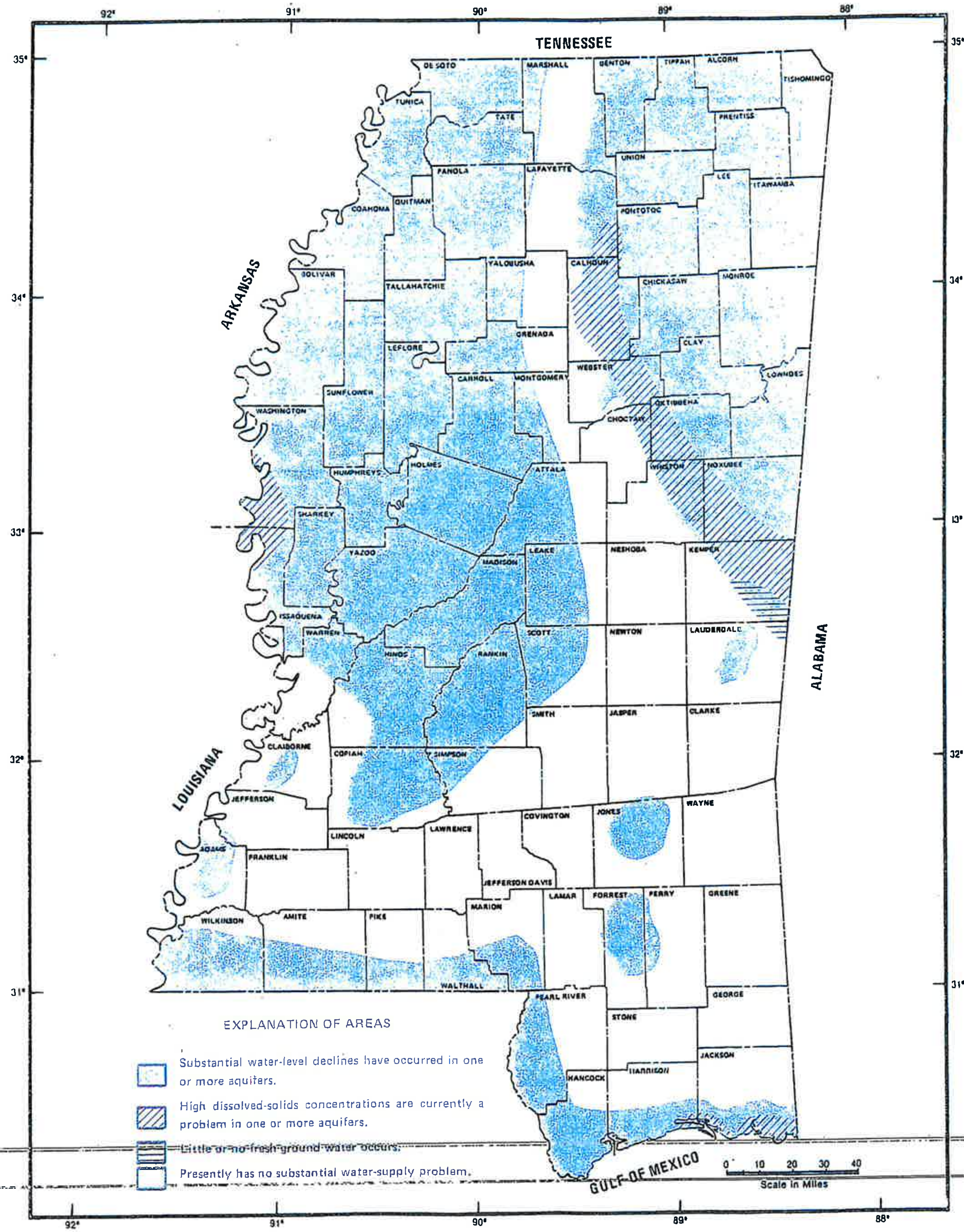
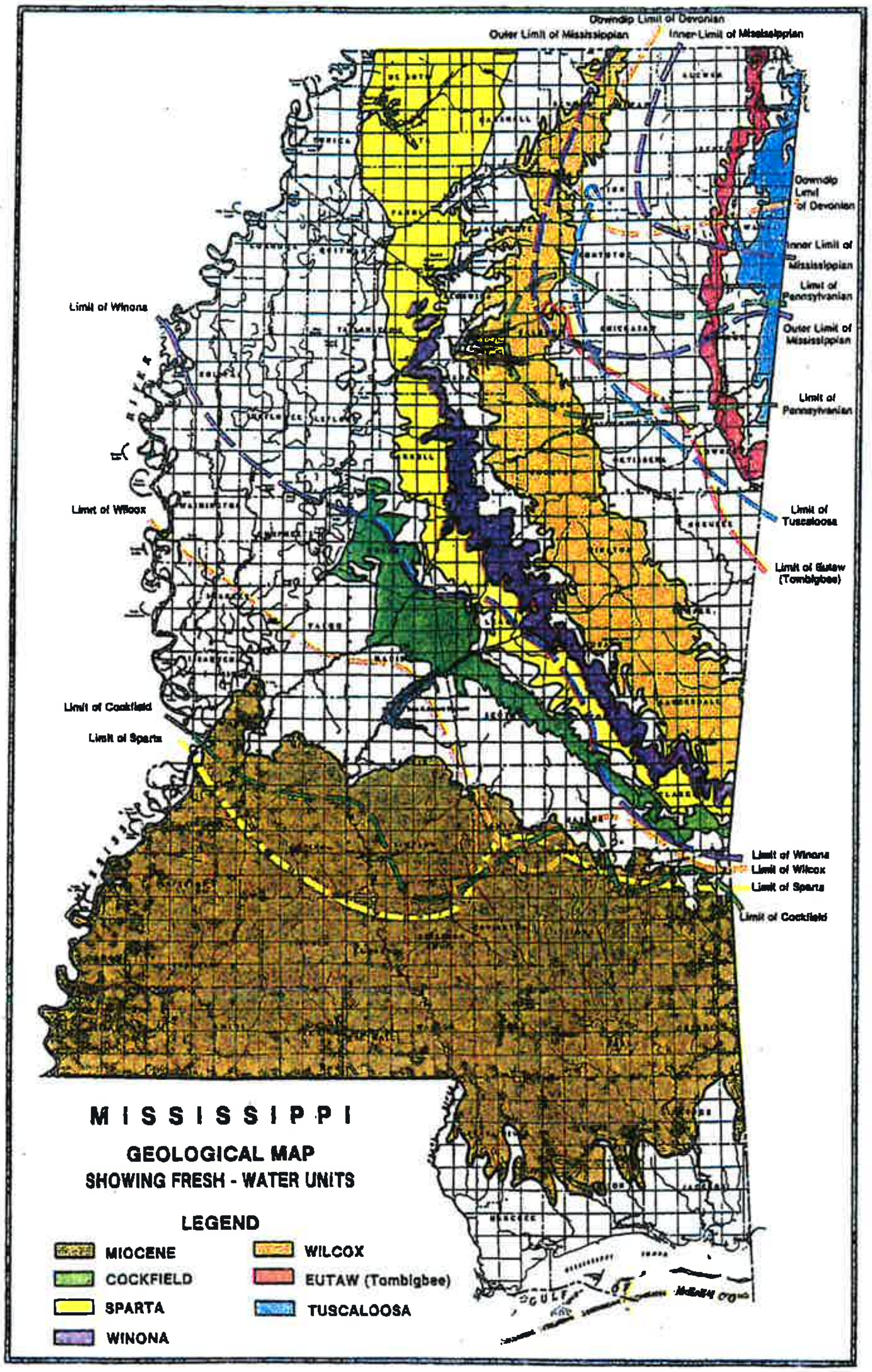


Figure 5-7

Generalized Geological Map Showing the Probable Downdip Limit of Freshwater in Each Aquifer



Source: Mississippi State Geological Survey, **Fresh Water Strata of Mississippi as Revealed by Electrical Log Studies**, by Richard Randall Priddy, Bulletin 83, (University, Mississippi, 1955)

The depth and arrangement of formation materials directly affect the rate at which water can be pumped from a well. Aquifers usually are sand, gravel, sandstone, lime-stone, or rock with fissures. Formations with large pore spaces offer little resistance to moving water and can produce a lot of water.

Permeability is the relative ease with which a liquid can flow through a porous medium. The term **permeability** is commonly used for **coefficient of permeability,** which is expressed in gallons per day per square foot (gpd/ft^2). It is the flow through a one-square-foot cross section of water-bearing material, under a hydraulic gradient of unity – one foot vertical per one foot horizontal.

Porosity measures the amount of water that the formation material will hold. Porosity is expressed as a percentage of the formation volume.

Porosity does not indicate how much water the material will yield. A clay or silt formation could have as much pore space as sand or gravel but yields little water because the openings are so small. Formations such as dense limestone, chalk, rock, clay, and silt are relatively unproductive and are classified as impermeable.

Mississippi has 15 principal freshwater aquifers. Some publications cite more or less, depending on how they define the term.

Figure 5-7 is a general geological map showing seven of the principal freshwater aquifers in Mississippi. A unique color identifies each outcrop area where a confined aquifer is exposed to the land surface. Water levels at the outcrop areas of aquifers range from land surface to 100 feet below land surface. The dashed lines indicate the probable downdip limit of each aquifer. Wells drilled down slope of this limit produce water with mineral content too high for public water supplies.

For more detailed maps and information on 14 significant freshwater aquifers in Mississippi, see reference 7.

The following paragraphs explain terms that describe the potential of aquifers and wells to supply water.

Transmissivity

Transmissivity describes the rate at which water flows through a vertical section of an aquifer. The term is related to permeability. Where permeability refers to the aquifer material, transmissivity applies to the aquifer itself. Transmissivity is measured at the thickness of the aquifer and width of one foot, when the hydraulic gradient is unity (one foot vertical per one foot horizontal). Transmissivity values vary throughout the length and width of an aquifer, from location to location.

Transmissivity is usually expressed as ft^2/day. That is, ft^3 of water per day per foot of aquifer width = ft^2/day.

Transmissivity values are used to estimate aquifer and well yields, but the calculations involved are beyond the scope of this manual. However, transmissivity values provide a convenient means to compare the relative potential of aquifers to transmit water at varying locations. Everything else being equal, the higher the transmissivity, the greater the potential yield of an aquifer. Transmissivities of aquifers in Mississippi range from five to more than 84,000 ft^2/day.

Specific capacity and drawdown

The amount of water that a well can produce depends on its **specific capacity** and the available **drawdown** space. The available drawdown space in a well is the distance from the static water level down to the pumping water level after stabilization. Specific capacity is the number of gallons of water that the well produces per minute for each foot of drawdown. To find the specific capacity of a well, divide the pumping rate, in gallons per minute, by the available drawdown space. The specific capacity reflects both the well's efficiency and characteristics of the aquifer.

Well yield

Well yield is the rate at which a well transmits water steadily, expressed in gpm or mgd. The product of drawdown and specific capacity is the maximum yield or production expected. Figure 5-8 illustrates the relationship of various well performance terms.

Ground-water quality

Ground-water suitable for most uses underlies much of Mississippi. However, quality can change from location to location in a confined aquifer. Water slowly percolating through aquifer materials is in contact with soluble minerals for a long time.

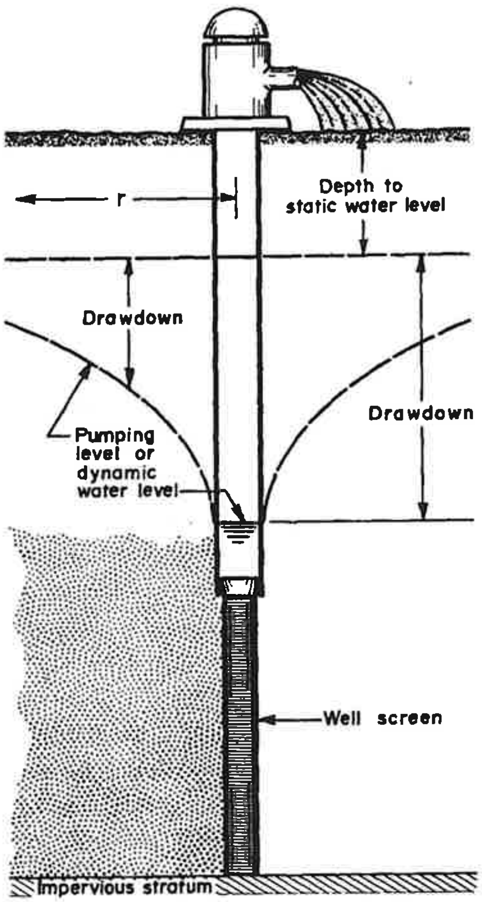


Figure 5-8
Measurements related to well performance and pumping tests of wells and aquifers.

The mineral content of the water increases as it moves down from the aquifer outcrop or recharge area. Water quality usually is similar to rainwater in the outcrop area, but at depths from 200 to over 3,000 feet the water might become saline.

The dissolved-solids concentration in water is a good judge of aquifer water quality. Mississippi ground water generally has less than 100 mg/l of dissolved solids near outcrops. A concentration of more than 1,000 mg/l is usually considered the freshwater downdip limit.

Several large pumping centers in the state are causing large cones of depression in some aquifers. Larger ground-water withdrawals and resulting deeper cones might draw highly mineralized water updip toward pump intakes and become significant problems.

Chapter 7, *Chemistry of ground water,* contains information on other chemical parameters.

Internal temperature of the earth and air temperature affect the temperature of ground water. The temperature of shallow ground water normally is about the same as the average annual air temperature. Temperature of ground water in Mississippi increases about 1°F with each 100 ft of depth.

The following agencies can provide more detailed information on the geology and ground water of a particular area:

U.S. Geological Survey
Water Resource Division
308 S. Airport Road
Pearl, MS 39208-6649
Telephone (601) 960-4600

Mississippi Department of Environmental Quality
Office of Land and Water Resources
2380 Hwy. 80, West (P. O. Box 10631)
Jackson, MS 39289
Telephone (601) 961-5200

Mississippi State Department of Health
Bureau of Public Water Supply
P. O. Box 1700
Jackson, MS 39215-1700
Telephone (601) 576-7518

Mississippi Department of Environmental Quality
Office of Geology
2380 Hwy. 80, West
P. O. Box 20307
Jackson, MS 39289-1307
Telephone (601) 961-5500

Well terminology

Aggregate: The mineral materials used to make concrete, such as sand or stone.

Annular space: The space between a bore hole and a casing pipe.

Boring: A hole or excavation that is not used to extract water. The term includes exploratory borings and environmental bore holes.

Consolidated material: Geological material cemented together in some way; e.g., sandstone, limestone, and various types of granite.

Cuttings: Material removed from the well during construction.

Dug well: A well with side walls supported by material other than the standard weight steel casing. Water enters a dug well through the side walls and bottom.

Environmental bore hole: A hole or excavation in the ground that penetrates a confining layer or is greater than 25 feet deep and enters or goes through a bearing layer and is used to monitor or measure physical, chemical, radiological, or biological parameters without extracting water.

Monitoring well: An excavation that is drilled, cored, bored, washed, driven, dug, jetted, or otherwise constructed to make water level measurements and extract ground water for physical, chemical, or biological testing; also includes ground-water quality sampling wells.

Unconsolidated material: Loose geological material not cemented together; e.g., sand and gravel.

Water supply well: A well used for potable water (public or private), irrigation, agricultural, commercial, or industrial water supply

Well: An excavation that is drilled, cored, bored, washed, driven, dug, jetted, or otherwise constructed for the location, diversion, artificial recharge, or acquisition of ground water.

Well pump: A device, machine, or material used to withdraw or otherwise obtain water from a well; includes all necessary seals, fittings, and pump controls.

Types of wells

Wells are complicated structures. The water well contractor must have a state license and a permit for withdrawal before drilling.

The well type refers to the method of construction — dug, bored, driven, or drilled. Dug, driven, and bored wells are usually in soft, easily excavated soils in shallow aquifers. These wells are limited as a water source. Most community water supplies obtain their water from drilled wells.

Drilled wells

Drilling rigs are used to construct drilled wells. The bore hole is lined with a casing to prevent the sides from caving. When the hole has been drilled into the aquifer, a screen is set in place. The screen collects water and holds back the fine material. Screens might not be necessary in some consolidated formations. Sand samples of the various strata encountered and well logs made during the drilling process should be saved for future reference

Drilled wells are the most important to the public water supply. Wells can be drilled into a variety of soils and depths and are limited by the depth of the aquifer. Well diameters range from two to 48 inches. Drilled wells can produce thousands of gallons of water per minute if the capacity of the aquifer is sufficient to supply the pumps.

The cable tool percussion method is used for drilling through very hard rock formations. The driller raises and drops a heavy drill bit and stem, using a walking beam. The drill bit breaks or crushes hard rock into small fragments and loosens softer soils. The reciprocating action of the bit mixes the crushed or loosened particles with water to form a slurry. The slurry is removed with a sand pump or bailer.

To prevent caving in loose soil, a casing slightly longer than the bit is driven into the ground. Rising or falling water level in the hole signals when the hole reaches a water-bearing formation because the slurry is not able to seal off an aquifer.

In unconsolidated formations, the drilling method is hydraulic rotary. A rotating drill stem and bit makes a hole. To remove loose soil, thick, viscous drilling mud is pumped down through the drilling stem and back up.

At the surface, the fluid is channeled into a pit, and the soil settles out. The fluid then flows into a second pit where it is picked up by the mud pump and returned to the hole.

The functions of drilling fluid:

- cool, clean, and lubricate the bit
- help prevent fluid loss into the formation
- remove cuttings from the hole
- keep the hole from caving

The reverse circulation method is similar to the conventional rotary method, except the drilling fluid flow is reversed. The mud pump pulls drilling fluid up through the drill stem and discharges it to a pit. Cuttings settle out, and the fluid returns to the hole by gravity. It moves down the hole and is thus continuously re-circulated.

The drilling fluid in this method is not as thick as that used for the conventional method. It is closer to muddy water than drilling mud. Bentonite, revert, and other additives are not used to make the fluid more viscous. The hole does not cave as long as the water level in the hole remains at ground level. Caving could be a problem when penetrating highly permeable formations of gravel.

Reverse circulation is used to drill holes from 18 to 60 inches in diameter. It is also quite useful for drilling wells that use a gravel packing around the screen. Well development is easier with this method. In the conventional rotary method, thick mud seals around the hole.

Screen placement and grouting methods are the same as for the rotary method. When the hole is complete, the drill stem is removed and the casing set. The drilling mud stays in place until the screen is set. The space between the casing and the hole is filled with a high, early-strength neat cement. Neat cement is Portland cement without sand or gravel. The cement is pumped into the annular space from the bottom of the casing until it reaches the ground surface. Sometimes bentonite clay is added to reduce shrinkage, during boring.

Test hole

Test holes are drilled to locate the aquifers, to determine their relative thickness, and to collect sand samples. With this pre-design information, the driller can anticipate problems before they happen. The importance of drilling a test hole is to get information about the geology and aquifer. The characteristics of the proposed well cannot be over-emphasized.

Well casing

The purposes of well casings:

- prevent caving
- prevent contamination of the aquifer from the surface or other aquifers
- protect the pump and drop pipe
- provide a reservoir of water for the pump

The casing must be manufactured to certain specifications and installed properly for the well to have a long, trouble-free life. Centering guides must be used at regular intervals to prevent the casing and/or screen from rupturing or bending.

Well casing can be made of steel, PVC, or various alloys. The type of casing selected should be based on the strength and corrosion resistance necessary for each well installation. Proper sizing of the casing is essential for correct production from the well.

Well grouting

The purpose of grouting a well:

- protect the well from contamination
- prevent the walls from caving
- keep out undesirable water from other formations
- protect the casing from corrosion

Grouting a well fills the annular space between the outside of the casing and the inside of the bore-hole wall with a cement or bentonite grout mixture. The Halliburton method or equivalent is recommended.

A well with both an inner and outer casing, might need grouting in the annular space between the two casings, as well as in the space outside the outer casing. After grouting is complete, the plug at the bottom of the casing is drilled out, and the screen and lap pipe are set in place. The length of lap pipe should extend at least 20 feet into the well casing.

In wells with corrosive water an EPA or NSF approved coating prevents corrosion on the interior of a mild steel outer casing, the lap pipe, the pump column, and tail pipe. Using corrosion resistant material such as stainless steel is an alternative. Give special attention to sealing the column pipe, coupling, threads and joints.

Well screens

Screens collect water from a water-bearing formation while keeping out formation material. Screens allow small particles to enter the well during development. Removing the fine particles improves well yield. Holding back large sand particles forms a natural graded sand barrier around the well screen.

Screen selection is an important part of well completion. The amount of water a well can produce depends directly on the amount of water extracted from the formation. The screen size is based on a sieve analysis of a representative sand sample collected from the formation. A consultant can perform the sieve analysis and recommend a suitable screen size.

Another consideration is corrosion. Screens installed in corrosive waters must be made of materials that resist corrosive action. More wells fail because of screen corrosion than because of casing corrosion.

Corrosion can enlarge screen openings, allowing sand into the well. The sand can seriously damage the pump and cause problems in a pressure tank or distribution system. Special alloy screens cost more than steel screens but have a longer service life and thus reduce costs over the lifetime of a well.

Mineral deposits can clog the screen openings. The growth of iron bacteria plugs the pores of the formation, reducing well capacity. Pouring muriatic acid into the well dissolves mineral deposits from incrusting ground water. This treatment can be dangerous and should be done by personnel with proper training and experience.

Treatment of the well water with a chlorine solution removes iron bacteria. After the chlorine solution, adding hydrochloric acid dissolves the materials so they can be pumped to waste. Treatments for incrustation and iron bacteria are quite corrosive. They should be used on well screens made to withstand these solutions.

Wells can be constructed as either straight wall or gravel packed. Straight-wall wells use the hole drilled to house the screen. After the screen is placed in the straight-wall well hole, it must be firmly sealed to the casing. To get a tight seal, install a neoprene packer at the top of the blank pipe or lap pipe. Fit the bottom of the screen with a backwash valve to permit washing the screen and to prevent inflow of sand.

Gravel-packed wells cost more than straight-wall wells, but higher yields are possible. An under-reamer enlarges the hole, and the enlarged space around the screen is filled with chlorinated gravel to the top of the blank pipe attached to the screen. This provides a reserve gravel supply to allow for settling around the screen. Selection of the gravel is based on a sieve analysis of the sand.

Well development

Wells must be developed to produce at maximum capacity. Development involves agitating the sand surrounding the well screen to remove the fine sand, silt, and drilling mud. This action produces a natural filter of coarser and more uniform size particles with increased permeability around the well screen. If excessive quantities of sand are removed from the well, caving in the aquifer could damage the screen beyond repair.

Development continues with over-pumping, surging, or jetting. Over-pumping is pumping the well at a higher rate than expected for normal service. However, this might leave some sand grains bridged in the formation and not completely stabilized. Never use the permanent pump for developing due to sand abrasion.

Pumps used for surging include an air-lift pump, a turbine pump, a plunger, and sometimes a centrifugal pump. Pumps raise water to ground level. The water is allowed to flow back into the well as quickly as possible. This raises and lowers the water level in the well creating flow in both directions, and dislodging fine materials around the screen.

Forcing water or jetting water at a high speed through the screen is the most effective method of well development. This method rearranges the silt, fine sand, and mud surrounding the screen and allows these materials to flow into the well for removal.

After the well has been completed, a pumping test determines the proper size pump and motor. An air line, tape measure, or other device is used to measure drawdown.

An air line is an open-ended copper line inserted into the well to a measured depth below the pumping level. A pressure gauge is attached to the air line. The line is pressurized until the pressure gauge shows no increase when air is added. The water level in the well is the gauge pressure in feet subtracted from the length of the air line.

Measure the output of the well with an orifice, weir, or meter. Measure the recovery time and well efficiency also. From this information, the specific yield can be calculated and the proper pump selected.

All water used in drilling and construction should come from sources of proven quality and meet the primary standards of the Safe Drinking Water Act Regulations. During the production test, pump the well until the water is clear and has no fine sand.

Upon completion, disinfect the well and adjacent aquifer, using a solution of 50 mg/l free chlorine applied for 24 hours. After disinfection, pump the well until two consecutive chlorine-free samples collected from the well show no coliform bacteria. Collect the second sample following at least two hours of continuous pumping after the first sample.

Do not apply a disinfectant between samples. The person collecting the official microbiological samples must be a representative of the Mississippi State Department of Health, the registered engineer on the project, or the certified operator for the public water supply.

Measurements, tests, and observations

The operator should monitor and calculate well efficiency and productivity on a regular schedule. Measurements include the following:

- Static water level
- Yield of the pumping well
- Comparison of chemical data

Routine inspection saves time, money, and effort. Attention ensures that the well provides a reliable source of water and allows prompt problem correction with limited damage.

Problem solving

Problem: Heavy reddish-brown iron oxide, stains in discharge, or red water.

Possible Conditions:
- Iron deposits
- Corrosive water attacking metal parts in the well
- Aeration of water in well: yield/specific capacity of well has dropped; possible hole in casing; or iron oxide scaling

Problem: Bubbles in the discharge water.

Possible Conditions:
- An environment with free carbon dioxide
- Naturally dissolved gases in the water
- Overpumping of the aquifer

Problem: Rotten egg smell (hydrogen sulfide odor)

Possible Conditions
- Hydrogen sulfide concentrations above 0.5 mg/l
- Iron bacteria or sulfur fixing bacteria in well

Test chemical and bacterial content of water for hydrogen sulfide concentrations. Levels of 0.5 mg/l or greater, damage to copper alloy parts of the well system.

Problem: Well efficiency decreased

Possible Conditions:
- Chemical and/or mechanical incrustation
- Decrease in regional water table
- Structural collapse caused by corrosion or other factors
- Change in water quality
- Improper well design
- Pumping in excess of well design

Problem: Pump is cavitating, providing variable discharge, and/or breaking suction

Possible Conditions:
- Well being pumped in excess of design capacity
- Drawdown level excessive in well
- Well screen and casing deterioration caused by corrosion
- Well screen encrusted

Sample questions

1. A water bearing formation that has an impervious formation above and below it is called a/an
   a) unconfined aquifer
   b) free ground water aquifer
   c) artesian aquifer
   d) confined aquifer

2. If water rises above the top of an aquifer when it is tapped by a well, the aquifer is called a/an
   a) water table aquifer
   b) free ground water reservoir
   c) artesian aquifer
   d) unconfined aquifer

3. The dissolved solids concentration measured in water from a confined aquifer usually
   a) is highest in water from the aquifer outcrop or recharge area.
   b) increases as one moves down the dip of the aquifer away from the outcrop area.
   c) is constant throughout the aquifer.
   d) decreases as one moves down the dip of the aquifer away from the outcrop area.

4. Temperature of ground water can be expected to
   a) decrease with the depth of the aquifer.
   b) increase with the depth of the aquifer.
   c) not be affected by the depth of the aquifer.

5. If the pumping rate of a well in a water table aquifer is 160 gpm and the drawdown is found to be 20 feet after the water level stabilizes, what is the specific capacity of the well at the time the measurements are taken?
   a) 3200 gpm/ft
   b) 8 gpm/ft
   c) 0.125 ft/gpm
   d) 160 gpm/ft

6. Confined aquifers are more easily polluted by industrial discharges, improper use of aquicultural chemical and septic tank effluent than are unconfined aquifers.
   True False

7. Water from wells tapped into an artesian aquifer will always rise to the top and overflow the well casing negating the need for pumping.
   True False

8. Match the following terms with the units in which they are usually reported.

____ Transmissivity	a. gpd/ft^2
____ Specific capacity	b. percent
____ Well yield	c. Mgal/d
____ Permeability	d. gpm/ft
____ Porosity	e. ft^2/d

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Chapter 6

Microbiology

Introduction

This chapter deals with microorganisms and how water systems treat source water to provide quality water to their customers. The primary objective in treating drinking water is to provide water of good quality that is free from chemical or microbial contamination.

Water sources and risks

Most drinking water comes from natural sources — rivers, reservoirs, and aquifers. Natural water sources could become polluted from home and industrial waste products.

Water treatment systems protect the public health. Methods have been effective, but increasing populations produce more sewage. Most sewage returns to natural bodies of water that could become drinking water sources. Sewage might contain pathogenic disease-causing microorganisms.

The purpose of federal and state Safe Drinking Water Acts is to protect drinking water quality. Potable water is free of pathogenic or disease-producing microorganisms and harmful chemical substances.

Microbiological monitoring maintains water quality and controls disease-causing microorganisms in water. Bacteria and microorganisms not only contribute to waterborne diseases but also cause operational challenges, from problems in source water to finished water. These problems range from encrustation and corrosion within the water system to water quality problems at the customer's tap.

Water microbiology

Water might be clear in appearance, free from peculiarities of odor and taste, and yet be contaminated. Microorganisms are too small to be seen without a microscope. The bacteriological laboratory tests are extremely sensitive and specific in detecting contamination. Testing assures that drinking water is potable.

Coliforms and *Escherichia coli* (*E. coli*) are normal inhabitants of the large intestine of man and other animals. These organisms are in sewage. Their presence in drinking water indicates potential contamination. Water systems monitor water quality and possible contamination through routine monthly testing for *Coliform* organisms

Waterborne diseases

Waterborne disease outbreaks increased steadily in the United States from the 1960s. When drinking water contains excessive bacteria or turbidity, the systems are not adequately treating their water.

All water, even distilled water, contains sufficient nutrients to support bacterial growth. Some ways to sterilize water are:

- Treat with chemicals, such as chlorine.
- Destroy bacteria by heating.
- Irradiate with ultra-violet light.

All natural water from surface or ground sources or precipitation contains microorganisms. Among microorganisms in drinking water are algae, bacteria, fungi, protozoans, viruses, and worms. At least five bacterial diseases transmit to man through sewage-contaminated water. Water polluted with human and animal wastes could contain infectious agents. Table 6-1 lists waterborne diseases and the organisms that cause these diseases.

Table 6-1
Diseases transmitted in water

Waterborne Disease	Causative Organism
Typhoid fever	*Salmonella*
Shigellosis (Bacillary dysentery)	*Shigella*
Leptospirosis (hepatitis)	*Leptospira*
Infectious hepatitis	Viral
Salmonellosis	*Salmonella*
Gastroenteritis	Various pathogens
Cholera	*Vibrio comma*
Giardiasis	*Giardia lamblia*
Cryptosporidiosis	*Cryptosporidium*

Analyzing for each type of pathogenic bacteria is impossible. They are difficult to isolate, and it would take too long. A more practical scheme is to examine the water for organisms specifically identified with sewage. Those of greatest interest to water treatment plant operators are the *Coliform* bacteria. *Coliform* presence indicates possible sewage contamination.

The *Coliform* group is an ideal index of sewage pollution. They are:

- always present when sewage is present
- always absent when contamination is absent
- survive longer in water than any pathogenic species
- are easily isolated and identified.

The *Coliform* group includes all of the aerobic and facultative anaerobic, Gram-negative, non-spore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35° C.

The terms "aerobic" and "facultative anaerobic" describe bacteria's need for oxygen. "Gram-negative" refers to an identification technique using stain. Bacteria that don't retain the stain when washed with alcohol are "Gram-negative." *Coliform* bacteria decompose lactose sugar within the time and temperature limits.

Microorganisms

Characteristics

Microorganisms are either plant or animal. Many microbes have characteristics typical of both plants and animals. Their classification is based upon dominant features. Table 6-2 lists basic microorganisms found in water. The most significant in drinking water is bacteria. Many bacteria are harmless, but some are capable of causing diseases.

Table 6-2
Microorganisms in water

Plants	Animals
Bacteria	Protozoa
Algae	Rotifera
Viruses	Crustacea
Fungi	Nematoda

Table 6-3 shows how microorganisms are classed as plant or animal.

Table 6-3
Classification of Microorganisms

Plant Characteristics	Animal Characteristics
Store energy	Release energy
Have no sensory organs or nervous system	Can have sensory organs and a nervous system
Release oxygen	Release carbon dioxide
Cell walls composed of cellulose – a carbohydrate	Cell walls principally protein
Metabolism by absorption of water and gases through root hairs and stomata – no digestion of food.	Metabolism dependent upon digestion of food within an alimentary canal

Bacteria are microscopic, single-cell plants that reproduce by binary fission. The waterworks operator must recognize different bacteria and learn how to deal with harmful bacteria and other nuisance organisms.

Bacteria

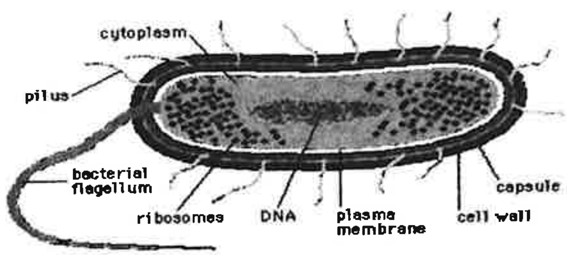
Structure

Bacteria are tiny living plants, each a single cell. They are too small to be seen with the unaided eye. Bacteria come in three different shapes:

coccus ....sphere shaped
bacillus ....rod shaped
spirillum... spiral shaped

More than 80 percent of bacteria are bacillus. *Salmonella typhi* is a typical cell, rod-shaped and about two microns long. About 13,000 of such bacterial cells lying end to end would measure only one inch. Even though the bacterial cell is tiny, its structure is complex. Table 6-1, below, shows the structure of a bacterial cell.

Table 6-1
Structure of a bacterial cell



A rigid membrane surrounds the cell. This wall encloses a non-rigid protoplast containing the cell nucleus and smaller bodies vital to cell functions. The density of the protoplast is greater at the outer layer next to the cell wall. This ectoplasm section, like the rigid cell wall, is semi-permeable. That means that all material entering or leaving the cell must be in solution to pass these two barriers.

Some bacterial cells have certain features not common to all. For example, flagella are hair-like appendages present on some species but not on others. Moreover, depending on the species, the number of flagella vary from one to many. Their locations vary from one end to both ends of the cell or even to the entire periphery of the cell wall. Flagella function clearly to provide locomotion.

Food Requirements

A bacteria cell gets its food from the environment outside the cell wall. Since only true solutions can get through the wall, food solids must become soluble for cell use. The cell manufactures enzymes that liquefy nutrients. The soluble food passes through the cell wall, and the cell metabolizes it.

Bacteria are either autotrophic or heterotrophic. Autotrophic bacteria consume simple inorganic chemicals such as ammonia or nitrates. Heterotrophic bacteria consume complex organic food such as dead plant and animal tissue. Saprophytes are heterotrophs that feed on organic matter in the water. Some saprophytes are autotrophic bacteria that feed on simple inorganic salts and dissolved gases. Figure 6-2, the nitrogen cycle, on the next page shows the properties of various types of bacteria and the part they play in nature.

Respiration

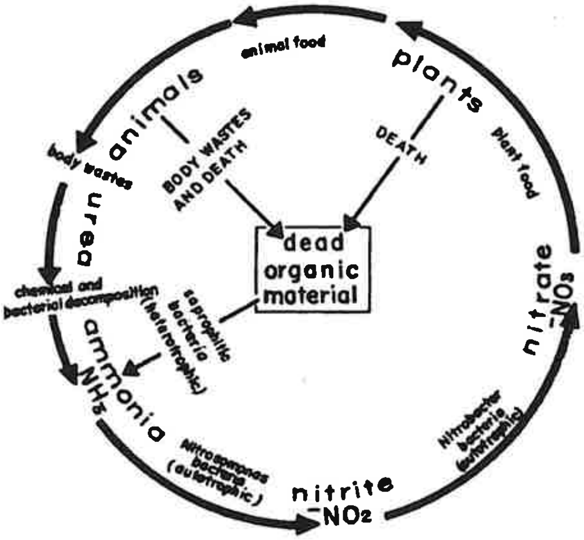
Bacteria are classified by their need for oxygen:

- Aerobes require oxygen in the environment.
- Anaerobes live with no oxygen.
- Facultative anaerobes prefer no oxygen but can survive with some oxygen.

Reproduction and growth

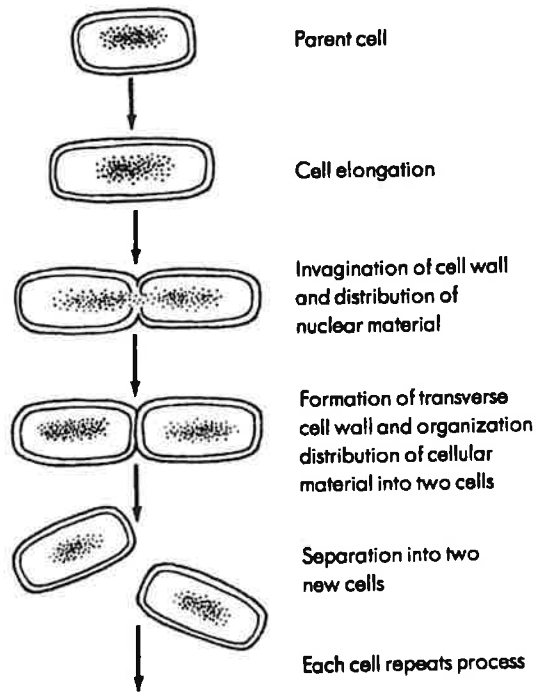
Bacteria reproduce by simple cell division or binary fission as it matures (Fig. 6-3). The bacterial cell constricts near the center. Constriction progresses until eventually the cell divides into two separate cells. In a favorable environment, a bacterial cell divides every 20 or 30 minutes. Within a few hours, this reproduction could produce millions of descendants from a single cell.

Figure 6-2



Nitrogen Cycle

Figure 6-3
Reproduction of bacteria



However, various factors limit growth and survival. An ordinary bacterial culture 24 hours old contains about 20 million individual cells per milliliter. In a closed system, the rate of growth gradually decreases to zero.

Some bacteria form spores, the resting stage of cells. Cells make spores when the environment becomes unsuitable for growth and reproduction. Typical reasons for spore formation are:

- lack of food
- lack of sufficient moisture
- higher than normal temperatures

In the spore stage, bacteria cannot reproduce but are able to resist destruction. Spores become vegetative cells with normal metabolic processes when the environment turns favorable.

Physical and chemical factors

Other conditions affecting the growth and survival of bacteria:

- temperature
- light
- moisture
- germicides

Temperature

The temperature for best bacteria growth varies with the species. Many bacteria thrive best at temperatures near that of the human body. These are "mesophilic" bacteria. Those that grow best at low temperatures, slightly above the freezing point of water, are "cryophilic" bacteria. Those that require high temperatures, between 40° and 65° C, are "thermophilic"bacteria.

Low temperatures do not destroy bacteria. However, most of them reproduce slowly or not at all in cold temperatures. When frozen bacteria thaw and get warm, they immediately go into a normal life cycle.

Extreme heat, on the other hand, destroys all bacterial species. Spores withstand much more heat than vegetative cells. Moist heat destroys bacteria better than dry heat.

A temperature above which no cells survive is the "thermal death point" of the species.

Light

Ultraviolet light destroys bacteria. Light rays below 2,900 angstrom units (290 millimicrons wavelength) are especially destructive. However the ray must strike the cell directly. Ultraviolet light can destroy bacteria in water that is clear enough to let the light rays through. Bacteria cells must be close to the light source because water absorbs some of the rays. Bacteria cells must be close to the light source because water absorbs some of the rays.

Moisture

Bacteria cannot reproduce without moisture. Drying food is a good preservation method. Spore-forming bacteria could survive in a dry environment, but they cannot function. If moisture becomes available, bacterial spores vegetate and resume a normal life cycle.

Pickling in a strong salt solution preserves meat and vegetables by destroying bacteria. The high concentration of salt outside the cell membrane draws water out of the cell, shrinking and killing it.

Germicides and antibodies

A germicide is anything that destroys a bacterial cell on contact. The best known germicide in water treatment is chlorine.

Most bacteria are highly sensitive to the pH of the medium in which they are growing. Most grow best in a medium that is neutral (pH 7.0) or slightly alkaline (pH 7.2 to 7.4).

Some organisms multiply best in a strong alkaline medium. The *Cholera spirillum*, for example, prefers a pH of about 8.0. Molds and yeasts grow especially well at pH between 5.0 and 7.0.

The natural antagonistic action of one microbe on another has been studied intensively. Bacteriologists have isolated substances that inhibit growth or kill disease germs. A substance produced by one living organism that injures another is called an antibiotic.

Types of microorganisms

Algae

Algae are simple, oxygen-producing organisms. They use light energy to convert carbon dioxide and water to carbohydrate. Algae are usually found in sunlit surface waters. During summer they might produce "blooms" which appear to cover whole sections of a pond.

Algal cells contain chlorophyll, the green color of plants. Chlorophyll enables the organism to make carbohydrate and give off oxygen as a by-product. The process is "photosynthesis." Oxygen promotes decay of organic debris, supports life, and favors aerobic saprophytic bacteria. These bacteria can decompose organic matter without making foul-smelling gases.

However, algae in water alter taste and cause odors. Large algae could rapidly cover the surface of sand filters and drastically reduce the length of filter life. Other adverse effects associated with algae are oxygen depletion and toxicity. Daily microscopic examination of raw water for algae, especially during the summer months, should be routine practice.

Algae photosynthesis also affects the pH and hardness of water. During daylight, the water hardness decreases, and pH rises in water with a lot of algae. The process reverses in darkness when photosynthesis stops. System operations should reflect the changes in the water chemical characteristics. Water systems that break pressure or store in open reservoirs should screen open aerators and protect open reservoirs.

Copper sulfate ($CuSO_4$) is the algicide of choice for potable water supplies. The amount of $CuSO_4$ needed depends on the chemistry of the water — particularly pH — and on algae sensitivities. For surface water, a burlap bag towed behind a boat is the traditional application method. Other methods include mechanical spreaders, sprayers, and helicopters. Monitor effect to minimize use of $CuSO_4$. Other methods for controlling algae include chlorination, artificial destratification, and nutrient control.

Viruses

Viruses are the smallest microorganisms. The electron microscope made it possible to photograph them and study their metabolism and relationship to disease. The largest viruses are about 200 millimicrons in diameter. Most viruses are much smaller, approximately 10 millimicrons in diameter. Particles that small pass freely through openings of most filters.

Viral diseases affect all life forms. The evidence is conclusive that polluted water transmits viral diseases; e.g., poliomyelitis and hepatitis. Viruses are quite resistant to many bactericides. For chlorine to destroy viruses, it must be in contact with the particles in much higher concentration and for longer periods of time than is necessary to destroy bacteria. Free residual chlorine in a concentration of 0.2 to 0.3 ppm destroys bacteria in 10 minutes at pH 7.0, but it takes 30 minutes of contact time to completely kill enteric viruses.

Viruses are in sewage and streams polluted with sewage. Their numbers are much less than the numbers of bacteria. Current water treatment methods probably are inadequate to actually destroy viral infectious agents.

Fungi

Fungi are plants, but they do not contain chlorophyll. They get their food from dead organic matter as saprophytes or as parasites feeding on living hosts. Water forms of fungi include phycomycetes, similar to algae, and ascomycetes, commonly called yeasts and molds.

Protozoans

Protozoa are one-celled animals found in natural waters and moist soils. They are often abundant in both surface and ground water. Some are quite troublesome to water plant operators. Protozoa might make water taste bad. They can clog filters and raise chlorine requirement. Occasionally larger protozoa in drinking water startle consumers.

Enteric protozoa cause intestinal disease. These organisms have two life stages:

- the trophozoite — actively feeding, growing, and reproducing stage
- the cyst or oocyst — resistant, dormant, survival stage

Only cysts and oocysts concern water treatment. They can move through filters. Many of these cysts and oocysts are more resistant to chemical disinfection than bacteria and viruses.

Amoeba and *Paramecium* are two common water protozoans. *Endamoeba histolytica* is a species of amoeba responsible for amoebic dysentery in humans. It could be transmitted from one individual to another through polluted water.

Giardia and *Cryptosporidium* cause outbreaks of waterborne disease. *Giardia lamblia* is a protozoan that infects the human intestinal tract. Giardiasis outbreaks are increasing more than other waterborne diseases. *Giardia* cysts survive for months in cold waters and resist disinfectants more than most other pathogens. *Giardia* control is complicated because they have a number of animal hosts, as well as humans. This increases the numbers of cysts and oocysts that could enter water treatment plants.

Cryptosporidium oocysts are the smallest of the enteric protozoa and get through even the best-maintained filters. The required high disinfectant concentrations and contact times are not practical for treating Crypto oocysts. To keep them out of public water systems requires multiple barriers — coagulation, filtration, and disinfection.

Rotifera, *Crustacea*, *Bryozoa*, and *Porifera* or microbial sponges are sometimes in great numbers in fresh water. Most of them are too small to see without a microscope.

Rotifers are microscopic, aquatic invertebrates found in uncovered finished water reservoirs, filter surfaces, and in basins. They are able to detach from floc particles and pass through filter media. Although not dangerous pathogens, they are annoying pests. Optimizing coagulation, flocculation, and filtration is the best available technology to remove these organisms.

Another nuisance organism in potable water supplies are the *Crustacea*. They discolor water and generate taste and odor complaints. Large numbers of crustaceans might block rapid gravity filters and disrupt filter operations. Floc break-through could increase the turbidity. They tend to concentrate in dead ends and areas of low flow, and some crustaceans breed in mains. Some species are quite resistant to disinfection. A systematic flushing program is the best preventive and control measure.

Nematodes (round worms) and Chironomus (blood worms) can infect surface water and get into drinking water. Live nematodes have been collected from residential faucets and fire hydrants, even in water with a free-chlorine residual. Nematodes are not a health threat, but their presence does not portray a quality product to the public. However, the worms could ingest pathogens and cause a waterborne disease outbreak.

Larger forms can be troublesome, creating bad taste, odors, and clogged filters. These problems are inevitable unfiltered supplies but occasionally occur in filtered water, usually by some mishap in the plant.

Conventional water treatment processes are not effective against nematodes. The organisms are resistant to free chlorine. Active nematodes pass through rapid sand filters. Coagulation, settling, lime softening, and chlorination can reduce the numbers of nematodes passing through the plant.

Iron bacteria

Iron bacteria create odor, color, and taste problems. They precipitate insoluble compounds in pipes, obstructing water flow. These bacteria transform iron and sometimes manganese to an insoluble form that fouls wells, treatment plants, and distribution systems. No single procedure could isolate and identify this group. Each group requires special techniques.

Iron bacteria can mask the presence of pathogenic bacteria and reduce disinfection efficiency. Biofilms surrounding iron bacteria harbor corrosion-producing bacteria and accelerate corrosion. The usual chlorine levels in drinking water don't affect established biofilms. Chemical and physical changes on the pipe surfaces could lead to the growth of other microorganisms that cause additional taste, odor, and corrosion problems.

Well design should reduce chemical oxidation, restrict inlet channel, and eliminate havens for growth. Backwashing and superchlorination or greensand filtration will control iron bacteria growth in filters. Replacement or shock chlorination of distribution lines could become necessary to control bacteria and corrosion. For dead-end areas, looping water lines maintains adequate chlorine residual to control bacterial growth.

Sulfur bacteria

Sulfur bacteria are serious nuisance organisms in water, causing bad taste and odor problems, as well as corrosion. Some sulfur bacteria produce and tolerate extreme acidity. Organisms of the genus *thiobacillus* oxidize elemental sulfur to sulfuric acid, lowering pH to the range of 1.0. Low pH could corrode pipes.

Desulfovibrio desulfuricans reduce sulfates and other sulfur compounds to hydrogen sulfide. These bacteria are suspected of causing taste and odor problems, especially those coming from water heaters. The temperature range of most water heaters is ideal for sulfate-reducing bacteria. Water heaters provide adequate contact time and free electrons from anode corrosion, making an ideal environment to produce that "rotten egg" odor. These odors are more common when a water system or well is not used for an extended period.

Remedies include replacing the magnesium anode with one that protects against corrosion without supporting sulfate reduction. Adequate chlorination inhibits bacterial activity.

Homeowners could disinfect and flush their water heater tanks with chlorine bleach solution. Increasing the temperature to the high setting (160° F or 71° C) for several hours kills the bacteria. (Note: the water heater should have an operable pressure relief valve, or this could be dangerous.) After flushing to remove dead cells, reset to the medium setting to prevent scalding and high energy costs. This is a temporary solution. Repeat when the bacteria population recovers.

Flushing low flow or low use lines and dead end lines periodically reduces problems. To suppress sulfur bacteria, apply the highest recommended chlorine dosage and use the longest contact time. Increase dissolved oxygen in the water.

Sources of contamination

The primary water quality issue is a water supply that is free from disease-causing organisms. Water systems can comply with bacteriological standards and still provide enough water at reasonable cost to meet customer needs.

A communicable disease is an illness caused by a microorganism. Humans or animals transmit disease-causing organisms to susceptible humans. Air, water, food, and soil serve as vehicles for disease-producing organisms but are not primary sources of contamination.

Communicable diseases transmit directly, indirectly, and through an intermediate host. Direct transmission usually takes a short period of time. Methods of direct transmission include:

- physical contact
- the use of contaminated cups, spoons, and other objects
- droplet infection from sneezing

Indirect infection might cover long distances and take weeks, months, or even years. The infection passes from person to person through food, water, soiled materials, soil — any suitable carrier. Many indirect infections enter through the mouth and pass from the body in feces. An intermediate host may be an insect or animal carrier that transmits the disease to man by piercing the skin.

One effective method to control communicable diseases is to stop transmission of the bacteria or virus from the carrier to a susceptible host. Table 6-4 lists methods to stop disease transmission in drinking water. References give additional information on preventing contaminants from entering the water system.

Table 6-4
Barriers to Disease Transmission

- Proper handling and storage of well drilling and construction materials
- Getting water for drilling from potable water supplies
- Proper grouting of a well
- Installing insect screens on well casing vents
- Properly sealing the space between the pump foundation and discharge head
- Installing insect screens on overflow pipes for finished water storage facilities (clear wells, elevated tanks, standpipes, reservoirs)
- Screening aerators or degassifiers to keep out birds and windblown trash
- Using pre-chlorination and post-chlorination as necessary
- Maintaining a minimum pressure of 20 psi in the distribution system
- Maintaining a free chlorine residual to the ends of the distribution system
- Disinfecting all new water lines and repairs of existing water lines

Microbiological monitoring

Types of samples

EPA regulations allow four kinds of sampling:

- initial
- routine (regular)
- check (re-sample)
- special purpose

Depending on the contaminant, either the operator or a representative of the Mississippi State Department of Health (MSDH) collects the samples. The MSDH public health laboratory analyzes all water quality samples.

Initial sampling means the first samples that new systems and wells collect. The frequency and length of the sampling period depend on:

- contaminant being monitored
- type of system — community or non-community
- water source — surface or ground water

Routine sampling means samples collected at regular time intervals. Regulations require that public water systems using ground water or surface water collect bacteriological samples monthly. These samples determine compliance with the bacteriological standards.

Check samples or re-samples are collected when a routine sample exceeds a maximum contaminant level (MCL) set forth in the regulations. A re-sample either confirms or disproves the routine sample results. Additional check samples are collected until samples show that the contamination has been eliminated. If analyses of different samples do not agree, then additional check sample are collected for verification. The number of check samples required depends on the MCL violated and the time needed to correct the problem.

Sample site selection

All systems must sample according to a sample siting plan that the state has approved. A minimum of five sampling locations must be identified that are representative of the entire system. Each site must be numbered, and each site must list a specific address — street number, route or box number, or a descriptive location.

Sampling frequency

Routine sampling from representative points throughout the distribution system assures water quality and proper maintenance of the system. This sampling can be the first signal of a bacterial contamination problem. The regulations require a minimum of five sample sites per system. Table 6-5 on the next page shows the number of bacteriological samples required per month.

Each water supplier is responsible for the proper collection and examination of the minimum number of bacteriological samples. The supplier must report results to the state if the data indicate non-compliance with a standard. This requirement does not apply when the state performs the analysis.

A supplier must notify the public when a violation occurs. Public notification depends on the type of violation and on whether the system is community or non-community. For specific information on compliance, refer to Appendix A.

Table 6-5

Minimum monthly bacteriological samples

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

Table 6-6 lists criteria for selecting a bacteriological sample site.

Table 6-6
Guide to bacteriological sample site selection

- Sampling points should be representative of the water in an area and located on a distribution main when possible. Sites may include looped water lines, storage facilities, high and low pressure zones and in some cases dead end lines.
- Sampling points should reflect the conditions of each different source of water entering the system. If four wells supply water to the system, select sampling points in each area.
- Select at least one sampling point where the source enters the system.
- Sample storage tanks during periods of high demand so water leaving the tank is collected, rather than water entering the tank.
- Consider locating more sampling points in populous areas.
- Never use faucets located in weeds, brush, bushes, or within approximately 12 inches of the ground.
- Never use faucets that leak or are dirty.
- Avoid chrome-plated fixtures, since heating can damage the finish.
- Do not use fire plugs as sampling points.
- Do not collect samples from inside washrooms or faucets.

Microbiological sampling procedure

Collect water samples for bacteriological analysis only in the special 100-milliliter sterilized bottles that the MSDH laboratory provides. County health departments provide sample forms and bottles. Return the sample to the local health department for transport to the laboratory in Jackson.

Check with the local health department about courier schedules and procedures for leaving samples. Each county health department has its own system for distributing sampling bottles and forms and receiving samples for shipment to the MSDH laboratory.

Sample collection

When collecting the sample, handle the bottle with care so that it does not become contaminated. The results are only as good as the sampling procedure followed. Bacteriological samples must be collected by trained personnel who realize the importance of proper sampling techniques. Suggestions for bacteriological sampling are listed in Table 6-7.

Table 6-7
Bacteriological sampling procedure

Collect the sample from a single, outside, cold-water faucet that can be heated without damaging the faucet.
1. Turn the faucet on and allow the water to run for 2-3 minutes to flush out the plumbing.
2. Check the water temperature.
3. Check the chlorine residual with a chlorine test kit.
4. Turn the faucet off and heat the faucet with a propane torch or wipe with a cotton ball soaked in alcohol. Be careful not to burn the rubber washer.
5. Turn the faucet on and adjust it to get a moderate, steady stream of water.
6. Fill the sample bottle to a little above the 100 ml mark and replace the cap immediately. Do not touch the bottle rim or inside of the cap while collecting the sample.
7. Do not add chlorine, Chlorox, alcohol, or other disinfectants to the sample. Do not heat the sample. The bottles are sterilized and contain a small amount of sodium thiosulfate to neutralize any chlorine in the water sample.
8. Complete the sample card completely, printing clearly. Wrap the card around the bottle and secure it with a rubber band. If more than one sample is to be collected, clearly number the bottle top and upper right hand corner of the corresponding card.
9. Be sure that the correct PWS facility identification number has been placed on the card.

The sample must be analyzed within 30 hours after collection. If the sample is late, it is returned and another sample must be collected.

Collect samples before the last week of the month to allow enough time for re-sampling, if necessary. Take samples to the county health department or an EPA-certified laboratory for analysis.

A water system that fails to meet sampling regulations any month will be "out of compliance" during that month. Contact the public health laboratory with questions about certification of a private lab.

Bacteriological card

A form must accompany every water sample submitted to the MSDH laboratory for analysis. Use Form 425 when sending all water samples to the MSDH laboratory for microbiological analysis. Form 425 is used for:

- routine compliance samples
- re-samples taken for compliance
- samples from new wells or wells to be placed back into service after repairs
- samples from new water lines or from lines to be placed back into service after repairs
- samples taken in response to customer complaints
- boil water samples
- special purpose samples

Bacteriological examination

The MSDH microbiology laboratory uses the Colilert method of P-A analysis for all routine bacteriologic examination of drinking water. Any sample that tests positive for total coliform must be analyzed for fecal coliforms or *Escherichia coli (E. coli)*. The MSDH laboratory checks all total coliform positive samples for *E. coli.*

The EPA has approved several analytical methods for total coliform analysis of water samples:

- Multiple-tube fermentation (MTF) technique
- Membrane filter (MF) technique
- Presence-absence (P-A) coliform test
- Minimal medium ONPG-MUG (MMO-MUG) test

Interpreting results

Detection of any coliform organisms in a 100-milliliter sample is an unsatisfactory or positive sample. If the sample is positive for coliforms, a series of re-samples must be collected within 24 hours from the time the system is notified.

Systems that are collecting one sample per month collect four re-samples. Systems that are collecting more than one routine sample per month must collect three re-samples for each positive routine sample.

In all cases, one of the re-samples must come from the same tap from which the positive routine sample came.

One re-sample must be collected within five service connections upstream from the site of the original positive sample. One re-sample must be taken within five service connections downstream of the original positive sample. Those systems that collect a fourth re-sample, must take it somewhere within that same 10-connection range.

For any positive routine sample during a particular month, the system must collect a minimum of five routine samples the following month. Systems that take more than five samples a month routinely need not increase the number of routine samples the month following a positive result.

A violation of drinking water microbiological standard is incurred when:

- more than one total coliform positive sample in any one month for systems that are required to take less than 40 samples per month, or
- more than 5% of samples collected are total coliform positive in any one month for systems that are required to take more than 40 samples per month, or
- any routine sample is positive for *E. coli* and is followed by a total coliform positive re-sample or when a total coliform positive routine sample is followed by an *E. coli* positive re-sample.

A positive result is the presence of total coliforms or presence of total coliforms and *E. coli* in the routine sample or re-sample. Failure to collect the minimum number of samples required per sampling period constitutes a monitoring violation for that grading period. Public notification must be issued for any of the above occurrences. Appendix A contains additional information about violations and public notification requirements.

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Sample questions

1. Microscopic organisms such as bacteria, viruses and protozoa which are capable of causing disease are
a) coliform
b) pathogenic
c) heterotrophic
d) shigella

2. Coliform are considered good indicator organisms because they are
a) absent in contaminated water
b) gram positive
c) aerobic
d) easily identified

3. Excessive amounts of iron and manganese in drinking water are objectionable because they:
a) cause corrosion of pipes
b) cause foul tastes and odors
c) consume excessive amounts of soap
d) encourage growth of sulfur bacteria
e) stain clothes

4. Microscopic plants which appreciably affect the pH and dissolved oxygen of the water are
a) bacteria
b) fungi
c) algae
d) protozoans

5. Water that does not contain objectionable pollution, contamination, minerals or infective agents and is considered satisfactory for drinking is
a) artesian
b) alkaline
c) potable
d) soft
e) caustic

6. A group of bacteria found in the intestines of warm-blooded animals including humans are called:
a) shigella
b) giardia
c) coliform
d) salmonella
e) hepatitis

7. The process designed to kill most microorganisms in water is
a) filtration
b) distillation
c) coagulation
d) disinfection
e) sedimentation

8. A water sample which is checked for *E. coli* is a
a) negative bacti sample
b) THM sample
c) micro sample
d) positive bacti sample

10. Organisms living on dead or decaying organic matter are
a) parasites
b) bacteria
c) saprophytes
d) terptophytes

11. All systems must have at least ____ bacti sample sites identified.
a) 10
b) 12
c) 3
d) 5

Chapter 7

Chemistry of ground water

Introduction

A basic knowledge of chemistry helps the operator understand chemical water treatment processes. This chapter gives some fundamental concepts about atomic structure and the forces within the atom that help to explain ionization and chemical bonds. Alkalinity, hardness, pH, and the chemistry of coagulation also are discussed.

Ground water

Rainfall percolates into the soil very slowly. The water seeps through a tight soil such as clay less than one foot per year. Water might move several feet per day in gravel aquifers.

During slow groundwater movement, minerals in the soil dissolve in water. The mineral content increases as the water moves to the water table. Eventually mineral content remains constant and is in equilibrium. Final equilibrium concentrations depend on the chemical composition of soil. Thus, the chemistry of ground water varies widely, even within the same aquifer.

In Lauderdale County, Mississippi the iron content of water in the lower Wilcox formation varies from 0.12 mg/l to 10 mg/l. The pH ranges from 8.3 to 6.81. Chemical and bacteriological water qualities remain relatively constant over the life of a well unless conditions change in the recharge area or aquifer.

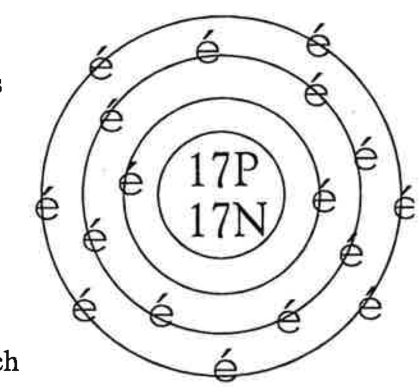
Natural aquifers are generally free of pathogenic bacteria. The soil removes bacteria by filtration.

Water temperatures below 50 to 100 feet remain constant. Shallow well water is coldest. Temperatures are higher in deeper wells.

The dissolved minerals in groundwater determine how much treatment water needs for intended use. Many aquifers yield water that is colorless, odorless, free of bacteria, and contains no suspended solids. However, waters with dissolved minerals, gases, or organic color might need treatment.

Materials dissolved in water separate into components called ions. Ions are electrically charged particles, either positive or negative. Ions can combine with other ions. Table salt (NaCl) dissolves in water by breaking down into positively charged sodium (Na^+) ions and negatively charged chloride (Cl^-) ions.

An atom is a nucleus surrounded by shells of electrons, as illustrated in the chlorine molecule, below. The nucleus contains positively charged particles called protons and particles with no charge called neutrons. The outer shells contain negatively charged particles called electrons.



Ions combine to form compounds such as:

- lime (calcium oxide — CaO)
- soda ash (sodium carbonate — Na_2CO_3)
- baking soda (sodium bicarbonate — $NaHCO_3$).

Protons and neutrons have an atomic mass unit of one. The sum of the atomic mass units within the nucleus makes up the atomic weight.

Molecular weight is the sum of the atomic weights in a molecule or compound. For example, hydrogen (H_2) has a molecular weight of 2.

Oxygen (O_2) has a molecular weight of 32. The chemical formula for water is H_2O and has a molecular weight of 18. This shows that a molecule of water is not composed of whole molecules of hydrogen and oxygen. Water is two atoms of hydrogen and one atom of oxygen.

Any number of similar or different atoms can make a molecule. The subscript 2 after H (H_2) shows that the water molecule has two atoms of hydrogen. Since no subscript follows the oxygen (O), it means one atom of oxygen. Therefore, the molecular weight of water is $2 + (32 \div 2) = 18$.

Hydrogen and oxygen combine to make water in this reaction:

$$2H_2 + O_2 \rightarrow \rightarrow 2H_2O$$

The equation is balanced because the molecular weight of 36 is the same on both sides of the arrow.

The arrow shows the direction of the reaction; that is two molecules of hydrogen combine with one molecule of oxygen to form two molecules of water. The reverse reaction shows that water breaks down into the same molecules from which it came:

$$2H_2O \rightarrow \rightarrow 2H_2 + O_2$$

Atoms always combine in exact proportions, based on the valence of each element. Hydrogen has a valence of +1, oxygen a valence of -2.

The number of positive charges must equal the number of negative charges in a compound. Thus, two hydrogen atoms with a total positive charge of +2 combine with oxygen to form a compound with an equal number of positive and negative charges.

Table 7-1 summarizes chemical elements and compounds, their symbols or formula, molecular and equivalent weight, and $CaCO_3$ equivalents.

Table 7-1
Chemical elements and compounds

				Multiplying factor (with molecular weight of $CaCO_3$ as 100)	
Chemical	Formula	Atomic or molecular weight	Equiva-lent weight	Chemical to $CaCO_3$ equivalent	$CaCO_3$ to chemical equivalent
Aluminum	Al	27.0	9.0	5.55	0.18
Aluminum sulfate	$Al_2(SO_4)_3 \cdot 18H_2O$	666.4	111.1	0.45	2.22
Aluminum sulfate	$Al_2(SO_4)_3$ anhydrous	342.1	57.0	0.88	1.14
Ammonia	NH_3	17.0	17.0	2.94	0.34
Ammonium (ion)	NH_4	18.0	18.0	2.78	0.36
Calcium	Ca	40.1	20.0	2.50	0.40
Calcium bicarbonate	$Ca(HCO_3)_2$	162.1	81.1	0.62	1.62
Calcium carbonate	$CaCO_3$	100.08	50.1	1.00	1.00
Calcium chloride	$CaCl_2$	111.0	55.5	0.90	1.11
Calcium hydrate	$Ca(OH)_2$	74.1	37.1	1.35	0.74
Calcium hypochlorite	$Ca(ClO)_2$	143.1	35.8	0.70	1.43
Calcium oxide	CaO	56.1	28.0	1.79	0.56
Calcium sulfate (gypsum)	$CaSO_4 \cdot 2H_2$	172.2	86.1	0.58	1.72
Carbon	C	12.0	3.0	16.67	0.06

				Multiplying factor (with molecular weight of $CaCO_3$ as 100)	
Chemical	Formula	Atomic or molecular weight	Equiva-lent weight	Chemical to $CaCO_3$ equivalent	$CaCO_3$ to chemical equivalent
Chlorine	Cl	35.5	35.3	1.41	0.71
Copper (cupric)	Cu	63.6	31.8	1.57	0.64
Copper sulfate (cupric)	Cu_2SO_4	160.0	80.0	0.68	1.60
Copper sulfate (cupric)	$Cu_2SO_4{\cdot}5H_2O$	250.0	125.0	0.40	2.50
Iron (ferrous)	Fe^{2+}	55.8	27.9	1.79	0.56
Iron (ferric)	Fe^{3+}	55.8	18.6	2.69	0.37
Ferrous hydroxide	$Fe(OH)_3$	89.9	44.9	1.11	0.90
Fluorine	F	19.0	19.0	2.66	0.38
Hydrogen (ion)	H^+	1.01	1.01	50.00	0.02
Hypochlorous acid	$HOCl$	52.5	52.5	0.95	1.05
Iodine	I	127.0	127.0	0.40	2.54
Lead	Pb	207.0	104.0	0.48	2.08
Magnesium	Mg	24.3	12.2	4.12	0.24
Magnesium oxide	MgO	40.3	20.2	2.48	0.40
Magnesium bicarbonate	$Mg(HCO_3)_2$	146.3	73.2	0.68	1.46
Magnesium carbonate	$MgCO_3$	84.3	42.2	1.19	0.84
Manganese (manganous)	Mn^{2+}	54.9	27.5	1.82	0.55
Manganese (manganic)	Mn^{3+}	54.9	18.3	2.73	0.37
Nitrogen	N	14.0	(varies)	(varies)	(varies)
Oxygen	O	16.0	8.0	6.25	0.16
Potassium	K	39.1	39.1	1.28	0.78
Sodium	Na	23.0	23.0	2.18	0.46
Sodium bicarbonate	$NaHCO_3$	84.0	84.0	0.60	1.68
Sodium carbonate	Na_2CO_3	106.0	53.0	0.94	1.06
Sodium carbonate	$Na_2CO_3{\cdot}10H_2O$	286.0	143.0	0.35	2.86
Sodium chloride	$NaCl$	58.5	58.5	0.85	1.17
Sodium fluoride	NaF	42.0	42.0	1.19	1.19
Sodium hypochlorite	$NaClO$	74.5	37.3	0.67	1.49
Sulfur	S	32.1	(varies)	(varies)	(varies)
Bicarbonate (ion)	HCO_3^-	61.0	61.0	0.82	1.22

				Multiplying factor (with molecular weight of $CaCO_3$ as 100)	
Chemical	Formula	Atomic or molecular weight	Equiva-lent weight	Chemical to $CaCO_3$ equivalent	$CaCO_3$ to chemical equivalent
Carbonate (ion)	CO_3^{-2}	60.0	30.0	1.67	0.60
Carbon dioxide	CO_2	44.0	44.0	1.14	0.88

Table 7-2 shows balanced equations common to the water treatment industry. For these equations to balance, the molecular weights on one side must equal the molecular weights on the other side. Convert the molecular weight to any other weight measurement — such as ounces — and the reactions remain the same.

Table 7-2
Water treatment chemical equations

Cl_2	+	H_2O			→	HCl	+	HOCl		
70.9		18				36.45		52.54		
$Ca(OCl)_2$	+	Na_2CO_3			→	2NaOCl	+	$CaCO_3$		
142.9		106.0				148.9		100		
CO_2	+	H_2O			→	H_2CO_3				
44		18				62				
$CaCO_3$	+	H_2CO_3			→	$Ca(HCO_3)_2$				
100		62				162				
$Al_2(SO_4)_3$	+	$3CaCO_3$	+	$3\ H_2O$	→	$Al_2(OH)_6$	+	$3\ CaSO_4$	+	$3\ CO_2$
342.1		300		54		155.9		408.2		132
$CaCO_3$	+	H_2SO_4			→	$CaSO_4$	+	H_2CO_3		
100		98				136		62		
$Ca(HCO_3)_2$	+	H_2SO_4			→	$CaSO_4$	+	$2\ H_2CO_3$		
162		98				136		124		
$Ca(HCO_3)_2$	+	$Ca(OH)_2$			→	$2\ CaCO_3$	+	$2\ H_2O$		
162		74				200		36		
HOCl	+	NH_3			→	NH_2Cl	+	H_2O		
52.45		17				51.45		18		
HOCl	+	NH_2Cl			→	$NHCl_2$	+	H_2O		

52.45				51.45				85.9				18
HOCl		+		$NHCl_2$		→		NCl_3		+		H_2O
52.45				85.9				120.35				18
$MnSO_4$	+	Cl_2	+	4 NaOH	→	MnO_2	+	2 NaCl	+	Na_2SO_4	+	2 H_2O
151		70.9		160		86.9		116.9		142		36

Solutions

A solution is a mixture in which every part is like every other part of the mixture. The Law of Definite Proportions does not apply to solutions because they consist of two parts:

- the dissolved substance, the solute
- the solvent, the liquid in which the solute dissolves

When sugar dissolves in water, the sugar molecules separate from their crystalline alignment, disperse in the water, and move into the spaces between water molecules. The spaces between molecules can hold only a certain amount of sugar at a given temperature and pressure. When they are filled, the solution is saturated. No more sugar will go into solution. Higher temperatures increase the size of the spaces, and more sugar will dissolve.

Gas solubility is directly proportional to pressure and temperature. Carbon dioxide added to soft drinks under pressure comes out of solution when the bottle is opened and pressure reduced.

A solution's properties depend on:

- freezing point
- boiling point
- vapor pressure
- concentration of other dissolved materials

Many water analyses use a standard solution. A standard solution has a measured amount of the solute dissolved in a fixed volume of solution. When the unknown amount is compared with the known, the analyst can calculate the amount of solute in the unknown.

The following terms express the strength of a standard solution: molar solution, molal solution, normal solution, or percent concentration. A molar solution is one gram-molecular weight of solute in one liter of solution. Dissolving 58 grams of NaCl in enough water to produce one liter of solution would give a one-molar solution. One gram-molecular weight of sodium chloride (NaCl) is the combined molecular weights of sodium and chlorine: 23 + 35 = 58.

A molal solution contains one gram-molecular weight of solute added to a liter of solvent. Dissolving 58 grams of NaCl in a liter of water would produce a molal solution.

A normal solution contains one gram-equivalent weight of solute in one liter of solution. The equivalent weight is molecular weight divided by its valence. Na and Cl have a valence of +1 and -1 respectively. Their equivalent weights are 23÷1 = 23 and 35÷1 = 35 respectively. Therefore 23 + 35 = 58, an equivalent weight of 58 for salt.

Sulfuric acid (H_2SO_4) has a valence of +2 for two hydrogen atoms, -2 for the sulfate radical (SO_4), and a molecular weight of 98. The equivalent weight of sulfuric acid is 98÷2 = 49. Dissolving 49 grams of H_2SO_4 in enough water to produce one liter of solution would be a one normal (1N) solution. A 0.5 normal (0.5N) solution would contain 0.5 x (98÷2) grams of H_2SO_4 .

A solution can contain a percent by weight or volume. A 10 percent by weight salt solution contains 10 grams of salt dissolved in enough water to produce 100 grams of solution. A percent by volume solution contains 10 ml solute and 90 ml solvent. For example: 10 gallons of sulfuric acid with 90 gallons of water is 100 gallons of 10 percent solution.

Milligrams per liter and parts per million

Milligrams per liter (mg/l) and parts per million (ppm) express concentrations of substances in water. One milligram per liter is approximately equal to one part per million, or 8.34 pounds per million gallons. One liter contains 1,000,000 milligrams of water, which is also 1 part in 1,000,000 parts of water. A 5 mg/l or ppm dosage of chlorine in water would be the same concentration as 5 pounds of chlorine in 1,000,000 pounds of water. One million pounds of water is 119,904 gallons, since one gallon of water weighs 8.34 pounds.

Pumps are generally rated in gallons per minute, and chemicals are measured in pounds. To find dosage, convert the water and chemical into the same units of measure. Since one gallon of water weighs 8.34 pounds, 8.34 pounds of chemical in 1,000,000 gallons or 8,340,000 pounds of water would be 1 mg/l or 1 ppm. Thus for a chlorine feed of 5 ppm, it takes 5 x 8.34 or 41.7 pounds of chlorine per million gallons of water.

This relationship can determine the amount of any chemical to reach 100 percent strength. If the chemical strength is less than 100 percent, divide the pounds of chemical by the purity of the active agent. For example: high-test calcium hypochlorite (HTH) is 65 percent available. It takes = 12.83 or about 13 pounds of HTH in 1,000,000 gallons of water to give a 1 mg/l concentration of chlorine.

To express a chemical concentration in grains per gallon (gpg) divide the concentration in mg/l or ppm by 17.1. For example, 51.3 mg/l is equal to 3 gpg.

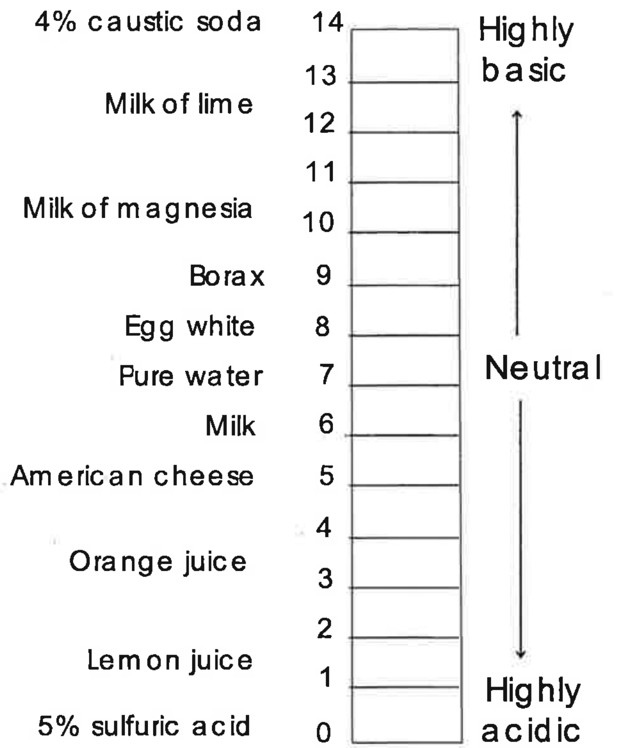
Hydrogen ion concentration - pH

Pure water does not exist in nature. Water naturally contains gases or minerals in solution. These solutes affect pH, a measure of hydrogen ion concentration. As the number of H^+ ions increases, the pH decreases.

The pH range extends from 0 to 14. Figure 7-1 illustrates pH values of some familiar compounds.

Table 7-3 illustrates the relationship of pH to the hydrogen ion concentration in moles per liter.

Figure 7-1
pH values of common substances



The use of pH values was adopted as a simple method to express the hydrogen ion concentration in mathematical terms. It is the negative logarithm of the hydrogen ion concentration (1 pH = - log [H^+] or pH = 1/log [H^+]).

Table 7-3
pH and hydrogen ion concentration

pH	Hydrogen ion moles/liter
1	0.1
2	0.01
3	0.001
4	0.0001
5	0.00001
6	0.000001
7	0.0000001
8	0.00000001
9	0.000000001
10	0.0000000001
11	0.00000000001
12	0.000000000001
13	0.0000000000001
14	0.00000000000001

In pure water, the concentrations of hydrogen ions (H^+) and hydroxyl ions (OH^-) are equal, and the water has a pH of 7, which is neutral. Values of pH less than 7 are acid and values greater than 7 are alkaline or basic. Table 7-4 lists chemicals commonly used in the water supply industry and their effect on pH.

Table 7-4
Effect of chemicals on pH

Adding the following chemicals to water lowers pH:
- Chlorine, forming hydroclorous acid(HOCl)
- Alum $Al_2(SO_4)_3 \cdot 14g\ H_20$, precipitating hydroxide (OH^-) and forming carbon dioxide (CO_2)
- Sulfuric acid H_2SO_4
- Hydrofluosilicic acid H_2SiF_6
- Carbon dioxide CO_2
- Carbonic acid H_2CO_3

Adding the following chemicals to water raises pH:
- Lime (hydrated) $Ca(OH)_2$
- Soda ash Na_2CO_3
- Sodium hydroxide (caustic soda) Na(OH)
- Hypochlorite

Many ground waters in Mississippi have low pH values because of carbon dioxide (CO_2) dissolved in the water. The CO_2 can be removed by aeration, which increases the pH and reduces the corrosiveness of the water. Aeration also adds oxygen, which aids in the oxidation of iron and manganese to an insoluble form that can be removed by sedimentation or filtration.

Either electrodes or color matching equipment is used to measure the pH of a water. When using electrodes, the pH meter must be calibrated. The chemicals used in color matching or comparators must be kept fresh to produce reliable results.

Alkalinity

Water alkalinity measures how substances in the water neutralize acid. Increasing alkalinity lowers acidity and raises the pH. Alkalinity in a water influences coagulation processes and water stability3.

Ground water alkalinity comes from rocks and soil as the water percolates downward to the ground water table. Hydroxyl (OH^-), carbonate (CO_3^{-2}), and bicarbonate (HCO_3^-) ions cause water alkalinity. These negative ions are present in calcium, magnesium, sodium, or potassium compounds. Borates, silicates, and phosphates also can cause alkalinity but are in much lower concentrations.

The most common alkaline compounds in ground waters:
- Calcium carbonate, $CaCO_3$
- Calcium bicarbonate, $Ca(HCO_3)_2$
- Magnesium carbonate, $MgCO_3$
- Magnesium bicarbonate, $Mg(HCO_3)_2$

Of these four, bicarbonate (HCO_3^-) salts provide most of the alkalinity in natural waters. Much of the earth's crust contains calcium and magnesium. Water and carbon dioxide combine with calcium and magnesium to form bicarbonate salts. Calcium and magnesium ions make ground water hard.

To test for alkalinity, titratation methods can be used. References contain additional information about alkalinity.

The relationship of hydroxide alkalinity, carbonate alkalinity and bicarbonate alkalinity is summarized in Table 7-5.

Table 7-5
Hydroxide, carbonate, bicarbonate alkalinity relationships

Result of titration	Hydroxide alkalinity as $CaCO_3$	Carbonate alkalinity as $CaCO_3$	Bicarbonate alkalinity as $CaCO_3$
P = 0	0	0	T
P < ½ T	0	2P	T - 2P
P = ½ T	0	2P	0
P > ½ T	2P - T	2 (T-P)	0
P = T	T	0	0

*Key: P-phenolphthalein alkalinity; T-total alkalinity

Hardness

Hard water takes a lot more soap than soft water to produce a lather or foam. The harder the water, the more soap it takes to make a lather. Bathtub "rings" or "curds" are the result of soap reacting with hard water.

Degree of hardness also predicts whether the water will deposit scale on pipes. Scale decreases the efficiency of boilers, water heaters, and other units that operate at higher temperatures.

The values for hardness listed in Table 7-6 warn when a water is too hard and must be softened. Base the decision to soften water on a complete analysis of the water and related economic factors.

Table 7-6
Guideline to water hardness

Hardness	Values mg/1 as $CaCO_3$)
Soft water	< 75
Moderately soft or moderately hard	75-150
Hard	150-200
Very hard	>200

Metal ions with a positive electrical charge and a valence of 2 cause hardness. Most of the hardness in natural waters is caused by calcium (Ca) and magnesium (Mg). Other cations in water include strontium (Sr), iron (Fe), manganese (Mn), and aluminum (Al).

The two kinds of hardness are carbonate and non-carbonate. Carbonate hardness usually refers to water containing cations Ca^{2+} and Mg^{2+} with anions OH^-, CO_3^{-2}, or HCO_3^-. Heat softens carbonate or temporary hardness. Heat drives off carbon dioxide (CO_2) and precipitates a carbonate compound.

Non-carbonate or permanent hardness forms a hard scale when its solubility limit is exceeded. Heat has no effect on non-carbonate hardness. Compounds of calcium and magnesium that cause carbonate and non-carbonate hardness are listed in Table 7-7.

The following excerpt explains how to distinguish the difference between carbonate and non-carbonate hardness:

1. Where the total alkalinity equals or exceeds the total hardness, all the hardness is carbonate. Where the total alkalinity is greater than the hardness, the excess usually is caused by sodium, which forms non-hardness compounds.
2. Where the total alkalinity is less than the total hardness, the carbonate hardness is equal to the alkalinity and the non-carbonate hardness is the total hardness less the total alkalinity.

Table 7-7
Compounds that make natural waters hard

Carbonate hardness	Non-carbonate hardness
Calcium carbonate, $CaCO_3$	Calcium sulfate,$CaSO_4$
Magnesium carbonate, $MgCO_3$	Magnesium sulfate, $MgSO_4$
Calcium bicarbonate, $Ca(HCO_2)_2$	Calcium chloride, $CaCl_2$
Magnesium bicarbonate, $Mg(HCO_3)_2$	Magnesium chloride, $MgCl_2$
	Calcium nitrate, $Ca(NO_3)_2$
	Magnesium nitrate, $Mg(NO_3)_2$
	Calcium silicate, $CaSiO_3$
	Magnesium silicate, $MgSiO_3$

Coagulation

Coagulation reduces the forces that keep suspended colloidal particles from joining together. Flocculation is when the suspended particles join together to form larger particles that sedimentation and filtration can remove. Alum, ferric or ferrous sulfate, and synthetic polyelectrolytes are the coagulant chemicals.

Coagulants react with alkalinity in the water to form hydroxides such as aluminum hydroxide or ferric hydroxide floc. These small floc join together and enmesh other particles such as microscopic organisms and particles that cause color and turbidity. A series of jar tests determine the type and amount of coagulant.

These tests use a machine with paddles to stir the water and a gauge to control the paddle speed.

Steps in the jar test:

1. Fill several jars with test water.
2. Add varying amounts of coagulants.
3. Mix vigorously for a short time.
4. Mix slowly for a long time to allow flocculation.

This process simulates the full-scale process. After a settling period, check the test water for color and turbidity to determine the optimum chemical dosages, mixing time, and settling time.

Most ground waters in Mississippi contain sufficient alkalinity for coagulation. However, some water requires added lime to boost alkalinity. If lime is required, add it before the coagulant in a separate feed line because lime and alum react.

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Sample questions

1. Materials dissolved in water separate into components called
   a. electrons
   b. neutrons
   c. ions
   d. radicals

2. The chemical formula of calcium oxide (lime) is
   a. CaOH
   b. CaO
   c. $Ca(OH)_3$
   d. NaO

3. A mixture in which every part is like every other part is a
   a. coagulant
   b. homogenous mixture
   c. heterotrophic mixture
   d. solution

4. One milligram per liter is approximately equal to
   a. one grain per gallon
   b. one kilogram per milliliter
   c. one part per million
   d. one centimeter per inch

5. Pure water
   a. does not exist in nature
   b. cannot be produced in a laboratory
   c. has tastes and odors associated with impurities
   d. is produced by ultra filtration

6. A measure of the hydrogen ion concentration is
   a. pH
   b. OH
   c. alkalinity
   d. hardness

7. The ability of a substance to neutralize acid is called
   a. pH
   b. pOH
   c. alkalinity
   d. hardness

8. Which of the following chemicals increases pH when added to water?
   a. hydrofluosilicic acid
   b. carbon dioxide
   c. caustic soda
   d. alum

9. Hardness refers to the presence of multivalent metal ions in water. The most common elements which cause hardness in Mississippi ground water are
   a. iron and manganese
   b. calcium and manganese
   c. calcium and magnesium
   d. sodium and sulfur

10. Carbonate hardness refers to hardness associated with
    a. sodium
    b. calcium
    c. alkalinity
    d. pH

Chapter 8

Water treatment

Introduction

Most water needs some type of treatment before it is safe to drink. All water should be disinfected. Water from wells – called groundwater – and water from lakes and rivers – called surface water – can contain substances that cause staining, color, taste and odor, and corrosion problems. Surface water can also contain turbidity, algae, and industrial or domestic waste.

Proper treatment removes these substances. Select treatment methods based on a chemical analysis of the water. A series of treatments is called a treatment train.

Factors that dictate which treatment processes required are:

- pH, whether the water is acid or alkaline
- hardness
- total dissolved solids
- concentrations of iron and manganese
- turbidity

This chapter is divided into three sections: Class D, Classes B and C, and Class A. Every certification candidate should read the first section. Class D section covers basic information about water treatment. Candidates for Class B or Class C certification should read the first and second section, basic information about water treatment in B and C class plants. Candidates for Class A certification should read all three sections.

Class D

This section describes water treatment in Class D plants. Class D operators need to read only this section, not the rest of the chapter. This part has the basic water treatment information that is included on the D certification test.

Disinfection

Disinfection kills disease-causing microbes in water. These microbes are called pathogens. Before disinfection became common, diseases could be spread through local water supplies. There are several ways to disinfect water:

- heat
- bromine
- iodine
- ultraviolet light
- ozone
- chlorine

Most water systems use chlorine. Chlorine works well over a broad range of conditions. It leaves a residual that protects the water from contamination after it leaves the plant.

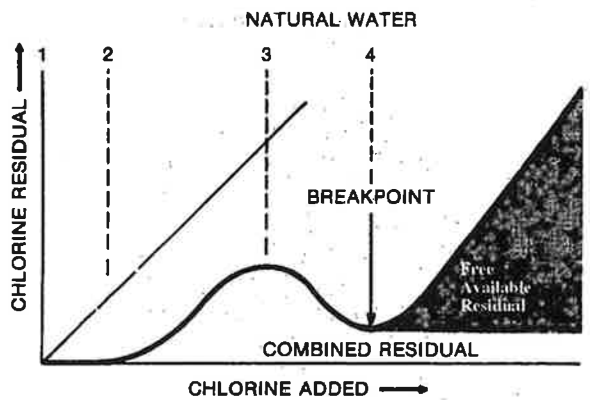
When chlorine is added to water, it first reacts with impurities in the water. These impurities include:

- organic matter
- nitrates

- iron
- manganese
- hydrogen sulfide

The amount of chlorine that reacts with these substances is called chlorine demand. For example, 1 mg/l of hydrogen sulfide reacts with 2.1 mg/l chlorine. That demand for chlorine is satisfied first. If other substances that combine with chlorine are present, then the demand for those must also be met before a residual is formed. In Figure 8D-1, zone 1 shows chlorine demand.

Figure 8D-1



Reactions of chlorine in water

After the chlorine demand is met, the remaining chlorine combines with ammonia in the water to form chloramines. Chloramines provide some disinfection but have a strong bleach odor. Zone 2 shows their formation. The amount of chloramines is called combined residual.

When chloramines have been formed, the remaining chlorine begins to react with them. This reduces the combined residual. Zone 3 shows the destruction of chloramines. Because they have a strong smell, raising the chlorine feed rate to reduce the amount of chloramines may actually reduce the chlorine smell in the water.

When the level of chloramines reaches its lowest point, any more chlorine added forms a free residual. This happens at the breakpoint. After reaching the breakpoint, increasing the amount of chlorine added increases the free residual.

Maintaining a free residual throughout the distribution system is important because:

- It insures the demand has been met.
- It insures that odor causing chloramines are at their lowest level.
- Free residual is a better disinfectant than combined residual.

It is the responsibility of the operator to test the chlorine residual at different locations and often enough to make sure a free residual is present in all of the distribution lines.

These factors influence how effective chlorine is as a disinfectant:

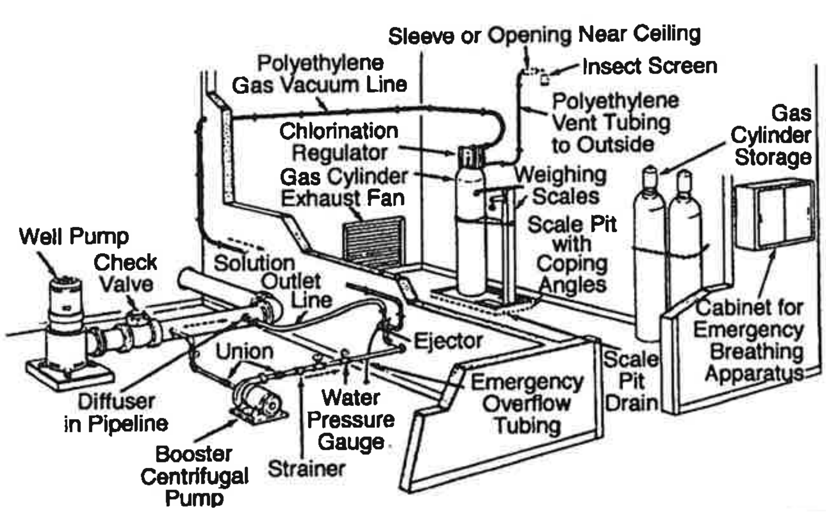
- **Concentration of residual and contact time**: Concentration and contact time are the most important factors affecting how well chlorine disinfects. Concentration is the amount of chlorine in the water. Contact time is the length of time chlorine is allowed to disinfect before the water is used. If the chlorine has longer to react, a lower residual may be needed. If a short contact time is provided, a higher residual is needed. Contact time of 15 to 30 minutes is recommended.
- **pH:** Free chlorine residual is made of hypochlorite ions (OCL^{-1}) and hypochlorous acid (HOCL). Hypochlorous acid is the stronger disinfectant. It is more prevalent at a lower pH, so disinfection is more effective at a lower pH.
- **Temperature:** Chlorine kills bacteria faster at higher temperatures.
- **Other substances in the water:** Impurities in water will react with the chlorine and reduce the amount available for disinfection. Also, suspended solids can shield bacteria and viruses from chlorine. This makes chlorine less effective. These substances are listed in table 8D-1 on the next page.

Table 8D-1
Substances affecting chlorination

Substance	Effect
Suspended solids	Shield bacteria and viruses from chlorine
Organic matter	Reacts with chlorine and reduces the amount available for disinfection
Ammonia	Combines with chlorine to form chloramines
Nitrates	React with chlorine and reduce the amount available for disinfection
Iron and manganese	Oxidized by chlorine and reduce the amount available for disinfection
Hydrogen sulfide	Reacts with chlorine and reduces the amount available for disinfection

Figure 8D-2 shows chlorination equipment. Chlorine gas is highly corrosive. The chlorine cylinders and chlorinator are stored away from the booster pump and electrical controls to protect electrical equipment from corrosion. Chlorine gas is heavier than air, so if it leaks it will settle to the floor. Vents are at the bottom of the equipment cabinet, so the gas can be removed. Switches for an exhaust fan and light should be placed on the outside of the cabinet.

Figure 8D-2
A typical chlorination equipment installation



To check for a chlorine leak, hold an ammonia-soaked cloth near the chlorinator. A white cloud of ammonium chloride will form at the leak. Chlorine gas is also highly toxic if inhaled. Water plants need special equipment – including gas masks – to move, store, and use chlorine. Chlorine gas suppliers can supply information on how to handle chlorine safely.

The example in Table 8D-2 illustrates a shorthand method for calculating the feed rate setting for a gaseous chlorinator.

Table 8D-2
Calculation of feed rate setting for a gaseous chlorinator

Given: 500 gpm well capacity
2 ppm chlorine dosage @ well is desired.
Formula: ppm x gpm x 0.012 = pounds/24 hours
2 ppm x 500 gpm x 0.012 = 12 pounds/24 hours

The chlorinator should be set to feed 12 pounds of chlorine for a 24- hour period.

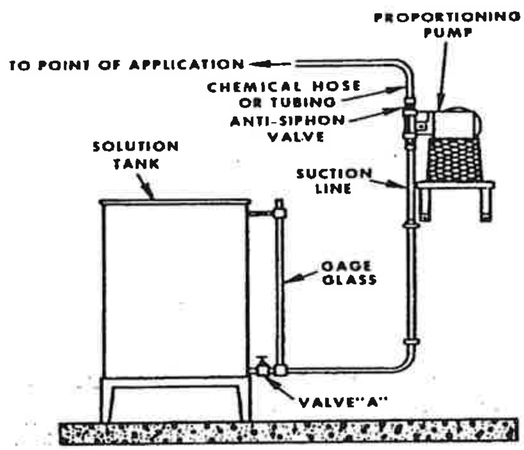
Note: The figure 0.012 is a conversion factor that converts ppm x gpm to pounds/24 hours and does not change for this particular calculation.

Liquid chlorine

Metering pumps called hypochlorinators put hypochlorite solutions into the water system. Most plants use positive displacement pumps. They are reliable, accurate, and easier to maintain than other types of pumps. Hypochlorinators can operate against system pressures of up to 100 psi and over a wide range of capacities.

Setting the number of strokes per minute and the stroke length adjusts the pumping rate. Hypochlorinators are simple but effective. They are easy to operate if the well flow rate and water quality are fairly constant. A varying water supply requires a flow metering device to coordinate the hypochlorinator with the flow. Systems with two or more pumps need a hypochlorinator at each pump. A typical hypochlorinator installation is illustrated in Figure 8D-3.

Figure 8D-3
Typical hypochlorinator installation



Fluoridation

Adding fluoride to drinking water reduces tooth decay among consumers who regularly drink the water. Extensive research shows a 50 to 65 percent decrease in dental cavities when children drink water containing 1 mg/l of fluoride ion from infancy.

Fluoride does not affect the taste, color, odor of water, or its use for industrial or domestic purposes. It occurs naturally in many groundwaters and surface waters. Fluoride compounds dissolve in water and disassociate into ions. Bones and teeth absorb the fluoride ions. Studies show that children's teeth absorb more fluoride than adults.

A concentration of 0.8 to 1.2 mg/l of natural fluoride is considered ideal. At least 47 Mississippi water systems have natural fluoride in the right range. About 120 other systems adjust fluoride levels to ideal ranges. Adding fluoride is much the same as feeding soda ash, lime, or alum into water supplies.

The word fluoride raises fears, just as chlorine did when it was introduced as a disinfectant. Supposed harmful effects from adding fluoride to public water are not supported by scientific research. The amount of fluoride that mottles or discolors teeth is much greater than the amount added to drinking water.

Fluoride chemical compounds

Sodium fluoride (NaF), hydrofluosilicic acid (H_2SiF_6), and sodium silicofluoride (Na_2SiF_6) are compounds used to add fluoride to water. All three are soluble and readily available.

Sodium Fluoride is a white, odorless salt. It comes as dry crystals or powder, both 90 to 98 percent pure. The crystalline form is more popular because it raises less dust than fine powder.

The salt has a formula weight of 42.0. Its solubility is practically constant at 4.0 grams per 100 milliliters, a 4% solution. Each pound of pure sodium fluoride contains 0.45 pounds of fluoride ion. At 98 percent purity, that means each pound of sodium fluoride contains 0.44 pounds of fluoride ion (0.45 x 0.98 = 0.44).

Store sodium fluoride in its container until it is used. Stack on pallets or in an area where moisture is not a problem. Wear face masks when transferring the chemical to avoid breathing the dust. Wear clothing that protects skin surfaces.

Hydrofluosilicic Acid is a colorless, transparent, corrosive, fuming liquid with a pungent odor that can irritate the skin. It is a 22 to 30 percent aqueous solution of H_2SiF_6. The pure acid has a formula weight of 144.

Each pound of pure acid contains 0.792 pounds of fluoride ion. Each pound of 25 percent solution contains 0.198 pounds of fluoride ion. A positive displacement or chemical metering pump can dilute the acid.

Hydrofluosilicic acid is very corrosive. Pay special attention to storage and transfer. Use corrosion resistant materials such as stainless steel or plastic. Avoid contact with the skin and eyes. Don't breathe the vapors. If the acid is not properly sealed, its vapors etch glass and attack electrical connections. Make sure hydrofluosilicic acid feed tanks are vented to the open atmosphere and have tight fitting covers.

Commercial hydrofluosilicic acid has excess silica. Diluting the acid forms a precipitate. Use the acid undiluted, if possible, or dilute with more than 20 parts water to one part acid.

Sodium Silicofluoride (Na_2SiF_6) is a white, odorless, crystalline powder. It is available in two forms: regular and fluffy. Regular is preferred because fluffy packs and plugs the feeder.

Larger plants use sodium silicofluoride as a dry powder because of low solubility. It has a formula weight of 188, contains 0.607 pounds of fluoride ion per pound of chemical, and is available in purities of 98 percent or more. Each pound of 98 percent pure sodium silicofluoride contains 0.59 pounds (0.607 x 0.98 = 0.59) of fluoride ion.

Store sodium silicofluoride like sodium fluoride. Safety precautions are also the same. Mixing with water produces an extremely corrosive solution. All materials in contact with the solution should be corrosion resistant.

Fluoridation Equipment

Add fluoride chemicals to drinking water by one of the following methods:

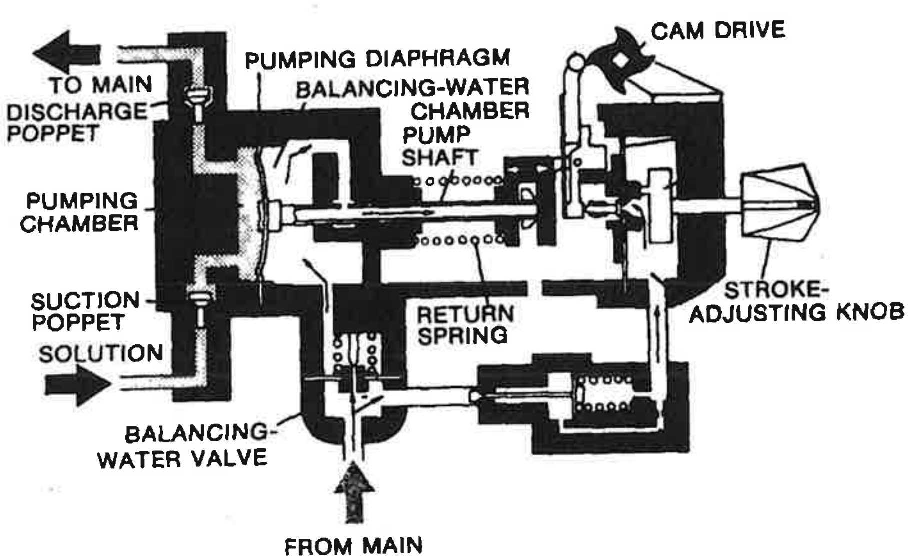
- as a solution
- as a slurry
- in dry form

The chemical feeder selected should allow the machine to operate in the middle of the feed range where it is most accurate.

Solution feed equipment

Inject fluoride solution into the water supply by piston or diaphragm-type positive displacement pump. Figure 8D-4 shows an example. This system can pump hydrofluosilicic acid or a saturated solution of sodium fluoride.

Figure 8D-4
Diaphragm positive displacement pump



Set the pump to run at a constant speed with a well or service pump. Maintain a constant ratio of fluoride to water flow. Careful control ensures that the dosing rate remains constant.

Control the fluoride solution pump so that the well or service pump starter energizes it. This prevents the solution pump from starting without the well or service pump.

A mechanical actuator on the pump discharge line is an added precaution. This ensures that water is actually flowing past the injection joint before fluoride solution pumps into the main. Few adjustments are necessary after the feed rate is set, as long as the pump discharge rate and solution strength remain the same.

Concentrated sodium fluoride reacts with hard water. Scale build ups in the metering pump and solution line. Scale prevents the valves in the pump head from operating properly. A water softener for the feed water solves the problem. Routine inspections can detect scale build-up. Pump a weak acid solution through the pump to clean it. Check manufacturer's service manual for recommendations before servicing the equipment. While the pump is out of service, check for leaks or wear. Make all necessary repairs.

Prepare sodium fluoride solution in a saturator tank. Two types of saturators are used – upflow and downflow. Upflow saturators work best and are easier to maintain than the downflow type. Conversion kits are available and can convert some downflow saturator models to the upflow mode.

Upflow models have a submerged inlet, which requires an atmospheric vacuum breaker on the highest point on the fill line. Tables 8D-3 and 8D-4 tell how to prepare both upflow and downflow saturators for use. When properly set up, they automatically prepare a 4% saturated solution of sodium fluoride.

Hydrofluosilicic acid is sold in 13-gallon carboys, 55-gallon drums, or in bulk. Most water plants,pump acid directly out of a carboy or drum without dilution. The commercial purity varies from 22 to 30 percent and might require re-calibrating the feed rate setting between batches. Acid feed tanks should have tight fitting covers and be vented to the outside.

Table 8D-3
Preparing an upflow saturator

1. With the distributor tubes in place, and the floating suction device removed, add 200 to 300 pounds of sodium fluoride directly to the tank. Any type of sodium fluoride can be used, from coarse crystal to fine powder. Fine crystal will produce less dust than powder and will dissolve better than coarse material.
2. Connect the solenoid water valve to an electric outlet. Turn on the water supply. The water level should be slightly below the overflow. If it is not, adjust the liquid level switch.
3. Replace the intake float and connect it to the feeder intake line. The saturator is now ready for use.
4. Check the level of undissolved sodium fluoride, looking through the translucent wall of the saturator tank. Whenever the level is low enough, add another 100 pounds quantity of fluoride.
5. The water distributor slits are essentially self-cleaning. Insolubles and precipitates are less of a problem than in a downflow saturator. However, periodic cleaning is still required. How much it is used and how much debris accumulates dictates how often it needs cleaning.
6. Because upflow saturators have a thicker bed of sodium fluoride, higher withdrawal rates are possible. With 300 pounds of sodium fluoride in the saturator tank, more than 1000 ml/min of saturated solution can be fed, a rate sufficient to treat about 5000 gpm of water to a fluoride level of 1.0 ppm.
7. Precautions regarding hard water apply to both types of saturators.
8. The method for calculating the solution feed rate and the amount of fluoride fed is the same for both types of saturators The fixed water inlet rate of 4 gpm should register satisfactorily on a 1/2" meter.

Table 8D-4
Preparing a downflow saturator

1. With the manifold (W & T) or cone (BIF) in place, carefully place by hand a 2-3" layer of coarse, clean gravel (1-2" size) in the saturator tank, around the manifold or cone and over the manifold or over the lower edge of the cone. Then place another 2-3" layer of finer gravel (½-1" size) over the coarse gravel.
2. Place a 4-6" layer of clean, sharp filter sand over the gravel. (Do not use beach sand, clayey sand or soil.) Level the sand surface. (A 12" bed of ⅛" to ¼" filter gravel can be substituted for the sand and coarse gravel layers.)
3. Add 200 pounds of coarse crystalline sodium fluoride (Olin 20-60 mesh, Allied coarse crystal, or similar. Do not use powdered NaF or fine crystal.) Add water to keep down the dust and to assist in leveling the fluoride surface.
4. Check to see if the float has room to operate. If necessary, make a depression in the fluoride surface to provide clearance for the float and float-rod.
5. Connect a cold-water supply line with a valve to the water intake of the saturator. A ½" water meter on the water inlet line shows the amount of fluoride fed daily. The fluoride dosage can be calculated daily if the water main flow is metered. However, it is more important to know the concentration of fluoride in the water by actual determination with a test kit.
6. Turn on the water supply and adjust the float position if necessary. The low-water level should be no less than 2" above the fluoride surface, and the high-water-level should be just below the overflow outlet.
7. Insert the feeder suction line into the pipe leading to the inner cone or manifold. Adjust the length of suction line so that the foot-valve and strainer are 2-3" above the bottom of the saturator tank. The saturator is now ready for use.
8. Look through the translucent wall of the saturator tank at the layers of fluoride, sand and gravel. When the thickness of the fluoride layer decreases to 6", add another 100 pounds of fluoride. Add the fluoride when the water is at its lowest level

or, if necessary, shut off the water temporarily until there is enough room for the fluoride without making the water overflow.

9. If the saturator is being used at a high rate, that is, if more than 1000 gpm of water are being treated, add fluoride daily, enough to keep the fluoride layer at least 10" thick. Make the same daily additions of fluoride if the make-up water temperature is below 60° F, even if less than 1000 gpm of water is being treated.

10. Before adding more fluoride to the saturator, scrape the surface of the fluoride layer in the saturator. Get rid of accumulated dirt, insoluble material, or the slimy film of fine particles that sometimes forms. Such routine maintenance permits better percolation of water through the fluoride layer and extends the length of the time between clean-outs.

11. At regular intervals, depending on use, clean the saturator. A typical schedule calls for a clean-out every three months when 100 gpm of water is being treated and accumulation of dirt in the saturator is moderate. The clean-out procedure is as follows: **a)** Continue using the saturator until the level of sodium fluoride in as low as practical. Shut off the water supply to permit the level of water to drop down to the fluoride layer. This step wastes a minimum of chemical and decreases the amount of material which has to be removed; **b)** Scoop out the remaining sodium fluoride, the sand and gravel. If the sand and gravel are to be re-used, place them in separate buckets. If fresh sand and gravel are available, bury the dirty material in an approved landfill. The old sodium fluoride can be flushed down a drain; **c)** Remove the inner cone or manifold assembly and clean the inside of the saturator tank. Replace the cleaned cone or manifold; **d)** If the old sand and gravel are to be re-used, wash them repeatedly with water until all traces of fluoride and dirt are removed. Then reconstruct the filter bed or sand and gravel as before with either cleaned or fresh material; **e)** Add sodium fluoride as before and return the saturator to normal operation. (Don't forget to turn on the water supply again.)

12. If the water supplied to the saturator is hard (more than 75 ppm hardness), a household-type water softener in the line minimizes the insoluble material accumulating in the saturator and thus increases the time between clean-outs.

13. Calculate the proper feed rate as shown in Example 1 on page 8D-9 and adjust the machine to the proper setting. Fine adjustment of the feed rate is necessary after determining the actual fluoride concentration in the finished water.

14. Use the readings of the water meter on the saturator supply line to calculate the amount of fluoride fed.

15. Use the readings on the saturator meter and the master meter to calculate the fluoride dosage. A 4% NaF solution is equivalent to 18,000 mg/1 F:

$$\text{m g/l F} = \frac{\text{(gallons water supplied to saturator)}}{\text{(gallons pumped by well)}}$$

Dry Feed Equipment

A dry feeder (see Figures 8D-4 and 8D-5) meters a powdered chemical at a pre-determined rate. This method is good for sodium silicofluoride and for sodium fluoride.

Figure 8D-4
Belt-type gravimetric dry feeder

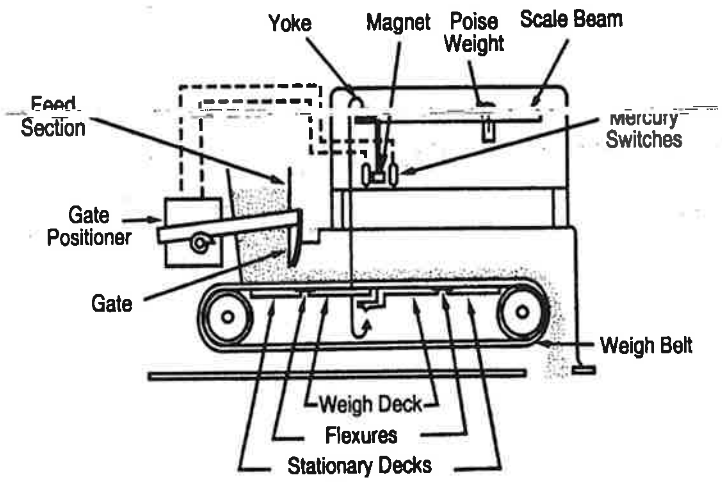
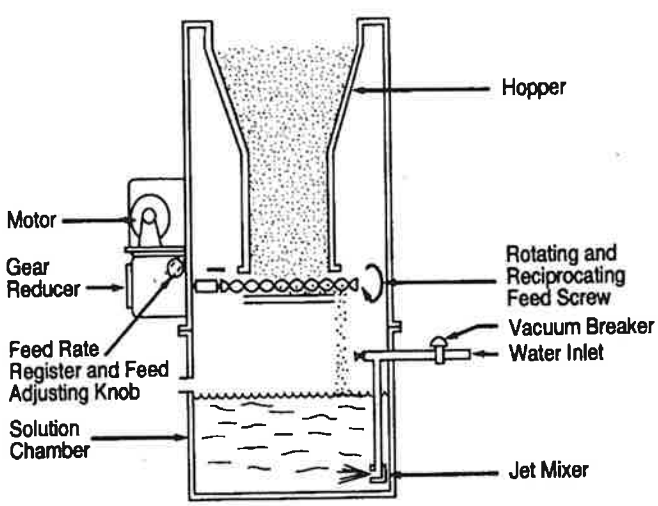


Figure 8-5
Screw-type volumetric dry feeder



Dry feed machines are of two types: gravimetric or volumetric. Gravimetric dry feeders deliver large quantities of chemical, are accurate and easily automated for variable flows. They cost more than volumetric machines.

Volumetric dry feeders are simpler, less costly, less accurate, and deliver smaller quantities than gravimetric machines. Volumetric feeders deliver a specific volume of material per unit of time. Gravimetric machines deliver a specific weight of material per unit of time. Variable density and chemical consistency have no effect on gravimetric machines. That's why they are more accurate.

The dry feeders deliver fluoride to a dissolving tank where it mixes with water. This solution or slurry flows by gravity to the clearwell or flume. An eductor can pump or pull the slurry into a water main.

Flooding the feeding mechanism with material that is too fine is one of the problems with dry-feed machines. Bridging of the material can form an arch which will collapse, creating a cloud of dust and flooding the feed mechanism. Moisture might cause lumps that interfere with the feed rate. To help eliminate quality problems, specify the *American Water Works Association Standards for Sodium Silicofluoride and Sodium Fluoride* when ordering.

Feeder location

Feeder location depends on the kind of water plant and the space available for installation. Fluoridation equipment requires:

- a dry, weatherproof space near the point of application
- storage space for chemicals
- water for mixing solution
- electricity to operate the pump
- proper ventilation

Fluoride application point

All the water must pass through the fluoride application point. Add fluoride either to finished water or with other chemicals in the treatment process. Add fluoride to the finished water whenever possible. The fluoride feed rate is easier to adjust when the flow rate remains relatively constant.

A well system with chlorination only must add fluoride after the well's check valve and before entering the storage tank. Water leaving a storage tank does not have a uniform flow.

A system with several scattered wells or plants must fluoridate at each point. If several wells pump to a central treatment plant, fluoridate the water at the plant.

In a conventional treatment plant consider type of treatment and other chemicals used when selecting an application point. More fluoride might be needed to reach 1 mg/l residual in the finished water in some cases. Treatments that lower fluoride levels:

- sedimentation and filtration
- lime-soda-ash softening when a high concentration of magnesium is present
- large amounts of alum
- chemicals that contain calcium (lime or calcium hypochlorite)

Fluoride sampling and records

The operator must check water samples daily for fluoride ion in solution and collect samples monthly for analysis in the state laboratory. Samples collected from selected points throughout the distribution system are representative of fluoride levels supplied to consumers. Keep the following records:

- daily and monthly test results
- any changes to the feeder system or distribution system
- problems and their solution
- gallons of water pumped
- amount of fluoride fed
- amount of water metered to the saturator, if applicable.

Standard Methods for the Examination of Water and Wastewater lists three analytical techniques to detect fluoride ion concentration:

- Alizarin visual (Scott-Sanchis)
- photometric (SPADNS)
- electrode methods

Commercial "test kits" simplify the analysis method and procedures. The SPADNS and electrode methods are the most widely used.

The SPADNS method uses a dye solution. Fluoride bleaches the dye in proportion to the amount of fluoride in the water. A photo-meter detects the difference in the unknown sample and a sample containing 1 mg/l. Accurate results depend on:

- calibrating the instrument with the standard sample set up under the same temperature and time conditions as the test samples
- measuring SPADNS solution carefully
- adding sodium arsenite solution to destroy any residual chlorine, which would bleach color and give false highs

The electrode method uses an ion electrode to detect the fluoride ion method. This is the procedure:

1. Add a buffer to the test sample to eliminate interference.
2. Calibrate the instrument using a 1 mg/1 fluoride.
3. Put the electrode in the water sample.
4. Read the concentration of fluoride present in the sample.

The machine reads the difference in electric potential and converts the difference to concentration of fluoride ions present.

Calculating fluoride feed fate

The strongest solution of sodium fluoride possible is 4%. About 17 pounds of sodium fluoride will dissolve in 50 gallons of water at 77° F. A 4% solution of sodium fluoride contains 40,000 mg/l of sodium fluoride or 18,095 mg/l of fluoride ion and 21,905 mg/l of sodium ion in solution.

Example problem 1: Calculate the feed rate for:

Water flow rate = 250 gpm
Sodium fluoride concentration = 4 percent
Fluoride concentration desired = 1.0 mg/l
Natural fluoride concentration = 0.3 mg/l
Solution metering pump with upflow saturator

Solve for feed rate in gallons per day (gpd).

Formula: $Q_1 \times C_1 \times 1440$ minutes/day $= Q_2 \times C_2$

Q_1 = water pump rate in gallons per minute (gpm)
C_1 = fluoride needed to reach fluoride content of 1.0 mg/l
Q_2 = solution feed rate in gallons per day (gpd)
C_2 = fluoride solution concentration in mg/l

Calculations: Since the water contains 0.30 mg/l fluoride naturally, the amount of fluoride which must be added is:

1.0 mg/l F (desired) - 0.3 mg/l F (natural) = 0.7 mg/l F (to be added)

250 gpm x 0.7 mg/l F x 1400 min/day = Q_2 x 18,095 mg/l F

$$\frac{\text{gal x mg/1 x min}}{\text{252,000 min. . . . . . day}} = Q_2 \times 18{,}095 \text{ mg/1 F}$$

$$\frac{\text{252,000 gallons/day}}{18{,}095} = Q_2$$

Q_2 = 13.9 gallons/day or about 14 gallons per day (gpd)

Thus, to add 0.7 mg/l to the natural F concentration of 0.3 mg/l, set the pump to deliver 14 gallons for every 24 hours of solution pump operation.

The solution pump and drive motor are set up to allow the solution pump to deliver the following maximum feed rates:

1st pulley--8 gallons/day
2nd pulley--15 gallons/day
3rd pulley--26 gallons/day
4th pulley--44 gallons/day

Since proper adjustment of most solution metering pumps is easiest in the middle of their feed range, the third pulley step would be a good selection.

Calculate the percent of stroke dial setting calculation is made in the following manner:

Percent of stroke =

$$\frac{\text{calculated feed rate setting (gpd)}}{\text{maximum feed rate setting at pulley step chosen(gpd)}} \times 100$$

$$= \frac{14\text{ gpd}}{26\text{ gpd}} \times 100$$
$$= 0.54 \times 100$$
$$= 54\%$$

Example 2: Hydrofluosilicic acid comes in solution form as a 22% to 30% strength acid. A pound of 25% solution contains 0.198 pounds of fluoride ion.

Water flow rate = 1000 gpm
Acid concentration = 25 percent
Fluoride concentration desired = 1.0 mg/1
Specific gravity = 1.22
Natural fluoride concentration = 0.0 mg/1
Fed with solution metering pump

What is the solution feed rate in gallons per day (gpd)?

Using the same pump noted in Example 1, what pulley setting should be used?

Where should the percent of stroke dial be set?

Calculations:
Flow (gpm) x mg/1 desired x 0.012 = pounds per day (ppd) of F to be fed

1000 gpm x 1.0 mg/1 x 0.012 = 12 ppd of F

Each gallon of solution weights 8.34lbs (H_2O) x 1.22 (specific gravity) = 10.18 lbs/gallon

Each gallon of solution contains 0.198 x 10.18 lbs/gallon = 2.02 lbs F

$$\frac{\text{12 pounds F/day}}{\text{2.02 pounds F/gallon solution}}$$
= 5.9 gallons/day of solution is required

The first or second pulley could be used. Using the first pulley, the percent of stroke setting would be:

$$\frac{5.9\text{ gpd}}{8\text{ gpd}} \times 100 = 74\%$$

Example 3: Sodium silicofluoride is 98% pure. It is only slightly soluble in water and is fed in dry form into a slurry or solution mixing tank.

Water flow rate = 1400 gpm
Na_2SiF_6 purity = 98%
Fluoride ion concentration = 60.7 percent (Na_2SiF_6)
Natural fluoride concentration = 0.0 mg/l
Fluoride concentration desired = 1.0 mg/l
Assume Na_2SiF_6 weighs 60 pounds per cubic foot

What is the desired feed rate in pounds per day and in cubic feet per hour?

1400 gpm x 1.0 mg/l x 0.012 = 16.8 pounds/day of F

Since Na_2SiF_6 is 60.7 percent F

$$\frac{16.8\text{ lb/day}}{0.607} = 27.8\text{ pounds/day}$$

or about 28 pounds/day of Na_2SiF_6

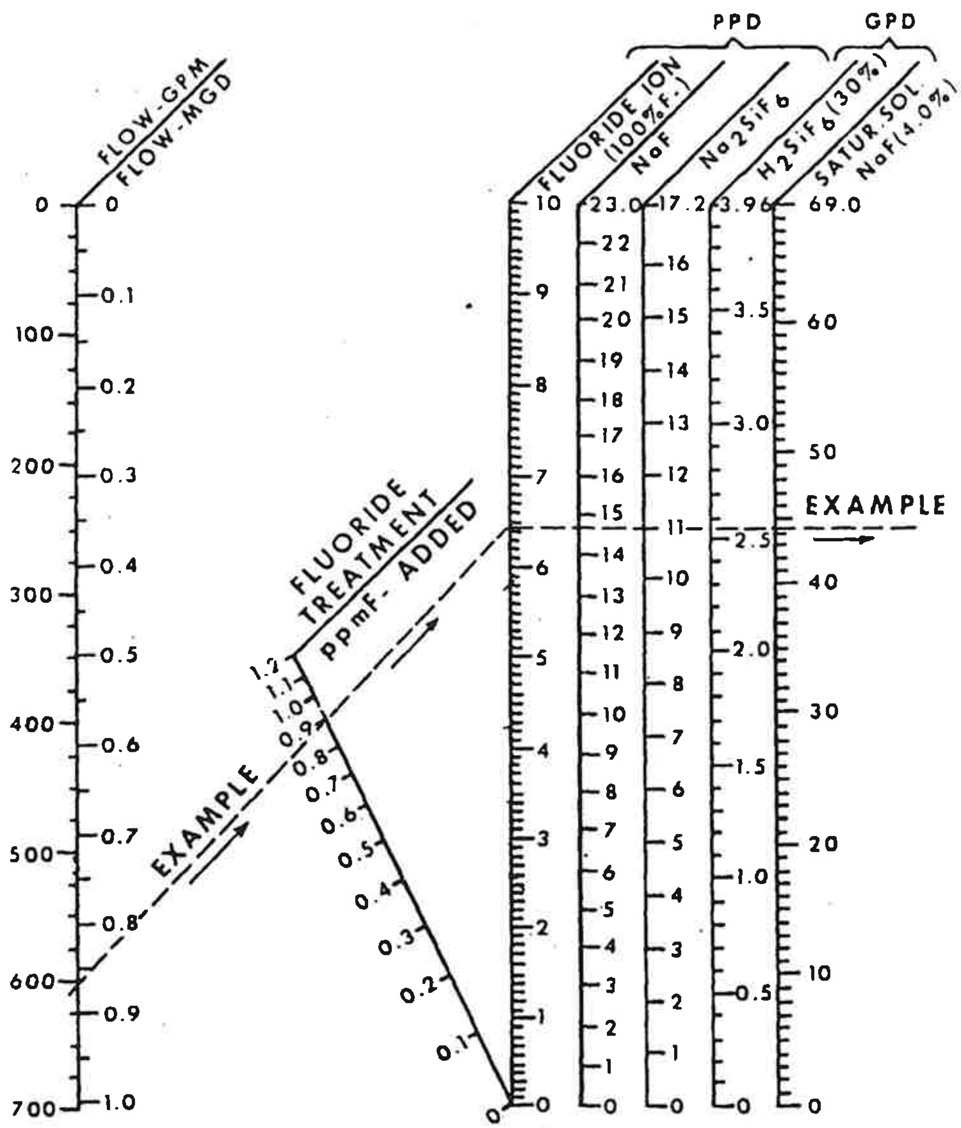
To convert to cubic feet per hour:

$$\frac{\text{28 lbs/day}}{\text{60 lbs/cu.ft. x 24 hr/day}} = 0.019\text{ cubic feet/hour}$$

Graphs and tables simplify the calculations. Figure 8D-6 and Table 8D-5 show some examples. Consult the references at the end of this section for additional information on fluoridation.

Figure 8D-6

Fluoridation nomograph



Instructions

1. Subtract the natural level from the desired level to get the fluoride treatment figure (ppm fluoride ion added).
2. Draw a line from the flow figure straight through the fluoride treatment figure to the fluoride ion line. The intersection shows the pounds of fluoride ion per day required.
3. To find this weight of fluoride ion from any of the chemicals listed: Starting at the pounds of fluoride ion per day required, draw a horizontal line to the right and read the weight of dry chemical or volume of liquid chemical required.
4. Thus in the example, a flow of 600 gpm requiring 0.9 ppm fluoride ion added requires 6.45 pounds of fluoride ion per day, available from 14.8 lb per day of sodium fluoride, 11.0 per day of sodium silicofluoride, 2.55 gal per day of 30% fluosilicic acid, or 44.2 gal per day of saturated sodium fluoride solution.

Table 8D-5
Fluoride calculation factors

Compound	Available F*	Commercial purity	lbs compound per million gal water to add 1.0 ppm F
Sodium fluoride	0.4525	95%	19.4
		96%	19.2
		97%	19.0
		98%	18.8
		99%	18.6
Sodium silico-fluoride	0.607	95%	14.5
		96%	14.3
		97%	14.1
		98%	14.0
		98.5%	13.9
		99%	13.8
Hydrofluo-silicic acid	0.792	20%	52.5
		21%	50.0
		22%	47.8
		23%	45.7
		24%	43.8
		25%	42.0
		26%	40.5
		27%	38.9
		28%	37.4
		29%	36.3
		30%	35.2

*lbs F per lb of 100% pure compound

Calculate amounts of fluoride compound to add for quantities of water more or less than one million gallons as follows:

- The amount of 97% sodium fluoride needed for 100,000 gallons: 100,000 ÷ 1,000,000 or 0.1 the amount indicated.
- For 2 million gallons, 1 million times 2.

To calculate amounts more or less than 1.0 ppm F, multiply figures in the right-hand column by the appropriate factor. For example:
With 0.3 ppm natural F in the water, and the optimum level is 0.8 ppm, add only 0.5 ppm, or 0.5 as much as indicated — 0.8 ppm level desired, minus 0.3 ppm natural fluoride = 0.5 ppm

Sample questions

1. Which of the agents listed is **not** used to disinfect?
   a. ultraviolet light
   b. bromine
   c. chlorine
   d. astadine

2. All the factors listed influence chlorine's effectiveness as a disinfectant, except one. Which one is wrong?
   a. low pH
   b. high temperature
   c. free chlorine residual
   d. ammonia

3. What chemical makes smoke when combined with chlorine gas?
   a. potassium permanganate
   b. hydrogen peroxide
   c. nitrogen
   d. ammonia

4. The sum of free residual and combined residual is called:
   a. total residual
   b. chlorine demand
   c. chlorine dosage
   d. chloramine

5. Calcium hypochlorite is more commonly known as:
   a. household bleach
   b. HTH
   c. chloramines
   d. fluoride

6. Adding chlorine to water will **not**:
   a. provide disinfection
   b. control iron and sulfur bacteria
   c. control growth of algae
   d. remove suspended solids

7. What is the strength of a saturated solution of sodium fluoride?
   a. 4%
   b. 10%
   c. .004%
   d. 15%

8. What is the proper concentration of fluoride in drinking water?
   a. 0.8 to 1.0 mg/l
   b. 4%
   c. 1%
   d. 2 cc per liter

9. Phosphates added to water will:
   a. remove iron and manganese
   b. sequester organic color
   c. oxidize taste- and odor-causing chemicals
   d. sequester iron and manganese

10. Which of the following is not corrosive when mixed with water?
    a. calcium hypochlorite
    b. sodium hypochlorite
    c. hydrofluosilic acid
    d. hexametaphosphate

Chapter 8B&C

Water treatment

Introduction

Most of the information in this section applies to Class B and C water treatment. Some material might overlap with information covered in Class A and D treatment. Class B and C plant operators must know the information in the previous section for Class D operators, as well as this section. Specific information referring to surface water treatment and water softening are covered in the Class A water treatment section.

This section contains detailed information on:

Coagulation and flocculation
Sedimentation
Basins
Filtration
Combined unit processes

Unit processes

Use individual or unit processes such as aeration, rapid mixing, sedimentation, and filtration individually or in combination. Experienced personnel should make the decision as to which combination will produce an acceptable water quality at the most economical price.

Disinfection - see class D section

Aeration

Aeration mixes air into water. Aeration of water:

- removes troublesome gases
- oxidizes impurities such as iron and manganese
- reduces certain types of tastes and odors
- introduces oxygen into the water

The components in water affected by aeration:

- carbon dioxide
- hydrogen sulfide
- methane
- iron
- manganese
- various chemicals causing tastes and odors
- dissolved oxygen

Aeration effectively removes carbon dioxide gas. Carbon dioxide (CO_2) is a gas found in many water supplies in Mississippi. Surface water sources are usually low in carbon dioxide, in the range of 0 to 5 mg/l.

Ground waters are relatively high in carbon dioxide. Carbon dioxide content in deep well water usually is under 50 mg/l. Shallow well waters typically contain 50 to 300 mg/l carbon dioxide.

Effects of carbon dioxide:

- makes the water corrosive
- tends to keep iron in solution making it difficult to remove
- reacts with added lime to elevate the pH
- increases chemical costs

Hydrogen sulfide gas (H_2S) is not harmful to humans at the levels in ground water. However, if the gas gathers in a closed space when water is aerated, concentrations could become fatal. Hydrogen sulfide could kill in 30 minutes at concentrations of 0.1 percent gas to air.

Hydrogen sulfide has a rotten-egg smell. It is corrosive to piping, tanks, water heaters, and metal alloys. Since hydrogen sulfide is unstable in water, aeration easily removes it. Provide adequate ventilation around the aerator.

Two serious problems caused by hydrogen sulfide:

1. Chlorine reacts with hydrogen sulfide. Therefore, more chlorine is required to get to the desired residual in the water. This increases the cost of chlorination.
2. Hydrogen sulfide corrodes metal and concrete surfaces in the treatment plant, distribution system and storage tanks.

Ground water drawn from aquifers near natural gas deposits could contain methane. Common names for methane are "swamp gas" or natural gas. Methane is a tasteless, odorless, colorless gas that is highly flammable. Since the gas is only slightly soluble in water, aeration easily removes it.

Iron and manganese are two minerals often present in ground water. Surface water is generally low in iron and manganese. The iron and manganese in ground water are dissolved from mineral deposits within the earth. Water containing more than 0.3 mg/l of iron stains fixtures and clothing a yellowish brown color. At concentrations of 1 mg/l or more, iron gives the water an unpleasant metallic taste. Manganese concentrations above a 0.05 mg/l could produce black stains.

The most common method to remove iron and manganese is aeration, followed by filtration. Aeration puts oxygen into the water. This oxidizes the iron and manganese to the insoluble state. Thirty minutes of detention time is recommended to complete oxidation of the compounds. Then filter to remove the insoluble iron and manganese precipitates.

Aeration often removes tastes and odors, depending on the cause. Aeration easily removes volatile compounds such as methane and hydrogen. Many taste- and odor-producing compounds originate from by-products of algae growth. Since these by-products are usually much less volatile than the gases, aeration removes only some of them.

Aeration can either add or remove dissolved oxygen (DO), depending on the water temperature and how much oxygen was in the water. The colder the water, the more oxygen that will dissolve.

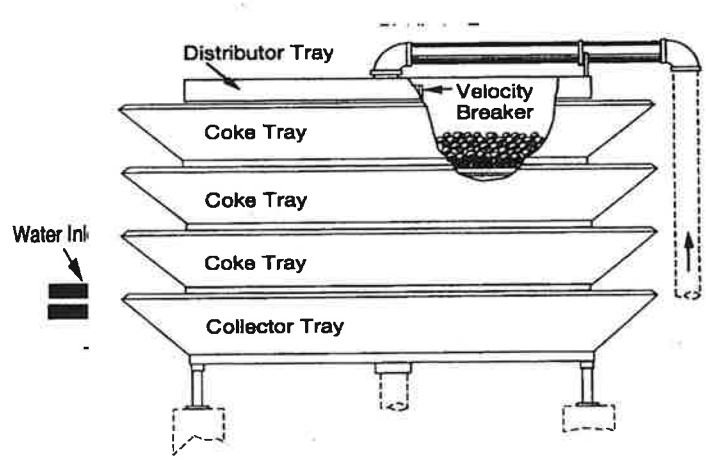
Dissolved oxygen can cause serious problems, such as corrosion and air binding of filters. Algae give off oxygen when exposed to sunlight. Surface waters that support large growths of algae often have high concentrations of DO. When super-saturated waters are aerated, oxygen levels actually decrease. This can be a critical step in the treatment of surface water.

Factors to compare when considering aeration: cost of the equipment, operation, and maintenance vs cost of chemicals required to achieve the same finished water quality.

Gravity aerators and mechanical draft aerators are the aeration equipment most small water plants use. Both types are effective in softening, controlling corrosion, and removing iron. Efficiency depends on the raw water quality, operation, and maintenance of the equipment.

Figure 8B&C-1 and Figure 8B&C-2 illustrate two common gravity aerators.

Figure 8B&C-1
Slat and coke tray aerator
Figure 8B&C-2



Schematic of a cone aerator

The gravity aerator uses trays filled with coke or other media. Water flows over the media. Turbulence exposes the water to the surrounding air. The air oxidizes iron and manganese and removes unwanted gases. Iron and manganese oxides coat the media, which then catalyzes iron and manganese oxidation.

Mechanical draft aerators are similar to gravity aerators except they are completely sealed. Air blows into the unit in a direction opposite to the flow of water.

Slat trays without any media are best when water contains lots of iron and manganese. In this case, mechanical draft aerators are completely closed units. Since they aren't easily cleaned, they would become plugged.

Loading rates range from 10 to 30 gallons per minute per square foot (gpm/ft^2). The aerators generally contain from three to 15 trays with vertical spacings of 12 to 30 inches.

Inspect either type of aerator at least once a year. When treating waters with a high iron content, the holes in the distributor tray might clog and the media bridge over. Check regularly and rake the media or clean as necessary to prevent bridging. Proper maintenance greatly improves efficiency.

Coagulation/flocculation

The coagulation/flocculation process helps remove solids that won't settle and particles so small that sedimentation and filtration alone can't remove them. During coagulation chemicals are fed into the water to begin formation of floc. Floc particles are a combination of the coagulant and the particles in the water.

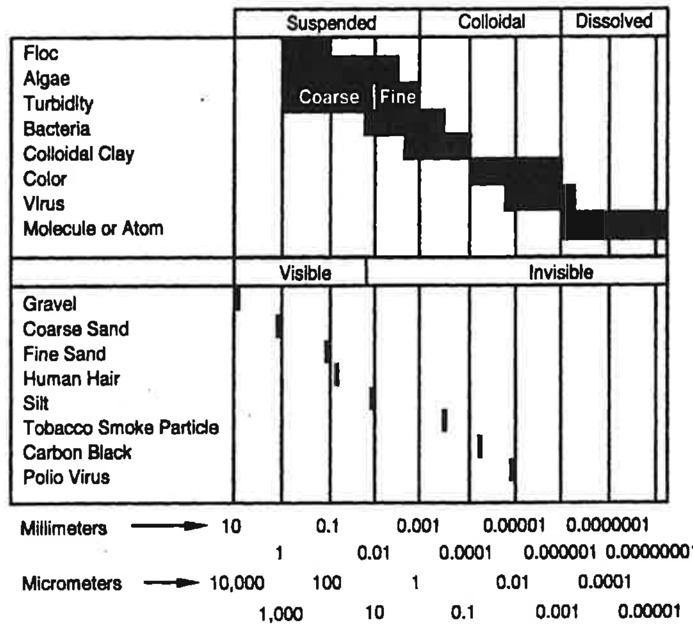
Coagulation and flocculation are processes that overlap. Coagulation is the rapid mixing of coagulant chemicals with the water to form floc particles. Flocculation involves gentle mixing of these floc particles, making them larger and heavier. The objective is to transform small particles that won't settle into larger ones that will settle. Floc particles are much easier to remove in the subsequent processes of sedimentation and filtration.

Small particles resist settling for two basic reasons:

- particle size
- natural forces between particles

Figure 8B&C-3 shows various types of particles in each of the three categories.

Figure 8B&C-3
Size range of solids



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Natural, untreated water contains three basic types of solids that resist settling. The particles are classified by size , from largest to smallest:

- suspended
- colloidal
- dissolved solids

Suspended solids are particles held in suspension by the natural action of flowing water. The smallest suspended solids — less than 0.1 mm — do not settle readily and are therefore called nonsettleable. Larger suspended solids (greater than 0.01 mm) are settleable solids since they settle unaided to the bottom of a container within four hours.

Colloids includes particles such as fine silts, bacteria, color-causing particles, and viruses. Individual colloid particles cannot be seen but show up as color or turbidity in water.

Dissolved solids are any organic or inorganic matter dissolved in water, such as salts, chemicals, or gases. A dissolved solid is invisible, about the size of a molecule. Most trace minerals and organic chemicals found in water are dissolved. Removing dissolved solids requires the coagulation/flocculation process.

One of the main reasons that particles resist settling is their small size. A drag force acts on particles which resist settling. When the drag force is approximately equal to the force of gravity on the particle, the particle cannot settle.

Another factor is natural forces on the particles. Most particles in water carry a negative electrical charge. Particles with like charges repel each other. This natural repelling force is the zeta potential of the particle. The force is strong enough to hold tiny colloidal particles apart and keep them in suspension.

Another force in nature is the Van der Waals force, which tends to pull particles together. This force acts opposite of the zeta potential. As long as the zeta potential is greater than the Van der Waals force the particles stay in suspension.

The coagulation/flocculation process neutralizes or reduces the zeta potential. This allows the Van der Waals force to pull the particles together and form micro-floc.

During flocculation, gentle mixing brings the micro-floc particles into contact with one another. Micro-floc forms larger floc particles which settle out. The fully developed floc is usually visible and looks like small tufts of cotton.

Most particles in drinking water are negatively charged. For this reason most coagulants carry a positive charge. The positive charges neutralize the negative charges and allow the particles to come together.

Coagulant chemicals are classified by the charge associated with each:

- monovalent
- bivalent
- trivalent

Monovalent coagulants contain ions that have only one positive charge when added to water. A compound containing sodium (Na^{+1}) is an example. Bivalent coagulants have ions with two positive charges, such as compounds with calcium (Ca^{+2}). Trivalent coagulants are those containing ions with three positive charges, e.g., aluminum (Al^{+3}) and iron (Fe^{+3}).

Coagulants with more positive charges are more effective at neutralizing negatively charged particles. For example, trivalent compounds are 700 to 1000 times more effective as coagulants than monovalent compounds.

The most commonly used coagulants in water treatment are aluminum sulfate, $Al_2(SO_4)_3$ and ferric sulfate, $Fe(SO_4)_3$. When either of these compounds is dissolved in water it forms trivalent ions. Table 8B&C-1 lists five of the most common coagulants, along with typical dosage ranges. Table 8B&C-2 summarizes some of the combinations of chemicals used in coagulation.

Table 8B&C-1
Common coagulants and doses

Coagulant	Chemical formula	Typical dose range mg/l
Aluminum sulfate	$Al_2(SO_4)_3$	15-100
Copper sulfate	$CuSO_4$	5-20
Ferric sulfate	$Fe_2(SO_4)_3$	10-50
Ferrous sulfate	$FeSO_4$	5-25
Sodium aluminate	$NaAlO_2$	5-50

Table 8B&C-2
Coagulants in combination

Coagulants	Typical dose ratio of first:second
Aluminum sulfate + caustic soda	3:1
Aluminum sulfate + hydrated lime	3:1
Aluminum sulfate + sodium aluminate	4:3
Aluminum sulfate + sodium carbonate	1:1 to 2:1
Copper sulfate + hydrated lime	3:1
Ferric sulfate + hydrated lime	5:2
Ferrous sulfate + hydrated lime	4:1
Ferrous sulfate + chlorine	8:1
Sodium aluminate + ferric chloride	1:1

Alum is the most common coagulant. This compound promotes settling of the smallest particles as follows:

1) When added to raw water, alum reacts with alkalinity to form jelly-like floc particles of aluminum hydroxide, $Al(OH)_3$. A certain amount of alkalinity is necessary for the reaction. Some waters are naturally alkaline; to some lime or soda ash is added in increase alkalinity.

2) The positively charged trivalent aluminum ion neutralizes the negatively charged particles. The reaction occurs within one or two seconds after the chemical is added to the water. That's why rapid mixing is critical to good coagulation.
3) The particles begin to come together to form larger particles
4) The smallest micro-floc still maintains a positive charge from the added coagulant. The micro-floc continues to neutralize negative particles and eventually becomes neutral.
5) Finally, the micro-floc particles begin to stick together to form larger floc particles that settle. This is flocculation.

Sedimentation

Sedimentation removes settleable solids such as sand, grit, organic compounds, chemical precipitates, pollutants, and floc. Sedimentation decreases the load on filtration and other treatment processes. Ideally, turbidity in the settling basin effluent should not exceed 10 NTU.

Water flows slowly in sedimentation basins, which allows suspended solids to settle to the bottom. Sedimentation comes after chemical precipitation and coagulation/flocculation and before filtration.

Plain sedimentation reduces heavy sediment load by gravity alone. Sedimentation following chemical addition removes solids that have become larger and heavier due to chemical treatment.

Two variations of the conventional sedimentation process are:

- shallow-depth sedimentation (tube settling)
- solids contact process

Sedimentation or settling basins can be rectangular, square, or circular. The most common types are the rectangular tank and the circular basin with center feed. In the rectangular basin the flow of the water is parallel to the basin's length, see Figure 8B&C-4. In circular basins, the water flows radially from the center of the basin outward to the edges, see Figure 8B&C-4. Most basins are steel or concrete and slope to allow sludge removal.

In all sedimentation basins, four distinct zones exist. Each has separate functions, as Figure8B&C-5 shows:

Figure 8B&C-4
Flow patterns in sedimentation basins
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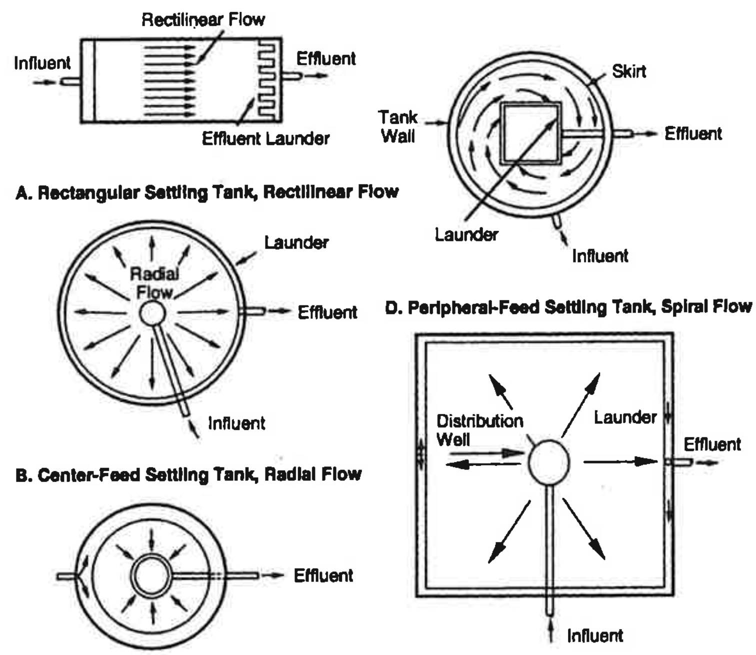
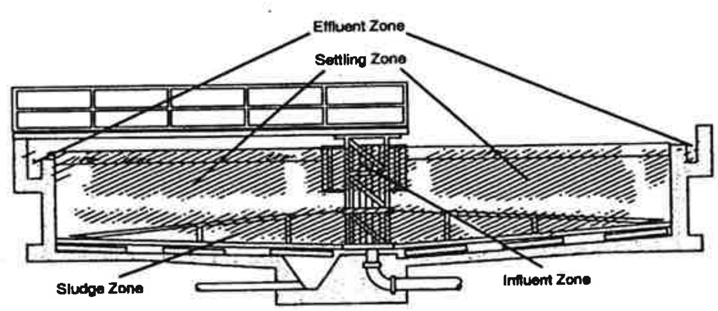


1. Inlet-zone: slows the velocity of the incoming water and distributes the flow evenly across the basin.
2. Settling zone: provides a calm area where suspended matter can settle.
3. Outlet zone: provides a smooth transition from the settling zone to the effluent flow area. This zone prevents turbulence that would stir up settled solids and carry them into the effluent.
4. Sludge zone: receives the settled solids and keeps them separate from other particles in the settling zone.

Figure 8B&C-5
Zones in a sedimentation basin



The design of settling basins varies. Figures 8B&C-6 and 7 show typical rectangular and circular basins.

Figure 8B&C-6
Typical rectangular sedimentation basin

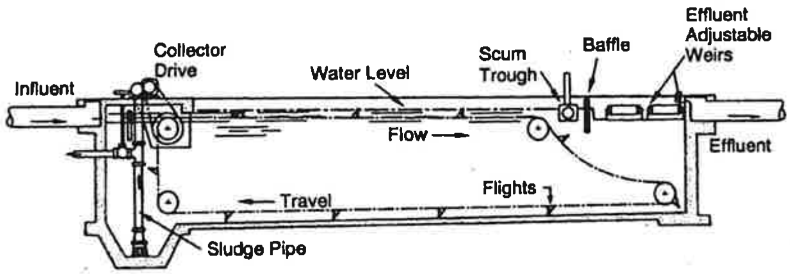
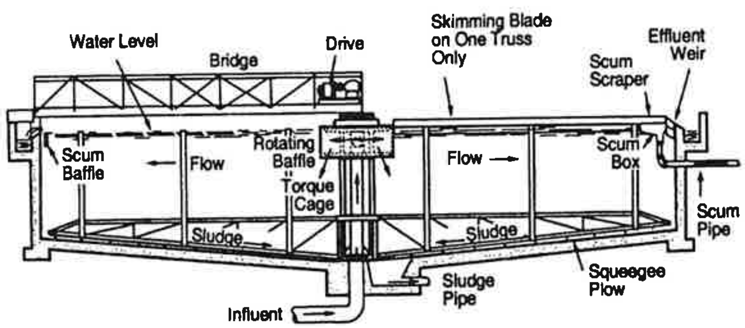


Figure 8B&C-7
Typical circular sedimentation basin



The inlet distributes the water evenly across the basin so the flow is uniform. A baffle installed downstream reduces the velocity of the water, allowing settling. The effluent launder collects the settled water, which effluent piping carries to the next process. An overflow weir evenly distributes the water going into the effluent launder.

A sludge layer develops as solids settle. This reduces efficiency. Manual removal, draining the basin and flushing out the sludge, is good for small installations or small build-ups. The operator washes or scrapes sludge into a sludge hopper and then discharges it to sludge treatment facilities. Continuous removal equipment is appropriate for larger plants.

Equipment such as tube settlers allow solids to settle out in a smaller, shallower basin. This saves on construction costs and allows shorter detention times. A typical unit contains approximately 750 tubes about two feet long, see in Figure 8B&C-8.

The tubes incline about 60 degrees causing a counter-current flow. As the water flows up through the tubes, the solids move downward. Tube settlers require continuous mechanical sludge removal because

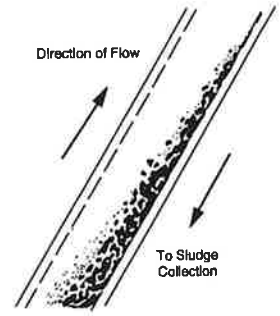


Figure 8B&C-8

better settling produces more sludge.

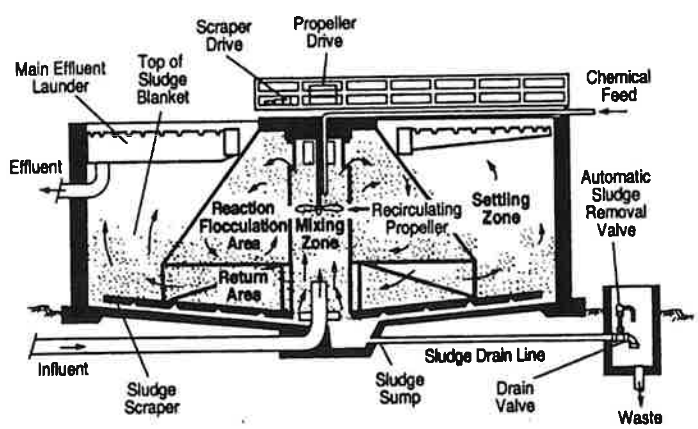
Solids contact basins, also called upflow clarifiers, are used primarily to soften water using the lime-soda ash process. These basins also remove organic color, iron, manganese, and turbidity. Baffles divide the basins into two distinct zones: mixing and settling, see Figure 8B&C-9, below.

In the mixing zone the raw water and coagulant chemicals mix together rapidly, initiating coagulation. The mixture then flows to the reaction/flocculation area where the mixture agitates slowly causing flocculation.

At the bottom of the basin the water travels around a baffle and upward into the settling zone. Here the water velocity begins to decrease. This is due to the larger area open to flow. As the settling velocity of the particles becomes greater than the water velocity, the particles begin to settle.

Figure 8B&C-9
Sludge-blanket clarifier

The point where the settling velocity and the water



velocity are equal defines the top of the sludge blanket. The water essentially filters through this blanket as new floc particles become trapped.

The water clarifies as it continues to travel upward and collects in the effluent troughs. The floc particles in the sludge blanket grow larger until they settle to the bottom. A portion of the sludge is recycled to the mixing zone. The rest settles into a concentration area for periodic removal.

The surface and weir overflow rates are critical to proper design and operation of sedimentation basins. The surface overflow rate is equal to the flow rate through the basin divided by the basin's surface area. The desired rate depends on the settling velocity of the floc particles. The lighter the floc particles, the smaller the overflow rate needed for proper settling. A typical overflow rate for floc produced with alum is 500 gpd/sq ft. Solids contact units used for turbidity removal need an overflow rate of about 1 gpm/sq ft.

The weir overflow rate is the flow rate through the basin divided by the length of the weir being used. Ideally the rate won't exceed 20,000 gpd/ft. An even lower rate works better for removing light alum floc from the basin.

Why should an operator concern himself with the surface and weir overflow rates when he can't control the flow rate and size of the basin? Through experimentation he may be able to learn the optimum rates for his facility. If the rates are less than optimum, he knows that he must make adjustments elsewhere to compensate for the poorer quality effluent.

Detention time is important to proper settling basin size. Detention time is the basin volume divided by the flow rate. Conventional basins typically have detention times in the range of two to six hours. However, this is a theoretical value; the actual detention time is often different. The difference between the actual and theoretical values is usually due to short circuiting. Table 8B&C-3 lists the basic criteria for proper design of a settling basin.

Table 8B&C-3
Design criteria for conventional sedimentation units

Detention time - Detention shall provide a minimum of four hours of settling time. This may be reduced to two hours for lime-soda softening facilities treating only groundwater.
Inlet devices - Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports and similar entrance arrangements are required. A baffle should be constructed across the basin close to the inlet and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows across the basin.
Outlet devices - Outlet devices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in flow.
Overflow rate - The rate of flow over the outlet weir shall not exceed 20,000 gallons per day per foot of weir length. Where submerged orifices are used as an alternate for over-flow weirs, they should not be lower than three feet below the flow line with flow rates equivalent to weir loading.
Velocity - The velocity through settling basins shall not exceed 0.5 feet per minute. The basins must be designed to minimize short-circuiting. Baffles must be provided as necessary.
Overflow - An overflow weir (or pipe) should be installed which will establish the maximum water level desired on top of the filters. It shall discharge with a free fall at a location where the discharge will be noted.
Superstructure - A superstructure over the sedimentation basins may be required. If there is no mechanical equipment in the basins and if provisions are included for adequate monitoring under all expected weather conditions, a cover may be provided in lieu of a superstructure
Sludge collection - Mechanical sludge collection equipment should be provided.

Drainage - Basins must be provided with a means for dewatering. Basin bottoms should slope toward the drain not less than one foot in 12 feet where mechanical sludge collection equipment is not required.

Flushing lines - Flushing lines or hydrants shall be provided and must be equipped with backflow prevention devices acceptable to the reviewing authority.

Safety - Permanent ladders or handholds should be provided on the inside walls of basins above the water level. Guard rails should be included.

Sludge disposal - Facilities are required by the reviewing authority for disposal of sludge. Provisions shall be made for the operator to observe or sample sludge being withdrawn from the unit.

Filtration

Filtration is the final process before consumers get their water. Filtration separates suspended and colloidal matter from water. The water flows through porous material, usually a bed of sand or some granular media. The flowing water deposits solids on the media or traps them between the grains of the media. Physical and chemical mechanisms in the filter bed trap matter smaller than the openings between sand grains.

Filters vary in hydraulic design and operation speed. The amount of water, in gallons per minute, delivered per square foot of filter surface area determines operation speed. Kinds of filters, classified by direction of water flow or media type are as follows:

- upflow
- downflow
- biflow
- fine-to-coarse
- coarse-to-fine

Filters use sand, anthracite coal, dual media, multimedia, or mixed media. Rapid sand filters are either gravity or pressure filters. Most water treatment plants in Mississippi that filter water use downflow rapid sand filters. The trend has been toward dual media, sand and anthracite coal. Two kinds of filters commonly used are illustrated in Figures 8B&C-10 and 11.

Figure 8B&C-10
Rapid sand filter with ceramic tile underdrains

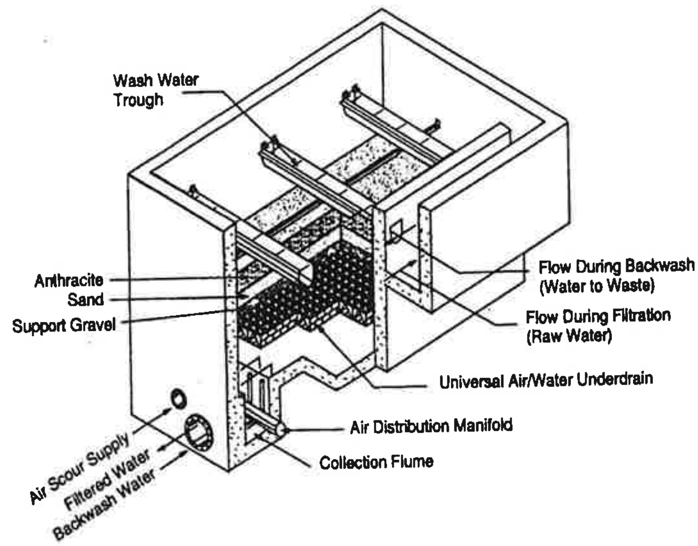
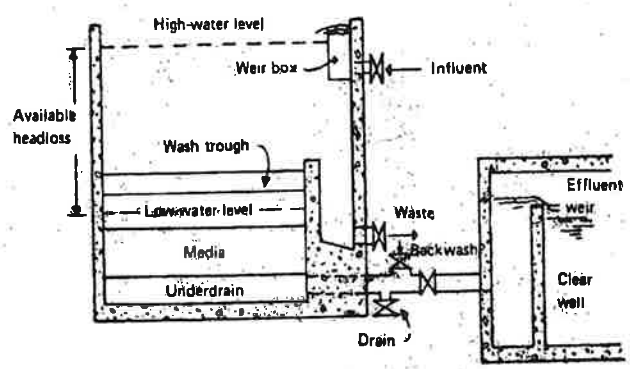


Figure 8B&C-11
Diagram of a conventional rapid sand system



Gravity rapid sand filters operate by gravity. In gravity filters backwashing follows downflow filtration to clean the filter. Most such filters are built of concrete. Small water plants might save construction costs with prefabricated filters. Almost all plants use rapid sand filters, which are the industry standard. Figures 8B&C-11, 12 and 13 illustrate the component parts of a gravity rapid sand filter.

Figure 8B&C-12
Filter tank construction

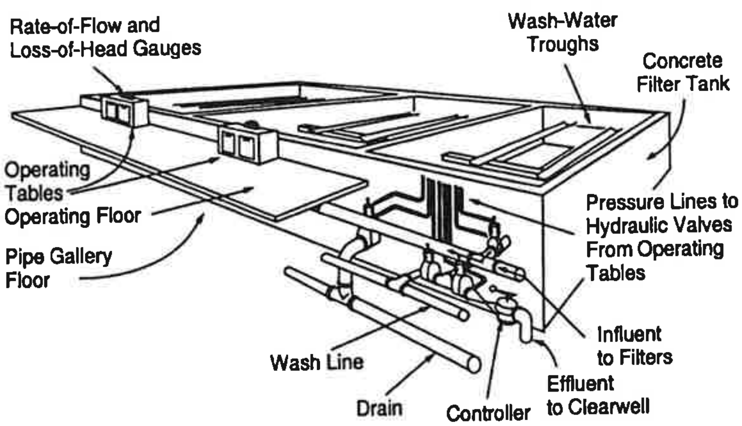
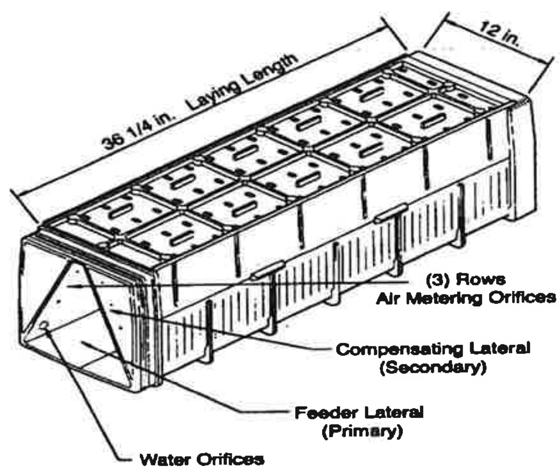


Figure 8B&C-13
Section of a perforated underdrain block



Gravity and pressure filters use various types of media. Pressure filters are similar to gravity filters except that the filter apparatus is enclosed in a steel shell, see Figure 8B&C-14, right.

Smaller plants use pressure filters to remove precipitated material in softened ground waters and precipitated iron and manganese from ground waters. Pressure filters receive water from a pump and operate at pressures significantly higher than those imposed on gravity filters. Higher operating pressures allow water to discharge from the filter directly into the distribution system, thus eliminating repumping the water. Pressure filters require less space and have lower initial costs than gravity filters.

Disadvantages of pressure filters include hidden loss of media during backwash and other filtration processes. Pressure filters could lose performance efficiency if the downstream pressure drops, and the efficiency loss might go undetected.

Choosing types of materials for filter media depends on:

- hydraulic properties
- filtration characteristics
- hardness
- durability
- purity
- low solubility

The operator should select filter media based on effective size and uniformity coefficient. The effective size is the sieve opening passing 10 percent of the media weight. The uniformity coefficient is the ratio of the sieve sizes that will pass 60 percent and 10 percent of the sample, respectively.

Torpedo sand or gravel placed on top of the filter underdrains or around perforated laterals supports filter media. The gravel bed keeps filter sand out of the underdrains and distributes wash water uniformly during backwashing.

Figure 8B&C-14
Schematic details of a vertical pressure filter

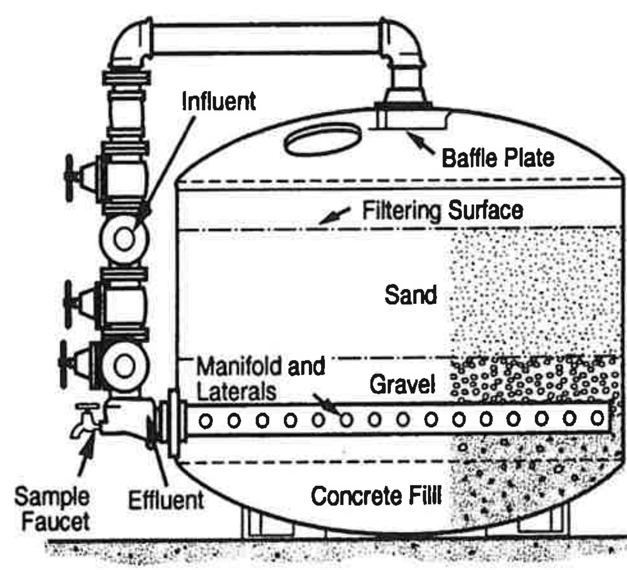


Table 8B&C-4 shows recommended specifications for filter media.

Table 8B&C-4
Typical specifications for coal and sand filter media

Media	Effective size (mm)	Uniformity coefficient	Depth (mm)
Sand	0.45 - 0.55	1.65	762*
Anthracite**	0.45 - 1.2	1.85	457
Torpedo sand	0.8 - 2.0	1.7	76
Gravel	38.1 - 55.88		127 - 203
	38.1 - 19.05		76 - 127
	19.05 - 12.7		76 - 127
	12.7 - 4.76		51 - 76
	4.76 - 2.38		51 - 76

* Single Media Filter (203 mm for dual media)
** Dual Media Filter

More water plants are using anthracite coal as a filter medium. Anthracite for filters is supplied by various manufacturers, some of which have patented or proprietary processes. A layer of anthracite coal over the top of sand is called a dual media filter. It permits increased filtration rates, longer filter runs, and less water for backwashing.

Filter operation improves as the effective depth of the medium increases. In a standard rapid sand filter, the effective depth is only a few inches deep. Filter sand hydraulically classifies itself during backwashing from fine grains at the top to coarse grains at the bottom of the filter. Particles passing through the fine sand at the top of the filter might pass through the entire filter bed. A coarse medium, such as anthracite, on top of the filter sand traps the large particles in the coarse medium and the smaller particles in the fine medium.

Plants designed for iron and/or manganese removal sometimes use manganese greensand media. A naturally occurring glauconite mineral, manganese greensand is specially processed to give it a harder and longer lasting surface. It acts as a zeolite or ion-exchange agent, removing soluble iron and manganese until the zeolite exchange sites are depleted. Manganese greensand is regenerated using potassium permanganate.

Filter media has a limited life expectancy. Media life depends on the raw water quality and treatment preceding filtration.

Media that has been in service too long can deteriorate the quality of finished water. The operator should check at least once a year and replace as necessary. Some experts suggest replacing media every four to six years.

To check media, put a sample under a microscope. The sand might appear to be scaly or gritty. Filter sand, which is angular when new, appears rounded or discolored when used too long. To find out if the sand is coated with calcium carbonate, apply hydrochloric acid and watch for a "smoking" effect.

The manufacturer, project engineer, Mississippi State Department of Health, or operator with experience in evaluating filter media can provide assistance in evaluating the condition of filter media. Inspect, repair, or replace filter underdrains when the media is replaced. Before putting the filter back into service, backwash, disinfect, and check for contamination.

The purpose of filter underdrains is to:

- support the filter media and gravel
- collect the filtered water
- uniformly distribute backwash water beneath the filter sand and gravel bed

Types of underdrains include perforated laterals, ceramic tile false bottoms, and perforated stainless steel plates. Figures 8B&C-10, 11 and 13 illustrate the first two types. The flow during backwash could be as much as three to seven times greater than during filtration. Flow governs the hydraulic design of the underdrain system.

Underdrains fall into two general classifications, conventional and gravel-less type. Conventional underdrain systems use supporting beds of gravel, typically 15 to 24 inches deep. A gravel-less system uses either stainless steel or plastic strainers with slots sized to retain the media.

Successful operation depends on flow uniformity through the underdrain system during filtration and backwash. Coagulated material could break through at the point of high velocities.

High velocities during backwash can create "boils." A boil occurs during excessive upflow velocity, which causes gravel displacement. Sand could enter the underdrains during filtration. Sand in the underdrains reduces the carrying capacity of the effluent piping and damage valves, fittings, and pumps.

Excessive backwash rates might cause filter media to wash into the underdrains. Excessive backwash rates also could cause structural failures in false bottom underdrains. Careful observation of the filters during filtration and backwashing helps to locate potential filter problems before they damage finished water quality.

The effluent piping generally includes a rate-of-flow controller, water seal in the filtered water flume, valves, fittings, and pipe, see Figure 8B&C-12. Flow controllers maintain a constant flow of water through the filters. This provides efficient operation and maximum removal of suspended particles and bacteria. A flow controller is:

- a flow measuring device
- a throttling valve on the filter effluent line
- a method for adjusting the valve to the desired flow

As filter sand becomes clogged, the flow controller opens the valve to permit the proper flow rate. The controller works in reverse to throttle the flow when it exceeds the pre-determined filter loading rate. Flow controllers also compensate for losses from filter clogging, see Figure 4-7.

Filter loading rates fall within a range of one to six gallons per minute per square foot of filter surface area. Design of conventional filters permit rates 50 percent higher than the rated capacity. Typically, single media filters operate at a loading rate of two gallons per minute per square foot. Dual media filters typically operate at three gallons per minute per square foot. These are typical rates. Actual rates will vary.

Multi-media filters might permit higher filtration rates. Increasing the filtration rate permits the use of smaller filters and reduces the construction cost. Before using higher filtration rates, first determine if the filter will perform satisfactorily. An effluent valve that can take the filter out of service is important. Some plants use the flow control valve to shut off the effluent. However, this could cause problems if the flow control valve requires maintenance.

The filter effluent pipe should have an air-tight water seal in the filtered water flume or the finished water reservoir. Keeping air out of the effluent piping and filter underdrain system prevents air from binding the filter. Backwashing can remove air trapped in a filter.

Backwash water applied gently slowly expels the air and avoids the loss of sand. Refilling the filter slowly avoids entrapping air again. Installing an air-release valve at the end of the washwater line and at high points in the line prevents air from reaching the filter.

Negative pressures or a vacuum created by excessive head loss can cause air binding. Dissolved gases released in the filter is another cause.

To correct air binding due to excessive head loss, backwash the filters before the head loss reaches 10 feet. To reduce dissolved gases in the water, add an aeration unit or modify an existing aeration unit. The procedure for removing trapped gas is the same as for removing air described above.

Backwashing filters removes the sediments that accumulate in the media. It's time to backwash when the head loss through the filter equals or exceeds a pre-set value or when the effluent is no longer suitable. Proper backwashing typically produces a finished water acceptable to the customers.

The proper time to backwash gravity filters is when the head loss through the filter reaches seven to 10 feet, see Figure 8B&C-12. Pressure filters might operate at higher head losses than gravity filters.

Backwash rates for rapid sand and dual media filters typically range from 15 to 20 and 10 to 15 gallons per minute per square foot of filter area, respectively.

The operator should backwash from three to 20 minutes or until the backwash water is clear. The duration of backwash depends upon:

- media
- underdrains
- raw water quality
- use of combined air-water
- pretreatment of raw water

A water level rise of 12 inches per minute is equal to a backwash rate of 7.5 gallons per minute per square foot of filter surface area. Percent of bed expansion means adjusting the flow rate during backwash to increase the depth of the filter by one-half for each 50 percent expansion. Typical values for bed expansion range from 20 to 50 percent. Table 8B&C-5 gives a generalized filter washing procedure.

A backwash pump discharges backwash water from the clear well upward through the filter. Sometimes pressure filters use filtered water from other operations, or water might come from a clear well using a backwash pump. At some plants, filters are backwashed with water from an elevated tank. Plants using pumps for backwashing must provide a non-slam check valve or a pump control valve to prevent surges from the pump at start-up and stop.

Table 8B&C-5
Steps for washing a filter

1.	Shut the filter influent valve and allow the water in the filter to drop to approximately 6 inches above the filter material. This prevents the loss of treated and settled water.
2.	Shut the effluent valve.
3.	Open the drain or sewer valve.
4.	Gradually open the surface wash valve until the surface wash is operating at maximum efficiency.
5.	At the end of approximately one minute, gradually open the wash water valve until the desired washwater rate has been reached. **Caution!** If the filter is air bound or has air entrapped, be sure to open the valve only slightly until the filter has vented itself of all the air. The filter can be damaged by opening the wash water valve too rapidly. Wash the filter about four minutes at 60 percent of established washwater rate, then increase to standard rate.
6.	Operate the surface wash for three to five minutes during washing cycle, but shut the surface wash valve at least two minutes prior to shutting the wash water valve; this will permit the agitated filter material to subside to normal level.
7.	Shut the wash water valve slowly when the desired clarity is obtained. (The time of wash may vary from three to 10 minutes.)
8.	Shut the drain valve.
9.	Open the influent valve slowly.
10.	The filter should remain out of service 30 to 60 minutes before it is returned to the filtering cycle if the filter-to-waste is not utilized.

Water pollution control regulations set by the Mississippi Department of Environmental Quality (DEQ), Office of Pollution Control, regulate stream quality in Mississippi. Filter backwash water might violate some stream standards; e.g., for suspended solids and pH. Proper disposal of backwash water or "waste" water represents a relatively new concept for water treatment plants. If sewers are available, the "waste" water can go into the sewers.

In some cases, it may be necessary to construct a waste water treatment facility adjacent to the water treatment plant. Plants must contact the Mississippi State Department of Health (MSDH), Division of Water Supply and the DEQ, Office of Pollution Control prior to disposal of "waste" water from a water treatment plant.

Filters collect backwash water in troughs to prevent media from being carried out of the filter during backwashing. The distance between the top of the filter media and the top of the wash water trough is pre-determined to prevent media loss. However, careful observation is important and will also reveal "boils," water spouts, or uneven washing.

The operator should draw down filters occasionally and check for cracks or mud balls. They can develop when a filter is not properly backwashed. The remedy is to break up or remove mud balls by washing at a higher rate. Methods for preventing cracks are similar to those for controlling mud balls. Backwashing aids such as hydraulic surface agitators, mechanical rakes, or compressed air can prevent mud balls or cracks, see Figure 8B&C-12.

Most rapid sand filters include a means to measure the head loss during filtration, such as:

- loss-of-head gauges
- rate-of-flow gauges
- water level indicators

Loss-of-head gauges indicate the pressure on top of the filter and in the effluent piping. The difference in the gauge readings is the head loss through the filter.

Rate-of-flow gauges measure the rate of flow that the controller is maintaining. The difference in pressure across a flow metering device such as a venturi controls the rate-of-flow gauges. Some water level indicators are steel or wooden rods graduated in increments of inches and feet. They show the height of the water surface above the bottom of the filter underdrain.

Numerous other devices indicate head loss through a filter, but they all do the same thing. The normal operation of a rapid sand filter is relatively simple if the upstream processes and the filter are maintained properly. The operator must always carefully observe each unit process to prevent conditions which may cause failures. Continuous, careful monitoring of the influent floc formation, effluent turbidity, and filter condition during filtration and backwashing aid detection of potential failures and allow time for corrective action.

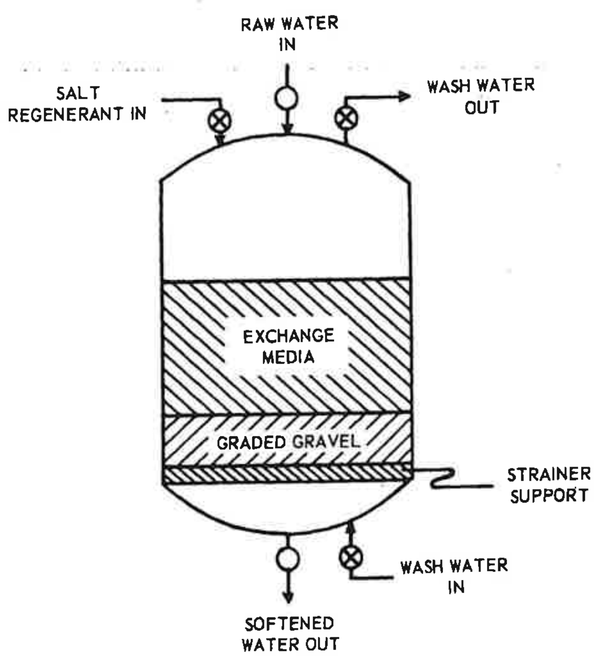
Ion exchange

Ion exchange is used selectively to replace one ion by another. In water treatment, the exchange of ions must be reversible so that the exchange medium can be regenerated and used again. Ion exchange softens water by removing calcium and magnesium ions, and demineralizes water by removing such ions as iron, manganese, fluoride, and sodium. Ion exchange is an excellent process for small water systems. Pressure units take up little space, operate under normal pressures, and do not require double pumping, see Figure 8B&C-15.

Figure 8B&C-15
Pressure filter adapted to operate as an ion exchanger

If economics permit, installing two or more units in parallel permits a continuous flow of water. Turbidity, iron, and manganese can foul the media, so pre-treating the water before softening is essential.

Water passes through the softener until the



sodium ions are exchanged or until hardness leaking through the filter exceeds a pre-determined concentration. Then the medium must be regenerated. Regeneration removes the calcium and magnesium ions exchanged during softening and replenishes the exchange medium with sodium cations. Regeneration typically consists of three steps:

(1) backwashing
(2) application of a sodium chloride solution
(3) rinsing

Backwashing removes particles trapped in the medium during softening. Backwash rates range from 4 to 10 gpm/ft^2 (240 to 600 m^3/m^2/day), depending on the backwash water temperature and density of the medium. Backwashing lasts from two to five minutes.

The cause of hard water usually is calcium and magnesium ions. Barium, aluminum, strontium, and other ions also contribute to hardness. These ions are positively charged cations. Cation exchange swaps loosely held ions in the medium for ions in the water; i.e., sodium ions for calcium and magnesium ions. Softened water contains sodium bicarbonate instead of calcium and magnesium bicarbonate.

Exchange capacities for typical softening media range from 10 to 28 kilograins per ft^3 (23 to 64 kg per m^3). The exchange capacity for a particular medium depends on temperature and regenerant dosage. Softener loading rates, ranging from 1 to 5 gpm/ft^3 (193 m^3/m^3/day to 965 m^3/m/day), determine the size of the filter enclosure. Gravel placed on top of an underdrain supports the media.

After backwashing, a strong salt solution applied to the medium regenerates its exchange capacity. Salt requirements for regeneration range from 6 to 14 lb/ft^3 (96 to 224 kg of salt per m^3) of resin. Contact times range from 20 to 35 minutes for complete regeneration. Brine solution strength and contact time directly affect the exchange capacity of the regenerated media.

Rinsing finished water through the unit for 35 to 70 minutes removes the remaining salt solution, calcium, and magnesium ions.

Rinse water volumes range from 700 to 3,200 gallons (2.7 to 12 m^3) of rinse water for each 35.3 ft^3 (1 m^3) of softening media. The rinse water contains calcium and magnesium chloride. The rinse water solution appears cloudy with a white color, and tends to foam. Regenerating the resin to 100 percent of its original capacity is not practical because some of the calcium and magnesium ions can't be exchanged.

Disposal of the brine solution and rinse water could pose a problem for some water systems if sewers are not available. The plant must contact the Department of Environmental Quality, Office of Pollution Control, or the Mississippi State Department of Health, Division of Water Supply about the proper method for rinse water disposal.

Ion exchange can remove iron and manganese ions in water. Unit processes include ion exchange, disinfection, and processes such as corrosion control required to treat the water after ion exchange is completed.

Ion exchange is appropriate for waters with low hardness and total dissolved-solids concentrations less than 2,000 mg/l because the exchange material also removes calcium and magnesium, which shortens the media's service life. Ion exchange is not satisfactory for water containing more than 0.3 mg/1 iron or manganese, or combination of iron and manganese. Neither the raw water nor wash water can contain dissolved oxygen, which would foul the media. Operation and backwash rates for synthetic-resin ion exchange beds vary from 6 to 8 gpm/ft^2.

Only a few water supplies in Mississippi use synthetic-resin ion exchange beds for removal of iron and manganese.

Combined unit processes

A treatment train for a water treatment facility combines several unit processes. The combination depends on such factors as the degree of treatment desired, the constituents to be removed, and capital and operating costs.

The choice for a particular water treatment application should be based on pilot plant tests, if possible, or bench-scale tests. Pilot plant tests permit simulation of the conditions encountered in full-scale operation and allow testing of various unit process combinations under various flow rates.

The following sections discuss some of the unit process combinations used in Mississippi for removing iron and manganese, controlling tastes and odors, corrosion control, and softening.

Iron and manganese control

Concentrations of iron greater than 0.3 mg/l and manganese greater than 0.05 mg/l can stain plumbing fixtures and laundered clothes, give an objectionable taste to water, and pose problems for some industrial processes. Some of the processes employed to control iron and manganese are:

- oxidation, detention, filtration
- water softening
- manganese greensand filtration
- ion exchange
- sequestration by polyphosphates

Figure 8B&C-16, next page, gives schematics for some processes.

(1) oxidation, detention, filtration
(2) water softening
(3) manganese greensand filtration
(4) ion exchange

The most common aerators have a distributor above trays made of wood, expanded metal, or fiberglass. Some aerators use four to six inches of coke, anthracite, or other medium in the trays to aid in contact oxidation of the soluble iron and to maintain uniform droplet distribution. Both gravity and mechanical draft aerators are used.

Processing using chlorine as the oxidizing agent maintains a free chlorine residual throughout the treatment process. The rate of iron or manganese oxidation depends on pH, chlorine dosage, temperature, and mixing conditions. Oxidation of manganese in some waters could require a catalyst.

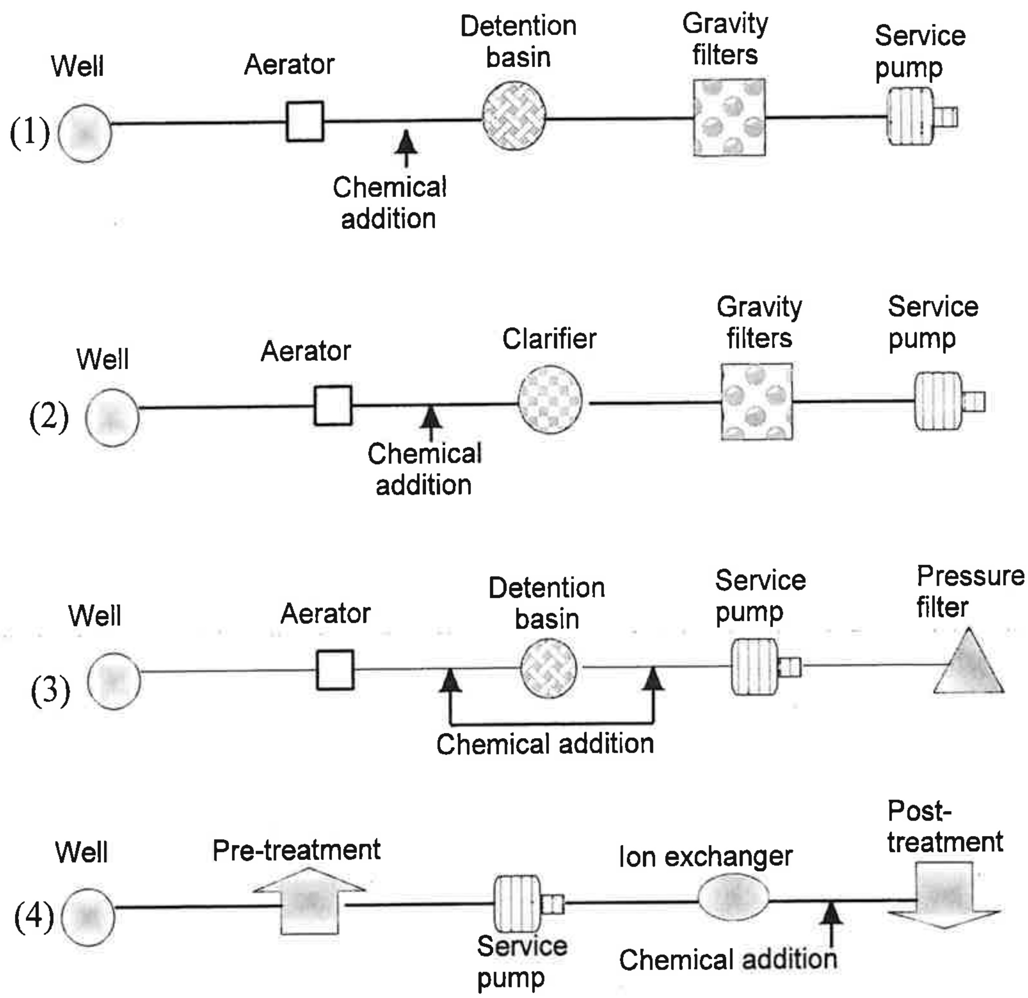
Theoretically, one mg/1 of $KMnO_4$ will oxidize 1.06 mg/l of iron or 0.52 mg/l of manganese. Practically, it takes about one mg/l of $KMnO_4$ for each one mg/l of total iron and manganese. Potassium permanganate as an oxidant is much faster than chlorine. Also, the reaction rate does not depend directly on pH within a range of pH 5 to pH 9.

A minimum detention time of 20 minutes allows the oxidation reactions to reach near completion. Detention tanks are holding tanks and generally do not have facilities for sludge removal. Sludge removal equipment is indicated when the iron and/or manganese concentration is high or where coagulation is used. The section on clarification provides additional information on coagulation.

Filtration removes the oxidized iron and manganese. Dual media, downflow, and rapid sand filters operate under gravity or pressure. Additional information on filtration is provided in the section of this manual on filtration.

Figure 8B&C-16
Schematics for water treatment processes

(1) oxidation, detention filtration (2) water softening (3) manganese greensand filtration (4) ion exchange



Both lime-soda ash and ion exchange softening also remove iron and manganese. Lime-soda ash softening uses lime [$Ca(OH)_2$] and soda ash (Na_2CO_3) to precipitate ions that cause hard water. Since the operation of a plant using this process is quite complicated, most small plants use a modification of this process or ion exchange. Some plants use a modified process that includes aeration, upflow clarification, and filtration. Aerating raw water reduces the carbon dioxide content to 10 to 15 mg/l. This process removes hydrogen sulfide and exposes iron and manganese to oxygen. Lime added to the water entering the clarifier raises the pH to 9.0 to 9.5. Settling takes about two hours.

Filtering clarified water removes turbidity. Filter loading and backwash rates are about the same as those described in the filtration section. The operator can reduce filtration rates if excess turbidity carries over into the filters.

This method reduces the raw water hardness to a range of approximately 150 mg/l to 200 mg/l, not enough for some industrial or commercial applications. Adding a sequestering agent helps overcome the tendency to form scale in water heaters and prevents precipitation of excess calcium carbonate in the distribution system. Most systems use sodium hexametaphosphate in the water leaving the filters, at a dosage rate of 2 mg/l. The section on stabilization and references provide additional information on the use of polyphosphates.

The manganese greensand filtration process can remove iron and manganese ions in solution. The process generally includes aeration, detention, and filtration through a dual media filter. Aeration removes gases such as carbon dioxide and hydrogen sulfide, and initiates oxidation of iron and manganese.

Chlorine can react with iron and manganese to reduce the $KMnO_4$ dose required. The operator adds chlorine and soda ash in the collector tray at the bottom of the aerator before potassium permanganate. Potassium permanganate concentration is 1 mg/l for each 1 mg/l of total iron and manganese. If iron is passing through the filter, the $KMnO_4$ feed rate is increased. If the finished water has a pinkish tint, the $KMnO_4$ feed rate is decreased. Any $KMnO_4$ not used up in the initial reaction continuously regenerates the greensand.

The detention tank is typically sized to allow 30 minutes for the oxidation of iron and manganese to near completion. Filtration and backwash rates are similar to those for conventional filtration. Typical filtration and backwash rates are 3 gpm/ft^2 and 8 to 10 gpm/ft^2, respectively. Air washing the filter aids in cleaning the filter medium.

The ion exchange process can remove both iron and manganese. Either a hydrogen or sodium cation exchange medium will work but only in waters with low hardness and low total dissolved solids content. Because iron fouls both sodium and hydrogen exchange media, manganese greensand is the best choice among the zeolite exchange materials.

Polyphosphates prevent precipitation of iron, manganese, and calcium in the distribution system. Don't use polyphosphates when concentrations of iron and manganese exceeds 1 mg/l.

Stabilization

Water leaving a treatment plant should be stable when it enters the distribution system. Water is considered stable when it neither dissolves nor deposits calcium carbonate. Adjustments to pH and adding polyphosphates stabilize water. Adding lime, soda ash, or sodium hydroxide boosts the pH of raw water. Use lime in soft waters lacking sufficient calcium ions. For hard waters, use soda ash or sodium hydroxide, which do not make the water harder.

Langelier developed a method for testing water stability, within a pH range of 6.5 to 9.5. The Langelier Saturation Index predicts whether a particular water will deposit or dissolve calcium carbonate. If the actual pH minus the Langelier Saturation Index is positive, the water is over-saturated and will precipitate calcium carbonate. A negative value indicates that the water is corrosive. Maintain the pH of the finished water at or just above the pH at saturation to deposit a thin coating of calcium carbonate on the pipe wall. This coating protects metal pipes against internal corrosion.

Polyphosphates prevent precipitation of iron, manganese, and calcium. When the raw water iron concentration is near the maximum of 0.3 mg/l, polyphosphates help eliminate "red water" problems and pipe tuberculation. Add polyphosphate before oxidation at 2 mg/l for each mg/l of iron and manganese present. To prevent precipitation of calcium carbonate, add polyphosphates after filtration and within a dosage range of 0.5 to 5.0 mg/l.

Some plants provide corrosion control and softening but not iron and manganese removal. In such plants adding polyphosphate before filtration prevents incrustation of the filter sand.

The choice between polyphosphate or some other treatment requires careful study of the distribution system. Polyphosphates break down quickly into simple phosphates. Phosphates are nutrients for iron and sulfur bacteria, thus creating taste and odor problems. Free residual chlorination helps control the growth of iron and sulfur bacteria in the distribution system. Mix polyphosphates with water and feed into the system with a hypochlorinator type pump.

Sample questions

1. Define a B class treatment plant.
2. What is the purpose of aeration in iron and manganese removal?
3. What is the purpose of rapid mix?
4. Discuss the benefits of an upflow clarifier.
5. Discuss the difference between precipitation chemistry and coagulation/flocculation for iron removal.
6. Why is alkalinity important in iron and manganese removal? How would you add alkalinity if there isn't enough naturally?
7. Discuss the effects of efficient clarification on filtration in general and filter run times.
8. Why is a dual media filter more efficient than a single media filter?
9. Discuss backwash rates and the overall effect of backwash efficiency on effluent water quality.
10. What are the two major methods of filter rate control? What are the advantages and disadvantages to each method?
11. What is the purpose of filter underdrains?
12. Why should you practice filtering to waste?
13. What is the importance of detention time in the sedimentation process?
14. Discuss the problems associated with sludge handling and ways to lessen sludge volume.
15. What is hydrogen sulfide and why must it be removed? Why is pH important in this process?
16. What is carbon dioxide and why must it be removed from water?
17. Name at least four constituents removed by aeration.
18. Why is good ventilation extremely important in aeration?
19. List five common operational problems associated with aeration.
20. What is air binding?

Chapter 8A

Water treatment

Introduction

This section provides the information that only operators of Class A water plants must know. Class A plant operators also must know all the information contained in the previous sections for Class D and Class B & C plant operators. The subjects covered in this chapter:

- Surface water contaminants
- Algae and methods of treating algae
- Pre-sedimentation
- Coagulation, flocculation, and coagulant aids
- Sedimentation and filtration
- Softening hard waters: lime soda ash and ion exchange, waste disposal
- Disinfection: chlorine and alternative treatments

Surface water

Ninety percent of Mississippi's population gets drinking water from wells. Elsewhere in the United States surface water accounts for 75 percent of the water supply. Urban areas use surface sources for lack of large, underground aquifer reserves that are self-replenishing. Only surface water sources can provide large population centers with enough water to prevent shortages.

However, pollution is much more likely in surface sources. Surface sources are affected more than groundwater sources by short-term weather patterns.

All surface waters contain contaminants that require some type of treatment to make them fit for human consumption. Microbiological contaminants — including pathogenic bacteria — are natural in surface waters. Surface waters contain algae and other microscopic organisms. These contaminants create the following problems:

- fouled pipelines
- cause taste and odor problems
- clog filters
- cause corrosion
- create potentially dangerous, slimy growths on treatment plant structures

These contaminants must be controlled at the source or removed in the treatment plant.

Algae

More than 30,000 species of algae range in size from microscopic to 200-foot long kelp. These organisms can interfere with water treatment processes and change the pH of the water.

The various kinds of coagulation or flocculation and sedimentation treatment control algae. Free chlorine residual reduces tastes and odors from algae. Since chlorine by-products make pre-chlorination risky, some treatment facilities use potassium permanganate and chlorine dioxide instead. Copper sulfate is an algicide, but destroyed algae in the water can produce objectionable odors.

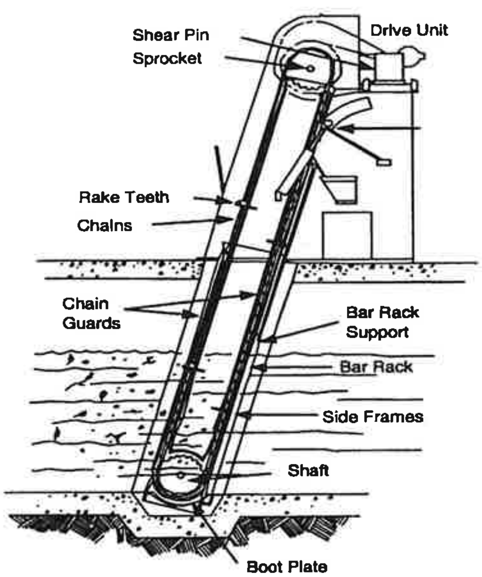
Preliminary treatment

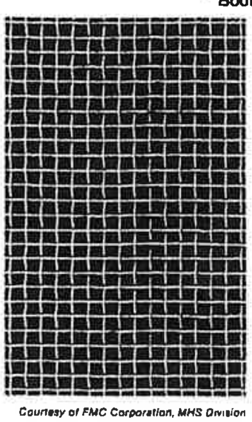
Pre-treatment is any physical, chemical, or mechanical process used before water gets to the main treatment. Pre-treatments include coagulation, flocculation, sedimentation, and disinfection. Any of these lessens the load by removing or altering some of water's objectionable characteristics.

Screening

Screens remove large objects such as rocks, logs, limbs, trees, and other debris that can damage or clog plant equipment. The most common types are bar screens and wire mesh screens. Bar screens are straight steel bars welded at the ends to two horizontal steel members. They are fine, medium, or coarse, depending on the distance between the bars. To make it easy to clean, a bar screen usually is installed in the stream at a 60 to 80 degree angle. A variety of methods are available for cleaning bar screens automatically. Figures 8A-1shows a typical example of an automatically cleaned bar screen.

Figure 8A-1
Automatically cleaned bar screen




Courtesy of FMC Corporation, MHS Division

A wire mesh screen (left) removes debris that is too small for a fine bar screen. These screens are constructed from stainless steel or other corrosion-resistant material. Because wire mesh screens tend to clog quickly, those that clean automatically and continuously are better than manually cleaned screens.

Pre-sedimentation

Pre-sedimentation is designed to remove sand, gravel, silt, and other material that might damage the treatment plant. The process can also buffer dramatic changes in raw water quality. Pre-sedimentation storage minimizes changes in turbidity and other raw water parameters from rain or upstream discharge. The treatment also gives personnel time to make changes in chemical additions if necessary. This process is useful when rivers or streams are the source water. Sometimes pre-sedimentation basins store enough water to minimize seasonal low flows.

Chemical treatment

The purposes of chemical treatment:

- coagulation
- disinfection
- taste and odor control
- chemical precipitation
- flocculation aid
- filter aid

Add chemicals to raw water at or just before rapid mixing. The sections that deal with corresponding unit processes discuss details of specific chemicals.

Rapid mixing

Rapid mixing ensures that added chemicals are evenly dispersed. Motorized mixers, diffusers, in-line mixers, and baffled basins achieve satisfactory results. The rapid mix basin must limit short-circuiting and promote particle contact.

Coagulation/flocculation

In the coagulation step, chemicals break down the forces that keep suspended particles apart. This allows suspended particles to settle. Sedimentation or filtration would not remove suspended particles until they are settleable.

These particles usually are colloidal suspensions — fine silts, bacteria, color-causing particles, and viruses. Colloids are visible only as a cloudiness called turbidity. Most of the colloidal particles that cause turbidity carry a negative charge. Because like-charged particles tend to repel each other, these forces keep them suspended.

These electro-chemical forces can actually be measured as the zeta potential. The purpose of coagulation is to reduce the zeta potential so particles that won't settle come together in an agglomeration called a floc.

Most coagulant chemicals that carry a positive charge treatment are metal salts such as aluminum or iron. Aluminum sulfate – $Al_2(SO4)_3$ – is the most common coagulant chemical. Alum added to raw water reacts with natural alkalinity to form a jelly-like floc of aluminum hydroxide, $AL(OH)_3$. The positively charged aluminum ion neutralizes the negative turbidity in raw water. This process takes one or two seconds after the alum is added. That's why adequate mixing is so important. Neutralizing the charge is the first step in coagulation. Some waters require chemicals such as lime or soda ash along with alum.

As the particles begin to come together, larger particles form. The small micro-floc particles still have a positive charge and participate in neutralizing other negative particles. Figure 8A-2 shows how larger particles build during chemical coagulation. As these positively charged particles continue to neutralize negatively charged particles, they become neutral. The positive and negative charges balance. Finally, the micro-floc particles begin to collide and stick together to form larger particles that settle.

Figure 8A-2
Microfloc

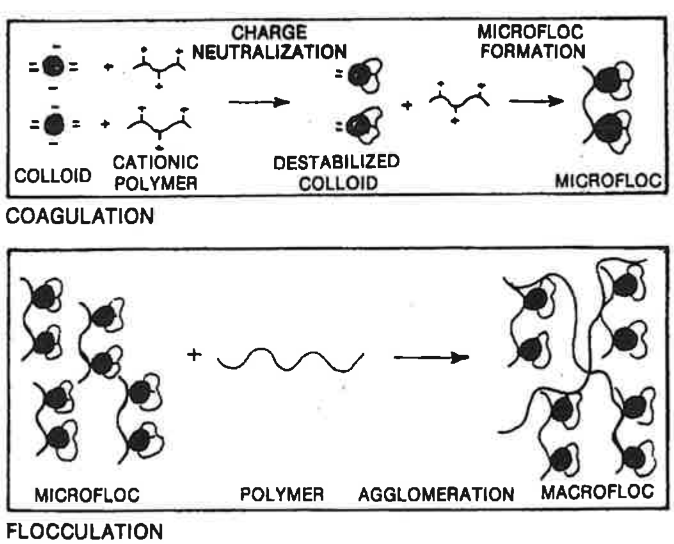


Table 8A-1
Common coagulants and doses

Coagulant	Chemical formula	Typical dose range mg/l
Aluminum sulfate	$Al_2(SO_4)_3$	15-100
Copper sulfate	$CuSO_4$	5-20
Ferric sulfate	$Fe_2(SO_4)_3$	10-50
Ferrous sulfate	$FeSO_4$	5-25
Sodium aluminate	$NaAlO_2$	5-50

Coagulant aids

A coagulant aid is a chemical that improves coagulation by any of the following:

- building a stronger floc
- overcoming temperature variations
- reducing the amount of coagulant needed
- reducing the amount of sludge produced

Alum sludge doesn't dry readily, so treatment and disposal are difficult. Minimizing alum sludge is a major factor in the choice of coagulant aid. These aids reduce the amount of alum needed, so less sludge results. Following is a partial list of coagulant aids:

Activated silica - This chemical aid must be made at the plant. To make it add an acid to sodium silicate, Na_2SiO_3. This activates the silica. Most plants use hypochlorous acid. Activated silica builds a tougher, more easily settled floc. However, if too much silica is present in the final product, coagulation could actually be hampered, and filters could become clogged.

Weighting agents - Bentonite clay is the most common weighting agent. In high-color, low-turbidity waters, it adds weight to settle the floc.

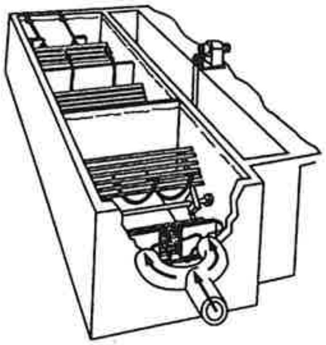
Polyelectrolytes (polymers) - Polymers come in cationic, anionic, and nonionic form. Cationic polymers are positively charged. Used with alum, they form a settling floc less dependent on pH and producing less sludge. Anionic polymers are negatively charged, removing positively charged solids. They increase floc size and decrease pH dependence. Nonionic polymers are balanced or neutral in charge. They release both positive and negative charges into the water. These balanced polymers help remove both positive and negative solids. Polyelectrolytes are expensive, but only small amounts are necessary. The major problem with polyelectrolytes is using too much, which can be expensive and clog filters.

Flocculation

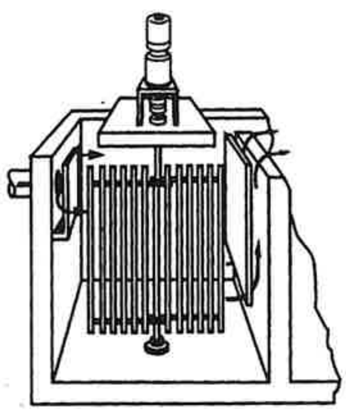
Building floc by gentle mixing is called flocculation. Slowly stirring the mixture after coagulation promotes particle contact. As the sticky floc particles collide, they remain together in a floc that settles or filters out. Stirring speed exerts the major control over flocculation.

Stirring methods include mechanical mixing, baffling, or air diffusion. Figure 8A-3 shows several common types of flocculators. Paddle-wheel probably is the most common.

Figure 8A-3
Types of flocculators

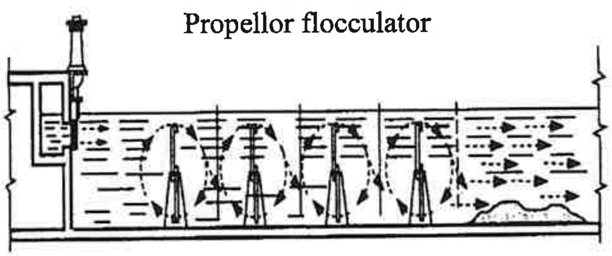


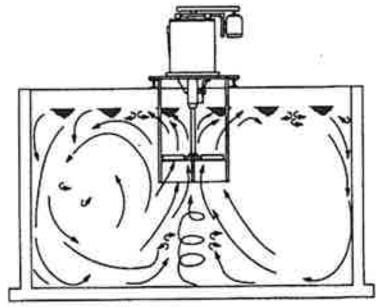
Baffles and horizontal paddle-wheel flocculator



Paddle-wheel flocculator, vertical type

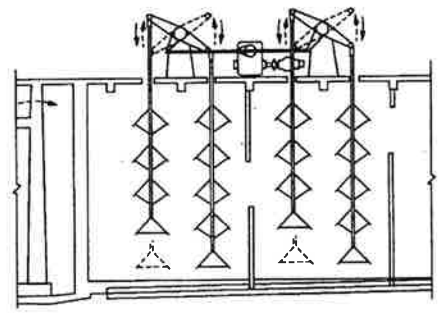
Propellor flocculator





Turbine flocculator

Walking beam flocculator



Excess mixing causes floc breakup. Mixing too slowly causes weak floc, which filtering can easily shear. One way to avoid mixing mistakes is with step-flocculation. In this process, the beginning mixing speed is fast to build small, tough floc. As the water continues through the flocculator, less mixing velocity, higher basin volume, or reduced paddle area slows mixing speed. This causes a larger floc that still retains the tough inner core. This floc settles and filters easily.

Operational control

Quality of surface water can vary widely, affected by:

- rain
- runoff
- seasonal reservoir adjustments
- various upstream conditions

These changes require adjustments in chemical feed, especially in coagulant amounts. Proper testing and record keeping gives the best control over dosages, see Table 8A-2, next page.

Most surface water treatment plants constantly monitor turbidity and chlorine. Other parameters that require careful monitoring:

- temperature
- pH
- alkalinity
- color

Table 8A-2

Record-keeping form

Type of coagulant______________________________ Date started____________________

Item	Results (by date)								
	Date	Date	Date	Date	Date	Date	Date	Date	Date
Coagulant dosage									
Raw water									
Temperature (° F)									
pH									
Alkalinity (mg/l as $CaCO_3$)									
Turbidity (NTU)									
Taste and odor									
Color (CU)									
Suspended solids (mg/l)									
Algae content									
Coagulated water									
Filtrability (volume/time)									
Zeta potential (mV)									
Settled-water turbidity									
Filtered water									
Turbidity (NTU)									
Color (CU)									
Taste and odor									
Algae content									
Residual coagulant (mg/l)									

One of the most common tests is the jar test. This is a small scale trial of treatments the plant could use. To run the test, place raw water in jars with different amounts of coagulant chemicals. Mix to simulate rapid mix and flocculation. Run these tests routinely, more often when water quality is changing.

A streaming current detector (SCD) or a zeta potentiometer can automate coagulant control. SCDs measure the electrical potential of the coagulated mixture and automatically adjust coagulant dosages to maximum efficiency. Trial and error at the treatment plant determines maximum efficiency. Since every water is different, the electrical potential that works best at each plant is different. Keeping good records is how to find out what works.

A zeta potentiometer actually measures the zeta potential of the coagulated water. Although this instrument can accurately determine the exact chemical dose needed, it is more difficult to calibrate.

Sedimentation

Sedimentation holds floc particles in a basin until they settle out by gravity. Usually sedimentation takes two to six hours in a conventional treatment plant. Tube settlers decrease surface area by 40 percent, shortening the time. Effective settling occurs in the sedimentation basin and not in the flocculator for two reasons:

- Settled material in the flocculator basin can short circuit the flocculation process.
- Adequate sludge handling facilities might not be available for the flocculator.

The maximum turbidity of effluent from the sedimentation tank is10 nephelometric turbidity units (NTU). If turbidity rises above 10 NTU, the operator should adjust the coagulation flocculation process.

Type of units

Figure 8A-4 shows sedimentation units from conventional straight flow units to upflow clarifiers. The two most common types of basins are:

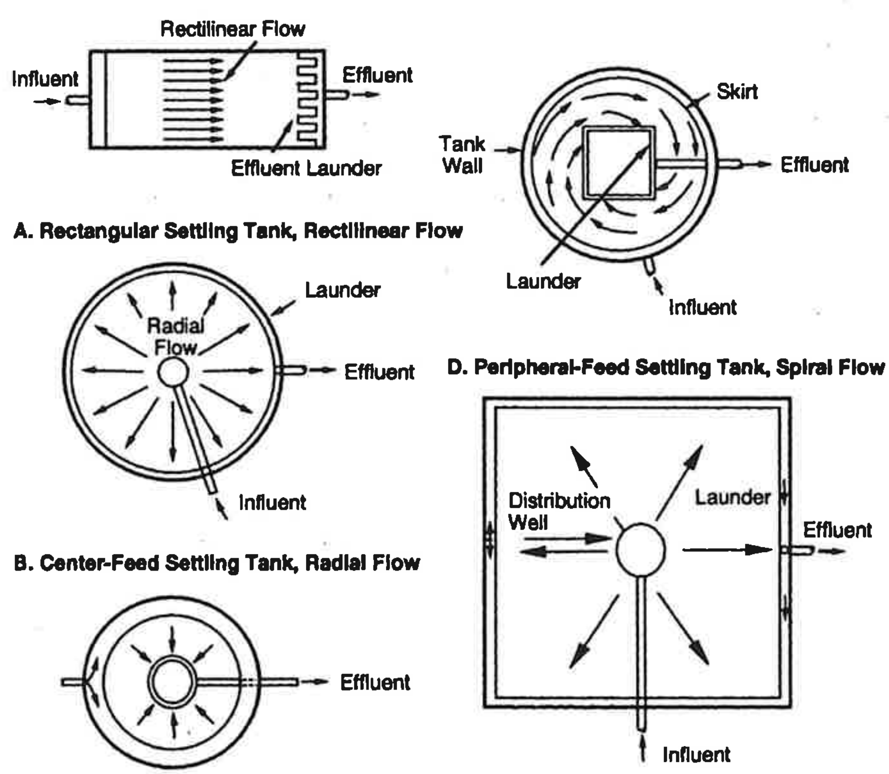
- the rectangular tank
- the circular tank with center feed

Most conventional treatment plants use rectangular basins with rectilinear flow. The flow is in one direction which is parallel to the basins's length. In center-feed circular basins, the water flows radially from the center to the outside edges. In both cases, the major problem is short circuiting.

Short circuiting is when the water is able to bypass the normal route through the basin and arrive at the effluent collector in less than the design detention time. This means that the detention time and hence the settling time is less than optimum. Short circuiting might make treatment inadequate and inconsistent.

The cause of short circuiting is poor influent baffling. If the inlet baffle is not properly designed or has worn, then the distribution of flow is uneven. Though the operator cannot change design flaws, he can watch for short circuiting problems and baffling deterioration. To correct these problems replace parts or adjust chemical dosages.

Figure 8A-4
Flow patterns in sedimentation basins



Tube settlers

Tube settlers can extend the sedimentation area, reducing the amount of detention time required in a sedimentation basin. The tubes usually are plastic, about two feet long, inclined at a 60 degree angle. As the water passes upward through the tubes, the particles settle down for removal. Figure 8A-6 shows several types of tube settler arrangements and illustrates how tube settlers increase the capacity of a basin.

Figure 8A-5
Counter-current flow in tubes

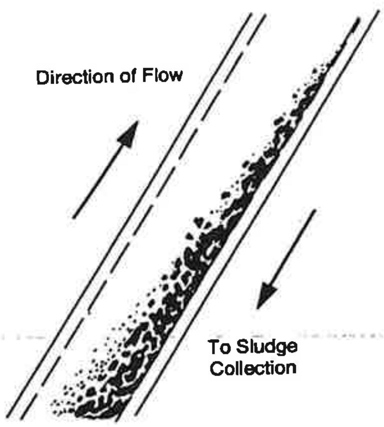
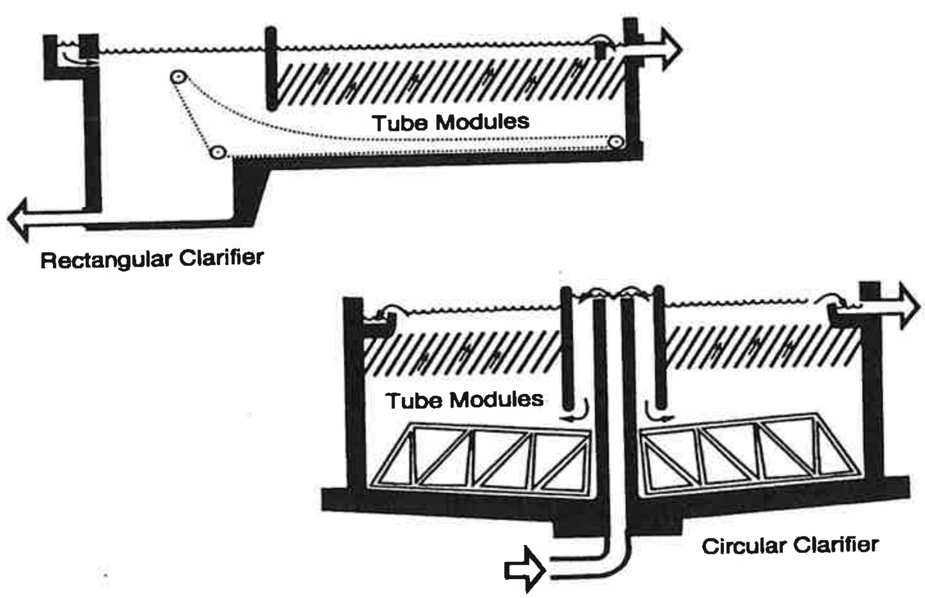


Figure 8A-6
Tube settlers installed in sedimentation basins



Solids contact basins

Solids contact basins are also called upflow clarifiers. They are softening units and iron removal plants. Figure 8A-7 on the next page shows a common basin design. Influent enters the middle mixing zone and is distributed by baffling to take advantage of step flocculation.

This design uses a cone shape to increase the volume of the basin as the water flows downward. The water then flows upward from under the cone bottom into a filtration action with settled sludge.

The advantage of this unit is faster and more complete chemical reactions in the mixing area due to recycling of sludge material. This allows much lower detention times than with conventional basins.

Maintenance

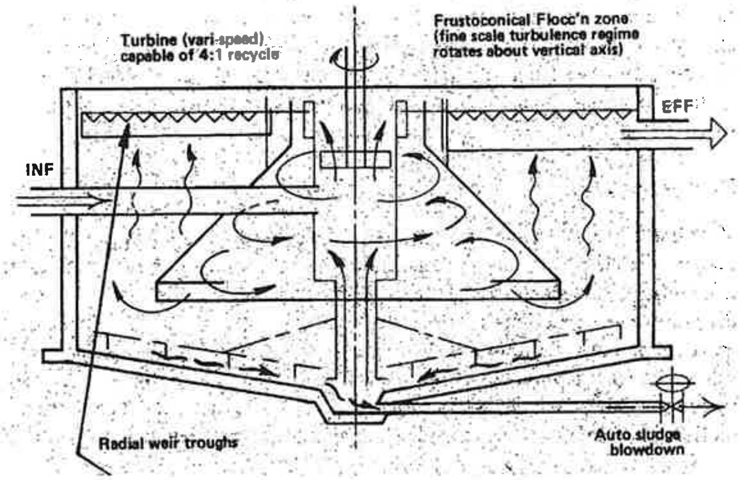
Drain and inspect conventional basins once a year to make sure that sludge handling equipment is operating properly. Accumulations in specific areas could indicate short circuiting. Inspect and repair inlet and outlet baffling and overflow weirs, clean algae and any other growth.

Sludge handling

Methods of sludge disposal vary with the type and amount of sludge the treatment plant produces. Alum sludge is the most common and the most difficult. Drying sludge is the biggest problem.

The most common method of dealing with alum sludge is pumping it to a lagoon. When the lagoon is full, it is left to dry. Even after a year or more the dried sludge may not be fit for disposal in a public landfill. The water treatment plant might have to dispose of the sludge onsite if it has enough land. Another option is drying beds or filters to prepare the sludge for disposal in a public facility, but these are expensive.

Figure 8A-7
Sludge-blanket clarifier



Filtration

Filtration is covered in detail in the B & C section.

Softening

Divalent metal ions such as calcium and magnesium cause hard water. Customers complain about hard water causing scale in pipes and requiring so much soap.

Hard water can react with soap to make bathtub rings that are difficult to clean. Hard water also can stain clothes during washing.

Softening methods

The two methods most widely used for softening public water supplies:

- lime-soda ash softening
- ion-exchange softening

Each softening process has advantages and limitations. Other methods that can soften water are complex and expensive, such as:

- electrodialysis
- distillation
- freezing
- reverse osmosis

Lime-soda ash softening

Lime and soda ash added to water react with calcium and magnesium salts to form two insoluble precipitates: calcium carbonate and magnesium hydroxide. Conventional sedimentation and filtration processes remove these precipitates.

Most larger treatment plants use the lime-soda ash process. With some modifications, the process can also remove turbidity and color. This method is appropriate to soften surface water.

Caustic soda; i.e., sodium hydroxide (NaOH) can substitute for lime and soda ash for removing carbonate and non-carbonate salts. The major advantage is that caustic soda produces less sludge. However, caustic soda is more expensive and increases the dissolved solids in the treated water.

Lime-soda ash softening process

If hard water contains calcium and magnesium, lime and soda ash will react to form insoluble precipitates. Calcium carbonate and magnesium carbonate cause carbonate hard water. Lime and excess lime treatment, respectively, soften such water.

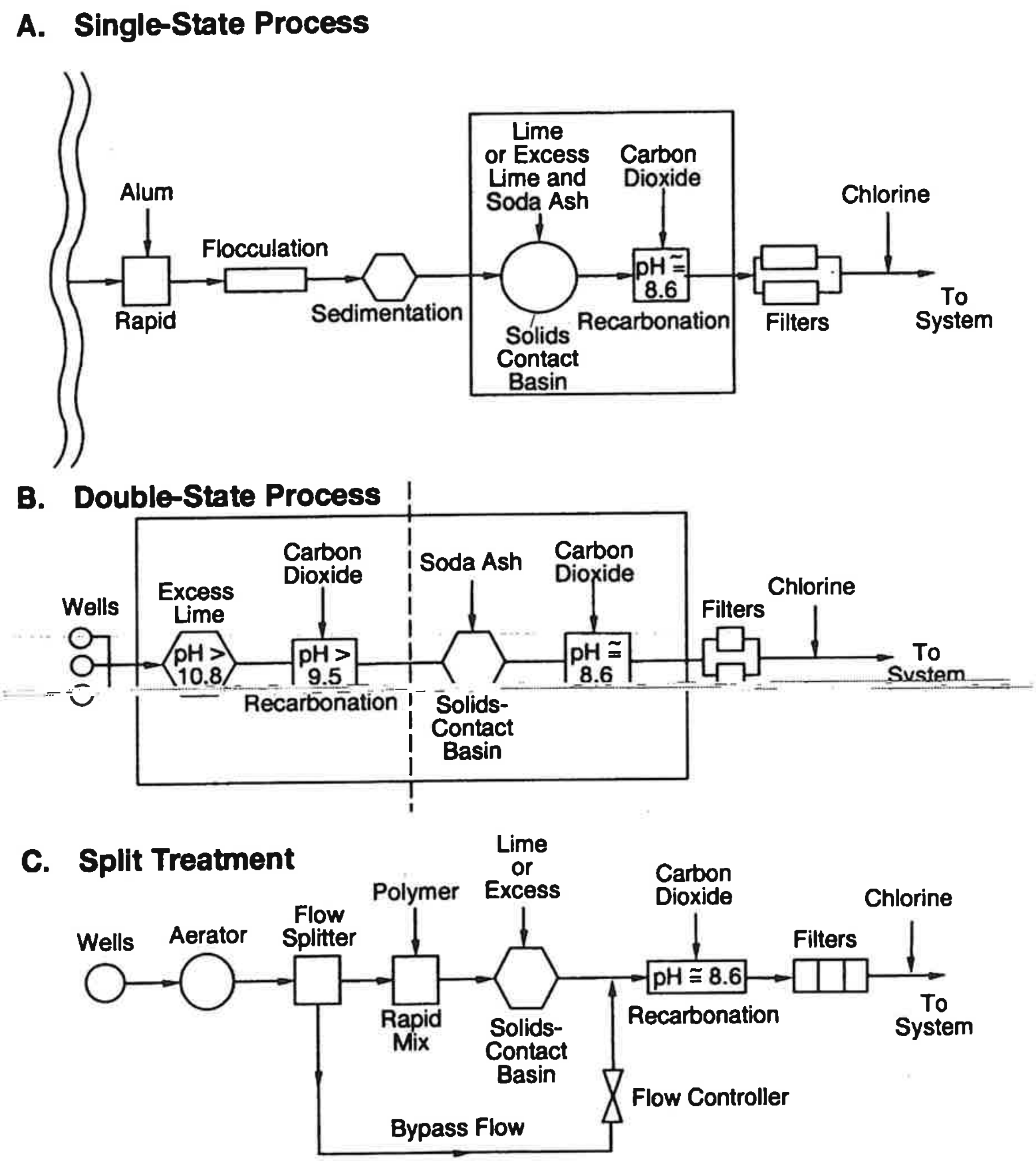
Soda ash is necessary only when calcium and magnesium compounds are non-carbonate, either sulfate or chloride salts. Such hard water is fairly rare in Mississippi. Non-carbonate salts form precipitates with lime and soda ash which conventional coagulation/flocculation, sedimentation, and filtration can remove. Water softened by this method retains 50 to 80 mg/l of hardness. Leftover hardness protects against corrosion typical with water softened by ion exchange.

Chemistry of lime-soda ash softening

Removing carbon dioxide is the first step in the softening process. At a pH of 8.3 carbon dioxide is totally converted to calcium carbonate. Carbon dioxide does not cause hardness but does consume lime, something to consider when estimating lime dosages.

Adding lime to treat carbonate removes calcium. Calcium carbonate precipitates at a pH of 9.4. Excess lime that raises pH to 10.6 converts magnesium to magnesium hydroxide. These precipitates settle and filter out by conventional methods as shown in Figure 8A-8. With non-carbonate salts, adding soda ash forms calcium carbonate and magnesium hydroxide.

Figure 8A-8
Lime-soda ash softening processes



In properly softened water, pH usually is around 11. Preventing calcium carbonate deposits requires re-carbonation. This stablizes the water and protects the filter and distribution system. Adding carbon dioxide to the water converts calcium carbonate to calcium bicarbonate, reducing the pH, ideally to 8.6.

Sludge handling in lime-soda ash softening

Lagoons typically handle the sludge from softening plants. Decanting and centrifuges are some of the drying techniques that prepare sludge for disposal or sale. The sludge can go into landfill. If there isn't too much alum, it makes a good conditioner for acid soil. Disposal of sludge is becoming an increasing problem as the Clean Water Act imposes additional requirements on treatment facilities.

Ion-exchange softening

Ion-exchange swaps one ion for another. The method replaces hard-water ions with sodium ions, which do not cause hardness.

This process uses ion-exchange materials such as polystyrene resins. Hard water passes through a unit containing the ion-exchange material. Calcium and magnesium ions attach to the resin, which releases sodium ions in exchange.

Ion-exchange resins eventually lose their ability to remove hard water ions. Regeneration involves passing salt-water through the ion-exchange unit.

Household softeners use ion-exchange, as do smaller municipal water treatment plants using ground water. When most hard water salts are non-carbonate, ion-exchange is less expensive than the lime-soda ash process. The process is not adaptable to treat surface waters.

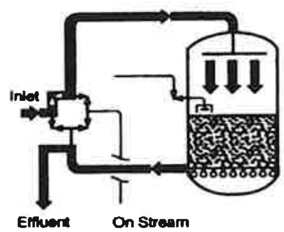
Ion exchange

Ion exchange removes all water hardness. Blending hard and softened water in the proper proportion produces a satisfactory product. Ion exchange is compact, low cost, easy to operate, and effective. However, turbidity, color, iron, and manganese can foul the ion exchange units. These contaminants must be removed before ion exchange begins.

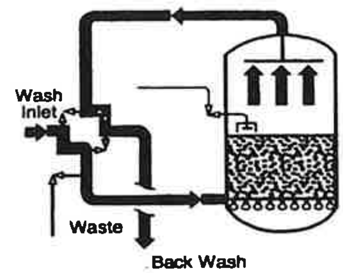
Figure 8A-9 shows the four basic cycles involved in the ion exchange process.

Figure 8A-9

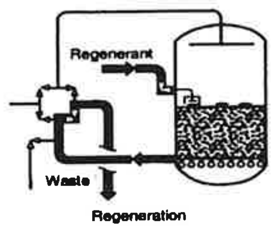
Four cycles in the ion exchange process



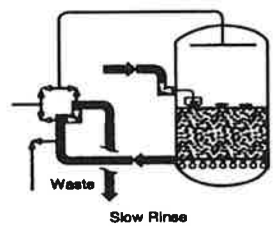
Softening. Influent water passes downward through the bed of ion exchange material to the effluent.



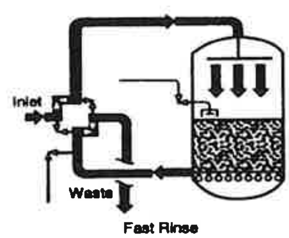
Backwash. Influent water is passed upward through the bed of ion exchange material to loosen the bed and remove suspended solids that may have been deposited in the bed during operation.



Regeneration. Regenerant solution is passed through the bed to waste at a controlled concentration and flow.



Slow rinse. Water is passed through the bed to displace the regenerant solution to waste.



Fast rinse. Influent water is passed through the bed to waste to remove the last traces of regenerant chemicals.

The exchange is complete and the cycle ends when hardness breaks through. The loading rate on an ion exchange unit depends on the type of media. Load zeolite units and most resins at 2 to 6 gpm/sqft. Load polystyrene resins at a rate of 10 to 15 gpm/sqft due to the rapid exchange rate for this resin.

The first step after break through is back-washing. Back washing removes accumulated particulate matter and expands the bed, which could compact during ion exchange. The backwash rate is usually 6 to 8 gpm/sqft or enough to expand the bed by 50 percent.

Second step involves passing a salt solution of about 10 percent slowly and continuously through the resin. A contact time of 20 to 35 minutes is ideal.

The concentration of sodium ions is strong enough to reverse ion exchange. The sodium ions from the brine exchange with the calcium and magnesium ions that were removed during softening. The loading rate for the brine solution is 1 gpm/cuft of resin. Resin loading rates in the unit are expressed in gpm/cuft instead of in gpm/sgft of surface area. This is used to determine regeneration and softening capacity.

A thorough rinsing cycle must follow the regeneration cycle. Rinsing removes all the unused salt. The loading rate for the rinse water is 2 gpm/sqft. Rinsing continues until the chloride level in the rinse water is approximately equal to that of the raw water.

Brine disposal

A major problem with ion-exchange regeneration is disposing of spent brine. Disposal cost might make other softening methods more cost-effective.

The amount of spent brine usually ranges from 1.5 to 7 percent of the amount of water softened. This wastewater from the regeneration cycle contains calcium chloride, magnesium chloride, and sodium chloride. Even when diluted by the backwash and rinse water, the total concentration of dissolved solids in the wastewater is from 35,000 to 45,000 mg/l.

Proper disposal of the brine is essential. Concentrations could have the following effects:

- destroy sewage treatment operations
- cause corrosion
- harm aquatic life
- make soil unusable for agriculture
- make water unusable for almost any purpose

Brine disposal methods include:

- lagoons
- dilution and discharge to surface water
- pumping wastewater through an injection well into deep saline aquifers

Method selected depends on each water utility's needs and the requirements of the Department of Environmental Quality.

Disinfection

Most surface and some ground waters contain natural organic compounds from decaying vegetation. These humic and fulvic acids cause taste, odor, and color problems. If exposed to free chlorine residual long enough, these compounds make complex chloro-organic compounds called trihalomethanes (THMs). The most common is chloroform. THMs are cancer causing agents.

One method of reducing THM formation is to change the point of chlorine application. If the point of chlorination is moved from the rapid mix to a point just ahead of the filters, then the processes of coagulation, flocculation, and sedimentation remove the organic material precursors from the water before chlorine is added. However, without prechlorination, algae control and disinfection in the treatment plant might require a substitute disinfecting agent.

Chloramines

Chlorine reacts with ammonia to form combined-residual chloramine, which is a disinfecting agent. Using chloramine for disinfection can reduce THMs in the distribution system. Chloramines are less likely than free chlorine to form THMs.

However, it would take 200 times as much chloramine to provide the same disinfection as free chlorine when pH is less than 7.0 — like most surface water. Combined residual would require carefully controlled dosage and contact time to assure adequate disinfection and algae control.

Chlorine dioxide

Chlorine dioxide is an extremely strong oxidizing agent. High pH does not affect chlorine dioxide. As the pH increases, chlorine dioxide becomes much more effective than free chlorine.

Chlorine dioxide does not form THMs when exposed to aquatic humic material. However, chlorine dioxide does react to form several other by-products: aldehydes, carboxylic acids, and ketones. It also forms inorganic compounds: chlorite, chloride, and chlorate. The chlorite ion has been implicated in causing methemoglobin anemia. The EPA recommends that the total distribution residual of chlorine dioxide, chlorite, and chlorate not exceed 1.0 mg/l.

As chlorine dioxide is not stable, treatment plant personnel must generate it on site, and use it immediately. Adding chlorine gas to chlorite makes chlorine dioxide. Undesirable chlorate ions can form during this reaction unless proper process control maximizes chlorine dioxide production. Maximum reactant concentrations and chlorine supplied as hypochlorous acid or elemental chlorine can accomplish the purpose.

Ozone

Ozone (O_3) is formed when a high voltage arc passes through air or oxygen between two electrodes. Ozone is a bluish, toxic gas with a pungent odor. A powerful disinfectant and oxidizing agent, ozone is used in many European countries. It is used less in the U.S. because it must be produced onsite and is expensive. Ozone leaves no residual.

Ozone is getting more attention because it does not form trihalomethanes. However, ozone does form other by-products being studied to determine health effects. If safety is assured, ozone could become an alternative to free chlorine in pre-treatment of surface water or ground water with high organic color concentrations.

Adsorption

Adsorption is adhesion of organic contaminants to an absorbent such as activated carbon. The organic material sticks to the surface of the absorbent, which must have a large surface area. Activated carbon has a vast network of pores that vary in size. It accepts both large and small organic molecules, providing excellent adsorption capability.

Activated carbon is produced from lignite coal. A furnace slowly heats the coal in an oxygen-free atmosphere so it doesn't burn. It becomes carbon.

Exposing the carbon to a stream-air mixture activates it. Activated carbon is crushed and screened to desired particle size. Powdered activated carbon (PAC) and granular activated carbon (GAC) are used in water treatment.

Powdered activated carbon

PAC controls tastes and odors and removes precursors that become THMs. PAC is finely ground and fed dry in a slurry like lime. For maximum effectiveness, add in the raw water as close to the intake as possible. Longest possible detention time is important; other chemicals interfere with adsorption. Adsorption becomes much more difficult if chlorine reacts with the organics to form trihalomethanes.

Granular activated carbon

GAC controls tastes and odors. It can remove organics before or after THM formation. GAC is similar to a normal filtration system and can replace anthracite or sand as a filter media. However, GAC adsorbs organic compounds. Without THMs, GAC could last for one to three years before regeneration. If THMs are present, then the GAC may only last a few weeks.

When the medium is exhausted, break through occurs. The operator must either replace GAC with virgin activated carbon or regenerate the exhausted medium. Regeneration subjects used GAC to a controlled atmosphere of steam and oxygen at temperatures approaching 1000° C. The filter needs new material, in addition to regenerated GAC, to make up for loses.

Using activated carbon to control THMs or its precursors might be impractical now. However, if regulations continue to lower acceptable THM levels, alternative disinfection practices could become necessary. Activated carbon is still being studied.

Sample questions

1. Discuss advantages and disadvantages of surface water vs ground water.
2. What does a sudden rise in the pH of an impound reservoir indicate?
3. What is turbidity?
4. How are streaming current detectors (SCD), zeta potentiometers, and particle counters used in water treatment?
5. What problems are associated with alum sludge and what can be done to reduce them?
6. What causes short circuiting and how does it effect treatment?
7. What is hardness and how is it removed? Discuss process and finished water pH and how it is affected by the type of hardness removed.
8. What is the purpose of recarbonation?
9. What are THMs and how can they be reduced?
10. What is the purpose of a bar screen and where is it located?

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Chapter 9

Distribution and storage

Introduction

The distribution system is the water utility's largest dollar investment but also the least visible and possibly the most neglected component. The distribution system includes all the equipment required to transport water from the well or treatment plant to the customer:

- water mains
- service lines and meter settings
- booster stations
- gate valves
- pressure regulators and other control valves

This section organizes responsibilities of a water distribution operator into three major areas: design, construction, and maintenance.

The second section on storage includes a discussion of the function and maintenance of hydropneumatic or pressure tanks, elevated tanks, standpipes, and ground level storage tanks.

Distribution

Design

The water operator or manager knows the most about the distribution system and is best equipped to offer planning suggestions to the engineer. Future growth and fire protection, including commercial and industrial growth for at least 10 years, should be considered.

The first step is an analysis of the following items:

- system needs
- proposed extensions and improvements
- materials required
- labor cost
- overhead
- contingencies
- engineering and inspection requirements
- legal expenses
- land acquisition
- excavation
- installation of mains, valves, hydrants, backfilling and repair
- flushing, disinfection, and testing

Consider methods of financing the distribution system. Common methods include:

- government grants and loans
- private capital
- revenue bonds
- water/sewer charges
- any combination of these methods

Be sure to consider area ordinances in planning.

Layout and mapping

The next step is a design and map of the system layout. A basic system map should show the following information:

- the existing system including main size, water pressure, valves, and hydrants
- existing and proposed streets
- ground-level elevation, contour lines, and topographic features

- existing underground utility services; includes sanitary sewers, storm sewers, water, gas, and underground electric, telephone, and television cables
- population densities, present and projected
- normal water consumption, present and projected
- proposed additions or changes to the system

A good distribution design shows few dead-end lines and as many looped lines as possible to provide a continuous flow of good-quality water to all parts of the system.

Main sizes

Four inches is the recommended minimum main size to carry adequate quantities of water. Domestic use requires a minimum pressure of 20 psi during peak flow. A water main supplying fire protection should be at least six inches in diameter.

Material selection

All materials for water mains and service connections must meet minimum AWWA standards.

Other factors to consider:

- replacement cost
- local conditions such as soil, high and low temperature ranges
- corrosive water qualities
- deteriorating future carrying capacities
- operating frequency of valves and other appurtenances
- possible water hammer

The materials most commonly used are:

- ductile iron
- prestressed concrete
- steel
- PVC

For service lines, the most common choices include:

- PVC
- copper
- polybutylene

No one material is best for all applications. Any one of the materials described above might be the best choice.

Table 9-1
Material characteristics

Material	Common sizes (inches)	Max working pressure (psi)	Advantages	Disadvantages
Ductile, cement lined	4- 30	350	Durable, strong, high flexural strength, high carrying capacity for external diameter, fracture resistant, easily tapped	Subject to electrolysis and attack from acid and alkali soils, heavy to handle
Reinforced concrete	12-168	50	Durable with low maintenance, good corrosion resistance, good flow characteristics, resists backfill and external loads	May deteriorate in alkali soil if cement type is improper or in acid soil if not protected
Pre-stressed concrete	16-120	250	Durable, low maintenance, corrosion resistant, good flow characteristics, resists backfill and external loads	Same as above

Material	Common sizes (inches)	Max working pressure (psi)	Advantages	Disadvantages
Steel	4-120	High	Light weight, easy to install, high tensile strength, low cost, good hydraulically when lined, adapted to locations where some movement may occur	Subject to electrolysis; external corrosion in acid or alkali soil; poor corrosion resistance unless properly lined, coated and wrapped; low resistance to external pressure in larger sizes; air vacuum valves imperative in large sizes, subject to tuberculation when unlined
Polyvinyl chloride	4-36	200	Light weight, easy to install, excellent resistance to corrosion, good flow characteristics, high tensile and impact strength	Difficult to locate underground, requires special care when tapping, susceptible to damage during handling

Corrosive water can deteriorate the distribution and domestic plumbing systems. Corrosion lowers quality of water thatthe customer receives. If the water is corrosive, treat it and use corrosion-resistant pipes.

Main location

Whenever possible locate mains in a standard position relative to property lines. Some factors to consider in establishing a standard position for lines:

- standard locations for other underground utilities
- kind of paving and highway restrictions
- practice of laying mains and services before paving
- soil conditions
- projected leak repair due to location.

Locate water mains on the opposite side of the street from sewers where possible. Lay water mains at least 10 feet horizontally from any sanitary sewer or manhole, unless local conditions prevent 10 feet horizontal separation. The two lines must be in separate trenches with adequate space for maintenance and with the bottom of the water line 18 inches above the top of the sewer line.

If these conditions cannot be met, then the water line should be ductile iron with water line joints located at the maximum distance possible from the sewer line joints. PVC pipe is acceptable if it is protected by a steel casing. Some cases might require special sewer line construction. Where water lines cross over sewer lines, center the pipe segments to provide maximum spacing of both water and sewer lines.

Service line sizing

Pressure in the range of 35 to 60 psi provides acceptable customer service, as long as the pressure never drops below 20 psi. Select line size to ensure that the pressure at the meter during periods of heavy usage is in the proper range. Before designing the service, collect the following information:

- pressure at the main
- length of service from main to meter
- quantity of water required through the meter
- residual pressure needed to furnish the required quantity of water

Line valves

Provide valves for line maintenance, repairs, and isolation of fire hydrants. Locate gate valves so a break in the main would not require shutting off more than about 500 feet in a demand district or 800 feet in other areas. Valves in larger mains bear wider spacing, especially if fire hydrants are on smaller lateral mains that are looped.

Gate valves 16 inches and larger usually have bypasses to aid in closing against a differential in head. Open the bypass valve before a shut-down in the larger valves to prevent surge or shock loads. All fire hydrants regardless of location should be valved on the fire hydrant lead.

Check valves open in the direction of normal flow and close with reversal flow. Installing check valves is an important means of protecting the system from contamination from backflow.

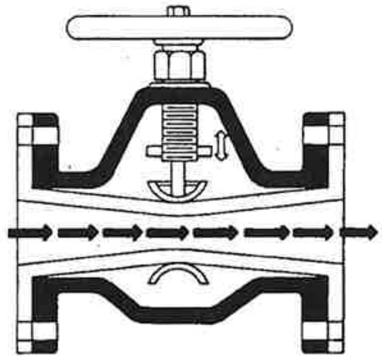


Figure 9-3 Pinch valve

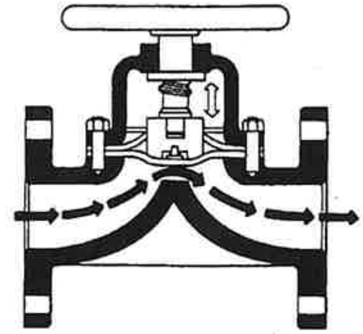


Figure 9-4 Diaphragm valve

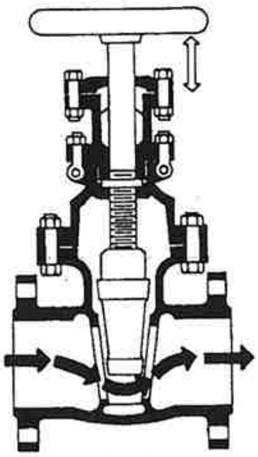


Figure 9-1 Gate valve

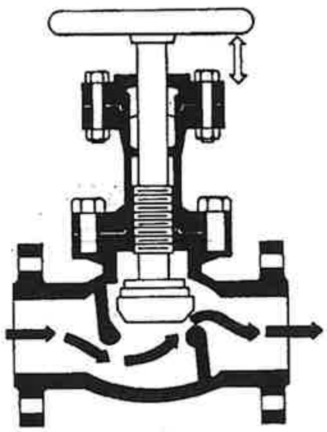


Figure 9-2 Globe valve

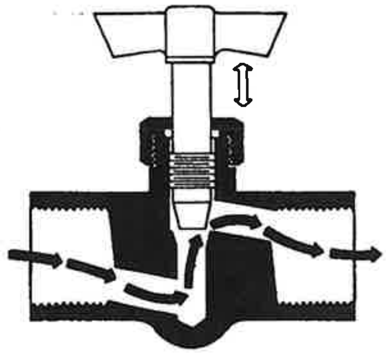


Figure 9-5 Needle valve

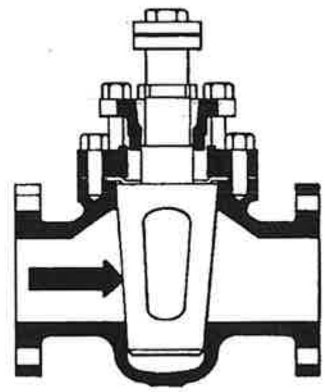


Figure 9-6 Plug valve

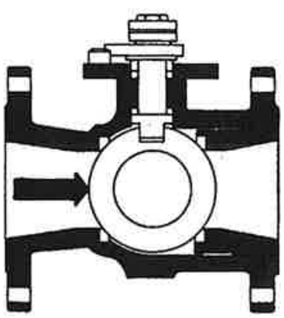


Figure 9-7 Ball valve

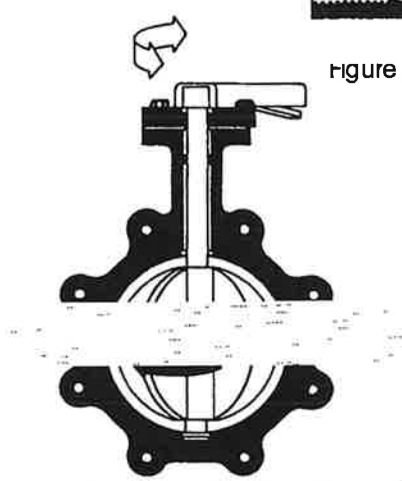


Figure 9-8 Butterfly valve

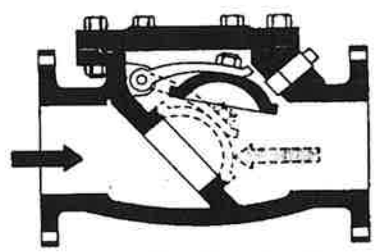


Figure 9-9 Check valve

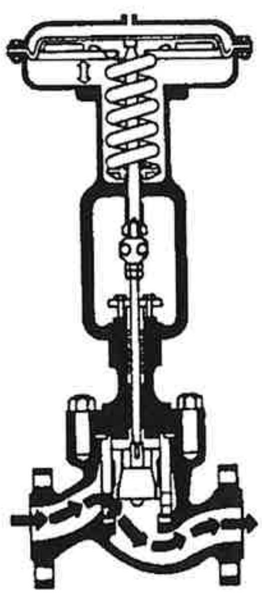


Figure 9-11 Control valve

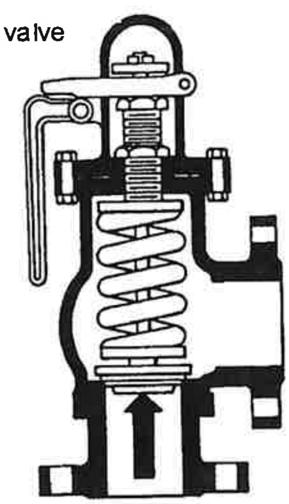


Figure 9-10 Relief valve

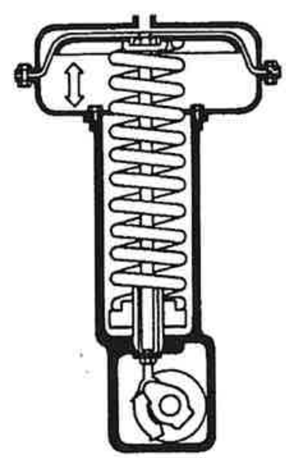


Figure 9-12
Pneumatic actuator

Valve selection

Consider the following factors when selecting valves:

- material to be handled and required flow speed
- control or shut off appropriate to service demands
- appropriate API, AWWA, ANSI, etc., standards
- ability to resist corrosion and erosion
- actuator requirements, if any
- installation requirements, such as weight and accessibility.

Special valves

Air relief valves at high points in the system release entrapped air. Air vacuum relief valves also release entrapped air that accumulates in normal service. This can cause loss in carrying capacity.

Pressure regulating valves reduce excess pressure to a normal range.

Altitude valves are similar in construction to pressure regulators and shut off the flow of water into a storage tank at a preset level to avoid overflow.

Check valves allow flow of water in one direction only. Both horizontal and vertical check valves are available. They are sometimes used to allow flow into but not out of a booster area.

Booster stations

Booster stations can increase water pressure in areas with high elevations. They are also used to increase pressure or volume at remote points on a system where friction loss has reduced the pressure below the required minimum. In such cases the booster station substitutes for larger mains or elevated storage.

The capacity of booster stations should provide a peak flow for at least 200 minutes in rural areas. A collector tank for equalizing storage should be sized with a 30-minute minimum detention time for chemical contact, based on the difference of influent and effluent.

Providing a bypass around the booster station allows maintenance crews to switch to temporary facilities during repairs. Chlorination equipment might be required to maintain adequate chlorine residuals beyond the booster station. Hydraulic calculations should be run to determine peak flows and fill conditions.

Construction

Plan all phases of construction before beginning. Pre-construction planning should include:

- locating other utility lines
- staking line and grade
- determining material quantities
- acquiring all necessary materials and tools, equipment and personnel
- obtaining safety equipment such as barricades and signs
- securing property easements and permits
- arranging temporary service if interrupting utility services becomes necessary

Installation

Pipe installation should comply with AWWA and industry standards of good workmanship. Inspect all materials before installation. Do not open the trench very far ahead of the pipe laying crew. Take care to close as much of the ditch as possible, and plug the ends of the pipes when stopping work.

Lower – never roll – pipes into the trench to prevent damage. Provide continuous, uniform bedding. Six inches of bedding and cover material above and below the pipe must be free of stones and debris. The trench depth must allow for at least 30 inches of cover over the main.

Use ductile iron pipe or pipe protected by steel casing for water lines crossing ditches and streams with less than 30 inches of cover. Provide adequate support and anchorage on both sides of the ditch. Protect PVC crossing roadways with steel casing. To allow for future expansion, casing size two diameter sizes larger than the pipe is recommended.

Install flushing hydrants on all dead end lines, and low areas — in any place that might require flushing.

Pressure and leak testing

In all installation of major length mains, perform a thorough hydrostatic and leakage test that conforms to the current AWWA Standard C600, Section 4. Pump water into the test section under pressure at least 50 percent greater than the normal operating pressure. Maintain pressure for at least one hour, and check the line for leakage.

Disinfection and bacteriological testing

After completing construction and pressure testing of the water distribution lines, flush and disinfect lines, using at least a 50 mg/l free chlorine solution for 24 hours or as described in the latest revision of AWWA C651. Large volume disposal of chlorinated water into streams or ditches might require dechlorination or a special permit from the Department of Environmental Quality.

Swab pipe fittings, clamps and sleeves with a concentrated chlorine solution before installation. Several methods are available for introducing chlorine into the pipe for 24-hour retention. One method is to place a small quantity of sodium hypochlorite in each joint. A more common and effective method is to pump a solution of chlorine and water into the main. Feed any of the following into the main, prepared in a one percent water solution (10,000 ppm):

- calcium hypochlorite, available as a commercial product under such names as HTH, Perchloron, and Pittchlor
- chlorinated lime, also called chloride of lime or bleaching powder
- sodium hypochlorite, liquid bleach

The amount required to make a one-percent solution depends on the chlorine content of the compound.

Introduce the disinfecting agent into the main through a corporation stop at the top of the pipe where the new line begins. Water from the existing system or another suitable source should flow into the new pipeline during chlorine application. Adjust water flow and chlorine mixture proportion so that the chlorine dosage will be no less than 50 ppm. Hold chlorinated water in the main for at least 24 hours and make sure there is at least a 10 ppm free chlorine residual at the end of the period.

Treated water should stand in the pipeline for at least 24 hours. During this time, operate all newly installed valves.

Flush mains until the chlorine is at normal concentration, 2 mg/l. The contractor shall then arrange for a representative of the state regulatory agency, the registered professional engineer in charge of the project, or the certified operator to collect at least one microbiological water sample from every deadend line and every major looped line. The samples go to the state laboratory or a laboratory certified by the state for analysis. All the chlorine should be gone after disinfection. The sample analyzed can contain no coliform bacteria. If the sample does contain coliforms, the disinfection procedure must be repeated.

Maintenance

The water works operator's first consideration always must be safety of customers' water. Waterborne diseases transmitted by bacteria are the greatest safety hazards, reinforcing the importance of bacteriological testing at regular and frequent intervals. The most important place to test the water is at the point of use.

The compliance section of this manual explains exactly how many routine samples are required each month and the procedure for collecting these samples. Check chlorine residuals routinely at the ends of the lines to ensure an adequate chlorine residual throughout the distribution system.

Many other components of the water distribution system require routine maintenance and performance checks:

- prv's - monthly
- valves - annually
- hydrants - biannually

Read meters as often as necessary and calibrate annually.

Flushing water mains regularly prevents the majority of customer complaints. High-velocity flushing of mains:

- removes sediments — sand, silt, iron deposits and stagnant water
- eliminates hydrogen sulfide odor
- maintains consistent chlorine residuals

Before flushing, get a current layout map of the distribution system that shows the location of all lines and valves. Valves and fire hydrants must be functional and located at all low spots and dead ends. Notify customers when to expect flushing.

Rules for flushing

1. Do not flush a large main from a single smaller one – the volume available is usually insufficient to flush the larger one.
2. Be careful not to shut down an area or main inadvertently. This can be a problem when working around mains already flushed and left isolated from unflushed mains.

3. Never reduce pressure at a fire hydrant to zero when services are connected to isolated mains behind it. Open the hydrant fully for only long enough to stir up the debris, then throttle the flow back to maintain a pressure of approximately 20 psi in all part of the distribution system.
4. **Caution**: Throttling operations should use the hydrant auxiliary valve rather than the hydrant itself so the hydrant barrel drain is not opened, which would allow water under pressure to escape into the ground at the base of the hydrant.
4. Do not proceed from the last flow at a given fire hydrant until "slugs" of discolored water have been removed from junctures with mains previously flushed. Open controlling gate valves while the last flow is ending.
5. Avoid opening or shutting hydrants rapidly to avoid water hammer.
6. Do not leave an area practically shut down overnight, as fire protection may be severely impaired. Try to schedule work so that each zone can be completed by the end of the day or at a natural stopping point requiring a minimum number of valves to be open for the night. Conversely, do not forget to shut them down again in the morning when flushing is resumed.
7. Avoid damage to streets or lawns. Direct the flow from hydrants into the wheel of a truck or devise an energy dissipater.
8. Be certain that valves are holding and that the flow of water is coming from the expected source only. A momentary shutdown of the source, with a relatively small flow before the hydrant is opened all the way, will help achieve this. Often, by listening to a valve key installed on an underground valve, tell-tale sounds of water running through a valve can be detected.
9. Mark closed valves on a map, and erase the marks when the gate valves are reopened. This procedure has proven effective in preventing some of the previously mentioned problems.
10. Watch out for construction projects or open manholes. The consequences of neglect can be extremely serious.
11. Be sure that all water contributing to a flow comes from cleaned areas or from mains large enough to resist being stirred up by the flow.
12. Remember to notify those customers who might be inconvenienced by reduced pressure or dirty water. This category would include hospitals, restaurants, laundries, and establishments with boilers, large air conditioners, or similar equipment.
13. Always match the flow to the pipe size. Usually a wide-open fire hydrant will provide adequate velocity. Flush taps must be of sufficient size to flush the main they are on. The necessary velocity can be determined by observing the pressure drop at start of flow and relating it to length and size of the main, using a simple hydraulic slide rule.

Leaks

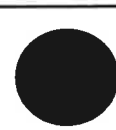
Check water mains for leaks routinely, especially during dry season. To develop a leak detection program, install master meters on the wells. Make sure all services are metered accurately.

Perform visual inspections of drainage ways during dry seasons. Look for unusual water flows in creeks, storm sewers, and sanitary sewers.

Close off a portion of the system that has a single source of supply. Measure all water into the area for several days. Read meters of customers in that area for that period.

Sound detection devices can pick up minute sounds and vibrations from the soil at a considerable distance from the leak. Equipment can range from a simple rod driven into the ground or placed against a pipe to modern electronic devices.

Table 9-3
Water loss versus pipe leak size

Size of leak*	Water loss per day (gal)	Water loss per month* (gal)
	360	11,160
	3,096	95,976
	8,424	261,144
	14,952	463,512

*Based on about 60 psi pressure

Repairing leaks

Every water main break is an emergency. Establish an action plan to deal with main breaks. Keep repair parts always available, including:

- excavating equipment
- ditch pumps, pipe cutters
- air compressors and pavement breakers
- emergency lighting equipment
- a complete stock of repair clamps, sleeves, extra pipe and fittings of all sizes
- all types of hand tools
- barricades with warning lights

The severity of the emergency is more directly related to the size of the pipe than the quantity of the leak. A small leak on a large pipeline in soft soil may become a major emergency before the valves can be closed. Repair it immediately if the leak is serious or in an area where it could quickly do extensive property damage.

The first step to repair a main break is to find all the valves necessary to stop the flow of water at the break. Close all but one — unless water flow from the break is causing excessive property damage. A limited flow of water makes it easier to find the exact location of the break as digging equipment exposes the pipe. Once the pipe is exposed, determine the method of repair and the supplies needed.

Notify all customers who will be without water, especially:

- buildings with sprinkler systems
- water cooled refrigeration units
- industrial water users
- hospitals and nursing homes

Ask customers not to draw water during the time it takes to repair the break. If pressure is reduced below 20 psi during repair, the system must issue a boil water notice to all affected customers. The notice is in effect until clear bacteriological samples have been collected.

All precautions taken during construction also apply when making a major repair — disinfection, testing, backfilling, and clean-up. Keep enough trained personnel always available to handle most emergency repairs.

Three or more breaks in 1000 feet of main suggests that replacing is more economical than repairing the main. If corrosion caused the breaks, replace with a less corrosive material or a material protected from corrosion. The most common place for leaks are joints, which are the weakest points in the distribution system.

Where the main is on one side of the street and the meter on the other, with a leak under the pavement, replacement of the service line is more economical than a pavement cut.

Customer complaints

The most common cause of water discoloration is when increased flow agitates sediment in the bottom of mains. This happens:

- after breaks
- after fires and fire hydrant tests
- following minor flushing of mains
- during the first of heavy consumption days in the summer, especially in areas where irrigation is common

The only cure is periodic, regular flushing. Anything short of full scale flushing of the system only transfers the problem from one area to another. A sudden rash of consumer complaints concerning pressure and water quality could be the first warning of an unreported break in a major pipeline.

The operator sometimes encounters black water that has a rotten egg smell when flushing hydrants or dead end mains. Hydrogen sulfide in the main causes this odor.

Sediment can cause customer complaints about black water. If the system has black discoloration on the pipe, manganese deposits inside the pipe probably is the cause.

Oxidized iron bacteria or iron from unlined steel or cast iron pipe causes red water. Iron leaves rust spots on laundered clothes. Occasionally, a customer's unlined hot water heater is the source of a red water complaint. Iron pipe on the customer's premises is another source, if it has not been flushed out recently.

Changes in velocity and direction of flow in the system most often cause dirty water. When new mains are placed in operation and especially when a line is looped, the direction of the flow changes and stirs up sediment in the pipe. Repeated large-scale flushing over a period of months eliminates this problem. Flushing keeps sand or calcium carbonate scale from being carried from the whole system into a few isolated areas. These sediments stop up meters and cause many industrial problems.

Finished Water Storage

Hydropneumatic (pressure) tanks

Purpose and function

Pressure tanks are used where elevated storage is not economically feasible. The primary function of pressure tanks – or hydropneumatic storage – is to provide a reasonable pump cycle time. A secondary function is to provide chlorine contact or detention time before the water enters the distribution system. Therefore, pressure tank volume cannot be classified as storage since no reserve water or fire protection is provided.

As an example, a 10,000-gallon pressure tank only provides about five to six minutes of "storage" for peak flows on a system with 250 meters, depending on the pressure range and location of the air volume controls. This amount is insignificant when compared to elevated storage volumes.

Pressure range

Obviously, the total volume of a pressure tank is not available as usable storage. Only that amount of water between the pump "on" and "off" levels in the pressure tank is available storage. These water levels correspond to an operating pressure range above which the pressures in the lower elevations of the distribution system might become excessive. Below this range, the pressures on the distribution system are likely to fall below safe levels.

Ideally, the pressures on a water distribution system should not fluctuate. Fluctuation might promote leaks and cause deposits on pipe interiors to break loose and get in the water flow. A large pressure fluctuation is necessary on a pressure tank system, however, to provide a reasonable period of pump operation each cycle.

Consider the pressure tank mentioned above with a volume of 10,000 gallons on a system with 250 customers. A 250 gallon per minute well is required to meet peak demands. The well controls are set up to allow a 15 psi pressure range. Depending on the location of the air volume controls, this allows only 1,200 to 1,500 gallons of water to be used out of the tank before the pressure drops from 60 psi to 45 psi, at which point the well starts up again. This 15 psi pressure range is equivalent to a drop in the water level in an elevated tank of approximately 35 feet. This is greater than the total head range of many average-sized elevated tanks.

A typical elevated tank control system would allow a head variation of six inches to five feet before calling for a well. This would depend upon a number of factors including the number of wells controlled by the tank.

Pump cycles

A long pump cycle minimizes pump and motor wear and electricity consumption. As with an automobile engine, a high rate of wear occurs in the initial seconds and minutes that a service pump or well pump operates.

Start-up is a critical time for a water-lubricated, vertical turbine pump. Unless the pump is properly pre-lubricated, significant wear occurs until pumped water reaches all the shaft bearings. Inadequate pre-lubrication can severely shorten the life of the line shaft bearings. Also, worn-out bearings can significantly reduce the capacity of the well pump due to the added resistance to rotation.

Starting currents for an electric motor can be as high as six to 10 times the run current. Therefore, the fewer times a motor starts, the more efficient is its electricity usage. High currents also shorten the life of the motor windings and control components.

The example tank would allow pumping 1,200 to 1,500 gallons into the tank for a consequent pressure increase from 45 psi to 60 psi each cycle. The 250 gpm well will pump this amount in five to six minutes. As some water usage could be expected during this time, pump cycles would normally be longer. Even so, this is a very minimal pump cycle. Maintaining a pump cycle as long as is practical is recommended.

Water levels

The value of a pressure tank lies not in the total volume of water it contains but in the volume it can deliver between the on and off pressure of the pump. Therefore, the objective is to maintain as much air volume as is practical to provide an air cushion to compress with stored water. The low water level is limited by the possibility of air becoming entrained by a vortex (whirlpool) and mixing with the water leaving the tank. A practical guide is to maintain the low water level at one-third of the tank diameter measured from the bottom.

An argument opposed to this practice maintains that air is less likely to become entrained in the distribution system during temporary power outages if the water is maintained at a higher level. This is a nuisance to customers. However, a properly sized and located air volume control will release the air if the water level falls too low.

The previous example would place the water level at 45 percent of the tank diameter when the well switches off. This corresponds to about 1,400 gallons of water pumped. With the same pressure range, but with the 45 psi "on" pressure at one-half of the tank depth, about 1,000 gallons of water is pumped before the well switches off.

Obviously the former would prolong pump life. With the minimum water level at one-third of the tank depth as opposed to one-half of the tank depth, approximately 40 percent more water is pumped each cycle.

Even so, a minimum pump cycle of less than six minutes is less desirable than an elevated tank system. An elevated tank 26 feet in diameter would allow a minimum run time of over 30 minutes with the controls set up to start a 250 gpm well when the water level drops two feet.

This change in the water level corresponds to a pressure differential of less than one psi. Peak flow would produce a greater differential.

Size

Pressure tank size depends upon the capacity of the pump. To provide a reasonable cycle time, the capacity of the tank in gallons should be at least 40 times the well or pump capacity in gallons per minute. Where the pressure tank is used only to suppress surges and the well or service pump pumps to a distant tank, the size depends on other factors and could be larger or smaller than this guideline.

Appurtenances

Recommended Minimum Design Criteria for Community Public Water Supplies (RMDC) suggests that appurtenances such as bypass piping be installed on pressure tanks. A number of other necessary appurtenances are included in the following table.

Table 9-4
Appurtenances needed on pressure tanks

1. Access manhole
2. Drain
3. Pressure gauge
4. Water level sight glass
5. Air release valve
6. Provision for adding air
7. Pressure operated pump controls

In addition, an adequately sized pressure valve is needed as protection against excess pressure.

Locate and size the tank bypass so the system can operate while the pressure tank is isolated for repair. The chlorinator booster pump suction line or the pressure source for a solenoid-controlled chlorine ejector should be tapped into this bypass line to maintain a flow through the line and to prevent stagnation. Inlet and outlet piping should be designed to cause the water to flow through the entire length of the tank.

An adequately sized drain permits the tank to be flushed or drained in a reasonable period of time. Fit the drain with an elbow for horizontal discharge. A drain must not be directly connected to sewers or storm drains to avoid a cross connection between the water supply and contaminated water.

Locate the manhole on the lower portion of the tank and make it big enough for easy access. RMDC recommends an 18-inch diameter manhole, although 18 inches by 24 inches might be more practical.

A pressure gauge is of questionable integrity unless it is checked regularly. Therefore, locate a valve to allow isolation of the gauge for testing and replacement.

Provide the pressure tank with an adequately sized pressure relief valve. Set the valve at a few psi above the maximum operating pressure to protect the tank in case controls fail.

Air volume controls

Automatic air volume controls replenish the air lost into the water due to absorption under pressure. The amount of absorption depends upon such factors as:

- pressure
- temperature
- surface area

- water usage

Therefore, the amount of air needed to maintain a constant water level range is variable. Air volume controls usually consist of some way to add more air than actually needed and an air release valve to release the excess. These can be installed separately or combined into one unit. An air release valve can be installed in either of two ways:

- mounted on the end of the tank
- mounted on the top of the tank with a drop pipe extending down into the tank

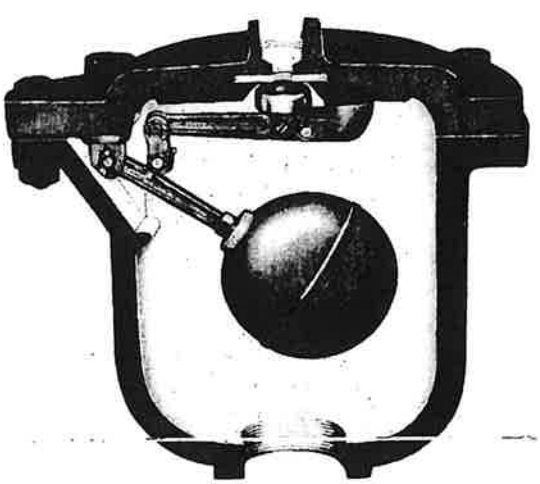
The air release valve should be large enough to bleed off excess air quickly so the pressure inside the tank drops to the "on" pressure of the pump when the water level drops below the air release valve entrance pipe. If mounted on the end of the tank, the air release valve should be tapped at one-third of the tank diameter as measured from the bottom.

If the valve is mounted on the top of the tank, a drop pipe should measure two-thirds of the tank diameter in length. The bottom of the drop pipe or the tap on the end of the tank to which the air release valve is attached will mark the minimum water level in the tank.

Two general types of air release valves are commonly in use. One is completely enclosed in a housing with an inlet at the bottom and an outlet at the top. Figure 9-13 shows a cut-away view of this type of valve.

Figure 9-13
Crispin type N pressure air valve

A float actuated lever inside the unit operates the valve so it releases air under pressure. Water rising inside the unit carries the float upward, closing the valve.



Another type works on the same principle but is installed so the float is actually inside the tank. This type of valve is not obvious from a distance.

Advantages to the exterior-mounted valve:

- It can be positioned on the end of the tank or on top of the tank with a drop pipe.
- It can be valved off and repaired without taking the tank out of service.

These valves require maintenance or replacement from time to time. A water level lower than normal indicates the valve is clogged.

Several proprietary devices on the market combine air volume controls into a single package. Pressure relief, electrodes, pressure switches, and a water level sight glass can be included in the unit.

The source of the air could be an air compressor, the well itself, or a hydraulic device using water pressure to pressurize air and inject it into the tank. A hydraulic device mounts directly on the tank and has a water tap and an air tap.

When the water level exceeds a certain point in the tank, the device periodically drains out on the ground, drawing in atmospheric air, and refills with water from the tank under pressure. This injects the trapped air into the pressure tank. The cycle is repeated until the water level in the tank drops to a preset level.

The controls for the air compressor can be integrated with the well or service pump controls. A simpler method uses a timer to operate the air compressor a few minutes each day. Since only a small amount of air is needed, a small air compressor of 0.5 cubic feet per minute capacity is usually satisfactory. A compressor tank is unnecessary since the compressor is pumping into the pressure tank.

A well that pumps directly into a pressure tank can be used to slug air into the tank with each cycle. This method requires an air check valve on the vacuum relief vent (which should be screened) to the well discharge line. The valve allows air to enter the pump column when the water level returns to the static level upon well shut-off.

At the beginning of each cycle, this air is discharged into the pressure tank. The operator should take care to tap the chlorinator booster pump suction line into a point beyond the pressure tank or on the bypass line to prevent air binding the booster pump.

This method injects more air than necessary into the pressure tank, depending upon the frequency of the well cycles and the depth to the static water level. Air volume should not cause a problem if the air release valve on the pressure tank is large enough to handle the excess air. However, a globe valve that partially closes off the air release valve can bypass the air check valve. This will allow some of the air to escape through the air release valve. Where static or dynamic well levels are either too high or too low, this method of air addition is unsuitable and might cause operating problems.

Submersible pumps usually have a foot valve at the bottom of the pump. To allow for slugging air into the pressure tank, a weep hole must be drilled in the column pipe some distance down.

An obvious disadvantage is that water also leaks through when the well is running. The hole can enlarge due to corrosion or can become plugged with encrustants. Oxygenation, chemical precipitation, screen plugging, and corrosion are often problems with this method, which is considered unsuitable.

Well or service pump controls can be pressure actuated or a combination of pressure and electrically (electrodes) actuated. Pressure controls should stop the well or service pump. A disadvantage of using probes inside the tank is that adjustment or replacement requires depressurizing the tank. The use of electrodes for both on and off controls is not satisfactory due to extreme problems of setting pressures and air volume controls.

Specifications

All welded steel tanks should conform to American Water Works Association specifications. Pressure tanks must conform to the "ASME Code for Unfired Pressure Vessels."

Elevated storage

Introduction

Elevated storage is necessary for efficient and reliable operation of a water system. Most elevated tanks either have multiple legs or a single pedestal. The advantage of the single pedestal design is aesthetic.

Locating a ground storage tank so that the elevation difference between the tank and the area it serves allows it to function as elevated storage.

The following table lists some of the advantages of elevated storage:

Table 9-5
Advantages of elevated storage

- Provides more efficient pumping
- Provides fire protection
- Provides reserve storage
- Increases the design capacity of the water system

Efficiency

An elevated tank allows more efficient use of electrical power in well and service pumps. A pump operates at peak efficiency only at a specific head, depending upon the design of the pump. An elevated tank allows a pump to operate at a relatively constant head. The operator should choose a pump that provides peak efficiency at the head conditions under which it must operate. Another advantage of elevated storage is long pump cycles.

Fire protection

A water system with elevated storage can supply some fire protection, although most rural systems are designed for domestic usage only. For a water system to provide fire hydrants with pumper connections, elevated storage as well as hydraulically adequate distribution piping is necessary. The distribution piping should supply fire flows to the hydrants while maintaining at least 20 psi in all areas of the system.

Systems using pressure tanks for storage are generally not designed to supply fire flows. The use of pumper connections on these systems can cause damage to the pressure tank and water lines. The water system also can become contaminated from low pressures, back-flow, or back siphonage.

Where hydrants have been inadvertently installed on a system not designed to handle the flows, they should be removed or larger pumper connections welded closed. Providing three-way hydrants in anticipation of adding elevated storage might be warranted, provided the pumper connections are temporarily tack welded.

Reserve storage

Elevated storage or ground storage at an elevation sufficient to provide water to the distribution system under normal pressures is reliable during emergencies which preclude the use of pumping facilities. Power outages and maintenance often take a well out of service, which would cause a pressure tank system with no back-up well to lose pressure. Elevated storage which can supply a day's average water usage greatly increases the reliability and safety of a water system.

Elevated storage increases the customer design capacity of a water system. With pressure storage, well capacity must be sufficient to supply peak demands. With elevated storage, both the well and elevated tank supply peak flows. Adequate elevated storage can, in some cases, double the number of customers that a well source is able to supply, provided the distribution system is designed to handle the flows.

Standpipes are frequently used as a form of elevated storage on rural systems. A standpipe is usually cheaper to build than an elevated tank the same height. The total volume of a standpipe cannot be considered as available storage. However, RMDC recommends that the maximum variation between high and low levels in storage structures providing pressure to a distribution system should not exceed 30 feet. Therefore, for a 100,000 gallon standpipe which is 80 feet tall and 15 feet in diameter, only the top 25 feet, or about 33,000 gallons, should be considered elevated storage.

Size requirements

The required size of an elevated tank depends upon such factors as:

- the total and projected number of customers
- whether fire protection is to be supplied
- average and maximum water usage data

According to the RMDC, systems without fire protection should provide an elevated storage volume equal to 50 percent of the average daily water usage. The Mississippi State Rating Bureau Fire flow requirements should be satisfied where fire protection is provided.

Appurtenances

Elevated tanks, as well as standpipes and ground level reservoirs, should have vents. The vent construction should keep out birds, insects, dust, and other contaminants.

The tank should have some provision for draining, but not a direct connection to a sewer or a storm drain. All water tanks should provide an overflow pipe sized to permit an overflow in excess of the filling rate. The overflow should be visible, with a splash pad to prevent erosion.

A water level gauge must allow daily inspection of the water level in the tank. A float and indicator-type gauge should be installed on all elevated tanks and standpipes unless pressure sensors are used to send a signal to a remote monitoring panel. Remote sensors are especially useful in systems with multiple elevated tanks.

Pump controls

Pump controls operate in conjunction with electrodes in the tank or a pressure sensor, usually a mercury switch. Information on the water level in a remote tank is transmitted to the wells or service pumps via telephone wire or radio signal.

Electrodes

Electrode systems complete an electrical circuit through the water between two submerged electrodes. The electrolytes dissolved in the water complete this circuit, which energizes a relay to stop a pump.

The voltage depends on the configuration and number of electrodes and the conductivity of the water. Due to the different chemical characteristics of waters and the different conductivities, each electrode system must be tailored to the particular application.

An electrode system for a single pump control requires a minimum of three electrodes. The top electrode is at the "stop" position, the middle electrode is at the "start" position, and the bottom electrode is the ground.

An additional pump may be controlled by one additional electrode located below the first "start" electrode. The first pump begins pumping when the water level falls to the first "start" electrode. If the demand is greater than this pump can supply, the next pump comes on when the water level falls to the second "start" electrode, and so on for each pump. The sequence should rotate to achieve equal wear on each pump.

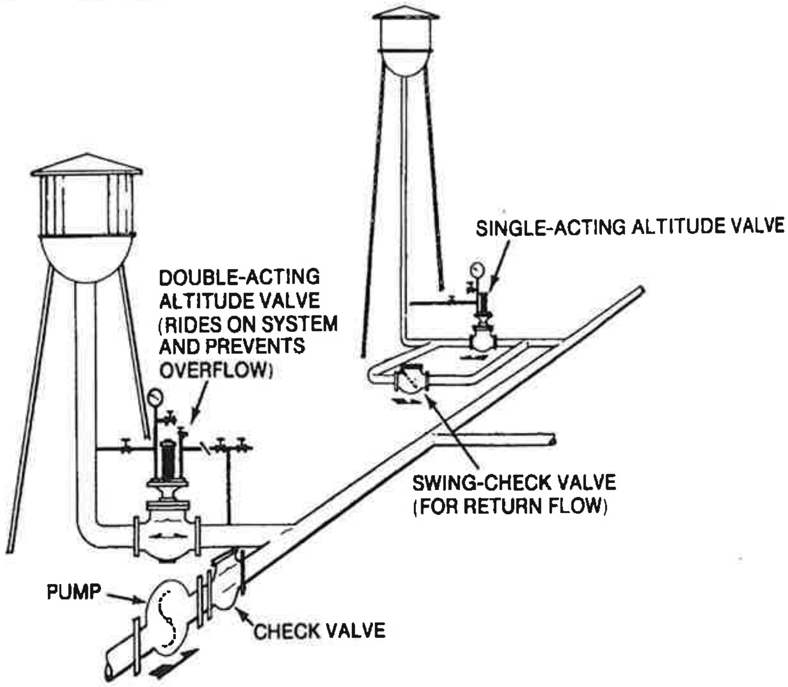
As an alternative control, wells can operate in groups, allowing widely spaced wells to operate together. Electrodes could be placed inside a stilling pipe to prevent rapid cycling due to waves.

A ground-level storage tank connected to a service pump suction line must have a low level electrode.

The electrode is located just above the suction line so the service pump stops if the water level drops to this level, preventing air binding damage to the pump. Advantages of electrode controls are economics and simplicity.

Pressure controls

A pressure-type control system can be designed to perform the same function as electrodes. Design of the pressure sensor can enable continuous monitoring of the water level. Other advantages to this type of control system are accessibility and adjustment ease.

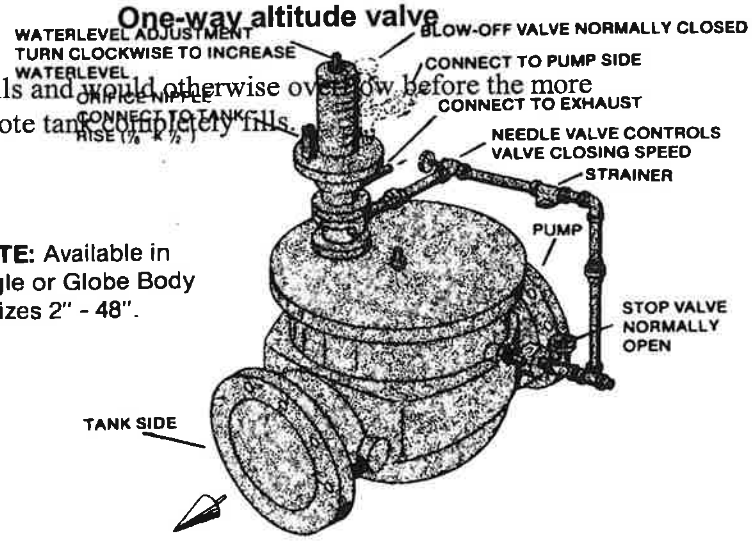


Altitude valves

Multiple tank systems should use altitude valves. This type of valve allows water to flow in and out of a tank but prevents overflow if higher pressures develop. When properly adjusted, this valve will maintain a uniform maximum water level within a three-inch to 12-inch range. Figure 9-14 shows a typical one way altitude valve.

An altitude valve is located on the tanks whose overflow elevations are lower than the tank which controls the wells; or on tanks which are closer to the wells and would otherwise overflow before the more remote tank completely fills.

Figure 9-14
One-way altitude valve



NOTE: Available in Angle or Globe Body in sizes 2" - 48".

Figure 9-15
One-way and two-way altitude valve arrangements

In operation, an altitude valve senses the pressure at the base of the tank and closes at a preset pressure which should correspond to the height of water to the overflow level. There are one-way and two-way altitude valves. A two-way valve allows flow in either direction, while a one-way valve allows flow in one direction only. Water flows through the valve to fill the tank but flows out of the tank through a bypass with a check valve. Diagrams of the two types of valves are shown in Figure 9-15.

The size of the altitude valve and the bypass piping is an engineering consideration that depends on the function of the valves and the flow conditions to which it is to be subjected.

Maintenance on altitude valves is usually uncomplicated and can be handled by the trained operator. As with other equipment, diagrams, maintenance instructions and specifications furnished by the supplier should be kept on file for reference. Table 9-6 is a list of malfunctions and their possible causes.

Table 9-6
Altitude valve malfunctions and causes

1. Tank overflow
   a. Improper spring adjustment
   b. Diaphragm control pipe not correctly piped to tank riser, base of tank, tank discharge or fill line to assure a uniform static head on the diaphragm
   c. Valve placed too far from tank
   d. Sediment accumulating on diaphragm or parts becoming clogged in main valve or pilot valve
   e. Piston sticking, or valve rod sticking if disc or cone seat is used
   f. Seat ring worn out
   g. Obstruction preventing seating of valve
2. Valve leakage – It is normal for some valves to have a momentary leakage at the exhaust port each time the valve opens. Constant leakage indicates a malfunction.
   a. Pilot exhaust valve does not seat properly
   b. Pilot cup needs replacing
   c. Diaphragm needs replacing
3. Water hammer
   a. Valve closes too fast – needle valve on control line needs throttling
   b. High velocity flows through the valve causing pulses of pressure on the diaphragm – valve undersized. Replace valve with appropriate size.
   c. Incorrect diaphragm control piping
   d. Valve installed too far from tank

Accessories

Standpipes in remote areas are usually controlled either with an altitude valve or with a float valve. The float valve is located at the top of the tank and shuts off the fill line when the water level reaches the float. The fill line is often restricted with an orifice to reduce the flow to a predetermined rate. The tank is sized to provide a day's storage for the area it serves. The tank refills over a 24-hour period at a low rate to avoid creating low pressures during periods of peak customer demand.

Keep access hatches on storage tanks locked to prevent unauthorized entrance. The hatch should consist of a frame extending at least six inches up from the top of the tank with an overlapping cover that extends down two inches on each side. Locate the access hatches adjacent to the electrode holder, water level indicator, or float valve to facilitate maintenance.

Tank coatings

Among the numerous acceptable coatings for water storage tanks, three prominent types are epoxy, vinyl, and zinc. Due to toxicity of certain organics in drinking water, avoid coal tar-based interior coatings. Asphaltic coatings, which are a petroleum derivative, should also be avoided. To prevent the possibility of unacceptable levels of lead leaching into the water, don't use lead primers for tank interiors.

The fact that a paint system has been placed on an "approved" list by the National Sanitation Foundation (NSF), the American Water Works Association, or other organization should not be the sole basis on which it is judged. These lists only indicate that compounds used in these coatings have not been shown to be toxic when applied properly. Listing does not mean that the coating is ideal for any application, though it might be acceptable in a specific situation. As an example, the materials in soft, wax-type coatings are compatible for use in water storage reservoirs, but these coatings do not provide a durable, lasting barrier to corrosion.

An elevated tank represents a dollar investment that warrants considerable expertise and planning. A qualified, registered professional engineer should prepare specifications on all materials and methods to be used.

The tank coating should give the most economical protection afforded. The Steel Structures Painting Council (SSPC) develops and promulgates standards for cleaning and painting steel materials. The American Water Works Association has standard specifications and recommended practices for painting elevated tanks, standpipes, and steel reservoirs.

Surface preparation

The degree of surface preparation depends upon the condition of the tank. Deteriorated surface conditions can be categorized in four main classes.

- Paint is almost completely intact. Some primer may show. Rust covers less than 0.1 percent of the surface.
- Finish coat somewhat weathered; primer might show a slight staining or blistering. After stains are wiped off, less than one percent of the area shows rust, blistering, loose mill scale, or loose paint film.
- Paint thoroughly weathered, blistered, or stained; up to 10 percent of the surface covered with rust, blisters, hard scale, or loose paint film; very little pitting visible to the naked eye.
- More than 10 percent of the surface is covered with rust, rust nodules, pits, and loose paint. Pitting is visible to the naked eye.

Class No. 1 would require a minimum amount of cleaning. The rust areas could be cleaned with hand tools and wire brushes, followed by solvent cleaning to remove grease, oil, and dirt. Spot priming and painting of rusted areas is usually enough. However, after spot priming, a complete coat of good paint might save an expensive blast cleaning and painting in a year or two.

Class No. 2 should receive the same treatment as condition No. 1. The job will take longer, but still can be done economically.

Class No. 3 requires a complete blast cleaning, priming, and painting. Hand tool cleaning of such large areas would not be practical at this degree of deterioration.

Class No. 4 should never have been allowed to happen. This degree of deterioration requires careful inspection and repair or replacement of damaged components.

Power tool cleaning should provide a better surface for priming than hand tool cleaning but is not adequate surface preparation for long term exterior exposure of most high performance coating systems. Care should prevent excessive roughing of the surface. Ridges, burrs, and sharp edges contribute to early paint failure since these areas are not protected by an adequate thickness of paint. Sandblasting provides a better surface profile to which the coating can adhere.

Table 9-7 list three common specifications for blast cleaning. Each has a particular function in the paint industry.

Neither the primer nor the top coat of epoxy paints are compatible with all other paints. Examples of incompatibility include alkyd, chlorinated rubber, oleoresins, vinyl, and oil based coatings. This incompatibility causes blistering and peeling.

Table 9-7
Blast cleaning specification

1. White metal blast cleaning – used in very corrosive environments.
2. Near white blast cleaning – 10 to 35 percent less expensive than white metal blasting and very satisfactory for general use in moderately corrosive environments.
3. Commercial blast cleaning – lowest in cost. This method is sufficient for the majority of jobs. When using epoxy paints, this method is usually sufficient for all new surfaces or mild environments.

Epoxy finishes tend to become chalky and lose gloss when exposed to sunlight. However, if loss in film thickness is negligible, its sealing and protective qualities are undamaged.

Tank isolation

Properly cleaning and repainting a water storage tank involves coordination between the contractor and the water superintendent so normal water service is uninterrupted. To bypass a pressure tank or elevated tank requires special provision to maintain pressure on the system. This usually means operating the well in the manual mode, while wasting water to prevent excessive pressure.

Flushing hydrants at the ends of lines is not satisfactory for pressure relief due to:

- differences in elevation
- the presence of pressure relief valves
- pressure drop due to friction

A diaphragm-type pressure sustaining valve is best to maintain normal pressure at the site of the bypassed tank. The valve should be sized to handle the full flow of the well.

From late night to predawn, when there is virtually no consumption, the total well output goes to waste. The well must not be switched off during these hours, since low and negative pressures allows possible back siphonage of contaminants. As the water demand increases, the valve senses a drop in pressure and begins to close. Then all the water, if necessary, is pumped into the system at normal pressures.

The location of the pressure relief valve in relation to chemical feed points is important. The application point of any chemical should be upstream of the valve to prevent variations in concentration of the chemical in the water entering the distribution system.

As an example, consider an elevated tank which needs repainting and is 119 feet high to the overflow. The well is 300 gpm and the **nearest** fire hydrant is 100 feet away but 20 feet lower than the tank foundation. The maximum static pressure at the fire hydrant is 119 feet + 20 feet = 139 feet, or 139 feet x .433 psi/foot = 60 psi. A pressure sustaining valve is selected which will discharge 300 gpm under 60 psi of pressure without exceeding the maximum recommended velocity of water through the valve. The valve is then attached and adjusted to maintain 60 psi pressure at the fire hydrant. The well operates on manual mataining normal system pressures.

Maintenance

Ground level storage tanks are frequently constructed of concrete. Concrete tanks require little maintenance except for hatches, vents, overflows, controls, and other appurtenances which may deteriorate in a corrosive environment. For safety the surface of these tanks should be sloped to drain.

Hairline cracks can develop into sizeable leaks, especially if the water is not stabilized in relation to corrosion control. These leaks should be repaired with an epoxy material. Some companies advertise the advantage of sub-surface applications of their products.

Any tank, concrete or steel, ground level or elevated, should be inspected inside and out on a schedule by a competent, unbiased inspector. Tanks require adequate ventilation because the oxygen supply inside the tank can become depleted. Also recent coatings can cause fumes.

Inside surfaces of water tanks are usually in worse condition than the exterior. Almost all tank bottoms that must be replaced have corroded through from the inside. Neglect in cleaning out bottom sediments can cause the leaks. The inside of tanks must be painted as often as the outside. If the water is corrosive, the inside probably needs painting more often.

Cathodic protection for steel elevated tanks

The corrosion of various metals involves an inherent flow of electrical current. Current in the form of positive metal ions flows away from an area of a steel tank through the water to another area of the steel surface.

The point where the current leaves the metal is called the anode. The water serves as an electrolyte. The point where the current enters the metal is called the cathode. The metal tank completes the circuit.

Current leaving the anodic area carries metal into solution. Approximately 20 pounds of steel per year is destroyed for each ampere of current. An accelerated rate of attack in specific areas causes pitting.

Corrosion is classified as galvanic, electrolytic, or chemical in nature. Galvanic corrosion is the result of the joining of dissimilar metals. This causes corrosion of the anodic metal and protection of the cathodic metal. Slight, localized differences in the steel surface and/or the electrolyte can cause the galvanic corrosion of steel tanks. This causes certain areas to act as anodes and become corroded while other areas act as cathodes.

Electrolytic corrosion is a result of stray electric currents produced by an external source. Sources of stray currents include:

- electric railways
- grounded direct current power
- electric welders
- cathodic protection systems for electroplating plants

A chemical reaction between steel and substances in the water – such as carbon dioxide and hydrogen sulfide – cause chemical corrosion. Regardless of the cause, corrosion occurs only at the anodic areas at any specific time. These areas can change due to the buildup of scale or sediment or due to localized variations in the water chemistry.

Sacrificial anodes substituted for the anodic areas of the tank can prevent corrosion. The facility must be electrically isolated to provide adequate protection from corrosion due to stray currents.

Direct current source wired to anodes within the tank provides cathodic protection. The power supply impresses a DC voltage on the anodes, which discharge current into the water. The current completes the circuit by flowing through the water to the tank structure and back to the power supply. Thus, the entire tank becomes cathodic, and corrosion only occurs at the sacrificial anodes.

Anode materials include iron alloys, aluminum, and platinum. Aluminum anodes require annual replacement. Long life anodes are made from various alloys.

The selection of the anode material, power unit, and positioning within the tank are among the design parameters. These parameters depend on:

- the structure dimensions
- coating characteristics
- water chemistry

Therefore, each system must be custom designed. Modern automatic systems do not require owner adjustment. A cathodic protection current is continually applied and automatically adjusted to suit changing water levels, temperature, and coating effectiveness. As a result, optimum protection is achieved while avoiding the costs of over-protection.

Cathodic protection does not limit the need for high quality coatings on tanks. Protection only affects the areas of the tank that are in contact with the water. Portions of the tank bottom that are covered by silt are not protected.

Where properly installed and maintained, cathodic protection systems are an economic alternative to frequent repainting. The systems are widely used in water storage tanks, water treatment equipment, deep wells, and other costly water works structures. The cost of cathodic protection runs less than one-third of the re-coating costs, according to a report on an installation using platinized niobium anodes.

Conclusion

Water storage tank construction, maintenance, and repair is a complex subject for which there are no textbook answers. Some of the more important items were discussed in this chapter. This chapter is not intended to be definitive, only to shed some light on an often abused and neglected part of water system operation and maintenance.

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Sample questions

1. Dirty water is most often caused by changes in _______________ of flow in the system.

2. When repairing a leak, if the pressure falls below ____ psi the system should issue a boil water notice.

3. High velocity flushing of mains will:
   a. remove sediments
   b. remove stagnant water
   c. eliminate hydrogen sulfide odor
   d. maintain consistent chlorine residuals
   e. all of the above

4. The most accurate way to measure system leaks is:
   a. visual inspection of drainage ways
   b. sound detection
   c. installing master meters on wells and meters for each service connection
   d. witching rod
   e. close portion of system, measure water into area

5. Chlorine tests should be run______________ to be sure that there is an adequate chlorine residual throughout the distribution system.

6. After disinfection of a system one of the following except the ______is required to collect at least one microbiological water sample at every deadline and every major loop.
   a. A representative of the Mississippi State Department of Health.
   b. The registered professional engineer
   c. The contractor
   d. The certified operator.

7. Water mains should be laid at least ___ feet horizontally and/or ___ inches vertically above any sanitary sewer or manhole.

8. Select reasons for providing water storage within a distribution system.
   a. equalize supply and demand
   b. increase operating convenience
   c. level out pumping requirements
   d. provide water during source or pump failure
   e. provide water to meet fire demands
   f. provide surge protection
   g. increase detention times
   h. blend water sources

9. The minimum main size for a line providing fire protection is ____ inches.
   a. 4
   b. 6
   c. 8
   d. 3
   e. 10

10. List uses for valves.
    a. isolation
    b. draining lines
    c. controlling water hammer
    d. releasing air and allowing air into lines
    e. preventing backflow

11. List the seven appurtenances needed on every hydropneumatic tank.

12. Where should the low water level be maintained on hydropneumatic storage?

13. What are the advantages and disadvantages of elevated storage?

14. List two types of pump controls and give a brief summary of their operation.

15. When should altitude valves be installed and why?

16. What are the four main classes of deteriorated tank surface conditions and how are these conditions repaired?

17. An elevated tank that needs repainting is 148 feet high to the overflow. The well is 350 gpm and the nearest fire hydrant is 80 feet away, but it is 10 feet higher than the tank foundation. What size pressure sustaining valve should be selected and attached to the fire hydrant so that normal system pressures will be maintained during the tank repainting?

Chapter 10

Chlorination

operation and maintenance

Introduction

Chlorination ensures that drinking water is safe. Water from an approved water treatment facility should be free of microbiological contamination without chlorination. Chlorine protects against contamination from small leaks or occasional back siphonage. This chapter describes the products and procedures involved in chlorination.

Chlorine

Chlorine is available in three forms and strengths. **Sodium hypochlorite** is a liquid. An example is a household bleach, which is 5.25% available chlorine. **Calcium hypochlorite** is a solid, usually granular in texture. It contains around 70% available chlorine. **Gaseous chlorine** is nearly 100% available chlorine.

Batch chlorination

Sodium hypochlorite or calcium hypochlorite are the usual chemicals for batch chlorination of a contaminated water tank or distribution line. The volume of water to be chlorinated and the amount of available chlorine in the chlorination product determine the chlorination dosage.

Automatic chlorination

Some water treatment plants pre-chlorinate to aid in the water treatment process. Most plants chlorinate water as it leaves the plant. This provides a chlorine residual out in the distribution system. The amount of chlorine added depends on:

- volume of water pumped
- chlorine demand
- expected chlorine residual

Chlorine reacts with old, corroded pipes. The chlorine demand from this reaction reduces the amount of chlorine reaching to the ends of the distribution lines. An operator should maintain enough chlorine to ensure acceptable bacteriological water samples. A **0.5 ppm free chlorine residual** near the end of the water distribution lines is recommended. Some systems require more chlorine to maintain a 0.5 ppm free residual, and some systems require less. Because of the chlorine demand, some systems find it hard to maintain a 0.5 ppm free residual, while other systems may consistently maintain a much higher residual.

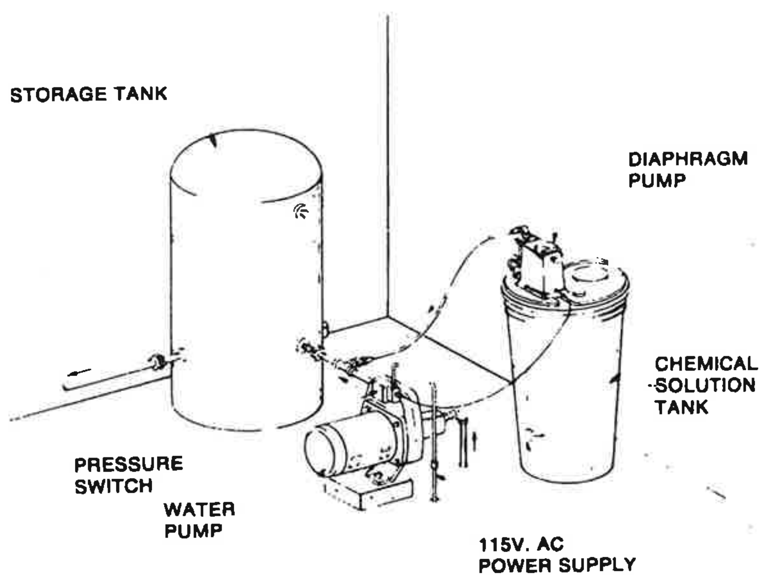


Figure 10-1 Typical installation

Chlorination with sodium hypochlorite

If a public water supply is fortunate enough to have a well that requires no water treatment, it should inject chlorine on the discharge side of the well's check valve. Gaseous chlorine is best in most cases, but sodium hypochlorite might be better for small wells with capacity of less than 50 gallons per minute. Small wells that serve fewer than 30 houses usually are not set up to handle gaseous chlorine.

For a small system like this sodium hypochlorite is purchased in a non-corrosive container or it is made by mixing (NSF approved) calcium hypochlorite with water in a non-corrosive container. The chlorine solution is then fed into the well's discharge line between the check valve and the pressure tank.

The solution is fed with an automatic chemical feed pump designed to pump the solution against the highest available well discharge pressure. The electrical controls are set to operate the chemical feed pump while water is being pumped by the well.

Figure 10-1 shows a piping diagram of a typical small chlorination system. This type of system requires daily maintenance to insure that the chlorine solution tank does not run low on sodium hypochlorite. If the operator is mixing the solution using calcium hypochlorite (which is the most economical), the operator must exercise caution in the handling and storage of the chemical. Calcium hypochlorite will explode or ignite when it comes into contact with organic materials such as oily rags.

Gaseous chlorination

Gaseous chlorination best serves a water system with a pump capacity greater than 50 gpm. The initial cost is more, but operation costs less. In a water system requiring no treatment, inject chlorine between the check valve and the water tank.

Gaseous chlorine is normally shipped in 150-pound or 2,000-pound (one ton) cylinders. Cylinders containing 150 pounds of chlorine are convenient for small plants with capacities of less than 0.5 mgd. A fusible plug is placed in the valve below the valve seat as a safety device set to melt at 158 to 165 degrees F to prevent buildup of pressure and the possibility of rupture due to a fire or high surrounding temperatures. A 150-pound cylinder has an approximate tare weight of 92 pounds. The tare weight is stamped on the shoulder of the cylinder. The 150-pound cylinders are constructed to reduce leaks at the bottom of the cylinders as shown in Figure 10-2.

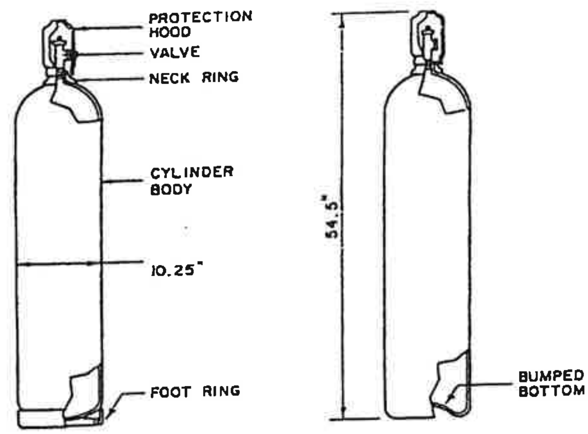


Figure 10-2 Chlorine cylinders

Do not use wrenches longer than six inches on chlorine valves. Do not use pipe wrenches or wrenches with an extension to open the valves. The valve should be opened by striking the wrench with the heel of the hand to rotate the valve stem in a counter-clockwise direction. Then it should be slowly opened one turn. If the valve cannot be opened in this manner, the packing nut should be loosened slightly and another attempt made. The valve should be opened and the packing nut re-tightened. If all attempts fail, the container should be returned to the supplier. Figure 10-3, below and on the next page, shows three valves for the 150-pound cylinder and ton cylinder.

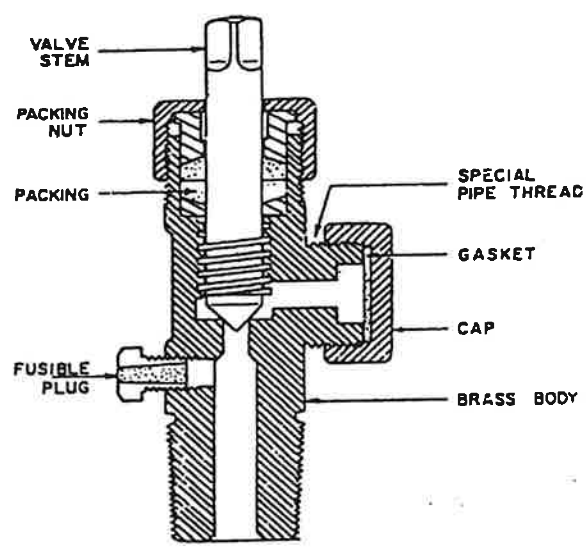
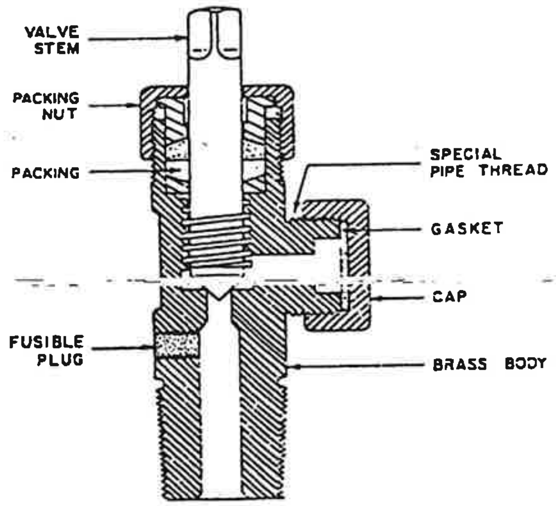
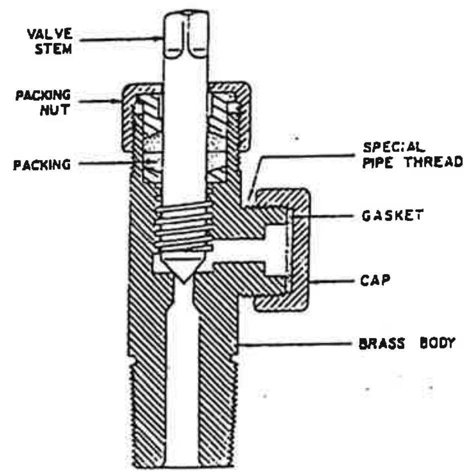


Figure 10-3
Standard cylinder valve
(screwed type fusible plug)



Standard cylinder valve
(poured type fusible plug)



Standard ton container valve

Never use organic lubricants on any part of the chlorinator system because chlorine can react violently with organic material. Observe the following safety procedures when moving cylinders:

1. Always replace the protective cap when moving a cylinder.
2. Move cylinders with a properly balanced hand truck that has supports that fasten around the cylinder two-thirds of the way up on the cylinder.
3. The 150-pound cylinders can be rolled in a vertical position. Avoid lifting these cylinders except with approved equipment. Use a lifting clamp, cradle or carrier. Never lift with homemade chain devices, rope slings, or magnetic hoists, and never lift the cylinder by its protective cap.
4. Keep cylinders away from direct heat and direct sunlight, especially in warm climates.
5. Transport and store cylinders in an upright position.
6. Firmly secure cylinders to an immoveable object when stored or in use.
7. Store empty cylinders separately from full cylinders, and label them clearly with information as to whether they are full or empty.

Never store chlorine near turpentine, ether, anhydrous ammonia, finely divided metals, hydrocarbons, or other materials that are flammable in air or that will react violently with chlorine.

Ton containers are the most common used in larger plants. This type of container holds 2,000 pounds (one ton or 1,000 kilos) of chlorine. The container itself weighs about 1,300 pounds, giving it a total weight of approximately 3,300 pounds when full. Ton containers are normally of the following construction:

- Welded steel construction with a length of approximately 80 inches and an outside diameter of 30 inches. The ends of the ton cylinders are crimped inwardly to provide a substantial grip for the lifting clamps.
- Ton containers generally have about eight openings for valve and fusible plugs. Normally two valves are placed on one end of the cylinder, along with three fusible plugs. The other end of the cylinder contains three additional fusible plugs. The fusible plugs melt at 158 to 165 degrees F., the same temperature as the ones on the 150-pound cylinder. A ton cylinder is shown in figure 10-4.

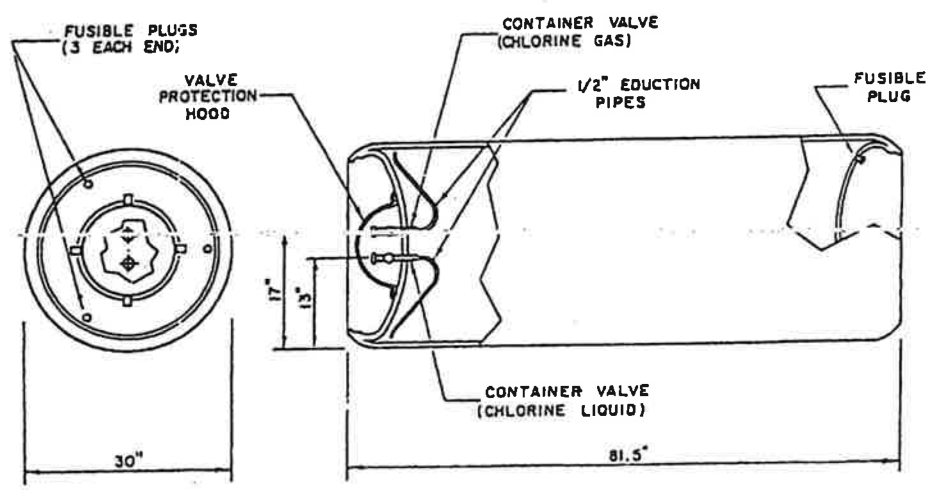


Figure 10-4 Ton cylinder

Gaseous chlorine leaks

Chlorine gas can be very dangerous, but proper handling prevents accidents. All waterworks operators should know proper procedures for handling chlorine gas.

When chlorine gas comes in contact with moisture it forms hydrochloric acid, which is extremely corrosive. Breathing chlorine gas can be very dangerous, due to moisture in the mouth and nose and in the air. Anyone who inhales a large amount of chlorine gas should seek medical care.

Always wear an approved chlorine gas mask into a room where chlorine gas might be leaking. Never handle a leak alone. Have a co-worker stand by.

Leaking chlorine gas is very corrosive to metals. Keep chlorine cylinders in an area separate from pumps and electrical equipment. This applies whether the cylinder is in use or in storage.

As chlorine gas is 2.5 times heavier than air, all room discharge vents should be near the floor. Never place a chlorine cylinder below ground level.

Equip any walk-in chlorine room with a vent fan. Locate the vent fan switch outside, and turn the switch on before entering. Because chlorine gas is corrosive to electrical motors, some chlorination rooms are designed so a fan blows air in at the top of the room and out the vent at the floor level.

Use ammonia to locate chlorine leaks. Ammonia fumes combine with chlorine gas to make a white smoke. Hold the ammonia bottle or swab under or around the suspected chlorine leak. Never pour ammonia or any liquid on a chlorine leak.

Use a commercial-grade ammonia to locate chlorine leaks. Household ammonia available at grocery stores will work, but it is weak and does not last long. Keep the ammonia out of sunlight to maintain its strength.

Chlorinator installation

A vacuum system is normally used to feed gaseous chlorine for safety reasons. All brands of gaseous chlorinators are reliable and will give good service if they are properly maintained. Chlorinators must be properly sized for the particular job. A chlorinator is sized according to the pump or well capacity and the chlorine demand of the water. The chlorinator should be large enough to allow normal operation at one-fourth to one-third of the rotometer scale. This leaves capacity for increasing feed rates and also increased chlorine demand imposed by other chemicals in raw water. The rotometer scale on a chlorinator indicates feed rates in pounds per 24 hours.

Figure 10-5 shows a typical chlorinator piping arrangement. Some chlorinators are wall mounted, but most are mounted directly on the chlorine cylinder, as shown. Valves should provide a way to isolate the chlorinator booster pump during repairs.

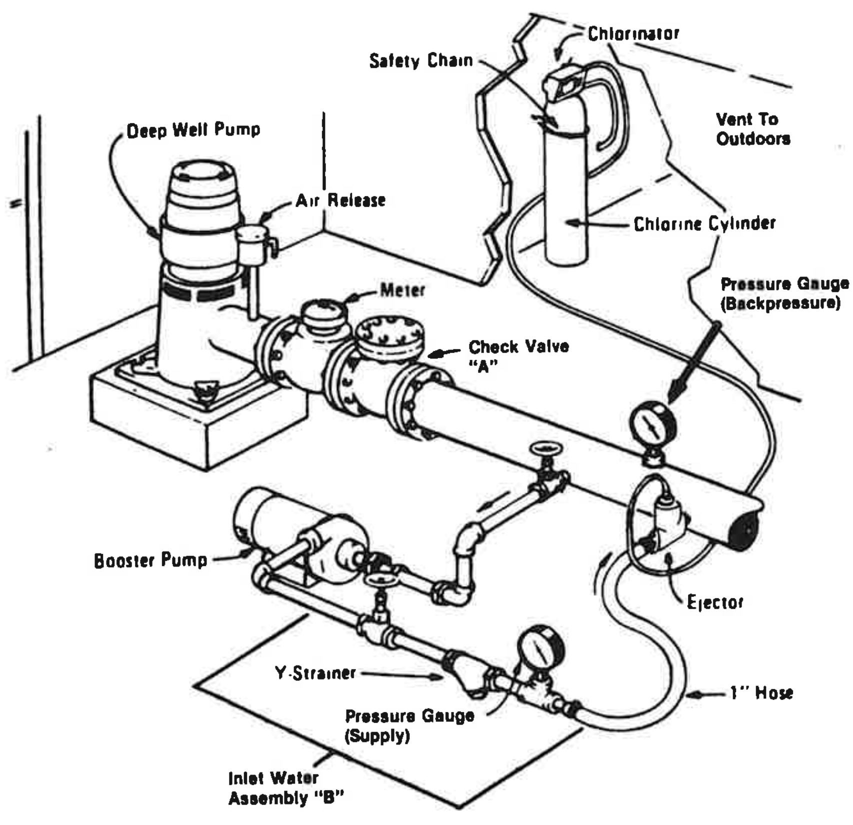


Figure 10-5 Typical gas chlorinator installation

The booster pump circulates water through the ejector with enough force to create a vacuum. Pump size is based on the size chlorinator and the water pressure at the injection point. The pump has to boost the pressure to about twice the pressure in the well discharge line. A pressure gauge on the discharge side of the booster pump shows if it is operating properly.

Install a y-strainer in-line ahead of the ejector. The strainer filters out small particles that could plug the ejector's small opening. A small line from the ejector to the well discharge line must be made of corrosion-resistant material. A schedule-80 pvc or a heavy duty flexible chemical hose is appropriate.

Figure 10-6 shows the flow of gas through a chlorinator. The operator who understands how a chlorinator works is equipped to trouble-shoot problems. As water runs through the ejector, it creates a vacuum which opens the ejector check valve. The vacuum transferred to the chlorinator opens the inlet valve which draws chlorine from the cylinder. As chlorine goes up through the rotometer, the rate indicator ball shows how much chlorine is fed in pounds per 24 hours. The rate valve at the top of the rotometer adjusts the feed rate. Every time a new chlorine cylinder is installed, move the valve up and down several turns to keep it lubricated.

When the booster pump is turned off, the flow stops in the ejector. The vacuum is lost, causing the ejector check valve to close. The chlorinator and the inlet safety valve close. This stops the flow of chlorine.

Tiny particles or scratches on the inlet valve prevent the valve from closing completely. This allows chlorine gas to leak out of the vent. When a chlorine odor is detected around the plant, it is usually because gas is coming out the vent line. Use ammonia to check for leaking chlorine or submerge the end of the vent line in a cup of water. If chlorine is escaping out the vent line, clean the inlet safety valve. When the chlorinator is in use, gas will not leak out the vent line.

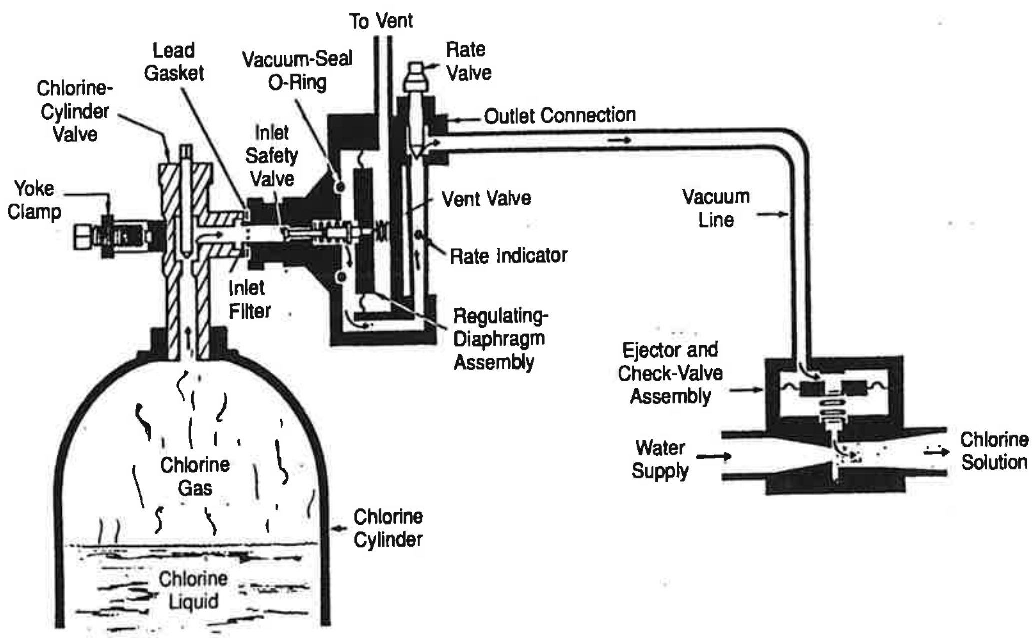


Figure 10-6 Schematic of direct-mounted gas chlorinator

Maintenance

1. When it is time to change chlorine cylinders, follow these steps:
   a. Close the chlorine cylinder valve.
   b. Vacuum chlorine out of the chlorinator and chlorinator lines.
   c. Check for chlorine leaks while disconnecting the empty chlorine cylinder to make sure the chlorine cylinder valve is completely closed off.
2. When installing the new chlorine cylinder, use only one new lead washer. Do not over-tighten the yolk, which would cause a chlorine leak.
3. Open and quickly close the cylinder valve.
   a. Check for leaks with a bottle of ammonia.
   b. If the installation is not leaking, open the valve one full turn.
   c. Turn the chlorinator rate control up and down and then adjust to the proper setting.
4. Change the ejector valve seat or the o-ring on a regular schedule. The life of the ejector valve seat depends on the number of times the ejector is turned on and off. Some operators replace the o-ring

every time they change cylinders.

5. Check the vacuum created by the ejector regularly. Inspect the chlorinator tubing regularly. Repair or replace as necessary. Replace routinely once a year.

Use genuine chlorinator parts for replacements. Most chlorinator o-rings, valve seats, and tubing are made and coated with special materials that resist chlorine deterioration.

Chlorine injection point

The only significant difference in chlorination at higher class water treatment plants is the location of the chlorine injection point. Chlorine usually is injected in a ground tank under the aerator or at a point that has little or no water pressure. This eliminates the need for a booster pump because there is enough pressure from the distribution line to create a vacuum in the chlorinator's ejector.

A solenoid valve, which is an electrically operated valve, is installed on the water line before the chlorinator ejector. The solenoid valve is connected to the controls of the well or main pump. When the well starts pumping, the solenoid valve opens, and chlorine is injected in the reservoir. When the well stops, the solenoid valve closes.

This is actually a simpler way to chlorinate because the need for a booster pump is eliminated. An over-chlorination problem can occur if the well stops pumping and the solenoid valve fails to close. For this reason the chlorinator and solenoid valve must be checked daily. The solenoid valve should be electrically wired to prevent manual operation.

If the solenoid valve can be opened by flipping a manual switch it is possible for someone to turn the valve on and forget to turn it off causing over chlorination. There can be other problems causing the solenoid valve not to close such as small particles lodging in the valve.

References

1. Volume I *Water Treatment Plant Operation* (California state University, Sacramento School of Engineering) 1994.
2. *Minnesota Water Works Operations Manual*, 1994.

Sample Questions

1. A gaseous chlorinator operates well. The well has a 500 gpm capacity. The chlorinator has a 20 ppd capacity. If the well runs four hours per day, and the chlorinator rate control is set on 8 ppd, how many pounds of chlorine are fed in a 24-hour period?
   a. 2.50
   b. 1.33
   c. 6.23
   d. 8.00

2. To allow leaking chlorine to vent out of a chlorination room, where should the vent be located?
   a. Near the floor
   b. Near the ceiling
   c. On the wall level with the top of the chlorinator cylinder
   d. In the middle of the ceiling

3. Where do most chlorine leaks occur?
   a. Near the chlorine booster pump
   b. Around the chlorinator
   c. Around the chlorine cylinder valve stem
   d. In the chlorine line between the chlorinator and the ejector

4. Ton (2,000 lb) chlorine cylinders are protected from cylinder rupture due to high pressure by:
   a. Two fusible plugs in the middle of the ton cylinder.
   b. By a lead fusible plug in the two valve stems.
   c. By three fusible plugs on each end of the ton cylinder.
   d. By a pressure relief valve on the top of the ton cylinder.

5. A solenoid valve on a chlorination system should
   a. Be installed inline with the chlorinator booster pump.
   b. Be turned on manually daily to determine if it is operating properly.
   c. Be controlled to open up only when the well is pumping.
   d. Be checked only once a week.

Chapter 11

Administration and safety

Introduction

This chapter discusses some of the management and public service policies with which a water utility must be concerned. Topics covered include:

- Water utility organization and structure
- A utility's obligations and service to the public
- Accounting procedures
- Purchasing policies and inventory
- Equipment maintenance
- Personnel policies and training
- Safety and public relations issues

The following is a list of objectives to help a utility build an adequate management strategy. The success of any organization depends on having a plan and following it.

- Build the organization upon utility objectives and tasks and not on an individual or a group of individuals.
- Assign each employee one supervisor, and route all direction and guidance through the one boss.
- Assign each supervisor a limited number of people for whom he/she is directly responsible.
- Keep to a minimum the number of management levels above the work level.
- Make decisions as close as possible to the action to which they apply.
- Make performance requirements explicit and equal to all employees doing a particular task.
- Define the basic purpose of the utility clearly in writing with every task of the organization clearly understood.
- Maintain the integrity of the relationship between the supervisor and each of his subordinates.
- Keep management organization simple, flexible, realistic, and dynamic.

Water utility organization

Water utilities vary widely in number of employees and size of organization. Large systems might have several levels of organization, while small systems might only have one level consisting of the guy on the backhoe. Even the smallest systems deal with the following functions of a water supply utility.

- *Supply*: Any utility is required to deliver the water to the treatment plant. Delivery includes such matters as operation and maintenance of wells, the watershed, raw water mains, transmission pumping stations, and intake structures.
- *Treatment*: Treatment personnel are responsible for all aspects of the treatment procedure, including the operation, maintenance and repair of all equipment, buildings, and structures involved in treatment, the requisition of required chemical supplies, and the laboratory control of the treatment processes.
- *Distribution*: Distribution personnel are responsible for transporting the finished water from the plant to the customer's service line. This task involves the construction, maintenance, and repair of the system of mains, reservoirs, and pumps that carry the supply.
- *Metering*: Metering personnel install, read, test, maintain, and repair customers' meters. In most

utilities, this division also assumes responsibility for responding to customers' complaints.

- *Billing*: The billing personnel send and collect bills on customers' accounts. This includes establishing and maintaining customer records and bookkeeping.
- *Legal*: The utility's attorney must advise on permits, rights-of-way, and other details of property acquisition and service extension. The vulnerability of the water utility to litigation usually makes sound legal advice a necessity. Federal, state, and local regulation of water utilities has increased in recent years, much of it written in legal terminology that requires interpretation for utility personnel to know what is expected. Regulations of Equal Employment Opportunity, the Occupational Safety and Health Act, and the Environmental Protection Agency all present complex legal requirements and problems.
- *Accounting*: the utility must provide budgeting, auditing, and information on taxes, insurance, and financing. Customer rates and service are also of concern in any accounting program.
- *Engineering*: An engineering department plans, designs, constructs, and maintains the facilities required for service. It also is concerned with the development of rates, the study of costs and depreciation, the development of special service and work equipment, and the development of specifications for, as well as purchase of, supplies, materials, and equipment.
- *Personnel*: All matters relating to personnel – from payroll to pensions, from holidays to hospitals, from uniforms to unions – constitute a definite category of necessary staff functions.
- *Public relations.* Although all employees of a water utility are concerned with public relations, establishing a purposeful program and its systematic implementation are still another specialized staff responsibility.

Just how many of the principles of good organization any utility can put into effect will depend on the autonomy it exercises or the influence it can bring to bear upon shared staff functions. Every water utility might not specifically use the above functions in separate categories of employees. Even the utility with only one employee uses all of these functions in one form or another to deliver the required service to customers or protect the utility's investment.

Utility responsibility

The primary purpose of a water utility is to furnish potable water. Potable water can be ingested without menace to health. It has physical, chemical, and biological characteristics satisfactory for drinking.

This purpose places the water utility under a moral obligation to furnish water that is both safe and palatable. Beyond the moral responsibility, a legal responsibility arises from federal, state, and local laws and regulations.

Federal public law 93-523, the Safe Drinking Water Act (SDWA), establishes criteria for bacteriological and chemical water quality. Some states have established regulations that might be broader and more restrictive than the federal standards. Mississippi's law is exactly the same as the federal law.

Every utility manager should be familiar with the laws applying to the manager's particular utility. In Mississippi, the Mississippi State Department of Health (MSDH) is charged with administering the SDWA. Information is available concerning the responsibilities of each utility under this act.

Each utility is expected to maintain its treatment plant and distribution system in such condition that it can furnish adequate service. No matter how well constructed, a water utility cannot provide adequate service without proper operation and maintenance.

Potable water involves not only the source, but the collection, treatment, transmission, storage facilities, and the distribution system of the utility. Responsibility for a safe water supply rests with the utility and its management.

Legal liability stems from responsibility. For example, it is generally accepted that damage from broken water mains or other water system facilities places a liability upon a water utility only if (1) the action that resulted in the damage involved a risk greater than the benefits normally expected, or (2) that the damage involved negligence on the part of the water utility.

Therefore the responsibility for proper installation, operation, and maintenance apparently rests with the water utility. If the installations were properly made, operations are carried on by trained, reasonable personnel, and the facilities are prudently maintained, then there would exist no negligence or liability for damage. If, however, installation, operation, or maintenance were improperly performed, such negligence on the part of the utility could result in liability for damages.

The utility's responsibility to provide a safe water supply starts at the source of supply. In obtaining a water source, management has the responsibility to respect the rights of other users of underground water supplies. Failure to do so often involves the utility in long and costly court action. The utility manager must determine his utility's right to its sources of supply, to protect those rights, and to acquire additional sources to meet expanding needs.

Water service

Water utilities provide a service that is essential to the welfare of the entire community. Therefore, water utilities are subject to varying degrees of public control to safeguard community interests. Among the utility's obligations:

- Serve all who apply within it's service area.
- Give equal and adequate service to all.
- Make the same charge for the same service except under special contracts.

The purpose of regulations governing water service between the customer and the utility is to promote good public utility practices. A water utility would have difficulty operating on a sound business basis without them. One portion of these regulations usually contains the obligations that the utility has to its customers. The other portion contains the regulations that the customer must observe.

Service area

The utility is required to serve water to all customers located in its service area. Service areas in Mississippi are regulated by the Public Service Commission (PSC).

Cities can serve up to one mile outside its city limits if no other entity already has exclusive service rights there. The PSC issues service areas for privately owned systems and water associations in response to requests by the utility.

What is service

A utility is required to provide a minimum level of service in the following areas:

- *Quantity*: The utility must deliver a continuous and sufficient supply of water at a minimum pressure and avoid any shortage or interruption in delivery.
- *Quality*: The utility must insure that all water furnished for human consumption meets the requirements of the SDWA.
- *Cost of service*: Rates charged for water service must be fair and equitable to every customer.

Service connections

A regulation covering service connections and meters usually lists the responsibility of the utility and the customer.

- *Service connections* : The customer will be charged for the installation of a water service. This rule also usually contains a provision that only duly authorized employees or agents of the utility are permitted to install the service so the utility can maintain control.
- *Meters* : The meter should be installed at the curb or property line. They shall be installed and removed by utility employees or agents.
- *Change in location of meters and services*: If a utility receives a request to change the location of a meter or service for the convenience of the customer, the customer should pay all cost of such a relocation.
- *Change in size of meter*: If a utility receives a request to change the size of customer's meter, the customer should pay all costs of changing meter size.

Multiple connections

MSDH requires that each connection be individually metered regardless of location or ownership. This is the only fair way to ensure that each customer pays his share for each gallon of water used.

Some utilities allow multiple connections to apartment complexes or family members who live on the same lot. This should be controlled so that each party pays the price of a single connection.

Bills payment

The service contract between the utility and a customer in rendering and payment of water bills usually includes the following:

- *Rendering of bills*: The meter should be read at regular intervals and at the time of turn-on or turn-off of service. Most utilities read meters monthly or every 27 to 33 days.
- *Bill payment*: Payment is due upon presentation. Most utilities provide for a late period after which

service may be discontinued. It is important that a cutoff policy is enforced fairly and swiftly.

Disputed bills

Every utility occasionally has a customer who disputes the accuracy of a bill. Frequently, office personnel are able to satisfy the customer. If not, the utility must have a written policy for dealing with these problems.

A common problem is an excessive bill caused by a leak on the customer's side of the meter. Since such leaks are not the fault of the utility, adjustments vary with each utility. Utilities can make some allowance in these case depending upon circumstances.

Termination of water service

Even though a water utility must serve all within its service area who apply, it must retain the right to discontinue service under the following conditions:

- *Nonpayment of bills*: Service may be discontinued for nonpayment if a bill is not paid within allotted time for payment. A customer's service should not be discontinued until the deposit, if any, has been fully absorbed in payment.
- *Unsafe apparatus*: If a condition exists in the customer's plumbing that could cause contamination of the utility's water supply, result in annoyance to other customers, or create an unsafe condition, service should be discontinued.
- *Service detrimental to others*: If the service to a customer causes service to other customers to be adversely affected, then service should be discontinued.
- *Fraud and abuse*: Service may be refused or discontinued so the utility can protect itself against fraud or abuse.
- *Noncompliance with regulations*: The regulations are established to protect both the customer and the utility. If the utility does not comply with the regulations, then the customer may call upon the public utilities commission or other regulatory body for protection. If the customer fails to comply with the regulations, then the utility usually can discontinue service.
- *Charge for restoration of service*: If a customer's service is discontinued for cause, the utility has the right to charge for restoring service.

Interruptions in service

A utility cannot guarantee against interruption of service. However, the utility is required to exercise reasonable diligence to furnish an adequate supply of water to its customers. The utility must sometimes suspend service temporarily to make necessary repairs or improvements to its system. Whenever possible, the utility should give the customers advance notice of the interruption of service and follow MSDH recommendations for restoring service.

Water rates

Every water utility should receive revenue sufficient to meet the costs of providing adequate service. The revenue requirements include:

- all of the cash obligations of the utility, such as operation and maintenance expenses
- debt service on existing bonds and bonds expected to be issued to finance needed improvements or additions to the system
- capital improvements from net revenues
- other cash payments, such as payment in lieu of taxes or developer refunds

A utility should make some capital improvements from net revenues each year. At a minimum, these might include routine replacements and minor extensions of mains.

Accounting

A good accounting system includes a complete set of accounts and also establishes proper procedures and internal control so that all transactions of the utility are properly recorded.

Revenues

The operating revenue accounts show, in detail, the revenues the utility gets from providing water service. Separate accounts and records should be maintained for the following classes of revenues, if possible:

- Water sales to residential customers
- Water sales to industrial customers
- Water sales to commercial customers
- Water sales for irrigation purposes
- Water sales for fire protection
- Water sales to other public entities
- Sales to other water utilities
- Penalties and other miscellaneous water revenues

Carefully maintaining these accounts is essential to establish rates and for management to analyze revenue trends and forecast future water requirements. These forecasts affect the amount and type of new construction the utility can undertake, the securing of additional water rights and franchises, and other preparations for expansion.

Expenses

The operating and maintenance expense reports should show in detail the cost of furnishing water service (except for depreciation, amortization, taxes, and certain other costs that are included as separate revenue deduction accounts in the summary income group). The following items usually make up these costs.

- Source of supply expense
- Power and pumping expenses
- Treatment expenses
- Transmission and distribution expenses
- Customer accounting and collection expenses
- Administrative and general expenses

Each of these categories is further subdivided to show, separately and in detail, maintenance expenses, supplies used in operation or maintenance, labor, supervision, engineering, and other operating expenses.

Stores control and inventory

Establishing proper procedures for handling and accounting for materials is extremely important for utilities. The value of materials and supplies that a utility carries in stock is usually greater than any of its other current assets. An internal control system for these materials is critical.

Each utility should have a centralized stores system, to avoid duplications and overstocking of materials, to ensure better storage facilities and better control over receiving, issuing, and transferring of material. In certain utilities, depending on size, it might be desirable to have sub-storerooms at outlying locations to facilitate operations and reduce travel and delivery costs.

Purchasing

Although utility size determines the complexity of the purchasing organization, there must be one department or person responsible for all purchasing. Among the most important reasons are:

- the price advantages possible with large purchases
- elimination of overstocking or duplications in stocking inherent in a system of decentralized purchasing
- the advantage of having one person or department that can specialize in this field
- accountability for results of the purchasing/stores function

The first step in purchasing is to ascertain the need for materials. Another department or the storekeeper may issue a request. The stores reports show the status of material on hand. The expected amount to be needed, the inventory balance, and the delivery period all influence the decision on the amount of stock to purchase. The method of ordering will depend on the amount to be ordered and the regulations of the utility.

Most municipally owned utilities are required by law to obtain competitive bids for purchases involving any significant sum of money. Even when not required by law, a utility might prefer to request formal bids before placing an order. In any case, the purchasing agency should obtain as much information as possible regarding prices and terms before selecting a vendor.

Another responsibility of purchasing personnel is obtaining the necessary authorizations to make a purchase. This includes the responsibility for verification that the budget is adequate and that the budget item is either included or can be considered a contingency item.

Receiving and storing materials

When the storeroom receives materials, personnel should inspect, count, and record the items. A proper purchase order system should ensure that any item purchased is authorized and meets specifications for the task required. A copy of the purchase order should be kept to verify compliance with the specifications. When the vendor's invoice is received, it should be compared with the purchase order and with the receiving report to ascertain that the prices, discounts, and quantities are in agreement. Resolve any irregularities before paying the vendor.

Material should be stored in a safe place. This means that it should be protected from loss due to weather or theft and also from theft or misuse by unauthorized employees. Material should be removed from the storeroom only with the proper authorization and written record. Only authorized personnel responsible for the material should have complete access to the warehouse or storeroom.

Handling stored materials

Material should be taken from the storeroom onlyupon receipt of a properly approved material requisition. The requisition serves two basic purposes: (1) to charge the cost of the material to the appropriate job or account number, and (2) to record the transaction as it affects the detailed stores records. The requisition should therefore include the quantity and description of each item ordered, delivery instruction, the job or account for which the material is to be used, and the proper approval or authorization.

An actual physical count of the material on hand must supplement the perpetual inventory records. This verifies the inventory records and substantiates the figures that appear in the utility's financial reports. The physical inventory is necessary to adjust the records, should any errors occur in preparing or recording material documents.

All material in stores should be physically inventoried at least once a year. An entity separate from the one responsible for the control of the material in the warehouse should perform the physical inventories.

Facilitate the physical inventory by having all material properly arranged and identified. If significant differences between the inventory records and the physical count are disclosed, then the inventory count should be carefully verified.

Investigate any significant differences between the inventory records and the physical count to determine whether they are caused by accidents, counting errors, recording errors, or theft. After this is completed, take proper steps to correct the situation. Then adjust inventory records to the figures disclosed by the physical count.

Equipment maintenance

Equipment maintenance is one of the keys to efficient operation of a water utility. Equipment purchased and operated by qualified persons will not continue to function properly unless cared for through:

(1) breakdown maintenance
(2) preventive maintenance

Breakdown maintenance is the repair of broken equipment and usually requires immediate action. Preventive maintenance is scheduled maintenance of the "fix it before it breaks" type, programmed to eliminate or minimize breakdown maintenance.

For uninterrupted service, a water plant cannot be plagued with major equipment failure. Usually, equipment breakdown occurs when the equipment is needed most or when it is most difficult to repair (Murphy's law).

It is not economically feasible to provide 100 percent standby for all equipment required for peak pumpage. Thus, by repairing and servicing equipment at periods of the year when customer service is not affected, planned maintenance can provide a reasonable chance that breakdowns will not occur when the equipment is needed. However, breakdown maintenance cannot be eliminated completely.

To bring breakdown maintenance to a reasonable level, a water plant must give maintenance the same careful attention as equipment operation. Some basic features of a sound maintenance policy are the following:

- Clearly define responsibility for maintenance and give it to competent personnel. (The supervisor usually directs and accepts this responsibility.)
- State maintenance objectives clearly.
- Provide proper tools, parts, test instruments, and maintenance facilities.
- Plan and schedule preventive action.
- Use written records and reports to control the program.

Maintenance organization

In organizing maintenance, a clear and definite assignment of responsibility is most important. When maintenance is everyone's business, equipment breakdown becomes no one person'sfault.

Responsibility for maintenance should be assigned to a person who is knowledgeable and is allowed time for the job. The person should then get the assistance he needs, as indicated by the type and amount of maintenance work required and the size of the operation.

If possible, operating personnel should not be responsible for maintaining the equipment they operate. Operators often have the time and know-how for routine preventive maintenance but might neglect either operating routines or maintenance when responsible for both.

Maintenance personnel must be qualified and experienced in maintenance work. Knowledge of such maintenance factors as what constitutes excessive vibration, when bearings should be replaced, when welding represents a safe repair, and what is a loose fit are acquired only by experience and education. Maintenance personnel cannot be allowed to learn by trial-and-error, as the utility will suffer.

After maintenance responsibilities are assigned to a competent person, that person's line of authority must be clearly established and supported to avoid "turf wars" over duties.

Maintenance policy

Maintenance must be the top priority of all employees for a maintenance policy to work. For best utility operation, management must believe in and promote a policy of thorough and regular equipment maintenance. This policy must recognize the economic and service gains to be achieved by keeping equipment in original operating condition and appearance.

Adequate maintenance requires that the necessary tools, facilities, and skills be available in the water utility. Managers sometimes overlook this need in favor of other budget items which are more visible. Annual utility budgets should provide for the purchase of new tools, replacements, or testing equipment. Many plants do not have adequate facilities for maintenance work because of management's indifference to such needs.

Preventive maintenance

Every utility should have a preventive maintenance program to ensure continuity of operations. Preventive maintenance refers to inspections and equipment care performed routinely according to the requirements of the equipment. For example, preventive maintenance means keeping equipment clean, in a state of good order and proper operation, free of excessive vibration, properly lubricated, and free of overloads and excessive heating. Preventive maintenance also requires periodic checks for wear and replacement or repair of parts before breakdowns occur.

Maintenance personnel should have a thorough knowledge of how the item of equipment works, its limitations, and its capabilities. Manufacturers' recommendations should be readily available to maintenance personnel. Preventive maintenance should be conducted as recommended and not just when the operator happens to remember to do it. Anything less invites failure.

Each equipment item must be studied individually. Similar pieces of equipment can have different maintenance requirements because of location and service. Make sure to purchase the correct replacement parts.

Maintenance records

A proper maintenance program requires a minimum of important records and forms. First, a maintenance schedule planned and scheduled on a calendar. Preventive maintenance operations are too numerous, even in a small water utility, to depend upon anyone's memory. Records show when preventive maintenance operations were last performed, who performed them, and what work was done. A record of unscheduled maintenance is also necessary.

Summary of maintenance

In a water utility, where continuity of service is of prime importance, good maintenance is good management. Good maintenance is scheduled preventive maintenance that will reduce down-time and keep equipment operating at peak efficiency. No water utility is too small to initiate a preventive maintenance program, and none is so well off that it can ignore good maintenance.

Personnel administration

Effective management requires establishing and maintaining good employee relations. All managers share the responsibility for ensuring high employee moral throughout the organization. The foundation of an organization is its personnel. The costs of wages and benefits generally represent the largest single item in a utility's budget.

The manager-supervisor sets an example for the employees by establishing work standards and requiring proper performance of duty. The manager establishes a work environment to ensure maximum performance, which provides a high standard of service to the water utility's customers.

Technical requirements of operating a water utility require a high level of skill and expertise from the managers and all the employees. The manager must be sure that the employees have the training and skills to meet these challenges.

Management must be able to select, train, and use productive employees. Equipment and procedures cannot produce quality public service without staff who are qualified and efficient. Personnel management is the supervisor's most important task.

Principles of personnel management

The basic principles of good personnel management don't change. The application of these principles will vary with the utility size, complexity, and condition. The following basic principles will help in maintaining sound employee relations:

- Select the best qualified applicants for employment.
- Tell all employees of the duties and responsibilities of their positions. Make completely clear the wages, benefits, and other conditions of employment.
- Establish and maintain employee records on a systematic and uniform basis conforming with federal law.
- Compensation should be compatible with the job required when compared to similar positions within the utility and the local labor market.
- All personnel policies and practices including work conditions, rules, and regulations should be in writing and readily available to all employees.
- Use fair standards of work performance so that each employee fully understands what is expected in the work area. Make periodic evaluations of how the individual's work compares to the standards.
- Explain fully organizational structures and write them down to ensure that each employee understands how promotion occurs and the level of performance required to move up in the organization.
- Include a written procedure for handling employee grievances and complaints. Efficient handling of complaints might be the most important tool for maintaining employee moral.
- Treat all employees exactly the same. Discipline, when necessary, must be handed out fairly and equitably. Managers must ensure that all employees are held responsible and accountable for their actions.

Talk to employees

The supervisor must inform an employee of the requirements of his job. Provide the employee every opportunity to ask questions concerning the job, the organization, and what is expected during the course of the work situation.

Provide the employee with an employee's handbook containing general information concerning the organization, its rules, regulations, and benefit programs. All employees should have access to the handbook.

Provide new employees with an orientation program. Orientation can provide information concerning the history, organization, general work rules, and benefit programs. An orientation program should answer questions that might not be asked during day-to-day activities.

An orientation program or handbook does not substitute for the personal interest by the employee's supervisor. The immediate supervisor must take an interest in the individual and make the new employee a part of the organization.

Personnel records

Establish individual personnel records for an employee immediately upon hire. These records should include the individual's employment and work history. The information should provide a method of reviewing an employee's progress with the organization. Files should include the following:

- application
- background information
- medical records
- salary changes
- changes in job responsibility
- training and safety data
- record of disciplinary actions or commendations received

Wages and benefits

Pay plans should be based on a systematic analysis of the job required. A comprehensive job analysis would include the following:

- A written description of each job including supervisor/employee relationships. Similar jobs should have similar or the same job description.
- Job descriptions should be ranked in order of responsibility. Jobs of similar responsibility will then be grouped together.

A salary survey of the labor market should be conducted to collect data on wages paid on similar jobs. Wages for every job can then be based on a competitive scale and ensure that the organization retains well trained employees. The salary survey should be repeated periodically to ensure that the scale remains competitive.

Retirement, hospital and life insurance, vacation, workers' compensation, education programs, and other benefits are a substantial part of the employee's compensation. Conduct surveys to be sure that the organization's benefits plan is competitive and remains competitive with the local market.

Promotions

"Promotion from within" provides employees with the opportunity to move into more responsible positions within the organization. Qualifications and requirements for promotions should be explained fully. Provide training so employees are prepared for advancement.

Grievance procedure

Write a grievance procedure and make it readily available to all employees. The immediate supervisor should provide the first and most important step in any grievance procedure. If possible, handle a grievance on an informal basis without requiring a written document.

Listening to the employee and understanding the grievance can be important in resolving the problem. Treat all grievances seriously, and provide the employee prompt and accurate answers. An employee who has a grievance is upset. A supervisor who dismisses the complaint as trivial will have a more difficult problem to resolve.

Additional steps in the grievance procedure depend upon the size of the organization. If the supervisor cannot resolve the problem, then all remaining phases require both written grievances and written responses. In all cases, the final step should be with the utility manager with some access to the governing body or policy-making group.

Summary

The basic principles of good personnel administration are applicable to all levels of management. Selection of good employees is wasted if the new employee is not properly trained. The best grievance procedure fails if the supervisor does not use it correctly. The most accurate job classification plan will be useless if it is not followed.

The paying customer deserves the best service possible. The service rendered by the water utility is directly dependent on the personnel who have been hired and trained. The manager must provide the leadership and judgment so that employees will accept responsibilities and conscientiously serve the community.

Training

Water utilities must have competent, well trained personnel. This can be accomplished through effective training programs.

Adequate employee training helps to control spiraling equipment and labor costs. Also, training is required to meet the changing requirements in federal, state, and local laws governing water quality management and fair employment practices.

Most states, including Mississippi, require that persons with specific training in protecting water quality operate public water supplies. Mississippi routinely provides training for water supply operators and also oversees the continuing education units (CEUs) offered by other entities. This includes bringing field experience – ways of doing things properly – in water treatment, distribution, quality control, safety, and maintenance into a more formalized setting.

Utility management must remember that even the newest employee will perceive the organization's attitudes toward training and will form an opinion as to the value placed on training and the utility's commitment to a well trained work force.

Once training needs are identified and priorities set, management must identify the solutions available. This requires answers to the questions, "What kinds of training and development experiences appropriately meet the needs we have identified?" and "From what sources can we obtain this training?"

Answers to these questions could include on-the-job training or coaching provided by people within the utility. They might include trade and technical schools, correspondence programs, college and university courses, continuing education or university extension offerings, special training conducted by suppliers or manufacturers, industry conferences and seminars, and a variety of training materials presently being marketed. Don't overlook rotational assignments within the utility and special tasks assigned within the parameters of the existing job.

Water works technology has expanded. Consumers demand fiscal accountability, rapid response time, and environmental quality. Newer, more sophisticated testing and monitoring procedures have led to more stringent regulations and controls. All of these affect how well a utility will survive. Workforce efficiency and effectiveness is the key to this survival and growth.

Safety

The most important factor in any safety program is assignment of responsibility. An effective safety program requires that all personnel understand their area of function, and also that the line of responsibility and authority is clearly defined. A well designed safety program must include leadership, training, establishment of safe working conditions, an accident record system, medical and first aid systems, acceptance of personal responsibility by all employees.

Prevention of accidents protects the employee and saves money. Most accidents are caused by unsafe acts of employees. According to studies, approximately 88 percent of accidents are caused by specific employee actions. Education and training of employees in safe work practices and procedures would prevent most of these accidents.

The objective of a safety program is to prevent accidents. To prevent accidents, determine what is causing them, and then take logical steps to eliminate the causes. Inspections of work site, corrective actions, safety training, and accurate record keeping will accomplish this.

Establishing a safety program

Any safety program must have a clear-cut policy statement for employees to follow. The statement should include a specific description of the utilities commitment to safety and a general policy for accomplishing safety goals.

The next step in the establishment of a successful safety program is to assign responsibility. In each area, employees and management should know immediately who is responsible for each phase of worksite safety.

Employees must know that the utility management is committed to safety. If workers do not believe that the effort is serious, the entire program will become ineffective.

Most accidents are preventable. Accidents are the result of an unsafe act or condition or a combination of both. If a safety program is to succeed, supervisors and workers must be trained in the principles of safety and safe work methods and procedures.

Accident reporting

Accurate reporting of accidents is necessary to a successful safety program. Studies of past accidents helps to determine the causes, frequency of occurrence, and severity of injury. A thorough investigation of each accident can determine unsafe acts and/or conditions and the departments or areas involved. Before choosing corrective action to prevent recurrence, one must know the cause of past accidents.

The supervisor should report each accident consistently. The completion of the report should be a cooperative effort to prevent repetition. Every known circumstance regarding the accident should be clearly indicated. The supervisor should make the report as soon as possible so that important details are not overlooked or forgotten.

The purpose of accident reports is to provide information, not to fix blame. Information regarding unsafe acts and unsafe conditions can be used to prevent similar accidents and determine why an unsafe condition existed, or why the injured person acted unsafely.

First aid

The Mississippi State Department of Health recommends that each utility have at least one person professionally trained to administer first aid at a minimum level. A successful first aid program should include some of the following:

- *Pre-employment physical examinations* - Knowing if an applicant has an existing condition that will affect his efficiency or safety, or the efficiency and safety of his co-workers, is important.
- *Treatment* - The utility should have a plan for the professional treatment of injuries by competent authorities
- *First aid service* - The utility should have a written policy concerning the treatment of first aid cases. Proper supplies and equipment should be provided at suitable locations, including first aid kits on utility trucks and vehicles.

Personal responsibility

The success or failure of a safety program depends upon employees realizing that they have a personal responsibility for the safety of themselves and their fellow employees. Education and training are the most important methods of ensuring that all employees are aware of their role in worksite safety.

Summary

Accidents cost money; therefore, the utility has a big stake in preventing them. Every injury imposes a financial burden on the victim, the utility, and the ratepayer. Safety programs prevent human suffering and save money. Statistics prove that preventing an accident costs much less than having one. Accidents cause direct expenses, such as medical, hospitalization, and compensation. Indirect expenses include time lost from work, time lost by other workers, time lost by the supervisor, and possible damage to tools and equipment. Some estimates put the indirect costs of accidents at four times the direct costs. Therefore, prevention is the most efficient use of available funds.

Public relations

Public relations, like other operations, should be a planned, programmed, continuous, professional function of water utilities.

Setting objectives

Establishing objectives is an effective way of organizing public relations. The objectives need to meet the following critical tests of logic:

- *Each objective must be achievable.* Each goal or objective must be realistic.
- *Each must be measurable.* There has to be a way to show what has been accomplished – dollars saved, customers gained, rates increased, opinions influenced.
- *Each goal should have a specific time for completion.*

Beginning at home

The water utility has a responsibility to keep employees well informed about the organization's purposes, plans, and practices.

The customer is always entitled to courteous treatment and an explanation of anything he doesn't understand from the water utility.

These are some common customer-utility contact situations:

Billing: In addition to an accounting of payment due, bills can carry a public relations message. Advertising in the form of a logo or simple "what's going on" statement can be a positive influence on the customer, counteracting the negative effect of receiving a bill. However, some negative statements are required by law and are usually attached to the water bill. Notices of violations are sent by mail. This is required by the Safe Drinking Water Act (PL 93-523).

Meter readers: Meter readers are sometimes blamed for mistreating pets, getting dirt on floors, waking babies, and leaving doors open. Since the meter reader is the only person from the utility that the customer is likely to see, his actions tend to determine the customer's views of whole organization. Being courteous, consistent, and informative will help the customer's perception.

Complaints and requests: Most customers don't bother to request information until they are disturbed or unhappy about something. Train people to handle all calls on the same basis; that is, with polite interest, sympathy, and consideration.

- Be patient with an irate customer. Patience can sometimes reduce the customer's anger.
- Be sure the office staff know where each type of complaint or question is supposed to be routed. Do not pass a concerned customer from person to person.
- A soft voice on the phone will help turn wrath or confusion into understanding.
- The customer should always be given the most factual information that is available.

Use of mass media

The most efficient and often most effective way to reach all the customers on the system is through mass media. Always use the proper news outlet for the proper purpose. Media do not have identical audiences.

Newspapers give more detailed coverage of stories than radio or television. Find out their deadlines, and get the story there on time.

Use radio for spot news and emergency situations.

Television is the most popular news medium and has a bigger audience. Television deals in sound bites, so keep the messages brief and to the point.

News releases

A news release promotes specific projects. Give only the facts, but have basic background information about the utility prepared and available. A fact sheet is useful, not only for reporters, but for concerned citizens. Included with the bill, the fact sheet keeps customers informed. Information should include system size, miles of pipe, gallons of water pumped per month or year, number of customers, treatment information, pumps, wells, reservoirs, lab facilities, number and types of tests made.

A news release should include the utility name, address, phone number, and date. Always begin with who, what, when, where, why, and how.

Public speaking

Personal contact and speaking at public forums in the community is an effective means of making an impression. Although fewer people are reached than through messages on bills or news releases, the impact of face-to-face presentation is greater.

Effective public speaking takes practice. Since people are interested in what happens on their water system, they want to hear about it. Everyone is nervous when speaking in public. But if the customers know that the speaker is making a sincere effort to inform them about their water supply, they will exchange lack of presentation for accurate information.

Preparation is the key to overcoming "nerves." Speakers must prepare in advance. Write out the message. Read it aloud. Then read it aloud while standing in front of a mirror.

Public speaking is one of the best and most important public relation tools. Don't talk for more than 15-20 minutes. Act and talk naturally. Keep sentences short and to the point. Apply the KISS (keep it simple, stupid) principle. Don't try to dazzle the audience with brilliance. If the speaker doesn't know more than they do, he is in the wrong business.

The interview

According to *AWWA Manual M5, Water Utility Management*, to prepare yourself in advance for an interview:

- Know what you are talking about. Rehearse in your mind everything important about the utility's operations.
- Think in advance what are the toughest questions that could possibly be asked. If there is something embarrassing, something you would really rather not discuss, count on being asked about it. And be prepared to say, "I can't discuss that," or face up to it with an answer.
- Don't ever make statements "off the record." If you don't want a statement quoted, then don't make it.
- Plan what you want to say in advance, and be sure to get it said, even if you have to volunteer the information. Do not enter an interview expecting to "play it by ear" and just hoping things work out well.

Especially in radio and television interviews, state your most important points clearly, concisely, and quickly. The reporter might talk with you for an hour, but you will be lucky to see more than 30 seconds or a minute on the air.

Do not argue with a rude reporter – ever. If his questions are offensive, do not repeat them. Say instead what you want to say. Remember, the reporter's questions are rarely quoted, but your answers are.

Public relations should be carefully planned and carried out in a professional manner. Even if a utility is excellent in every other category of operation, poor public relations can cause a negative public perception. Every utility should plan positive, timely, and factual information to show consumers that, for the most part, "We get it right!"

References

American Water Works Association (AWWA), *Water Utility management*, Manual of Water Supply Practices M5.

AWWA *Water Treatment Plant Design* (New York: AWWA reprinted ed. 1990).

AWWA *Automation and Instrumentation*, Manual of Water Supply Practices M2.

AWWA, *Water Audits and Leak Detection*, Manual of Water Supply Practices M36.

AWWA, *Revenue Requirements*, Manual of Water Supply Practices M35.

Sample questions

1. A utility is required to serve all customers within its service area. The service area for a utility in Mississippi is regulated by:
   a. The county board of supervisors
   b. The Mississippi State Department of Health
   c. The Pubic Service Commission
   d. The Department of Transportation

2. A cutoff policy should be enforced:
   a. fairly and swiftly
   b. according to the customer's ability to pay
   c. on all but members of the board
   d. at the discretion of the certified operator

3. Disputed bills should be handled:
   a. by the certified operator
   b. with a written, evenly enforced policy
   c. by the office personnel
   d. with another reading of the meter

4. Internal controls for parts inventory is essential. The system should include:
   a. records of parts purchases
   b. records of engineering costs
   c. records of storeroom supplies
   d. a and c

5. The process of competitive bids will:
   a. be unnecessary if large quantities are ordered
   b. ensure that the utility receives a competitive price
   c. ensure that the utility receives the howest possible price
   d. ensure that the selected vendor supplies quality products.

6. Total access to the storeroom should be limited to:
   a. system personnel who use the parts
   b. the storeroom supervisor
   c. authorized personnel responsible for the material
   d. the certified operator

7. Breakdown maintenance is
   a. repair of broken equipment requiring immediate action
   b. the practice of providing backup equipment
   c. routine measures to "fix it before it breaks."
   d. following manufacturers' recommendations for replacing bearings.

8. Who is ultimately responsible for maintenance?
   a. the certified operator
   b. the equipment operator
   c. the supervisor
   d. the association president

9. The supervisor's most important task is:
   a. equipment maintenance
   b. safety assurance
   c. employee performance
   d. personnel management

10. According to the most recent statistics, most accidents in the work place are caused by:
    a. equipment malfunction
    b. improper safety precautions by management
    c. specific unsafe acts by employees
    d. horseplay

Chapter 12

Cross connection control

Introduction

Advances in technology make it possible to deliver clean, safe drinking water to the public. However, an unprotected cross connection can allow polluted water to flow from the customer's plumbing into the water system pipes. It can then be spread throughout the distribution system. To insure a safe supply of water, systems must protect against this.

This chapter will:

- Define and describe cross connections and backflow.
- List and describe backflow prevention devises and their uses.
- Consider responsibility for prevention and control.

Cross connections and backflow

A cross connection is any arrangement of piping where a potable water line is connected to potentially contaminated water.

A cross connection is either:

- a pipe-to-pipe connection, where potable and contaminated water are directly connected, or
- a pipe-to-water connection, where the potable water outlet is submerged in contaminated water.

Cross connections are usually made unintentionally. Their hazards are not recognized or are under estimated. Most water lines end at a faucet, sink, or commode, which is also the beginning of the sewage system. Here, the difference between a cross connection and a safe installation could be inches. A cross connection can also exist if the potable and non-potable systems are separated by a gate valve or check valve, since these valves often leak undetected.

Backflow occurs when the direction of flow is reversed and contaminated water moves through the cross connection into the potable water supply, creating a hazard.

There are two causes of backflow:

- back pressure
- back-siphonage

Back pressure backflow happens when contaminated water's pressure is greater than the pressure in the potable water lines. This can happen when non-potable water is being pumped or is stored at a higher elevation. If the pressure in the potable water line drops below the pressure of the non-potable system, the non-potable water pushes into the potable system.

Back-siphonage backflow results from a vacuum being created in a water line. The vacuum draws contaminated water into the potable supply. Breaks or repairs on a main water line and changes in flow due to nearby fire fighting – these emergencies can create a vacuum in the distribution system.

The degree of hazard depends on both the probability of contamination and the toxicity of the contaminant. The toxicity of the potential contaminant is the greatest concern and dictates the selection of the backflow prevention device.

Contamination potential from backflow is classified as high hazard or low hazard:

- High hazard: A cross connection or potential cross connection that could allow any contaminant into the distribution system that could cause death, illness, or spread disease.

- Low hazard: A cross connection or potential cross connection that could allow a pollutant into the system that is not a health hazard, but is displeasing or a nuisance in the potable water supply.

Backflow prevention devices

Sometimes eliminating the cross connection is impossible. These cases require an approved backflow prevention device. There are five basic devices used to protect the potable water system from backflow through a cross connection:

- air gap (AG)
- atmospheric vacuum breaker (AVB)
- pressure vacuum breaker (PVB)
- double check valve assembly (DC)
- reduced pressure zone backflow preventer (RPZ)

All types of backflow prevention devices must be inspected and tested annually. Each device has a specific application.

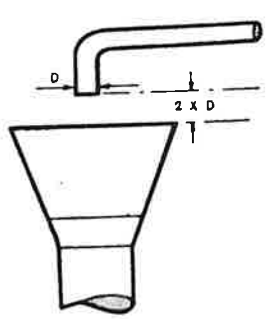


Figure 12-1
Air gap

Air gap

An air gap physically separates potable from contaminated water with an air space (Figure 12-1). It exists when the inlet piping ends far enough above a contaminant to prevent backflow. The vertical distance between the supply pipe and the overflow rim of the receiving vessel should be two times the diameter of the supply pipe, but never less than one inch. An air gap protects against both back-siphonage and back pressure. It is appropriate for all toxic substances. It is used with any installation that doesn't require a solid physical connection, such as:

- open spigots
- surge tanks
- watering stations

Be careful that a later change to the piping doesn't create a direct connection.

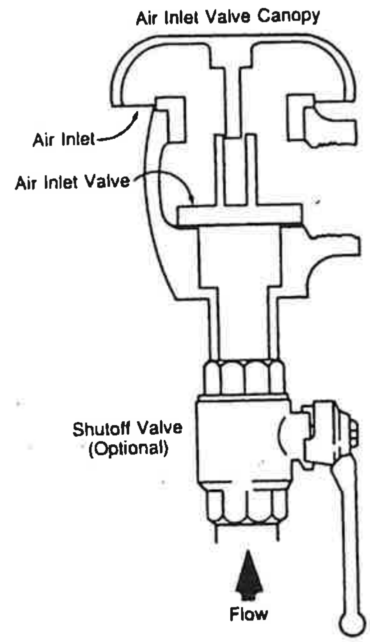


Figure 12-2
Atmospheric vacuum breaker

Atmospheric vacuum breaker

An atmospheric vacuum breaker (AVB) is a device that uses an air inlet to prevent back-siphonage (Figure 12-2). When potable water is flowing in the normal direction, the force of the water is used to seal off the air inlet, allowing water to flow through the device. When the flow stops, the loss of water pressure permits the air inlet valve (or check valve) to drop. This seals off the supply line and opens the air inlet vent, allowing air into the system. This keeps a vacuum from developing. AVBs may be used on most inlet-type water connections that are not subject to back pressure. Some examples are:

- a fixture with a hose attachment
- lawn sprinkler systems
- commercial dishwashers
- fluoride saturators

AVBs must be installed at least 12 inches above the highest point of use and downstream of all control valves. AVBs are not designed for continuous use. They protect against back-siphonage, but not back pressure.

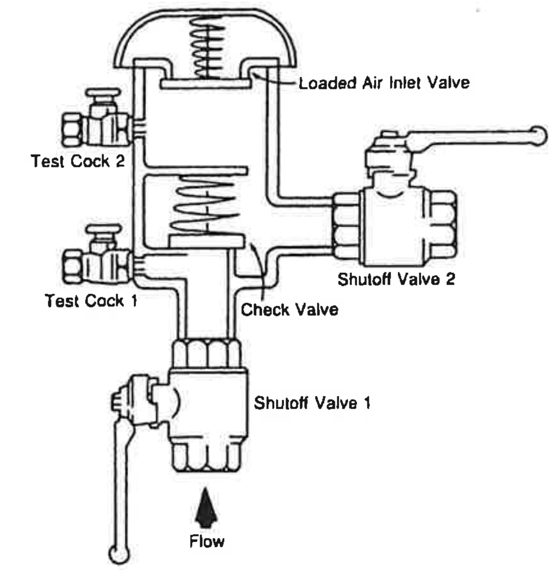


Figure 12-3
Fressure vacuum breaker

Pressure vacuum breakers

A pressure vacuum breaker (PVB) is similar to an AVB, but it includes a spring to help close the check valve when flow stops (Figure 12-3). PVBs may be used in the same applications as AVBs, but PVBs will work under continuous pressure. Since neither device protects against back pressure, each must be installed 12 inches above the highest usage point. PVBs are typically used for multi-zone lawn sprinkler systems.

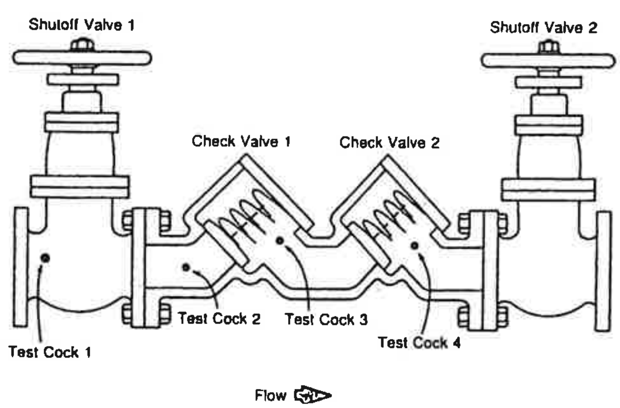


Figure 12-4
Double check valve assembly

Double check valve assembly

A double-check valve assembly is two springloaded check valves housed in one unit with test cocks and gate valves (Figure 12-4). The device protects direct connections through which foreign material might enter the potable system. It is used where concentrations of air, steam, food, or other material are a nuisance but not a health hazard. Double-check valve assemblies are appropriate where the hazard is low to intermediate; that is the non-potable source is polluted rather than contaminated.

The head-loss through a double-check valve is usually less than 10 psi. Double-check valves protect against back-siphonage and back pressure. Home-made double check valves are not acceptable. They cannot be tested for proper operation.

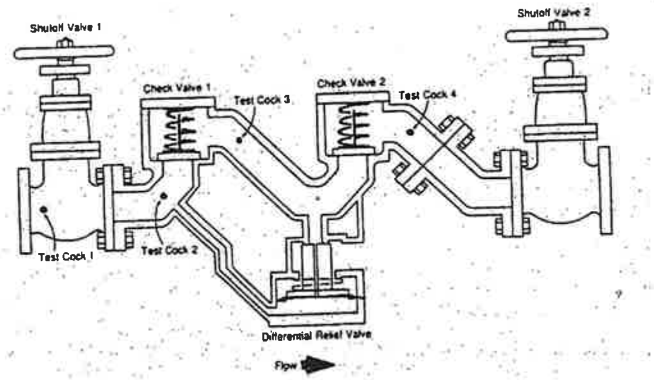
Reduced pressure zone backflow preventer

A reduced pressure zone (RPZ) backflow preventer consists of two spring loaded, pressure-reducing check valves with a pressure regulated relief valve between them. Flow from the supply side passes through the first check valve, lowering pressure by a set amount. The relief valve keeps pressure in the central chamber lower than the pressure on the supply side. This valve releases pressure into the atmosphere whenever the central chamber pressure gets close to supply side pressure.

The second check valve is loaded lightly, so it opens if normal flow pressure drops 1 psi. It closes and prevents backflow if pressure downstream of the device rises, reversing flow. If the second check valve fails, contaminated water flowing back into the central chamber is vented to the atmosphere, preventing backflow. If the supply side pressure drops to atmospheric, the relief valve remains open, preventing back-siphonage.

A continuous stream of water from the relief port indicates malfunction of one or both check valves or the relief port. A little water comes through the port during normal operation. Never allow the relief port to become obstructed or submerged. An open relief port assures safe operation.

Normal pressure loss through this device is between 10 and 20 psi, depending on the size of the



device and flow. An RPZ is recommended in any hazardous installation subject to backflow and back-siphonage where an air gap is not feasible. Certified personnel must install and inspect an RPZ annually. A bypass line installed around an RPZ to allow the unit to be taken out of service must also contain an RPZ.

Backflow prevention device usage

The following discussion and selection chart come from the AWWA manual, *Recommended Practice For Backflow Prevention and Cross-Connection Control.*

The correct selection of a backflow prevention device requires a thorough knowledge of:

- function of the device
- limitations of the device
- cause of back-siphonage and backflow
- assessment of the degree of hazard

Table 12-1
Guide to assessment of hazard and selection of assemblies for premises isolation

Description of premises	Assessment of hazard	Recommended assembly on water service pipe
Hospitals, mortuaries, clinics, laboratories	Health	RPBA
Plants using radioactive materials	Health	RPBA
Petroleum processing or storage facilities	Health	RPBA
Premises where inspection is restricted	Health	RPBA
Sewage treatment plant	Health	RPBA
Sewage lift stations	Health	RPBA
Commercial laundry	Health	RPBA
Plating or chemical plants	Health	RPBA
Docks and dockside facilities	Health	RPBA
Food and beverage processing plants	Health	RPBA
Pleasure-boat marina	Health	RPBA
Tall buildings (protection against excessive head of water)	Nonhealth	DCVA
Steam plants	Nonhealth	RPBA
Reclaimed water systems	Health	RPBA

RPBA: reduced pressure principle backflow-prevention assembly; DCVA: double check valve backflow prevention assembly.

Selection of a backflow prevention device is subjective. Table 12-1 can help water system operators and managers decide on the correct device for a particular installation.

If possible, internal isolation should be provided instead of premises isolation. In-plant personnel are protected and, in most cases, the assembly can be smaller because in-plant piping is smaller. The choice of backflow prevention devices for internal protection or premises isolation also depends on whether or not the actual or potential cross connection constitutes a health hazard.

Responsibilities

An effective cross connection control program requires the full cooperation of water users, suppliers, health agencies, and plumbers.

Water users

The customer has the **primary** responsibility to prevent contamination of the water supply. This responsibility begins at the water meter and includes all water pipes from the meter to the sewer. A negligent customer who changes piping or misuses equipment can accidently create a cross-connection. A customer's plumbing can create a cross connection with bypass arrangements, jumper connections, removable sections, swivel or changeover assemblies, hoses and hose bibs, or an abundance of mystery piping. If a cross connection or potential cross connection exists, the customer must install, test, and maintain approved backflow prevention at the customer's expense. A customer whose drinking water becomes contaminated by backflow is obligated to notify MSDH and the water supplier promptly so that the contamination and its cause can be eliminated.

Water supplier

The water supplier is responsible for preventing contamination of the water system. This responsibility begins at the source, includes the entire water supply distribution system, and ends at the meter. Each water system must take steps to identify and eliminate cross connections. These steps should include:

- surveying the system regularly to identify potential cross connections
- educating the public about the dangers of backflow into the local water supply
- eliminating cross connections that are identified adopting policies that minimize cross connection threats
- maintaining adequate pressure (20 psi) to reduce the risk of back-siphonage and backflow from cross connections.

To reduce the chances of hazardous cross connections, water suppliers should not connect to unapproved water systems or private wells. If the system serves waste-water treatment plants, chicken houses, boiler plants – sites with inherently dangerous contaminants – the connections must be carefully monitored.

Because the number of serious backflow cases is growing, many water systems require dual check valves at all residential water meters. Dual check valves are not the same as a double check valve assembly. Dual check valves are simply two check valves in one unit that operate independently of one another.

MSDH does not require that dual check valves be installed. The head-loss through these devices could drop the pressure at the meter below the required 20 psi. For systems with adequate pressure, dual check valves are recommended. A hydraulic analysis of the system can determine if dual check valves are safe.

Some systems also provide hose bib vacuum breakers to their customers at wholesale cost to prevent back-siphonage through garden hoses.

Mississippi State Department of Health

MSDH is responsible for enforcing rules that control cross connections. The agency must ensure that water suppliers maintain internal protection and adequate backflow prevention programs.

Plumber

The plumber is the first line of defense against unprotected cross connections. The plumber prevents cross connections by properly installing plumbing fixtures. When the plumber finds a potential or existing cross connection, he should immediately notify the water system.

Conclusion

Backflow prevention is one of the simplest yet most effective methods of protecting public health, although it can be costly. To fully realize the benefit of a well organized and effective cross connection control program, consider the cost of no protection. Documented cases of contamination by cross connections show that the results of one unprotected incident can be devastating.

References

American Water Works Association, *Recommended Practice for Backflow Prevention and Cross Connection Control*, Manual of Water Supply Practices M14.

American Water Works Association, *Water Utility Management*, Manual of Water Supply Practices M5.

American Water Works Association, *Water Treatment Plant Design* (New York: American Water Works Association), reprint ed. 1990.

American Water Works Association, *Automation and Instrumentation*, Manual of Water Supply Practices M2

American Water Works Association, *Distribution Network Analysis for Water Utilities*, Manual of Water Supply Practices M32.

Sample questions

1. What is a cross connection?
2. Will an atmospheric vacuum breaker protect against back pressure backflow?
3. Can an atmospheric vacuum breaker be used under continuous pressure?
4. What is the difference between high hazard and low hazard backflow?
5. What is the minimum vertical distance needed with an air gap?
6. List the five devices used to control cross connections.
7. How often should backflow prevention be tested?
8. Who has the primary responsibility to prevent contamination of the water supply?
9. What steps should be taken by the water supplier to identify and eliminate cross connections?
10. Where are dual check valves used?

APPENDIX A

United States Environmental Protection Agency

Revised Total Coliform Rule: A Quick Reference Guide

Overview of the Rule

Title*	Revised Total Coliform Rule (RTCR) 78 FR 10269, February 13, 2013, Vol. 78, No. 30
Purpose	Increase public health protection through the reduction of potential pathways of entry for fecal contamination into distribution systems.
General Description	The RTCR establishes a maximum contaminant level (MCL) for *E. coli* and uses *E. coli* and total coliforms to initiate a "find and fix" approach to address fecal contamination that could enter into the distribution system. It requires public water systems (PWSs) to perform assessments to identify sanitary defects and subsequently take action to correct them.
Utilities Covered	The RTCR applies to all PWSs.

* This document provides a summary of federal drinking water requirements; to ensure full compliance, please consult the federal regulations at 40 CFR 141 and any approved state requirements.

Public Health Benefits

Implementation of the RTCR will result in:

- ▶ A decrease in the pathways by which fecal contamination can enter the drinking water distribution system.
- ▶ Reduction in fecal contamination *should* reduce the potential risk from all waterborne pathogens including bacteria, viruses, parasitic protozoa, and their associated illnesses.

Critical Deadlines and Requirements

For Public Water Systems

Before **April 1, 2016**	▶ PWSs must develop a written sample siting plan that identifies the system's sample collection schedule and all sample sites, including sites for routine and repeat monitoring. ▶ PWSs monitoring quarterly or annually must also identify additional routine monitoring sites in their sample siting plans. ▶ Sample siting plans are subject to state review and revision.
Beginning **April 1, 2016**	PWSs must comply with the RTCR requirements unless the state selects an earlier implementation date.

For State Drinking Water Agencies

By **February 13, 2015**	State submits final primacy program revision package to the EPA Region, including: ▶ Adopted State Regulations. ▶ Regulation Crosswalk. ▶ 40 CFR 142.10 Primacy Update Checklist. ▶ 40 CFR 142.14 and 142.15 Reporting and Recordkeeping. ▶ 40 CFR 142.16 Special Primacy Requirements. ▶ Attorney General's Enforceability Certification. NOTE: EPA regulations allow states until February 13, 2015, for this submittal. An extension of up to 2 years may be requested by the state.
Before **February 13, 2015**	State must submit a primacy program revision extension request if it does not plan to submit the final primacy program revision package by February 13, 2015. The state extension request is submitted to the EPA Region including all of the information required in 40 CFR 142.12(b): ▶ A schedule (not to exceed 2 years) for the submission of the final primacy program revision package. ▶ Justification that meets the federal requirements for an extension request. ▶ Confirmation that the state is implementing the RTCR within its scope of its current authorities and capabilities. ▶ An approved workload agreement with the EPA Region.
No later than **February 13, 2017**	For states with an approved extension, submit complete and final program revision package by the agreed upon extension date.

What are the Major Provisions?

Routine Sampling Requirements

- ▶ Total coliform samples must be collected by PWSs at sites which are representative of water quality throughout the distribution system according to a written sample siting plan subject to state review and revision.
- ▶ For PWSs collecting more than one sample per month, collect total coliform samples at regular intervals throughout the month, except that ground water systems serving 4,900 or fewer people may collect all required samples on a single day if the samples are taken from different sites.

Routine Sampling Requirements (cont.)

- Each total coliform-positive (TC+) routine sample must be tested for the presence of *E. coli*.
- If any TC+ sample is also *E. coli*-positive (EC+), then the EC+ sample result must be reported to the state by the end of the day that the PWS is notified.

- If any routine sample is TC+, repeat samples are required.
  - PWSs on quarterly or annual monitoring must take a minimum of three additional routine sample (known as additional routine monitoring) the month following a TC+ routine or repeat sample.

- Reduced monitoring may be available for PWSs using only ground water and serving 1,000 or fewer persons that meet certain additional PWS criteria.

Repeat Sampling Requirements

Within 24 hours of learning of a TC+ routine sample result, at least 3 repeat samples must be collected and analyzed for total coliform:	▶ One repeat sample must be collected from the same tap as the original sample. ▶ One repeat sample must be collected from within five service connections upstream. ▶ One repeat sample must be collected from within five service connections downstream. ▶ The PWS may propose alternative repeat monitoring locations that are expected to better represent pathways of contamination into the distribution system.
If one or more repeat sample is TC+:	▶ The TC+ sample must be analyzed for the presence of *E. coli.* ▶ If any repeat TC+ sample is also EC+, then the EC+ sample result must be reported to the state by the end of the day that the PWS is notified. ▶ The PWS must collect another set of repeat samples, unless an assessment has been triggered and the PWS has notified the state.

Assessments and Corrective Action

The RTCR requires PWSs that have an indication of coliform contamination (e.g., as a result of TC+ samples, *E. coli* MCL violations, performance failure) to assess the problem and take corrective action. There are two levels of assessments (i.e., Level 1 and Level 2) based on the severity or frequency of the problem.

Purpose of Level 1 and Level 2 Assessments	To find sanitary defects at the PWS including: ▶ Sanitary defects that could provide a pathway of entry for microbial contamination, or ▶ Sanitary defects that indicate failure (existing or potential) of protective barriers against microbial contamination. *Guidance on how to conduct Level 1 and Level 2 Assessments and how to corre sanitary defects found during the Assessments can be found at:* http://water.epa.gov/lawsregs/rulesregs/sdwa/tcr/regulation_revisions.cfm.
Deadline for Completing Corrective Actions	When sanitary defects are identified during a Level 1 or Level 2 Assessment, they should be corrected as soon as possible to protect public health. The PWS must complete corrective actions by one of the following timeframes: ▶ No later than the time the assessment form is submitted to the state, which must be within 30 days of triggering the assessment, or ▶ Within state-approved timeframe which was proposed in the assessment form.

Level 1 Assessments

Conducting Level 1 Assessments	▶ Performed by the PWS owner or operator each time a Level 1 Assessment is triggered. ▶ Upon trigger of a Level 1 Assessment, the Level 1 Assessment form must be submitted within 30 days to the state.
Level 1 Assessment Triggers	Level 1 Assessment is triggered if any one of the following occurs: ▶ A PWS collecting fewer than 40 samples per month has 2 or more TC+ routine/repeat samples in the same month. ▶ A PWS collecting at least 40 samples per month has greater than 5.0 percent of the routine/repeat samples in the same month that are TC+. ▶ A PWS fails to take every required repeat sample after any single TC+ sample.

Level 2 Assessments

Conducting Level 2 Assessments	▶ Performed by the state or state-approved entity each time a Level 2 Assessment is triggered. ▶ The PWS is responsible for ensuring that the Level 2 Assessment is conducted regardless of the entity conducting the Level 2 Assessment. ▶ Upon trigger of a Level 2 Assessment, the Level 2 Assessment form must be submitted within 30 days to the state.
Level 2 Assessment Triggers	Level 2 Assessment is triggered if any one of the following occurs: ▶ A PWS incurs an *E. coli* MCL violation. ▶ A PWS has a second Level 1 Assessment within a rolling 12-month period. ▶ A PWS on state-approved annual monitoring has a Level 1 Assessment trigger in 2 consecutive years.

For additional information on the RTCR:

Call the Safe Drinking Water Hotline at 1-800-426-4791; visit the EPA website at http://water.epa.gov/lawsregs/rulesregs/sdwa/tcr/regulation_revisions.cfm; or contact yo[…]ate drinking water rep[…]entative.

Seasonal System Provisions

The RTCR defines seasonal systems and specifies additional requirements for these types of PWSs:

- A seasonal system is defined as a non-community water system that is not operated as a PWS on a year-round basis and starts up and shuts down at the beginning and end of each operating season.

Start-up Procedures for Seasonal Systems	At the beginning of each operating period, before serving water to the public, seasonal water systems must: ▶ Conduct state-approved start-up procedures. ▶ Certify completion of state-approved start-up procedures. ▶ An exemption from conducting state-approved start-up procedures may be available for seasonal systems that maintain pressure throughout the distribution system during non-operating periods. Examples of state-approved start-up procedures, which need to be completed prior to serving water to the public, may include one or more of the following: ▶ Disinfection. ▶ Distribution system flushing. ▶ Sampling for total coliform and *E. coli*. ▶ Site visit by state. ▶ Verification that any current or historical sanitary defects have been corrected.
Routine Monitoring for Seasonal Systems	▶ The baseline monitoring frequency for seasonal systems is monthly. ▶ A reduced monitoring frequency may be available for seasonal systems that use ground water only and serve fewer than 1,000 persons.

Other Provisions for the State Drinking Water Agency

Special Monitoring Evaluation	The state must perform a special monitoring evaluation at all ground water systems serving 1,000 or fewer persons during each sanitary survey to review the status of the PWS and to determine whether the sample sites and monitoring schedule need to be modified.

Major Violations

E. coli MCL Violation

A PWS will receive an *E. coli* MCL violation when there is any combination of an EC+ sample result with a routine/repeat TC+ or EC+ sample result:

E. coli MCL Violation Occurs with the Following Sample Result Combination	
Routine	**Repeat**
EC+	TC+
EC+	Any missing sample
EC+	EC+
TC+	EC+
TC+	TC+ (but no *E. coli* analysis)

Treatment Technique Violation

A PWS will receive a Treatment Technique violation when any of the following occur:

- Failure to conduct a Level 1 or Level 2 Assessment within 30 days of a trigger.
- Failure to correct all sanitary defects from a Level 1 or Level 2 Assessment within 30 days of a trigger or in accordance with the state-approved timeframe.
- Failure of a seasonal system to complete state-approved start-up procedures prior to serving water to the public.

Key Points for Public Water Systems to Remember

Find and correct sanitary defects as soon as you become aware of them.

- This can help reduce *E. coli* MCL violations, which trigger a Level 2 Assessment.
- This can help reduce TC+ sample results, which may trigger a Level 1 Assessment.

Make sure to collect all routine and repeat samples as required.

- Timely and correct monitoring can help reduce triggering a Level 1 or Level 2 Assessment because:
  - Failure to conduct repeat monitoring triggers a Level 1 Assessment.
  - A Level 1 Assessment triggered twice within a certain timeframe triggers a Level 2 Assessment.

APPENDIX B-1

Minimum Job Performance Guidelines for Certified Waterworks Operators in the State of Mississippi

Prepared by
Mississippi State Department of Health
Bureau of Public Water Supply

Minimum Job Performance Guidelines for
Certified Waterworks Operators in the State of Mississippi
and
Regulation Governing the Certification
of Water System Operators

Introduction

This booklet presents the minimum job performance duties and responsibilities for certified waterworks operators in the State of Mississippi. The guidelines contained in this booklet are the minimum duties and responsibilities for certified waterworks operators in the State of Mississippi. While these guidelines are comprehensive, they do not and cannot include everything operators should do to operate a water system efficiently. Because individual systems vary so much based on size and facilities, MDH's Bureau of Public Water Supply has determined that the job performance guidelines published in this booklet should be used as the basis of an operator's job requirements and should consider their individual system when adding duties. We also provide these guidelines to serve as a "blueprint" for Boards of Directors and other officials of water supplies to use when they employ a waterworks operator. By outlining the minimum duties and frequency of those duties, both the operator and officials should have a better understanding not only of what is expected, but what is required of a waterworks operator.

Mississippi State law requires that each community and non-transient non-community public water system be operated by an individual who has been certified by the Mississippi Department of Health (MDH). Included with this booklet is a copy of the State regulation governing the certification of waterworks operators. We have provided the regulation in this booklet to give waterworks operators, Boards of Directors and other public water system officials a reference to the requirements for certification as a waterworks operator. Additionally, the regulation details the requirements for renewal of a waterworks operator certificate.

As always, the Bureau of Public Water Supply's goal is to work with public water supplies to ensure clean, safe drinking water for all Mississippians. The continued and strong support of operators and officials is both necessary and appreciated in support of our efforts.

If you have any comments or questions about these Minimum Guidelines or the waterworks operator regulation, please forward them to:

MSDH Bureau of Public Water Supply
Training and Certification Branch
P.O. Box 1700
Jackson, MS 39215-1700

Classification of Public Water Systems And Respective Operator Qualifications for Certification

Class of Water System	Public Water System Classification	Waterworks Operator Qualifications for Certification
Class A	Systems with surface water treatment, lime softening, or coagulation and filtration for the removal of constituents other than iron or manganese.	The applicant must have a bachelor's degree in engineering or applied sciences from an accredited college or university, at least one year experience in Class A water system, and pass the required written examination , or He/She must be a graduate of an accredited high school, or equivalent (GED), have at least six years experience in Class A or B water system, of which one year must be in a Class A water system, and pass the required written examination.
Class B	System with two or more Class C treatment facilities of different types, or with iron or manganese removal facilities breaking pressure or requiring flocculation and/or sedimentation.	The applicant must have graduated from an accredited high school, or possess an equivalent (GED), have at least three years experience in a Class A, B or C water system, of which one year must be in a Class A or B system, and pass the required written examination.
Class C	System with aeration, pH adjustment, corrosion control or closed pressure type treatment facilities including zeolite softening or iron and/or manganese removal.	The applicant must have graduated from an accredited high school or possess an equivalent (GED), have at least two years experience in a Class A, B, C or D water plant of which one year must be in a Class A, B, or C water plant and pass the required written examination.
Class D	System with no treatment other than chlorination and fluoridation, or direct chemical feed such as polyphosphate.	The applicant must have graduated from an accredited high school or possess an equivalent (GED), have at least one year experience in a Class A, B, C, or D water system. In addition the applicant must pass the required written examination.
Class E	Systems that purchase water only and do not provide additional treatment. This classification also applies to waterworks operators whose only job responsibility is working on the water distribution system of a public water supply.	The applicant must have at least one year experience in a Class A, B, C, D, or E water system and pass the required written examination.

NOTE: Each applicant must demonstrate that he/she has worked for one year under the supervision of a certified waterworks operator who possesses a non-restricted MSDH operator's license at a classification as high or higher than that for which the applicant is applying. In addition each applicant must be recommended by two additional certified waterworks operators other than the supervising operator.

Minimum Job Performance Guidelines for Certified Waterworks Operators Class "A"

The certified waterworks' operator has a critically important role in protecting the public health of Mississippians since he or she is the person designated by Mississippi State law with the responsibility for ensuring that the public water system is routinely providing safe and adequate drinking water to its customers.

Specifically, the certified waterworks' operator is the person responsible for the daily operation of all water treatment facilities, water plants, distribution systems, intake structures, storage tanks, control systems, and other related appurtenances of the public water system. He or she should perform all routine duties as necessary to ensure that the public water system routinely complies with all requirements of the Federal and Mississippi Safe Drinking Water Acts and is properly operated and maintained. Occasionally, the certified operator may have a representative(s) under his or her supervision who also works with the water system. The authorized representative(s) can complete routine operational and maintenance duties and responsibilities as assigned by the certified operator without the certified operator being present.

The certified waterworks' operator is responsible for keeping the water system officials informed of all actions required to comply with the Safe Drinking Water Acts and ensuring, as authorized by the water system officials, that they implement these actions. The certified operator is also responsible for ensuring that all required water quality samples are collected and analyzed according to the requirements of the Mississippi Department of Health's Bureau of Public Water Supply. Required samples include the monthly bacteriological samples, lead samples, copper samples, nitrate samples, radiological samples, and others as required by the Federal Safe Drinking Water Act.

The minimum job performance duties and responsibilities of the Class "A" certified waterworks operators are outlined below:

1. As a minimum, personally inspect the system and treatment facilities daily, depending on the characteristics of each particular public water system, and perform all necessary and appropriate operational and maintenance activities required of the distribution system and related equipment.

2. Maintain an approved Public Water System Operations Log Book documenting all activities completed on the public water system where he serves as the official certified waterworks operator. This log book must be available for inspection by Bureau staff. The Public Water System Operations Log Book is the property of the public water system and must remain as part of the official records of the Public Water System.

3. Develop and implement an ongoing cross connection control program by: (1) identifying and tracking all existing cross connections on the water system, (2) ensuring that each existing cross connection is isolated from the water system by the correct type of cross connection control assembly, (3) evaluating all new connections to the water system to ensure that cross connection control devices are installed where needed, and (4) developing a written program to track each cross connection control device on the water system to ensure that each device is tested each year by an MDH approved & licensed backflow device tester.

4. Ensure that the public water system develops and maintains an organized record keeping system to retain all correspondence and reports received from MDH Bureau of Public Water Supply and to retain the results of all water quality analysis required by the Safe Drinking Water Acts. These records should be maintained on-site whenever possible and must be available for review by Bureau staff.

5. Ensure that all extensions to the water distribution system designed to serve 2 or more customers have been approved by the MDH Bureau of Public Water Supply before beginning construction.

6. Serve as the point of contact for the staff of the MDH Bureau of Public Water Supply in all matters related to compliance with the Federal and Mississippi Safe Drinking Water Acts and all related laws and regulations.

7. Ensure that the MDH can contact the Certified Waterworks Operator 24 hours a day by immediately notifying the Bureau of Public Water Supply of changes in the Operator's address or telephone number, business or personal.

8. Be available on a 24-hour a day basis to answer all customer complaints, investigate and resolve problems with the operation or water quality of the system.

9. Ensure that all monitoring programs -- such as lead and copper sampling -- are organized and carried out according to the requirements of the MDH, Bureau of Public Water Supply and the Federal Safe Drinking Water Act.

10. Ensure that all distribution line valves are located and operated on a regular schedule to keep them in proper working order. The Bureau of Public Water Supply strongly recommends that records of all regularly scheduled/completed maintenance be maintained by the certified operator or his or her representative.

11. Ensure that all water tanks -- pressure and storage -- are regularly inspected to ensure that they are operating properly; the water level in the tank should rise and fall to keep water in the tank circulating. The operator should visually

inspect the tank frequently and coordinate proper maintenance service as needed.

12. Periodically inspect all pumps (raw water, chemical feed, transfer, and/or high service), and equipment to ensure proper operation.

13. Analyze and record daily, monthly and annual water use and use water quality analysis to help detect leaks or other problems on the system.

14. Develop and implement a routine flushing schedule program based on chemical quality of the water. All dead end water lines should be flushed on a routine schedule; the frequency of flushing depends on the chemical quality of water and the type of water lines.

15. Develop a written set of standard operating procedures (SOP) for the public water system. The public water system should develop these procedures in sufficient detail and routinely update them to identify all activities required to efficiently operate and maintain all components of the water system. The responsible official of the public water system should review and approve this set of standard operating procedures. The operator should maintain the SOP in the official records of the water system so that it will be available for use by the water system.

16. Maintain an emergency operation plan for the public water system and be prepared to implement this plan when necessary.

17. Ensure that an adequate inventory is maintained of all supplies, chemicals, and equipment required to properly operate the public water system.

The certified operator or someone under his or her direct supervision should:

1. Test and record the chlorine residual free and total continuously on the discharge of the treatment facilities along with routine checks on the distribution system. Maintain a minimum "free" chlorine residual of 0.5 mg/l at the ends of the water distribution system unless the systems disinfection is treating with chloramines then a minimum of 0.5 mg/l total residual should be maintained.

2. Collect bacteriological water samples on the system as required by the Safe Drinking Water Act. These samples must be collected from locations on the water distribution system that the Bureau of Public Water Supply approved on the microbiological sampling site plan for the water system.

3. Read and record readings from all master meters regularly.

Minimum Job Performance Guidelines for Certified Waterworks Operators Class "B"

The certified waterworks' operator has a critically important role in protecting the public health of Mississippians since he or she is the person designated by Mississippi State law with the responsibility for ensuring that the public water system is routinely providing safe and adequate drinking water to its customers.

Specifically, the certified waterworks' operator is the person responsible for the daily operation of all water treatment facilities, water plants, distribution systems, intake structures, storage tanks, control systems, and other related appurtenances of the public water system. He or she should perform all routine duties as necessary to ensure that the public water system routinely complies with all requirements of the Federal and Mississippi Safe Drinking Water Acts and is properly operated and maintained. Occasionally, the certified operator may have a representative(s) under his or her supervision who also works with the water system. The authorized representative(s) can complete routine operational and maintenance duties and responsibilities as assigned by the certified operator without the certified operator being present.

The certified waterworks' operator is responsible for keeping the water system officials informed of all actions required to comply with the Safe Drinking Water Acts and ensuring, as authorized by the water system officials, that they implement these actions. The certified operator is also responsible for ensuring that all required water quality samples are collected and analyzed according to the requirements of the Mississippi Department of Health's Bureau of Public Water Supply. Required samples include the monthly bacteriological samples, lead samples, copper samples, nitrate samples, radiological samples, and others as required by the Federal Safe Drinking Water Act.

The minimum job performance duties and responsibilities of the Class "B" certified waterworks operators are outlined below:

1. As a minimum, inspect the system daily and perform all required operational and maintenance duties.

2 Maintain an approved Public Water System Operations Log Book documenting all activities completed on the public water system where he serves as the official certified waterworks operator. This log book must be available for inspection by Bureau staff. The Public Water System Operations Log Book is the property of the public water system and must remain as part of the official records of the Public Water System.

3. Develop and implement an ongoing cross connection control program by: (1) identifying and tracking all existing cross connections on the water system, (2) ensuring that each existing cross connection is isolated from the water system by the correct type of cross connection control assembly, (3) evaluating all new connections to the water system to ensure that cross connection control devices are installed where needed, and (4) developing a written program to track each cross connection control device on the water system to ensure that each device is tested each year by an MDH approved & licensed backflow device tester.

4. Ensure that the public water system develops and maintains an organized record keeping system to retain all correspondence and reports received from MDH Bureau of Public Water Supply and to retain the results of all water quality analyses required by the Safe Drinking Water Acts. These records should be maintained on-site whenever possible and must be available for review by Bureau of Public Water Supply staff.

5. Ensure that all extensions to the water distribution system that are designed to serve 2 or more customers have been approved by the MDH Bureau of Public Water Supply prior to beginning construction.

6. Serve as the point of contact for the staff of the MDH Bureau of Public Water Supply in all matters related to compliance with the Federal and Mississippi Safe Drinking Water Acts and all related laws and regulations.

7. Ensure that the MDH is able to contact the Certified Waterworks Operator, 24 hours a day, by immediately notifying the MDH Bureau of Public Water Supply when there is a change in the Operator's address or telephone number, either business or personal.

8. Be available 24 hours a day to answer all customer complaints, investigate and resolve all problems with the operation or water quality of the system.

9. Ensure that all water quality monitoring programs -- such as lead and copper sampling -- are organized and carried out according to the requirements of the MDH Bureau of Public Water Supply and the Federal and Mississippi Safe Drinking Water Acts.

10. Ensure that all distribution line valves are located and operated on a regular schedule to keep them in proper working order. The Bureau of Public Water Supply strongly recommends that records of all regularly scheduled/completed maintenance be maintained by the certified operator or his or her representative.

11. Ensure that all water tanks -- pressure and storage -- are inspected periodically to determine if they are operating properly; the water level in the tank should rise and fall to keep water in the tank circulating. The operator should visually inspect the tank frequently and coordinate proper maintenance service as needed.

12. Periodically inspect all pumps (raw water, chemical feed, transfer and/or high serve) and equipment to ensure proper operation.

13. Analyze and record daily, monthly and annual water use and use results of water quality analyses to help detect leaks or other problems on the system.

14. Develop and implement a routine flushing program based on chemical quality of the water. All dead end water lines should be flushed on a routine schedule; the frequency of flushing depends on the chemical quality of water and the type of water lines.

15. Ensure that the water treatment plant(s) and well site(s) are properly secured to prevent vandalism and accidents.

16. Develop a written set of standard operating procedures (SOP) for the public water system. The public water system should develop these procedures in sufficient detail and routinely update them to identify all activities required to efficiently operate and maintain all components of the water system. The responsible official of the public water system should review and approve this set of standard operating procedures. The operator should maintain the SOP in the official records of the water system so that it will be available for use by the water system.

17. Ensure that an emergency operation plan for the public water system is developed and properly implemented when necessary.

18. Ensure that an adequate inventory is maintained of all supplies, chemicals and equipment required to properly operate the public water system.

The certified operator or someone under his or her direct supervision should:

1. Test and record the chlorine residual free and total continuously on the discharge of the treatment facilities along with routine checks on the distribution system. Maintain a minimum "free" chlorine residual of 0.5 mg/l at the ends of the water distribution system unless the systems disinfection is treating with chloramines then a minimum of 0.5 mg/l total residual should be maintained.

2. Collect bacteriological water samples on the system as required by the Safe Drinking Water Acts. These samples must be collected from locations on the water distribution system that the Bureau of Public Water System approved on the bacteriological sample site plan for the system.

3. Read and record the readings from all master meters on a daily basis.

4. Check all wells daily to determine if they are performing as required. The well cycle run time should be checked and the master meter(s) should be used to record the pumping capacity of the well(s). The operator should also schedule annual checks of each well by an outside contractor for drawdown, pump submergence, pumping capacity and general well operation.

5. Check the chlorinator daily to see if it is operating properly. The operator should also check for chlorine leaks and replace chlorine tanks promptly as needed.

6. Inspect the fluoridation feeding equipment **daily**. The operator is also responsible for monitoring fluoride levels to determine if they are within acceptable ranges, and for providing monthly fluoride samples to MDH for analysis.

7. Inspect the aerator and associated equipment daily.

8. Regularly inspect the chemical feeder(s) used to raise the pH. The operator should perform tests for pH of the treated water leaving the plant daily and keep a written record of pH results.

9. Inspect all chemical feeders daily (potassium permanganate, polyphosphate, etc.).

10. Check all filters daily and backwash as needed according to recommended procedures.

11. Run daily tests for iron and manganese (where needed) on the finished water to evaluate filter efficiency and to ensure proper iron and manganese removal.

12. Inspect clarifiers daily (includes the mixing chamber for chemicals).

Minimum Job Performance Guidelines
for Certified Waterworks Operators
Class "C"

The certified waterworks' operator has a critically important role in protecting the public health of Mississippians since he or she is the person designated by Mississippi State law with the responsibility for ensuring that the public water system is routinely providing safe and adequate drinking water to its customers.

Specifically, the certified waterworks' operator is the person responsible for the daily operation of all water treatment facilities, water plants, distribution systems, intake structures, storage tanks, control systems, and other related appurtenances of the public water system. He or she should perform all routine duties as necessary to ensure that the public water system routinely complies with all requirements of the Federal and Mississippi Safe Drinking Water Acts and is properly operated and maintained. Occasionally, the certified operator may have a representative(s) under his or her supervision who also works with the water system. The authorized representative(s) can complete routine operational and maintenance duties and responsibilities as assigned by the certified operator without the certified operator being present.

The certified waterworks' operator is responsible for keeping the water system officials informed of all actions required to comply with the Safe Drinking Water Acts and ensuring, as authorized by the water system officials, that they implement these actions. The certified operator is also responsible for ensuring that all required water quality samples are collected and analyzed according to the requirements of the Mississippi Department of Health's Bureau of Public Water Supply. Required samples include the monthly bacteriological samples, lead samples, copper samples, nitrate samples, radiological samples, and others as required by the Federal Safe Drinking Water Act.

The minimum job performance duties and responsibilities of the Class "C" certified waterworks operators are outlined below:

1. As a minimum, inspect the system every other day and perform all needed and appropriate operational and maintenance activities.

2. Maintain an approved Public Water System Operations Log Book documenting all activities completed on the public water system where he serves as the official certified waterworks operator. This log book must be available for inspection by Bureau staff. The Public Water System Operations Log Book is the property of the public water system and must remain as part of the official records of the Public Water System.

3. Ensure that the public water system develops and maintains an organized record keeping system to retain all correspondence and reports received from MDH Bureau of Public Water Supply and to retain the results of all water quality analyses required by the Safe Drinking Water Acts. These records should be maintained on-site whenever possible and must be available for review by Bureau staff.

4. Develop and implement and on-going cross connection control program by: (1) identifying and tracking all existing cross connections on the water system, (2) ensuring that each existing cross connection is isolated from the water system by the correct type of cross connection control assembly, (3) evaluating all new connections to the water system to ensure that cross connection control devices are installed where needed, and (4) developing a written program to track each cross connection control device on the water system to ensure that each device is tested each year by an MDH approved & licensed backflow device tester.

5. Ensure that all extensions to the water distribution system that are designed to serve 2 or more customers have been approved by the MDH Bureau of Public Water Supply prior to beginning construction.

6. Serve as the point of contact for the staff of the MDH Bureau of Public Water Supply for all matters related to compliance with the Federal and Mississippi Safe Drinking Water Acts and all other applicable laws and regulations.

7. Ensure that the MDH is able to contact the Certified Waterworks Operator 24 hours a day by immediately notifying the Bureau of Public Water Supply of changes in the Operator's address or telephone number, business or personal.

8. Be available 24 hours a day to answer customer complaints, investigate and resolve problems with the operation or water quality of the water system.

9. Ensure that all water quality monitoring programs -- such as lead and copper sampling -- are organized and carried out according to the requirements of the MDH Bureau of Public Water Supply and the Federal Safe Drinking Water Act.

10. Ensure that all distribution line valves are located and operated on a regular schedule to keep them in proper working order. The Bureau of Public Water Supply strongly recommends that records of all regularly scheduled/completed maintenance be maintained by the certified operator or his or her representative.

11. Periodically inspect all pumps to ensure proper operation.

12. Ensure that all water tanks -- pressure and storage -- are inspected periodically to determine if they are operating properly; the water level in the tank should rise and fall to keep water in the tank circulating. The operator should visually inspect the tank on a routine basis and coordinate proper maintenance service.

13. Analyze and record daily, monthly and annual water use and use the results of water quality analyses to help detect leaks or other problems on the system.

14. Ensure that water treatment facilities and water well sites are properly secured to prevent vandalism and accidents.

15. Develop and implement a routine flushing schedule program based on chemical quality of the water. All dead end water lines should be flushed on a routine schedule; the frequency of flushing depends on the chemical quality of the water and the type of water lines.

16. Develop a written set of standard operating procedures (SOP) for the public water system. The public water system should develop these procedures in sufficient detail and routinely update them to identify all activities required to efficiently operate and maintain all components of the water system. The responsible official of the public water system should review and approve this set of standard operating procedures. The operator should maintain the SOP in the official records of the water system so that it will be available for use by the water system.

17. Develop an emergency operation plan and ensure that this plan is effectively implemented when necessary.

18. Ensure that an adequate inventory is maintained of all supplies, chemicals, and equipment required to properly operate the public water system.

The certified operator or someone under his or her direct supervision should:

1. Test and record "free" chlorine residual in the water distribution system daily. Maintain a minimum "free" chlorine residual of 0.5 mg/l at the extremities of the water distribution system.

2. Collect bacteriological water samples on the system as required by the Safe Drinking Water Act. These samples must be collected from locations on the water distribution system that were approved by the Bureau of Public Water Supply on the sampling site plan for the system.

3. Read and record the readings of all master meters on a routine basis.

4. Check all wells daily to determine if they are performing as required. The well cycle run time should be checked and master meter(s) should be used to record the pumping capacity of the well(s). The operator should also schedule annual checks of each well by an outside contractor for drawdown, pump submergence, pumping capacity and general well operation.

5. Check the chlorinator daily to see if it is operating properly. The operator should also check for chlorine leaks and replace chlorine tanks promptly as needed.

6. Inspect the aerator and associated equipment daily.

7. Inspect the fluoridation feeding equipment daily. The operator is also responsible for monitoring fluoride levels to determine if they are within acceptable ranges, and to provide monthly fluoride samples to MDH for analysis.

8. Regularly inspect the chemical feeder(s) used to adjust the pH. The operator should perform, on a daily basis, tests for pH of the treated water leaving the plant and keep a written record of pH results.

9. Inspect all chemical feeders daily (potassium permanganate, polyphosphate, etc.).

10. Check all pressure filters daily and backwash as needed according to recommended procedures.

Minimum Job Performance Guidelines for Certified Waterworks Operators Class "D"

The certified waterworks' operator has a critically important role in protecting the public health of Mississippians since he or she is the person designated by Mississippi State law with the responsibility for ensuring that the public water system is routinely providing safe and adequate drinking water to its customers.

Specifically, the certified waterworks' operator is the person responsible for the daily operation of all water treatment facilities, water plants, distribution systems, intake structures, storage tanks, control systems, and other related appurtenances of the public water system. He or she should perform all routine duties as necessary to ensure that the public water system routinely complies with all requirements of the Federal and Mississippi Safe Drinking Water Acts and is properly operated and maintained. Occasionally, the certified operator may have a representative(s) under his or her supervision who also works with the water system. The authorized representative(s) can complete routine operational and maintenance duties and responsibilities as assigned by the certified operator without the certified operator being present.

The certified waterworks' operator is responsible for keeping the water system officials informed of all actions required to comply with the Safe Drinking Water Acts and ensuring, as authorized by the water system officials, that they implement these actions. The certified operator is also responsible for ensuring that all required water quality samples are collected and analyzed according to the requirements of the Mississippi Department of Health's Bureau of Public Water Supply. Required samples include the monthly bacteriological samples, lead samples, copper samples, nitrate samples, radiological samples, and others as required by the Federal Safe Drinking Water Act.

The minimum job performance duties and responsibilities of the Class "D" certified waterworks operators are outlined below:

1. As a minimum, personally inspect the system two or three days each week, depending on the characteristics of each particular public water system, and perform all necessary and appropriate operational and maintenance activities.

2. Maintain an approved Public Water System Operations Log Book documenting all activities completed on the public water system where he serves as the official certified waterworks operator. This log book must be available for inspection by Bureau staff. The Public Water System Operations Log Book is the property of the public water system and must remain as part of the official records of the Public Water System.

3. Develop and implement an on-going cross connection control program by: (1) identifying and tracking all existing cross connections on the water system, (2) ensuring that each existing cross connection is isolated from the water system by the correct type of cross connection control assembly, (3) evaluating all new connections to the water system to ensure that cross connection control devices are installed where needed, and (4) developing a written program to track each cross connection control device on the water system to ensure that each device is tested each year by an MDH approved & licensed backflow device tester.

4. Ensure that the public water system develops and maintains an organized record keeping system to retain all correspondence and reports received from MDH Bureau of Public Water Supply and to retain the results of all water quality analyses required by the Safe Drinking Water Acts. These records should be maintained on-site whenever possible and must be available for review by Bureau of Public Water Supply staff.

5. Ensure that all extensions to the water distribution system that are designed to serve 2 or more customers have been approved by the MDH Division of Water Supply prior to beginning construction.

6. Serve as the point of contact for the staff of the MDH Bureau of Public Water Supply in all matters related to compliance with the Federal and Mississippi Safe Drinking Water Acts and all related laws and regulations.

7. Ensure that the MDH is able to contact the Certified Waterworks Operator 24 hours a day by immediately notifying the Bureau of Public Water Supply of changes in the operators address or telephone number, business or personal.

8. Be available on a 24-hour a day basis to answer all customer complaints and investigate and resolve problems with the operation or water quality of the system.

9. Ensure that all monitoring programs -- such as lead and copper sampling -- are organized and carried out according to the requirements of the MDH/ Bureau of Public Water Supply and the Federal Safe Drinking Water Act.

10. Ensure that all distribution line valves are located and operated on a regular schedule to keep them in proper working order. The Bureau of Public Water Supply strongly recommends that records of all regularly scheduled/completed maintenance be maintained by the certified operator or his/her representative.

11. Ensure that all water tanks -- pressure and storage -- are regularly inspected to ensure that they are operating properly; the water level in the tank should rise and fall to keep water in the tank circulating. The operator should visually inspect the tank on a routine basis and coordinate proper maintenance service as needed.

12. Periodically inspect all pumps to ensure proper operation.

13. Analyze and record daily, monthly and annual water use and use water quality analyses to help detect leaks or other problems on the system.

14. Develop and implement a routine flushing schedule program based on chemical quality of the water. All dead end water lines should be flushed on a routine schedule; the frequency of flushing depends on the chemical quality of water and the type of water lines.

15. Ensure that water treatment facilities, well sites, etc. are properly secured to prevent vandalism or accidents.

16. Develop a written set of standard operating procedures (SOP) for the public water system. The public water system should develop these procedures in sufficient detail and routinely update them to identify all activities required to efficiently operate and maintain all components of the water system. The responsible official of the public water system should review and approve this set of standard operating procedures. The operator should maintain the SOP in the official records of the water system so that it will be available for use by the water system.

17. Maintain an emergency operation plan for the public water system and be prepared to implement this plan when necessary.

18. Ensure that an adequate inventory is maintained of all supplies, chemicals, and equipment required to properly operate the public water system.

The certified operator or someone under his or her direct supervision should:

1. Test and record the "free" chlorine residual in the water distribution system routinely. Maintain a minimum "free" chlorine residual of 0.5 mg/l at the ends of the water distribution system.

2. Collect bacteriological water samples on the system as required by the Safe Drinking Water Act. These samples must be collected from locations on the water distribution system that were approved by the Bureau of Public Water Supply on the microbiological sampling site plan for the water system.

3. Read and record readings from all master meters on a routine basis.

4. Check all wells routinely to determine if they are performing as required. The well cycle run time should be checked and the master meter(s) should be used to record the pumping capacity of the well(s). The operator should also schedule annual checks by an outside contractor for factors such as drawdown, pump submergence, pumping capacity and general well operation.

5. Check the chlorinator routinely to see if it is operating properly. The operator should also check for chlorine leaks and replace chlorine tanks promptly as needed.

6. Inspect the fluoridation feeding equipment routinely (daily if possible). The operator is also responsible for monitoring fluoride levels to determine if they are within acceptable ranges, and to provide monthly fluoride samples to MDH for analysis.

7. Inspect all chemical feeders routinely (sodium fluoride, polyphosphate, etc.).

Minimum Job Performance Guidelines
for Certified Waterworks Operators
Class "E"

The certified waterworks' operator has a critically important role in protecting the public health of Mississippians since he or she is the person designated by Mississippi State law with the responsibility for ensuring that the public water system is routinely providing safe and adequate drinking water to its customers.

Specifically, the certified waterworks' operator is the person responsible for the daily operation of all water treatment facilities, water plants, distribution systems, intake structures, storage tanks, control systems, and other related appurtenances of the public water system. He or she should perform all routine duties as necessary to ensure that the public water system routinely complies with all requirements of the Federal and Mississippi Safe Drinking Water Acts and is properly operated and maintained. Occasionally, the certified operator may have a representative(s) under his or her supervision who also works with the water system. The authorized representative(s) can complete routine operational and maintenance duties and responsibilities as assigned by the certified operator without the certified operator being present.

The certified waterworks' operator is responsible for keeping the water system officials informed of all actions required to comply with the Safe Drinking Water Acts and ensuring, as authorized by the water system officials, that they implement these actions. The certified operator is also responsible for ensuring that all required water quality samples are collected and analyzed according to the requirements of the Mississippi Department of Health's Bureau of Public Water Supply. Required samples include the monthly bacteriological samples, lead samples, copper samples, nitrate samples, radiological samples, and others as required by the Federal Safe Drinking Water Act.

The minimum job performance duties and responsibilities of the Class "E" certified waterworks operators are outlined below:

1. As a minimum, personally inspect the system a minimum of one (1) day each week, depending on the characteristics of each particular public water system, and perform all necessary and appropriate operational and maintenance activities required on the distribution system.

2. Maintain an approved Public Water System Operations Log Book documenting all activities completed on the public water system where he or she serves as the official certified waterworks operator. This Log Book must be available for inspection by Bureau staff. The Public Water System Operations Log Book is the property of the public water system and must remain as part of the official records of the Public Water System.

3. Develop and implement and on-going cross connection control program by: (1) identifying and tracking all existing cross connections on the water system, (2) ensuring that each existing cross connection is isolated from the water system by the correct type of cross connection control assembly, (3) evaluating all new connections to the water system to ensure that cross connection control devices are installed where needed, and (4) developing a written program to track each cross connection control device on the water system to ensure that each device is tested each year by an MDH approved and licensed backflow device tester.

4. Ensure that the public water system develops and maintains an organized record keeping system to retain all correspondence and reports received from MDH Bureau of Public Water Supply and to retain the results of all water quality analysis required by the Safe Drinking Water Acts. These records should be maintained on-site whenever possible and must be available for review by Bureau of Public Water Supply staff.

5. Ensure that all extensions to the water distribution system that are designed to serve 2 or more customers have been approved by the MDH Bureau of Public Water Supply prior to beginning construction.

6. Serve as the point of contact for the staff of the MDH Bureau of Public Water Supply in all matters related to compliance with the Federal and Mississippi Safe Drinking Water Acts and all related laws and regulations.

7. Ensure that the MDH is able to contact the Certified Waterworks Operator 24 hours a day by immediately notifying the Bureau of Public Water Supply of changes in the Operator's address or telephone number, business or personal.

8. Be available on a 24-hour a day basis to answer all customer complaints and to investigate and resolve problems with the operation or water quality of the system.

9. Ensure that all monitoring programs -- such as lead and copper sampling -- are organized and carried out according to the requirements of the MDH/ Bureau of Public Water Supply and the Federal Safe Drinking Water Act.

10. Ensure that all distribution line valves are located and operated on a regular schedule to keep them in proper working order. The Bureau of Public Water Supply strongly recommends that records of all regularly scheduled/completed maintenance be maintained by the certified operator or his or her representative.

11. Ensure that all water tanks -- pressure and storage -- are regularly inspected to ensure that they are operating properly; the water level in the tank should rise and fall to keep water in the tank circulating. The operator should visually inspect the tank on a routine basis and coordinate proper maintenance service as needed.

12. Periodically inspect all pumps (if applicable) to ensure proper operation.

13. Analyze and record daily, monthly and annual water use and use water quality analyses to help detect leaks or other problems on the system.

14. Develop and implement a routine flushing schedule program based on chemical quality of the water. All dead end water lines should be flushed on a routine schedule; the frequency of flushing depends on the chemical quality of water and the type of water lines.

15. Develop a written set of standard operating procedures (SOP) for the public water system. The public water system should develop these procedures in sufficient detail and routinely update them to identify all activities required to efficiently operate and maintain all components of the public water system. The responsible official of the public water system should review and approve this set of standard operating procedures. The operator should maintain the SOP in the official records of the water system so that it will be available for use by the water system.

16. Maintain an emergency operation plan for the public water system and be prepared to implement this plan when necessary.

17. Ensure that an adequate inventory is maintained of all supplies, chemicals, and equipment required to properly operate the public water system.

The certified operator or someone under his or her direct supervision should:

1. Test and record the chlorine residual free and total continuously on the discharge of the treatment facilities along with routine checks on the distribution system. Maintain a minimum "free" chlorine residual of 0.5 mg/l at the ends of the water distribution system unless the systems disinfection is treating with chloramines then a minimum of 0.5 mg/l total residual should be maintained.

2. Collect bacteriological water samples on the system as required by the Safe Drinking Water Act. These samples must be collected from locations on the water distribution system that the Bureau of Public Water Supply approved on the microbiological sampling site plan for the water system.

3. Read and record readings from all master meters on a routine basis.

APPENDIX B-2

Mississippi Primary Drinking Water Regulation

Prepared by
Mississippi State Department of Health
Bureau of Public Water Supply

Title 15 - Mississippi Department of Health

Part 20: Bureau of Public Water Supply

Subpart 72: Public Water Supply

CHAPTER 1. MISSISSIPPI PRIMARY DRINKING WATER REGULATION

Subchapter 1. General Provisions:

Rule 1.1.1. **Legal Authority**. This regulation has been promulgated under the authority of and pursuant to the Mississippi Safe Drinking Water Act of 1997 (Section 41-26-1 through Section 41-26-101, Mississippi Code of 1972, Annotated).

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.1.2. **Definitions**.

1. **Department** shall mean the Mississippi State Department of Health.

2. **Director** shall mean the Executive Officer of the Mississippi State Department of Health or his authorized agent.

3. **Municipality** shall mean a city, town, village, or other public body created by state law, or an Indian tribal organization authorized by law.

4. **Federal Agency** shall mean any department, agency, or instrumentality of the United States.

5. **Administrator** shall mean the Administrator of the U.S. Environmental Protection Agency or his authorized representative.

6. **Federal Act** shall mean the Safe Drinking Water Act of 1974, cited as Public Law 93-523, or any subsequent revisions thereto.

7. **Regulations** shall mean primary drinking water regulations promulgated by the administrator pursuant to the federal act.

8. **Backflow** shall mean the reversal of normal flow direction where water flows from the intended point of delivery towards the public water supply.

9. **Cross Connection** shall mean any direct interconnection between a public water system and a non-public water system or other source which may result in the contamination of the drinking water provided by the public water system. This definition includes any arrangement of piping where a potable water line is connected to non potable water; it may be a pipe-to-pipe connection where potable and non potable water lines are directly connected or a pipe-to-water connection where the potable water outlet is submerged in non potable water. If

the potable and non-potable source are separated by gate valves, check valves or devices other than the appropriate backflow preventer as outlined by this regulation, a cross connection exists. By-pass arrangements, jumper connections, swivel or change over assemblies, or other temporary or permanent assemblies through which, or because of which, backflow may occur are considered to be cross connections.

10. **Public water system** means a system for the provision to the public of water for human consumption through pipes or, after August 5, 1998, other constructed conveyances, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year. Such term includes: Any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system; and any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. Such term does not include any "special irrigation district." Service connection, as used in the definition of public water system, does not include a connection to a system that delivers water by a constructed conveyance other than a pipe if:

a. The water is used exclusively for purposes other than residential uses (consisting of drinking, bathing, cooking, or other similar uses);

b. The Director or Administrator determines that alternative water to achieve the equivalent level of public health protection provided by the applicable national primary drinking water regulation is provided for residential or similar uses for drinking and cooking; or

c. The Director or Administrator determines that the water provided for residential or similar uses for drinking, cooking, and bathing is centrally treated or treated at the point of entry by the provider, a pass-through entity, or the user to achieve the equivalent level of protection provided by the applicable national primary drinking water regulation.

d. Special irrigation district means an irrigation district in existence prior to May 18, 1994, that provides primarily agricultural service through a piped water system with only incidental residential or similar use where the system or the residential or similar users of the system comply with the exclusion provisions in Section 1401(4)(B)(i)(II) or (III) of the Federal Safe Drinking Water Act.

11. **Professionally installed** shall mean installed in a workmanlike manner with no apparent errors in installation.

12. **Significant deficiencies** cause or have the potential to cause the introduction of contamination into drinking water delivered to customers of a public water supply. This could include defects in design, operation or maintenance of the source, treatment or distribution systems.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.1.3. The definitions as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.2 are hereby adopted.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.1.4. **Coverage**. This regulation shall apply to each public water system in the State, except that it shall not apply to a public water system:

1. Which consists only of distribution and storage facilities which does not have any collection and treatment facilities; and
2. Which obtains all of its water from, but is not owned or operated by, a public water system to which such regulation applies; and
3. Which does not sell water to any person; and
4. Which is not a carrier which conveys passengers in interstate or intrastate commerce.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.1.5. **Variances and Exemptions**. Variances and exemptions may be issued by the Director in accordance with Sections 1415 and 1416 of the federal act. Treatment utilizing best available technology, as stipulated in Title 40 Code of Federal Regulations, Part 142, Subparts F and G, may be required in order to grant variances and exemptions under this regulation. Variances and exemptions shall not be issued if not allowed by the National Primary Drinking Water Regulations.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.1.6. **Preconstruction and Treatment Requirements.**

1. **Siting Requirements**. Before a person may initiate construction of a new community or non-transient non-community public water system or increase the capacity of an existing community or non-transient non-community public water system, he shall submit sufficient information to the Director for evaluation of the proposed site, to determine whether the site and design of the proposed construction or modification will enable the system to comply with this regulation.
2. **Plans and Specifications Approval**. Prior to advertising for bids and/or initiating construction of a new community or non-transient non-community public water system or making significant extensions or alterations to an existing community or non-transient non-community public water system which may effect the operation of that system, plans and specifications for the proposed

construction shall be approved by the Director. Plans and specifications submitted to the Director for approval shall be prepared by a professional engineer licensed to practice in the State of Mississippi.

3. **Operation and Maintenance Plans**. Each applicant for a new community or non-transient non-community public water system shall submit an operation and maintenance plan for review and approval by the Director. The plan must be approved by the Director prior to beginning construction.

4. **Financial and Managerial Viability**. Each applicant for a new community or non-transient non-community public water system shall submit financial and managerial information as required by the Public Utilities Staff. Plans and specifications shall not be approved by the Director until written certification of the financial and managerial viability of the new water system is received from the Executive Director of the Public Utilities Staff.

5. **Changes to Existing Public Water Systems**. Plans and specification for changes to an existing community or non-transient non-community public water systems shall not be approved if the Director determines the changes would threaten the viability of the water system or if the changes may overload the operational capabilities of the water system.

6. **Non-Centralized Treatment Devices**. Public water systems may utilize point-of-entry devices to comply with maximum contaminant levels as stipulated in the National Primary Drinking Water regulations as published at Title 40 Code of Federal Regulations Sections 141.100 and 141.101.

7. **Ban of Use of Lead Products**. Any pipe, solder, or flux used in the installation or repair of any public water system, or any plumbing in a residential or nonresidential facility providing water for human consumption which is connected to a public water system shall be lead free. Solders and flux are defined as "lead free" when they contain not more than 0.2 percent lead. Pipes and pipe fittings are defined as "lead free" when they contain not more than 8.0 percent lead. Plumbing fittings and fixtures intended by the manufacturer to dispense water for human ingestion are defined as “lead free” when they comply with standards established in accordance with 42 U.S.C. 300g-6(e).

8. **Lead Service Line Replacement**. It shall be the responsibility of each supplier of water to comply with the lead service line replacement requirements and lead service line reporting requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.84 and 141.90.

9. **Overloaded Public Water Systems**. Public water systems that are serving customers in excess of the design capacity as determined by the Director shall be identified as overloaded and shall immediately, upon written notification by the Director, cease adding new customers. Public water systems identified as

overloaded shall not add new customers until notified, in writing, by the Director that the system's design capacity has been increased and that the water system can resume adding new customers.

SOURCE: Miss. Code Ann. §41-26-6

Subchapter 2. Maximum Contaminant Levels

Rule 1.2.1. **Microbiological**. All microbiological maximum contaminant levels shall apply to public water systems as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.52 and 141.63.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.2.2. **Inorganic Chemicals**. All inorganic chemical maximum contaminant levels and action levels shall apply to public water systems as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.6, 141.11, 141.23 (d & e), 141.51, 141.60, 141.62 (b, c & d) and 141.80.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.2.3. **Organic Chemicals**. All organic chemical maximum contaminant levels shall apply to public water systems as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.50, 141.60 and 141.61.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.2.4. **Turbidity**. The maximum contaminant levels for turbidity shall apply to public water systems as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.13, 141.73 and 141.173.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.2.5. **Radionuclides**. All radionuclide maximum contaminant levels and maximum contaminant level goals shall apply to public water systems as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.15, 141.16, 141.55 and 141.66.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.2.6. **Disinfectant Residuals**, Disinfection Byproducts, and Disinfection Byproduct Precursors. All disinfectant residuals, disinfection byproduct and disinfection byproduct precursor maximum contaminant levels, operational evaluation levels, best technologies, treatment techniques, and other means available for achieving compliance shall apply to public water systems as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.53, 141.54, 141.64, 141.65, 141.130, 141.620 and 141.626.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.2.7. **Miscellaneous Contaminants.** All maximum contaminant levels not previously referenced in this regulation shall apply to public water systems as stipulated in the latest revision of the National Primary Drinking Water Regulations.

SOURCE: Miss. Code Ann. §41-26-6

Subchapter 3. Monitoring, Analytical, And Treatment Technique Requirements

Rule 1.3.1. **Coliform Sampling and Analyses.** It shall be the responsibility of each supplier of water to comply with the Coliform Monitoring and Analytical Requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.21 or any subsequent revisions thereto except that the following optional provisions of Title 40 Code of Federal Regulations Section 141.21 are not adopted:

1. The provision of Title 40 Code of Federal Regulations Section 141.21 (a)(2) concerning the reduction of the monitoring frequency for community water systems serving 1,000 or fewer persons;

2. The provision of Title 40 Code of Federal Regulations Section 141.21 (a)(5) concerning waiver of the time limit for sampling after a turbidity sampling result exceeds 1 NTU;

3. The provision of Title 40 Code of Federal Regulations Section 141.21 (b)(3) concerning collection of large volume repeat samples in containers of any size;

4. The provision of Title 40 Code of Federal Regulations Section 141.21 (d) concerning agents other than State personnel conducting sanitary surveys;

5. The provisions of Title 40 Code of Federal Regulations Section 141.21 (e)(2) with respect to waiver of fecal coliform or E. Coli testing on a total coliform positive sample;

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.3.2. **Inorganic Chemical Sampling and Analyses.** It shall be the responsibility of each supplier of water to comply with the inorganic chemical sampling/analysis requirements, analytical techniques, and water quality parameters as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.6, 141.23, 141.86, 141.87, 141.88 and 141.89 except that the following optional provisions of Title 40 Code of Federal

Regulations are not adopted: Section 141.23 (a)(4) and Section 141.88(a)(1)(iv) which allow compositing of samples. The provisions of Title 40 Code of Federal Regulations, Section 141, Subpart I – Control of Lead and Copper are hereby incorporated by reference including any subsequent amendments and editions.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.3.3. **Organic Chemical Sampling and Analyses.** It shall be the responsibility of each supplier of water to comply with the organic chemical sampling and analysis requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.6, 141.24, 141.30 and 141.40 except that the following optional provisions of Title 40 Code of Federal Regulations are not adopted: Sections 141.24 (f) (14) and (h) (10) and Section 141.40 (n)(9) which allow compositing of samples.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.3.4. **Radionuclides**. It shall be the responsibility of each supplier of water to comply with the radionuclide sampling and analysis requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.25 and 141.26.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.3.5. **Turbidity and Source Water Sampling and Analyses.** It shall be the responsibility of each supplier of water to comply with the turbidity and source water sampling and analysis requirements and state notification procedures as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.22, 141.174, 141.560 – 141.564, 141.701 – 141.704, 141.707 and Appendix B to Subpart Q of Part 41.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.3.6. **Disinfectant Residuals, Disinfection Byproducts, and Disinfection Byproduct Precursors Sampling and Analyses.** It shall be the responsibility of each supplier of water to comply with the disinfection byproduct sampling, analysis and all other requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.131, 141.132, 141.531, 141.600-605, 141.620-625, 141.627, and 141.628. Compliance with this section shall be determined as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.133 and 141.620.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.3.7. **Ground Water Microbial Sampling and Analyses.** It shall be the responsibility of each supplier of ground water to comply with the source microbial monitoring and analytical requirements and if requested, provide any information that will allow the state to perform a hydrogeologic sensitivity assessment_as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.400 and 141.402.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.3.8. **Filtration and Disinfection**. It shall be the responsibility of each supplier of water to comply with the filtration and disinfection analytical and monitoring requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.70, 141.73, 141.74, and 141.174.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.3.9. **Miscellaneous Contaminants**. It shall be the responsibility of the supplier of water to comply with the special monitoring requirements of the National Primary Drinking Water Regulation Title 40 Code of Federal Regulations Section 141.41 (special monitoring for sodium) and Section 141.42 (special monitoring for corrosivity characteristics). It shall also be the responsibility of the supplier of water to comply with all other monitoring and analysis requirements not previously addressed in this regulation as stipulated in the National Primary Drinking Water Regulations.

SOURCE: Miss. Code Ann. §41-26-6

Subchapter 4. Sanitary Surveys.

Rule 1.4.1. **Surface Water Systems:** The Mississippi State Department of Health shall make periodic on-site surveys of each public surface water system for the purpose of determining the adequacy of the water source, facilities, equipment, watershed control program, operation and maintenance procedures and monitoring and compliance as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.522 and 141.723. These surveys include the right to inspect all records, take water quality samples, or verify procedures, to determine compliance with this regulation. Significant deficiencies, as determined by the Department utilizing current EPA guidance manuals, shall be identified by Department staff during the conduct of sanitary surveys. Public water systems shall, upon receipt of the sanitary survey report, provide a written response to all significant deficiencies identified in the report to the Department within 45 days of receipt of the report. In this written response, the public water system shall outline its plan to correct the significant deficiencies identified in the survey report. After reviewing the public water system's written response, the Director shall require, by means of a written order, that the public water system correct the significant deficiencies within a reasonable period of time as determined by the Department.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.4.2. **Ground Water Systems:** The Mississippi State Department of Health shall make periodic on-site surveys of each public ground water system for the purpose of determining the adequacy of the water source, treatment, distribution, storage, pumps, reporting, management and operator compliance as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.401. These surveys include the right to inspect all records, take water quality samples, or verify procedures, to determine compliance with this regulation. Significant deficiencies, as determined by the Department utilizing current EPA guidance, shall be identified by Department staff during the conduct of sanitary surveys. Public water systems shall, upon receipt of the sanitary survey report, provide a written response to all significant deficiencies identified in the report to the Department within 30 days of receipt of the report. In this written response, the public water system shall outline its plan to correct the significant deficiencies identified in the survey report. After reviewing the public water system's written response, the Director shall require, by means of a written order, that the public water system correct the significant deficiencies within 120 days or within a reasonable period of time as determined by the Department.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.4.3. **Treatment Techniques**. It shall be the responsibility of each supplier of water to comply with the treatment techniques as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.76, 141.81, 141.82, 141.83, 141.110, 141.111, 141.135, 141.403, and 141.404. Violations as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.403 and 141.404 are hereby incorporated.

SOURCE: Miss. Code Ann. §41-26-6

Subchapter 5. Reporting, Records, And Public Notification

Rule 1.5.1. **Reporting Requirements.**

1. The supplier of water shall provide the results of all water quality analyses to be utilized for compliance with this regulation to the Director as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.31, 141.35, 141.73, 141.75, 141.76, 141.90, 141.134, 141.173, 141.175, 141.405, 141.570, 141.601, 141.602, 141.629, 141.706, 141.710 and 141.712.

2. The supplier of water shall report to the Director the failure to comply with these regulations, including failure to comply with monitoring and analytical requirements, and failure to meet maximum contaminant levels as stipulated in the National Primary Drinking Water Regulations as published under Title 40

Code of Federal Regulations Sections 141.31, 141.35, 141.73, 141.75, 141.76, 141.173, 141.175 and 141.405.

3. The supplier of water shall provide proof of public notification to the Director as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.31(d), 141.90(f) and 141.405.

4. The supplier of water shall maintain records and submit to the Director copies of all required records as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.31 (e), 141.90, 141.91, 141.75, 141.76, 141.175, 141.405, 141.721 and 141.722.

5. The state shall be responsible for submitting to the Administrator all information stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 142.15.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.5.2. **Public Notification and Education**. Each supplier of water shall provide public notification or education as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.35, 141.71, 141.73, 141.74, 141.85, 141.90(f), 141.170-141.174, 141.201-141.211, 141.402(g) and (h), 141.403(d), 141.404(d), 141.500-141.553, 141.560-141.564 and Appendices A-C to Subpart Q of Part 141. Public notification of fluoride content is required of all public water suppliers as stipulated in Title 40 Code of Federal Regulations Section 143.5.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.5.3. **Record Maintenance**. Each supplier of water shall retain records and make such records available to the Director as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.33, 141.35, 141.75, 141.76, 141.134, 141.155, 141.175, 141.571, 141.601, 141.602, 141.629, and 142.62.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.5.4. **Records Kept by States**. Records of currently applicable or most recent tests, measurements, analyses, decisions, and determinations performed on each public water system, including all supporting information and an explanation of the technical basis of each decision to determine compliance with applicable provisions of the Mississippi Primary Drinking Water Regulations will be maintained in accordance with the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 142.14.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.5.5. **Laboratory Certification.**

1. The Director may prescribe minimum requirements for a laboratory to be certified by the Mississippi State Department of Health to perform water quality analyses required under this regulation.

2. Each supplier of water must utilize the services of certified laboratory or party approved by the state where applicable to complete all water quality analyses as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.28 and 141.705.

SOURCE: Miss. Code Ann. §41-26-6

Subchapter 6. Filtration and Disinfection - Surface Water Treatment Rule.

Rule 1.6.1. **General Requirements**: Each public water system that uses a surface water source or a ground water source under the direct influence of surface water must comply with the treatment technique requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.70.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.6.2. **Criteria for Avoiding Filtration**: In order to avoid filtration, a public water system that uses a surface water source or a ground water source under the direct influence of surface water must comply with the criteria for avoiding filtration as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.71.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.6.3. **Disinfection**: A public water system that uses a surface water source or a ground water source under the direct influence of surface water must comply with the disinfection requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.72.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.6.4. **Filtration**: A public water system that uses a surface water source or a ground water source under the direct influence of surface water and does not meet all of the criteria in Title 40 Code of Federal Regulations Section 141.71 for avoiding filtration must comply with the treatment requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.73.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.6.5. **Recycle Provisions**: A public water system that uses a surface water source or a ground water source under the direct influence of surface water must comply with the recycle provisions as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.76.

SOURCE: Miss. Code Ann. §41-26-6

Subchapter 7. Enhanced Filtration and Disinfection - Surface Water Treatment Rule.

Rule 1.7.1. **General Requirements**: Each public water system that uses a surface water source or a ground water source under the direct influence of surface water must comply with the treatment technique and microbial protection requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.170, 141.500-141.503, 141.510-141.511, 141.520, 141.700, 141.710 – 141.720.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.7.2. **Criteria for Avoiding Filtration**: In order to avoid filtration, a public water system that uses a surface water source or a ground water source under the direct influence of surface water must comply with the criteria for avoiding filtration as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.171 and 141.521.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.7.3. **Disinfection**: A public water system that uses a surface water source or a ground water source under the direct influence of surface water must comply with the disinfection, profiling and benchmarking requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.172, 141.530-141.536, 141.540-141.544, 141.708 and 141.709.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.7.4. **Filtration**: A public water system that uses a surface water source or a ground water source under the direct influence of surface water and does not meet all of the criteria in Title 40 Code of Federal Regulations Section 141.171 for avoiding filtration must comply with the monitoring, reporting, records maintenance, assessment and treatment requirements as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Sections 141.173, 141.550-141.553, and 141.560-141.564. A public water system that uses a surface water source or a ground water source under the influence of surface water shall arrange for the conduct of a comprehensive performance evaluation by the Department or a third party approved by the Department within 30 days of exceeding the filter performance triggers stipulated by the National Primary Drinking Water Regulations published under Title 40

Code of Federal Regulations Section 141.175 (b)(4). Based upon the results of this comprehensive performance evaluation, the public water system shall arrange for the completion of a composite correction program developed in accordance with current EPA guidance documents. This composite correction program shall be submitted to the Department for review and approval prior to actual implementation. The Director, after reviewing and approving the composite correction program, shall, by means of a written order, require the public water system to implement the approved composite correction program on a time schedule approved by the Department as stipulated in Title 40 Code of Federal Regulations Section 142.16(g)(1) and 142.16(j)(1).

SOURCE: Miss. Code Ann. §41-26-6

Subchapter 8. Cross Connections

Rule 1.8.1. **Cross Connections Prohibited**. No person shall install, permit to be installed or maintain any cross connection between a public water system and any other non-public water system or a line from any container of liquids or other substances, except as specifically authorized by this regulation, unless a backflow prevention assembly is installed between the public water system and the source of contamination. Direct connections between a public water supply and sewer or storm sewer are prohibited.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.8.2. **Low Hazard Cross Connection.**

1. A connection between a public water system and a service or other water system not hazardous to health but not meeting established water quality standards for public water systems and not cross connected within its system with a potentially dangerous substance shall be considered a low hazard category cross connection. An appropriate backflow prevention assembly or device recommended by the Department for low hazard cross connections shall be installed except as provided in section 104.02(2).

2. Pursuant to Section 41-26-14(2)(b) of the Mississippi Code of 1972, as amended, the following cross connections shall be considered as low hazard posing a very low risk and shall not be required to have a backflow preventer device:

    a. Any lawn sprinkler system or lawn irrigation system that is connected to a public water system and was professionally installed regardless of whether the system is underground or above ground or whether the system has pop-up sprinkler heads.

    b. Any swimming pool that is connected to a public water system and was professionally installed or any swimming pool that is connected to a public water system and has a fill line with an anti-siphon air gap.

c. Any water fountain or cooler that provides drinking water for human consumption that is connected to a public water system and was professionally installed.

d. Any fire sprinkler system that contains only water or a dry pipe and no chemicals that is connected to a public water system and was professionally installed.

e. Any commercial establishment that is connected to a public water system that contains no cross connections directly with a dangerous or hazardous substance or material.

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 9. High Hazard Cross Connection.

Rule 1.9.1. A connection between a public water system and a non-public water system or other source of contamination which has or may have any material in the water dangerous to health, or connected to any material dangerous to health, that is or may be handled under pressure, or subject to negative pressure, shall be considered a high hazard category cross connection. The cross connection shall be eliminated by air gap separation or shall be protected by the installation of an appropriate backflow prevention assembly or device recommended by the Department for high hazard cross connections.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.9.2. Any lawn sprinkler system or lawn irrigation system that is connected to a public water system and either injects or stores lawn chemicals or is connected to a wastewater supply shall be considered a high hazard cross connection and shall be protected by the installation of a backflow prevention assembly or device.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.9.3. Additional backflow prevention assemblies or devices shall not be required for carbonated beverage dispensers if 1) the water supply connection to the carbonated beverage dispenser is protected against backflow by a backflow prevention assembly or device that conforms to ASSE 1022 or by an air gap, and 2) the backflow prevention assembly or device and the piping downstream from the device are not affected by carbon dioxide gas.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.9.4. **Distinction Between Low and High Hazard Cross Connection**. The distinction between low hazard cross connection and high hazard cross connections shall be made by an authorized representative of the public water system subject to review by the Department.

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 10. Responsibility Of Public Water Systems To Establish Cross Connection Control Programs

Rule 1.10.1. **Cross Connection Control Program**. All public water supplies shall adopt and enforce a cross connection control policy or ordinance that is no less stringent than the provisions of this regulation; however, the adopted policy or ordinance shall not be more stringent than the provisions of House Bill 692 enacted by the 2001 Mississippi Legislature, as codified in Section 41-26-14 et. seq. of the Mississippi Code of 1972, Annotated. This policy or ordinance shall establish a cross connection control program consisting of the following:

1. Locating and eliminating unprotected cross connections.

2. Preventing the occurrence of new cross connections with the public water system.

3. Maintaining records pertaining to the location of existing backflow prevention assemblies, type and size of each assembly and results of all tests of backflow prevention assemblies by a tester certified by the Department.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.10.2. **Cross Connection Surveys**. It shall be the responsibility of each public water system to conduct surveys and on-site visits as necessary to locate existing cross connections. Single family dwellings and multi-family dwellings shall not be included in this survey unless the officials of the public water system have reason to believe that a cross connection exists. This survey shall be performed by an authorized representative of the public water system utilizing established written guidelines as published by the Department.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.10.3. Each public water system shall complete an initial cross connection survey by December 31, 2000.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.10.4. Upon completion of the required cross connection survey, the responsible official of each public water system shall certify to the Department, on forms provided by the Department, that the required survey has been properly completed in accordance with the written guidelines published by the Department.

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 11. Installation of Backflow Preventers

Rule 1.11.1. Across connection is identified, the public water system shall require that the property owner eliminate the cross connection or install the proper type backflow prevention assembly.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.11.2. When a cross connection is identified, the public water system shall notify the property owner, in writing and within ten (10) days, of the existence of the cross connection and that the cross connection must be eliminated or protected.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.11.3. If the public water system determines that the cross connection is a high hazard category cross connection, it shall be eliminated or protected by the appropriate backflow preventer by June 30, 2001. If a public water system identifies an existing high hazard cross connection after June 30, 2001, the high hazard cross connection shall be eliminated or protected by the property owner within ninety (90) days of written notification by the public water system. If the property owner has an existing backflow preventer, the public water system shall allow the backflow preventer to remain in place until it fails to function properly.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.11.4. If the public water system determines that the cross connection is a low hazard cross connection, it shall be eliminated or protected by the property owner by installing an appropriate backflow preventer by June 30, 2004. If an existing low hazard cross connection is identified by a public water system after June 30, 2004, the cross connection shall be eliminated or protected by the property owner by installing an approved backflow preventer within one (1) year of written notification by the public water system. If the property owner has an existing backflow preventer, the public water system shall consider the backflow preventer approved and shall allow the installed backflow preventer to remain in place until the backflow preventer fails to function properly.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.11.5. **Public Water System Enforcement Actions**. In the event a customer refuses to comply with the cross connection control provisions of this regulation, the public water system is authorized to discontinue water service to the customer until such time as the customer complies with this regulation.

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 12. Recommended Backflow Preventers

Rule 1.12.1. **List of Recommended Backflow Preventers**. The Department shall prepare and publish a list of backflow prevention assemblies recommended for use in the State of Mississippi. The Department shall routinely update this list as necessary.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.12.2. **Recommended Devices for High Hazard Cross Connections.**

1. Reduced Pressure Principle Backflow Prevention Assemblies. Backflow prevention assemblies recommended to protect high hazard cross connections shall include reduced pressure principle backflow prevention assemblies.

2. Pressure Vacuum Breaker Assemblies. Backflow prevention assemblies recommended to protect high hazard cross connections shall include pressure vacuum breaker assemblies. Pressure vacuum breaker assemblies shall not be used in locations where the vacuum breaker may be subject to back pressure and shall not be used in locations where the vacuum breaker is not higher than all downstream connections.

3. Atmospheric Vacuum Breakers. Backflow prevention devices recommended to protect high hazard cross connections shall include atmospheric vacuum breakers. Atmospheric vacuum breakers shall not be installed in locations that may be subject to back pressure, shall not be installed in locations where the vacuum breaker is not higher than all downstream locations, shall not be installed in locations with valves downstream and shall not be installed in locations of continuous use.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.12.3. **Low Hazard Cross Connections**. Backflow prevention assemblies recommended to protect low hazard cross connections shall include reduced pressure principle assemblies, pressure vacuum breaker assemblies, atmospheric vacuum breaker assemblies, and double check valve assemblies. Pressure vacuum breaker assemblies shall not be used in locations where the vacuum breaker may be subject to back pressure and shall not be used in locations where the vacuum breaker is not higher than all downstream connections. Atmospheric vacuum breakers shall not be installed in locations that may be subject to back pressure, shall not be installed in locations where the vacuum breaker is not higher than all downstream locations, shall not be installed in locations with valves downstream and shall not be installed in locations of continuous use.

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 13. Installation Requirements.

Rule 1.13.1. Reduced pressure principle backflow prevention assemblies, double check valve assemblies, and pressure vacuum breaker assemblies shall be installed in a location that provides adequate access for testing and repair of the assembly.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.13.2. Reduced pressure principle backflow prevention assemblies and double check valve assemblies shall not be subject to possible flooding. Reduced pressure principle backflow prevention assemblies and double check valve assemblies shall not be located in a pit below ground level.

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 14. Testing Of Backflow Prevention Assemblies

Rule 1.14.1. **Testing By Certified Tester**. When a reduced pressure principle backflow prevention assembly, double check valve assembly, or pressure vacuum breaker assembly is installed to protect a public water system against the possibility of a backflow from a customer's water service, inspection and testing of the assembly, where required by this regulation, shall be performed by an individual who has been licensed as a Certified Tester by the Department.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.14.2. Each backflow prevention assembly shall be inspected and tested by a Certified Tester after installation and before use by the customer. Reduced pressure principle backflow prevention assemblies and pressure vacuum breakers shall be inspected and tested at least once a year by a Certified Tester.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.14.3. The Certified Tester shall provide the property owner and the public water system with a written report of the inspection and test results on each assembly tested. This written report shall be on a form provided by the Department. The report shall be prepared and submitted by the Certified Tester making the inspection and test. The Certified Tester and the public water system shall retain all backflow prevention assembly test and inspection results for at least five (5) years from the date of test and inspection.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.14.4. Reduced pressure principle backflow prevention assemblies and pressure vacuum breaker assemblies that fail to function properly or fail the routine required test shall be repaired or replaced within thirty (30) days of identification of the failure. Double check valves that fail to function properly shall be repaired or replaced within ninety (90) days of identification of the failure.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.14.5. **Licensing of Certified Testers**. Each Certified Tester shall be licensed by the Department. All tester training shall be submitted to the Department for approval at least 45 days prior to the scheduled date of training. The Department shall review the instructors and course curriculum for all proposed tester training. The Department shall approve proposed tester training if it determines that the proposed training program and instructor(s) meets the Department's minimum guidelines. The Department shall develop and administer the backflow tester certification test at the conclusion of each approved tester training program. A minimum score of 70% on the Department's written examination and successful performance of prescribed tests on a reduced pressure principle backflow prevention assembly, double check valve assembly, and pressure vacuum breaker assembly will be required for certification. Any applicant not successfully completing both the written and performance tests must attend a Department approved tester training program before taking the certification tests again. Under special circumstances and upon receipt of a written request by the applicant, the Department may allow an applicant to take the written and performance tests without attending a Department approved tester training program.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.14.6. The Department may issue, solely at its discretion and without testing, certification to a Tester possessing certification from a nationally recognized backflow prevention assembly tester certification program.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.14.7. Each Tester's certification will expire three (3) years from the date issued. To become re-certified, the Tester must successfully complete a recertification examination developed by the Department and administered by the Department or an authorized representative of the Department.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.14.8. The Certified Tester shall maintain the accuracy of the testing equipment to be used to test backflow prevention devices. The testing equipment shall be checked for proper calibration and shall be recalibrated, as needed, in accordance with the recommendations of the manufacturer. Only properly trained individuals shall perform calibration adjustments or repair or testing equipment. Calibration standards utilized in the testing or repair of this testing equipment shall have their accuracy checked and adjusted to within allowable tolerances against standard instruments traceable to the National Institute for Standards and Technology (NIST).

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 15. Suspension or Revocation of Tester's Certificate.

Rule 1.15.1. A Tester's Certificate may be revoked or suspended by the Department for just cause. Causes include, but are not limited to, the following:

1. Fraud, deception, or misrepresentation of a material fact to either the public or the Department ;

2. Misfeasance, malfeasance or nonfeasance;

3. Failure to file any official reports required by the Department;

4. Failure to maintain all official records required by the Department;

5. Failure to respond to any official correspondence from the Department;

6. Failure to obey a lawful order of the Director or any duly appointed Administrative Hearing Officer of the Department;

7. Failure to exercise reasonable care or judgment in the testing of backflow prevention devices;

8. Failure to comply with the terms of a suspension of a certificate issued by the Department;

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.15.2. No Tester's Certificate will be suspended or revoked without notice to the Certificate holder and an opportunity for a hearing. Hearings shall be held in conformity with Sections 41-26-17 and 41-26-21 Mississippi Code of 1972 Annotated.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.15.3. Notwithstanding the requirement for a hearing, the Director may, if he determines that public health is threatened, issue any such orders as are deemed necessary to protect the public health, including, but not limited to, orders to individual(s) to cease all actions as a Certified Tester of backflow prevention devices in the State of Mississippi.

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 16. Cross Connection Control Waivers

Rule 1.16.1. **Waivers.** The Director may issue a waiver to a public water system to any part or parts of the cross connection control provisions of this regulation if the Department deems such waiver to be appropriate and will not potentially jeopardize public health.

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 17. Application And Fees For Certified Tester

Rule 1.17.1. **Filing Application.**

1. A tester desiring certification shall file an application with the Department on forms provided by the Department.

2. The Department shall review the application and supporting documents, determine the eligibility of the applicant, and issue a certificate when the minimum requirements are met.

SOURCE: Miss. Code Ann. §41-26-14

Rule 1.17.2. **Backflow Prevention Assembly Tester Certification Fees.**

1. An initial fee of fifty dollars ($50.00) shall be charged for certification as a Backflow Prevention Assembly Tester. The Department shall invoice each applicant for the $50 fee and the certificate will not be issued until the fee is received by the Department.

2. A fee of thirty dollars ($30.00) shall be charged for the renewal of a certificate. The Department shall invoice each applicant for the $30 fee and the renewal certificate will not be issued until the fee is received by the Department.

SOURCE: Miss. Code Ann. §41-26-14

Subchapter 18. Consumer Confidence Reports

Rule 1.18.1. **Purpose and Applicability**. Each community public water system shall prepare and deliver to their customers an annual consumer confidence report as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.151.

1. **Effective Dates.** The effective dates for community public water supplies to prepare and deliver annual consumer confidence reports shall be as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.152.

2. **Content of the Reports**. The content of the Consumer Confidence Reports prepared by community public water supplies shall be as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.153.

3. **Required Additional Health Information**. It shall be the responsibility of each community public water supply preparing a consumer confidence report to include the required additional health information as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.154.

4. **Report Delivery**. Delivery of Consumer Confidence Reports prepared by community public water supplies shall be as stipulated in the National Primary Drinking Water Regulations as published under Title 40 Code of Federal Regulations Section 141.155.

SOURCE: Miss. Code Ann. §41-26-6

Subchapter 19. Emergency Conditions And Enforcement

Rule 1.19.1. **Emergency Conditions.** The Director is authorized to develop and implement a plan for the provision of safe drinking water in emergency circumstances for any public water system.

SOURCE: Miss. Code Ann. §41-26-6

Rule 1.19.2. **Enforcement.** Violations of any requirement of this regulation shall be subject to the enforcement provisions of the Mississippi Safe Drinking Water Act of 1997 as found at Sections 41-26-1 through 41-26-101, Mississippi Code of 1972, Annotated.

SOURCE: Miss. Code Ann. §41-26-6

Chapter 2. REGULATION GOVERNING THE CERTIFICATION OF MUNICIPAL AND DOMESTIC WATER SYSTEM OPERATORS

Subchapter 1. General Provisions

Rule 2.1.1. **Legal Authority.** This regulation has been promulgated under the authority of and pursuant to the Municipal and Domestic Water and Wastewater System Operator's Certification Act of 1986, Sections 21-27-201 through 21-27-221, Mississippi Code of 1972. Annotated.

*SOURCE: Miss. Code Ann. §§*21-27-207 and 41-26-6

Rule 2.1.2. **Definitions**

1. **Association** shall mean the Mississippi Water and Pollution Control Operators Association, Inc.

2. **Available** shall mean a certified operator employed by the water system holding an operator's certificate equivalent or higher than the class of the public water system, whose principle residence is no more than fifty (50) miles from the water system. The water system must be able to contact this certified operator at all times by telephone, pager or other reliable mode of communication acceptable to the Mississippi Department of Health to address system needs and problems as they occur.

3. **Board** shall mean the Mississippi State Board of Health.

4. **Bureau** shall mean the Bureau of Public Water Supply of the Mississippi Department of Health.

5. **Community Water System** shall mean any water system serving piped water for human consumption to fifteen (15) or more individual service connections used year-round by consumers or regularly serving twenty-five (25) or more individual

consumers year-round, including, but not limited to, any collection, pretreatment, treatment, storage and/or distribution facilities or equipment used primarily as part of, or in connection with such system, regardless of whether or not such components are under the ownership or control of the operator of such system.

6. **Department** shall mean the Mississippi Department of Health.

7. **Director** shall mean the director of the Mississippi Department of Health or his designated representative.

8. **Distribution System** shall mean all water mains, repumping facilities, and appurtenances past treatment.

9. **Non-transient non-community water system** shall mean a public water system that is not a community water system and that regularly serves at least 25 of the same persons.

10. **Operator** shall mean the certified waterworks operator who directly supervises and is personally responsible for the daily operation and maintenance of a community or non-transient non-community public water system.

11. **Part-time operator** shall mean any certified waterworks operator who is employed as the certified waterworks operator for a public water system and is not considered a full-time employee of the public water system. This definition shall include certified waterworks operators who are serving as the certified waterworks operator for public water systems through privately owned operating companies.

12. **Person** shall mean the state or other agency or institution thereof, any municipality, political subdivision, public or private corporation, individual, partnership, association or other entity, and includes any officer or governing or managing body of any municipality, political subdivision, or public or private corporation, or the United States or any officer or employee thereof..

13. **Responsible Charge** shall mean a certified operator, holding a Department waterworks operator's license at a class equivalent to or higher than the class of the water system, who is officially designated by the owner or responsible official of the water system as the operator responsible for making all decisions regarding the daily operational activities of the public water system including all components of the water system such as treatment plants, water wells, distribution systems, etc. Under special circumstances, the Department may authorize a water system to have more than one operator in responsible charge.

*SOURCE: Miss. Code Ann. §*21-27-203

Rule 2.1.3. **Certificates.** Effective July 1, 1987, all municipal and domestic community water systems must be operated by persons who are certified by the Mississippi Department of Health as qualified to operate such facilities. Effective July 1, 1998, all non-transient non-community public water systems must be operated by persons who are certified by the Department to operate such facilities.

1. Certificates of competency will be issued by the Bureau only after the applicant has passed the appropriate examination and has met the minimum requirements as specified in Rule 2.2.7.

2. Certificates issued in accordance with section 21-27-213 (Grandfather Clause) of the Municipal and Domestic Water and Wastewater System Operator's Certification Act of 1986, shall be valid only for the particular public water system operated by the applicant at the time the certificate was issued, and then only so long as the system remains in the same or lower classification as at the time the application was filed.

3. Certificates shall be valid for three (3) years from the date of issuance, unless suspended or revoked for cause.

4. In the event of temporary loss of an operator, notice shall be immediately given to the Bureau and the continued operation of such system, without a certified operator, may proceed on an interim basis for a period not to exceed one hundred eighty (180) days, except for good cause shown upon petition to the Bureau.

5. Certificates may be issued, without examination, in a comparable classification to an operator who holds a certificate in any state, territory, or possession of the United States or any country that has entered into a reciprocity agreement with the Bureau.

6. Any person allowed to actually make physical changes on a public water system that impact water quality or quantity must hold a waterworks operator's license issued by the Bureau at a class equivalent to or higher than the class of the public water system.

*SOURCE: Miss. Code Ann. §§*21-27-205 and 21-27-211

Subchapter 2. Classification of Public Water Systems & Operator in Responsible Charge

Rule 2.2.1. **Classes of Water Systems.** Water systems shall be classified in accordance with criteria outlined below. Special systems which do not fall within these guidelines shall be considered as individual cases and be classified by the Bureau. All public water systems shall be under the direct supervision of a Department licensed waterworks operator who is designated by the owner or responsible official of the system as the operator in responsible charge of the water system. In those situations where a public water system contracts with a private operating company to operate the public water system, the responsible official of the public water system may authorize the private company to designate an operator employed by the company as the operator in responsible charge of the water system. In either case, the water system shall identify, by means of the Public

Water System Annual Report submitted each year to the Department, the certified operator in responsible charge of the public water system.

1. **Class E.** Water systems that purchase water only and do not provide additional treatment. This classification shall also apply to waterworks operators whose only job responsibility is the operation and maintenance of distribution system(s). The certified operator in responsible charge shall be available 24 hours a day to address system needs and problems as they occur.

2. **Class D**. Water systems with no treatment other than chlorination and/or fluoridation or direct chemical feed such as polyphosphate. The certified operator in responsible charge shall be available 24 hours per day to address system needs and problems as they occur.

3. **Class C**. Water systems with aeration, pH adjustment, corrosion control or closed pressure filtration treatment facilities including zeolite softening or iron removal. The certified operator in responsible charge shall be available 24 hours per day to address system needs and problems as they occur.

4. **Class B**. Water systems with two (2) or more Class C treatment facilities of different types, or with iron or manganese removal facilities breaking pressure or requiring flocculation and/or sedimentation. The certified operator in responsible charge shall be available 24 hours per day to address system needs and problems as they occur.

5. **Class A**. Systems with surface water treatment, lime softening, or coagulation and filtration for the removal of constituents other than iron or manganese. A licensed class A operator shall be onsite whenever the treatment plant for a Class A public water system treating surface water is in operation. The certified operator in responsible charge shall be available 24 hours per day to address system needs and problems as they occur.

SOURCE: Miss. Code Ann. §21-27-205

Subchapter 3. Operator Qualifications. Qualification for Each Class Operator:

Rule 2.3.1. **Class A.** The applicant must have at least a bachelor's degree in engineering or applied sciences from an accredited college or university, at least one ~~years~~ of experience in a Class A water plant, and pass the written examination required by the Bureau, or the applicant must be a graduate of an accredited high school or possess an equivalent (GED), have at least six (6) years experience in a Class A or B water plant, of which at least one year must be in a Class A plant, and pass the written examination required by the Bureau.

SOURCE: Miss. Code Ann. §21-27-205

Rule 2.3.2. **Class B.** The applicant must have graduated from an accredited high school or possess an equivalent (GED), have at least three (3) years of experience in a Class

A,.B, or C water plant, of which one year must be in a Class A or B plant, and pass the written examination required by the Bureau.

SOURCE: Miss.Code Ann. §21-27-205

Rule 2.3.3. **Class C.** The applicant must have graduated from an accredited high school or possess an equivalent (GED), have at least two (2) years of experience in a Class A, B, C, or D water plant of which one year must be in a Class A, B, or C water plant, and pass the written examination required by the Bureau

SOURCE: Miss. Code Ann. §21-27-205

Rule 2.3.4. **Class D.** The applicant must have graduated from an accredited high school or possess an equivalent (GED), and the applicant must have at least one year of experience in the same class facility as being applied for or a higher level. In addition, the applicant must pass the written examination required by the Bureau.

SOURCE: Miss. Code Ann. §21-27-205

Rule 2.3.5. **Class E.** The applicant must have graduated from an accredited high school, or possess an equivalent (GED) and the applicant must have at least one year of experience in the same class facility as being applied for or a higher level. In addition, the applicant must pass the written examination required by the Bureau.

SOURCE: Miss. Code Ann. §21-27-205

Subchapter 4. General Qualifications for all Certified Waterworks Operators

Rule 2.4.1. One year of the required experience must be earned under the direct supervision of a certified waterworks operator who holds a valid non-restricted certificate issued by the Department at a class equivalent to or higher than that for which certification is being requested. The year of supervision must be obtained in a public water system of a class equivalent to or higher than the class certificate being requested. The supervising operator must sign a certification statement verifying the successful completion of the required period of supervision. In addition, two Department certified waterworks operators, other than the operator who provided this supervision, must sign a certification statement recommending the applicant for certification. Under special circumstances, the Department may waive the requirements of this section based upon written evidence of good cause.

SOURCE: Miss. Code Ann. §21-27-205

Rule 2.4.2. To be eligible to serve as the certified operator for a community or non-transient non-community public water system, an operator's principal residence must be no more than fifty (50) miles from the system. Under special circumstances, an operator may apply to the Bureau in writing for a waiver of the 50 mile requirement.

SOURCE: Miss. Code Ann. §21-27-205

Rule 2.4.3. An individual whose operator's license has been expired for 24 months or less shall be eligible to receive a new waterworks operator's license at a level no higher than the license previously issued by the Bureau if he/she successfully passes the written examination required by the Bureau. To be eligible to retake the examination, the operator must comply with the provisions of Rule 4.1.5 of this regulation. The provisions of Rule 2.3.1 of this regulation shall be waived for applications received under this section. Operators whose license has been expired more than 24 months must successfully pass the written examination required by the Bureau and comply fully with the provisions of section 2.3.1.

SOURCE: Miss. Code Ann. §21-27-205

Rule 2.4.4. Operators who have received special vocational training, such as special schools, short courses, correspondence courses, etc., may be given credit for some portion of the deficiency in their experience. Special vocational training programs shall be approved in writing and in advance of the training. Approval shall be at the discretion of the Bureau. After a specific program of special vocational training has been approved, the Bureau shall award credit for experience using the following criteria:

1. Eight (8) weeks of classroom instruction will be equivalent to one year experience.
2. One week of on-the-job training will be equivalent to one week experience.
3. Special vocational training programs that have combinations of classroom instruction and on-the-job training will be evaluated by first separating classroom instruction from on-the-job training. Credit will be for experience on the basis of the two previous criteria. The total credit awarded for the program will be the sum of the two parts.
4. Each year of college successfully completed in engineering, biological sciences, mathematics, chemistry, or physics will be considered the equivalent of two (2) years experience.
5. At least one year of water system experience is required in all classes. This one year of experience cannot be substituted by special vocational training programs or college education.

SOURCE: Miss. Code Ann. §21-27-205

Subchapter 5. Application and Fees

Rule 2.5.1. **Filing Application**

1. Applicants for licensure as a certified waterworks operator shall file an application with the Bureau on a form provided by the Bureau.

2. The Bureau will review the application and supporting documents, determine the eligibility of the applicant, and issue a certificate when the applicant meets the minimum requirements of the class requested.

SOURCE: Miss. Code Ann. §21-27-205

Rule 2.5.2. **Fees**

1. A fee of fifty dollars ($50.00) shall be charged for initial certification or reactivation of an expired certificate in any classification and must be paid to the Bureau prior to actual issuance of the certificate.

2. A fee of thirty dollars ($30.00) shall be charged for the renewal of an active certificate and must be paid to the Bureau prior to actual issuance of the renewal certificate.

3. All application fees must be received within *fifteen (15)* days of being invoiced by the Department. Application fees received after *fifteen (15)* days will be returned to the applicant and the applicant must reapply to the Department for certification or renewal.

SOURCE: Miss. Code Ann. §21-27-207

Subchapter 6. Examinations

Rule 2.6.1. **Written Examinations**

1. The Bureau shall prepare written examinations to be used in determining knowledge, ability, and judgment of operators.

2. Examinations shall be held at places and times set by the Bureau.

3. An individual who passes an examination must be certified within three (3) years following the date the examination was taken. Otherwise, the individual will be required to pass another written examination in order to be certified.

4. Examination papers will not be returned to the individuals.

5. To be eligible to take a written examination, an individual must satisfactorily demonstrate to the Bureau that he/she has attended a Bureau sponsored waterworks operators' short course within the previous 12 months.

*SOURCE: Miss. Code Ann. §*21-27-215

Rule 2.6.2. **Renewal of Waterworks Operator Certificates**

1. Certificates may be renewed without examination. An application for renewal of a waterworks operator's certificate of competency must be physically received by the Bureau within thirty (30) days following the date the certificate expires. This application must be accompanied by proof of completion of the continuing education requirements found in Rule 2.8.2. Upon approval of the renewal application, the applicant will be invoiced for the renewal fee of $30.00. The Bureau must receive this renewal fee prior to issuing the new waterworks operator's certificate of competency. Certified operators who file renewal applications more than thirty (30) days after expiration of their certificate will be denied renewal of their certificate and must pass the appropriate written examination and apply for a new certificate.

2. Operators who have been continuously licensed by the Bureau less than nine (9) years must complete at least forty-eight (48) hours of related continuing education (CEUs) per three (3) year certificate renewal period with at least 12 hours of these CEUs in Bureau approved "Regulation and Compliance" training programs. Operators who have been continuously licensed by the Bureau for nine (9) years or more are required to obtain 24 hours of CEUs in the three year certificate renewal period with at least twelve (12) hours of these CEUs in Bureau approved "Regulation and Compliance" training programs. All continuing education requirements must be met prior to the expiration date of the certificate. These CEUs must be appropriate for the classification held by the operator and may only be obtained by attending training sessions approved by the Bureau. All training, correspondence courses, etc., shall be approved in writing and in advance of the training. Approval shall be strictly at the discretion of the Bureau. Training will be evaluated by the Bureau on an hour for hour basis for continuing education credit.

SOURCE: Miss. Code Ann. §21-27-207

Rule 2.6.3. Mississippi Department of Environmental Quality approved wastewater training programs will be awarded CEU credit by the Bureau at the rate of (1) water CEU hour for every 2 wastewater CEU hours earned.

SOURCE: Miss. Code Ann. §21-27-207

Rule 2.6.4. Each certified operator is responsible for maintaining all necessary records to document the completion of the required hours of continuing education. Original documentation of the completion of the required continuing education must be submitted with the application for renewal of the operator's certificate of competency. Copies of CEU certificates are not acceptable. Any waterworks operator who is issued a restricted (grandfather) license by the Department after May 2000, in order to qualify for renewal of this license, shall attend a Department sponsored short course during the 3 year restricted (grandfather) license period. This short course must be at the level of classification of the water system or higher.

SOURCE: Miss. Code Ann. §21-27-207

Subchapter 7. Certified Waterworks Operator Job Performance, Record Keeping and Reporting Requirements

Rule 2.7.1. **Annual Reporting Requirements**

1. Each certified waterworks operator and responsible official shall sign the certification statement on the Public Water System Annual Report for each public water system for which he/she is the designated certified waterworks operator in responsible charge of the public water system as required by Mississippi State Law. If a public water system fails to provide a completed Public Water System Annual Report to the Bureau within 45 days of this Report being mailed to the water system by the Bureau, the Department shall officially declare the public water system to be without a certified waterworks operator and the water system shall be in violation of this regulation and Mississippi State law.

2. Each certified waterworks operator, or his/her representative(s), shall maintain an approved Public Water System Operations Log Book documenting all activities completed on the public water system where he serves as the official certified waterworks operator. This log book must be available for inspection by Bureau staff. The Public Water System Operations Log Book is the property of the public water system and must remain as part of the official records of the Public Water System.

SOURCE: Miss. Code Ann. §21-27-207

Rule 2.7.2. **Job Performance:** Each certified waterworks operator shall abide by the current edition of the Minimum Job Performance Guidelines booklet published by the Bureau of Public Water Supply. This booklet presents the minimum duties and responsibilities for Department certified waterworks operators in the State of Mississippi.

SOURCE: Miss. Code Ann. §21-27-207

Rule 2.7.3. **Presence of Certified Waterworks Operator during Sanitary Surveys and Inspections:** The certified waterworks operator for a public water system shall be present for the conduct of sanitary surveys and inspections by Bureau staff when requested by Bureau staff and when provided at least 24 hours notice of the survey or inspection. Under special circumstances, this requirement may be waived provided the certified operator arranges for someone to represent him/her during the survey or inspection.

SOURCE: Miss. Code Ann. §21-27-207

Rule 2.7.4. **Waterworks Operator Licensure Waiver:** The Director may waive any part or parts of this regulation if the Director determines that such waiver will not potentially jeopardize public health.

SOURCE: Miss. Code Ann. §21-27-207

Subchapter 8. Suspension and Revocation of Certificates. Criteria for Suspension or Revocation of a Waterworks Operator's Certificate

Rule 2.8.1. A waterworks operator's certificate of competency may be revoked or suspended by the Department for just cause. Causes include, but are not limited to, the following:

1. Fraud or deception;
2. Misfeasance, malfeasance or nonfeasance;
3. Violation of any provision of the "Mississippi Municipal and Domestic Water and Wastewater System Operators' Certification Law of 1986," or any rule or regulation of the Department promulgated there under;
4. Violation of any provision of the Federal Safe Drinking Water Act or the Mississippi Safe Drinking Water Act; or any rule or regulation, federal or state, promulgated under these laws;
5. Failure to file any official reports required by the Department;
6. Failure to maintain all official records required by the Department;
7. Failure to respond to any official correspondence from the Department;
8. Failure to obey a lawful order of the Director or any duly appointed Administrative Hearing Officer of the Department;
9. Failure to exercise reasonable care or judgment in the operation of a public water supply or in the performance of official duties;
10. Failure to comply with the terms of a suspension of certificate issued by the Department.

*SOURCE: Miss. Code Ann. §*21-27-219

Rule 2.8.2. No certificate of competency will be suspended or revoked without notice to the waterworks operator and an opportunity for a hearing. Hearings shall be held in conformity with Sections 21-27-219 and 21-27-221 Mississippi Code of 1972 Annotated.

*SOURCE: Miss. Code Ann. §§*21-27-219 and 21-27-221

Rule 2.8.3. Notwithstanding the requirement for a hearing, the Department may, if it determines that public health is threatened, issue any such orders as are deemed necessary to protect the public health, including, but not limited to, orders to individual(s) to cease all actions as a certified waterworks operator in the State of Mississippi.

*SOURCE: Miss. Code Ann. §§*21-27-217 and 21-27-219

Subchapter 9. Enforcement and Appeals Procedures

Rule 2.9.1. **Procedures:** Enforcement and appeals shall be in accordance with the Municipal and Domestic Water and Wastewater System Operator's Certification Act of 1986.

*SOURCE: Miss. Code Ann. §§*21-27-217 through 21-27-221

Chapter 3 REGULATION GOVERNING FLUORIDATION OF COMMUNITY WATER SUPPLIES

Subchapter 1 GENERAL PROVISIONS

Rule 3.1.1 **Coverage**

1. This regulation shall only apply to community water systems (CWS) serving a population of at least two thousand (2,000).

2. Each CWS shall be required to acquire and install fluoridation treatment equipment capable of maintaining fluoride levels within the optimal range as defined in this regulation, and shall comply with all requirements of this regulation for the purpose of protecting the dental health of the citizens of this State. No System shall be required to comply unless sufficient funds are identified by the Department, whether by appropriation, capital outlay, grants or similar means or source of funds, as available to that system for the cost of acquiring and installing fluoridation equipment, and the cost of material required to fluoridate said system for at least one year from the date of initial installation.

SOURCE: Miss. Code Ann. § 41-26-6

Rule 3.1.2 **Definitions.**

1. **Adjusted fluoridated water system** shall mean a public water system that adjusts the fluoride concentration in the drinking water to the optimal level for consumption (within the recommended control range).

2. **Community Water System (CWS)** shall mean any water system serving piped water for human consumption to fifteen (15) or more individual service connections used year-round by consumers or regularly serving twenty-five (25) or more individual consumers year-round, including, but not limited to, any collection, pretreatment, treatment, storage and/or distribution facilities or equipment used primarily as part of, or in connection with such system, regardless

of whether or not such components are under the ownership or control of the operator of such system.

3. **Department** shall mean the Mississippi State Department of Health.

4. **Entry point** shall mean a location following one or more finished (fluoridated) water sampling points but prior to the beginning of the distribution system of the public water system.

5. **Natural fluoride content** shall mean the concentration of fluoride in milligrams per liter (mg/L) that is present in the water source from naturally occurring fluoride sources.

6. **Optimal fluoride level** in Mississippi shall mean the amount of fluoride in water that is found naturally or adjusted within a recommended control range of 0.7-1.3 parts per million fluoride (ppm) with the optimal fluoride level being 0.8 ppm.

7. **Parts per million** shall mean a unit of measurement that is equivalent to 1 milligram per liter (mg/L) where the density of the liquid measured is 1.0 gram per cubic centimeter (the density of water is 1.0).

8. **Public water system (CWS)** means a system for the provision to the public of water for human consumption through pipes or, after August 5, 1998, other constructed conveyances, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year.

9. **Raw water** is defined as water that has not been treated or had fluoride injected into it by the CWS and that contains only naturally occurring levels of fluoride.

SOURCE: Miss. Code Ann. § 41-26-6

Subchapter 2 ADJUSTED FLUORIDATED WATER SYSTEM REQUIREMENTS

Rule 3.2.1 **Testing.** : A minimum of three (3) water samples shall be taken by designated CWS personnel on different days each week at all entry points and analyzed for fluoride content. At least once each month at each entry point, designated CWS personnel shall divide (split) one sample (hereinafter referred to as the split sample) and have one portion analyzed for fluoride by designated CWS personnel and the other portion analyzed by the Department's laboratory or a private lab certified by the Department for fluoride testing.

SOURCE: Miss. Code Ann. § 41-26-6

Rule 3.2.2 **Verification.** : Designated CWS personnel shall use water sample fluoride content results to compare with a calculated fluoride dosage to verify fluoridation program operation. The calculated dosage is defined as the calculated amount of fluoride that has been added to a water system. The calculation is based on the total amount of fluoride (weight) that was added to the water system and the total amount of water (volume) that was produced plus the naturally occurring fluoride at the source.

SOURCE: Miss. Code Ann. § 41-26-6

Subchapter 3 Optimal Fluoridation Requirements

Rule 3.3.1 **Monitoring**

1. The monthly average fluoride content of all water samples requested in section 101.01 shall have fluoride content within the optimal fluoride control range defined in section 100.02.

2. The designated CWS personnel shall collect no less than 13 water samples per month from each entry point for analysis for fluoride and at least 90% of collected samples shall have fluoride content within the optimal fluoride control range defined in section 100.02.

3. The split sample result determined through analysis by designated CWS personnel shall agree with the result analyzed by the Department within a range of +/- 0.2 ppm in at least nine of 12 months during the calendar year.

4. Designated CWS personnel shall submit a report of the results of required water sample testing each month to the Department and shall include the type of fluoride chemical used.

SOURCE: Miss. Code Ann. § 41-26-6

Rule 3.3.2 **Quality Assurance**

1. MSDH Bureau of Water Supply will assess each system's compliance with this policy on a monthly basis and send letters to the Responsible Official and Operator if the system is not compliant.

2. MSDH will prepare a compliance progress report on a monthly basis that will be made available to interested parties.

3. Each CWS that complies with the optimal fluoridation requirements during the calendar year to the satisfaction of the Department shall be recognized by the Department pursuant to its health promotion policies and guidelines.

SOURCE: Miss. Code Ann. § 41-26-6

Subchapter 4 Compliance

Rule 3.4.1 **Compliance**

1. CWS that fluoridate shall list in the Consumer Confidence Report the number of months in the previous calendar year that average sample results from a certified laboratory were within the optimal range.

2. Each CWS that fluoridates shall list in the Consumer Confidence Report the percentage of all samples collected in the previous calendar year that sample results were within the optimal range.

SOURCE: Miss. Code Ann. § 41-26-6

Subchapter 5 AUTHORITY TO REQUEST RAW WATER SAMPLE

Rule 3.5.1 **Verification.** : The Department shall have the authority to request samples of the CWS raw water source seasonally for fluoride content analysis at the Department's laboratory.

SOURCE: Miss. Code Ann. § 41-26-6

Chapter 4 REGULATION GOVERNING DRINKING WATER QUALITY ANALYSIS FUND

Subchapter 1 General Provisions:

Rule 4.1.1. **Legal Authority**. This regulation has been promulgated under the authority of and pursuant to the Mississippi Safe Drinking Water Act of 1997 (Section 41-26-1 through Section 41-26-101, Mississippi Code of 1972, Annotated).

SOURCE: Miss. Code Ann. §41-26-23

Subchapter 2 Assessment and Collection of Fees

Rule 4.2.1. **Fees**. The department annually shall assess and collect fees for water quality analysis and related activities as required by the federal Safe Drinking Water Act, as amended, which shall not exceed Two Dollars and Eighty Cents ($2.80) per connection or Forty Thousand Dollars ($40,000.00) per system, whichever is less. The department annually shall adopt by rule, in accordance with the Administrative Procedures Law and following a public hearing, a fee schedule to cover all reasonable direct and indirect costs of water quality analysis and related activities as required by the federal Safe Drinking Water Act, as amended. In adopting a fee schedule, the department shall consider the recommendations of the advisory committee created in this section, if those recommendations are made in a timely manner as provided.

SOURCE: Miss. Code Ann. §41-26-23

Rule 4.2.2. **Advisory Committee.** An advisory committee is created to study the program needs and costs for the implementation of the water quality analysis program and to conduct an annual review of the needs and costs of administering that program. The annual review shall include an independent recommendation on an equitable fee schedule for the succeeding fiscal year. Each annual review report shall be due to the department by May 1. The advisory committee shall consist of one (1) member appointed by the Mississippi Rural Water Association, one (1) member appointed by the Mississippi Municipal Association, one (1) member appointed by the Mississippi Association of Supervisors and one (1) member appointed by the Mississippi Water and Pollution Control Operators Association, Inc.

SOURCE: Miss. Code Ann. §41-26-23

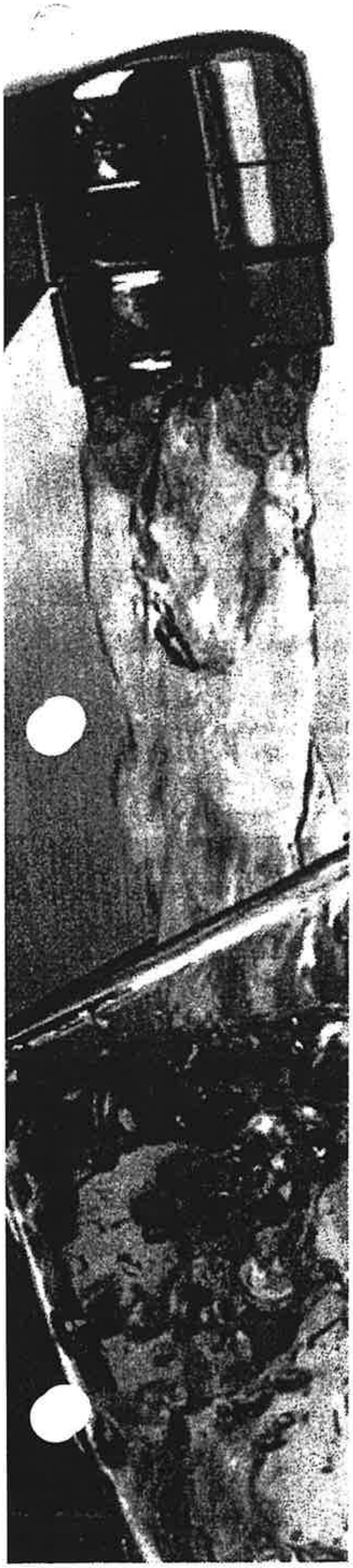
Rule 4.2.3. **Payments and Penalties.** All suppliers of water for which water quality analysis and related activities as required by the federal Safe Drinking Water Act, as amended, are performed by the State Department of Health shall pay the water quality analysis fee within forty-five (45) days following receipt of an invoice from the department. In the discretion of the department, any supplier of water required to pay the fee shall be liable for a penalty equal to a maximum of two (2) times the amount of fees due and payable plus an amount necessary to reimburse the costs of delinquent fee collection for failure to pay the fee within ninety (90) days following the receipt of the invoice. Any person making sales to customers of water for residential, noncommercial or nonagricultural use and who recovers the fee required by this section or any portion thereof from any customer shall indicate on each statement rendered to customers that these fees are for water quality analyses required by the federal government under the Safe Drinking Water Act, as amended.

SOURCE: Miss. Code Ann. §41-26-23

APPENDIX C

EPA
United States
Environmental Protection
Agency

Ground Water Rule Compliance Monitoring: A Quick Reference Guide



Overview of the Rule

Title	Ground Water Rule (GWR) 71 FR 65574, November 8, 2006, Vol. 71, No. 216 Correction 71 FR 67427, November 21, 2006, Vol. 71, No. 224
Purpose	Reduce the risk of illness caused by microbial contamination in public ground water systems (GWSs).
General Description	The GWR establishes a risk-targeted approach to identify GWSs susceptible to fecal contamination and requires corrective action to correct significant deficiencies and address source water fecal contamination in all public GWSs.
Utilities Covered	The GWR applies to all public water systems (PWSs) that use ground water, including consecutive systems, except that it does not apply to PWSs that combine all of their ground water with surface water or with ground water under the direct influence of surface water prior to treatment.

Purpose of Compliance Monitoring

- Compliance monitoring ensures that GWSs that provide at least 4-log treatment of viruses using chemical disinfection, membrane filtration, or a State-approved alternative treatment technology are consistently and effectively achieving this level of treatment.

When is Compliance Monitoring Required?

- GWSs that provide at least 4-log treatment of viruses **as a corrective action** must conduct compliance monitoring.
- GWSs that provide at least **4-log treatment of viruses** at or before the first customer using chemical disinfection, membrane filtration, or a State-approved alternative treatment technology and do not conduct GWR triggered source water monitoring must **notify their State in writing** that they provide treatment and begin compliance monitoring.
- The compliance dates for systems that provide 4-log treatment in lieu of GWR triggered source water monitoring are as follows:
  - GWSs with **existing ground water sources** must notify the State by **December 1, 2009**, that they provide at least 4-log treatment of viruses and begin compliance monitoring.
  - GWSs with **new ground water sources** placed into service **after November 30, 2009**, must notify the State that they provide at least 4-log treatment of viruses and begin compliance monitoring within 30 days.

What are the Compliance Monitoring Requirements for Chemical Disinfection?

GWSs Serving 3,300 or Fewer

- GWSs using chemical disinfection and serving 3,300 or fewer persons must monitor for the **residual disinfectant concentration** and meet the **State specified** minimum concentration at or before the first customer.
- GWSs must monitor on a **daily** basis and collect a grab sample during the hour of peak flow or at another time specified by the State.
  - If any daily grab sample is less than the minimum disinfectant residual concentration, the system must take follow-up samples **every four hours** until the residual meets or exceeds the State-specified minimum concentration.
  - These systems also have the option to monitor **continuously**.
    - If the GWS monitors continuously, the system must meet the monitoring requirements for GWSs serving greater than 3,300 persons (see below).
- GWSs must monitor at a State-approved location.

GWSs Serving Greater than 3,300 Persons

- ► GWSs using chemical disinfection and serving greater than 3,300 persons that conduct compliance monitoring must monitor for the **residual disinfectant concentration** and meet the **State specified** minimum concentration at or before the first customer.
  - ■ GWSs of this size must monitor **continuously** and record the lowest residual disinfectant concentration each day that water from the ground water source is served to the public.
- ► GWSs must monitor at a State-approved location.

Failure of Continuous Monitoring Equipment

- ► In the event of equipment failure for continuous monitoring, provisions are available for all GWSs serving greater than 3,300 persons and GWSs serving 3,300 persons or fewer who opt to monitor continuously.
  - ■ If there is a failure in continuous monitoring equipment, the ground water system must **conduct grab sampling every four hours** until the continuous monitoring equipment is returned to service.
  - ■ The system must resume continuous residual disinfectant monitoring **within 14 days.**

What are the Compliance Monitoring Requirements for Membrane Filtration?

- ► GWSs that use membrane filtration systems to achieve 4-log virus treatment to meet GWR requirements must:
  - ■ Operate the process in accordance with State-specified compliance requirements.
  - ■ Monitor the membrane filtration process in accordance with all State-specified monitoring requirements.
  - ■ Verify that the integrity of the membrane is intact.
- ► The **frequency** and **location** of samples for systems conducting membrane filtration will be determined by the State.

What are the Compliance Monitoring Requirements for Alternative Treatment?

- ► GWSs that use alternative treatment systems to achieve 4-log virus treatment to meet GWR requirements must:
  - ■ Operate the process in accordance with State-specified compliance requirements.
  - ■ Monitor the process in accordance with State-specified monitoring requirements.

Compliance Monitoring and Validation Testing for Ultraviolet (UV) Disinfection

- ► GWSs using UV disinfection as an alternative technology to meet GWR requirements should:
  - ■ Monitor for UV intensity, as measured by a UV sensor, flow rate and UV lamp status and any additional State-specified parameters.
  - ■ Verify the calibration of UV sensors, and recalibrate in accordance with a State-approved protocol, at least monthly.
- ► UV reactors should undergo validation testing to determine the operating conditions under which the reactor delivers the UV dose corresponding to the virus log removal credit received. See "Ultraviolet Disinfection Guidance for the Final Long Term 2 Enhanced Surface Water Treatment Rule" (http://www.epa.gov/ogwdw/disinfection/lt2/pdfs/guide_lt2_uvguidance.pdf) for more information.

Summary

- ► The following table summarizes the compliance monitoring requirements for systems providing 4-log virus treatment in lieu of triggered source water monitoring or as a corrective action under the GWR.

System Type	Monitor For	Frequency	Sample Location
GWSs serving ≤ 3,300 using chemical disinfection	Residual disinfectant concentration (must meet State minimum)	Daily or continuous	State-approved location(s)
GWSs serving > 3,300 using chemical disinfection		Continuous only	
GWSs using membrane filtration	Membrane filtration process effectiveness	Consult State for specific information	
GWSs using State-approved alternative treatment	Alternative treatment effectiveness		

- ► If operation according to the criteria or requirements for compliance monitoring (minimum residual disinfectant concentration, membrane operating criteria or membrane integrity, alternative treatment operating criteria, etc.) is not restored **within four hours**, a GWS must **notify the State as soon as possible.**
- ► For all GWSs conducting compliance monitoring, failure to conduct required compliance monitoring (Sec. 141.403(b)) requires a **Tier 3 public notice.**
- ► If any GWS wishes to **discontinue** 4-log treatment of viruses before or at the first customer, the GWS then becomes subject to the **GWR triggered source water monitoring requirements.**
  - ■ See "Ground Water Rule Factsheet: Monitoring Requirements" and "Ground Water Rule Triggered and Representative Monitoring: A Quick Reference Guide" for more information.

APPENDIX D

GLOSSARY

Chemical Glossary

Activated Alumina – The chemical compound aluminum oxide, which can be used to remove fluoride and arsenic from water by adsorption.

Activated Carbon – A highly adsorptive material used to remove organic substances from water.

Activated Silica – A coagulant aid used to form a denser, stronger floc.

Alkalinity – A measurement of how substances in the water can neutralize an acid.

Alum – The most common chemical used for coagulation. It is also called Aluminum Sulfate.

Calcium Carbonate – The principal hardness and scale-causing compound in water. The thin film created for corrosion control.

Calcium Hardness – The portion of total hardness caused by calcium compounds such as Calcium Carbonate ($CaCO_3$) and Calcium Sulfate ($CaSO_4$).

Calcium Hypochlorite – A dry solid powder used in disinfection. It is best to be applied by preparing a solution and feeding a clear liquid at the contact point. It is also called by its common name HTH.

Carbon Dioxide – A common gas in t he atmosphere that is very soluble in water. High concentrations of CO_2 in water can cause it to be corrosive. It is added to water after the lime softening process to lower the pH in order to reduce Calcium Carbonate scale formation. This process is known as recarbonization.

Carbonate Hardness – Hardness caused primarily by compounds containing carbonate (CO_3), such as Calcium Carbonate ($CaCO_3$) and Magnesium Carbonate ($MgCO_3$).

Caustic Soda - A common chemical used to raise the pH of the water to form Calcium Carbonate stability for corrosion control or to preciptate dissolved iron and manganese for removal. It's chemical name is Sodium Hydroxide (NaOH). It adds only Alkalinity to the water.

Chloramines – They are formed from a reaction with chlorine and ammonia. They can be used for disinfection. They are less likely to form THMs. It takes 200 times more to provide the same disinfection as free chlorine.

Chlorine – A yellowish green gas with a pungent odor used in disinfection. It is the most commonly used disinfectant for water treatment. It is 2 ½ times heavier than air. One volume of liquid yields 460 volumes of gas. It also can be used as an oxidizer.

Chlorine Dioxide (ClO_2) – It is a synthetic yellowish green gas with chlorine like odor. It is unstable as a gas and decomposes to form chlorine gas, oxygen gas, and heat. It is very stable and soluble in an aqueous solution. It can be used for disinfection. It does not form THMs. As pH increases, it becomes much more effective than free chlorine.

Cooper Sulfate – A common chemical used for coagulation.

Ferric Iron – It is the precipitated from of iron. It has a +3 charge (Fe^{+3}). It precipitates from the oxidation of ferrous iron to ferric iron where it reacts with substances in the water to precipitate ferric hydroxide [$Fe(OH)_3$].

Ferric Sulfate – A common chemical used for coagulation.

Ferrous Iron – It is the soluble ion form of iron. It has a +2 charge (Fe^{+2}).

Ferrous Sulfate – A common chemical used for coagulation.

Granular Activated Carbon (GAC) – Activated carbon in a granular form, which is used in a bed, much like a conventional filter, to adsorb organic substances from the water.

Hardness – A characteristic of water, caused primarily by the salts of calcium and magnesium. It causes deposition of scale in boilers, damage in some industrial processes, and sometimes objectionable taste.

Hydrofluosilicic Acid – A strongly acidic liquid used to fluoridate drinking water. Also called Fluosilic Acid.

Hydrogen Sulfide (H_2S) – A toxic gas produced by the anaerobic decomposition of organic matter and by sulfate reducing bacteria. It has a very noticeable rotten egg odor. It is commonly removed by aeration.

Iron (Fe) – An abundant element found naturally in the earth. As a result, dissolved iron is found in most water supplies. When the concentration of iron exceeds 0.3 mg/L, it causes red stains on plumbing fixtures and other items in contact with water. Dissolved iron can also be present in water due to corrosion of cast-iron or steel pipes. This is usually the cause of red-water problems.

Iron bacteria – Bacteria that use dissolved iron as an energy source. They can create serious problems in a water system since they form large, slimy masses that clog screens, pumps, and other equipment.

Lime – A common chemical used to raise the pH of the water to form Calcium Carbonate stability for corrosion control or to preciptate dissolved iron and manganese for removal. It's chemical name is Calcium Hydroxide [$Ca(OH)_2$]. It adds Calcium Hardness and Alkalinity to the water.

Magnesium Hardness – The portion of total hardness caused by magnesium compounds such as Magnesium Carbonate ($MgCO_3$) and Magnesium Sulfate ($MgSO_4$).

Manganese (Mg) – An abundant element found naturally in the earth. Dissolved manganese is found in many water supplies. At concentrations above 0.05 mg/L, it causes black stains in plumbing fixtures, laundry, and other items in contact with the water.

Methane (CH_4) – A colorless, odorless, flammable gas formed by the anaerobic decomposition of organic matter. When dissolved in water, methane causes a garlic-like taste. It is also called natural gas.

Muratic Acid – Another name for Hydrochloric Acid (HCl).

Orthophosphate – A liquid chemical used as a corrosion control inhibitor.

Ozone (O_3) – It is a bluish, toxic gas with a pungent odor. It is a powerful disinfectant and oxidizer. It is formed when a high voltage arc passes through air or oxygen between two electrodes. It does not form THMs, and it does not leave a residual.

pH – A measurement of the hydrogen ion concentration. The measurement ranges from 0 to 14. It is acidic between 0 and 7, and it is basic or alkaline between 7 and 14. 7 is neutral.

Polyphosphate – A liquid chemical used to sequester iron and manganese and keep it in solution.

Potassium Permanganate ($KMnO_4$) – A dry chemical used to oxidize iron and manganese to precipitate out of solution for removal. It is purple in color.

Powdered Activated Carbon (PAC) – Activated carbon in a powder form. It is added to water in a slurry form to remove those organic compounds primarily causing tastes and odors.

Quicklime – Another name for Calcium Oxide (CaO), which is used in water softening and stabilization.

Soda Ash – A dry chemical used to raise the pH of the water to form Calcium Carbonate stability for corrosion control or to preciptate dissolved iron and manganese for removal. It's chemical name is Sodium Carbonate (Na_2CO_3). It adds just Alkalinity to the water.

Sodium Aluminate – A common chemical used for coagulation.

Sodium Fluoride (NaF) – A dry chemical used in fluoridation of drinking water. It is commonly used in saturators.

Sodium Hypochlorite – A liquid chemical used in disinfection. Typically injected using positive displacement pumps. It is also known as bleach.

Sodium Silicofluoride – A dry chemical used in fluoridation of drinking water. It is derived from Hydrofluosilicic Acid.

Total Organic Carbon (TOC) – The amount of carbon bound in organic compounds in a water sample as determined by a standard laboratory test.

Trihalomethane (THM) – Compound formed when natural organic substances from decaying vegetation and soil (such as humic and fulvic acids) react with chlorine.

Turbidity – A physical characteristic of water making the water appear cloudy. The condition is caused by the presence of suspended matter.

Treatment Glossary

Adsorption – The water treatment process used primarily to remove organic contaminants from water. It involves the sticking together of contaminants to an adsorbent like activated carbon.

Aeration – The process of bringing water and air into close contact to remove or modify constituents in the water. Its driving force is surface to air and water contact. It can remove gases such as carbon dioxide, hydrogen sulfide, and methane, and it adds oxygen to oxidize iron and manganese.

Air Binding – A condition that occurs in filters when air comes out of solution as a result of pressure decrease and temperature increase. The air clogs the voids between the filter media grains, which can cause increased head loss through the filter and shorter filter run times.

Backwash – The reversal of flow through a filter to remove material trapped on and in between the filter media grains.

Baffle – A metal, wooden, or plastic plate installed in a flow of water to slow the water velocity and to provide uniform distribution of flow.

Bar Screen – A series of straight steel bars welded at their ends to horizontal steel beams to form a grid. They are places on intakes or waterways to remove large debris.

Break Point Chlorination – The addition point of chlorine to water where the chlorine demand has been satisfied and further additions of chlorine will result in free residual chlorine. It also insures that odor causing chloramines are at its lowest level.

Breakthrough – The point in the filter cycle at which turbidity causing material passes through the filter.

Centrate – The water that is separated from sludge and discharged from a centrifuge.

Centrifugation – A method of dewatering sludge using a mechanical device that spins the sludge at a high speed.

Chlorination – The process of adding chlorine to water to kill disease-causing (pathogenic) organisms or to act as an oxidizing agent.

Chlorinator – A device used to add chlorine.

Chlorine Demand – The difference in the amount of chlorine applied to the flow and the residual chlorine remaining at a specified time.

Chlorine Dose – The total amount of chlorine that is added to the water.

Clarification – Any process or combination of processes that reduce the amount of suspended matter in water.

Clarifier – A sedimentation basin or tank in which water is retained to allow settleable matter, such as floc, to settle by gravity. It can also be called a settling basin, settling tank, or sedimentation tank.

Coagulant – Any chemical used for coagulation such as alum or ferric sulfate.

Coagulant Aid – Any chemical added during coagulation to improve the process by stimulating floc formation or to strengthen the floc so that it holds better.

Coagulation – The water treatment process that causes very small-suspended particles to attract one another and form larger particles. It is accomplished by adding a coagulant that neutralizes the electrostatic charges on the particles and causes them to repel each other.

Coagulation/Flocculation – The water treatment process that converts small particles of suspended solids into larger more settleable clumps.

Combined Chlorine Residual - The portion of the total residual chlorine remaining in water at the end of a specified contact period that will react chemically and biologically as chloramines or organic compounds.

Contactor – A vertical steel cylindrical pressure vessel used to hold the activated carbon bed.

Corrosion – The gradual degradation of a material by chemical action. It proceeds inwards from the surface.

Corrosive – To deteriorate material through electrochemical processes.

Coupon Test – A method of determining the rate of corrosion or scale formation by placing metal strips of known weight in a pipe.

Decant – To draw off the liquid from a basin or tank without stirring up the sediment on the bottom.

Detention Time – The average length of time a drop of water or a suspended particle remains in a tank or chamber. Mathematically it is the volume of water in the tank divided by the flow rte through the tank.

Disinfection – The water treatment process that kills disease-causing (pathogenic) organisms in water.

Eductor – A device used to mix a chemical with water. Water is forced through a constricted section of pipe (venturi) to create a low pressure, which allows the chemical to be drawn into the stream.

Effluent Launder – A trough that collects the water from the basin effluent and transports it to the effluent piping.

Ejector – The portion of the chlorination system that feeds the chlorine solution into a pipe under pressure. It can also be called an injector.

Empty Bed Contact Time (EBCT) – The volume of the tank holding an activated carbon bed divided by the flow rate of the water. It is expressed in minutes and corresponds to detention time in a sedimentation basin.

Excess-Lime Treatment – A modification of the lime-soda ash method that uses additional lime to remove magnesium compounds.

Filter Agitation – A method used to achieve a more effective cleaning of the filter bed. It uses nozzles attached to a fixed or rotating pipe installed just above the media. Water or a water/air mixture is fed at a high pressure to help agitate the media and break loose accumulated suspended matter. It is also called an Auxiliary Scour or a Surface Wash.

Filtration – The water treatment process involving the removal of suspended matter by passing the water through a porous medium such as sand.

Floc – Collections of smaller particles that have come together (agglomerated) into larger more settleable particles as a result of the coagulation/flocculation process.

Flocculation – The water treatment process that follows coagulation, which uses gentle stirring to bring smaller particles together so they will form floc.

Flow Proportional Control – A method of controlling the chemical feed rates by having the feed rate increase or decrease with the flow.

Fluoridation – The water treatment process in which a chemical is added to the water to increase the concentration of fluoride levels to an optimum level. Its purpose is to reduce dental cavities especially in children.

Free Chlorine Residual - The portion of the total residual chlorine remaining in water at the end of a specified contact period that will react chemically and biologically as hypochlorous acid or hypochlorite ion after break point chlorination is achieved.

Freeboard – The distance between the sand level and the lip of the wash water trough in a filter.

Gravel Bed – Layers of gravel of specific sizes that support the media and help distribute the backwash water uniformly.

Gravimetric Feeder – A chemical feeder that adds specific weights of dry chemicals.

Hypochlorination – Chlorination using solutions of calcium hypochlorite or sodium hypochlorite.

Inlet Zone – The initial zone in a sedimentation basin, which decreases the velocity of the incoming water and distributes it evenly across the basin.

Ion-Exchange Process – A process to remove hardness from water, which depends on special material known as ion-exchange resins. The resins trade non-hardness ions (usually sodium) for the hardness causing ions calcium and magnesium. It will practically remove all hardness from the water.

Ion-Exchange Water Softener – A treatment unit used to remove calcium and magnesium from water using ion-exchange resins.

Jar Tests – A procedure for evaluating the coagulation, flocculation, and sedimentation processes used to estimate proper coagulant dosages.

Lamella Plates – A series of thin, parallel plates installed at a 45-degree angle for shallow depth sedimentation.

Langlier Index (LI) – A numerical index for determining if calcium carbonate will be deposited or dissolved in the distribution. It indicates the corrosivity of the water. If positive, calcium carbonate deposits, and if negative, it stays dissolved.

Lime-Soda Ash Method – The process used to remove carbonate and non-carbonate hardness.

Loading Rate – The flow rate per unit area (gpm/ft^2) of a filter or ion exchange unit at which the water passed through them.

Manifold – A pipe with several branches or fittings to allow water or gas to be discharged at several points. In aeration, manifolds are used to spray water through several nozzles.

Manual Solution Feed – A method of feeding a chemical solution for small water systems. The chemical is dissolved in a small plastic tank, transferred to another tank, and fed to the system using positive displacement pumps.

Metering Pump – A chemical solution feed pump that adds a measured volume of solution with each stroke or rotation of the pump.

Microfloc – The initial floc formed immediately after coagulation, composed of small clumps of solids.

Microstrainer – A rotating drum lined with a finely woven material such as stainless steel. They are used to remove algae and small debris before they enter the treatment plant.

Mudball – Accumulation of filter media grains and suspended material that creates clogging problems in filters.

Nephelometric turbidity unit (NTU) – The unit of measure for turbidity.

Orifice Plate – A type of primary element used in a pressure differential meter, consisting of a thin plate with a precise hole through the center. The plate responds to flow velocity by causing a pressure drop as the water passes through the hole.

Outlet Zone – The final zone in a sedimentation basin, which provides a smooth transition from the settling zone to the effluent piping.

Overflow Weir – A steel or fiberglass plate designed to evenly distribute flow. In a sedimentation basin, the weir is attached to the effluent launder.

Oxidation – The chemical reaction in which the valence of an element increases due to the loss of electrons. It is also the conversion of organic substances to simpler, more stable forms by either chemical or biological means.

Oxidize – To chemically combine with oxygen.

Pipe-Lateral System – A filter underdrain system using a main pipe (header) with several smaller perforated pipes (laterals) branching from it on both sides.

Piston Pump – A positive displacement pump that uses a piston moving back and forth in a cylinder to deliver a specific volume of liquid being pumped.

Plain Sedimentation – The sedimentation of suspended matter without the use of chemicals or other special means.

Polystyrene Resin – The most common resin used in the ion exchange process.

Porous Plate – A patented filter underdrain system using a ceramic plate supported by perforated clay saddles. It is often used without a gravel layer so the plates are directly under the media.

Positive Displacement Pump – A pump that delivers a specific volume of liquid for each stroke of the piston or rotation of the impeller.

Precipitate – A substance separated from a solution or suspension caused by a chemical reaction.

Preliminary Treatment – Any physical, chemical, or mechanical process used before the main water treatment process. It can include screening, pre-sedimentation, and chemical addition. It is also called pretreatment.

Pre-sedimentation – A pretreatment process used to remove gravel, sand, and other gritty material from the raw water before it enters the main treatment plant. It is usually done without the use of coagulating chemicals.

Pre-sedimentation Impoundment – A large earthen or concrete basin used for pre-sedimentation of raw water. It can be useful for storage and reducing the impact of raw water quality changes on water treatment plant processes.

Pressure Differential Meter – Any flow-measuring device that creates and measures a difference in pressure proportionate to the rate of flow. Examples include the venturi meter, orifice meter, and flow nozzle.

Pressure-Sand Filter – A sand filter placed in a cylindrical steel pressure vessel. The water is forced through the media by pumping.

Primary Element – The part of a Pressure Differential Meter that creates the proportional signal in relation to the water velocity.

Propeller Meter – A meter for measuring flow rate by measuring the speed at which the propeller spins, and hence the velocity at which the water is moving through the conduit of known cross sectional area.

Proportional Meter – Any flow meter that diverts a small portion of the main flow and measures the flow rate of that portion as an indication of the rate of the main flow. The rate of the diverted flow is proportional to the rate of the main flow.

Rapid Mixing – The process of quickly mixing a chemical solution uniformly through the water. Also known as flash mixing.

Rate-of-Flow Controller – A control valve used to maintain a constant flow through the filter media.

Reactivate – To remove the absorbed materials from spent activated carbon and restore the carbons porous structure so that it can be used again. The reactivation process is similar to that used to active carbon.

Recarbonation – The reintroduction of carbon dioxide into the water, either during or after lime-soda ash softening.

Receiver – The part of a pressure differential meter that converts the signal into a flow rate that an operator can read.

Regeneration – The process of reversing the ion exchange softening reaction of ion exchange materials, removing the hardness ions from the used materials and replacing them with no troublesome ions, thus rendering the materials fit for reuse in the process.

Regeneration Rate – The flow rate per unit area (gpm/ft^2) of an ion exchange resin at which the regeneration solution is passed through the resin.

Resin – The synthetic bead-like material used in the ion exchange process.

Rotameter – A flow-measuring device for gases.

Sand Boil – A violent washing action in a filter caused by uneven distribution of backwash water.

Saturator – A piece of equipment that feeds a sodium fluoride solution into water for fluoridation. A layer of sodium fluoride is placed in a plastic tank and water is allowed to trickle through the layer forming a constant solution (4%), which is fed to the water system.

Screening – A pretreatment method using coarse screens to remove large debris from the water to prevent clogging of pipes or channels to the treatment process.

Sedimentation – The water treatment process that involves reducing the velocity of water in a basins so that suspended material can settle by gravity.

Sequestering Agent – A chemical compound such as EDTA or certain polymers that chemically tie up (sequester) other compounds or ions so they cannot be involved in chemical reactions.

Settleability Test – A determination of the settleablity of solids in suspension by measuring the volume of solids settled out of a measured volume of sample in a specified time interval, usually reported in milliliters per liter.

Settling Zone – The zone in a sedimentation basin that provides a calm area so that suspended matter can settle.

Shallow-Depth Sedimentation – A modification of traditional sedimentation process using tubes or plates to reduce the distance the settling particles have to travel to be removed.

Short-circuiting – Its a hydraulic condition in a basin in which the actual flow time of water through the basin is less than the designed flow time.

Slake – The addition of water to quicklime to form calcium hydroxide, which can be used in the softening or stabilization process.

Slaker – The part of a quicklime feeder that mixes the quicklime with water to form hydrated lime (calcium hydroxide).

Sludge – The accumulated solids separated from the water during treatment.

Sludge Blow Down – The controlled withdrawal of sludge from a solids contact basin to maintain the proper level of settled solids in the basin.

Sludge Zone – It's the bottom zone of the sedimentation basin, which receives and stores the settled particles.

Slurry – A thin mixture of water and any insoluble material such as activated carbon.

Softening – The water treatment process that removes the hardness causing constituents, Calcium and Magnesium.

Solids-contact Basin – A basin in which coagulation, flocculation, and sedimentation processes are combined. The flow of water is upward through the basin. It is primarily used in the lime softening of the water. It can also be called an up flow clarifier or sludge blanket clarifier.

Solids-contact process – A process combining coagulation, flocculation, and sedimentation in one unit, in which flow is vertical.

Spray Tower – A tower built around a spray aerator to keep the wind from blowing the spray and to prevent freezing during cold temperatures.

Stabilization – The water treatment process intended to reduce the corrosive or scale forming tendencies of water.

Sterilization – The destruction of all organisms.

Surface-Overflow Rate – A measurement of the amount of water leaving a sedimentation tank per square foot of tank surface area. Mathematically, it is the gallons per day flow rate from the tank divided by the square feet of the tank surface.

Total Chlorine Residual – The sum of the free and combined chlorine residual.

Tracer Study – It's a study using a substance that can readily be identified in water (such as dye) to determine the distribution and rate of flow in a basin, pipe, or channel.

Transmitter – The part of a pressure differential meter that measures the signal from the primary element and sends another signal to the receiver.

Trunnion – A roller device, placed under ton cylinders of chlorine to hold them in place.

Tube Settlers – A series of plastic tubes about 2 square inches used for shallow depth sedimentation.

Tube settling – A shallow depth sedimentation process that uses a series of inclined tubes.

Turbine Meter – A meter for measuring flow rates by measuring the speed at which a turbine spins in water, indicating the velocity at which the water is moving through a conduit of known cross sectional area.

UV disinfection – Disinfection using UV light.

Ultrasonic Flow Meter – A water meter that measures flow rate by measuring the difference in the velocity of sound beams directed through the water.

Underdrain – The bottom part of the filter that collects filtered water and uniformly distributes the backwash water.

Velocity Meter – A meter that using a rotor with vanes (such as a propeller) and operating on the principle that the vanes move at the same velocity as the flowing water.

Venturi Tube – A type of primary element used in the pressure differential meter that measure flow velocity by the amount of pressure drop through the tube. It's used in a filter rate of flow controller.

Volumetric Feeder – Chemical feeder that adds specific volumes of chemicals.

Wash-water Troughs – Trough placed above the filter media to collect the backwash water and carry it to the drainage system.

Weighting Agent – A material, such as bentonite, added to low turbidity waters to provide additional particle for good floc formation.

Weir Overflow Rate – A measurement of the number of gallons per day of water flowing over each foot of weir in a sedimentation tank or circular clarifier. Mathematically, it is the gallons per day flow over the weir divided by the total length of the weir in feet.

Wheeler Bottom – A patented filter underdrain system using small porcelain spheres of various sizes in conical depressions.

Wire-mesh Screen – Screen made of wire fabric attached to a metal frame. The screen is usually equipped with a motor so it can more continuously through the water and be automatically cleaned with a water spray. It is used to remove finer debris from the water than the bar screen is able to.

Hydraulic & Additional Terms

Air Gap – A physical break between the water supply and possible source of contamination.

Altitude Valve – A valve that automatically shuts off the flow into an elevated tank when the water level reaches a predetermined level. It automatically opens when the pressure in the distribution system drops below the static pressure of the tank.

Appurtenances – Machinery, appliances, structures, and other parts of the main structure of a distribution system necessary to allow it to operate as intended. It includes pipes, storage facilities, pumping stations, valves, meters, and fire hydrants.

Aquifer – A water bearing formation of rock, sand, and/or gravel.

Artesian – Pertaining to groundwater, it's a well or underground deposit of water where the water is under a pressure greater than atmospheric and will rise above the level of its upper confining surface.

Average Demand – The total demand of water during a period of time dived by the number of days in that period. It is also called Average Daily Demand.

Back Pressure – A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public water system.

Backflow – A reverse flow condition, created by difference in water pressures, which causes water to flow back into the distribution system of a potable water supply from any source or sources other than the intended source.

Backsiphonage – A form of backflow caused by negative or below atmospheric pressure within the water system.

Pump Bowls – The submerged pumping unit in a well including the shaft, impellers, and housing.

C Factor – A factor of value used to indicate the smoothness of the interior of the pipe. The higher the C factor, the smoother the pipe, the greater the carrying capacity, and the smaller the head losses due to friction.

Centrifugal Pump – A pump consisting of a fixed impeller on a rotating shaft that is enclosed in a casing, and having an inlet and discharge connection. As the rotating impeller whirls the water around, centrifugal force builds up enough pressure to force the water through the discharge outlet.

Check Valve – A special valve with a hinged disc or flap that opens in the direction of normal flow and is forced shut when flow attempt to go in the reverse direction. It allows for one-way flow.

Cone of Depression – The depression, roughly conical shaped, produced by the water table by the pumping of water from a well.

Contamination – The introduction into water of microorganisms, chemicals, toxic substances, wastes or wastewater in a concentration that makes the water unfit for its intended use.

Curb Stop – A water service shutoff valve located in a water service pipe near the curb and between the water main and building. It is usually operated by a wrench or valve key and is used to stop and start flows in the water service line to the building.

Drawdown – The drop in the water table or level of water in the ground when water is being pumped from a well.

Dynamic Pressure (Head) – Pressure exhibited from moving water.

Flushing – A method used to clean distribution lines. Hydrants are opened and water flows through the pipes at a high velocity, removing any deposits from the pipe, and flows out of the hydrant.

Friction Losses – The head, pressure, or energy lost by water flowing in a pipe or channel as a results of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restrictions caused by fittings. Water flowing in a pipe loses pressure as a result of friction losses.

Head – The vertical distance in feet equal to the pressure in psi at a specific point. The pressure head in feet is equal to the pressure in psi times 2.31 ft/psi.

Hydraulic Grade Line – In a pipe under pressure, the level at which water would rise in a vertical tube connected perpendicular to the pie.

Hydropneumatic (Pressure) Tank – A type of tank usually found in smaller water systems which allows the automatic controlling of the pumping cycle for a well through air pressure in a tank.

Impeller – A rotating set of vanes in a pump designed to pump or lift water. It is the primary moving component in a centrifugal pump.

Multi-stage Pump – A pump that has more than one impeller.

Non-Potable – Water that may contain objectionable pollution, contamination, minerals, or ineffective agents and is considered unsafe and/or unpalatable for consumption.
Palatable – Water at a desired temperature that is free from objectionable tastes, odors, colors, or turbidity.

Peak Demand – The maximum momentary load placed on a treatment plant, pumping station, or distribution system. This demand is usually the maximum average load in one hour or less, but may be specified as instantaneous or during some other short time period.

Potable Water – Water that does not contain objectionable pollution, contamination, minerals, or ineffective agents and is considered satisfactory for consumption.

Prime – The action of filling a pump casing with water to remove the air. Most pumps must be primed before startup or they will not pump any water. A centrifugal pump with a positive head on the suction side would not need this.

Pumping Water Level – The vertical distance in feet from the center line of the pump to the water level in the well as water is being pumped from it.

Repeatability – The ability of an instrument to obtain the same answer again

Screen – A device that allows the maximum amount of water from the aquifer to enter the well with a minimum amount of resistance and without the excessive passage of sand during pumping.

Single-Stage Pump – A pump that only has one impeller.

Static Pressure (Head) – Pressure exhibited when the water is not moving.

Static Water Level – The vertical distance in feet from the centerline of the pump discharge down to the water level in a well while no water is being pumped from the well.

Thrust Block – A mass of concrete of similar material appropriately placed around the pipe to prevent movement when the pipe is carrying water. Usually placed at bends and valve structures.

Water Hammer – The force against a distribution system that is created when the flow of water is changed significantly, either by pump shutoff or the rapid closing of valves. Whenever the flow of water is quickly changed, the water pressure in the pipe will quickly increase and decrease back and forth very quickly, possibly causing serious damage to the system.