

STATE OF OKLAHOMA

DISTRIBUTION/COLLECTION MANUAL



This Study Guide is Dedicated to the
Certified Distribution/Collection
Technicians and Operators
of the State of Oklahoma
"Protectors of Public Health"



For information concerning Oklahoma operator certification
requirements or application procedures, please contact:

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Operator Certification Section
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INTRODUCTION

This study guide has been prepared for persons interested in obtaining or upgrading their Oklahoma distribution/collection technician (D level) or operator (C level) certification. The chapters in this guide offer information designed to help with both levels of certification. Class D is entry level, and Class C is the more advanced of the certifications.

This guide is not intended to be a reference manual for technical information. Its purpose is to help guide operators in their studies of each of the major subject areas. Each chapter in this guide covers a different subject. Suggested guidelines for each subject area are listed by certification level at the beginning of each chapter. Each chapter is concluded with sample questions. The study guide is used by both instructors and students of approved technician and operator training classes.

Components of Each Chapter in this Study Guide

Study Guidelines

The *Study Guidelines* describe knowledge that may be needed by distribution/collection technicians and operators. These guidelines are designed to help direct study but do NOT address every item of information that a technician or an operator may need to know when taking a certification exam or when performing actual job duties. The guidelines are designed to be used as a "checklist" when studying for a certification exam to help ensure sufficient preparation.

Entry Level Discussion

The *Entry Level Discussion* is offered only as an introduction to the chapter subject. It should be used as a starting point for all persons preparing to take an exam. The answers to most of the questions that may be on the distribution/collection technician (Class D) and the collection operator (Class C) certification exams can be found in chapters one through six. **Please remember that the Entry Level Discussion should never be used as a reference for actual system operation or maintenance.**

References

References are listed which will provide a more extensive discussion of the chapter topic and may help the technician/operator better understand the material in the chapter.

Sample Questions

These are questions representing the approximate difficulty level and format of the questions found on certification exams. The answers to the questions can be found within the chapter. Answers to the *Sample Questions* are listed near the back of this guide.

How to Use this Study Guide to Prepare for State Certification Exams

Distribution/Collection Technician and Operator Certification

Preparation for the distribution/collection technician and operator exams should include the use of this guide (chapters one through six) for both personal study and during attendance at an approved distribution/collection class. See page v for a list of topics for technicians and operators. APPENDIX A includes practice problems and explanations that may help to refresh basic math skills.

Oklahoma Certification Exam Qualifications

Distribution/Collection Technician and Operator Examination Applications are available from the DEQ Operator Certification Section, County DEQ offices, and the DEQ website, www.deq.state.ok.us. Examination sessions are offered throughout the State on a regular basis. The dates and locations of all examination sessions as well as most approved training classes are published in *The Main Event* newsletter. *The Main Event* is mailed to all certified technicians and operators. To obtain a current copy, please call the Operator Certification Section.

Minimum qualifications for operator certification exams are listed in the table below.

MINIMUM QUALIFICATIONS FOR CERTIFICATION EXAMS		
CLASSES	TRAINING ¹	EXPERIENCE ²
D Technician	8 hrs of DEQ approved training	None
D Operator	16 hrs of DEQ approved training	None
C Operator	36 hrs of DEQ approved training	(a) For water works or wastewater works operators, one year of water works or wastewater works operation (b) For distribution/collection operators, one year of distribution/collection operation
B Operator	100 hrs of DEQ approved training or its approved equivalent	3 years of water works or wastewater works operation including one year actual hands-on operating experience
A Operator	200 hrs of approved training, including at least 40 hrs of DEQ approved courses in advanced treatment and managerial training or its approved equivalent ³	5 years of water works or wastewater works operation including two years actual hands-on operating experience
¹ Experience that is used to meet the experience requirement for any class of certification may not be used to meet the education or training requirements.		
² Training credit will be granted only for courses or workshops listed as approved by the DEQ or for courses, workshops or alternative activities which have been approved in writing by the DEQ in advance.		
³ Approved equivalents are listed in 252:710-36.		

Properly completed and signed exam applications must be received by the Operator Certification Unit at least three weeks before the exam is to be taken. An application fee is charged for each exam taken. Payment of the application fee must be made by check, money order, or credit card, made payable to the Operator Certification Section, and must be submitted with the exam application.

Oklahoma Operator Certification Exam Information

Distribution/collection technician certification examination consists of 50 multiple-choice questions. Each question on the exam is worth two points. The opportunity to take the test orally will be provided. Distribution/Collection Operator certification examination consists of 100 multiple-choice questions. Each question is worth one point. At least 70% of the questions must be answered correctly in order to pass either exam. When you take your exam, you are given an exam booklet, an answer sheet, and scratch paper. Most math formulas needed are provided in the exam booklet (see APPENDIX A and APPENDIX B for more information). The only items you should bring into the exam session are a calculator, two No. 2 pencils, and the approval notification for your exam.

Usually within three weeks of exam completion, a report of your exam results will be mailed to your home. **Please do not call for exam results.** Your exam report will specify the number of questions which were included for each category on the exam taken and the percentage that were answered correctly. Exam categories correspond directly to the chapters and/or sections in this study guide. **Your exam report is designed to help direct your future studies and professional development.** For example, if you passed the exam but scored only 60% in the category of Technician/Operator Safety, you would be encouraged to review the corresponding chapter (Chapter 1) in this study guide.

If you did not pass your exam, you should carefully re-study all categories in which you scored below 70%. You may also want to review all the chapters in this study guide and/or attend additional training before retaking your exam. You must wait at least 30 days before retaking a certification exam unless additional approved training has been completed in the interim.

Area of Competency	Study Emphasis	
Topics	Technician (D)	Operator (C)
1. Technician/Operator Safety	★	★
2. Positioning of Lines	★	★
3. Identification of Lines	★	★
4. ODEQ Certification Requirements	★	★
5. Equipment	★	★
6. Disinfection	★	★
7. Line capacities		★
8. Reading a transit for Elevation Differences		★
9. Pipe Fittings		★
10. Pipe Fitting Material		★
11. Flow Velocities		★
12. System Hydraulics		★

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This *Distribution/Collection Certification Study Guide* ("Study Guide") is not intended to be used as a manual for technical information regarding system operation or maintenance or to change, supersede, or replace any statute, rule, regulation, standard or other legal requirement currently in effect or that may be in effect subsequent to publication of this Guide. The purchase, use and/or study of this Guide shall not be considered a guarantee that the user will successfully complete the certification examination. Any mention of trade names or commercial products does not constitute an endorsement or recommendation for use by the State of Oklahoma, the Oklahoma Department of Environmental Quality or the Waterworks and Wastewater Works Advisory Council.

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Chapter 1

Technician/Operator Safety

Some of the information in this chapter is referred to separately within this study guide. This chapter on safety is provided to concentrate special attention to this important topic.

STUDY GUIDELINES

Distribution/Collection Technician (Class D) and Operator (Class C)

Be prepared to answer questions concerning:

- ◆ The general safety concerns and procedures as they apply to excavation and shoring
- ◆ Where the spoil should be placed
- ◆ When a trench or excavation **SHOULD** have adequate cave-in protection
- ◆ When a trench or excavation **MUST** have adequate cave-in protection
- ◆ The general safety concerns and procedures as they apply to confined space entry
- ◆ The requirements that must be met before entering a permit-required confined space
- ◆ The specific responsibilities for entry supervisors, attendants, entrants and rescue personnel
- ◆ The procedures regarding confined space entry permits including recordkeeping requirements
- ◆ The characteristics and dangers associated with gases found in confined spaces
- ◆ The general safety concerns and procedures as they apply to electrical hazards
- ◆ The procedures and significance of proper lockout-tagout practices
- ◆ The basic procedure for emergency rescue of victims of electrical shock
- ◆ The safety concerns and procedures as they apply to other dangers operators may face including:
 - hazardous chemicals
 - noise
 - physical hazards
 - traffic
- ◆ The name of the service available in the case of an emergency involving hazardous chemicals
- ◆ The importance of and how to read a Material Safety Data Sheet (MSDS)
- ◆ The general guidelines for personal protective equipment and protective clothing

ENTRY LEVEL DISCUSSION

This chapter is provided as a general guideline to technician/operator safety but is not all inclusive. Technicians/Operators are required to follow the safety rules as stated by OSHA and the Oklahoma Department of Labor.

Why should safety be of such interest to distribution/ collection technicians and operators? Stop and think of the wide variety of hazards associated with this work. In any one working day, technicians/operators could be exposed to any or all of the following.

1. Trenching and Excavation -- OSHA Regulation Title 29 (1926.650)
2. Confined Spaces -- OSHA Regulation Title 29 (1910.146)
3. Electrical and Mechanical Hazards -- OSHA Regulation Title 29 (1910.147)
4. Hazardous Chemicals -- Oklahoma Haz Com (O.S. 380.45)
5. Noise -- OSHA Title 29 (1910.95)
6. Physical Hazards -- OSHA Title 29 (1900-1926)
7. Traffic
8. Blood Borne Pathogens -- OSHA Title 29 (1910.151, .1030)
9. Fire Protection
10. Infectious Material

Ways operators deal with these day to day hazards may be detailed in a safety program. Aspects of a safety program may include the following.

1. Personal Protective Equipment -- OSHA Title 29 (1910.132-134)
2. Process Safety Management -- OSHA Title 29 (1910.119)
3. Chemical Hygiene Plan -- OSHA Title 29 (1910.1450)

We need to be aware of the potential for injury in all our activities. The best person to prevent an injury from occurring is YOU. By thinking ahead, being aware of the potential for an accident, and developing good work habits—many injuries will be eliminated. Poor work habits, those short cuts you may take, or the messes that are left behind ultimately won't pay off. Eventually it will catch up with you or someone else and an injury will result. The trip to the doctor and days of lost time will more than make up for any time you may have thought you were saving.

Injuries on the job have negative consequences for all involved. Injured technicians/operators not only suffer pain and discomfort, they may be unable to return immediately to work. This can result in a loss of full wages and a hardship to both the technician/operator and his or her family. The distribution/collection system is also affected. Injuries rob the system of needed technicians/operators. Others who may be less skilled may have to fill in. Even large crews may have to work shorthanded or on overtime. This creates fatigue among the technicians/operators and results in an overtime expense to the system.

Common Causes of Injuries

Most injuries involve either the back, legs, or hands. The vast majority of injuries are caused by one of the following three categories of accidents.

1. **Sprains and strains** result from improper lifting, awkward positions, pushing, and slips and falls.
2. **Being struck by objects** that are falling, moving, stationary, flying, sharp, or blunt.
3. **Slips and falls** from platforms, ladders, stairs, or from one level to another.

Years of experience is a factor in who is most likely to be injured. As the experience level increases, the worker is more likely to have become more highly certified and educated about the hazards of the job. He or she may have moved up to a supervisory level where exposure to hazards is less, or may have learned about certain dangerous activities through his/her own experiences or experiences of others.

Technician/Operator Safety Training Programs

On-the-job training (OJT) is a very valuable tool to not only upgrade operational skills, but also to protect the worker's health. Improvements in the safety programs at water treatment and distribution systems should be a constant goal. The desire for a good safety program must start at the very top of the organization. Without this support, many efforts will not be given the authority and financial resources to carry through. Some of the aspects of a good operator safety program are listed below.

1. Develop a written **Standard Operating Procedure (SOP)** for routine duties or equipment operation and have regular training sessions over each SOP. This will not only point out safety aspects of the job, but will also be a way to train people in the most efficient way to work.
2. Have **safety meetings** for all workers at least once a month. Each supervisor should take turns presenting a meeting.

3. Form a **safety committee** to review accidents, inspect the facility for unsafe conditions, to post warnings or suggest improvements to risky areas, and enforce good work habits.
4. Have all personnel learn **CPR** and **First Aid** skills. This can be done through the Red Cross, the American Heart Association, or maybe even your local fire department or ambulance service. If the Operator Certification Unit is notified in advance in writing, these classes may be approved as training credit for certified operators.
5. **Recognize safe workers** with a certificate or some type of tangible recognition. Make safety and good work habits a part of annual evaluations and a factor in merit raises.

Call Okie Two Working Days BEFORE You Dig!

Uniform Color Code Used for Identifying Public Works Pipe and Cables

Red	◆ electric power lines ◆ lighting cables ◆ conduit
Yellow	◆ gas ◆ oil ◆ steam ◆ petroleum
Orange	◆ communication cables ◆ alarm cables ◆ signal lines
Blue	◆ potable water ◆ irrigation water ◆ slurry lines
Green	◆ sewers ◆ drain lines
Pink	◆ temporary survey markings
White	◆ proposed excavation

Trenching and Excavation Hazards

Accidents at the site of trenching and shoring activities are all too common. Almost anyone working for several years in this field can remember personally witnessing or being told about a real life incident where workers were injured or killed in a cave-in. It doesn't matter how short a time you might work in a trench, if there is no adequate cave-in protection provided you could easily be buried under tons of dirt. THERE IS USUALLY NO WARNING AND NO TIME TO ESCAPE.

It is strongly recommended that some type of adequate cave-in protection be provided when the trench is four (4) or more feet deep. OSHA REQUIREMENTS STATE THAT ADEQUATE PROTECTION IS ABSOLUTELY REQUIRED IF THE TRENCH IS FIVE (5) FEET OR MORE IN DEPTH. In addition, A PERSON DESIGNATED AS QUALIFIED AND COMPETENT TO RECOGNIZE AND EVALUATE HAZARDS must be present to inspect the equipment, be able to identify the hazards, and have the authority to stop work if conditions warrant. Methods of adequate protection include shoring, shielding, and sloping.

Shoring

Shoring is a complete framework of wood and/or metal that is designed to support the walls of the trench (see Figure 1.1). **Sheeting** is the solid material placed directly against the side of the trench. Either wooden sheets or metal plates might be used. Any space between the sheeting and the sides of the excavation should be filled in and compacted in order to prevent a cave-in from starting. **Uprights** are used to support the sheeting. They are usually placed vertically along the face of the trench wall. Spacing between the uprights varies depending upon the stability of the soil. **Stringers** are placed horizontally along the uprights. **Trench braces** are attached to the stringers and run across the excavation. The trench braces must be adequate to support the weight of the wall to prevent a cave-in. Examples of types of trench braces include solid wood or steel, screw jacks, or hydraulic jacks.

Shielding

Shielding is accomplished by using a two-sided, braced steel box that is open on the top, bottom, and ends. This "drag shield", as it is sometimes called, is pulled through the excavation as the trench is dug out in front and filled in behind. Operators using a drag shield should always work only within the walls of the shield. If the trench is left open behind or in front of the shield, it could be tempting to wander outside of the shield's protection sometime during the job. In addition, the heavy equipment operator must be very careful to dig trench walls which are straight and are the same width as the drag shield, so that there is no opportunity for a cave-in to start. There have been cases where this was not done and the shield was literally crushed by the weight of a collapsing trench wall.

Shoring

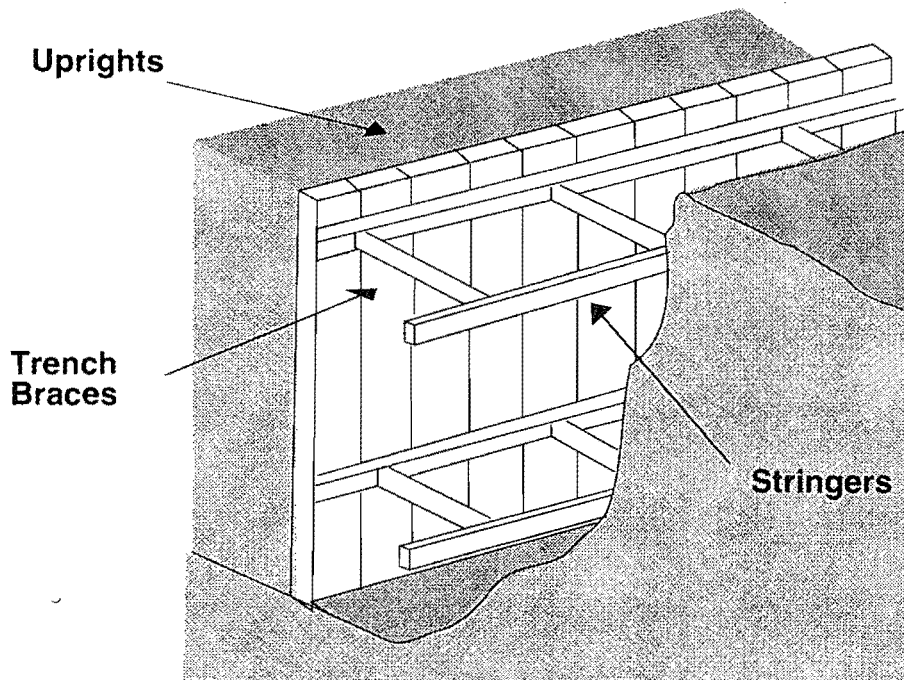


Figure 1.1

Sloping

Sloping is a practice that simply removes the trench wall itself. The amount of soil needed to be removed will vary, depending on the stability of the soil. A good rule of thumb is to always slope at least one foot back for every one foot of depth on **BOTH** sides of the excavation. For deep trenches, sloping will usually require more space than is available.

Other Trenching Requirements

Certain soil conditions can contribute to the chances of a cave-in. These conditions include low cohesion, high moisture content, freezing conditions, or a recent excavation at the same site. Other factors to be considered are the depth of the trench, the soil weight, the weight of nearby equipment, and vibration from equipment or traffic. It is worth repeating that regardless of the presence or absence of any or all of the above factors, the trench must still have proper cave-in protection if it is five or more feet deep. The **spoil** (dirt removed from the trench) must be placed at least two feet back from the trench and should be placed on one side of the trench only. **A LADDER IS REQUIRED FOR EACH WORKER IN THE TRENCH IF IT IS FOUR OR MORE FEET DEEP.**

CONFINED SPACE ENTRY PERMIT

Date of Entry: _____ **Time:** _____ **Authorized Duration:** _____ hours (12 hours maximum)

Site Location & Description: _____

Potential Hazards of Space: _____ Atmospheric _____ Engulfment _____ Entrapment _____ Other _____

Comments: _____

Purpose of Entry: _____

Entry Supervisor: _____ (use separate roster to note replacement)

Authorized Attendant : _____ (use separate roster to note replacement)

Authorized Entrant(s): _____

(separate roster must be used to track all who are currently in the space)

Communication Procedures: _____

All requirements to be completed and reviewed prior to entry. (Enter N/A for items that do not apply)

Requirements Completed:	Date	Time	Requirements Completed:	Date	Time
Lock-out/De-energize/Try-out	_____	_____	Full Body Harness w/ "D" Ring	_____	_____
Line(s) Broken-Capped-Blanked	_____	_____	Lifelines	_____	_____
Purge-Flush and Vent	_____	_____	Non-Entry Retrieval Equipment	_____	_____
Ventilation	_____	_____	Fire Extinguishers	_____	_____
Secure Area (Post and Flag)	_____	_____	Lighting	_____	_____
Warning Signs, Barricades	_____	_____	Protective Clothing	_____	_____
MSDS Review	_____	_____	Hearing Protection	_____	_____

Continuous Monitoring	Permissible Entry Level	Record Monitoring Every Two Hours			
Oxygen	19.5% to 23.5%	_____	_____	_____	_____
Methane	Less than 0.5%	_____	_____	_____	_____
Hydrogen Sulfide	Less than 10 ppm	_____	_____	_____	_____
Carbon Dioxide	Less than 10,000 ppm	_____	_____	_____	_____
Time Tests Were Performed	_____	_____	_____	_____	_____
Tester's Initials	_____	_____	_____	_____	_____
Testing Instrument _____	Model/Serial# _____	Date of Calibration _____			

Rescue

All Emergencies (Fire, Rescue, Medical, Ambulance) - Call # _____

Safety Supervisor - Call # _____ Nearest Phone: _____

Rescue Personnel: _____

Internal _____ Outside _____

Required Rescue Equipment: _____

Authorizing Entry Supervisor: _____ **Date** _____ **Time** _____

All required conditions satisfied? Yes _____ No _____ (Permit will remain at site until job completion)

Entry Supervisor Signature _____ Entry Concluded: **Date** _____ **Time** _____

Other Required Permits For Job: _____

Figure 1.2

Some of the Common Dangerous Gases Found in Water Treatment Plants and Distribution Systems						
Name of Gas	Chemical Formula	Specific Gravity (Air=1.00)	Explosive Range (% in air)		Common Properties	Physical Effects
			LEL	UEL		
Methane	CH ₄	0.55	5.0%	15.0%	Colorless Tasteless Flammable Explosive	Asphyxiant Doesn't support life
Hydrogen Sulfide	H ₂ S	1.19	4.3%	46.0%	Rotten-egg odor Colorless Flammable Explosive Poisonous	Death in a few minutes at 0.2% Paralyzes respiratory center. Odor not detectable at high levels
Carbon Dioxide	CO ₂	1.53	Not flammable		Colorless Tasteless Odorless	10% can't be endured for more than 10 min. Acts on nerves of respiration
Chlorine	Cl ₂	2.5	Not flammable Not explosive		Greenish-yellow Strong odor Highly corrosive	30 ppm coughing 40-60 ppm dangerous 1000 ppm fatal in a few breaths

Figure 1.3

Figure 1.3

THE LADDER MUST BE must PLACED WITHIN 25 FEET OF THE WORKER AND MUST EXTEND AT LEAST THREE FEET ABOVE THE EXCAVATION WALL.

Confined Spaces

According to OSHA's Confined Space Entry Rule, a **confined space** is defined as an area large enough for entry with a limited ability to enter and exit and that is not intended for continuous occupancy. One easy way to identify a confined space is by whether or not you can enter it by simply walking while standing fully upright. If you must duck, crawl, climb, or squeeze into the space, it is probably considered a confined space.

A **permit-required confined space** is defined as a confined space that presents or has the potential for hazards related to atmospheric conditions or any other serious hazard. The potential for buildup of toxic or explosive gas mixtures and/or oxygen deficiency exists in many confined spaces found at water systems. Employees entering a permit required confined space must wear a harness and utilize emergency retrieval equipment.

Employers must evaluate all workplaces and determine which confined spaces require an entry permit. One example of a confined space entry permit is shown in Figure 1.2. An entry permit requiring different information might be used for some confined spaces if they are difficult to completely isolate and/or present special hazards.

Job Designations and Responsibilities

Before entering a permit-required confined space, an **entry supervisor** must prepare and sign an entry permit. The entry supervisor must know the potential hazards of confined spaces, verify that all atmospheric tests have been conducted and all procedures and equipment are in place before endorsing the entry permit. The entry supervisor also must determine that acceptable conditions continue until the work is completed. The entry permit is "canceled" after a significant break, work is completed or the approved duration of permit has passed, whichever comes first. All canceled entry permits must be kept for at least one year to allow for an annual review of the program.

The law also requires that an **attendant** be stationed outside confined spaces while the work is done (also known as the **buddy system**). The attendant must know the potential hazards of confined spaces, be aware of behavioral effects of potential exposures, and communicate with entrants as necessary to monitor their status. The attendant must remain outside the space until relieved. Attendants also must monitor activities inside and outside the permit space and order exit if required, summon rescuers if necessary, prevent unauthorized entry into confined space, and perform non-entry rescues. An attendant may not perform other duties that interfere with the primary duty of monitoring and protecting the safety of authorized entrants.

All authorized **entrants** (persons entering the confined space) must be trained in the hazards they may face, be able to recognize signs or symptoms of exposure and understand the consequences of exposure to hazards. They must also know how to use any needed equipment, communicate with attendants as necessary, alert attendants when a warning symptom or other hazardous condition exists. Entrants must exit as quickly as possible whenever ordered or alerted to do so. All **contractors** must be provided information by the system owner on permit spaces and likely hazards that the contractor might encounter. Joint entries must be coordinated.

Special training is necessary to provide all employees with the understanding, skills and knowledge to perform their individual duties. Training is required for all new employees and whenever duties change, the hazards in a space change or whenever an evaluation shows a need for additional training.

Rescue services (either on-site or off-site) must be readily available and able to be summoned quickly. On-site teams must be properly equipped. They must receive the same training as authorized entrants plus additional training on how to use personal protective and rescue equipment and first aid training, including CPR. Simulated rescues must be

performed at least once every 12 months. Outside rescue services must be made aware of hazards and receive access to comparable permit spaces to develop rescue plans and practice rescues.

Ventilation and Continuous Monitoring

CONFINED SPACES MUST BE PROPERLY VENTILATED USING SPECIALLY DESIGNED **FORCED-AIR VENTILATORS**. This crucial step must be taken even if gas detection and oxygen-deficiency detection instruments show the atmosphere to be safe. Because some of the gases likely to be found are explosive, the blowers used must be specially designed to be **intrinsically safe**. This means that the blower itself will not create a spark and cause an explosion.

THE ATMOSPHERE MUST BE CONTINUOUSLY CHECKED WITH RELIABLE, CALIBRATED INSTRUMENTS. Several instruments are available that check for toxic gases, flammable gases and for oxygen deficiency. The oxygen concentration in normal breathing air is 20.9%. The atmosphere in the confined space must never fall below 19.5% oxygen.

THE SENSE OF SMELL IS ABSOLUTELY USELESS FOR EVALUATING THE PRESENCE OF GASES. Many dangerous gases have no odor at all. Furthermore, **HYDROGEN SULFIDE PARALYZES THE SENSE OF SMELL**. The higher the concentration of hydrogen sulfide, the faster the loss of smell.

The **upper explosive limit (UEL)** and **lower explosive limit (LEL)** indicate the range of concentrations at which combustible/explosive gases will explode upon ignition (see **Figure 1.3**). No explosion occurs when the concentration is outside of these ranges. The **specific gravity** of a gas indicates its weight as compared to air. Air has a specific gravity of exactly 1.0. Several gases (including hydrogen sulfide and chlorine) have a tendency to collect in low places because they have a specific gravity of greater than 1.0. This means that these gases are heavier than air. Methane will rise out of low places because it has a specific gravity of less than 1.0 and is lighter than air. Only **non-sparking tools and lamps** should be used. Obviously, there should be no smoking anywhere near the entrance to a confined space.

Electrical and Mechanical Hazards

ELECTRICAL HAZARDS CAN CAUSE SERIOUS INJURY LEADING TO DEATH. UNDER NO CIRCUMSTANCES SHOULD PERSONS OPEN AN ELECTRICAL PANEL OR ATTEMPT ELECTRICAL REPAIRS UNLESS THEY ARE BOTH QUALIFIED AND AUTHORIZED.

Electrical energy of only 50 volts can be fatal if a good ground is made. Electricity is

capable of paralyzing the nervous system and stopping the muscular action responsible for breathing and pumping blood.

In the event of electrical shock, the following steps should be taken.

1. Survey the scene and see if it is safe to enter.
2. If necessary, free the victim from a live power source by shutting power off at a nearby disconnect, or by using a dry stick or some other non-conducting object to move the victim.
3. Send for help to call 911 or whatever the emergency number is in your community. Check for breathing and pulse. Begin CPR immediately if needed.

There are several things to keep in mind whenever working on electrical equipment.

1. Always lockout and tagout any electrical equipment being serviced. NEVER remove someone else's lock or tag.
2. Use only grounded power tools.
3. Do not use metal ladders when working on electrical equipment.
4. Only trained and legally licensed persons working in pairs should attempt electrical repairs.

Basic Lock-out/Tag-out Procedures

According to OSHA law, all equipment that could unexpectedly start-up or release stored energy must be locked out or tagged out to protect against accidental injury to personnel. Some of the most common forms of stored energy are electrical and hydraulic energy, among others. Whenever major replacement, repair, renovation, or modification of equipment is performed, the energy isolating devices (switch, valve, etc.) for the equipment must be designed to accept a lockout device. A **lockout device** uses a positive means such as a lock, either key or combination type, to hold the switch in the safe position and prevent the equipment from becoming energized. A **tagout device** is a prominent warning, such as a tag, which can be securely fastened to the energy isolating device in accordance with an established procedure, to indicate that both it and the equipment being controlled may not be operated until the tagout device is removed. The basic procedures required for proper lock-out/tag-out are listed below.

1. Notify all affected employees that a lockout or tagout system is going to be utilized and the reason why. The authorized employee should know the type and magnitude of energy that the equipment utilizes and should understand the potential hazards.

2. If the equipment is operating, shut it down by the normal stopping procedure.
3. Operate the switch, valve, or other energy isolating device(s) so that the equipment is isolated from its energy source(s). Stored energy (such as that in springs, elevated machine members, rotating flywheels, hydraulic systems, and air, gas, steam, or water pressure, etc.) must be dissipated or restrained by methods such as repositioning, blocking, or bleeding down.
4. Lockout and/or tagout the energy isolating device with your assigned individual lock or tag.
5. After ensuring that no personnel are exposed, and as a check that the energy source is disconnected, operate the push button or other normal operating controls to make certain the equipment will not operate. **CAUTION! RETURN OPERATING CONTROLS TO THE NEUTRAL OR OFF POSITION AFTER THE TEST.**
6. The equipment is now locked out or tagged out and work on the equipment may begin.
7. After the work on the equipment is complete, all tools have been removed, guards have been reinstalled, and all personnel are in the clear, remove all lockout or tagout devices. Operate the energy isolating devices to restore energy to the equipment.

Hazardous Chemicals

Hazardous chemicals are present in many areas of the system. The plant laboratory uses a wide variety of acids, bases, and other potentially dangerous compounds. Water system operators will also likely come in contact with various forms of chlorine (see also Chapter 6 for specific information on chlorine safety). Each worker should be trained in safe chemical and handling procedures as required by the **Rules for Oklahoma Hazard Communication Standard**. These rules are based on a federal law designed to help minimize injuries among workers from chemical overexposure. **A MATERIAL SAFETY DATA SHEET (MSDS) FOR EACH AND EVERY CHEMICAL THAT IS PRESENT OR PRODUCED IN THE SYSTEM MUST BE READILY AVAILABLE TO ALL OPERATORS.** The MSDS is a reliable reference (usually provided by the manufacturer) for the type of hazards the chemical presents and what to do in the case of an emergency. All operators should be familiar with the MSDS through training provided by the employer and personal study.

Safely handling chemicals used in daily water treatment is an operator's responsibility. However, if the situation ever gets out of hand, there are emergency teams that can respond with help anywhere there is an emergency. **Chemtrec** will provide immediate advice for those at the scene of an emergency and then quickly alert experts whose products are involved for more detailed assistance and appropriate follow-up. The toll-free Chemtrec number is 1-800-424-9300.

Noise

Noise is a hazard often overlooked. Prolonged exposure to high noise levels (85 decibels or greater) can lead to permanent hearing loss. Excessive noise can come from motor rooms, lawn mowers, and other tools and equipment. Noise levels should be checked using a noise dosimeter. In general, if you have to shout or cannot hear someone talking to you in a normal tone of voice, the noise level is excessive. Hearing protection such as ear plugs or muffs is required if the noise cannot be eliminated.

Physical Hazards

Physical hazards include falls and slips from stairs, ladders, rough ground, or slick surfaces. Other physical hazards are moving machinery, automatically operated equipment, and obstructing pipes or walkways. Some of these are called **built-in hazards** because they are built into the plant. Built-in hazards should be modified if possible, or clearly labeled and personnel made aware of the hazard. **Protective clothing** is needed by all operators. **Hardhats and steel-toed shoes** are often appropriate.

Other ways of avoiding injuries from physical hazards are to use the proper ladder or tool for the job, fill in holes, or post barricades, put additional tread on the steps, and paint slick areas with pumice paint. Emphasis should be put on good housekeeping as a way to eliminate accidents. Oil, water, polymer, or other debris left in walkways causes many slips and falls. Cleaning up spills as they occur and using oil soak or oil soak booms can eliminate much of this. Placing trash barrels in all areas of the facility will help stop clutter. Enforcing **good housekeeping habits** among all workers is a must.

Traffic

Traffic controls are absolutely essential for those working in the distribution system. This is important for line maintenance workers, meter readers, field samplers, and others. Some of the things you can do to eliminate injury from traffic are to:

1. **DON'T WORK IN RUSH HOUR TRAFFIC.**
2. **PUT UP WARNINGS OR POST A FLAGMAN 500 FEET AHEAD OF ONCOMING TRAFFIC.**
3. **ALWAYS USE WARNINGS INCLUDING VESTS AND FLASHING LIGHTS.**
4. **PLACE A BARRIER BETWEEN THE WORKERS AND TRAFFIC** such as a truck. The general rule is the bigger, the better.

Bloodborne Pathogens

Regulations governing exposure to bloodborne pathogens are mandated by OSHA. It is the employer's responsibility to develop an exposure control plan and provide training to those workers potentially exposed to bloodborne pathogens that may be present in body fluids. First aid procedures should outline the appropriate response for an employee to follow when rendering first aid. First aid kits should contain disposable gloves and biohazard bags to contain contaminated bandages or gauze.

Fire Protection

The best fire protection the plant operator can provide is fire prevention. Fire hazards can be easily removed and the local fire department can give advice on fire prevention in and around the treatment plant. Fire classifications are important for determining the type of fire extinguisher needed to control the fire. Fires are classified as:

- A -- Ordinary combustibles
- B -- Flammable liquids
- C -- Electrical equipment
- D -- Combustible metals

Infectious Agents

Infectious agents are present in wastewater. It is commonly known that wastewater carries a host of pathogenic organisms. There are several ways that the risk of becoming infected can be reduced.

1. COVER ALL OPEN WOUNDS. Clean wounds immediately and frequently thereafter.
2. DO NOT SMOKE, EAT, OR DRINK IN WORK AREAS and wash thoroughly before doing so.
3. Don't wear work clothes or shoes home if possible. Don't wash work clothes with other laundry.
4. Follow your doctor's recommendations for adult immunizations and boosters.

Personal Protective Equipment

A Personal Protective Equipment (PPE) evaluation should be completed by the employer for each task performed by the employee and adequate protection should be provided.

Process Safety Management Plan

The main objective of the process safety management of highly hazardous chemicals is to prevent unwanted release of hazardous chemicals especially into locations that could expose employees and others to serious hazards. With this objective in mind in 1992 OSHA issued one of its most comprehensive regulations -- Process Safety Management of Highly Hazardous Chemicals (29 CFR 1910.119).

The standard applies to water treatment facilities that process chemicals over threshold amounts: such as chlorine at 1500 pounds. Process Hazard Analysis (PHA) is the most essential part of a Process Safety Management Program. PHA is directed toward analyzing potential causes and consequences of fires, explosions, release of toxic or flammable chemicals and major spill of hazardous chemicals. PHA focus on instrumentation, equipment, utilities, human actions, and external factors that might impact the process. Operating Procedure is another important element. It describes tasks to be performed, data to be recorded, operation conditions to be maintained, samples to be collected, and safety and health precautions to be taken.

Chemical Hygiene Plan

This program describes various chemicals in use in the laboratory, PPE to be used in handling them, and precautions to be used by designated personnel in case of spills or release. A primary and secondary response person shall be designated in the plan to respond to spills. Hazards to be analyzed and protection provided for include: eye protection, fall protection, foot protection, hand protection, head protection, hearing conservation, and respiratory protection.

Personal Responsibility for Safety

The final thing to remember about safety is that it is your life and health and that of your co-workers that is to be protected. THE FINAL RESPONSIBILITY LIES WITHIN YOU. The supervisor, manager, or mayor cannot be there at all times to make sure you do the safe thing. The safety gear provided should be used as it is intended to be used. Safety gear not already provided should be requested. DENIAL OF REQUESTS FOR LEGALLY REQUIRED SAFETY GEAR OR OTHER UNRESOLVED SAFETY VIOLATIONS SHOULD BE REPORTED TO THE:

Oklahoma State Department of Labor
Public Employees Health and Safety Division
(405) 528-1500 ext. 226

Most importantly, always approach each job with the question, "HOW CAN I DO THIS SAFELY?"

REFERENCES

California State University, Sacramento - **Water Treatment Plant Operation, Vol. 2**

Chapter 20 Safety

California State University, Sacramento - **Water Distribution System Operation & Maintenance**

Chapter 3 Distribution System Facilities (especially sections 3.653 and 3.659)

Chapter 6 Disinfection (especially sections 6.4 and 6.6)

Chapter 7 Safety

Rules for Oklahoma Hazard Communication Standard

Title 40 - Oklahoma Statutes for General Safety and Health

OSHA Confined Space Entry Rule

SAMPLE QUESTIONS

Technician

The chemical information sheet that is supplied by manufacturers is called the

- A. plant operations and maintenance manual
- B. monthly operational report (MOR)
- C. material safety data sheet (MSDS)

Operator

Probably the two MOST dangerous gases that operators might encounter at a water system are

- A. Cl_2 and CO_2
- B. Cl_2 and H_2S
- C. CH_4 and CO_2

Chapter 2

Distribution Systems

STUDY GUIDELINES

Distribution/Collection Technician (Class D)

Be prepared to answer questions concerning:

- ◆ The basic design and operation of water distribution systems
- ◆ The definition and significance of a pipe's pressure rating and pipe schedule
- ◆ The proper distances of separation between water and sewer lines and the minimum soil cover
- ◆ The proper methods of laying pipe including bedding and backfilling requirements
- ◆ The minimum size water line required when fire protection is provided
- ◆ The minimum size water line sometimes allowed when fire protection is not provided
- ◆ The basic requirements for disinfection and bac-t samples for new or repaired lines and tanks
- ◆ The basic descriptions of various types of water storage facilities including advantages and disadvantages of each
- ◆ The basic advantages and disadvantages of the different types of piping materials
- ◆ Common problems that may occur in the distribution system and how to avoid them
- ◆ The special safety considerations for distribution system operators

Distribution/Collection Operator (Class C)

Be prepared to answer questions concerning guidelines listed for Class D certification and:

- ◆ The basic operational and maintenance practices of water storage facilities
- ◆ The different types, descriptions, and applications of piping and joints
- ◆ The advantages and disadvantages of different types of lines
- ◆ The definition and significance of a pipe's C Factor
- ◆ The descriptions and uses for commonly used valves and their operational characteristics
- ◆ The basic descriptions of the various types of meters and their common applications
- ◆ The importance and basic setup of cross connection control programs
- ◆ How to calculate problems involving flow rates, water pressures, volumes, and chemical dosages involving disinfection of lines and tanks

ENTRY LEVEL DISCUSSION

The distribution system consists of a network that delivers water to homes, businesses and industries for drinking and other uses. The network must have sufficient capacity to meet maximum water demands—plus fire-fighting requirements—and still maintain adequate water pressures throughout the water distribution system.

Water Storage Facilities

The main purpose of a water storage facility is to provide a sufficient amount of water to equalize the daily demands on the water supply system. The storage facility should be able to provide water for both average and peak demands. Storage facilities also help to maintain adequate pressures throughout the entire distribution system.

Other important purposes of water storage include meeting the needs for fire protection, industrial requirements, and to provide reserve storage. During a fire or other type of emergency, sufficient storage should be available to meet fire demands, while still maintaining system pressures. In many communities the water supply system will serve some type of industry. Storage requirements will depend on the type of industry and the flow and pressure demands of the industrial activities of each facility served by the water supply system. Reserve storage requirements depend on standby requirements and alternate sources of water supply. Reserve requirements might be specified by fire insurance regulations. Reserve storage capacity may be provided to meet future growth and development demands of the area being served.

Types of Water Storage Facilities

ELEVATED TANKS. Elevated tanks are used primarily to maintain an adequate and fairly uniform pressure in the distribution system or area of the distribution system. They may be installed where the land is flat or on high ground. One limitation of elevated tanks is that the pressure in the distribution system may vary with the water level in the tank. Elevated tanks are used to:

1. Eliminate the need for continuous pumping.
2. Minimize variations in distribution system water pressures due to short-term shutdown of power or pumps.
3. Equalize the water pressure in the distribution system by the proper location of the tanks.
4. Provide a reserve amount of water in storage (especially to meet demands such as fires).
5. Reduce auxiliary power requirements.

STAND PIPES. A **stand pipe** is a storage tank that is set on the ground and has a height greater than its diameter. Stand pipes may be constructed of steel or concrete and are usually located on high ground, near a well field, or at a point in the system where storage is needed. When compared with elevated storage tanks, standpipes are sometimes preferred because they are:

1. Generally easier to maintain.
2. More accessible for observation and sampling to determine quality of stored water.
3. Safer to work around.
4. Less objectionable from an aesthetic viewpoint.

GROUND-LEVEL STORAGE TANKS. **Ground-level storage tanks** are usually constructed of concrete and are either circular or rectangular in shape. They may be buried in the ground or located on the ground surface. Some concrete storage tanks are built with parks, parking lots, or tennis courts on top of them.

PRESSURE TANKS. **Pressure tanks** are storage systems in which a water pump is controlled by the air pressure in a tightly sealed tank partially filled with water. Pressure tanks are used to maintain water pressures in the system and to control pump operation. This type of storage is usually found only at small ground water systems that do not have a large storage facility. The well provides the source of water pumped to the tank. Air in the tank then helps maintain water pressure in the distribution system. Extra care must be taken because of the high pressure in the tank when operating and maintaining these facilities, especially the pressure relief valves.

Operation and Maintenance of Storage Facilities

All storage tanks should be operated according to the design engineer's and manufacturer's instructions. Most distribution systems will establish a steady water usage pattern which the operator should study in order to better anticipate system demands. Extra water is supplied from storage during the hours that consumption is above average and the storage facility is refilled during the hours that consumption is below average. As a result, water levels in the storage facility will drop during peak demands and gain during low demands.

Water level indicators are essential to successful storage facility operation. Devices used for this purpose may be as simple as a float that is connected to an indicator on a gauge which the operator can then read and record. Many other water systems are fully instrumented and automated. At these systems, electronically-controlled instruments are used to measure water levels in storage tanks as well as measure water pressures automatically throughout the distribution system. Whenever water levels or water pressures drop below minimum target levels, pumps will automatically be started and will

stay on until the maximum levels that have been set are reached. Operators at automated systems must still inspect and check the measuring instruments for proper measurement and must also make sure the pumps start and stop at the proper levels.

Care must be taken to ensure that runoff water and debris cannot enter the tank and contaminate the water. For this reason, all storage tanks should be covered and located above drainage areas and locations subject to flooding. All **overflow vents** and **air vents** should be screened so that birds, rodents, and debris cannot enter the tank. Vents must be adequate and never be blocked so air can flow freely without any obstruction. Properly functioning vents are essential to prevent pressure from developing in the tank when it is filled or a vacuum being created when it is emptied or partially drained. All storage facilities should be fenced to prevent access by vandals or other unauthorized persons.

Many water systems try to paint the outside of their steel tanks once every five years. A tank's interior coating will generally protect the interior for a three-to-five year period, depending on local conditions. **Routine inspection** is the best way to determine when a tank needs painting. Inspections of storage tanks for flaking, peeling, and rust should be made at least once a year. Special care must be used in the selection of the tank's interior coating. It must be nontoxic and not impart objectionable tastes or odors in the water. The paint should meet American Water Works Association (AWWA) specifications and be listed by the National Sanitation Foundation (NSF) or Underwriter's Laboratories (UL).

Cathodic Protection

The principle of **cathodic protection** in a storage facility is perhaps most easily understood by comparing the tank to a simple glass of water. Imagine a glass of water with rods of two different types of metal in it. If you were to hook a voltage meter between these two rods, you would find that a very low voltage reading (probably less than 1 volt) would be detectable. Voltage is actually the result of a flow of electrons. Electrons are very small particles with electrical charges. In a storage tank, the impurities in the water (including metals) and the tank wall will often cause this same type of low voltage to be generated. The result, in most cases, is that the tank itself will lose metal into the water as the voltage goes from the tank to the water.

To eliminate this voltage or flow of electrons from the tank to the water, some type of cathodic protection is often installed. The basic theory of cathodic protection is to supply an small amount of D.C. electricity from an outside source through an **anode** into the tank. The anode is usually a aluminum, steel, or magnesium rod about 12 to 15 inches long. The **cathode** in this exchange of electrons is actually the tank itself. The voltage that is set up between the anode and the cathode (the tank) just barely compensates for the voltage between the tank and the water. The D.C. electricity causes the anode to give up metal to the tank replacing the metal that the tank has lost to the water. The anode usually needs replacement at least annually. Cathodic protection is also sometimes used for piping materials. Cathodic protection is corrosion prevention.

Pipes and Pipe Couplings

Many different materials are used for distribution system construction, including different types of piping used at different systems and situations. Each type of piping has advantages and disadvantages and serious consideration should be given before making decisions involving material selection.

One consideration when selecting piping is the *C-factor* of the pipe. The **C-factor**, also called the coefficient of roughness, is an indication of how much friction (slowing down of the flow) is caused by the pipe material itself. The higher the C-Factor, the smoother the inside of the pipe. Even when brand new, all piping materials have some roughness which resists water flow and causes a drop in pressure.

The **pressure rating** of a pipe is also an important consideration. The pipe must be adequate to handle the pressures that it may encounter in the system. Generally, only four classes of pressure ratings will be encountered — 100, 150, 200, and 250 psi (pounds per square inch). Pipes may rupture or be crushed when subjected to internal or external pressures that exceed its ratings. Another characteristic of pipe is the pipe schedule. The **pipe schedule** indicates the pipe's wall thickness. The higher the number, the thicker the wall.

Gray Cast Iron Pipe (CIP)

Gray cast iron pipe (CIP) offers a long service life and is relatively strong. Its main disadvantage is the brittleness of the pipe. Where corrosive soils are a problem, the outside of cast iron pipe should be protected by encasing it in a sleeve of polyethylene plastic or by using standard cathodic protection methods. The interior of unlined cast iron pipe is subject to tuberculation (the pitting and growth of nodules), which reduces the inside diameter and increases the pipe roughness. Methods of preventing tuberculation include a cement or bituminous tar lining as well as reducing the corrosivity of the water. Flanged or mechanical joints are used to connect lengths of pipe. Newer installations are using bell and spigot push-on joints which provide a more watertight seal.

Ductile Iron Pipe (DIP)

Ductile iron pipe (DIP) is very malleable (easily worked) as compared to CIP and has roughly twice the strength. DIP is particularly useful for buried water lines exposed to heavy loads, shocks, and unstable pipe bedding. Because of its strength it is sometimes used for transmission lines. Also because of its strength DIP is easier to install than CIP and is easily drilled and tapped for service lines. The disadvantage of DIP is similar to CIP in that it is subject to corrosion from both inside and outside often requiring preventive measures.

Steel Pipe

Steel pipe has been in use in the United States since the mid 1800s and is still often used where pressures are high and large diameter pipe is required. Steel pipe is much stronger than CIP and is slightly stronger than DIP. In addition, it is somewhat lighter than iron pipe. It is relatively inexpensive, easy to install, and is easier to transport. Steel pipe is resistant to shock loads and is somewhat flexible. However, steel pipe will not withstand the external loads that iron pipe will. A negative pressure, or vacuum caused by rapidly emptying steel pipe could result in distortion or total collapse.

Corrosion of steel pipe can often be more severe than in iron pipe. In fact, special linings and coatings may be required to prevent the thin walls of steel pipe from corroding. Bitumastic enamel, a coal-tar material, is commonly used to coat steel pipe for corrosion control. Cement-mortar lining and epoxy lining may also be used for corrosion protection. Caution should be taken to prevent damage to the coatings. Small scars or chips in the coating will result in accelerated corrosion rates in the area of the damage.

Plastic Pipe

ALL PLASTIC PIPING USED IN DISTRIBUTION SYSTEMS MUST HAVE THE NATIONAL SANITATION FOUNDATION (NSF) STAMP INDICATING THAT IT IS APPROVED FOR USE WITH POTABLE WATER.

Plastic pipe is a relatively new pipe material but it is rapidly gaining acceptance in the water distribution field. **Polyvinyl chloride (PVC)** is one of the most popular plastic pipes. Since PVC is non-metallic, it will not corrode from electrolysis or electrochemical action. Soil corrosion will also have very little effect on PVC. Therefore, corrosion resistant coatings, cathodic protection, and other corrosion protection devices are unnecessary. Plastic pipe is generally considered to be the piping material most resistant to corrosion. Another advantage of plastic pipe is that it is relatively light and is easily cut and assembled without the need for special tools.

Disadvantages of PVC include its relatively thin wall design, sometimes causing deflection in larger size pipe. Another drawback to plastic pipe is that ultraviolet rays will cause it to deteriorate. For this reason, plastic pipe should never be stored where it can come into direct contact with sunlight. If it is necessary to leave plastic pipe in an open trench for more than a few days, the pipe should be covered with a small amount of backfill or with black heavy plastic sheeting. Plastic pipe can also be damaged by rocks or other rough material if it is not properly bedded.

Finally, because of its composition, petroleum products will cause severe deterioration in plastic pipe. Therefore, it must be kept at a distance from gasoline storage tanks. The two joints used for PVC are solvent welds for smaller sizes (up to six inch diameter) and the rubber ring push-on joints for larger sizes.

Reinforced Concrete Pipe (RCP)

Reinforced concrete pipe (RCP) is widely used for large distribution and transmission lines. RCP can be classified into two general types: non-steel cylinder type and steel cylinder type.

NON-STEEL CYLINDER RCP. Non-steel cylinder RCP is constructed by forming from one to three cages of reinforcing steel. The cage(s) are then placed in a mold and are coated with concrete. This type of pipe is designed for low pressure applications. Because concrete is a somewhat porous material, non-steel cylinder RCP has a tendency to leak.

STEEL CYLINDER RCP. Steel cylinder RCP, sometimes referred to as pressure pipe, is constructed with a steel cylinder lined with cement mortar. Wire is then wrapped around the structure and a mortar coating is added over it. This pipe is capable of being used in high pressure applications.

RCP is used in large lines due to its high compressive strength and capability of being used under high backfill loads. It is also a low maintenance pipe and is usually not subject to tuberculation, although corrosive water can harm it. Many types of specialized interior coatings are available to ensure water tightness and to prevent any tuberculation. Because of its composition, RCP is resistant to electrolysis and corrosive soil conditions. It is somewhat difficult to tap and may be hard to repair if damaged. Bell and spigot or push-on joints are used for connections.

Asbestos Cement Pipe (ACP)

Asbestos-cement pipe (ACP) was a relatively popular pipe material until people became concerned about breathing asbestos fibers. Because of this serious health concern, ACP is no longer being installed in distribution systems. It is very important for operators to take special care to avoid health hazards when working with any existing ACP in their system, especially if it is being cut or machined. Respirators must be worn whenever there is a possibility of inhaling airborne asbestos fibers.

Valves

Valves have many uses in the distribution system. Valves are commonly used to stop flow, regulate flow, drain lines, or isolate a section of a line. These valves can be operated manually or by motorized controls that may be operated through a remote control circuit. Other types of valves include several specialized valves used to protect the line. These valves usually operate automatically to prevent backflow, bleed-off air, take in air, or prevent water hammer.

Valves should always be opened and closed slowly. All valves in the system should be exercised regularly according to the manufacturer's recommendations, usually once a year.

Shutoff and Flow Regulation

BUTTERFLY VALVES. The butterfly valve is constructed with a movable disc rotating on a spindle and housed in a valve body. When the valve is fully open it does create some head (pressure) loss, however, this valve is easy to operate and can be used to throttle flows. Under higher pressures (above 125 psi) the metal seats may not provide dripless closure. For high pressure situations, a rubber seat is recommended. Butterfly valves are relatively easy to open under high pressure because the pressure pushing on half of the upstream side of the disc tends to force it open, balancing the pressure on the other half which tends to force it closed.

GATE VALVES. A gate valve uses either an iron disc plate or a gate made of resilient material (material that springs back into shape) that is moved upward and downward in the valve body by a standard operating nut. Gate valves are commonly used in distribution lines to stop flow, isolate sections of a line, and to drain lines. They are very rugged, resistant to leakage, and are suitable for use under high pressure as they create no head loss when fully open. Because of the tremendous pressures that may be exerted against a gate valve, valves 16 inches or larger are usually provided with gearing to make opening the valve easier. In some instances a motor-driven operation is utilized.

There is a special type of gate valve known as a tapping valve. When used with a tapping sleeve it allows connection to the water main without shutting down the line.

Butterfly Valve

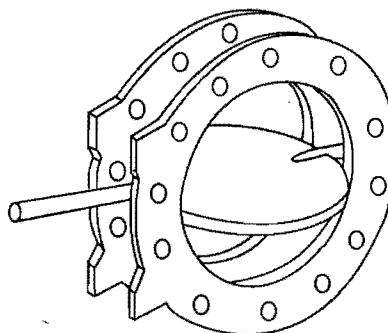


Figure 2.1

Gate Valve

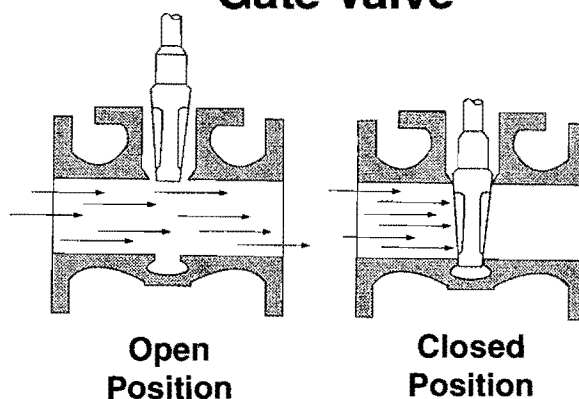


Figure 2.2

Plug Valve

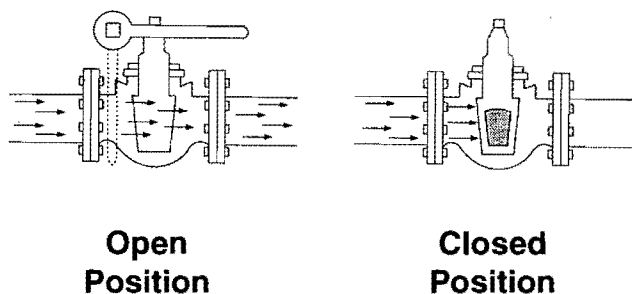


Figure 2.3

GLOBE VALVES. **Globe valves** are often used for ordinary household water faucets. A globe valve has a circular disc that moves down into a port to shut off the flow. Because the water has to make several turns as it moves through the valve, the globe valve will produce high head loss even when fully open. For this reason, globe valves are not suitable where head loss is critical. Globe valves can be used to drain distribution lines if rapid drainage is not important.

PLUG VALVE. The **plug valve** is a machined-surface cylinder with a bored port or passageway. The cylinder is mounted on a shaft inside the valve body. When the shaft is turned 90 degrees the cylinder will move from an open position to a closed position. There are different types of plug valves available. **Multiport plug valves** can be used to divert flow from one pipe branch to another without stopping the flow of water. **Round port plug valves** offer virtually no head loss when fully open and are not easily fouled by water with a high solids content (raw surface water).

Specialized Valves

CHECK VALVES. **Check valves** are valves that operate automatically to prevent backflow from pumps. When a pump is shut off, the discharge line contains water that has been pumped. If there is not a check valve in place the water will drain back through the pump, turning it backward and possibly causing severe damage to the pump and motor. Check valves prevent this type of damage by preventing the backflow. In addition, by keeping the water in the discharge line, it will provide pressure for the pump to work against when it is restarted. This will prevent the pump motor from burning out under no-load conditions. Backflow prevention will also save time and energy because the water that has drained back out of the discharge line won't need to be re-pumped.

PRESSURE RELIEF VALVES. When a flow of water is abruptly stopped, such as might occur when a fire hydrant is quickly shut, it will result in a rapid and sudden increase in pressure in the line which could result in damage in the form of breaks and leaks. This condition is commonly referred to as water hammer (water hammer will be discussed in more detail later in this chapter). Water hammer can be controlled by using **pressure relief valves**. These valves have a spring tension pre-set to a certain operating pressure. If the operating pressure is exceeded the valve will open, allowing water to escape thus preventing the buildup of excessive pressures. The pressure relief valve is used primarily on small pipelines. It is necessary to use surge tanks to protect large pipelines due to the excessive pressures that are encountered.

AIR AND VACUUM RELIEF VALVES. In long distribution lines air can accumulate at the high points in the line. This causes a condition referred to as air binding. Air binding is the partial blockage of flow due to the entrapped air. An **air and vacuum relief valve** can prevent air binding in distribution systems by automatically venting the unwanted air. Quite frequently, pipelines must be drained for routine maintenance or repair. As the water drains out through drainage valves a vacuum can be created inside the pipeline. If the vacuum becomes great enough it can cause a line to completely collapse. The air and

vacuum relief valve will allow air into the pipeline to occupy the volume that was filled by water, thus preventing the formation of a vacuum. This will not only prevent pipeline collapse but will also reduce the amount of time required to drain the line.

Pumps

Pumps are also a very important part of the distribution system. Pump installations can vary in size from small, single pumps that deliver a few gallons per minute, to large, multiple-pump installations delivering thousands of gallons per minute.

Only one general category of pump is commonly used in distribution systems. These are called **centrifugal pumps**. Centrifugal pumps operate by the centrifugal force created when an impeller rotates inside its casing. They cannot operate unless the impeller is submerged in water. Therefore centrifugal pumps should NEVER be started until they are properly primed. The **volute pump** is the most common type of centrifugal pump used in water distribution systems.

Hydrants

Hydrants are an important part of the distribution system that are used to fight fires and flush pipelines. Hydrants used for fire protection are usually located at street intersections so that they are accessible from four directions. These hydrants should always be spaced close enough that in the case of a fire the hose lines would not exceed 500 to 600 feet. In high value districts, fire hydrants might be spaced as close as 150 feet apart. If the hydrant is designed to fight fires, it will have a four and one-half (4.5) inch pumper outlet. To avoid collapsing lines when attached to a pumper unit, these hydrants MUST always be installed with service lines that are a minimum of six inches in diameter.

Hydrants with outlets of only two and one-half (2.5) inches are used only for flushing lines or for filling tankers and rural fire trucks. These smaller hydrants might be used at virtually any location in the distribution system, and are often found on dead-end mains for flushing purposes.

Flow Measurement

Flow measurement is one of the most useful measurements that an operator will make. It is important that operators know exactly how much water is being delivered to the treatment plant or to the distribution system. Flow measurement will be used to determine the correct dosage rates for chemical treatment, to measure the loading on individual treatment units, to complete reports to local and state agencies, and to make sure that the community is being supplied the necessary amount of water.

Some meters are used to measure large flow volumes, such as the amount of water supplied to a community. Other meters are used to measure small flows, such as chlorine feed rates, chemical feed rates, and flows to individual households. This discussion will concentrate on the large-volume flow meters used in water distribution systems.

Pressure Pipe Flow Measurement

VENTURI METERS. Venturi meters fall into a category of meter known as pressure differential meters. The meter itself is an enclosed section of pipe shaped like an hourglass to create a throat and is equipped with pressure taps for manual or automatic sensing of pressure at two points. The rate of flow through a Venturi meter is determined by comparing the low pressure at the throat with the high pressure upstream of the throat. The difference in pressure can be converted to a flow rate in gpd. The flow conversion is usually done automatically using instruments that electronically convert the differential to a flow signal. The primary advantage of the Venturi meter is that it will perform reliably and little maintenance is required. The meter will create some head loss, but the loss is relatively small considering the advantages of this meter and its simplicity of use.

TURBINE METERS. Turbine meters for large flows are usually bypass meters, in which a small portion of the flow in the main pipeline is diverted through a bypass chamber. The diverted flow, which will vary in proportion to the main flow, turns a turbine wheel. The turbine wheel generates an electric current, which is also proportional with the main flow. This current is converted into a flow rate. Turbine meters are very accurate, and the bypass type will produce little head loss. However, bypass meters can sometimes be difficult to maintain.

PROPELLER METERS. The propeller meter uses a propeller instead of a turbine but otherwise operates on the same principle. The propeller is usually mounted in a bypass chamber similar to the turbine meter. Head loss with a bypass propeller meter is less than the turbine type. However, propeller meters are generally less accurate.

MAGNETIC FLOW METERS. The magnetic flow meter appears to be only a short section of flanged pipe. However, inside the pipe is a smooth insulating liner. Between this liner and the pipe are two magnetic coils. When an electric current is passed through the coils an electromagnetic field is generated around the pipe. The water flowing through the magnetic field induces a small electric current that increases in proportion to an increase in the flow of water through the pipe. The electric current that is produced is measured and converted electronically to a measurement of flow rate. Magnetic meters can be obtained in many pipe sizes. The primary advantage to the magnetic flow meter is that no head loss is created because there are no obstructions to flow in the section of pipe. The main disadvantage is high cost.

State Construction Standards

According to Oklahoma standards, all water lines must be laid to provide a **minimum horizontal separation** of 10 feet from existing or proposed sewer lines or storm sewers. A **minimum vertical separation** of 24 inches (2 feet) from the outside edge of a water line to the outside edge of a sewer line is also required at all pipe crossings. All water lines must also be located a minimum of 10 feet horizontally from other utilities including gas lines and buried electric lines. PVC water lines must be located a minimum of 50 feet horizontally from any gasoline storage tank.

All distribution systems must be designed to maintain a **minimum pressure** of 25 psi (pounds per square inch) at ground level at all points in the system and under all conditions of flow. A minimum water line size of six inches in residential areas and eight inches in high value districts is recommended where cross connecting mains are not more than 600 feet apart. Rural water systems that provide domestic water only and do not have full fire protection may be allowed to have a minimum size water main of 2 inches if the required pressure can be maintained.

A **minimum earth cover** of 30 inches or other sufficient insulation material is required for all water lines in order to prevent freezing. Select **backfill material** (free of large clods, stones, or other unstable material) must be used to fill at least six inches under the pipe, around the pipe, and to a sufficient height above the pipe to provide adequate support and protection.

Disinfection in the Distribution System (also see Chapter 6)

Whenever any part of the distribution system is subject to contamination, such as during repairs, additions, or modifications, disinfection procedures utilizing chlorine must be used before returning it to service. Although chlorine gas or chlorine bleach might sometimes be used, the form of chlorine most commonly used to disinfect sections of the distribution system is calcium hypochlorite $\text{Ca}(\text{OCl}_2)$, also known as HTH. As discussed in other chapters, HTH should be used with great care and according to the manufacturer's instructions.

The appropriate procedure to be used for disinfection depends on which part of the distribution system is involved and other factors. More information about "batch treatment" with chlorine can be found in the appropriate sections of the *Suggested References for Study* listed in this chapter (or from similar references). The most complete directions for disinfecting water mains, water storage facilities, and wells are listed in standards developed by the **American Water Works Association (AWWA)** and approved by the **American National Standards Institute (ANSI)**. For information on how to obtain these documents see the "Reference Source Sheet" at the back of this study guide.

Disinfection of New or Repaired Mains

Disinfection of new, cleaned, or repaired distribution lines is always required except when a repair is made with the line continuously full of water and under pressure. Although several methods are approved by AWWA and ANSI, probably the most commonly used method for disinfecting new lines is to dose the lines with a **50–100 mg/L chlorine for a contact time of 24 hours**. Another approved method that is especially appropriate for disinfecting cleaned or repaired water lines is to increase the dosage to as much as 300 mg/L while reducing the contact time to as little as 15 minutes. In emergency repairs, any new piping or fittings used are sometimes disinfected by thoroughly (yet carefully) swabbing or spraying the inside of the mains with a very high concentration of chlorine (10,000 mg/L) just before they are installed.

In the case of new lines, **two bac-t samples** must be collected on successive days that are reported safe (no coliform bacteria found) before the line can be put into service. Bac-t samples should also be taken from lines that have been cleaned or repaired. If one of these samples is positive, daily sampling must continue until two consecutive safe samples have been obtained.

One of the most effective steps in disinfecting new or repaired water lines is to do everything possible to prevent them from becoming contaminated in the first place. Install **watertight plugs** in all open-end joints whenever the trench is unattended for any length of time (unless ground water would cause the closed pipe to float). All pipes, fittings, valves and other items which will not be disinfected by the filled line must be pre-cleaned and disinfected. **Clean tools** should also be used. Each service line should be disinfected before being connected to a water main.

Thorough **flushing** is also important to help remove contamination introduced during repairs. If valve and hydrant locations permit, flushing toward the work location from both directions is recommended. Flushing should be started as soon as the repairs are completed and should be continued until discolored water is eliminated.

Disinfection of Storage Facilities

There are several approved methods for disinfection of storage tanks. The best method to use depends on the particular situation. After the chlorination procedure is completed and before the tank is put into service, bac-t samples from the full facility should always be collected to ensure the tank has been sufficiently disinfected. Brief summaries of some of the approved methods used in different situations are provided below.

1. Scrubbing the walls and floors with a solution containing 100 mg/L chlorine. The tank is then rinsed and filled with water containing 2 mg/L and allowed to stand. If after eight hours has passed, a chlorine residual of 1 mg/L remains, the reservoir is ready for use.

2. Chlorination of the full storage facility with a chlorine dose sufficient to allow a 10 mg/L chlorine residual. The contact time for this method should be at least six hours if chlorinated uniformly using chlorine gas or at least 24 hours if using HTH or liquid bleach.
3. Filling approximately 5 percent of the total storage volume with water containing a 50 mg/L chlorine dosage and holding for at least six hours. The remainder of the tank is then filled to the overflow level and a free chlorine residual of 2 mg/L is maintained for at least 24 hours.

Heavily chlorinated water produced by disinfection procedures must be properly handled. In the case of storage facilities, heavily chlorinated water is sometimes able to be diluted as it flows out of the tank and into the rest of the system. Another possible means of disposal is sanitary sewers. If this alternative is used, there should be adequate dilution and travel time so that there will be no chlorine residual when the water reaches the wastewater treatment plant. Also, the operators of the wastewater plant should be notified in advance. If a storm sewer is used, no chlorine residual should reach the receiving waters. Land disposal may be acceptable in some situations if percolation rates are high. Finally, if there is any question of whether the water could cause any damage to persons, property, or the environment, an adequate amount of a reducing agent, such as sodium sulfite (Na_2SO_3) or sodium bisulfate (NaHSO_3) should be used to neutralize the chlorine.

Common Distribution System Problems

A **cross connection** is the connection between a potable (drinking) water supply and a water source that is either of unsafe or unknown quality. The best prevention for all cross connections is an **air gap**. A good rule of thumb is to provide a gap at least two times the width of the inside diameter of the pipe. Another less reliable but adequate device used in some situations is the reduced pressure principle (RPP) device. Double check valves are normally NOT acceptable. Vacuum breakers do not provide adequate protection in most situations. All distribution system operators should be constantly alert for situations where cross-connections are likely to exist. Operators must also watch for any illegal bypassing of backflow prevention devices.

Another common problem encountered in distribution systems is **galvanic corrosion**. This corrosion is caused by the connection of two different types of metal that react chemically when they are in contact with each other. Certain combinations of metals are more likely to react when connected than others.

Water hammer occurs when a flow of water is abruptly stopped. The sound created is similar to someone hammering on a pipe. Whenever a valve position is changed quickly, such as might occur when a fire hydrant is quickly shut, the water pressure in a pipe will increase and decrease very quickly. This rise and fall in pressure causes water hammer

and can do serious damage to the distribution system in the form of breaks and leaks. Actually, any sudden change in the water pressure could result in water hammer. This includes when pumps are turned on or off. Operators can help protect against water hammer damage by using pressure relief valves and surge tanks. Even with protective equipment, valves should always be opened and closed slowly.

Water systems can experience significant revenue loss due to inaccurate meters. Meters very rarely over-register but older meters tend to **under-register**. Water systems should establish a schedule in which small meters are tested for accuracy once every five to ten years, and large ones every one to four years. It is also a good idea to test new meters before installation.

In too many systems, there has been a tendency to not keep current maps of the various components of the system. As a result, operators may not know or even be able to find the construction details in their distribution system. Comprehensive maps as well as sectional plats should be used. All important structures should be shown, including water intakes, treatment plants, wells, reservoirs, mains, hydrants, and valves. Leak survey maps are also used that show the locations where leaks have been found and pinpoint problem areas. All maps should show the system **"as built."** This means that whenever there is any change whatsoever in the original construction plans, the maps should be updated to clearly reflect these changes.

Special Safety Considerations (also see Chapter 1)

Probably the two most likely causes of serious injury or death to distribution system operators are contact with dangerous gases and trench cave-ins. Chapter 1 of this study guide provides a brief introduction to these and some of the other many potential dangers present in the distribution system as well as basic guidelines on how to avoid these dangers. In addition, personal study and on-the-job training (OJT) along with strict obedience to all safety-related requirements is absolutely essential to reduce the chances of injury or death among distribution system operators.

REFERENCES

California State University, Sacramento - **Water Distribution System Operation & Maintenance**

- Chapter 1 The Water Distribution System Operator
- Chapter 2 Storage Facilities
- Chapter 3 Distribution System Facilities
- Chapter 4 Water Quality Considerations in Distribution Systems
- Chapter 5 Distribution System Operation & Maintenance

American Water Works Assn. - Reference Handbook: Basic Science Concepts and Applications

Hydraulics Section

SAMPLE QUESTIONS

Technician

The minimum horizontal separation required between sewer lines and water lines is

- A. 5 feet
- B. 8 feet
- C. 10 feet

Operator

A 200 foot run of 8 inch I.D. pipe will contain approximately how many gallons of water?

- A. 375
- B. 414
- C. 521

Chapter 3

Collection Systems

STUDY GUIDELINES

Distribution/Collection Technician (Class D)

Be prepared to answer questions concerning:

- ◆ The basic design and operation of wastewater collection systems
- ◆ The required minimum and recommended maximum velocity of wastewater in the collection system and the reasons for these limits
- ◆ The proper distances of separation between potable water lines and wastewater collection lines
- ◆ Basic practices used when laying pipe including pipe bedding and backfill requirements
- ◆ The minimum size lateral line required under normal conditions
- ◆ Typical problems with lines and types of repairs
- ◆ General cleaning methods including flushing, rodding, and high velocity cleaners
- ◆ The definitions of inflow, infiltration, rodding, cross connection, and galvanic corrosion
- ◆ Know the special safety considerations for collection system operators

Distribution/Collection Operator (Class C)

Be prepared to answer questions concerning guidelines listed for Class D certification and:

- ◆ The basic design, operation, and maintenance of lift stations
- ◆ Troubleshooting typical problems with lift stations
- ◆ What types of pipe construction materials are resistant to corrosion
- ◆ How to identify the cause of line stoppages
- ◆ Which cleaning method to use for each type of stoppage
- ◆ The preventive maintenance requirements/recommendations for collection lines
- ◆ The regulations concerning collection systems including minimum soil cover, and the required placement of manholes

ENTRY LEVEL DISCUSSION

The first step in the treatment and disposal of wastewater is the collection system. This system consists of piping which is used to transport wastes to the treatment facility; manholes which provide access for cleaning, flushing and inspection; and lift stations which assist the gravity flow when a change in elevation occurs.

As discussed in Chapter 1, the national average of wastewater generated per person per day is about 70 -100 gallons. Many factors may alter this "average" amount. Industry may contribute more flow depending on the nature of the business. Seasonal variations effect flow rates, with increases of as much as 30 percent during the summer months. People in warmer climates or in affluent communities tend to use more water. Also, higher cost of water in some communities may lower water usage.

In the early 1900's, the same piping system was used to collect storm water runoff and wastewater. This practice caused many serious problems, including the fact that treatment plants would lose treatment efficiency or be damaged by large flows after a storm. **CURRENT STATE AND FEDERAL REGULATIONS PROHIBIT THE COMBINATION OF STORM SEWERS AND SANITARY SEWERS.** The definitions of these two types of collection systems are listed below.

1. **Storm water collection systems** (sometimes called storm sewers) are specifically designed to carry the storm runoff from pavement and roof drains into drainage ditches.
2. **Wastewater collection systems** (often called sanitary sewers) carry domestic and industrial municipal wastes to the wastewater treatment plant.

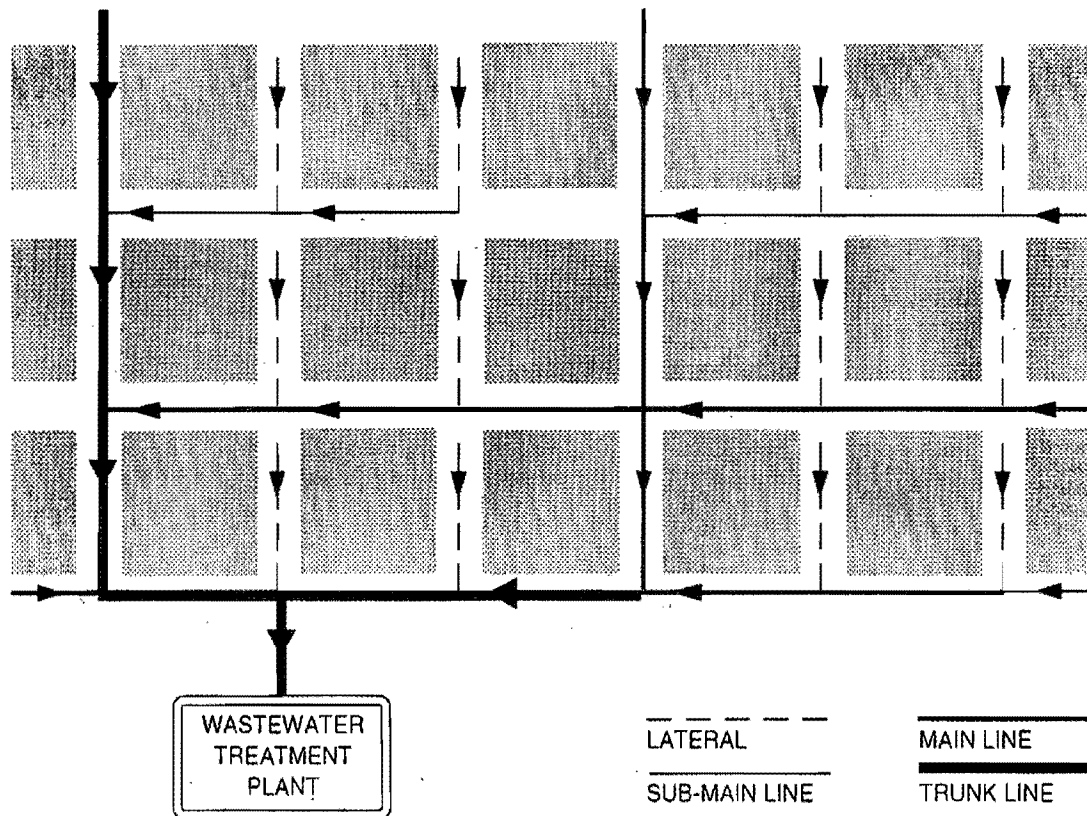
This discussion will focus only on the operation and maintenance of wastewater collection systems.

Components of the Collection System

The different sections of the wastewater collection system each have specific roles to play (see **Figure 3.1**). The **lateral sewer** or **gravity sewer** collects wastes only from sources such as houses or businesses. A **sub-main line** or **branch sewer** receives flow from two or more lateral lines. The **main line** receives flow from the sub-mains. The mains connect to the larger trunk sewers. The **trunk sewer** is the line that carries the collected wastes to the treatment plant. Throughout the collection system are **manholes** which are necessary for cleaning and inspection. Manholes might be constructed from brick, concrete block, pre-cast or poured concrete, or fiberglass materials.

Generally speaking, collection systems are gravity flow. As a result, each size (diameter)

Wastewater Collection System Lines



3.1

of pipe has a minimum slope which must be used to maintain proper velocities. If there is a change in the natural topography, or any other cause of preventing sufficient gravity flow, a **lift station** is used to "lift" the wastewater so it can continue along its way to the treatment plant.

Piping Materials

Many different materials are used for collection system construction, including different types of piping used at different systems, and for different situations. All materials used to construct the collection system should have sufficient strength to resist hydraulic pressure, earth and traffic loads, and be resistant to corrosion and abrasion. Many different materials are used for collection systems including ductile iron, plastic, concrete and clay. The best type of material depends on individual situations within each system. Each type of piping has advantages and disadvantages and serious consideration should be given before making decisions involving material selection.

Ductile Iron Pipe (DIP)

Ductile iron pipe (DIP) is used mainly in submains and trunk lines where heavy loads or depths are encountered. This type of pipe often has a polyvinyl coating on the outside to protect it from corrosive ground soil. The inside is often coated with a bituminous (tar) material for protection from hydrogen sulfide gas. It is also used in lift station piping because of its wall strength.

DIP is very malleable (easily worked) yet it is strong. Because of its strength DIP is easily drilled and tapped for service lines. The disadvantage of DIP is that it is subject to corrosion from both inside and outside often requiring preventive measures. Flanged or mechanical joints are used to connect lengths of pipe.

Plastic Pipe

Plastic pipe is a relatively new pipe material but it is rapidly gaining acceptance for use in collection systems. Lateral and sub-main lines are especially common uses for plastic pipe because they are shallow. **Polyvinyl chloride (PVC)** is one of the most popular plastic pipes. Since PVC is non-metallic, it will not corrode from electrolysis or electrochemical action. Corrosive soils will also have very little effect on PVC. Another advantage of plastic pipe is that it is relatively light and is easily cut and assembled without the need for special tools.

Disadvantages of PVC include its relatively thin wall design, sometimes causing deflection in larger size pipe. Another drawback to plastic pipe is that ultraviolet rays will cause it to deteriorate. For this reason, plastic pipe should never be stored where it can come into direct contact with sunlight. If it is necessary to leave plastic pipe in an open trench for more than a few days, the pipe should be covered with a small amount of backfill or with black, heavy plastic sheeting. Plastic pipe can also be damaged by rocks or other rough material if it is not properly bedded. Finally, because of its composition, petroleum products will cause severe deterioration in plastic pipe. Therefore it must be kept at a distance from gasoline storage tanks. The two joints used for PVC are a solvent weld for smaller sizes (up to six inch diameter) and the rubber ring push-on for larger sizes.

Reinforced Concrete Pipe (RCP)

Reinforced concrete pipe (RCP) has been widely used in the wastewater systems since the turn of the century. RCP can be classified into two general types: non-steel cylinder type and steel cylinder type.

NON-STEEL CYLINDER RCP. Non-steel cylinder RCP is constructed by forming up to three cages of reinforcing steel. These cages are then placed in a mold and are coated with concrete.

STEEL CYLINDER RCP. Steel cylinder RCP is constructed by taking a steel cylinder and lining it with cement mortar. Wire is then wrapped around the structure and a mortar coating is added over it.

Concrete pipe has a high compressive strength and can be installed under high backfill loads. Because of its strength, RCP is sometimes used in collection system submains and trunk lines. One disadvantage of concrete pipe is that hydrogen sulfide will damage and deteriorate it. Modern manufacturing techniques provide interior coatings which greatly reduce this problem. RCP is somewhat difficult to tap and may be hard to repair if damaged. Bell and spigot or push-on joints are used for connections.

Vitrified Clay Pipe (VCP)

Vitrified clay pipe (VCP) has been used in wastewater collection systems for over 100 years. It is made from a combination of clays and shales which is then fired. VCP is used in lateral lines, submains, and trunk lines. Its main advantage is that it is not damaged by hydrogen sulfide gases. The main disadvantages of VCP is that it is very rigid. Therefore, proper and very even bedding and backfill must be maintained to prevent cracking. Bell and spigot joints with a rubber seal are used for connections.

Asbestos Cement Pipe (ACP)

Asbestos-cement pipe (ACP) was a relatively popular pipe material until people became concerned about breathing asbestos fibers. Because of this serious health concern, ACP is no longer being used. It is very important for operators to take special care to avoid health hazards when working with any existing ACP in their system, especially if it is being cut or machined. Respirators must be worn whenever there is a possibility of inhaling airborne asbestos fibers.

ELEVATION AND GRADE

In the times past, many sewer lines were laid on the premise that a quarter "bubble" was all that was needed for adequate fall. This method utilized a straight edge level or string level to determine the grade or "fall" of the sewer. Whenever possible sewer lines are constructed so that one end of the pipe is higher than the other so that gravity keeps the flow going down hill. If there is not enough fall, and the flow is too slow, less than two feet per second, then solids are settled in the line. If grade is too steep, the flow exceeds ten feet per second and the flow is too fast. Fast flows scourges pipe and erodes lines.

Modern means of determining grade include surveyor's level and rod and or laser transits. Procedure for surveying a sewer line is as follows:

1. Surveyor locates the level instrument at a location where backward and forward sightings can be made. Level the instrument.
2. The surveyor assistant holds the rod plumb on a point of known elevation called a benchmark.
3. The surveyor back sights the telescope of the surveyor's level on the rod. Record the distance on the rod that the cross hair is above the benchmark.
4. To determine the height of the instrument above the benchmark, add the distance sighted in the cross hairs to the benchmark. If referencing a manhole invert, then add that depth for the total elevation. This may be referred to as station 0+00.
5. For the Fore Sight mark, move the rod and hold plumb on the fore sight side of the level. Turn level telescope and sight on rod. Read distance on cross hair.
6. Ground level is Instrument height minus reading on rod. Upstream manhole invert elevation would be ground level minus manhole depth. This may be referred to as Station 1+00.
7. Some times when objects are in the way a secondary benchmark or turning mark has to be made.

The Slope of a sewer is defined as the rise over the run. In other words, the difference in height from Station 0+00 to Station 1+00 is divided by the distance. Many times this may be expressed as a percent slope. Multiply percent slope by 100 to get feet of fall per one hundred feet.

SEWER SIZE DIAMETER PIPE, INCHES	MINIMUM SLOPE IN FEET/100FEET DROP IN FEET PER 100 FEET
4	1.00
6	0.50
8	0.40
10	0.29
12	0.22
14	0.17
15	0.15
16	0.14
18	0.12
21	0.10
24	0.08

An example is when the station is 0+00, the stake elevation is 105.60, the invert grade is 100, and the cut is 5.60. At station 0+50 the stake elevation is 106.12, the invert grade is 100.25, and the cut is 5.87.

Lift Stations

At some points in the system the waste has flowed by gravity to a low point. A **lift station** is installed to pump the wastewater up to an elevation where it may again flow by gravity. There are two types of lift stations: drywell and wetwell installations.

Drywell stations have the pumps and controls housed in a separate dry compartment and the wastewater flows into a separate wetwell. This type of station is better protected from corrosion and is easier to ventilate when checking controls, valves, and pumps.

Two types of pumping systems are used in dry well stations: centrifugal pumps and, less commonly, pneumatic ejectors. Centrifugal pumps should be capable of passing objects up to three inches in size. A pneumatic ejector allows waste to flow into a large pot. When the liquid level in the pot reaches a set point, a solenoid opens and allows compressed air into the pot. The air displaces the wastewater up and out. Pneumatic ejectors work well in systems with flows less than 150 gpm.

Wetwells utilize one compartment with submersible pumps in the wetwell or suction lift pumps above the wetwell and enclosed in a housing or cover. Disadvantages of some wetwell installations are difficult access to service pumps and difficulties in ventilating gases. If designed and constructed properly, the pumps should be easy to remove and replace without having to dewater the lift station. Submersible pumps used in wetwells must also be especially designed for pumping raw wastewater. Wetwell stations have the advantage of lower construction costs.

Suction lift pumps are either self-priming or vacuum-priming. The pumping equipment compartment must be isolated from the wetwell by being above or offset from it. These pumps are generally limited to a suction lift of 22 feet.

Regardless of which type of pumping system is used, there must always be a stand-by. All lift stations should include at least two pumping units to allow for maintenance and repair. In the case of the pneumatic ejector, in a drywell lift station, backup is provided by a stand-by air compressor.

Lift Station Control Systems

Alarm systems are required for all lift stations to report any malfunction that might allow a bypass (an unpermitted discharge) of wastewater to occur. All lift stations will also include backup methods to prevent an overflow or bypass. These methods include the use of holding ponds, portable pumps, or emergency generators.

The control system of the lift station should start and stop the pumps at pre-set levels. Failure of the control systems will burn up the pump motors, cause wastewater to back up in the collection system and/or cause a bypass. Pump performance can be monitored by taking regularly spaced kilowatt readings. Unusual readings may indicate the need for maintenance.

The controls may work off pressure (air bubblers), encapsulated floats, or by flow measurement. The pressure system requires an air compressor, storage tank, pressure regulator, and bubbler tube. The pressure is created against the compressed air flow in the bubbler tube when the water rises in the tube as wastewater fills the wetwell. When the pressure reaches a pre-set point, the pump kicks on. When the pressure drops to a pre-set point, the pump shuts off. **Floats** are suspended in the wetwell. When the wastewater touches a point on the float, the float tips and activates a mercury switch inside the float. A bottom float will shut the pump off. Scum is a problem with most water level controls that operate pumps and it must be removed on a regular basis.

Preventing Stoppages

Stoppages are a major problem in the collection system. Routine preventive maintenance including proper construction practices can eliminate most stoppages from ever developing. In fact, some operators claim that as many as 85% of these problems can be avoided by a good preventive maintenance program. Even when there is not a complete stoppage, poor construction or maintenance will result in less flow capacity and lower velocity. This can lead to settling of solids and septic (anaerobic) conditions causing undesirable odors and the formation of toxic gases.

Industries can sometimes cause stoppages by overloading the system with **grease**. A strong pre-treatment enforcement program can be effective in reducing these types of stoppages. Another cause of stoppages are **rags** or other large materials. **Roots** are probably the single most common cause of stoppages in collection systems.

Removing and Preventing Roots in Lines

The best way to control roots is to install sewer lines that don't leak. Modern pipe materials can be installed without leaks so roots can't enter a sewer line. In older sections of the collection system where there is the potential for root intrusion several methods are sometimes used. Some of these methods include:

1. Clearing roots from the sewer using rodding equipment with a cutting tool attached. Rodding is a method of opening a blocked pipe by pushing or pulling a steel rod through a pipe. It should be kept in mind that every time a root is cut, it will add new growth and increase in diameter which can break the pipe or open the joint even more.
2. Using root control chemicals. Root control using chemicals is not as fast as removing roots by cutting them off by a rodder, but it is more permanent. Use of chemicals must be very carefully researched and planned to avoid danger to the environment, the treatment plant, or the operator. With proper chemicals and application, root control is a very desirable cost effective preventive maintenance program and can control roots in a sewer for as long as two to five years.

3. Removing roots and then using internal sealing techniques such as grout sealing. Internal sealing is one of the most widely used methods of rehabilitating old collection systems. Internal sealing is effective when the sewer line to be repaired is in an area that is unsuitable for excavation and has leaking joints, cracks or small holes.
4. Inserting a liner in the collection line. This method is normally used only on sections of lines with very few or no service connections.
5. Eliminating deep rooted trees and not allowing trees to be planted over wastewater collection lines. Poor construction practices can also allow **solids** in the wastewater to settle out or let **sand** and other materials to enter and stop up the collection system. Examples of poor construction in collection systems include flat or below grade sections, misaligned joints, collapsed lines, and illegal taps.

General Cleaning Methods

Preventing and clearing stoppages can be performed by either hydraulic or mechanical methods. Both methods should be used to help maintain the collection system in good working condition and to help reduce odors.

Hydraulic cleaning methods are methods that use water under pressure to produce high velocities that will wash most grit, grease, and debris through the sewer line and leave the pipe clean. One type of hydraulic cleaning equipment used is a "jet cleaner" or "jet rodder." This instrument uses jets of high velocity water sprayed into wastewater collection lines through a nozzle at the end of a hose.

Another type of hydraulic cleaning method is to use a ball or other device with a large volume of water behind it to push it along. The volume of water creates a flushing action as it picks up velocity when it moves around the ball. The ball bounces and rotates in the flow which further breaks loose debris.

Simply flushing with large amounts of water is the easiest, but the least effective hydraulic cleaning method. This may break loose some of the debris, but more often it merely moves it to the next bend in the line. This can work if the debris can be caught at the next manhole.

Mechanical cleaning methods use equipment that scrapes, cuts, pulls, or pushes the material out of the pipe. Mechanical cleaning equipment includes power rodders and hand rods. Special machines and winches are sometimes used for pulling buckets or scrapers through a line. Mechanical devices are more effective at clearing than at cleaning and the sewers sometimes still have to be flushed after being cleared.

Before clearing a large stoppage that may have gone septic (anaerobic), the operator should notify the treatment plant downstream. When a large volume of septic wastewater reaches the treatment plant without special preparations being made to minimize the impact, the plant operation could become "upset" and fail to perform adequately.

Common Problems in Collection Systems

Inflow is water that flows into a wastewater collection system. Inflow is usually caused by holes in manhole covers, yard drains connected to the wastewater collection system, and other cross connections with storm water systems. **Infiltration** refers to the ground water that has entered a wastewater collection system through defective pipes, pipe joints, connections or manhole walls. Both inflow and infiltration, abbreviated "**I & I**" are considered undesirable because of the added hydraulic load placed on the system and the plant. **Exfiltration** is wastewater that is similarly leaking out of a collection system and into the environment.

A common method used to discover sources of I & I in collection systems is referred to as **smoke testing**. This method can be very effective in finding cross connections and "holes" in the system. However, it should NEVER be performed without advance public notification and the assistance of a specially trained and experienced smoke testing crew.

A **cross connection** is the connection between a potable (drinking) water supply and water from an unsafe or unknown source. This term is also used to describe a connection between a wastewater collection system and a storm water system. The best prevention of all cross connections is an **air gap**. A good "rule of thumb" is to provide a gap at least two times the width of the inside diameter of the discharge pipe.

A bypass or **unpermitted discharge** is any discharge from a collection system or wastewater treatment facility other than exactly what was allowed in the NPDES discharge permit. One example of an unpermitted discharge occurring in the collection system is when a manhole overflows due to a line stoppage or high inflow. **ALL UNPERMITTED DISCHARGES MUST BE PROPERLY REPORTED** (see Chapter 4 for reporting procedures).

State Construction Standards

According to Oklahoma standards, all wastewater collection lines must be laid to provide a **minimum horizontal separation** of 10 feet from any existing or proposed water line and a **minimum vertical separation** of 24 inches (two feet) from the outside of the collection line to the outside of the water line. If it is impossible to obtain the minimum vertical or horizontal separations, the sewers must be constructed of special pipe and pressure tested to the highest pressure under the most severe head (pressure) conditions of

the collection systems. Leakage test for newly constructed sewer lines must not exceed 10 gallons/inch of pipe diameter/mile/day. Wastewater lines must also be located a minimum of 50 feet horizontally from all petroleum storage tanks or any existing or proposed water well and a minimum of 10 feet horizontally from all other utilities.

Gravity sewer lines should never be less than eight inches in diameter except that six inch lines may be used where the run of the line is less than 400 feet. In order to help prevent seepage at the joints, lines should be laid with the bell pointing upgrade. To prevent freezing, a **minimum earth cover** of 30 inches is required for all collection lines constructed of any material other than cast/ductile iron.

State standards require that bedding materials meeting specific standards must be used below the pipe to support the anticipated load. Select **backfill material**, free of large clods or stones or other unstable material must be used for the first 24 inches (two feet) of backfill above the pipe.

The required **minimum velocity** of wastewater in collection lines is two feet per second (fps). The recommended **maximum velocity** in sewer lines is 10 fps. When velocities exceed 10 fps, special provisions must be made to prevent movement and damage of the pipes. **Manholes** should be installed at the end of each line, and at all changes in grade, size, or alignment. They must also be installed at all intersections or at distances no greater than every 400 feet for lines with a diameter of 15 inches or less and every 500 feet for lines 18 to 30 inches in diameter. Remember, the purpose of manholes is to provide easy access to the collection system for inspection and maintenance.

All collection system maps should show the system "**as built**." This means that whenever there is any change whatsoever in the original construction plans, the maps should be updated to clearly reflect these changes.

Special Safety Considerations (Also see Chapter 1)

Probably the two most likely causes of serious injury or death to collection system workers are contact with dangerous gases and trench cave-ins. Chapter 6 of this study guide provides a brief introduction to these and some of the other many potential dangers present in the collection system as well as basic guidelines on how to avoid these dangers. However, additional study and on-the-job training (OJT) in conjunction with strict obedience to all safety-related requirements is absolutely essential to reduce the chances of injury or death among collection system workers.

REFERENCES

California State University, Sacramento - **Operation and Maintenance of Wastewater Collection Systems - Vol. 1**

- | | |
|-----------|--|
| Chapter 3 | Wastewater Collection System (Purpose, Components and Design) |
| Chapter 4 | Safe Procedures |
| Chapter 5 | Inspecting and Testing Collection Systems |
| Chapter 6 | Pipeline Cleaning and Maintenance Methods (especially sections 6.1, 6.3) |
| Chapter 7 | Underground Repair |

California State University, Sacramento - **Operation and Maintenance of Wastewater Collection Systems - Vol. 2**

- | | |
|------------|--|
| Chapter 8 | Lift Stations |
| Chapter 9 | Equipment Maintenance |
| Chapter 11 | Safety Program for Collection System Operators |

Reference Handbook: Basic Science Concepts and Applications (American Water Works Assn.)

Hydraulics Section

SAMPLE QUESTIONS

Technician

The minimum horizontal separation required between wastewater collection lines and drinking water lines is

- A. 2 feet
- B. 5 feet
- C. 10 feet

Operator

If a sewer is to have a slope of 0.4% or 0.004, it means there will be 0.4 feet of fall per _____ of sewer length.

- A. 1 foot
- B. 100 feet
- C. 40 feet

Chapter 4

General Regulations and Management

INTRODUCTION TO CHAPTER 4

This chapter is designed to serve as an introduction to some of the more fundamental legal requirements of system operation and to provide references to sources for additional information concerning regulations. The suggested references for this chapter also address the management-related skills especially needed by the supervisors and superintendents of community water systems.

SUGGESTED STUDY GUIDELINES

Distribution/Collection Technician (Class D) and Operator (Class C)

Be prepared to answer questions concerning:

- ◆ Who must be certified and how to renew a certificate
- ◆ The basic requirements for certification including temporary certification
- ◆ The regulations concerning Monthly Operational Reports (MORs) and Discharge Monitoring Reports (DMR)
- ◆ How long to keep records at water systems
- ◆ The importance of and need for records
- ◆ The penalties for falsification of records
- ◆ The definition of a un-permitted discharge (by pass)
- ◆ The reporting requirements for un-permitted discharges and the possible penalties if not met

ENTRY LEVEL DISCUSSION

Operator Certification Requirements

State law requires that all operators of community water and wastewater systems be certified within ten days of employment or appointment as an operator. A **water operator** is a person who performs work on, or determines the method of working on, water works or who changes water quality either directly or by order. This includes a person who sets or removes meters, makes service connections, or repairs lines. "**Water works**" means all facilities used in the procurement, treatment, storage, pumping, or distribution of water for human consumption. A **wastewater operator** is any person who is at any time responsible for the operation of a wastewater works in part or in whole and shall include any person who can through a direct act or command, affect the quality of the wastewater. "**Wastewater works**" means wastewater treatment systems and facilities used in the collection, transmission, storage, pumping, treatment, or disposal of liquid or waterborne wastes.

Every certified operator should understand the operator certification requirements found in Chapter 710 **Waterworks and Wastewater Works Operator Certification Rules**. This document may be obtained from the Department of Environmental Quality (DEQ) Operator Certification Section. Some of the more important rules and policies concerning operator certification are discussed here.

Level of Certification Required

Operators who are not supervisors or superintendents may hold any level of current certification. All operators are encouraged to obtain the highest level of certification for which they qualify. The superintendent must hold at least the same level of certification as the classification level of the water works that he or she is responsible for. The **superintendent** is the operator in direct responsible charge of an entire plant or distribution system. This is true even if other official titles are sometimes assigned by employers. Determinations concerning classification of water works are made by the Operator Certification Unit based on complexity and population served. Population categories are listed in the box below.

Class "D"	1,500 or less
Class "C"	>1,500 - <15,000
Class "B"	15,000 - 50,000
Class "A"	>50,000

All water works utilizing surface water or discharging wastewater works must be operated by a superintendent with at least a Class C certification for population less than 15,000. A population over 15,000 requires a Class B or A certification, depending on the

complexity of the water plant. Temporary certification is not available to superintendents, assistant superintendents, supervisors, or managers of superintendents who make decisions regarding the daily operational activities of water/wastewater works.

Persons who are in direct responsible charge of their system or laboratory must hold a valid certification equal to or greater than the classification of the system or laboratory. Employers may require their employees to hold a higher certification level than is required by state law.

Temporary Certification

If permanent certification is not already held, **temporary certification** must be applied for within ten days of employment or appointment as an operator. Applications are available at County DEQ offices, and the Operator Certification Section. Individuals who have temporary certificates must work under the general supervision of a permanently certified operator. Direct, constant supervision is not required. Temporary certificates expire one year from the date of initial employment and cannot be renewed.

After receiving temporary certification, the operator should immediately begin to make plans to attend an approved entry level standard water operations training course and an exam session in order to obtain at least Class D operator certification or Class D collection/distribution technician before the temporary certificate expires.

Laboratory Operator Certification

All surface water plants must have a properly certified designated laboratory operator. The designated certified lab operator is required to give general supervision of all laboratory tests performed and is held responsible for all test results. Certified laboratory operators are authorized to work in laboratories only. They are not certified to operate or make decisions concerning the operation of the plant. However, many individuals are certified as both operators and laboratory operators and perform work in both areas at their facilities.

All discharging wastewater facilities must have a properly certified designated laboratory technician. The designated certified lab technician is required to give general supervision of all laboratory tests performed and is held responsible for all test results. Certified laboratory technicians are authorized to work in laboratories only. They are not certified to operate or make decisions concerning the operation of the plant. Many individuals are certified as both operators and laboratory technicians and perform work in both areas at their facilities. Owners of water and wastewater facilities that contract for laboratory services must notify the Operator Certification Section within ten (10) days of the contract and state the analyses to be performed. Also, the contracting laboratory must notify the Operator Certification Section within ten (10) days of the contract and state what analyses are performed by them.

One of the requirements of the laboratory operator certification program is that the results of all laboratory analyses shall be recorded in a bound volume at the time of analysis. Each entry in this volume shall be signed and dated by the person who performed the analysis. These volumes will be kept on file at the laboratory for ten (10) years for water systems and three (3) years for wastewater systems.

Annual Renewal of Certificates

All permanent certificates expire on June 30 of each year and must be renewed by June 30 to remain current. Operators are responsible for renewal of their certificates regardless of notification. Before renewing a certificate, the operator must have completed at least four hours of approved training within the last fiscal year (July 1 - June 30). The renewal application should not be submitted until the training requirement has been met. A person who passes an exam between April 1 and June 30 shall not be required to renew the newly obtained certification until June of the next calendar year. Renewal applications/invoices are mailed to all certified operators during late spring of each year. The application must be completed and then submitted with payment of renewal fees. Expired (delinquent) certificates may be reinstated for up to two years after the expiration date. After two years, the examination must be retaken to become certified. *A temporary certification is valid for one year from the date of employment and is not renewable.*

Other Requirements

It is the responsibility of the operator as well as the employer to see that his or her certification is the proper certification according to operator certification regulations. Owners of water and wastewater works must give their operators reasonable opportunity to obtain the necessary hours of training for their required certification upgrades and renewals. Owners must also furnish the necessary equipment and materials for adequate maintenance and operation of the treatment plant, laboratory, and supporting facilities. Possible penalties for violation of the Operator Certification Act are loss of certification, a fine, and/or a jail term.

Operational Rules and Standards

There are at least three documents that every operator should be aware of which specify legal requirements involved in the operation of public water and wastewater systems. These are:

Public Water Supply Construction Standards (Chapter 626)

Water Pollution Control Facility Construction (Chapter 565)

Rules for Oklahoma Hazard Communication Standard

Discharge Standard (Chapters 605)

General Water Quality (Chapter 611)

Non Industrial Impoundments and Land Application (Chapter 621)

Land Application of Biosolids (Chapter 648)

Underground Injection Control (Chapter 652)

If you are not the operator-in-charge (superintendent) at your system, IT IS PROBABLY NOT NECESSARY THAT YOU HAVE YOUR OWN PERSONAL COPIES OF THESE THREE DOCUMENTS. However, you should have access to them at your facility or local Public Works Department. All superintendents should have their own current copies of these documents and be very familiar with the requirements found therein (see the "Reference Source Sheet" for information on how to obtain them). A brief summary of each of the documents is offered below.

Public Water Supply Construction Standards (Chapter 626)

These standards list requirements generally related to construction and/or modification of the physical system of public water supply systems. This document is also implemented by the Water Quality Division of the Oklahoma Department of Environmental Quality.

Water Pollution Control Facility Construction (Chapter 656)

These standards list requirements generally related to construction and/or modification of the physical system of wastewater systems. This document is also implemented by the Water Quality Division of the Oklahoma Department of Environmental Quality

Rules for Oklahoma Hazard Communication Standard

These rules include several requirements applicable to publicly-owned systems regarding the transmission of necessary information to employees about the properties and potential hazards of hazardous substances in the workplace. These rules are implemented and enforced by the Public Employees Health and Safety Division of the Oklahoma State Department of Labor.

Discharge - OPDES (Chapter 605)

This program regulates discharges into Oklahoma's waters from point sources, including municipal, industrial, commercial and certain agricultural sources. They include the basic

provisions for the operation and maintenance of systems with lagoons.

General Water Quality (Chapter 611)

This chapter contains the requirements for TMDL's and other wastewater planning issues. Also, requirements for groundwater monitoring and remediation, and requirements for non-point source pollution under the DEQ's jurisdiction.

Non Industrial Impoundments and Land Application (Chapter 621)

These regulations list many requirements related to the actual operation of wastewater systems. These regulations are implemented by the Water Quality Division of the Oklahoma Department of Environmental Quality.

Reports of Unpermitted Discharges

A bypass or **unpermitted discharge** is any discharge from a wastewater treatment facility or collection system other than exactly what was allowed in the OPDES discharge permit. **ALL UNPERMITTED DISCHARGES MUST BE PROPERLY REPORTED.** An unpermitted discharge or diversion of wastes from any part of the treatment facilities or collection system is prohibited unless each of the following conditions are met.

1. It is unavoidable to prevent loss of life, personal injury or severe property damage.
2. There are no feasible alternatives.
3. The system must submit notice by telephone within 24 hours to the DEQ Water Quality Division, a brief description of the discharge and cause of noncompliance; the period of noncompliance, including exact dates and times (or the anticipated time the noncompliance is expected to continue); and steps taken to reduce, eliminate and prevent the recurrence of the noncomplying discharge.

A written submission must follow within five (5) days. When it is known in advance that an unpermitted discharge will occur, notification must be submitted ten (10) days or as long a time as possible before the discharge. Failure to report an unpermitted discharge can result in administrative actions or criminal charges filed against operators and/or owners.

Records

Generally speaking, the more records that are kept, and the greater the accuracy of those records, the better the chances of the system being properly operated and maintained. Thorough and accurate records help operators see current problems and anticipate possible problems.

One of the most important sets of safety records required are the Material Safety Data Sheets (MSDS), this is part of the Oklahoma Hazard Communication Standard. An **MSDS** is required for each chemical used or stored in your system. These are available from the manufacturer or distributor of the product. The MSDS for each chemical must be readily available and fully understood by all persons who use the chemical and/or work around it, or stored in your system.

Records

According to regulations, the records of all laboratory checks and control tests, including a copy of the MOR and DMR should be kept on file at the facility for at least 10 years. Other records concerning system operation should also be kept. These include plant performance records, personnel records, budget records, inventory records, maintenance records, and others.

Generally speaking, the more records that are kept, and the greater the accuracy of those records, the better the chances of the system being properly operated and maintained. Thorough and accurate records help operators see current problems and anticipate upcoming problems. Records are also important from a legal standpoint to protect the system (and the operator) from accusations or inquiries based on incorrect or incomplete information.

Safety Records (see also Chapter 1)

Another very important category of records that must be kept by all systems are those that concern safety. These records include—but are not limited to—**accident reports** and **safety checklists**, as well as **emergency guidelines and procedures**.

One of the most important sets of safety records required are the Material Safety Data Sheets (MSDS), this is part of the Oklahoma Hazard Communication Standard.

Falsification

Sometimes frustration levels reach such a high point for some operators that they resort to a very dangerous practice known as **falsification**. This practice endangers public health and also puts the operator in personal jeopardy of criminal prosecution, and/or loss of certification. The best advice when frustrated is to inquire (and even complain when necessary) as you seek a positive, safe, and legal way to solve problems. Some may think that by falsifying records they are protecting their system from "getting into trouble". Actually, they are making the situation much, much worse. If there is something that has not been done or has not been done properly, the best choice by far is to simply note the problem and the reason why it occurred in the remarks column on the required reports.

NEVER FALSIFY RECORDS OR REPORTS.

Falsification of system records or reports is considered gross inefficiency and incompetence under the Oklahoma Operator Certification Act and is punishable by loss of certification, a fine, a jail term or all three of these penalties combined. Federal penalties for falsification of records may reach up to one year in prison and \$25,000 per violation.

REFERENCES

California State University, Sacramento - **Water Treatment Plant Operation - Vol. 1**

Chapter 10 Plant Operation

California State University, Sacramento - **Water Treatment Plant Operation - Vol. 2**

Chapter 22 Drinking Water Regulations

Chapter 23 Administration

Oklahoma Operator Certification Rules (Chapter 710)

Public Water Supply Construction Standards (Chapter 626)

Public Water Supply Operation (Chapter 631)

Rules for Oklahoma Hazard Communication Standard

SAMPLE QUESTIONS

Technician

Records at water systems must be kept for

- A. 2 years
- B. 4 years
- C. 10 years

Operator

The superintendent of a water system treating surface water for a community of about 550 persons must hold at least

- A. Class D certification
- B. Class C certification
- C. Class B certification

Chapter 5

Maintenance

INTRODUCTION TO CHAPTER 5

Maintenance procedures will vary for different pieces of equipment found at different systems. Therefore, questions regarding details of specific maintenance procedures are not asked on certification exams. Although you will not need to know specific procedures for exams, they must be understood by operators actually working with the equipment. On-the-job training (OJT) is essential for learning this information.

Questions of a general nature regarding the basic operation and maintenance of common pieces of equipment will be found on certification exams.

SUGGESTED STUDY GUIDELINES

Class D

Be prepared to answer questions concerning:

- ◆ The importance and the basic aspects of a good preventive maintenance program
- ◆ The names and purposes of the two types of maintenance cards that are kept for equipment
- ◆ What information should be recorded for each piece of equipment
- ◆ Where to find the most complete information on maintenance for a piece of equipment
- ◆ The condition under which centrifugal pumps should never be operated
- ◆ The condition under which reciprocating pumps should never be operated
- ◆ The special safety considerations when working around electrical or mechanical equipment

Class C

Be prepared to answer questions concerning guidelines listed for Class D certification and:

- ◆ The fundamentals of electricity (including how much you should do)
- ◆ The basic preventive maintenance procedures for electric motors including
 - lubrication
 - ventilation
 - bearing and motor temperature
 - amperage measurement
 - controls and wiring (including how much you should do)
- ◆ The basic procedures for proper alignment and maintenance of couplings and power drives
- ◆ How centrifugal and positive displacement pumps operate including starting,

- ◆ How to identify typical problems with centrifugal and positive displacement pumps
- ◆ The basic routine and preventive maintenance for pumps including
 - inspection (what to look and listen for)
 - packing and seals
 - lubrication
 - replaceable parts
- ◆ The basic routine and preventive maintenance for compressors
- ◆ The basic routine and preventive maintenance for valves
- ◆ How to perform calculations involving volume and pumping rates
- ◆ How to develop and maintain a maintenance recordkeeping system that will provide information to protect equipment warranties

ENTRY LEVEL DISCUSSION

An important duty of an operator is plant and distribution system maintenance. A successful maintenance program will cover everything from mechanical equipment to the care of plant grounds, buildings and structures.

Mechanical maintenance is of prime importance as the equipment must be kept in good operating condition in order for the plant to maintain peak performance. Manufacturers usually provide the most complete information on the mechanical maintenance of their equipment. You should thoroughly read their literature on your plant equipment and understand the procedures. Contact the manufacturer or the local representative if you have any questions. Follow the instructions very carefully when performing maintenance on equipment. You also must recognize tasks that may be beyond your capabilities or repair facilities, and you should request assistance when needed.

For a successful maintenance program, your supervisors must understand the need for and benefits from equipment that operates continuously as intended. Disabled or improperly working equipment is a threat to the quality of the plant output, and repair costs for poorly maintained equipment usually exceed the cost of proper maintenance.

Preventive Maintenance Records

Preventive programs help operating personnel keep equipment in satisfactory operating condition and aid in detecting and correcting malfunctions before they develop into major problems.

A frequent occurrence in a preventive maintenance program is the failure of the operator to record the work after it is completed. When this happens the operator must rely on memory to know when to perform each preventive maintenance function. As days pass into weeks and months, the preventive maintenance program is lost in the turmoil of everyday operations.

The only way an operator can keep track of a preventive maintenance program is by **good recordkeeping**. Whatever record system is used it should be kept up to date on a daily basis and not left to memory for some other time. Equipment service cards are easy to set up and require little time to keep up to date.

Equipment Service Cards & Service Record Cards

An **equipment service card** or "master card" should be prepared for each piece of equipment in the plant and distribution system. Each card should have the name of the piece of equipment clearly written on it, such as "Raw Water Intake Pump No.1." In addition, each card should include the following information.

1. List each required maintenance service with an item number.
2. List maintenance services in order of frequency of performance. For instance, daily service might be shown as items #1, #2, and #3 on the card; weekly items as #4 and #5; monthly items as #6, #7, #8, and #9; and so on.
3. Describe each type of service to be performed.

Make sure all necessary inspections and services are shown. Specific references should be listed for each of the items. The frequency of service and the day or month that service is due should also be listed for each item. See the *Suggested References for Study* in this chapter to find examples of how a service card can be set up to contain this information. Service card information may be changed to fit the needs of your plant or particular equipment as recommended by the equipment manufacturer. Make sure the information on the cards is complete and correct.

The **service record card** should have the date and work done, listed by item number and signed by the operator who performed the service. Some operators prefer to keep both cards clipped together, while others place the service record card near the equipment.

When the service record card is filled, it should be filed for future reference and a new card attached to the master card. The *equipment service card* tells what should be done and when to do it, while the *service record card* is a record of what you did and when you did it.

In addition to the use of service cards for scheduling and tracking maintenance procedures, many systems now use computer programs that have been created especially for this purpose.

Other Maintenance Records

All of the information on the nameplate of a piece of equipment including the serial and/or model numbers should be recorded and placed in a file for future reference. Many times the nameplate is painted, corroded, or missing from the unit when the information is needed to repair the equipment or replace parts. The date of installation and service startup for each piece of equipment should be logged and filed. A parts inventory is also essential for key pieces of equipment.

Buildings and Plant Grounds

Building maintenance programs depend on the age, type, and use of a building. New buildings require a thorough check to be certain essential items are available and working properly. Older buildings require careful watching and prompt attention to keep ahead of leaks, breakdowns, replacements, and changing uses of the building. Attention must be

given to the maintenance requirements of many items in all plant buildings. For safety's sake, periodically check all stairways, ladders, catwalks, and platforms for adequate lighting, head clearance, and sturdy and convenient guardrails. Protective devices should be around all moving equipment. Whenever any repairs alterations or additions are being built, avoid building accident traps such as pipes laid on top of floors or hung from the ceiling at head height which could create serious safety hazards.

All tools and plant equipment should be kept clean and in their proper place. Floors, walls and windows should be cleaned at regular intervals. A treatment plant kept in a neat, orderly condition makes a safe place to work and aids in building good public and employer relations. Plant grounds that are well groomed and kept in neat condition will greatly add to the appearance of the overall plant area. This is also important to the operator in building good public relations with plant neighbors as well as the general public.

Electrical Equipment

THIS DISCUSSION SHOULD NOT BE CONSIDERED A SOURCE OF TECHNICAL INFORMATION FOR ACTUAL OPERATION AND MAINTENANCE PROCEDURES. IT SHOULD BE USED ONLY AS A BRIEF INTRODUCTION OR REVIEW OF GENERAL INFORMATION.

ONLY QUALIFIED AND AUTHORIZED PERSONS SHOULD WORK ON ELECTRICAL EQUIPMENT OR CIRCUITRY

Fundamentals of Electricity

In all water systems, there is a need for the operators to know something about electricity. However, very few operators, even those operators who specialize in maintenance, ever do the actual electrical repairs or troubleshooting because it is such a highly specialized field. Unqualified persons can severely injure themselves and damage costly equipment.

VOLTS. Voltage (also known as electromotive force or E.M.F.) is the electrical pressure available to cause a flow of current (amperage) when an electrical circuit is closed. This pressure can be compared with the pressure or force that causes water to flow in a pipe. Pressure is required to make the water move. The same is true of electricity. A force is needed to push electricity or electric current through a wire. This force is called voltage. There are two types of current: Direct Current (D.C.) and Alternating Current (A.C.)

DIRECT CURRENT. Direct current (D.C.) flows in one direction only and is essentially free from pulsation. Direct current is seldom used in water systems except in electronic equipment, some control components of pump drives and stand-by lighting.

ALTERNATING CURRENT. An **alternating current (A.C.)** is one in which the voltage and current periodically change direction and amplitude. In other words, the current goes from zero to maximum strength, back to zero and to the same strength in the opposite direction. Most A.C. circuits have a frequency of 60 cycles per second. Alternating current may be classified as one of three types.

1. Single-phase
2. Two-phase
3. Three-phase (sometimes called polyphase)

The most common of these are single phase and three phase. Single-phase power is found in lighting systems, small pump motors, various portable tools and throughout residential homes. This power is usually 120 volts and sometimes 240 volts. Single-phase means that only one phase of power is supplied to the main electrical panel at 240 volts and has three wires or leads. Two of these leads have 120 volts each and the other lead is neutral.

Three-phase power is generally used with motors and transformers found in water systems. Generally, motors above two horsepower are three-phase. Three-phase power usually is brought in to the point of use with three leads. There is power on all three leads. If a fourth lead is brought in, it is a neutral lead. Incoming power goes through a meter and then some type of disconnecting switch such as a fuse or circuit breaker.

FUSE. A **fuse** is a protective device having a strip or wire of fusible metal which, when placed in a circuit, will melt and break the electrical circuit when subjected to an excessive temperature. This temperature will develop in the fuse when a current flows through the fuse in excess of what the circuit will carry safely.

CIRCUIT BREAKERS. The **circuit breaker** is another safety device and is used in the same place as a fuse. Most circuit breakers consist of a switch that opens automatically when the current or the voltage exceeds or falls below a certain limit. Unlike a fuse that has to be replaced each time it "blows," a circuit breaker can be reset after a short delay to allow time for cooling.

OVERLOAD RELAYS. Three-phase motors are usually protected by **overload relays**. This is accomplished by having heater strips, bimetal, or solder pots which open when overheated stopping power to the motor. Such relays are also known as "heaters" or "thermal overloads".

AMPS. Amperage is the measurement of current or electron flow and is an indication of work being done or "how hard the electricity is working." The **amp** or **ampere** is the practical unit of electric current. The actual definition of an ampere is the current produced by a pressure of one volt in a circuit that has a resistance of one ohm. Most electrical equipment used in water systems is labeled with nameplate information indicating the proper voltage and allowable current in amps.

OHM. The **ohm** is the unit of measurement for electrical resistance.

WATTS AND KILOWATTS. **Watts** and **kilowatts** are the units of measurement of the rate at which power is being used or generated. 1000 watts is equal to 1 kilowatt. Power requirements are expressed in kilowatt hours. 500 watts for two hours or one watt for 1000 hours equals one kilowatt hour. The electric company charges so many cents per kilowatt hour.

Mechanical Maintenance

THIS DISCUSSION SHOULD NOT BE CONSIDERED A SOURCE OF TECHNICAL INFORMATION FOR ACTUAL OPERATION AND MAINTENANCE PROCEDURES. IT SHOULD BE USED ONLY AS A BRIEF INTRODUCTION OR REVIEW OF GENERAL INFORMATION.

The first step for any type of mechanical equipment maintenance is to get the manufacturer's instruction book and read it completely. Each piece of equipment is different and the particular manufacturer will provide its recommended maintenance schedules and procedures. If you do not have an instruction booklet, you might obtain one by contacting the manufacturer's representative in your area.

Pumps

Pumps serve many purposes in water systems. They may be classified by the character of the material handled such as raw or filtered water. Or, they may relate to the conditions of pumping: high lift, low lift, or high capacity. They may be further classified by principle of operation, such as centrifugal, propeller, reciprocating, and turbine.

The type of material to be handled and the function or required performance of the pump vary so widely that the design engineer must use great care in preparing specifications for the pump and its controls. *Similarly, the operator must conduct a maintenance and management program adapted to the particular characteristics of the equipment.*

Two very commonly used types of pumps are centrifugal pumps and reciprocating pumps.

Centrifugal pumps consist of an impeller rotating in a casing. The impeller (a paddle wheel device) is supported on a shaft which is, in turn, supported by bearings. Liquid coming in at the center (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and then is thrown out by centrifugal force into the discharge. Centrifugal pumps cannot operate unless the impeller is submerged in water. Therefore they should NEVER be started until they are properly primed.

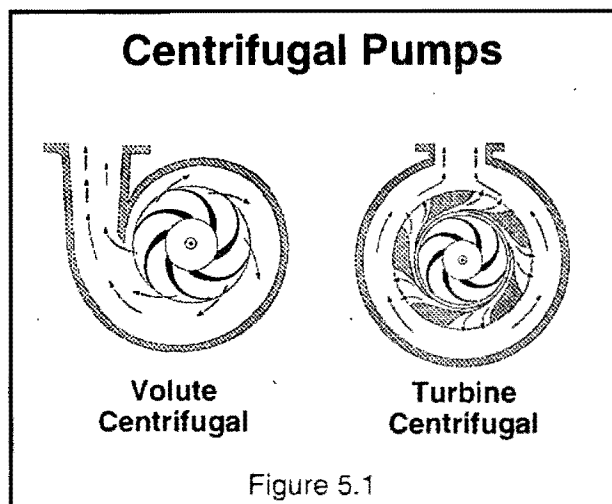


Figure 5.1

One common type of centrifugal pump is the **volute centrifugal pump** (see Figure 5.1). The term "volute" comes from the spiral-shaped interior of the casing. As the impeller spins the centrifugal force created throws the water outward into the volute. This creates a partial vacuum at the center of the impeller, which draws more water into the pump from the suction opening. Pressure will increase as more and more water is thrown into the volute, which forces water around the spiral and out of the discharge. The volute shape of the casing changes the high velocity and low pressure head of the water leaving the impeller to a lower velocity and higher pressure head at the discharge. The movement of water during pumping is radially outward, away from the shaft.

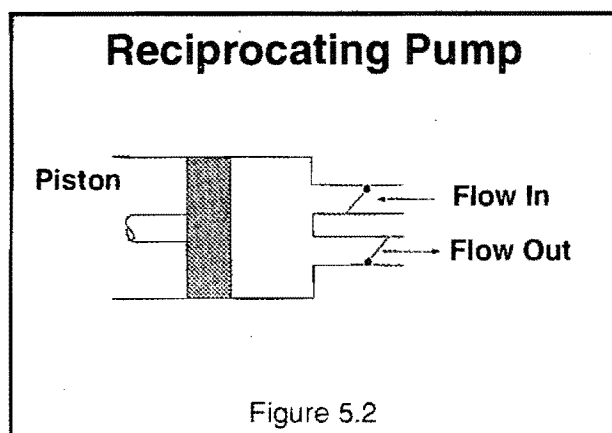


Figure 5.2

Another type of centrifugal pump is the **turbine centrifugal pump**. In this pump the impeller is mounted at the center of a circular casing. The pump has stationary diffuser vanes fixed to the inside of the casing which convert the velocity of the outwardly-thrown water to pressure head.

Turbine pumps are generally considered to be more efficient than the volute pump. Because of their efficiency they are especially useful in high-head applications. However, the turbine pump has small clearances between the impeller and diffuser vanes and can be easily fouled by dirt.

The word "reciprocating" means "moving back and forth", so a **reciprocating pump** is one that moves water or sludge by a piston that moves back and forth (see Figure 5.2). Two check valves alternately open and close as the piston cycles. For obvious reasons, positive displacement pumps such as reciprocating pumps or piston pumps should NEVER be operated against a closed discharge valve.

Packing is used to keep air from being drawn into pumps. Water leakage rate around packing should be 20-60 drops per minute. Packing should be replaced periodically depending upon conditions of operation. Use the packing recommended by the pump manufacturer. The stagger of the packing joints can be determined by dividing 360° by the number of rings of packing used. Many pumps being produced today use mechanical seals in place of packing. Mechanical seals serve the same purpose as packing; that is, they prevent leakage between the pump casing and the shaft. If clear water seal is use on the

packing, the pressure of the clear water at the packing box should be maintained at least 5 psi greater than the maximum pump suction pressure.

Bearings should usually last for years if serviced properly and used in their proper application. There are several types of bearings used in pumps. These include ball bearings, roller bearings, and sleeve bearings. The type of bearing used in each pump depends on the manufacturer's design and application. Whenever a bearing failure occurs, the bearing should be examined to determine the cause and then, if possible, eliminate the problem.

Unless **couplings** between the driving and driven elements of a pump or any other piece of equipment are kept in proper alignment, breaking and excessive wear in the pump and/or the motor can be the result. Burned out bearings, sprung or broken shafts, or ruined gears are some of the damages caused by misalignment. To prevent outages and the expense of installing replacement parts, regularly check the alignment of all equipment. Many large systems have fully equipped machine shops staffed with competent mechanics. But for smaller plants, adequate machine shop facilities for rebuilding pumps and other mechanical equipment often can be found in the community. Most pump manufacturers maintain pump repair departments where pumps can be fully reconditioned.

Electric Motors

Electric motors are the machines most commonly used to convert electrical energy into mechanical energy. A motor usually consists of a stator, rotor, end bells, and windings. The rotor has an extending shaft which allows a machine to be coupled to it. Motors are of many different types. The most common of these is the squirrel cage induction motor. Some pumping stations use wound rotor induction motors when speed control is needed.

Electric motors generally require little attention and under average operating conditions the factory lubrication of the bearing will last approximately one year. Check with the manufacturer for the average number of operating hours for bearings. Pumps, motors, and drives should be oiled and greased in strict accordance with the recommendations of the manufacturer.

Most of the trouble encountered with electrical motors results from bad bearings, shorted windings due to insulation breakdown, or excessive moisture. If single phasing occurs in a three phase motor, one phase loses power; if the motor is running it will tend to overheat and damage itself unless stopped. The amperage and voltage readings on motors should be taken periodically by qualified persons to ensure they are operating properly.

A motor starter is a device or group of devices which are used to connect the electrical power to a motor. These starters range in complexity from manually controlled starters such as on/off switches to automatically controlled magnetic starters using timers and

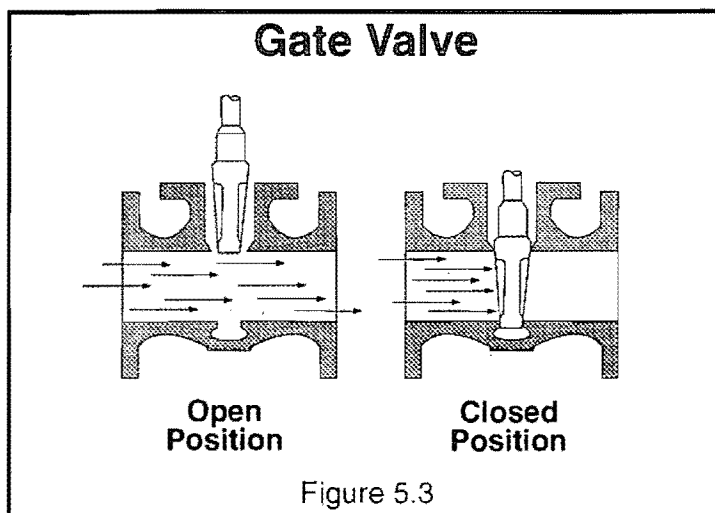


Figure 5.3

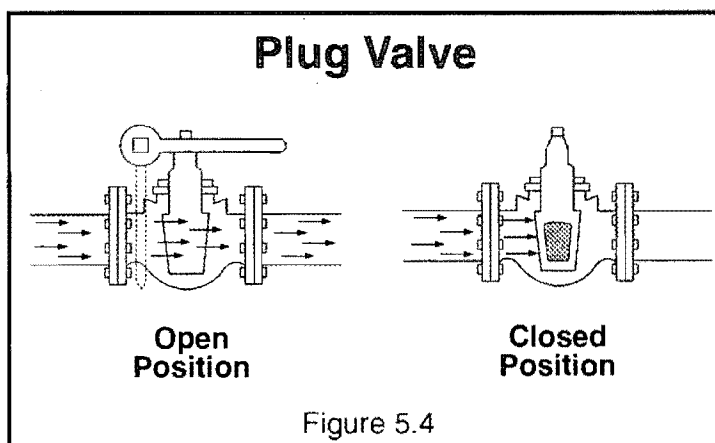


Figure 5.4

coils. When you install a three phase motor and it runs in the wrong direction, change the connections and reverse any two lead wires.

Valves

Valves are the controlling devices placed in piping systems to stop, regulate, check, divert, or otherwise modify the flow of liquids or gases. There are specific valves that are more suitable for certain jobs than others. A brief introduction to the several different types of valves and their applications was offered in Chapter 2. All valves require regular maintenance as specified by the manufacturer to operate properly and minimize chance of failure.

Plug valves consist of a rotating plug within the valve body (**see**

Figure 5.4). Many systems specify plug valves as opposed to gate valves as they are less susceptible to being fouled by debris. The most common type of **check valve** is the swing check valve normally installed in the discharge of pumps. This valve consists of a valve body with a "clapper arm" attached to a hinge that opens when a pump comes on and closes to seat when a pump is shut off. Each of these valves require regular maintenance as specified by the manufacturer to operate properly and minimize chance of failure.

Most valves suffer from lack of operation rather than from wear. A comprehensive program of inspection, exercising and maintenance of valves on a regular basis can help water systems avoid potentially serious problems when the need to use a valve arises. In general, it is recommended that all valves be exercised at least once a year. Exercising the valves verifies valve location, determines whether or not the valve works and extends valve life by helping to clean encrustations from the valve seats and gates. Valves should be exercised in both directions fully closed and fully opened and the number of turns and direction of operation recorded. Any valves that do not completely open or close should be replaced. Valves which leak around the stem should be repacked.

Chlorinators

All **chlorinators** can give continuous trouble-free operation if properly maintained and operated. Each chlorinator manufacturer provides with each machine a maintenance and operations booklet with line diagrams showing the operation of the component parts of the machine. Manufacturer's instructions should be followed for maintenance and lubrication of your particular chlorinator. Operators should never attempt maintenance tasks which they are not qualified to perform. There are considerable possibilities for serious accidents when operating or maintaining chlorinators.

Special Safety Considerations (see also Chapter 1)

DO NOT OPERATE ELECTRICAL SYSTEMS OR CONTROLS UNLESS YOU ARE QUALIFIED AND AUTHORIZED TO DO SO. Even when qualified and authorized, caution should be used when operating electrical controls, circuits and equipment. Operate only those switches and electrical controls installed for the purpose of your job. DO NOT OPEN OR WORK INSIDE ELECTRICAL CABINETS OR SWITCH BOXES UNLESS ABSOLUTELY NECESSARY AND ONLY IF YOU ARE QUALIFIED TO PERFORM THESE VERY SPECIALIZED SKILLS.

Be aware of moving equipment, especially reciprocating equipment and rotating shafts. Guards over couplings and shafts should be provided and should be in place at all times. Do not wear loose clothing, rings, or other jewelry around machinery. Long hair must be secured. Wear gloves when cleaning pump casings to protect your hands from dangerous sharp objects.

REFERENCES

California State University, Sacramento - **Water Treatment Plant Operation, Vol. 2**

Chapter 18 Maintenance
(especially sections 18.1, 18.2)

Chapter 19 Instrumentation

California State University, Sacramento - **Small Water System Operation & Maintenance**

Chapter 3 Wells

California State University, Sacramento - **Water Distribution System Operation & Maintenance**

Chapter 5 Distribution System Operation & Maintenance

SAMPLE QUESTIONS

Technician

A neat, orderly, and well maintained water facility is

- A. not very important as long as everything is working properly
- B. a good idea, but only if you have the time
- C. very important to help prevent equipment breakdowns and to help maintain good public relations

Operator

The maintenance card that is used to record what you did and when you did it is called

- A. the service record card
- B. the equipment service card
- C. the repair and maintenance card

Chapter 6

Disinfection

STUDY GUIDELINES

Distribution/Collection Technician (Class D) Certification

- ◆ Where in the typical surface water treatment sequence the chlorination processes are located
- ◆ The purpose of disinfection
- ◆ The basic definitions of chlorine dose, chlorine demand, chlorine residual, and breakpoint chlorination
- ◆ The name of the testing procedure that should be used for measurement of chlorine residual
- ◆ The minimum chlorine residual required in potable water leaving the water treatment plant and the minimum required chlorine residual throughout the distribution system
- ◆ What concentrations of chlorine are in high-test hypochlorite (HTH) and liquid bleach
- ◆ The characteristics of chlorine gas including its color and its weight as compared to air
- ◆ The special safety considerations for working with chlorine and chlorine equipment
- ◆ The characteristics and hazards of the different forms of chlorine
- ◆ The proper procedures for safe storage and handling of chlorine
- ◆ The proper procedure for changing a chlorine gas cylinder
- ◆ The most common cause of chlorine leaks and how to prevent it
- ◆ How to check for chlorine leaks and what to do when a leak is detected
- ◆ Where the self-contained breathing apparatus (SCBA) should be located
- ◆ The procedures to prepare for emergencies in the chlorine room including the buddy system
- ◆ How to perform basic dosage calculations

Distribution/Collection Operator (Class C) Certification

- ◆ The chemical symbols for calcium hypochlorite, sodium hypochlorite, chlorine gas, hypochlorous acid, and hydrochloric acid
- ◆ The simple reactions of chlorine with water and chlorination chemicals
- ◆ The major factors in trihalomethane formation
- ◆ Which substances may produce a chlorine taste and odor in water
- ◆ The basic processes of hypochlorination and gas chlorination including the equipment used
- ◆ How to perform a variety of dosage calculations involving chlorine gas and HTH

ENTRY LEVEL DISCUSSION

Purpose of Disinfection

The purpose of **disinfection** is to make the water safe for human consumption. Water carries a host of dissolved as well as suspended materials. Among these suspended materials are microscopic organisms, many of which have the potential to produce disease in humans. Diseases transmitted through water supplies are referred to as **water-borne diseases**. Due to the growth of human populations, it would be very difficult to find a surface water supply that has not been contaminated by both man and animals to some degree. Therefore it is necessary to disinfect water in addition to other treatments.

It is important to distinguish between disinfection and sterilization. **Disinfection** is the destruction of most of the pathogenic organisms whereas **sterilization** is the complete destruction of all organisms. Complete sterilization of drinking water and wastewater effluent is not only unnecessary, it is also not cost effective.

Chlorination processes normally take place in a **chlorine contact basin** which is located at the very end of the wastewater treatment process. The chlorine is usually added only after all other plant processes have been accomplished and the treated wastewater is about to be discharged.

Reasons for Using Chlorine

Disinfection of water supplies in the United States is almost always accomplished by using chlorine. Disinfection with chlorine, combined with the other surface water treatment processes has greatly reduced the incidence of water-borne disease among humans in the United States. It is this proven record and the familiarity with chlorine that makes chlorine the disinfecting agent used at most systems. There are three basic reasons that chlorine is usually the disinfectant of choice.

1. Chlorine is the most cost-effective disinfectant available considering its disinfecting power.
2. Chlorine is easily obtained through a variety of sources.
3. Chlorine produces a disinfecting residual.

However, it should also be said that there are also two clear disadvantages or drawbacks to the use of chlorine.

1. Chlorine must be used and handled very carefully to prevent serious hazards to operators.
2. Chlorine can sometimes form trihalomethanes (THMs) in water supplies. Concentrations of THMs above the maximum contaminant levels (MCLs) are suspected of causing cancer.

Forms of Chlorine

There are three forms of chlorine that are commonly used as a disinfectant in the United States: chlorine gas, calcium hypochlorite, and sodium hypochlorite. **Chlorine gas** (Cl_2) is 100 percent available chlorine and comes in 150 pound and one ton cylinders.

Calcium hypochlorite ($\text{Ca}(\text{OCl})_2$), also known as **High Test Hypochlorite** or **HTH** can be purchased in tablet, powder or granulated form. HTH is often used as a back-up system for systems that normally use chlorine gas. At smaller systems it may be used as the primary disinfectant for continuous feed. HTH is about 65 percent available chlorine, depending on the manufacturer. HTH is fed by a device called a **hypochlorinator**.

Sodium hypochlorite (NaOCl) is also available in a powder form but it is usually purchased in the form of **liquid bleach**. Chlorine bleach is usually used for batch treatment, such as disinfecting a newly drilled well, but is also fed continuously by some very small community water systems. The concentration of common household bleach is about 5.25 percent available chlorine. However, most water (or wastewater) systems that use bleach will use a 10 to 15 percent concentration.

Of the three major sources of chlorine, chlorine gas is by far the most common source used for continuous disinfection of water supplies and will be the main focus of this discussion.

Characteristics of Chlorine Gas

Chlorine gas must be handled with care because it is very **toxic** and **corrosive**. This gas can cause severe injury to anyone who comes into direct contact with it, especially if it is inhaled or comes into contact with the eyes. Chlorine gas is also dangerous because it is approximately **2.5 times heavier than air**, which means it has a tendency to collect in low places and will not float away without forced ventilation. Chlorine gas has a **greenish-yellow color** and a very distinctive and pungent odor. Chlorine gas cylinders actually contain very concentrated chlorine gas in a liquid form. One liter of this concentrated liquid chlorine produces 450 liters of chlorine gas upon evaporation.

In addition, chlorine gas has a very high **coefficient of expansion**, which means that it has a tendency to expand even further if the temperature increases. For example, if there was a temperature increase of 50°F (28°C), the volume of the chlorine gas in the cylinder would increase by 84 to 89 percent. This much expansion could easily cause enough pressure to rupture a chlorine cylinder or a line full of liquid chlorine. For this reason, chlorine gas cylinders are never filled to their total capacity.

Chlorine Gas Safety

Chlorine (Cl_2) reacts with water (H_2O) to form hypochlorous acid (HOCl) and hydrochloric acid (HCl). **Hypochlorous acid** is a weak acid that gives chlorine its disinfectant properties. **Hydrochloric acid** has very little disinfectant properties but is a very strong acid. Whenever chlorine comes into contact with moisture, this strong acid is formed. When chlorine gas is inhaled it will cause severe **lung damage** and can cause **blindness** if it comes into contact with the eyes.

IT IS EXTREMELY IMPORTANT FOR ALL FACILITIES THAT USE CHLORINE GAS OR ANY OTHER FORM OF CHLORINE TO FOLLOW ALL SAFETY PRECAUTIONS.

One of the most common problems with chlorination equipment is leakage. In this case, the best cure is prevention. For example, **NEVER** reuse the gasket and washer when replacing a chlorine cylinder, even if they appear to be in good condition. Reusing gaskets and washers on chlorine cylinders is probably the most common source of chlorine leaks.

Ammonia vapors can be used as a simple method of chlorine leak detection. If you place a clean rag that has been wetted with an ammonia water solution near a connection that has a chlorine leak, a visible white vapor will appear. Only a commercial grade of ammonia should be used for this purpose. Care should be taken to avoid applying the ammonia solution directly to the fittings because a strong acid will form that will corrode metal.

Improper storage temperature can contribute to the occurrence of leaks because of the high coefficient of expansion that chlorine gas possesses. Remember, chlorine will expand when heated. On the other hand, chlorine hydrate icing may occur on the connections of chlorine cylinders if the temperature in the chlorine room falls below 60°F (16°C). Chlorine containers should be stored away from heat or direct sunlight and the chlorine room should be kept in climate controlled conditions at normal room temperatures. Also, cylinders should never be connected to a common manifold unless special precautions are taken to prevent one cylinder from backfeeding to another.

Because of its weight, chlorine gas will have a tendency to collect in low places. For this reason, exhaust ducts for chlorine rooms are placed near the floor. Mechanical ventilation equipment (built-in fans) must be turned on and must provide at least one complete air change per minute whenever the chlorine room is occupied. A **self-contained breathing apparatus** (SCBA) or other respiratory air-pac protection equipment meeting the requirements of the National Institute for Occupational Safety and Health (NIOSH) must be available and stored at a location convenient to the chlorine room but **NEVER** inside the chlorine room. Instructions for using this equipment must be posted and comprehensive chlorine safety training including chlorine emergency drills using safety equipment should be held on a regular basis. The SCBA units should be compatible with those that are used by the local fire department. Individuals must be fit-tested while wearing their SCBA to

ensure a leak-proof seal, facial hair or scars may prevent an effective seal. Persons wearing an SCBA must undergo a medical evaluation consisting of a questionnaire and quite possibly a physical examination.

One of the most important safety precautions when working around chlorine gas or performing any other potentially dangerous job is to use the **buddy system**. Under the buddy system, a person is simply NEVER allowed to be left alone when performing dangerous work. Another person trained in emergency techniques and procedures must always be present and alertly watching the work being done from a safe position. All chlorine rooms must be equipped with an inspection window from which the buddy can safely observe the progress of the work without having to enter the room.

It is also very important that all equipment used for chlorination or chlorine safety be used and maintained properly. The manufacturer's instructions for using chlorine should be closely followed. Finally, the material safety data sheet (MSDS) for all chemical products should be understood by all persons who work on or around them.

Additional Safety Hazards When Using HTH

It should always be remembered that working with ANY form of chlorine can be very hazardous and that it must always be stored, handled, and used with extreme care. HTH is a strong oxidizer and is **extremely reactive** when it comes in contact with either organic material or water. If HTH is allowed to come into contact with petroleum products or organic solvents it can explode violently. HTH should be kept away from any source of organic matter including dirt, oils, or dirty rags.

When HTH is mixed with water, pure chlorine gas and heat is given off. Therefore, it is very important that HTH is stored and used properly. Storage of this chemical should only be in a cool, dry place separate from other chemicals and WITHOUT a sprinkler system.

All operators working at systems using HTH should be aware of the consequences of the substance coming in contact with small amounts of water. In order to disperse the heat generated, the HTH should always be added to the correct volume of water, rather than adding the water to the HTH. If HTH is introduced to large amounts of water, it's okay, but if it's improperly stored or handled and gets wet, watch out! A toxic chlorine gas cloud will likely result.

Improper handling of HTH can lead to skin, eye, and lung damage. Therefore, a face shield, long rubber gloves, a rubber apron, and a dust mask should be used at all times. A portable eye wash should also be available. HTH should never be handled with bare hands. Use only thoroughly clean, dry utensils and make sure that there is adequate ventilation when handling. Contaminated clothing should be washed before wearing again. HTH should be stored in the original container only. When the container is empty it should not be reused.

Principles of Chlorination

The exact mechanism of chlorine disinfection is actually not yet completely understood. One theory states that the chlorine exerts a direct action on the organism itself, thus destroying it. Another theory is that the toxic nature of chlorine destroys the enzymes that enable living microorganisms to use their food supply and the organisms die of starvation.

The total amount of chlorine added is called the **chlorine dose**. When chlorine is added to water that contains certain organic and inorganic substances, it will immediately begin to react with them to form compounds that do not have any disinfecting properties. These compounds, in fact, consume some of the chlorine that is added to the water. The amount of chlorine that is consumed by these compounds is referred to as the **chlorine demand**. After the chlorine demand has been "satisfied", the remaining chlorine that is available for disinfection purposes is referred to as the **chlorine residual**. There are two types of chlorine residual; free chlorine residual and combined chlorine residual.

$$\text{Chlorine Dose} = \text{Chlorine Demand} + \text{Chlorine Residual}$$

$$\text{Chlorine Residual} = \text{Combined Chlorine Residual} + \text{Free Chlorine Residual}$$

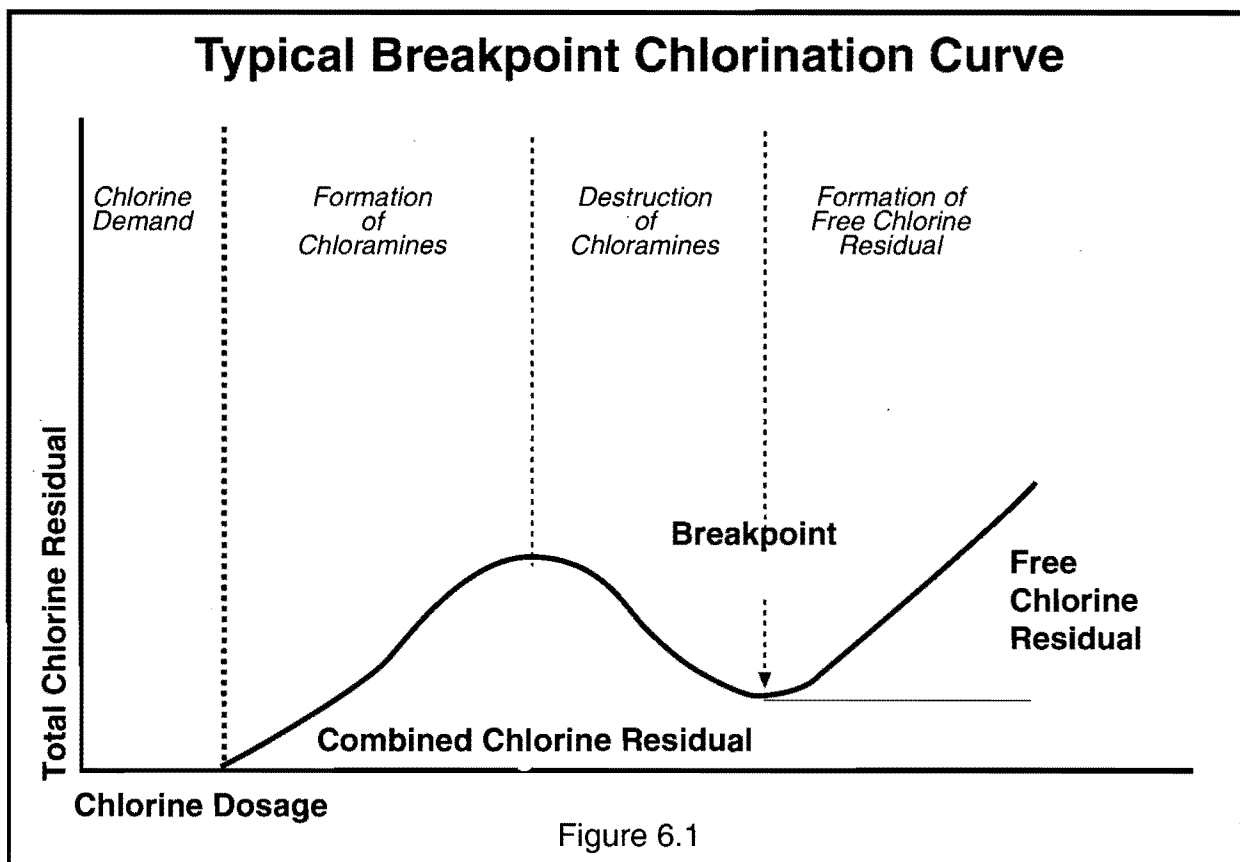
When chlorine is added to water, the hypochlorous acid that is produced will immediately react with ammonia to form a group of compounds called **chloramines**. Chloramines are in fact a disinfecting residual often referred to as the **combined residual**. Combined residuals such as chloramines are relatively weak disinfecting agents. In order to obtain a **free chlorine residual**, a chlorination technique called breakpoint chlorination must be utilized.

Breakpoint Chlorination

Breakpoint chlorination is the process of adding chlorine until a free chlorine residual is formed. Any chlorine added after this "breakpoint" will result in a free chlorine residual that is directly proportional to the additional dosage. The **breakpoint** is actually defined as the point of chlorine addition (dosage) where the chlorine demand and combined chlorine residual have been broken down and a free chlorine residual has formed.

When you look at a graph showing breakpoint chlorination (see **Figure 6.1**), you can begin to see what actually occurs during the chlorination process. Assume the water being chlorinated in this example contains various types of impurities such as iron, manganese, nitrate, organic matter, and ammonia. Every water supply will have a different breakpoint chlorination "curve" depending on the types and amounts of impurities present.

When a small amount of chlorine is added, it will react with the impurities and be consumed with no residual production and no significant amount of disinfection taking place. This is illustrated by the flat area on the far left side of the graph where no residual is present. This is the chlorine demand.



When more chlorine is added it reacts with organic material and ammonia to produce chlororganic compounds and chloramines. As mentioned earlier, the disinfection power of the combined chlorine residual is very weak. In addition, this type of residual may produce taste and odor problems.

When still more chlorine is added, the chloramines will be broken down as shown by the drop in the residual curve on the graph. As the dosage increases the curve will finally bottom out and begin to rise once again. The residual then being produced is called the free chlorine residual. This type of residual is both a strong disinfectant and is free of taste and odor.

Chlorine Residual Testing and Minimum Residuals Required

Chlorine residual testing has often been performed by one of two methods: the orthotolidine method or the DPD method. The DPD method should be used. ORTHOTOLIDINE SHOULD NOT BE USED BECAUSE IT HAS BEEN DETERMINED THAT IT IS CARCINOGENIC (CAUSES CANCER).

The DPD method of determining chlorine residual is **colorimetric** which means that the results are determined by the intensity of the color produced. The DPD method produces a pink color change. The more intense the color produced, the higher the chlorine residual.

This method can be used to determine either the total chlorine residual or the free chlorine residual only. All systems required to disinfect, including all surface water treatment plants and most groundwater systems, must provide a minimum free chlorine residual of 1.0 mg/L in the water entering the distribution system. There must also be a minimum of 0.2 mg/L of free chlorine residual maintained throughout the distribution system. For this reason, it may be necessary to leave the plant with a much higher chlorine residual or to provide supplemental points of chlorination in the distribution system.

Water systems that do not utilize breakpoint chlorination and rely completely upon a combined chlorine residual (chloramines) for disinfection must provide a total chlorine residual of at least 2.0 mg/L and maintain at least 1.0 mg/L throughout the distribution system. This higher level is required because a combined chlorine residual is not as effective as a free chlorine residual.

Chemical Reactions of Chlorine

Chlorine will react with many substances that are found in or added to the water as well as reacting with water itself. The following discussion offers a brief explanation of some of the most important reactions that involve chlorine.

Chlorine Gas with Water

Free chlorine (Cl_2) reacts with water (H_2O) to form **hypochlorous acid** (HOCl) and **hydrochloric acid** (HCl). Hypochlorous acid is the main disinfectant and is the reason why chlorine is utilized by water treatment operators. The hydrochloric acid has little disinfection properties but is important for operator safety considerations due to its toxic and corrosive nature.

Calcium Hypochlorite (or HTH) with Water

When calcium hypochlorite ($\text{Ca}(\text{OCl})_2$) is added to water it reacts to form hypochlorous acid (HOCl) and calcium hydroxide ($\text{Ca}(\text{OH})_2$). Since the major by-product produced in the reaction is a strong base—calcium hydroxide—the pH will have tendency to increase depending on the dosage used. This is just the opposite of what can be expected when using chlorine gas, as a major by-product of that reaction is hydrochloric acid (HCl) which tends to lower the pH.

Sodium Hypochlorite (Bleach) with Water

Sodium hypochlorite (NaOCl) reacts with water to form hypochlorous acid (HOCl) and sodium hydroxide (NaOH). Once again a major by-product of the reaction is a strong base which will tend to raise the pH of the water.

Chlorine with Ammonia

When chlorine is added to water, the hypochlorous acid (HOCl) that is produced will immediately react with any naturally-occurring ammonia to form chloramines (the combined chlorine residual).

The particular type of chloramines formed largely depends on the pH. At pH levels that are normally found in water (pH 6.5 to 8.5) monochloramine (NH_2Cl) will be the dominant type. At pH levels between 4.0 and 5.5 dichloramine (NHCl_2) is found by itself, and at pH levels below 4.0, trichloramine (NCl_3) is the only chloramine found.

However, chloramines do not react with organics in the water to form trihalomethanes, also known as THMs. Therefore, they have become a popular solution to the problem of high THM levels. The intentional formation of chloramines that are used as a disinfecting residual will be discussed later in this chapter.

Factors Affecting Chlorine Disinfection

pH

A simple fact to remember is that the lower the pH, the better free chlorine disinfects. However, the loss of disinfection power due to higher pH levels generally does not become significant until the pH exceeds a value of about 8.0 to 8.5.

Temperature

Temperature will also effect how well chlorine is able to disinfect the water. The higher the temperature of the water, the easier it is to disinfect. The colder the water, the longer the contact time required to achieve adequate disinfection. Another factor related to chlorination and temperature is that warmer temperatures cause more of the chlorine to dissipate out of the water and into the air.

Contact Time

The final factor to be considered is **contact time**. The more contact time that a water supply has for disinfecting residuals, the better the disinfection. Contact time is especially important for systems that have a high pH or for colder periods of the year. Contact time is also critical for systems that use chloramines for disinfection because of their weaker disinfecting capabilities.

Points of Chlorination

Water

Prechlorination is the application of chlorine ahead of any other treatment processes. Prechlorination is sometimes quite beneficial. The primary benefits of prechlorination are as follows.

1. Control of algae and slime growth.
2. Control of mudball formation in filters.
3. Improvements in coagulation.
4. Reduction of tastes and odors.
5. Increased chlorine contact time.
6. Increased in-plant safety and better disinfection when treating heavily contaminated and polluted waters.

Unfortunately, prechlorination will also increase the occurrence of trihalomethanes (THMs) because these substances are formed by a combination of organic material and free chlorine.

Postchlorination is the application of chlorine after the water has been treated and just before it enters the distribution system. This is the most important point of disinfection and is normally the last application of any disinfectant. Postchlorination may also be the last form of treatment provided before the water is consumed by the public. Some water plants find it necessary to practice **rechlorination**, which is the addition of chlorine at strategic points in the distribution system. The application point could be any place where there is adequate mixing available.

Wastewater

Chlorine may be added at lift station wetwells to help reduce odors. Always discuss this treatment with the plant operators first. Chlorination processes normally take place in a **chlorine contact basin** which is located at the very end of the wastewater treatment process. The chlorine is usually added only after all other plant processes have been accomplished and the treated wastewater is about to be discharged.

Alternative Disinfectants

Chloramines

Chloramine disinfection (chloramination) is the most commonly utilized alternative to free chlorine disinfection. When using this alternative, ammonia is added at a specific point in the treatment process and at a certain dosage level. Ammonia can be obtained for this purpose in three forms: liquid, aqueous, and solid. Liquid ammonia is probably the most cost effective of the three forms and is the most commonly used source of ammonia for large treatment plants. Chloramine disinfection can be effective in reducing levels of THMs. Another advantage to a chloramine residual is that it is more stable and does not dissipate as rapidly as the free chlorine residual. Hence, it is easier to maintain a chloramine residual in the distribution system than a free chlorine residual.

Using chloramines as an alternative to free chlorine also has some drawbacks. For example, chloramines are a much weaker disinfecting agent than free chlorine and therefore a higher residual with longer contact time is necessary in most situations. Chloramines are not a powerful oxidizing agent and will not oxidize taste and odor causing substances, nor will they be of any aid for special purposes such as iron and manganese control. In addition, chloramines can easily produce their own taste and odor problems if not utilized properly. Finally, the stability of chloramines in the water supply also means it is more difficult to remove chloramine residuals, which can cause problems for persons on kidney dialysis machines and for persons who own fish aquariums.

Chloramines are formed in water by the reaction of ammonia with chlorine. During chloramine formation three species of chloramines will form: monochloramines, dichloramines, and trichloramines. Under the conditions normally associated with water treatment, monochloramine is the dominant and preferred form.

Ozone

Ozone (O_3) is produced by passing oxygen through an electrical discharge. Ozone is an extremely powerful oxidizing agent and disinfectant. It has been used as a primary disinfectant in both Europe and Japan for many years. In spite of its power to oxidize and disinfect, ozone may have too many disadvantages to be used by a large number of systems in this country. One major disadvantage is that ozone does not produce a disinfecting residual. In addition, ozone must be generated on-site using high-voltage electrical generators with high initial setup and operating costs. For these reasons, ozone is generally only used as a pre-oxidation system for THM precursor removal.

Chlorine dioxide

Chlorine dioxide (ClO_2) is produced by the reaction of free chlorine and sodium chlorite. Chlorine dioxide is a very effective oxidizing agent, producing a powerful disinfecting residual that will not produce THMs. However, several problems are associated with the use of chlorine dioxide. The initial setup and maintenance of a chlorine dioxide system can be quite expensive, requiring additional training for the operators and new laboratory procedures. Another potential problem with the use of chlorine dioxide is that chlorite and chlorate may be produced as by-products. These compounds are considered highly carcinogenic.

REFERENCES

California State University, Sacramento - **Water Treatment Plant Operation, Vol. 1**

Chapter 7 Disinfection

California State University, Sacramento - **Water Distribution System Operation & Maintenance**

Chapter 6 Disinfection

California State University, Sacramento - **Water Treatment Plant Operation, Vol. 2**

Chapter 15 Trihalomethanes

SAMPLE QUESTIONS

Technician

The chlorine that remains after the chlorine demand has been satisfied is called the

- A. chlorine dose
- B. chlorine residual
- C. chlorine demand

Operator

The chemical that is mainly responsible for the disinfectant properties of chlorine is

- A. HOCl
- B. HCl
- C. NaOH

Appendix A

Introduction to Basic Operator Math

This appendix offers some examples of how to work basic operator math problems. The “simplified” math formulas used in this Appendix will be provided with the test questions on the Class D exams. However, some of the conversion factors and abbreviations listed in this appendix must be memorized for the certification exam. To find out exactly what you need to know for your Class D exam, please refer to the *Suggested Study Guidelines* in each chapter of this study guide.

Also included in this Appendix are some practice problems. It is important to practice to improve your ability to work the problems while you are actually taking your exam. Some of the basic math practice problems in this appendix may require additional explanations not offered here. A more complete explanation concerning basic operator math skills can be found within the *Suggested References for Study* listed in Chapter 1 of this study guide. Many approved operator training classes also offer help in learning how to solve math problems. It is recommended that all new operators read this appendix and work the math problems before attending an approved standard entry level class.

Instructions for using APPENDIX A

1. Read completely.
2. Read each section again before working the practice problems for that section.
3. Compare your answers to answers on the last page of APPENDIX A. Don't be concerned if your answer is slightly different than the answer given.
4. Review before taking your certification exam.

*The #1 factor in how well you do in math can be summarized by the old saying;
“If you don’t use it, you lose it.”*

VOLUME-TIME UNITS

Volume-time units measure the volume of flow over a specific period of time. There are many other volume-time units that are used for many different purposes. Two very commonly used volume-time units are MGD and gpd.

MGD (Million Gallons per day)
gpd (gallons per day)

It is important that all operators know how to convert between these two units. The real key to converting between MGD and gpd is to know how to move the decimal place exactly six places. This method of conversion works because the only difference between MGD and gpd is one million. One million is equal to six decimal places. If it's a little difficult at first, a little practice is all that's needed.

Basic Abbreviations

ac	acre
ac-ft	acre feet
amp	ampere
°C	degrees Celcius
cfm	cubic feet per minute
cfs	cubic feet per second
cm	centimeter
cu ft or ft ³	cubic feet
cu in or in ³	cubic inch
cu yd or yd ³	cubic yard
°F	degrees Fahrenheit
ft	feet or foot
gal	gallon
gm	gram
gpd	gallons per day
gpm	gallons per minute
HP	horsepower
hr	hour
in	inch
k	kilo
kg	kilogram
km	kilometer
kW	kilowatt
kWh	kilowatt-hour
L	liter
lb	pound
m	meter
M	million
mg	milligram
mg/L	milligram per liter
MGD	million gallons per day
ml	milliliter
min	minute
psf	pounds per square foot
psi	pounds per square inch
ppb	parts per billion
ppm	parts per million
sec	second
sq ft or ft ²	square feet
sq in or in ²	square inches
W	watt

Basic Conversion Factors

Length

12 in	1 ft	12 in / ft
3 ft	1 yd	3 ft / yd
5280 ft	1 mi	5280 ft / mi

Area

144 sq in	1 sq ft	144 sq in / sq ft
43,560 sq ft	1 acre	43,560 sq ft / acre

Volume

7.48 gal	1 cu ft	7.48 gal / cu ft
1000 ml	1 liter	1000 ml / liter
3.785 L	1 gal	3.785 L / gal
231 cu in	1 gal	231 cu in / gal
0.326 MG	1 ac-ft	0.326 MG / ac-ft

Weight

1000 mg	1 gm	1000 mg / gm
1000 gm	1 kg	1000 gm / kg
454 gm	1 lb	454 gm / lb
2.2 lbs	1 kg	2.2 lbs / kg

Power

.746 kW	1 HP	.746 kW / HP
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Density of Water

8.34 lbs	1 gal	8.34 lbs / gal
62.4 lbs	1 cu ft	62.4 lbs / cu ft

Dosage

1 mg/l	1 ppm	mg/l / ppm
17.1 mg/l	1 grain/gal	17.1 mg/l / grain/gal

Pressure

2.31 ft water	1 psi	2.31 ft water / psi
0.433 psi	1 ft water	0.433 psi / ft water

Flow

1,000,000 gpd	1 MGD	1,000,000 gpd / MGD
694 gpm	1 MGD	694 gpm / MGD
1.55 cfs	1 MGD	1.55 cfs / MGD

Time

60 secs	1 min	60 secs / min
60 min	1 hr	60 min / hr
1440 min	1 day	1440 min / day
24 hr	1 day	24 hr / day

PROBLEM

You have a flow of 17,000 gpd. What is the flow in MGD?

SOLUTION

First, start by writing down what you know. You know you have a flow of 17,000 gpd and you want to know what the flow is in MGD.

$$17,000 \text{ gpd} = ? \text{ MGD}$$

The decimal place is now just to the right of the last zero, at the end of the whole numbers.

$$17,000. \text{ gpd} = ? \text{ MGD}$$

Next, move the decimal place exactly six places to the left. You will see as you count out the six places to the left that you must add one zero to make room for the last decimal place. After this is done you can “drop off” the three zeroes that are “left over” on the right.

$$17,000. \text{ gpd} = .017 \text{ MGD}$$

PROBLEM

You have a flow of 2.3 MGD. What is the flow in gpd?

SOLUTION

Once again, start by writing down what you know. You know you have a flow of 2.3 MGD and you want to know what the flow is in gpd.

$$2.3 \text{ MGD} = ? \text{ gpd}$$

Next, move the decimal place exactly six places to the right. You will see as you do this that you must add five zeros on the right.

$$2.3 \text{ MGD} = 2,300,000 \text{ gpd}$$

VOLUME/TIME PRACTICE PROBLEMS

1. The flow is 100,000 gpd. What is the flow in MGD?
2. The flow is 1,200,000 gpd. What is the flow in MGD?
3. The flow is 120,000 gpd. What is the flow in MGD?
4. The flow is 56,000 gpd. What is the flow in MGD?
5. The flow is 8,200,000 gpd. What is the flow in MGD?
6. The flow is 5,300 gpd. What is the flow in MGD?
7. The flow is 11,000 gpd. What is the flow in MGD?
8. The flow is 4,336,000 gpd. What is the flow in MGD?
9. The flow is 1.60 MGD. What is the flow in gpd?

10. The flow is 2.36 MGD. What is the flow in gpd? _____
11. The flow is .08 MGD. What is the flow in gpd? _____
12. The flow is .004 MGD. What is the flow in gpd? _____
13. The flow is .876 MGD. What is the flow in gpd? _____
14. The flow is .054 MGD. What is the flow in gpd? _____
15. The flow is 1.76 MGD. What is the flow in gpd? _____

AREA AND VOLUME

Area and Volume of Squares and Rectangles

The formula for calculating the **surface area** of a square or rectangle is:

$$A = L \times W$$

A = Area

L = Length

W = Width

The formula for calculating the **volume** of a square or rectangle is:

$$V = L \times W \times H$$

V = Volume

L = Length

W = Width

H = Height or depth

Notice that the formula for area is the same as for the formula for volume except that one more “dimension” has been added (the height or depth).

PROBLEM

What is the surface area of a basin that is 40 feet long and 20 feet wide?

SOLUTION

The first thing to do when working with any math problem that requires the use of a formula is to write down the formula.

$$A = L \times W$$

Now place the numbers into the formula and multiply.

$$A = 40\text{ft} \times 20 \text{ ft}$$

And you are left with:

$$A = 800\text{ft} \times \text{ft}$$

A better way of saying "ft x ft" is "ft²" which is read as "square feet."

$$A = 800\text{ft}^2$$

PROBLEM

What is the volume of a basin that is 40 feet long, 20 feet wide, and 10 feet deep?

SOLUTION

First, write down the formula you are going to use.

$$V = L \times W \times H$$

Place the numbers into the formula and multiply.

$$V = 40\text{ft} \times 20\text{ft} \times 10\text{ft}$$

And you are left with:

$$V = 8,000\text{ft}$$

A better way of saying "ft x ft x ft" is "ft³" which is read as "cubic feet."

$$V = 8,000 \text{ ft}^3$$

Area and Volume of Cylinders

The formula for calculating the **surface area** of a round or cylindrical container is

$$A = \pi \times R^2$$

$$\pi = 3.1416$$

$$R^2 = R \times R = \text{radius} \times \text{radius}$$

The formula for calculating the **volume** of a round or cylindrical container is

$$V = \pi \times R^2 \times H$$

$$\pi = 3.1416$$

$$R^2 = R \times R = \text{radius} \times \text{radius}$$

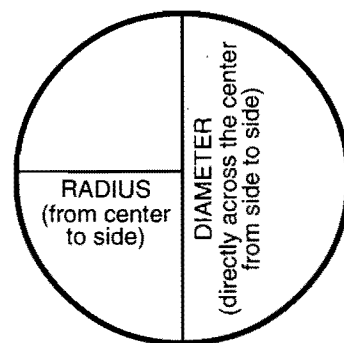
$$H = \text{height or depth}$$

The symbol “ π ” is the Greek letter pi (pronounced pie). π is a symbol used to represent the relationship of the diameter of a cylinder to its circumference. The circumference of a cylinder is always 3.1416 times greater than the diameter.

The letter “R” stands for radius.

The radius of a cylinder is exactly one-half of the diameter.

CIRCUMFERENCE
(all the way around)



PROBLEM

What is the surface area of a basin that has a diameter of 60 ft?

SOLUTION

First, write down the formula.

$$A = \pi \times R^2$$

As you work the formula from left to right, the first thing to do is replace π with the number 3.1416.

$$A = 3.1416 \times R^2$$

R² means “R squared” or “R x R.”

$$A = 3.1416 \times R \times R$$

Remember that the R stands for radius. If the diameter is 60 feet, the radius is 30 feet because the radius is always exactly one-half of the diameter.

$$A = 3.1416 \times 30\text{ft} \times 30\text{ft}$$

Now use your calculator to solve the problem.

$$A = 3.1416 \times 30\text{ft} \times 30\text{ft}$$

And you are left with

$$A = 2,827 \text{ ft} \times \text{ft}$$

$$A = 2,827 \text{ ft}^2$$

PROBLEM

What is the volume of a basin that is 60 ft in diameter and 15 feet deep?

SOLUTION

First, write down the formula.

$$V = \pi \times R^2 \times H$$

As you work the formula from left to right, the first thing to do is replace the symbol π with the number 3.1416.

$$V = 3.1416 \times R^2 \times H$$

Another way of saying R^2 is " $R \times R$."

$$V = 3.1416 \times R \times R \times H$$

If the diameter is 60 feet, the radius is 30 feet.

$$V = 3.1416 \times 30\text{ft} \times 30\text{ft} \times H$$

The H stands for the height or depth which is 15 feet.

$$V = 3.1416 \times 30\text{ft} \times 30\text{ft} \times 15\text{ft}$$

Now use your calculator to solve the problem.

$$V = 3.1416 \times 30\text{ft} \times 30\text{ft} \times 15\text{ft}$$

$$V = 42,412\text{ft} \times \text{ft} \times \text{ft}$$

$$V = 42,412\text{ft}^3$$

PROBLEM

What is the volume in **gallons** of a basin 60 feet in diameter and 15 feet deep?

SOLUTION

This is the same as the last problem except that the answer needs to be given in gallons instead of in cubic feet. Therefore, this problem will be worked exactly the same as the last problem except that one more step must be taken to convert from cubic feet to gallons.

There are 7.48 gallons in each cubic foot of water (see Common Conversion Factors in the Appendix).

In order to find out how many gallons are in the basin this conversion factor must be used.

$$V, \text{ gal} = 42,412 \text{ ft}^3 \times \frac{7.48 \text{ gal}}{\text{ft}^3}$$

And the correct answer is

$$V, \text{ gal} = 317,242 \text{ gal}$$

PROBLEM

What is the volume in **pounds** of a basin 60 feet in diameter and 15 feet deep?

SOLUTION

Now the question is how many pounds of water are in the basin. This is the same as the last problem except that the answer needs to be reported in pounds instead of in gallons. This type of information might be necessary in order to determine dosage rates, because dosages are often calculated in pounds of chemical added for every million pounds of water being treated.

A gallon of water weighs or has a "mass" of 8.34 lbs (see the Common Conversion Factors listed in this Appendix). In order to find out how many pounds of water are in the basin, this conversion factor must be used.

$$\text{Mass, lbs} = 317,242 \text{ gal} \times \frac{8.34 \text{ lbs}}{\text{gal}}$$

And the correct answer is

$$\text{Mass, lbs} = 2,645,796 \text{ lbs}$$

If the answer was "rounded off" and the decimal place was moved six places, it could also be correctly written as

$$\text{Mass, lbs} = 2.65 \text{ Mlbs}$$

AREA AND VOLUME PRACTICE PROBLEMS

1. A basin is 60 feet long and 30 feet wide. What is the surface area? _____
2. A basin is 35 feet long and 20 feet wide. What is the surface area? _____
3. A basin is 40 feet in diameter. What is the surface area? _____
4. A basin is 82 feet in diameter. What is the surface area? _____
5. A basin is 12 feet in diameter. What is the surface area? _____
6. What is the volume of a basin 20 feet long, 10 feet wide, and 5 feet deep? _____
7. What is the volume in gallons of the basin in question #6? _____
8. How many pounds of water are in the basin in question #6? _____
9. What is the volume of a basin 40 feet long, 15 feet wide, and 10 feet deep? _____
10. What is the volume in gallons of the basin in question #9? _____
11. How many pounds of water are in the basin in question #9? _____
12. What is the volume of a basin 30 feet in diameter and 10 feet deep? _____

13. What is the volume in gallons of the basin in question #12? _____
14. How many pounds of water are in the basin in question #12? _____
15. What is the volume of a basin 50 feet in diameter and 8 feet deep? _____
16. What is the volume in gallons of the basin in question #15? _____
17. How many pounds of water are in the basin in question #15? _____
18. What is the volume of a basin 45 feet in diameter and 15 feet deep? _____
19. What is the volume in gallons of the basin in question #18? _____
20. How many pounds of water are in the basin in question #18? _____

BASIC DOSAGE CALCULATIONS

A common way of expressing dosage levels in both water and wastewater treatment is in milligrams per liter, (mg/L)

A milligram per liter is one one-thousandth of a gram for every liter of water.

A mg/L is a unit of measurement often used for expressing a dosage of a substance in water or wastewater. **A mg/L is the same thing as a ppm.**

The ppm or mg/L are the pounds of the substance for every million pounds of water being treated. For example, 1 pound of chlorine in 1 million pounds of water would be 1 mg/L. Concentrations will always be expressed as mg/L.

There are two basic formulas that are used for dosage calculations. Which of the two formulas you use depends upon what you need to know.

If you need to know what the mg/L is, this formula can be used.

$$\text{Dose, mg/L} = \frac{\text{Chemical, lbs}}{\text{H}_2\text{O, Mlbs}}$$

If you need to know how many pounds of chemical you need to use for the dosage level you want, this formula can be used.

$$\text{Chemical, lbs} = (\text{Dose, mg/L}) (\text{H}_2\text{O, Mlbs})$$

PROBLEM

You have a flow of 2.3 MG that is being treated with 115 lbs of chlorine gas. What is the dosage in mg/L?

SOLUTION

First, choose the formula that will give you what you need to know and write it down

$$\text{Dose, mg/L} = \frac{\text{Chemical, lbs}}{\text{H}_2\text{O, Mlbs}}$$

This is the correct dosage calculation formula to use because mg/L is what you are looking for.

Next, make sure that you have all the information needed to work the problem. The formula needs the pounds of chemical being added each day and the million pounds of water being treated each day. You already know how many pounds of chemical are being used (115 lbs). However, the flow is listed in million gallons instead of in million pounds.

Therefore, you must convert the MG to Mlbs before you can work the dosage problem. This is done by multiplying the MG of water by 8.34 because each gallon of water weighs 8.34 lbs. (See the Common Conversion Factors listed in this Appendix)

$$2.3 \text{ MG} \times \frac{8.34 \text{ lbs}}{\text{gal}} = 19.2 \text{ Mlbs}$$

Now you know have all of the information needed for the formula in the proper units and you are ready to proceed.

Place the numbers in the proper places in the formula and finish the problem using division.

$$\text{Dose, mg/L} = \frac{115 \text{ lbs}}{19.2 \text{ Mlbs}}$$

$$\text{Dose} = 6 \text{ mg/L}$$

PROBLEM

Your plant has a flow of 3.8 MG and requires a chlorine dose of 8 mg/L. How many pounds of chlorine gas is needed to achieve this dosage?

SOLUTION

First, choose the formula that will give you what you need to know and write it down.

$$\text{Chemical, lbs} = (\text{Dose, mg/L}) (\text{H}_2\text{O, Mlbs})$$

This is the correct dosage calculation formula to use because pounds is what you need to know. Once again, you must make sure that you have all the information needed to work the problem. And once again you need to convert the MG to Mlbs before you can use the formula.

$$3.8 \text{ MG} \times \frac{8.34}{\text{gal}} = 31.7 \text{ Mlbs}$$

Now you are ready to proceed with the formula. Place the numbers into the formula and multiply.

$$\text{Chemical, lbs} = (8 \text{ mg/L}) (31.7 \text{ Mlbs})$$

And the answer is

$$\text{Chemical, lbs} = 254 \text{ lbs}$$

PROBLEM

Your plant has a flow of 3.8 MG and requires a chlorine dose of 8 mg/L. How many pounds of 65% HTH would be needed to achieve this dosage?

SOLUTION

This is the same as the previous problem except that 65% HTH is to be used instead of 100% chlorine gas. Probably the easiest way for most people to work this problem is to start by finding out how much chlorine gas would be needed, and then convert it to HTH.

First, work the problem in the same way it was done in the last problem.

$$\text{Chemical, lbs} = 254 \text{ lbs}$$

Because 65% HTH is being used, it will take more pounds than would be needed for chlorine gas. To get the correct answer, divide the number of pounds of chlorine gas that would be needed by 0.65 to find out how many pounds of 65% HTH would be needed.

$$\text{Chemical, lbs} = \frac{254 \text{ lbs}}{.65}$$

$$\text{HTH, lbs} = 391 \text{ lbs}$$

BASIC DOSAGE PRACTICE PROBLEMS

1. The flow is 2.4 MGD and the chlorine gas feed rate is 40 lbs/day. What is the dose in mg/L?
2. The flow is 1.2 MGD and the chlorine gas feed rate is 50 lbs/day. What is the dose in mg/L?
3. The flow is 0.60 MGD and the chlorine gas feed rate is 15 lbs/day. What is the dose in mg/L?
4. The flow is 0.30 MGD and the chlorine gas feed rate is 18 lbs/day. What is the dose in mg/L?

5. The flow is 2.4 MGD and a chlorine dose of 4 mg/L is required. How many pounds of chlorine gas must be used?

6. The flow is 1.8 MGD and a chlorine dose of 2 mg/L is required. How many pounds of chlorine gas must be used?

7. The flow is 3.0 MGD and a chlorine dose of 6 mg/L is required. How many pounds of chlorine gas must be used?

8. The flow is 0.3 MGD and a chlorine dose of 3 mg/L is required. How many pounds of chlorine gas must be used?

9. The flow is 0.5 MGD and a chlorine dose of 5 mg/L is required. How many pounds of 65% HTH must be used?

10. The flow is 0.018 MGD and a chlorine dose of 6 mg/L is required. How many pounds of 65% HTH must be used?

THE METRIC SYSTEM

The metric system is the main method of measurement in almost all of the industrialized countries in the world. Although many persons in the United States think that the metric system is confusing, it is probably even easier than the “english” system once you learn how to use it. Generally speaking, there are only three types of measurement; length, weight, and volume.

In the english system, length is measured in inches, feet, yards, miles, etc. In the metric system, length is measured in **meters**. In the english system, weight is measured in ounces, pounds, tons, etc. In the metric system, weight is measured in **grams**. In the english system, volume is measured in fluid ounces, pints, quarts, gallons, etc. In the metric system volume is measured in **liters**. The metric system is actually simpler than the english system because there is only one basic unit for length, one basic unit for weight, and one basic unit for volume.

Unit	Symbol	Measurement
Meter	m	Length
Gram	g or gm	Weight (or mass)
Liter	l or L	Volume

But how many or what part of a meter, gram, or liter? In the metric system, a prefix is used to tell you this. A prefix is something that is put in front of a word to modify it. In the metric system, a prefix is often used in front of one of the three basic units of measurement.

Prefix	Symbol	Meaning
Mega	M	one million (1,000,000)
Kilo	k	one thousand (1000)
Hecto	h	one hundred (100)
Deka	da	ten (10)
Deci	d	one tenth (0.1)
Centi	c	one one-hundredth (0.01)
Milli	m	one one-thousandth (0.001)
Micro	μ	one one-millionth (0.000001)

QUESTION

What is a ml?

ANSWER

The m is the prefix (it comes first). The prefix m is the symbol for milli which means one one-thousandth (1/1000). The l is a symbol for liter. A liter is the basic unit for measuring volume in the metric system.

ml is a symbol for **milliliter** which is **one one-thousandth of a liter**.

QUESTION

What is a mg?

ANSWER

The m is the prefix (it comes first). The prefix m is the symbol for milli which means one one-thousandth (1/1000). The g is a symbol for gram. A gram is the basic unit for measuring weight in the metric system.

mg is a symbol for **milligram** which is **one one-thousandth of a gram**.

QUESTION

What is a mg/L?

ANSWER

A mg is a milligram which is one one-thousandth of a gram. L is the symbol for liter. The slash (/) means "per" or "in every".

A mg/L is a symbol for a **milligram per liter**.

A **milligram per liter** is **one one-thousandth of a gram for every liter of water**.

Note: A mg/L is a unit of measurement often used for expressing a dosage of a substance in water or wastewater. A mg/L is the same thing as a ppm.

ANSWERS TO APPENDIX A PRACTICE PROBLEMS

Volume/Time Units Practice Problems

1. 0.10 MGD
2. 1.2 MGD
3. 0.12 MGD
4. 0.056 MGD
5. 8.2 MGD
6. 0.0053 MGD
7. 0.011 MGD
8. 4.34 MGD
9. 1,600,000 gpd
10. 2,360,000 gpd
11. 80,000 gpd
12. 4000 gpd
13. 876,000 gpd
14. 54,000 gpd
15. 1,760,000 gpd

Area and Volume Practice Problems

1. 1800 ft²
2. 700 ft²
3. 1257 ft²
4. 5281 ft²
5. 113 ft²
6. 1000 ft³
7. 7480 gals

8. 62,383 lbs or 0.06 Mlbs
9. 6000 ft³
10. 44,880 gals
11. 374,299 lbs or 0.37 Mlbs
12. 7069 ft³
13. 52,873 gals
14. 440,962 lbs or 0.44 Mlbs
15. 15,708 ft³
16. 117,496 gals
17. 979,915 lbs or 0.98 Mlbs
18. 23,857 ft³
19. 178,447 gals
20. 1,488,246 lbs or 1.49 Mlbs

Dosage Calculations Practice Problems

1. 2.0 mg/L
2. 5.0 mg/L
3. 3.0 mg/L
4. 7.2 mg/L
5. 80 lbs
6. 30 lbs
7. 150 lbs
8. 7.5 lbs
9. 32 lbs
10. 1.4 lbs

Appendix B

Certification Exam Formula Sheet

Listed in this appendix is the exam formula sheet. Examinees must be familiar enough with the formulas to be able to recognize it and use it properly if it is needed while taking the exam.

Distribution/Collection Certification Exam Formula Sheet

$$\frac{\text{Chemical, lbs}}{\text{Flow, Mlbs}}$$

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

$$\text{Flow, ft}^3/\text{min} = (\text{Area, ft}^2)(\text{Velocity, ft/min})$$

Appendix C

SOME COMMON CHEMICAL COMPOUNDS		
Chemical Name	Common Name(s)	Chemical Symbol
Aluminum sulfate	alum	$\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$
Ammonia	ammonia	NH_3
Calcium carbonate	calcium carbonate	CaCO_3
Calcium oxide	lime	CaO
Calcium hydroxide	lime / slaked lime / hydrated lime	$\text{Ca}(\text{OH})_2$
Calcium hypochlorite	high-test hypochlorite / HTH	$\text{Ca}(\text{OCl})_2$
Carbon dioxide	carbon dioxide gas	CO_2
Chlorine	chlorine	Cl_2
Copper sulfate	blue vitriol / bluestone	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
Hydrochloric Acid	muriatic acid	HCl
Hypochlorous Acid	hypochlorous acid	HOCl
Hydrogen sulfide	hydrogen sulfide gas	H_2S
Ferrous sulfate	copperas	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
Fluorosilicic Acid	(also called hydrofluorosilicic acid)	H_2SiF_6
Methane	methane gas	CH_4
Potassium permanganate	permanganate	KMnO_4
Sodium carbonate	soda ash	Na_2CO_3
Sodium bicarbonate	baking soda	NaHCO_3
Sodium hydroxide	caustic / caustic soda / lye	NaOH
Sodium hypochlorite	bleach	NaOCl
Sodium fluoride	sodium fluoride	NaF
Sodium fluorosilicate	(also called sodium silicofluoride)	Na_2SiF_6
Sulfuric Acid	sulfuric acid	H_2SO_4

Appendix C Table 1

SOME COMMON CHEMICAL REACTIONS									
Chlorine and Water $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HOCl} + \text{HCl}$ Calcium Hypochlorite (HTH) and Water $\text{Ca}(\text{OCl})_2 + 2\text{H}_2\text{O} \rightarrow 2\text{HOCl} + \text{Ca}(\text{OH})_2$ Sodium Hypochlorite (Bleach) and Water $\text{NaOCl} + \text{H}_2\text{O} \rightarrow \text{HOCl} + \text{NaOH}$ Sulfur Dioxide and Chlorinated Water $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3 + \text{HOCl} \rightarrow \text{H}_2\text{SO}_4 + \text{HCl}$	<table> <tr> <th colspan="2">KEY</th></tr> <tr> <td>$\rightarrow$</td><td>yields or produces</td></tr> <tr> <td>$\uparrow$</td><td>liberates as a gas</td></tr> <tr> <td>$\downarrow$</td><td>precipitates as a solid</td></tr> </table>	KEY		$\rightarrow$	yields or produces	$\uparrow$	liberates as a gas	$\downarrow$	precipitates as a solid
KEY									
$\rightarrow$	yields or produces								
$\uparrow$	liberates as a gas								
$\downarrow$	precipitates as a solid								

Appendix C Table 2

Answers to Sample Questions

CHAPTER 1

Class D C

Class C B

CHAPTER 2

Class D C

Class C C

CHAPTER 3

Class D C

Class C B

CHAPTER 4

Class D C

Class C B

CHAPTER 5

Class D C

Class C A

CHAPTER 6

Class D B

Class C A

COMPLETE SUGGESTED REFERENCES FOR STUDY

California State University, Sacramento - Water Treatment Plant Operation, Vol. 1

Chapter 1	The Water Treatment Plant Operator
Chapter 2	Water Sources and Treatment
Chapter 3	Reservoir Management and Intake Structures
Chapter 4	Coagulation and Flocculation
Chapter 5	Sedimentation
Chapter 6	Filtration
Chapter 7	Disinfection
Chapter 8	Corrosion Control
Chapter 9	Taste and Odor Control
Chapter 10	Plant Operation
Chapter 11	Laboratory Procedures
Appendix	How to Solve Water Treatment Plant Arithmetic Problems

California State University, Sacramento - Water Treatment Plant Operation, Vol. 2

Chapter 12	Iron and Manganese Control
Chapter 13	Fluoridation
Chapter 14	Softening
Chapter 15	Trihalomethanes
Chapter 16	Demineralization
Chapter 17	Handling and Disposal of Process Wastes
Chapter 18	Maintenance
Chapter 19	Instrumentation
Chapter 20	Safety
Chapter 21	Advanced Laboratory Procedures
Chapter 22	Drinking Water Regulations
Chapter 23	Administration

California State University, Sacramento - Small Water System Operation and Maintenance

Chapter 3	Wells
-----------	-------

California State University, Sacramento - Water Distribution System Operation and Maintenance

Chapter 1	The Water Distribution System Operator
Chapter 2	Storage Facilities
Chapter 3	Distribution System Facilities
Chapter 4	Water Quality Considerations in Distribution Systems
Chapter 5	Distribution System Operation
Chapter 6	Disinfection
Chapter 7	Safety

Oklahoma Operator Certification Rules (Chapter 710)

Public Water Supply Operations (Chapter 631)

Rules for Oklahoma Hazard Communication Standard

Title 40 - Oklahoma Statutes for General Safety and Health

OSHA Confined Space Entry Rule

*** AWWA Reference Handbook: Basic Science Concepts and Applications - Hydraulics Section**

** needed for certification purposes only by those persons preparing for a Class A examination.*

REFERENCE SOURCES

(for all references listed in the Suggested References for Study and Other Study Suggestions)

CSUS Water Treatment Plant Operation, Volume I
CSUS Water Treatment Plant Operation, Volume II
CSUS Water Distribution System Operation and Maintenance
CSUS Small Water System Operation and Maintenance

Kenneth D. Kerri, Office of Water Programs
6000 J Street
Sacramento, California 95819-6025
(916) 278-6142 **Website:** www.owp.csus.edu

Water and Wastewater Works Operator Certification (Chapter 710)

Oklahoma Department of Environmental Quality
Customer Service
PO Box 1677
707 N. Robinson
Okla. City, OK 73101-1677
(405) 702-9100 **Website:** www.deq.state.ok.us

Public Water Supply Operations (Chapter 631)

Public Water Supply Constuction Standards (Chapter 625)

Oklahoma Department of Environmental Quality
Customer Assistance
PO Box 1677
707 N. Robinson
Okla. City, OK 73101-1677
(405) 702-9100 **Website:** www.deq.state.ok.us

Rules for Oklahoma Hazard Communication Standard

Title 40 - Oklahoma Statutes for General Safety and Health

OSHA Confined Space Entry Rule

Oklahoma State Department of Labor
Division of Public Employees Safety and Health
4001 N. Lincoln Blvd.
Okla. City, OK 73105
(405) 528-1500 ext. 266 **Website:** www.state.ok.us/~okdol

AWWA WSO Basic Science Textbook & Workbook

AWWA Standard for Disinfecting Water Mains (C651-99)

AWWA Standard for Disinfection of Water Storage Facilities (C652-92)

AWWA Standard for Disinfection of Water Treatment Plants (C653-97)

AWWA Standard Disinfection of Wells (C654-97)

American Water Works Association
6666 West Quincy Ave.
Denver, Colorado 80235
1-800-926-7337 **Website:** www.awwa.org

Chlorine Manual (Chlorine Institute Pamphlet #1 Edition 5, 1986)

Chlorine Institute
2001 L St. N.W. Suite 506
Washington D.C. 20036
(202) 775-2790

SOURCES OF ADDITIONAL STUDY MATERIAL

Operator Training Handbooks, References and Materials

American Water Works Association
6666 West Quincy Ave.
Denver, Colorado 80235
1-800-926-7337
(catalog available)
Website: www.awwa.org

Operator Training Publications and Materials

Water Environment Federation
601 Wythe Street
Alexandria, Virginia 22314-1994
1-800-666-0206
(catalog available)
Website: www.wef.org

Safety Publications and Materials

U.S. Dept. of Labor
Occupational Sfty. & Hlth. Adm.(OSHA)
(202) 219-4667
(catalog available)

Safety Publications and Materials

Oklahoma Safety Council
2725 E. Skelly Dr.
Tulsa, OK 74105
1-800-324-6458
(catalog available)
Website: www.oksafety@ionet.net

Operator Math Manuals and Workbooks

Technomic Publishing Company
851 New Holland Avenue, Box 3535
Lancaster, Pennsylvania 17604
1-800-233-9936
(catalog available)
Website: techpub.com

EPA Technical Manuals and Materials

National Drinking Water Clearinghouse
1-800-624-8301
(catalog available)

Federal SDWA Amendments, Code of Federal Regulations

EPA Safe Drinking Water Act Hotline
1-800-426-4791

Operator Training Material Information

National Environmental Training Center
1-800-624-8301



Pictured on front cover:

Tom Cooksey, Water Meter Technician with Oklahoma City Line Maintenance