WATER DISTRIBUTION
CERTIFICATION REVIEW COURSE

Technical Learning College

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http://www.abctlc.com/PDF/WDPrepASS.pdf

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You can obtain a printed version from TLC for an additional $69.95 plus shipping charges.

All downloads are electronically tracked and monitored for security purposes.

Some States and many employers require the final exam to be proctored.

Do not solely depend on TLC's Approval list for it may be outdated.

A second certificate of completion for a second State Agency $25 processing fee.

Most of our students prefer to do the assignment in Word and e-mail or fax the assignment back to us. We also teach this course in a conventional hands-on class. Call us and schedule a class today.

Responsibility

This course contains EPA's federal rule requirements. Please be aware that each state implements drinking water/wastewater/safety regulations that may be more stringent than EPA's or OSHA's regulations. Check with your state environmental agency for more information. You are solely responsible in ensuring that you abide with your jurisdiction or agency's rules and regulations.

Contributing Editors
James L. Six Received a Bachelor of Science Degree in Civil Engineering from the University of Akron in June of 1976, Registered Professional Engineer in the State of Ohio, Number 45031 (Retired), Class IV Water Supply Operator issued by Ohio EPA, Number WS4-1012914-08, Class II Wastewater Collection System Operator issued by Ohio EPA, Number WC2-1012914-94

Joseph Camerata has a BS in Management with honors (magna cum laude). He retired as a Chemist in 2006 having worked in the field of chemical, environmental, and industrial hygiene sampling and analysis for 40 years. He has been a professional presenter at an EPA analytical conference at the Biosphere in Arizona and a presenter at an AWWA conference in Mesa, Arizona. He also taught safety classes at the Honeywell and City of Phoenix, and is a motivational/inspirational speaker nationally and internationally.

James Bevan, Water Quality Inspector S.M.E. Twenty years of experience in the environmental field dealing with all aspects of water regulations on the federal, state, and local levels. Teacher and Proctor in Charge for Backflow Certification Testing at the ASETT Center in Tucson for the past 15 years and possess an Arizona Community College, Special Teaching Certificate in Environmental Studies.

Dr. Pete Greer S.M.E., Retired biology instructor, chemistry and biological review.

Jack White, Environmental, Health, Safety expert, City of Phoenix. Art Credits.

Technical Learning College's Scope and Function

Welcome to the Program,

Technical Learning College (TLC) offers affordable continuing education for today's working professionals who need to maintain licenses or certifications. TLC holds several different governmental agency approvals for granting of continuing education credit.

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. TLC's distance based or independent study courses are offered in a print - based distance educational format. We will beat any other training competitor's price for the same CEU material or classroom training.

Our courses are designed to be flexible and for you do finish the material on your leisure. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and instruction to obtain the assignments. All of TLC's CEU courses allow students to submit assignments using e-mail or fax, or by postal mail. (See the course description for more information.)

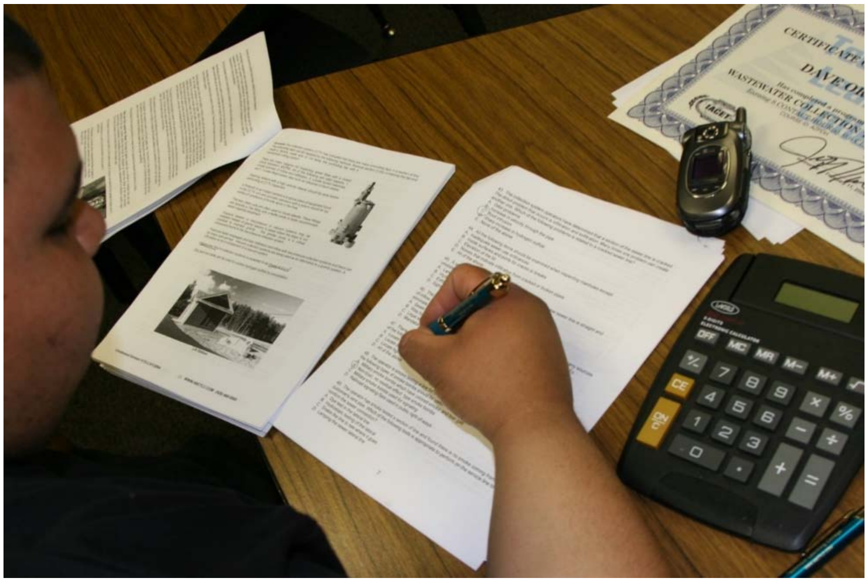
Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling, i.e., printer, Microsoft Word and/or Adobe Acrobat Reader. Some courses may require proctored closed-book exams depending upon your state or employer requirements.

Flexible Learning
At TLC, there are no scheduled online sessions or passwords you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus based student. You can work at your own pace, completing assignments in time-frames that work best for you. TLC's method of flexible individualized instruction is designed to provide each student the guidance and support needed for successful course completion.

Course Structure
TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student friendly course design allows you the most flexibility in choosing when and where you will study.

Classroom of One
TLC offers you the best of both worlds. You learn on your own terms, on your own time, but you are never on your own. Once enrolled, you will be assigned a personal Student Service Representative who works with you on an individualized basis throughout your program of study. Course specific faculty members (S.M.E.) are assigned at the beginning of each course providing the academic support you need to successfully complete each course. Please call or email us for assistance.

Satisfaction Guaranteed
We have many years of experience, dealing with thousands of students. We assure you, our customer satisfaction is second to none. This is one reason we have taught more than 20,000 students.



We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail.

If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of $50.

We welcome you to complete the assignment in Word.

Once we grade it, we will mail a certificate of completion to you. Call us if you need any help.

Contact Numbers
Fax (928) 468-0675
Email Info@tlch2o.com
Telephone (866) 557-1746

Course Description

Distribution Certification Preparation and Review CEU Training Course
Review of water distribution systems, groundwater mining, related chlorination/treatment fundamentals and operator math principles related to operator certification. This course will cover the basic requirements of the Safe Drinking Water Act and general water distribution principles. This study guide will present basic and complex math principles and formulas for water distribution operators to understand and to work out. Math includes: area, volume, temperature conversions, flow rates, pressure, pounds and % efficiency. The student will be required to properly calculate complex mathematical formulas for: pounds per day, volume, flow and related distribution and treatment formulas. The objective for this class is to prepare the student to successfully pas the operator certification examination and obtain CEU credit.

Proper calculation of concentration is contingent upon accurate determination of volume of water to be treated. If you are uncertain as to the volume of water to be treated, then take the time to measure the size of the tank or channel so that volume can be accurately determined. Ideally, all chemical treatments should be carried out in a special treatment or quarantine tank, but this is not always practical.

You will not need any other materials for this course. Task Analysis and Training Needs Assessments have been conducted to determine or set Needs-To-Know for this course. The following is a listing of some of those who have conducted extensive valid studies from which TLC has based this program upon: the Environmental Protection Agency (EPA), the Arizona Department of Environmental Quality (ADEQ), the Texas Commission of Environmental Quality (TCEQ) and the American Boards of Certification (ABC).

Final Examination for Credit
Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

Course Procedures for Registration and Support
All of Technical Learning College's correspondence courses have complete registration and support services offered. Delivery of services will include, e-mail, web site, telephone, fax and mail support. TLC will attempt immediate and prompt service.

When a student registers for a distance or correspondence course, he/she is assigned a start date and an end date. It is the student's responsibility to note dates for assignments and keep up with the course work. If a student falls behind, he/she must contact TLC and request an end date extension in order to complete the course. It is the prerogative of TLC to decide whether to grant the request. All students will be tracked by a unique number assigned to the student.

Instructions for Written Assignments
The Distribution Certification Preparation and Review CEU training course uses a multiple choice answer key. If you should need any assistance, please email all concerns and the final test to: info@tlch2o.com. You may write your answers or type out your own answer key. TLC would prefer that you utilize the answer key found on the TLC website under Assignments and e-mail the answer key to TLC, but it is not required. You may also fax the answer key. Please call us a couple hours later to ensure we received your information.

Feedback Mechanism (examination procedures)
Each student will receive a feedback form as part of their study packet. You will be able to find this form in the front of the assignment. You will have 90 days from receipt of this manual to complete it in order to receive your Continuing Education Units (**CEUs**) or Professional Development Hours (**PDHs**). A score of 70% or better is necessary to pass this course.

Security and Integrity
All students are required to do their own work. All lesson sheets and final exams are not returned to the student to discourage sharing of answers. Any fraud or deceit and the student will forfeit all fees and the appropriate agency will be notified.

Grading Criteria
TLC will offer the student either pass/fail or a standard letter grading assignment. If TLC is not notified, you will only receive a pass/fail notice.

Required Texts
The Distribution Certification Preparation CEU training course will not require any other materials. This course comes complete. No other materials are needed.

Recordkeeping and Reporting Practices
TLC will keep all student records for a minimum of seven years. It is the student's responsibility to give the completion certificate to the appropriate agencies. If necessary, we will send the required information to your State for your certificate renewals.

ADA Compliance
TLC will make reasonable accommodations for persons with documented disabilities. Students should notify TLC and their instructors of any special needs. Course content may vary from this outline to meet the needs of this particular group.

Educational Mission
The educational mission of TLC is:

- ✓ *To provide TLC students with comprehensive and ongoing training in the theory and skills needed for the environmental education field,*
- ✓ *To provide TLC students with opportunities to apply and understand the theory and skills needed for operator certification,*
- ✓ *To provide opportunities for TLC students to learn and practice environmental educational skills with members of the community for the purpose of sharing diverse perspectives and experience,*
- ✓ *To provide a forum in which students can exchange experiences and ideas related to environmental education,*
- ✓ *To provide a forum for the collection and dissemination of current information related to environmental education, and to maintain an environment that nurtures academic and personal growth.*

Objective: *To train distribution operators in the safe and effective maintenance and operation of various water distribution systems and related daily operations in order to understand and pass operator certification requirements*.

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Safety Section Chapter 7

Utility Counter-Terrorism Chapter 1

Defending against and responding to Catastrophic Threats*.* The expertise, technology, and material needed to build the most deadly weapons known to mankind—including chemical, biological, radiological, and nuclear weapons—are spreading inexorably. If our enemies acquire these weapons, they are likely to try to use them.

The consequences of such an attack could be far more devastating than those we suffered on September 11—a chemical, biological, radiological, or nuclear terrorist attack in the United States could cause large numbers of casualties, mass psychological disruption, contamination, significant economic damage, and could overwhelm local medical capabilities.

Protecting Critical Infrastructure and Key Assets*.* Our society and modern way of life are dependent on networks of infrastructure—both physical networks such as our utility and transportation systems and virtual networks such as the Internet. If terrorists attack one or more pieces of our critical infrastructure, they may disrupt entire systems and cause significant damage to the Nation.

We must therefore improve protection of the individual pieces and interconnecting systems that make up our critical infrastructure. Protecting America's critical infrastructure and key assets will not only make us more secure from terrorist attack, but will also reduce our vulnerability to natural disasters, organized crime, and computer hackers.

The basic goal of the ***Utility Counter-Terrorism course*** is to make sure utility employers and employees know about potential terrorist hazards, how to recognize them and, most importantly, how to protect themselves and correct the hazards.

Reduce America's vulnerability. Homeland security involves a systematic, comprehensive, and strategic effort to reduce America's vulnerability to terrorist attack. We must recognize that as a vibrant and prosperous free society, we present an ever-evolving, ever-changing target.

Homeland security. This is a concerted national effort to prevent terrorist attacks within the United States; reduce America's vulnerability to terrorism; minimize the damage and have the ability to recover from attacks that do occur.

Minimize the damage*.* The United States will prepare to manage the consequences of any future terrorist attacks that may occur despite our best efforts at prevention.

Some operator certification examinations are designed to help minimize the possible incidence or damage from terrorism.

Where are the Regulations?

Terrorism, Utility Security and Emergency Plans are found in the **Federal Response Plan**, **Presidential Decision Directive 39, Patriot Act, Homeland Security Presidential Directive** and amendments to the **Safe Drinking Water Act**.

These Acts and Directives require that our utilities and workplaces are prepared for acts of terrorism. It's important that you have some basic understanding of the Act and the benefits and requirements necessary for a safer America.

The federal law or **Patriot Act** requires that all dangers and escapes in your workplace be fully evaluated for possible physical or health hazards. And, it mandates that all information relating to these hazards be available to other agencies in case of a disaster.

SEC. 1433.: 42 USC 300i-2
TERRORIST AND OTHER INTENTIONAL ACTS.

Vulnerability Assessments. --(1) Each community water system serving a population of greater than 3,300 persons shall conduct an assessment of the vulnerability of its system to a terrorist attack or other intentional acts intended to substantially disrupt the ability of the system to provide a safe and reliable supply of drinking water.

The vulnerability assessment shall include, but not be limited to, a review of pipes and constructed conveyances, physical barriers, water collection, pretreatment, treatment, storage and distribution facilities, electronic, computer or other automated systems which are utilized by the public water system, the use, storage, or handling of various chemicals, and the operation and maintenance of such system. The Administrator, not later than August 1, 2002, after consultation with appropriate departments and agencies of the Federal Government and with State and local governments, shall provide baseline information to community water systems required to conduct vulnerability assessments regarding which kinds of terrorist attacks or other intentional acts are the probable threats to--

``(A) substantially disrupt the ability of the system to provide a safe and reliable supply of drinking water; or
``(B) otherwise present significant public health concerns.

This course prepares first responders to take appropriate actions, such as secure the scene, initiate self-protective measures, and notify appropriate agencies of a potential terrorist incident. It gives learners a general understanding and ability to recognize terrorist weapons that are biological, nuclear, incendiary, chemical, or explosive.

Goals
You are one of the first to arrive on the scene of a suspected terrorist incident. As a first responder trained at the awareness level, you are among the first to witness or discover an incident involving criminal activity or terrorism and to initiate an emergency response sequence by notifying the proper authorities. In this role you need the following competencies which you can acquire through training and professional experience:
An understanding of what terrorism is and the risks associated with such an incident;

- An understanding of the potential outcomes associated with a terrorist incident;
- The ability to recognize the presence of, and identify, criminal activity or terrorism in an emergency;
- An understanding of the role of the first responder as it relates to components of an emergency response plan, including site security and the U.S. Department of Transportation's (**DOT**) North American Emergency Response Guidebook;
- The ability to realize the need for additional resources, and to make appropriate notifications to an emergency communication center; and
- The ability to self-protect, keeping responder safety as a priority.
- Understand Homeland advisory system and security methods.

USA Patriot Act

What must we protect? The USA Patriot Act defines critical infrastructure as those "***systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters***."

Our critical infrastructures are particularly important because of the functions or services they provide to our country. Our critical infrastructures are also particularly important because they are complex systems: the effects of a terrorist attack can spread far beyond the direct target, and reverberate long after the immediate damage.

America's critical infrastructure encompasses a large number of sectors. Our agriculture, food, and water sectors, along with the public health and emergency services sectors, provide the essential goods and services Americans need to survive. Our institutions of government guarantee our national security and freedom, and administer key public functions.

Our defense industrial base provides essential capabilities to help safeguard our population from external threats. Our information and telecommunications sector enables economic productivity and growth, and is particularly important because it connects and helps control many other infrastructure sectors. Our utilities, transportation, banking and finance, chemical industry, and postal and shipping sectors help sustain our economy and touch the lives of Americans every day.

The assets, functions, and systems within each critical infrastructure sector are not equally important. The transportation sector is vital, but not every bridge is critical to the Nation as a whole. Accordingly, the federal government will apply a consistent methodology to focus its effort on the highest priorities, and the federal budget will differentiate resources required for critical infrastructure protection from resources required for other important protection activities.

The federal government will work closely with state and local governments to develop and apply compatible approaches to ensure protection for critical assets, systems, and functions at all levels of society. For example, utilities, local schools, courthouses, and bridges are critical to the communities they serve.

Protecting America's critical infrastructure and key assets requires more than just resources. The federal government can use a broad range of measures to help enable state, local, and private sector entities to better protect the assets and infrastructures they control. For example, the government can create venues to share information on infrastructure vulnerabilities and best-practice solutions, or create a more effective means of providing specific and useful threat information to non-federal entities in a timely fashion.

A ticking time bomb, all it needs is a Terrorist to set the fuse. A possible diversion? A possible "*Sucker Punch*"?

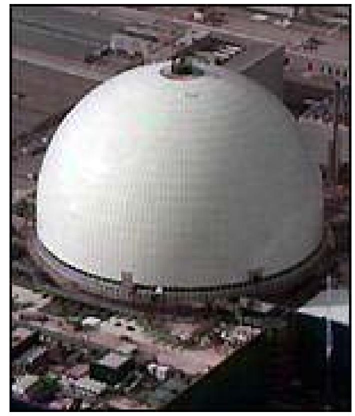
Ever thought about the access Trash Collection or Delivery Vehicles have and the potential for Terrorist to use these trucks for a bomb or to sneak into your facility?

The Secret Service will shut down and search Routine Delivery and Sanitation Trucks within a 5 mile area when the President is in the area. They create a wall of steel to protect the President.

How about the security at your facility? Is it an elderly or unskilled person? Is there a real live person? In most cases, it is an unskilled or uneducated person who may have a criminal background. Think about the importance of a background check and reference checks.

Critical Infrastructure Sectors

- ✓ **Agriculture**
- ✓ **Food**
- ✓ **Water**
- ✓ **Public Health**
- ✓ **Emergency Services**
- ✓ **Government**
- ✓ **Defense Industrial Base**
- ✓ **Information and Telecommunications**
- ✓ **Energy**
- ✓ **Transportation**
- ✓ **Banking and Finance**
- ✓ **Chemical Industry**
- ✓ **Postal and Shipping**



Nuclear Plant

Major Initiatives

Unify America's infrastructure protection effort in the Department of Homeland Security. Our country requires a single accountable official to ensure we address vulnerabilities that involve more than one infrastructure sector or require action by more than one agency.

Our country also requires a single accountable official to assess threats and vulnerabilities comprehensively across all infrastructure sectors to ensure we reduce the overall risk to our country, instead of inadvertently shifting risk from one potential set of targets to another.

The Department of Homeland Security will assume responsibility for integrating and coordinating federal infra-structure protection responsibilities.

The Department of Homeland Security would consolidate and focus the activities performed by the Critical Infrastructure Assurance Office (currently part of the Department of Commerce) and the National Infrastructure Protection Center (FBI), less those portions that investigate computer crime.

The Department would augment those capabilities with the Federal Computer Incident Response Center (General Services Administration), the Computer Security Division of the National Institute of Standards and Technology (Commerce), and the National Communications System (Defense).

The Department of Homeland Security would also unify the responsibility for coordinating cyber and physical infrastructure protection efforts.

Currently, the federal government divides responsibility for cyber and physical infrastructure, and key cyber security activities are scattered in multiple departments.

While securing cyberspace poses unique challenges and issues, requiring unique tools and solutions, our physical and cyber infrastructures are interconnected.

The devices that control our physical systems, including our electrical distribution system, transportation systems, dams, and other important infrastructure, are increasingly connected to the Internet.

Thus, the consequences of an attack on our cyber infrastructure can cascade across many sectors. Moreover, the number, virulence, and maliciousness of cyber-attacks have increased dramatically in recent years.

Hoover Dam

If your water comes from surface water or impounded water, are you prepared for a water shortage or catastrophic flood from a levee or dam break?

Have you wondered why they built and bridge over the dam?

Vulnerability Statements, *Memorize these statements for your exam.*

Superfund Amendments and Reauthorization Act (SARA), Title II federal legislation requires water and wastewater systems to inform local emergency response agencies about hazardous chemicals used and stored on site. Always store your toxic and hazardous wastes in a secure area.

The USEPA Response Protocol Tool Box is a planning tool used for emergency response.

An emergency response plan for a treatment facility should be specific for the facility and be updated on an annual basis. Your critical customer list should be updated on a quarterly basis.

Completed security vulnerability assessments (VAs) and emergency response plans (ERPs) for your treatment or utility systems should be distributed to personnel with a "need to know" only. You do not need to share this information with the public.

Preparedness, Response, Recovery, and Mitigation are the four phases of emergency management that should be addressed in emergency response plans. Preparing emergency response plans for water- wastewater systems is part of the Preparedness phase of emergency management, so is stockpiling supplies, equipment and other resources to be used in the event of an emergency. Actions taken to prevent an emergency or to lessen the harmful effects of an emergency are part of the Mitigation phase of emergency management. Initial actions taken during an emergency or disaster are part of the Response phase of emergency management. The threat management process consists of two parallel activities--threat evaluation and response decisions.

The **Incident Command System** should be utilized as a model tool for command, control and coordination of an emergency response to a public crisis. The most important part of an emergency is public notification. It is essential to assign one spokesperson to oversee this task as well as dissemination of information to the public.

Involve all of your employees in the security program in a positive manner. This is an advantage of a security awareness program.

There are three FEMA classifications of emergencies and disasters; natural, technological, and national security. The difference between an emergency and a disaster is that a disaster requires outside governmental assistance.

Protection of personnel, protection of the public, and mitigation procedures are priorities when training personnel to respond to hazardous materials released to the collection system or treatment works.

From a security perspective, deliveries of chemicals and other supplies should be performed in the presence of utilities system personnel. Always verify the credentials of all delivery drivers and check the manifest before allowing vendor or contractor personnel unescorted access to a utility’s facilities.

The utility may want to adopt a policy that requires vendors to have an employee screening process. This security process may increase the cost of the services that the vendor is providing for your facility.

Detection and deterrence at your facility will improve after installing a new closed circuit TV (CCTV) around your treatment plant's perimeter fencing and additional lighting to meet the camera's lumen requirement. Remember detection and deterrence! Remove any debris that may be utilized to gain unlawful access to your facility too. Always trim bushes and other vegetation to see critical components.

Emergency back-up power generators for treatment facilities should be tested under load at least monthly.

In case your computer is damaged or suffers from a hacker attack, it is a good idea to regularly copy critical data on backup tapes or disks and store them at a secure, off-site location. Never connect your SCADA system to the Internet.

The least secure computer is a wireless computer; and the most secure system is a hard-wired system. We have seen that most cities have removed wireless systems from their networks.

Scenario:
An operator has discovered that a lock was cut from the opening of an utility system's storage tank. Until the incident is confirmed, a good business practice is to treat this type of security breach as a potential contamination threat.

Elevating the threat evaluation stage without definitive analytical data should be based on a preponderance of evidence such as a security breach, along with signs of contamination and abnormal test results. You should have an on-line monitor in a distribution system that detects an unexpected change in pH and chlorine residual.

This activity may indicate an early warning of possible contamination. If there is a contamination incident of a water supply. Water flow analysis, hydraulic modeling, areas of customer complaints, and field analysis are methods of estimating the spread.

Security Examination

Answers in rear.

1. What document assigns specific responsibilities to individuals and teams to take actions other than their normal required duties?

2. Which of the following is most useful in a water emergency?

3. At a minimum, how often should an emergency response plan be updated?

4. What is the term for a systematic process for evaluating the susceptibility of critical facilities to potential threats and identifying corrective actions that can reduce or mitigate the risk of serious consequences associated with these threats?

5. What document describes the actions that a waterworks would enact during disasters or other unexpected incidents?

6. Hazardous chemicals should be separated from other chemicals and stored in a designated area that is?

7. Often utility vehicles contain schematics, maps, and other sensitive documents. How do you protect these sensitive documents before parking the vehicle at the end of the day?

8. Placing devices to keep an individual from pumping contaminants from residential, industrial, and commercial customer sites or other access points, such as fire hydrants, into the distribution system network is known as?

9. Because the signal is transmitted directly to the receiver and not over the air, which of the following best describes hardwired surveillance systems' susceptibility to a cyber-attack?

10. A means of quickly notifying the public residing in the affected area of a “Do Not Drink” notice resulting from a health hazard in the water supply is?

11. Vegetation around the perimeter of water facilities needs to be?

12. Name an important step involved in conducting a vulnerability assessment?

13. In a plot to contaminate drinking water, microbial agents might be used because the contaminants?

14. It is important to have prepared a contact list of critical customers, like hospitals, in case you need to?

15. What is the most reliable means of confirming a water contamination incident?

16. What is one of a system's primary concerns in a contamination event?

17. How should customers and the public be notified of health hazards caused by the disruption of water treatment?

18. What is the most effective way to disseminate information to the public in the event of an emergency?

19. Adequate lighting around a distribution system's perimeter fencing may result in deterrence and?

Security Examination Answers

1. Emergency response plan
2. Sources of alternative water supplies
3. Annually
4. Vulnerability assessment
5. Emergency response plan
6. Secure with restricted access
7. Any critical information should be removed
8. Backflow prevention
9. More secure than wireless systems
10. Broadcast phone or “reverse 911” messages
11. Should be evaluated to minimize vulnerability
12. Determine against what type of assailants and threats you are trying to protect
13. Are extremely difficult to detect
14. Form a stakeholder committee
15. Analytical confirmation
16. Public notification
17. By the fastest means available
18. Designate one spokesperson for the system
19. Recovery

EPA Rules Chapter 2 *Memorize this section for your exam* *

Arsenic (As) *
Arsenic is a chemical that occurs naturally in the earth's crust. When rocks, minerals, and soil erode, they release arsenic into water supplies. When people either drink this water or eat animals and plants that drink it, they are exposed to arsenic. For most people in the U.S., eating and drinking are the most common ways that people are exposed to arsenic, although it can also come from industrial sources. Studies have linked long-term exposure of arsenic in drinking water to a variety of cancers in humans.

To protect human health, an EPA standard limits the amount of arsenic in drinking water. In January 2001, the EPA revised the standard from 50 parts per billion (**ppb**), ordering that it fall to 10 ppb by 2006. After adopting 10ppb as the new standard for arsenic in drinking water, the EPA decided to review the decision to ensure that the final standard was based on sound science and accurate estimates of costs and benefits.

ICR, *Know this section for exam.*
The EPA has collected data required by the Information Collection Rule (**ICR**) ***** to support future regulation of microbial contaminants, disinfectants, and disinfection byproducts. The rule is intended to provide EPA with information on chemical byproducts that form when disinfectants used for microbial control react with chemicals already present in source water (disinfection byproducts (**DBPs**)); disease-causing microorganisms (pathogens), including Cryptosporidium; and engineering data to control these contaminants.

***Disinfection byproducts** are formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter (i.e., decaying vegetation) present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts for which regulations have been established have been identified in drinking water, including trihalomethanes, haloacetic acids, bromate, and chlorite.

****Memorize this section for exam.***
***Trihalomethanes** (**THM**) are a group of four chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The trihalomethanes are chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

Chlorite is a byproduct formed when chlorine dioxide is used to disinfect water. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate chlorite at a monthly average level of 1 part per million in drinking water. This standard became effective for large surface water public water systems in December 2001 and small surface water and all ground water public water systems in December 2003.

Microbial Regulations, *Memorize this section for exam.*
One of the key regulations developed and implemented by the United States Environmental Protection Agency (**USEPA**) to counter pathogens in drinking water is the **Surface Water Treatment Rule***. Among its provisions, the rule requires that a public water system, using surface water (or ground water under the direct influence of surface water) as its source, have sufficient treatment to reduce the source water concentration of ***Giardia*** and viruses by at least 99.9% and 99.99%, respectively. The Surface Water Treatment Rule specifies treatment criteria to assure that these performance requirements are met; they include turbidity limits, disinfectant residual and disinfectant contact time conditions.

*Turbidity is an indicator of the physical removal of particulates, including pathogens.

Disinfection Rules Stages 1 & 2 DBPR

The following are EPA's federal rule requirements. Please be aware that each state implements drinking water regulations that may be more stringent than EPA's regulations. Check with your state environmental agency for more information.

Stage 2 DBPR

EPA finalized the Stage 2 Disinfectants and Disinfection Byproduct Rule (DBPR) to reduce potential health risks from DBPs. The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) is being finalized and implemented at the same time as the Stage 2 DBPR to ensure that drinking water is safe from both microbial pathogens and DBPs.

General Requirements

To comply with the Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR), published on January 4, 2006 (71 FR 388) systems must do the following:

• **Conduct an Initial Distribution System Evaluation (IDSE)** to find locations in the distribution system that have high levels of TTHM and HAA5 and that can be used as compliance monitoring sites for the Stage 2 DBPR.

• **Use a locational running annual average (LRAA) calculation to determine compliance** with the Stage 2 DBPR maximum contaminant levels (MCLs) of:

– 0.080 mg/L for total trihalomethanes (TTHM), and

– 0.060 mg/L for five haloacetic acids (HAA5).

Note: The MCL values are the same as the Stage 1 MCLs; only the calculation method changes.

Compliance Timeline

Your compliance schedule for the Stage 2 DBPR are based on whether your system is part of a *combined distribution system*:

• If your system **is** part of a combined distribution system, you must comply with the revised MCLs by the same date as required for the largest system in your combined distribution system.

Example: if your system serves 8,000 people, but you purchase water from a system that serves 250,000 people, you must comply by the dates shown in Schedule 1.
• If your system **is not** part of a combined distribution system, compliance dates are based on the population served by your system.

If you are using this guidance manual, you likely serve fewer than 10,000 people and you must comply by the dates shown in Schedule 4.

Note: You are on the same schedule for Stage 2 DBPR compliance as you were on for the IDSE.
The timeline on the next page shows important dates for the Stage 2 DBPR as well as periods for *Cryptosporidium* and *E. coli* required under the LT2ESWTR.

Note: The figure shows the 2-year period after systems must begin compliance as a "possible extension." States may give you up to an additional 2 years to comply if you need time to install capital improvements.

How Does this Rule Relate to Other Federal, State, and Local Requirements?
As noted earlier, the Stage 2 DBPR is an extension of the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR). The Stage 2 DBPR and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) were published together to address the balance between protection from microbial pathogens and the potential health effects from disinfectants and their byproducts. You are still required to continue to meet all existing federal requirements. You may call the Safe Drinking Water Hotline at (800) 426-4791 (e-mail: hotline-sdwa@epa.gov) for more information on other drinking water rules.

Where do DBPs come from?
Chlorine and other chemical disinfectants have been widely used by public water systems (along with filtration) to protect the public from microbial pathogens in drinking water. DBPs are formed when certain disinfectants react with DBP precursors (organic and inorganic materials) in source waters.

In most cases, natural organic matter (NOM) is an important factor that affects the levels of DBPs that form (NOM is usually measured as TOC). The levels of DBPs in drinking water can vary significantly from one point in a distribution system to another, as many continue to form in the distribution system. DBP levels are generally higher in surface water systems because surface water usually contains higher DBP precursor levels and requires stronger disinfection.

Ensuring Safe Drinking Water
All drinking water systems want to provide water that is safe. One aspect of providing safe drinking water is limiting the levels of DBPs in it. Long-term exposure to DBPs has been linked to bladder cancer, and possibly colon and rectal cancers. More recent studies have shown that shorter-term exposure to high levels of DBPs may be associated with adverse reproductive and developmental health effects.

Limiting the levels of DBPs in your drinking water may require you to make some adjustments to your current operations, such as:
• Making operational improvements at the plant or in the distribution system • Modifying current treatment operations to remove more DBP precursors or form lower levels of DBPs
• Upgrading or installing a new treatment technology

What Does Compliance Monitoring Involve?
Monitoring requirements for TTHM and HAA5 are based on your source water type and the population your system serves. Note that this is different than the Stage 1 DBPR monitoring requirements that were based on the number of treatment plants in your system.

With population-based monitoring, there are five categories of small systems under the Stage 2 DBPR:

• Subpart H systems that serve fewer than 500 people.
• Subpart H systems that serve 500 to 3,300 people.
• Subpart H systems that serve 3,301 to 9,999 people.
• Ground water systems that serve fewer than 500 people.
• Ground water systems that serve 500 to 9,999 people.

If you do not know what type of system you are, you should contact your State to confirm this information.

Older Stage 1 DBPR Information

Disinfection Byproduct Regulations

In December 1998, the EPA established the Stage 1 Disinfectants/Disinfection Byproducts Rule that requires public water systems to use treatment measures to reduce the formation of disinfection byproducts and to meet the following specific standards:

Total Trihalomethanes (TTHM)	80 parts per billion (ppb)
Haloacetic Acids (HAA5)	60 ppb
Bromate	10 ppb
Chlorite	1.0 parts per million (ppm)

Trihalomethanes were regulated at a maximum allowable annual average level of 100 parts per billion for water systems serving over 10,000 people under the Total Trihalomethane Rule finalized by the EPA in 1979. The Stage 1 Disinfectant/Disinfection Byproduct Rule standards became effective for trihalomethanes and other disinfection byproducts listed above in December 2001 for large surface water public water systems. Those standards became effective in December 2003 for small surface water and all ground water public water systems.

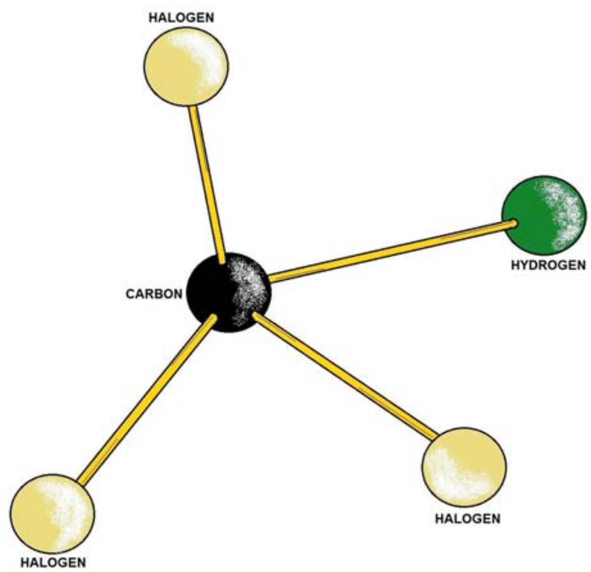
Disinfection byproducts are formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter (i.e., decaying vegetation) present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts for which regulations have been established have been identified in drinking water, including trihalomethanes, haloacetic acids, bromate, and chlorite.

Trihalomethanes (**THM**) are a group of four chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The trihalomethanes are chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The EPA has published the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate total trihalomethanes (TTHM) at a maximum allowable annual average level of 80 parts per billion. This new standard replaced the old standard of a maximum allowable annual average level of 100 parts per billion back in December 2001 for large surface water public water systems.

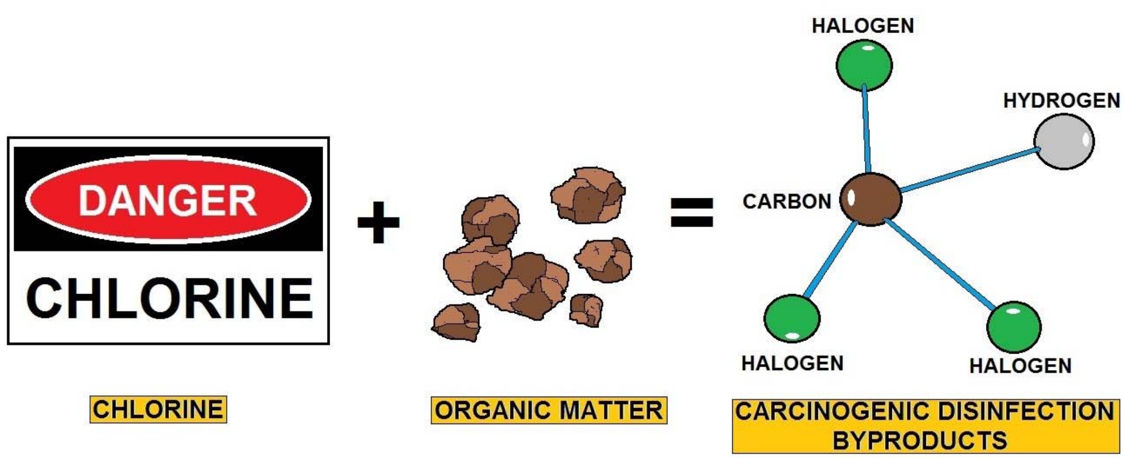
The standard became effective for the first time back in December 2003 for small surface water and all ground water systems.

Haloacetic Acids (**HAA5**) are a group of chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The regulated haloacetic acids, known as HAA5, are: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid. EPA has published the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate HAA5 at 60 parts per billion annual average.

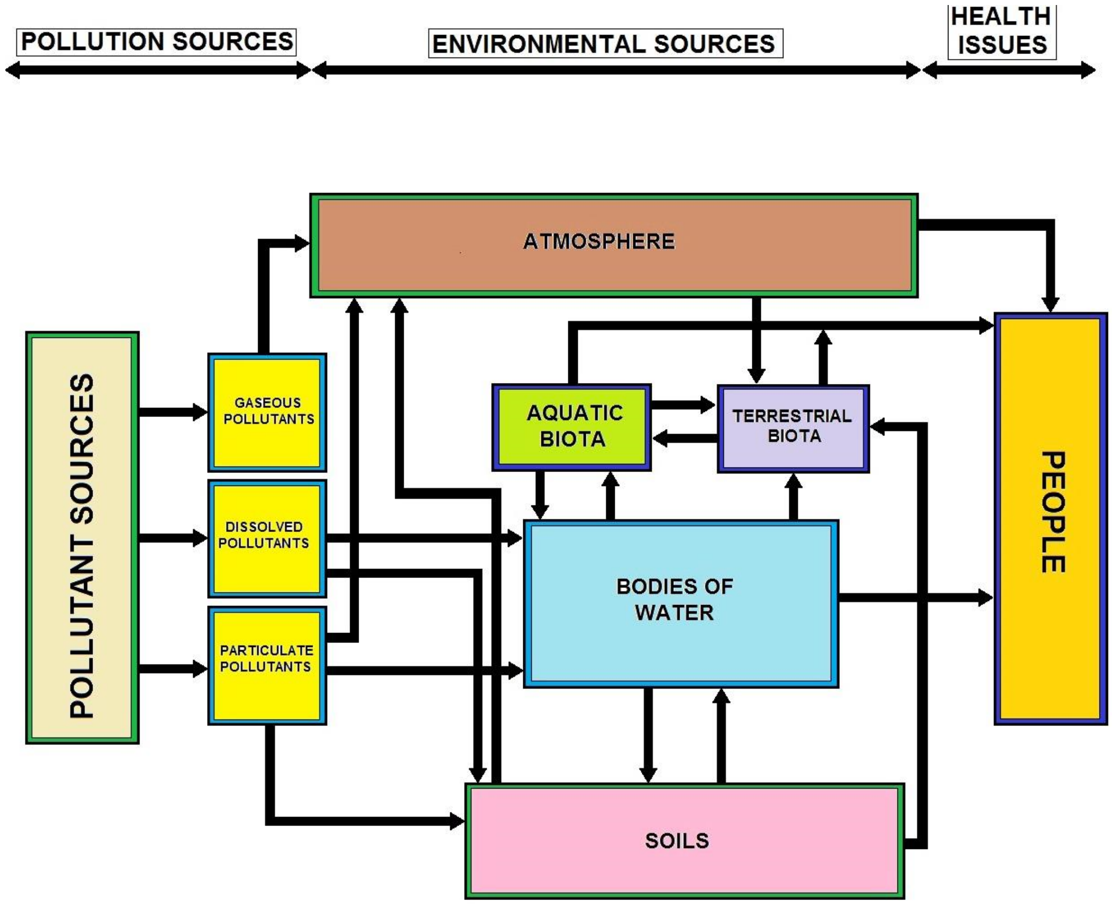
This standard became effective for large surface water public water systems back in December 2001 and for small surface water and all ground water public water systems back in December 2003.



TRIHALOMETHANE
(THM'S)



DISINFECTION BYPRODUCT PRODUCTION DIAGRAM



WATER QUALITY INDICATORS

Revised Total Coliform Rule (RTCR)

The following are EPA's federal rule requirements. Please be aware that each state implements drinking water regulations that may be more stringent than EPA's regulations. Check with your state environmental agency for more information.

EPA published the Revised Total Coliform Rule (RTCR) in the Federal Register (FR) on February 13, 2013 (78 FR 10269). It is the revision to the 1989 Total Coliform Rule (TCR).

Why revise the 1989 TCR?
The 1996 amendments to the Safe Drinking Water Act [Section 1412(b) (9)] require the Administrator to review and revise, as appropriate, each national primary drinking water regulation not less often that every six years. EPA published its decision to revise the TCR in July 2003 as part of its National Primary Drinking Water Regulation (NPDWR) review.

The RTCR:

- Upholds the purpose of the 1989 TCR to protect public health by ensuring the integrity of the drinking water distribution system and monitoring for the presence of microbial contamination.
- Requires public water systems (PWSs) to meet a legal limit for E. coli, as demonstrated by required monitoring.
- Specifies the frequency and timing of required microbial testing based on population served, public water system type and source water type: ground water or surface water.

When must PWSs comply with the RTCR requirements?
Unless a State determines an earlier effective date, all PWSs must comply with the RTCR requirements starting April 1, 2016. All PWSs include:

- Community Water Systems (CWSs),
- Non-Transient Non-Community Water Systems (NTNCWSs), and
- Transient Non-Community Water Systems (TNCWSs).

Minor Corrections to the Revised Total Coliform Rule (RTCR)
Minor corrections to the final RTCR became effective on April 28, 2014. No comments were received on the Direct Final Rule published on February 26, 2014 and the corrections therefore became effective without further notice. See the **Direct Final Rule** Federal Register Notice.

Revised Total Coliform Rule (RTCR) – Final Rule
On February 13, 2013, EPA published in the Federal Register the revisions to the 1989 TCR. EPA anticipates greater public health protection under the Revised Total Coliform Rule (RTCR) requirements. The RTCR:

- Requires public water systems that are vulnerable to microbial contamination to identify and fix problems; and
- Establishes criteria for systems to qualify for and stay on reduced monitoring, which could reduce water system burden and provide incentives for better system operation.

Public water systems (PWSs) and primacy agencies must comply with the revised requirements by April, 2016. Until then, PWSs and primacy agencies must continue complying with the 1989 TCR.

What are the key provisions PWSs must comply with under the RTCR?

Provision Category	**Key Provisions**
Contaminant Level	• Addresses the presence of total coliforms and E. coli in drinking water. • For E. coli (EC), the Maximum Contaminant Level Goal (MCLG) is set at zero and the Maximum Contaminant Level (MCL) is based on the occurrence of a condition that includes routine and repeat samples. • For total coliforms (TC), PWSs must conduct a Level 1 or Level 2 assessment of their system when they exceed a specified frequency of total coliform occurrence. Other events such as an MCL violation or failure to take repeat samples following a routine total coliform-positive sample will also trigger an assessment. Any sanitary defects identified during an assessment must be corrected by the PWS. These are the treatment technique requirements of the RTCR.
Monitoring	• Develop and follow a sample siting plan that designates the PWS's collection schedule and location of routine and repeat water samples. • Collect routine water samples on a regular basis (monthly, quarterly, annually) and have them tested for the presence of total coliforms by a state certified laboratory. • Analyze all routine or repeat samples that are total coliform positive (TC+) for E. coli. • Collect repeat samples (at least 3) for each TC+ positive routine sample. • For PWSs on quarterly or annual routine sampling, collect additional routine samples (at least 3) in the month after a TC+ routine or repeat sample. • Seasonal systems must monitor and certify the completion of a state-approved start-up procedures
Level 1 and Level 2 Assessments and Corrective Actions	• PWSs are required to conduct a Level 1 or Level 2 assessment if certain conditions indicate that they might be vulnerable to contamination, and fix any sanitary defects within a required timeframe.
Reporting and Recordkeeping	• PWSs are required to report certain items to their states. These reporting and recordkeeping requirements are essentially the same as under TCR with the addition of Level 1 and Level 2 requirements.

Violations, Public Notification (PN) and Consumer Confidence Report (CCR)	• PWSs incur violations if they do not comply with the requirements of the RTCR. The violation types are essentially the same as under the TCR with few changes. The biggest change is no acute or monthly MCL violation for total coliform positive samples only. • PN is required for violations incurred. Within required timeframes, the PWS must use the required health effects language and notify the public if they did not comply with certain requirements of the RTCR. The type of PN depends on the severity of the violation. • Community water systems (CWSs) must use specific language in their CCRs when they must conduct an assessment or if they incur an E. coli MCL violation.

More on the Current Stage 2 DBP Rule

The following are EPA's federal rule requirements. Please be aware that each state implements drinking water regulations that may be more stringent than EPA's regulations. Check with your state environmental agency for more information.

The Stage 2 DBP rule is one part of the Microbial and Disinfection Byproducts Rules (MDBPs), which are a set of interrelated regulations that address risks from microbial pathogens and disinfectants/disinfection byproducts.

The Stage 2 DBP rule focuses on public health protection by limiting exposure to DBPs, specifically total trihalomethanes (TTHM) and five haloacetic acids (HAA5), which can form in water through disinfectants used to control microbial pathogens. This rule will apply to all community water systems and nontransient noncommunity water systems that add a primary or residual disinfectant other than ultraviolet (UV) light or deliver water that has been disinfected by a primary or residual disinfectant other than UV.

Amendments to the SDWA in 1996 require EPA to develop rules to balance the risks between microbial pathogens and disinfection byproducts (DBPs). The Stage 1 Disinfectants and Disinfection Byproducts Rule and Interim Enhanced Surface Water Treatment Rule, promulgated in December 1998, were the first phase in a rulemaking strategy required by Congress as part of the 1996 Amendments to the Safe Drinking Water Act.

The Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR) builds upon the Stage 1 DBPR to address higher risk public water systems for protection measures beyond those required for existing regulations. The Stage 2 DBPR and the Long Term 2 Enhanced Surface Water Treatment Rule are the second phase of rules required by Congress. These rules strengthen protection against microbial contaminants, especially *Cryptosporidium*, and at the same time, reduce potential health risks of DBPs.

What is the Stage 2 DBPR?

The Stage 2 Disinfection Byproducts Rule will reduce potential cancer and reproductive and developmental health risks from disinfection byproducts (DBPs) in drinking water, which form when disinfectants are used to control microbial pathogens. Over 260 million individuals are exposed to DBPs.

This final rule strengthens public health protection for customers by tightening compliance monitoring requirements for two groups of DBPs, trihalomethanes (TTHM) and haloacetic acids (HAA5). The rule targets systems with the greatest risk and builds incrementally on existing rules. This regulation will reduce DBP exposure and related potential health risks and provide more equitable public health protection. The Stage 2 DBPR is being promulgated simultaneously with the Long Term 2 Enhanced Surface Water Treatment Rule to address concerns about risk tradeoffs between pathogens and DBPs.

What does the rule require?

Under the Stage 2 DBPR, systems will conduct an evaluation of their distribution systems, known as an Initial Distribution System Evaluation (IDSE), to identify the locations with high disinfection byproduct concentrations. These locations will then be used by the systems as the sampling sites for Stage 2 DBPR compliance monitoring. Compliance with the maximum contaminant levels for two groups of disinfection byproducts (TTHM and HAA5) will be calculated for each monitoring location in the distribution system. This approach, referred to as the locational running annual average (LRAA), differs from current requirements, which determine compliance by calculating the running annual average of samples from all monitoring locations across the system.

The Stage 2 DBPR also requires each system to determine if they have exceeded an operational evaluation level, which is identified using their compliance monitoring results. The operational evaluation level provides an early warning of possible future MCL violations, which allows the system to take proactive steps to remain in compliance.

A system that exceeds an operational evaluation level is required to review their operational practices and submit a report to their state that identifies actions that may be taken to mitigate future high DBP levels, particularly those that may jeopardize their compliance with the DBP MCLs.

Who must comply with the rule?

Entities potentially regulated by the Stage 2 DBPR are community and nontransient noncommunity water systems that produce and/or deliver water that is treated with a primary or residual disinfectant other than ultraviolet light.

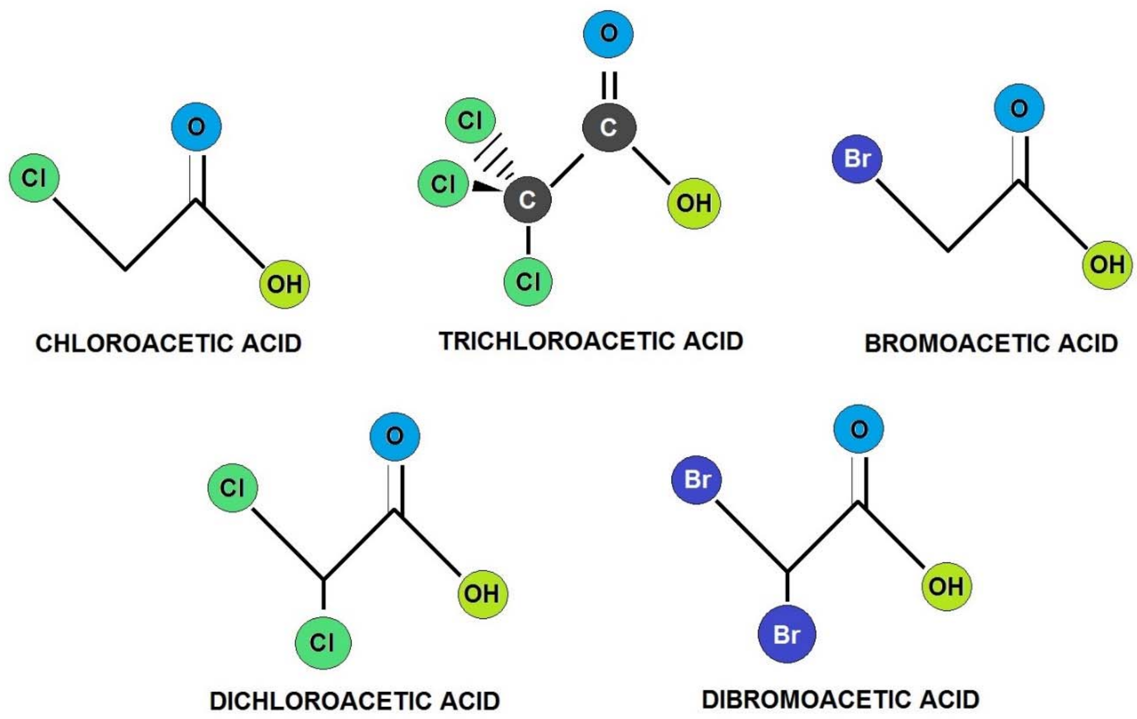
A community water system (CWS) is a public water system that serves year-round residents of a community, subdivision, or mobile home park that has at least 15 service connections or an average of at least 25 residents.

A nontransient noncommunity water system (NTNCWS) is a water system that serves at least 25 of the same people more than six months of the year, but not as primary residence, such as schools, businesses, and day care facilities.

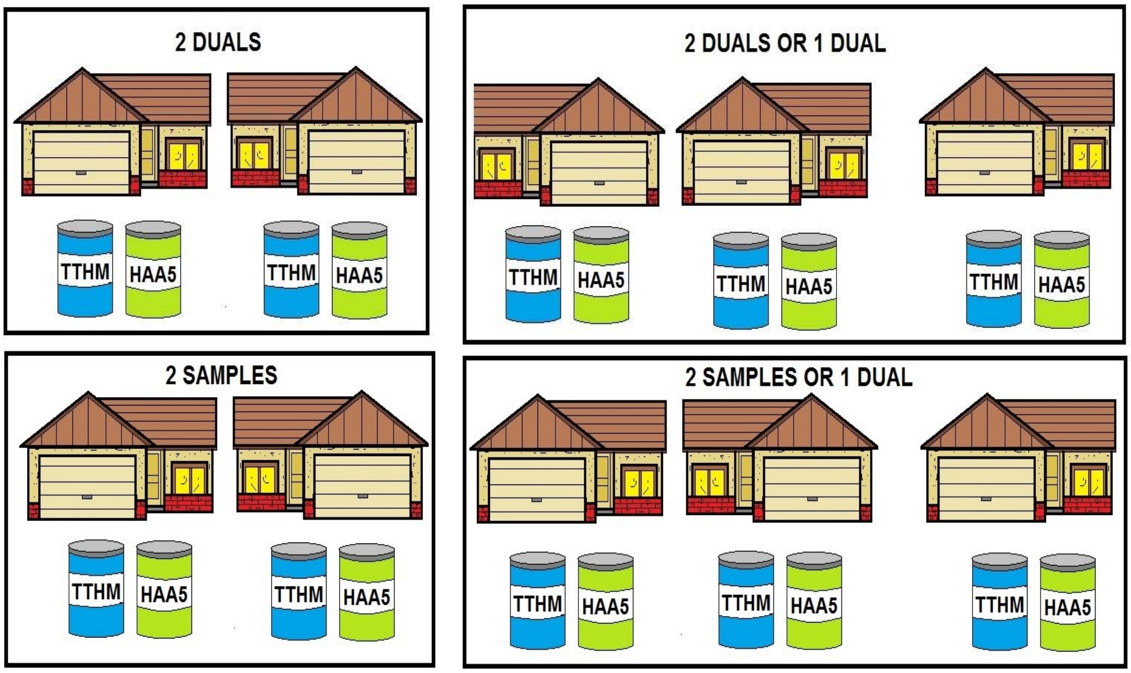
What are disinfection byproducts (DBPs)?
Disinfectants are an essential element of drinking water treatment because of the barrier they provide against waterborne disease-causing microorganisms. Disinfection byproducts (DBPs) form when disinfectants used to treat drinking water react with naturally occurring materials in the water (e.g., decomposing plant material).

Total trihalomethanes (TTHM - chloroform, bromoform, bromodichloromethane, and dibromochloromethane) and haloacetic acids (HAA5 - monochloro-, dichloro-, trichloro-, monobromo-, dibromo-) are widely occurring classes of DBPs formed during disinfection with chlorine and chloramine. The amount of trihalomethanes and haloacetic acids in drinking water can change from day to day, depending on the season, water temperature, amount of disinfectant added, the amount of plant material in the water, and a variety of other factors.

Are THMs and HAAs the only disinfection byproducts?
No. The four THMs (TTHM) and five HAAs (HAA5) measured and regulated in the Stage 2 DBPR act as indicators for DBP occurrence. There are many other known DBPs, in addition to the possibility of unidentified DBPs present in disinfected water. THMs and HAAs typically occur at higher levels than other known and unknown DBPs. The presence of TTHM and HAA5 is representative of the occurrence of many other chlorination DBPs; thus, a reduction in the TTHM and HAA5 generally indicates a reduction of DBPs from chlorination.



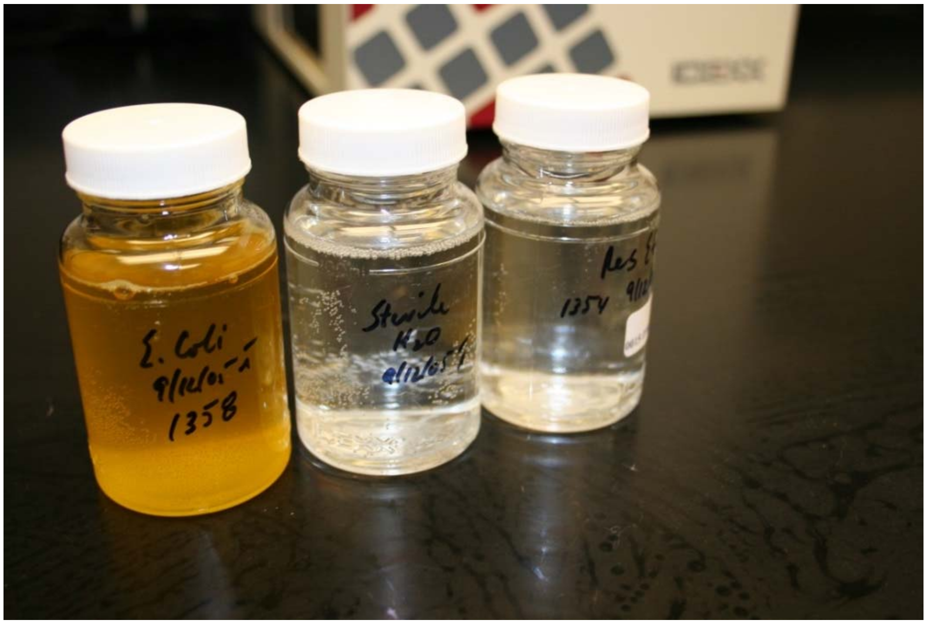
HALOACETIC ACIDS (HAA5)



STAGE 2 DISINFECTION BYPRODUCT RULE

Microbes

Coliform bacteria are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can cause disease.



Fecal Coliform and E coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause short-term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms.

Cryptosporidium is a parasite that enters lakes and rivers through sewage and animal waste. It causes cryptosporidiosis, a mild gastrointestinal disease. However, the disease can be severe or fatal for people with severely weakened immune systems. The EPA and CDC have prepared advice for those with severely compromised immune systems who are concerned about *Cryptosporidium*.

Giardia lamblia is a parasite that enters lakes and rivers through sewage and animal waste. It causes gastrointestinal illness (e.g. diarrhea, vomiting, and cramps).

Radionuclides
Alpha emitters. Certain minerals are radioactive and may emit a form of radiation known as alpha radiation. Some people who drink water containing alpha emitters in excess of EPA standards over many years may have an increased risk of getting cancer.

Beta/photon emitters. Certain minerals are radioactive and may emit forms of radiation known as photons and beta radiation. Some people who drink water containing beta and photon emitters in excess of EPA standards over many years may have an increased risk of getting cancer.

Combined Radium 226/228. Some people who drink water containing radium 226 or 228 in excess of EPA standards over many years may have an increased risk of getting cancer.

Radon gas can dissolve and accumulate in underground water sources, such as wells, and in the air in your home. Breathing radon can cause lung cancer. Drinking water containing radon presents a risk of developing cancer. Radon in air is more dangerous than radon in water.

Inorganic Contaminants

Antimony	Cadmium	Cyanide	Nitrite
Asbestos	Chromium	Mercury	Selenium
Barium	Copper	Nitrate	Thallium
Beryllium			

***Arsenic.** Some people who drink water containing arsenic in excess of EPA standards over many years could experience skin damage or problems with their circulatory system, and may have an increased risk of getting cancer.

*** Fluoride.** ***Memorize this section for exam.*** Many communities add fluoride to their drinking water to promote dental health. Each community makes its own decision about whether or not to add fluoride. The EPA has set an enforceable drinking water standard for fluoride of 4 mg/L (some people who drink water containing fluoride in excess of this level over many years could get bone disease, including pain and tenderness of the bones). The EPA has also set a secondary fluoride standard of 2 mg/L to protect against dental fluorosis. Dental fluorosis, in its moderate or severe forms, may result in a brown staining and/or pitting of the permanent teeth. This problem occurs only in developing teeth, before they erupt from the gums. Children under nine should not drink water that has more than 2 mg/L of fluoride. Know the different types of Fluorides.

Lead typically leaches into water from plumbing in older buildings. Lead pipes and plumbing fittings have been banned since August 1998. Children and pregnant women are most susceptible to lead health risks.

Synthetic Organic Contaminants (SOCs), including pesticides & herbicides

2,4-D	Dibromochloropropane	Hexachlorobenzene
2,4,5-TP (Silvex)	Dinoseb	Hexachlorocyclopentadiene
Acrylamide	Dioxin (2,3,7,8-TCDD)	Lindane
Alachlor	Diquat	Methoxychlor
Atrazine	Endothall	Oxamyl [Vydate]
Benzoapyrene	Endrin	PCBs [Polychlorinated biphenyls]
Carbofuran	Epichlorohydrin	Pentachlorophenol
Chlordane	Ethylene dibromide	Picloram
Dalapon	Glyphosate	Simazine
Di 2-ethylhexyl adipate	Heptachlor	Toxaphene
Di 2-ethylhexyl phthalate	Heptachlor epoxide	

National Primary Drinking Water Regulations

Inorganic Chemicals	MCLG [1] (mg/L) [4]	MCL [2] or TT [3] (mg/L) [4]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood glucose	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0.01[5]	0.010	Skin damage; circulatory system problems; increased risk of cancer	Discharge from semiconductor manufacturing; petroleum refining; wood preservatives; animal feed additives; herbicides; erosion of natural deposits
Asbestos (fiber >10 micrometers)	7 million fibers per Liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Some people who use water containing chromium well in excess of the MCL over many years could experience allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	Action Level=1.3; TT[6]	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. Those with Wilson's Disease should consult their personal doctor if their water systems exceed the copper action level.	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth.	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	Action Level=0.015; TT[6]	Infants and children: Delays in physical or mental development. Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits

Inorganic Mercury	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and cropland
Nitrate (measured as Nitrogen)	10	10	"Blue baby syndrome" in infants under six months - life threatening without immediate medical attention. Symptoms: Infant looks blue and has shortness of breath.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as Nitrogen)	1	1	"Blue baby syndrome" in infants under six months - life threatening without immediate medical attention. Symptoms: Infant looks blue and has shortness of breath.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and pharmaceutical companies

Organic Chemicals	**MCLG [1] (mg/L) [4]**	**MCL[2] or TT[3] (mg/L) [4]**	**Potential Health Effects from Ingestion of Water**	**Sources of Contaminant in Drinking Water**
Acrylamide	zero	TT[7]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system problems; reproductive difficulties	Runoff from herbicide used on row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood or nervous system; reproductive difficulties.	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharger from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops

Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1-1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-1, 2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from pharmaceutical and chemical factories
1-2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl)adipate	0.4	0.4	General toxic effects or reproductive difficulties	Leaching from PVC plumbing systems; discharge from chemical factories
Di(2-ethylhexyl)phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Nervous system effects	Residue of banned insecticide
Epichlorohydrin	zero	TT[7]	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from industrial chemical factories; added to water during treatment process
Ethylbenzene	0.7	0.7	Liver or kidney problems	Discharge from petroleum refineries
Ethelyne dibromide	zero	0.00005	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of hepatachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens

Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased risk of cancer	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, and circulatory problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Total Trihalomethanes (TTHMs)	none[5]	0.10	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.20	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from petroleum refineries
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories

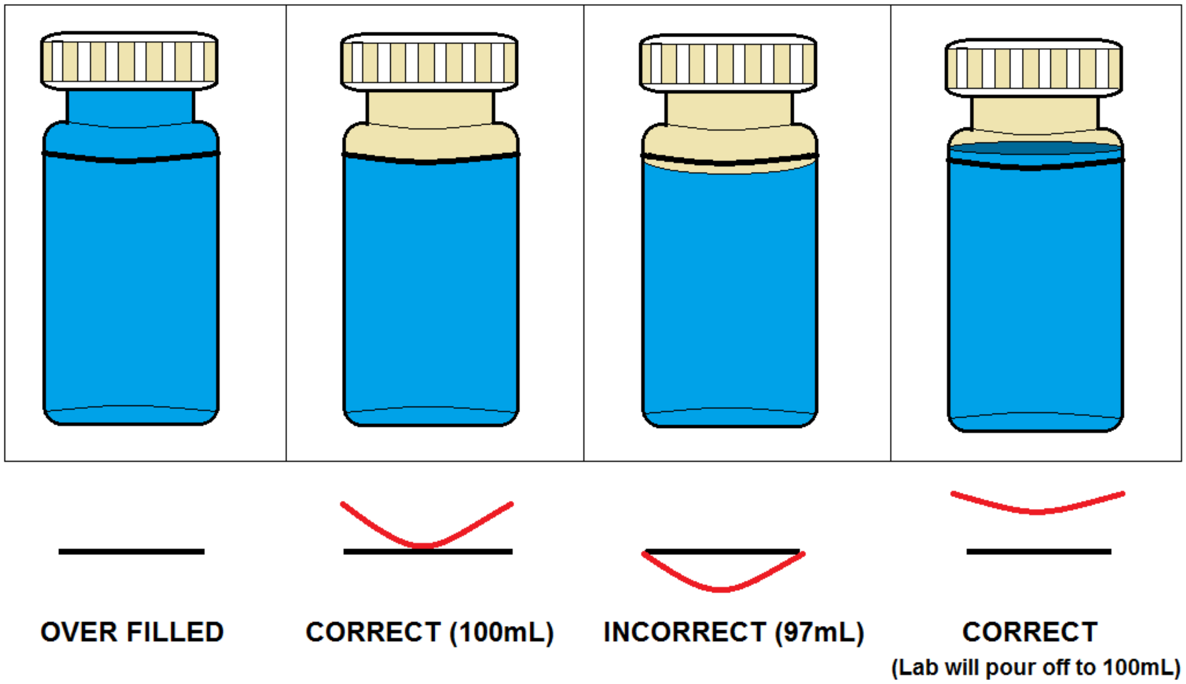
Radionuclides	**MCLG [1] (mg/L) [4]**	**MCL[2] or TT[3] (mg/L) [4]**	**Potential Health Effects from Ingestion of Water**	**Sources of Contaminant in Drinking Water**
Beta particles and photon emitters	none[5]	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits
Gross alpha particle activity	none[5]	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits

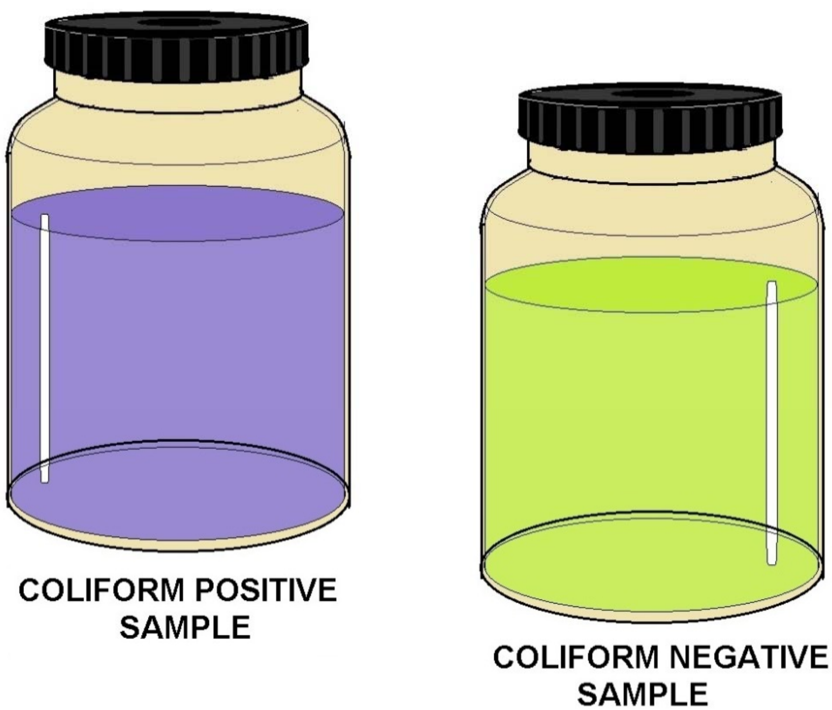
Radium 226 and Radium 228 (combined)	none[5]	5 pCi/L	Increased risk of cancer	Erosion of natural deposits

Microorganisms	MCLG [1] (mg/L) [4]	MCL[2] or TT[3] (mg/L) [4]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Giardia lamblia	zero	TT[8]	Giardiasis, a gastroenteric disease	Human and animal fecal waste
Heterotrophic plate count	N/A	TT[8]	HPC has no health effects, but can indicate how effective treatment is at controlling microorganisms.	n/a
Legionella	zero	TT[8]	Legionnaire's Disease, commonly known as pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and *E. Coli*)	zero	5.0%[9]	Used as an indicator that other potentially harmful bacteria may be present[10]	Human and animal fecal waste
Turbidity	N/A	TT[8]	Turbidity has no health effects but can interfere with disinfection and provide a medium for microbial growth. It may indicate the presence of microbes.	Soil runoff
Viruses (enteric)	zero	TT[8]	Gastroenteric disease	Human and animal fecal waste

Abbreviations

BOD – biochemical oxygen demand
DO – dissolved oxygen
ft – feet
gpd – gallons per day
gpg – grains per gallon
gpm – gallons per minute
lbs – pounds
mg/L – milligrams per liter
MGD – millions of gallons per day
mL – milliliter
MLSS – mixed liquor suspended solids
MLVSS – mixed liquor volatile suspended solids
TSS – Total Suspended Solids





COLIFORM BACTERIA COLOR TESTING

*National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (NSDWRs) or secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L ***Know both primary and secondary for exam***
Corrosivity	noncorrosive
Fluoride	2.0 mg/L ***Know both primary and secondary for exam***
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

Notes

[1] Maximum Contaminant Level Goal (**MCLG**) - The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health effect of persons would occur, and which allows for an proper margin of safety. MCLGs are non-enforceable public health goals.
[2] Maximum Contaminant Level (**MCL**) - The maximum permissible level of a contaminant in water which is delivered to any user of a public water system. MCLs are enforceable standards. The margins of safety in MCLGs ensure that exceeding the MCL slightly does not pose significant risk to public health.
[3] Treatment Technique - An enforceable procedure or level of technical performance which public water systems must follow to ensure control of a contaminant.
[4] Units are in milligrams per Liter (mg/L) unless otherwise noted.
[5] MCLGs were not established before the 1986 Amendments to the Safe Drinking Water Act. Therefore, there is no MCLG for this contaminant.
[6] Lead and copper are regulated in a Treatment Technique which requires systems to take tap water samples at sites with lead pipes or copper pipes that have lead solder and/or are served by lead service lines. The action level, which triggers water systems into taking treatment steps if exceeded in more than 10% of tap water samples, for copper is 1.3 mg/L, and for lead is 0.015mg/L.
[7] Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:
Acrylamide = 0.05% dosed at 1 mg/L (or equivalent)
Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)
[8] The Surface Water Treatment Rule requires systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:
Giardia lamblia*:* 99.9% killed/inactivated
Viruses: 99.99% killed/inactivated
Legionella*:* No limit, but EPA believes that if ***Giardia*** and viruses are inactivated, ***Legionella*** will also be controlled.
Turbidity: At no time can turbidity (**cloudiness of water**) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month.
HPC: NO more than 500 bacterial colonies per milliliter.
[9] No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive). Every sample that has total coliforms must be analyzed for fecal coliforms. There cannot be any fecal coliforms.
[10] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human animal wastes. Microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms.

Safe Drinking Water Act Terms *Memorize this section for exam.**

***Community Water System (CWS).** A public water system that serves at least 15 service connections used by year-round residents of the area served by the system or regularly serves at least 25 year-round residents.

Class V Underground Injection Control (UIC) Rule. A rule under development covering wells not included in Class I, II, III or IV in which nonhazardous fluids are injected into or above underground sources of drinking water.

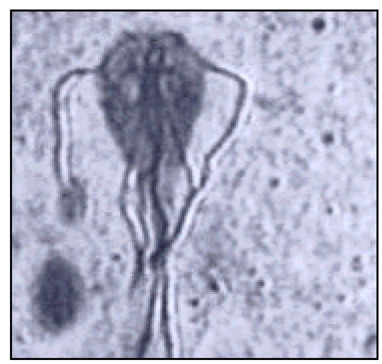
Contamination Source Inventory. The process of identifying and inventorying contaminant sources within delineated source water protection areas through recording existing data, describing sources within the source water protection area, targeting likely sources for further investigation, collecting and interpreting new information on existing or potential sources through surveys, and verifying accuracy and reliability of the information gathered.

Cryptosporidium A protozoan associated with the disease cryptosporidiosis in humans. The disease can be transmitted through ingestion of drinking water, person-to-person contact, or other exposure routes. Cryptosporidiosis may cause acute diarrhea, abdominal pain, vomiting, and fever that last 1-2 weeks in healthy adults, but may be chronic or fatal in immuno-compromised people.

Drinking Water State Revolving Fund (DWSRF). Under section 1452 of the SDWA, EPA awards capitalization grants to states to develop drinking water revolving loan funds to help finance drinking water system infrastructure improvements, source water protection, to enhance operations and management of drinking water systems, and other activities to encourage public water system compliance and protection of public health.

Exposure Contact between a person and a chemical. Exposures are calculated as the amount of chemical available for absorption by a person.

Giardia lamblia A protozoan, which can survive in water for 1 to 3 months, associated with the disease giardiasis. Ingestion of this protozoan in contaminated drinking water, exposure from person-to-person contact, and other exposure routes may cause giardiasis. The symptoms of this gastrointestinal disease may persist for weeks or months and include diarrhea, fatigue, and cramps.



Ground Water Disinfection Rule (GWDR). Under section 107 of the SDWA Amendments of 1996, the statute reads, ". . . the Administrator shall also promulgate national primary drinking water regulations requiring disinfection as a treatment technique for all public water systems, including surface water systems, and as necessary, ground water systems."

***Maximum Contaminant Level (MCL).** In the SDWA, an MCL is defined as "*the maximum permissible level of a contaminant in water which is delivered to any user of a public water system."* MCLs are enforceable standards.

Maximum Contaminant Level Goal (MCLG) The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health effect of persons would occur, and which allows for an adequate margin of safety. MCLGs are non-enforceable public health goals.

***Nephelolometric Turbidity Units. (NTU)** A unit of measure used to describe the turbidity of water. Turbidity is the cloudiness in water.

***Nitrates** Inorganic compounds that can enter water supplies from fertilizer runoff and sanitary wastewater discharges. Nitrates in drinking water are associated with methemoglobanemia, or blue baby syndrome, which results from interferences in the blood's ability to carry oxygen.

***Non-Community Water System (NCWS).** A public water system that is not a community water system. There are two types of NCWSs: transient and non-transient.

Organics Chemical molecules that contain carbon and other elements such as hydrogen. Organic contaminants of concern to drinking water include chlorohydrocarbons, pesticides, and others.

Phase I Contaminants The Phase I Rule became effective on January 9. 1989. This rule, also called the Volatile Organic Chemical Rule, or VOC Rule, set water quality standards for 8 VOCs and required all community and Non-Transient, Non-Community water systems to monitor for, and if necessary, treat their supplies for these chemicals. The 8 VOCs regulated under this rule are: Benzene, Carbon Tetrachloride, para-dichlorobenzene, trichloroethylene, vinyl chloride, 1,1,2-trichlorethane, 1,1-dichloroethylene, and 1,2-dichlorothane.

Per capita Per person; generally used in expressions of water use, gallons per capita per day (gpcd).

Point-of-Use Water Treatment Refers to devices used in the home or office on a specific tap to provide additional drinking water treatment.

Point-of-Entry Water Treatment Refers to devices used in the home where water pipes enter to provide additional treatment of drinking water used throughout the home.

Primacy State. State that has the responsibility for ensuring a law is implemented, and has the authority to enforce the law and related regulations. State has adopted rules at least as stringent as federal regulations and has been granted primary enforcement responsibility.

Radionuclides Elements that undergo a process of natural decay. As radionuclides decay, they emit radiation in the form of alpha or beta particles and gamma photons. Radiation can cause adverse health effects, such as cancer, so limits are placed on radionuclide concentrations in drinking water.

Risk The potential for harm to people exposed to chemicals. In order for there to be risk, there must be hazard and there must be exposure.

SDWA - The Safe Drinking Water Act. The Safe Drinking Water Act was first passed in 1974 and established the basic requirements under which the nation's public water supplies were regulated. The US Environmental Protection Agency (**EPA**) is responsible for setting the national drinking water regulations while individual states are responsible for ensuring that public water systems under their jurisdiction are complying with the regulations. The SDWA was amended in 1986 and again in 1996.

Significant Potential Source of Contamination. A facility or activity that stores, uses, or produces chemicals or elements, and that has the potential to release contaminants identified in a state program (contaminants with MCLs plus any others a state considers a health threat) within a source water protection area in an amount which could contribute significantly to the concentration of the contaminants in the source waters of the public water supply.

Sole Source Aquifer (SSA) Designation. The surface area above a sole source aquifer and its recharge area.

Source Water Protection Area (SWPA). The area delineated by the state for a PWS or including numerous PWSs, whether the source is ground water or surface water or both, as part of the state SWAP approved by EPA under section 1453 of the SDWA.

Sub watershed. A topographic boundary that is the perimeter of the catchment area of a tributary of a stream.

Surface Water Treatment Rule (SWTR).** The rule specifies maximum contaminant level goals for ***Giardia lamblia, viruses and ***Legionella,*** and promulgated filtration and disinfection requirements for public water systems using surface water sources, or by ground water sources under the direct influence of surface water. The regulations also specify water quality, treatment, and watershed protection criteria under which filtration may be avoided.

Legionella

Susceptibility Analysis. An analysis to determine, with a clear understanding of where the significant potential sources of contamination are located, the susceptibility of the public water systems in the source water protection area to contamination from these sources. This analysis will assist the state in determining which potential sources of contamination are "**significant**."

To the Extent Practical. States must inventory sources of contamination to the extent they have the technology and resources to complete an inventory for a Source Water Protection Area delineated as described in the guidance. All information sources may be used, particularly previous Federal and state inventories of sources.

***Transient/Non-Transient, Non-Community Water Systems (T/NT,NCWS).** Water systems that are non-community systems: transient systems serve 25 non-resident persons per day for 6 months or less per year. Transient non-community systems typically are restaurants, hotels, large stores, etc. Non-transient systems regularly serve at least 25 of the same non-resident persons per day for more than 6 months per year. These systems typically are schools, offices, churches, factories, etc.

Treatment Technique A specific treatment method required by EPA to be used to control the level of a contaminant in drinking water. In specific cases where EPA has determined it is not technically or economically feasible to establish an MCL, the EPA can instead specify a treatment technique. A treatment technique is an enforceable procedure or level of technical performance which public water systems must follow to ensure control of a contaminant.

Total Coliform Bacteria that are used as indicators of fecal contaminants in drinking water.

Toxicity The property of a chemical to harm people who come into contact with it.

Underground Injection Control (UIC) Program. The program is designed to prevent underground injection which endangers drinking water sources. The program applies to injection well owners and operators on Federal facilities, Native American lands, and on all U.S. land and territories.

***Watershed.** A topographic boundary area that is the perimeter of the catchment area of a stream.

Watershed Area. A topographic area that is within a line drawn connecting the highest points uphill of a drinking water intake, from which overland flow drains to the intake.

Related State Definitions

Depending on your State, these definitions will change, but generally these terms are universal and can be used on in the assignment.

The terms in this Article have the following meanings:
"Certified operator" or "operator" means an individual who holds a current certificate issued by the Department in the field of water or wastewater treatment, water distribution, or wastewater collection, and is responsible for the daily onsite operation or the remote operation from a central location of all or a part of a facility.

"Direct responsible charge" means day-to-day decision making responsibility for a facility or a major portion of a facility.

"Distribution system" means a pipeline, appurtenance, or device of a public water system that conducts water from a water source or treatment plant to consumers for domestic or potable use.

"Facility" means a water treatment plant, wastewater treatment plant, distribution system, or collection system.

"Onsite operator" means an operator who visits a facility at least daily to ensure that it is operating properly.

"Onsite representative" means a person located at a facility who monitors the daily operation at the facility and maintains contact with the remote operator regarding the facility.

"Operator" has the same meaning as certified operator, defined in this Section.

"PDH" means professional development hour.

"Professional development hour" means one hour of participation in an organized educational activity related to engineering, biological or chemical sciences, a closely related technical or scientific discipline, or operations management.

"Remote operator" means an operator who is not an onsite operator.

Various Definitions *Know these terms.*

"Action level" means a concentration of 0.015 mg/L for lead or 1.3 mg/L for copper.

"Air-gap separation" means a physical separation, between the discharge end of a supply pipe and the top rim of its receiving vessel, of at least one inch or twice the diameter of the supply pipe, whichever is greater.

"Backflow" means a reverse flow condition that causes water or mixtures of water and other liquids, gases, or substances to flow back into the distribution system. Backflow can be created by a difference in water pressure (backpressure), a vacuum or partial vacuum (backsiphonage), or a combination of both.

"Backflow-prevention assembly" means a mechanical device used to prevent backflow.

"BAT" means best available technology.

"Coagulation" means a treatment process that uses coagulant chemicals and mixing to destabilize and agglomerate colloidal and suspended materials into flocs.

"Community water system" means a public water system that serves 15 or more service connections used by year-round residents or that serves 25 or more year-round residents.

"Compliance cycle" means a nine-calendar-year time-frame during which a public water system is required to monitor.

"Compliance period" means a three-calendar-year time-frame within a compliance cycle.

"Conventional filtration" means a series of treatment processes, including coagulation, flocculation, sedimentation, and filtration that result in substantial particulate removal.

"Cross connection" means a physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow.

"CWS" means community water system.

"Detected" means measured in a laboratory at a concentration that is at or above the method detection limit.

"Direct filtration" means a series of treatment processes, including coagulation and filtration but excluding sedimentation, that result in substantial particulate removal.

"Disinfectant" means an oxidant, including chlorine, chlorine dioxide, chloramines, ozone, or an equivalent agent or process such as ultraviolet light, that kills or inactivates pathogenic organisms.

"Double check valve assembly" means a backflow-prevention assembly that contains two independently acting check valves with tightly closing, resilient-seated shut-off valves on each end of the assembly and properly located, resilient-seated test cocks.

“Elementary business plan” means a document containing all items, required to be submitted for evaluation, necessary for a complete review for technical, managerial, and financial capacity of a new public water system.

“Filtration” means a treatment process for removing particulate matter from water by passage through porous media.

“Financial capacity” means the ability of a public water system to acquire and manage sufficient financial resources for the system to achieve and maintain compliance with the federal Safe Drinking Water Act.

“Flocculation” means a treatment process to enhance agglomeration or collection of smaller floc particles into larger and more easily settleable particles through gentle stirring by hydraulic or mechanical means.

“GAC” means granular activated carbon.

“HPC” means heterotrophic plate count.

“Initial monitoring year” means the calendar year designated by the Department within a compliance period in which a public water system conducts initial monitoring at a sampling point.

“Large water system,” means a public water system that serves more than 50,000 persons.

“Managerial capacity” means the ability of a public water system to conduct its affairs in a manner that will meet and maintain compliance with the requirements of the federal Safe Drinking Water Act.

“Maximum contaminant level” means the maximum permissible level for a contaminant in drinking water that is delivered to any person who is served by a public water system.

“Medium water system,” means a public water system that serves more than 3,300 persons and 50,000 or fewer persons.

“Nephelometric turbidity unit” means the unit of measure for turbidity. Turbidity is a measure of light scatter or absorption caused by suspended or colloidal matter in water. Turbidity is measured as an indicator of the effectiveness of filtration treatment.

“NTNCWS” means nontransient, noncommunity water system.

“NTU” means nephelometric turbidity unit.

“Sanitary survey” means an onsite review of the water source, facilities, equipment, operation, and maintenance of a public water system to evaluate their adequacy to produce and distribute safe drinking water.

“Sedimentation” means a treatment process that holds water in a low-flow condition before filtration to remove solids by gravity or separation.

“Slow sand filtration” means a treatment process that involves the passage of raw water through a bed of sand at low velocity, generally less than 0.4 m/h, and results in substantial particulate removal by physical and biological mechanisms.

“Small water system,” means a public water system that serves 3,300 or fewer persons.

“SOC” means synthetic organic chemical.

“TNCWS” means transient, noncommunity water system.

“TOC” means total organic carbon. “Total organic carbon” means total organic carbon in mg/L measured using heat, oxygen, ultraviolet irradiation, chemical oxidants, or combinations of these oxidants that convert organic carbon to carbon dioxide, rounded to two significant figures.
“Total trihalomethanes” means the sum of the concentrations of the following trihalomethane compounds: trichloromethane (chloroform), dibromochloromethane, bromo-dichloromethane, and tribromomethane (bromoform).

“Transient, noncommunity water system” means a public water system that: Serves 15 or more service connections, but does not serve 15 or more service connections that are used by the same persons for more than six months per year; or serves an average of at least 25 persons per day for at least 60 days per year, but does not serve the same 25 persons for more than six months per year.

“Trihalomethane” means one of the families of organic compounds, named as derivatives of methane, in which three of four hydrogen atoms in methane are substituted by a halogen atom in the molecular structure.

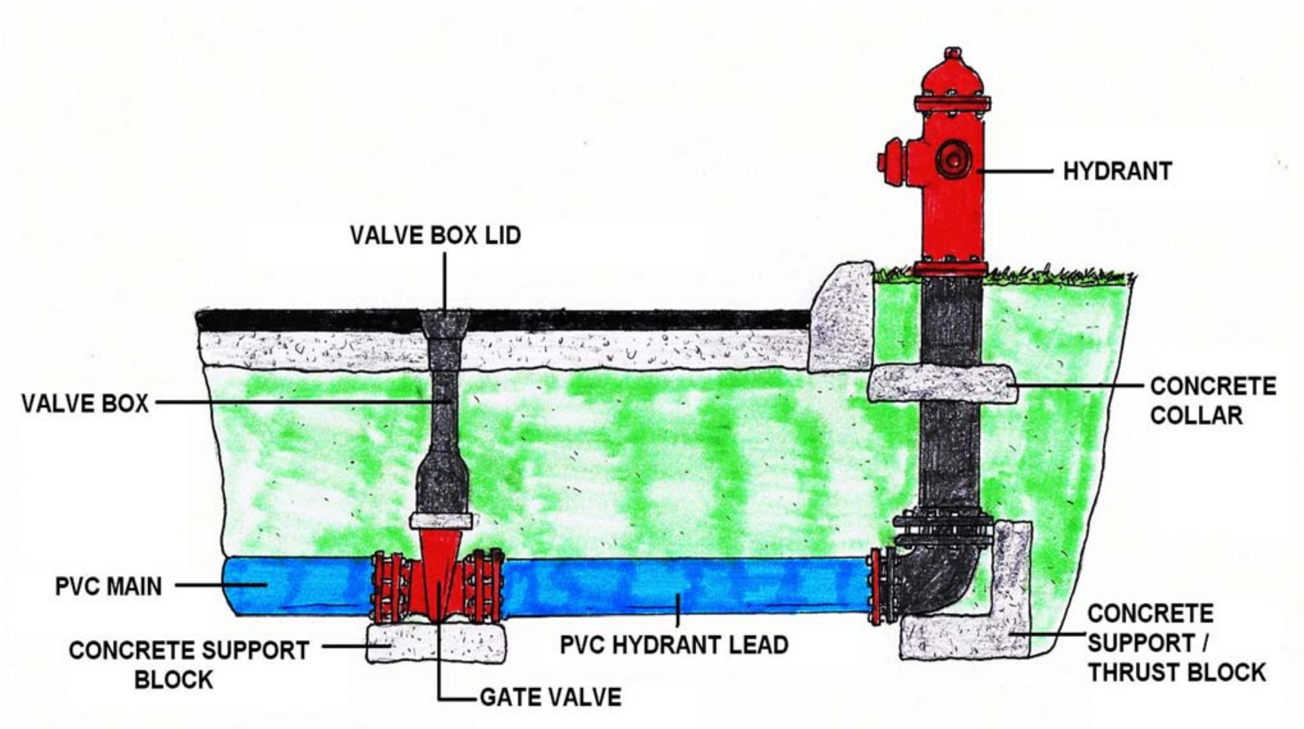
“VOC” means volatile organic chemical.

“Water treatment plant” means a process, device, or structure used to improve the physical, chemical, or biological quality of the water in a public water system.

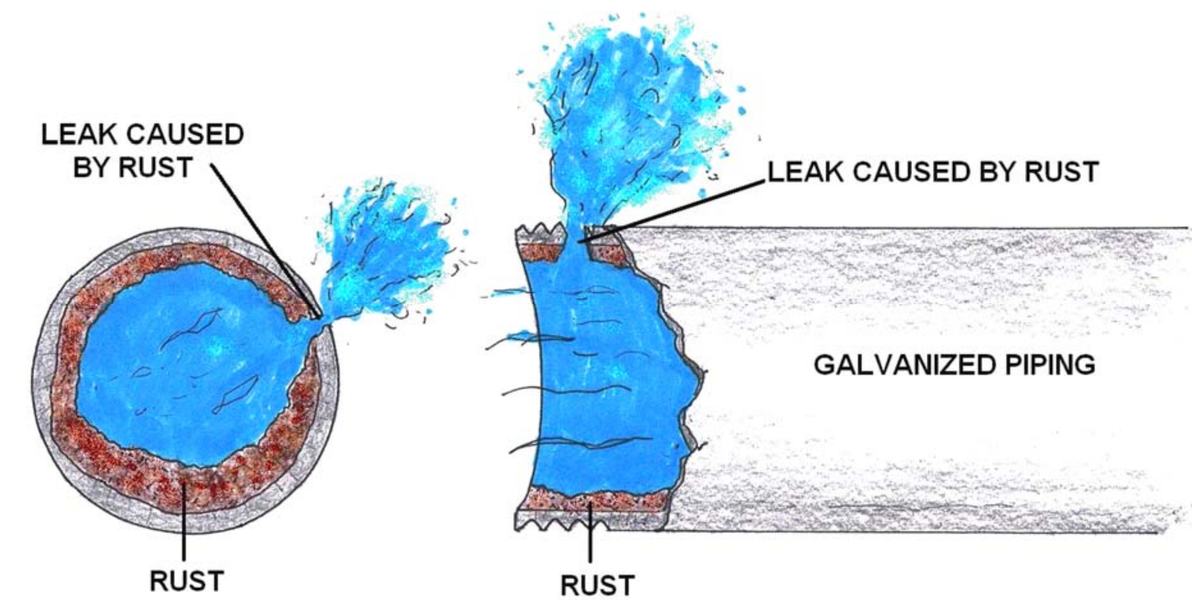
CL_2 Gas Safety: Gas leak is the primary safety concern when using chlorine gas as opposed to calcium hypochlorite or sodium hypochlorite.

Cl_2 Gas will Accumulate: If a Cl_2 leak occurs, the Cl_2 gas will accumulate on the floor.

CL_2 Gaskets: Replace according to manufacturer’s recommendations should be done with the gaskets when making a new connection on a chlorine feed system.



The above diagram is for proper fire hydrant and isolating gate valve installation. The diagram below represents how rust and electrolysis creates a hole or break in iron based water mains.



Bacteriological Monitoring

Most waterborne disease and illnesses have been related to the microbiological quality of drinking water. The routine microbiological analysis of your water is for coliform bacteria. The coliform bacteria group is used as an indicator organism to determine the biological quality of your water.

*The presence of an indicator or pathogenic bacteria in your drinking water is an important health concern. Indicator bacteria signal possible fecal contamination and therefore, the potential presence of pathogens. They are used to monitor for pathogens because of the difficulties in determining the presence of specific disease-causing microorganisms.

Indicator bacteria are usually harmless, occur in high densities in their natural environment and are easily cultured in relatively simple bacteriological media. Indicators in common use today for routine monitoring of drinking water include total coliforms, fecal coliforms and *Escherichia coli (E. coli).*

Bacteria Sampling
Water samples for bacteria tests must always be collected in a sterile container. Take the sample from an inside faucet with the aerator removed. Sterilize by spraying a 5% household bleach or alcohol solution or flaming the end of the tap with a propane torch.

Run the water for five minutes to clear the water lines and bring in fresh water. Do not touch or contaminate the inside of the bottle or cap. Carefully open the sample container and hold the outside of the cap. Fill the container and replace the top.

Refrigerate the sample and transport it to the testing laboratory within six hours (in an ice chest). Many labs will not accept bacteria samples on Friday so check the lab's schedule. Mailing bacteria samples is not recommended because laboratory analysis results are not as reliable.

*Iron bacteria forms an obvious slime on the inside of pipes and fixtures. A water test is not needed for identification. Check for a reddish-brown slime inside a toilet tank or where water stands for several days.

Standard Sample Coliform Bacteria Bac-T.

***Bac-T Sample Bottle,** often referred to as a Standard Sample, 100 mls, Notice the white powder inside the bottle. That is **Sodium Thiosulfate**, a de-chlorination agent. Be careful not to wash-out this chemical while sampling. Notice the custody seal on the bottle.

***Coliform bacteria** are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can cause disease.

Laboratory Procedures
The laboratory may perform the total coliform analysis in one of four methods approved by the U.S. EPA and your local environmental or health division:

Methods
The MMO-MUG test, a product marketed as Colilert, is the most common. The sample results will be reported by the laboratories as simply coliforms present or absent. If coliforms are present, the laboratory will analyze the sample further to determine if these are fecal coliforms or E. coli and report their presence or absence.

Types of Water Samples
It is important to properly identify the type of sample you are collecting. Please indicate in the space provided on the laboratory form the type of sample.
The three (3) types of samples are:
1. **Routine:** Samples collected on a routine basis to monitor for contamination. Collection should be in accordance with an approved sampling plan.
2. **Repeat:** Samples collected following a '***coliform present'*** routine sample. The number of repeat samples to be collected is based on the number of routine samples you normally collect.
3. **Special:** Samples collected for other reasons.
Examples would be a sample collected after repairs to the system and before it is placed back into operation or a sample collected at a wellhead prior to a disinfection injection point.

Routine Coliform Sampling
Noncommunity and nontransient noncommunity public water systems will sample at the same frequency as a like sized community public water system if: 1. It has more than 1,000 daily population and has ground water as a source, or 2. It serves 25 or more daily population and utilizes surface water as a source or ground water under the direct influence of surface water as its source.

Noncommunity and nontransient, noncommunity water systems with less than 1,000 daily population and groundwater as a source will sample on a quarterly basis.

Granular Activated Carbon / Powdered Activated Carbon

*Along with aeration, granular activated carbon (**GAC**) and powdered activated carbon (**PAC**) are suitable treatments for removal of organic contaminants such as VOCs, solvents, PCBs, herbicides and pesticides.

*Activated carbon is carbon that has been exposed to very high temperature, creating a vast network of pores with a very large internal surface area; one gram of activated carbon has a surface area equivalent to that of a football field. It removes contaminants through adsorption, a process in which dissolved contaminants adhere to the surface of the carbon particles.

*GAC can be used as a replacement for existing media (such as sand) in a conventional filter or it can be used in a separate contactor such as a vertical steel pressure vessel used to hold the activated carbon bed.

After a period of a few months or years, depending on the concentration of the contaminants, the surface of the pores in the GAC can no longer adsorb contaminants and the carbon must be replaced. Several operational and maintenance factors affect the performance of granular activated carbon. Contaminants in the water can occupy adsorption sites, whether or not they are targeted for removal. Also, adsorbed contaminants can be replaced by other contaminants with which GAC has a greater affinity, so their presence might interfere with removal of contaminants of concern.

A significant drop in the contaminant level in influent water can cause a GAC filter to desorb, or slough off adsorbed contaminants, because GAC is essentially an equilibrium process. As a result, raw water with frequently changing contaminant levels can result in treated water of unpredictable quality. Bacterial growth on the carbon is another potential problem. Excessive bacterial growth may cause clogging and higher bacterial counts in the treated water. The disinfection process must be carefully monitored in order to avoid this problem.

*Powdered activated carbon consists of finely ground particles and exhibits the same adsorptive properties as the granular form. PAC is normally applied to the water in a slurry and then filtered out. The addition of PAC can improve the organic removal effectiveness of conventional treatment processes and also remove tastes and odors.

*Advantages of PAC are that it can be used on a short-term or emergency basis with conventional treatment, creates no headloss, does not encourage microbial growth, and has relatively small capital costs. The main disadvantage is that some contaminants require large doses of PAC for removal. It is also somewhat ineffective in removing natural organic matter due to the competition from other contaminants for surface adsorption and the limited contact time between the water and the carbon.

Corrosion Control

Corrosion is the deterioration of a substance by chemical action. Lead, cadmium, zinc, copper and iron might be found in water when metals in water distribution systems corrode. Drinking water contaminated with certain metals (such as lead and cadmium) can harm human health. Corrosion also reduces the useful life of water distribution systems and can promote the growth of microorganisms, resulting in disagreeable tastes, odors, slimes, and further corrosion. Because it is widespread and highly toxic, lead is the corrosion product of greatest concern.

The EPA has banned the use of lead solders, fluxes, and pipes in the installation or repair of any public water system. In the past, solder used in plumbing has been 50% tin and 50% lead. Using lead-free solders, such as silver-tin and antimony-tin is a key factor in lead corrosion control. The highest level of lead in consumers' tap water will be found in water that has been standing in the pipes after periods of nonuse (overnight or longer). This is because standing water tends to leach lead or copper out of the metals in the distribution system more readily than does moving water.

Therefore, the simplest short-term or immediate measure that can be taken to reduce exposure to lead in drinking water is to let the water run for two to three minutes before each use. Also, drinking water should not be taken from the hot water tap, as hot water tends to leach lead more readily than cold. Long-term measures for addressing lead and other corrosion by-products include pH and alkalinity adjustment; corrosion inhibitors; coatings and linings; and cathodic protection.

Cathodic Protection

Cathodic protection protects steel from corrosion, which is the natural electrochemical process that results in the deterioration of a material because of its reaction with its environment.

Metallic structures, components, and equipment exposed to aqueous environments, soil or seawater can be subject to corrosive attack and accelerated deterioration. Therefore, it is often necessary to utilize either impressed current or sacrificial anode cathodic protection (**CP**) in combination with coatings as a means of suppressing the natural degradation phenomenon to provide a long and useful service life. However, if proper considerations are not given, problems can arise which can produce unexpected, premature failure.

Corrosion Inhibitors

Inhibitors reduce corrosion by forming protective coatings on pipes. The most common corrosion inhibitors are inorganic phosphates, sodium silicates, and mixtures of phosphates and silicates. These chemicals have proven successful in reducing corrosion in many water systems.

The phosphates used as corrosion inhibitors include polyphosphates, orthophosphates, glassy phosphates, and bimetallic phosphates. In some cases, zinc is added in conjunction with orthophosphates or polyphosphates.

*Glassy phosphates, such as sodium hexametaphosphate, effectively reduce iron corrosion at dosages of 20 to 40 mg/l.

*Glassy phosphate has an appearance of broken glass and can cut the operator. Sodium silicates have been used for over 50 years to inhibit corrosion. The effectiveness depends on the water pH and carbonate concentration. Sodium silicates are particularly effective for systems with high water velocities, low hardness, low alkalinity and a pH of less than 8.4. Typical coating maintenance doses range from 2 to 12 mg/1. They offer advantages in hot water systems because of their chemical stability. For this reason, they are often used in boilers of steam heating systems.

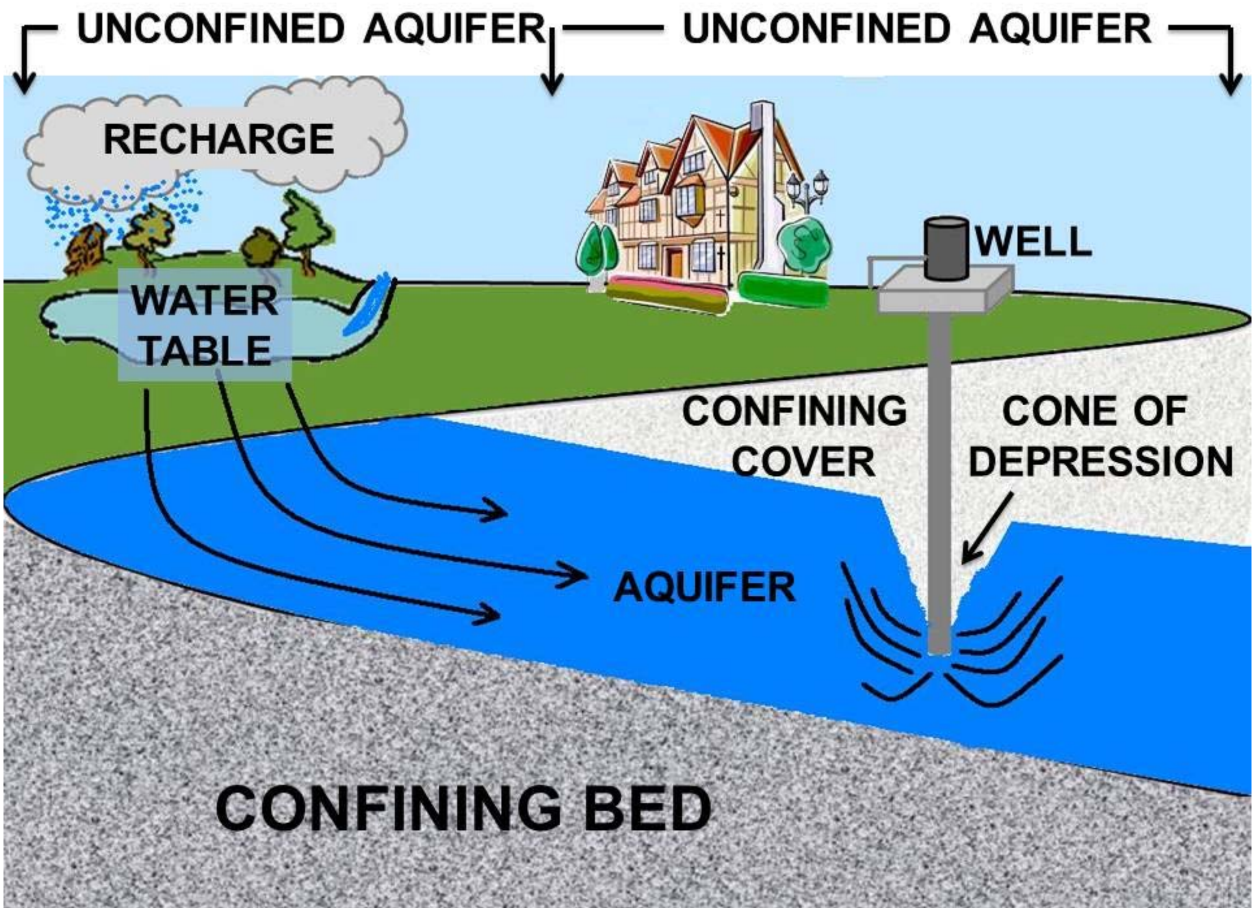
Groundwater and Well Section Chapter 3

A well can be easily contaminated if it is not properly constructed or if toxic materials are released into the well. Toxic material spilled or dumped near a well can leach into the aquifer and contaminate the groundwater drawn from that well.

Contaminated wells used for drinking water are especially dangerous. Wells can be tested to see what chemicals may be in the well and if they are present in dangerous quantities.

Groundwater is withdrawn from wells to provide water for everything from drinking water for the home and business to water to irrigate crops to industrial processing water. When water is pumped from the ground, the dynamics of groundwater flow change in response to this withdrawal.

Groundwater flows slowly through water-bearing formations (***aquifers;** ***know for the exam)*** at different rates. In some places, where groundwater has dissolved limestone to form caverns and large openings, its rate of flow can be relatively fast, but this is exceptional.



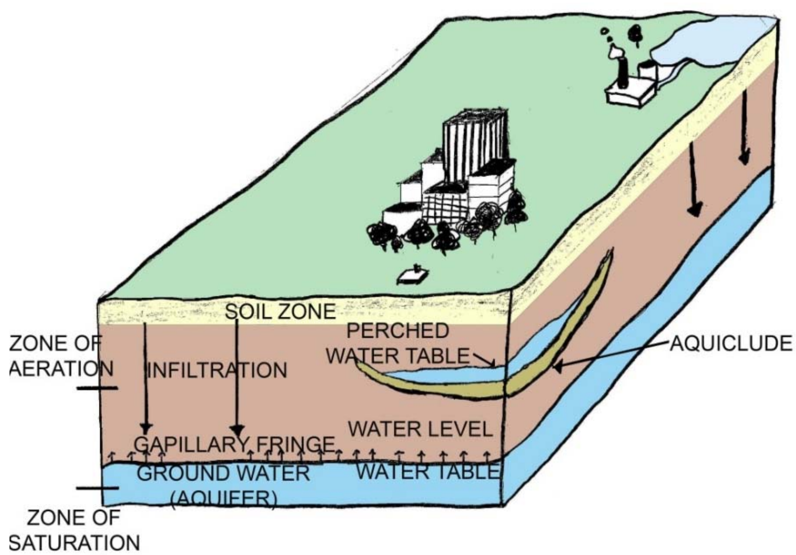
Groundwater Resource Terms

Many terms are used to describe the nature and extent of the groundwater resource. The level below which all the spaces are filled with water is called the ***water table***. Above the water table lies the ***unsaturated zone*.** Here the spaces in the rock and soil contain both air and water. Water in this zone is called ***soil moisture*.** The entire region below the water table is called the ***saturated zone*** and water in this saturated zone is called ***groundwater.***

Fractured aquifers are rocks in which the groundwater moves through cracks, joints or fractures in otherwise solid rock. Examples of fractured aquifers include granite and basalt. Limestones are often fractured aquifers, but here the cracks and fractures may be enlarged by solution, forming large channels or even caverns.

Limestone terrain where solution has been very active is termed ***karst***. Porous media such as sandstone may become so highly cemented or recrystalized that all of the original space is filled. In this case, the rock is no longer a porous medium. However, if it contains cracks it can still act as a fractured aquifer.

Most of the aquifers of importance to us are unconsolidated porous media such as sand and gravel. Some very porous materials are not permeable. Clay, for instance, has many spaces between its grains, but the spaces are not large enough to permit free movement of water.

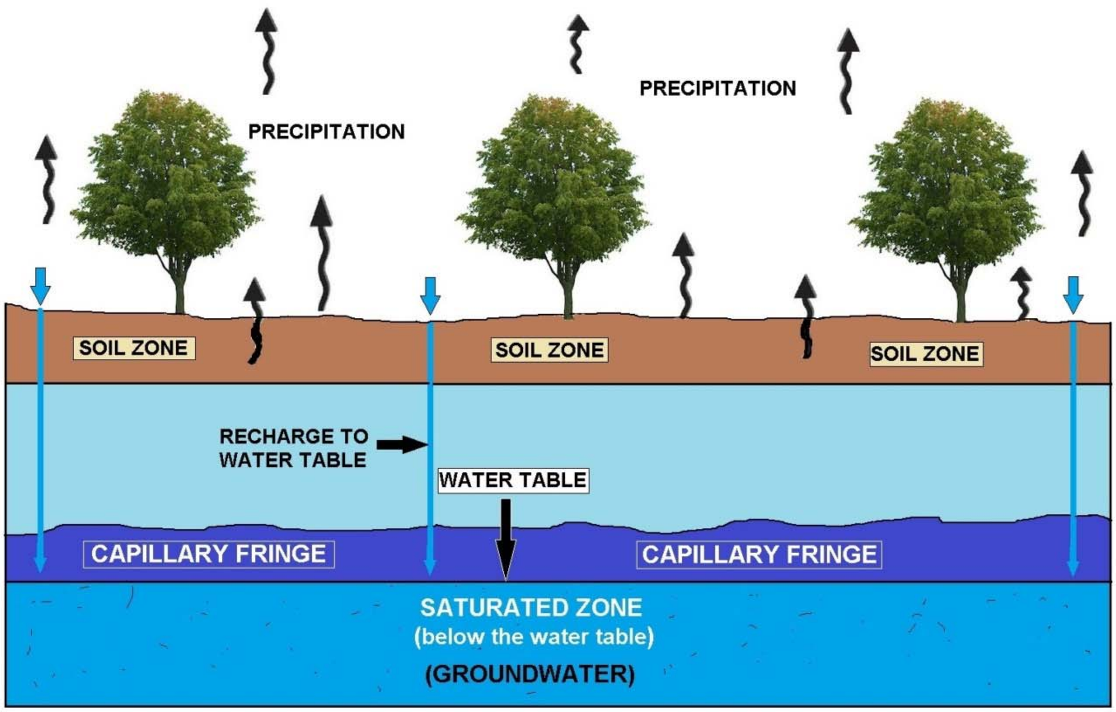


Groundwater usually flows downhill with the slope of the water table. Like surface water, groundwater flows toward, and eventually drains into streams, rivers, lakes and the oceans. Groundwater flow in the aquifers underlying surface drainage basins, however, does not always mirror the flow of water on the surface. Therefore, groundwater may move in different directions below the ground than the water flowing on the surface.

Unconfined aquifers are those that are bounded by the water table. Some aquifers, however, lie beneath layers of impermeable materials. These are called *confined aquifers*, or sometimes *artesian aquifers*.

A well in such an aquifer is called an *artesian well*. The water in these wells rises higher than the top of the aquifer because of confining pressure. If the water level rises above the ground surface a ***flowing artesian well*** occurs. The ****piezometric surface*** is the level to which the water in an artesian aquifer will rise.

Water Sources



CAPILLARY FRINGE
(Material above water table that may contain water by capillary pressure in small voids)

Water Cycle Terms

***Precipitation**: The process by which atmospheric moisture falls onto the land or water surface as rain, snow, hail or other forms of moisture.
***Infiltration**: The gradual flow or movement of water into and through the pores of the soil.
***Evaporation**: The process by which the water or other liquids become a gas.
***Condensation**: The collection of the evaporated water in the atmosphere.
***Runoff**: Water that drains from a saturated or impermeable surface into stream channels or other surface water areas. Most lakes and rivers are formed this way.
***Transpiration**: Moisture that will come from plants as a byproduct of photosynthesis.

Once the precipitation begins, water is no longer in its purest form. Water will be collected as surface supplies or circulate to form in the ground. As it becomes rain or snow it may be polluted with organisms, organic compounds, and inorganic compounds.

Because of this, we must treat the water for human consumption.

Water Rights

***Appropriative:** Acquired water rights for exclusive use.

***Prescriptive:** Rights based upon legal prescription or long use or custom.

***Riparian:** Water rights because property is adjacent to a river or surface water.

Quality of Water **Know these to pass your exam***

If you classified the way water characteristics change as it passes on the surface and below the ground it would be in four categories:

***Physical** characteristics such as taste, odor, temperature, and turbidity. This is how the consumer judges how well the provider is treating the water.

***Chemical** characteristics are the elements found that are considered alkali, metals, and non-metals such as fluoride, sulfides or acids. The consumer relates it to scaling of faucets or staining.

***Biological** characteristics are the presence of living or dead organisms. This will also interact with the chemical composition of the water. The consumer will become sick or complain about hydrogen sulfide odors, the rotten egg smell.

***Radiological** characteristics are the result of water coming in contact with radioactive materials. This could be associated with atomic energy.

Surface Water

Some of the water will be immediately impounded in lakes and reservoirs, and some will collect as runoff to form streams and rivers that will then flow into the ocean. Water is known as the universal solvent because most substances that come in contact with it will dissolve. What's the difference between lakes and reservoirs? Reservoirs are lakes with man-made dams.

Surface water is usually contaminated and unsafe to drink. Depending on the region, some lakes and rivers receive discharge from sewer facilities or defective septic tanks. Runoff could produce mud, leaves, decayed vegetation, and human and animal refuse. The discharge from industry could increase volatile organic compounds. Some lakes and reservoirs may experience seasonal turnover. Changes in the dissolved oxygen, algae, temperature, suspended solids, turbidity, and carbon dioxide will change because of biological activities.

Another aspect of quality control is aquatic plants. The ecological balance in lakes and reservoirs plays a natural part in the purification of and sustaining the life of the lake.

For example, algae and rooted aquatic plants are essential in the food chain of fish and birds. Algae growth is the result of photosynthesis.

Algae growth is supplied by the energy of the sun. As algae absorb this energy it converts carbon dioxide to oxygen. This creates **aerobic** conditions that supply fish with oxygen. Without sun light, the algae would consume oxygen and release carbon dioxide. The lack of dissolved oxygen in water is known as **anaerobic** conditions. Certain vegetation removes the excess nutrients that would promote the growth of algae. Too much algae will imbalance the lake and this will result in fish kill.

*Groundwater Review Statements

Runoff: Surface water sources such as a river or lake are primarily the result of which of the following natural processes?

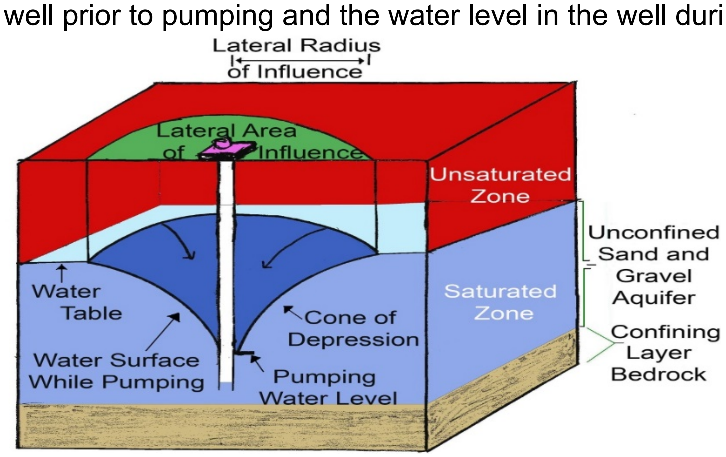
Safe yield: What is a possible consequence when the "***safe yield***" of a well is exceeded and water continues to be pumped from a well? Land subsidence around the well will occur.

Pressure Head: The measure of the pressure of water expressed in feet of height of water.
1 psi = 2.31 feet of water. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

Cone of Depression

When pumping begins, water begins to flow towards the well in contrast to the natural direction of groundwater movement. The water level in the well falls below the water table in the surrounding aquifer.

As a result, water begins to move from the aquifer into the well. As pumping continues, the water level in the well continues to increase until the rate of flow into the well equals the rate of withdrawal from pumping. The movement of water from an aquifer into a well results in the formation of a cone of depression. The cone of depression describes a three-dimensional inverted cone surrounding the well that represents the volume of water removed as a result of pumping. Drawdown is the vertical drop in the height between the water level in the well prior to pumping and the water level in the well during pumping.



When a well is installed in an unconfined aquifer, water moves from the aquifer into the well through small holes or slits in the well casing or, in some types of wells, through the open bottom of the well. The level of the water in the well is the same as the water level in the aquifer. Groundwater continues to flow through and around the well in one direction in response to gravity.

Water Use or Demand

Water system demand comes from a number of sources including residential, commercial, industrial, and public consumers, as well as some unavoidable loss and waste. If fire protection is desired, that could also represent a rather significant (although not continuous) demand upon the system. The combination of storage reservoirs and distribution lines must be capable of meeting consumers' needs for quality, quantity and pressure at all times.

The quantity of water used in any community varies from 50 to 500 gallons per person per day. A common design assumption is to use from 100 to 150 gallons per person per day for average domestic use. The maximum daily use is approximately 2 to 3 times the average daily use. Maximum daily use is usually encountered during the summer months and can vary widely depending on irrigation practices.

*Water Pressure

For ordinary domestic use, water pressure should be between *25 and 45 psi. 35 psi is desirable. A minimum of 60 psi at a fire hydrant is usually adequate, since that allows for up to 20 psi pressure drop in fire hoses. In commercial and industrial districts, it may be common to have 75 psi or higher. 20 psi is considered the minimum required at any point in the water system, so that backflow and infiltration is prevented. Pressure is provided by the direct force of the water (such as water from a pump), or by the height of the water (such as a storage reservoir). *2.31 feet of water is equal to 1 psi, or 1 foot of water is equal to about a half a pound (.433 pounds to be exact).

Storage and Distribution

All pipes, joints, and fittings should be pressure tested and disinfected with a 5% chlorine solution such as household bleach before backfilling. It is also important that all materials in contact with potable water meet the requirements of the National Sanitation Foundation (**NSF**) or American Water Works Association (**AWWA**) or have equivalent third-party certification. This includes solders (must be lead-free), pipes, joining and sealing materials, and protective coatings.

Water Storage Facilities

*Water storage facilities and tanks vary in size, shape, and application. There are different types that are used in the water distribution systems, such as stand pipes, elevated tanks and reservoirs, hydropneumatic tanks and surge tanks.

These tanks serve multiple purposes in the distribution system. Just the name alone can give you an idea of its purpose.
Surge Tanks
Reservoirs
Elevated Tanks *Water towers and Standpipes*

Surge Tanks

What really causes water main breaks - **ENERGY -** when released in a confined space, such as a water distribution system. Shock waves are created when hydrants, valves, or pumps are opened and closed quickly, trapping the kinetic energy of moving water within the confined space of a piping system.

These shock waves can create a turbulence that travels at the speed of sound, seeking a point of release. The release the surge usually finds is an elevated tank, but the surge doesn't always find this release quickly enough. Something has to give, and oftentimes, it's your pipe fittings. Distribution operators are aware of this phenomenon! It's called ***WATER HAMMER.***

Storage Reservoirs

Storage reservoirs allow the system to meet the fluctuations in demand described earlier. It is recommended that the volume of storage be equal to from one to three days of the system's average daily use. It is also recommended that storage reservoirs be located at a high enough elevation to allow the water to flow by gravity to the distribution system. This, coupled with restricted usage on the part of the consumers, should provide an uninterrupted water supply in the event of pump failure, loss of power or an acute contamination event or cross-connection.

Also, if applicable, some storage for fire protection should be provided. Reservoirs are also used as detention basins to provide the required chlorine contact time necessary to ensure the adequacy of disinfection. As such, the contact time in a reservoir is greatly improved when the reservoir is constructed with a separate inlet and outlet pipe, preferably located on opposite sides of the reservoir and at different levels. Also, baffles inside the reservoir (walls, curtains, or spirals) increase the contact time by preventing the water from leaving the reservoir too quickly *(known as "***short-circuiting***").

Steel Reservoirs

Steel reservoirs are usually welded or bolted together and are manufactured in a variety of sizes. Small steel reservoirs can be manufactured off-site and then trucked and lifted into place. Steel tanks should be inspected once a year and repainted every *5-7 years. Steel tanks should also have cathodic protection and be screened to keep birds and insects out. The maintenance program for reservoir tanks should call for annual draining for a complete inspection of the interior. Cleaning and disinfection prior to placing the reservoir or tank back in service is necessary.

Disinfection by chlorine can be accomplished by one of three methods.

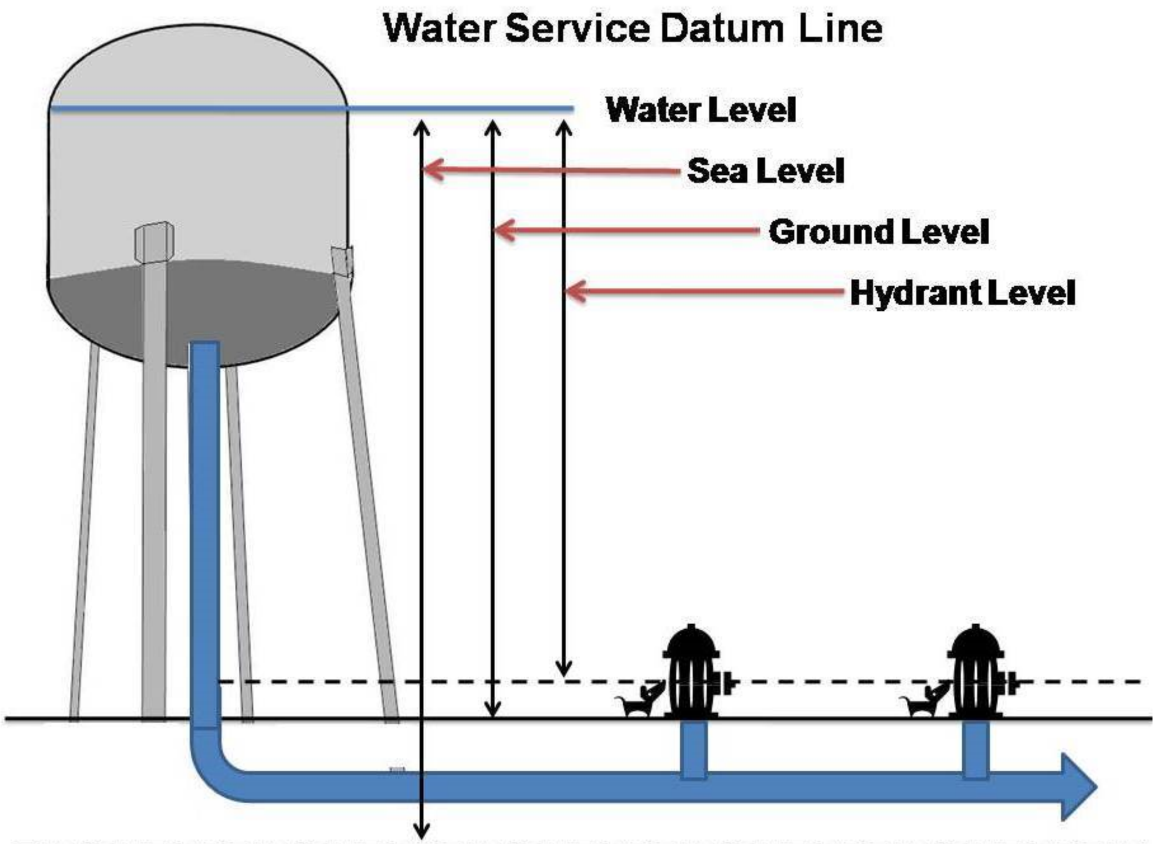
1. Fill the tank or reservoir with a 25 mg/1chlorine solution and leave it for 24 hours.
*2. Fill the reservoir with a 50 mg/1 chlorine solution and leave it for 3 hours.
*3. Spray or brush on a 200 mg/1 chlorine solution and allow it to remain for 3 hours.

The chlorinated water shall be disposed of in a manner that will not have an adverse effect on the environment. Check with your state environmental, health or drinking water section.

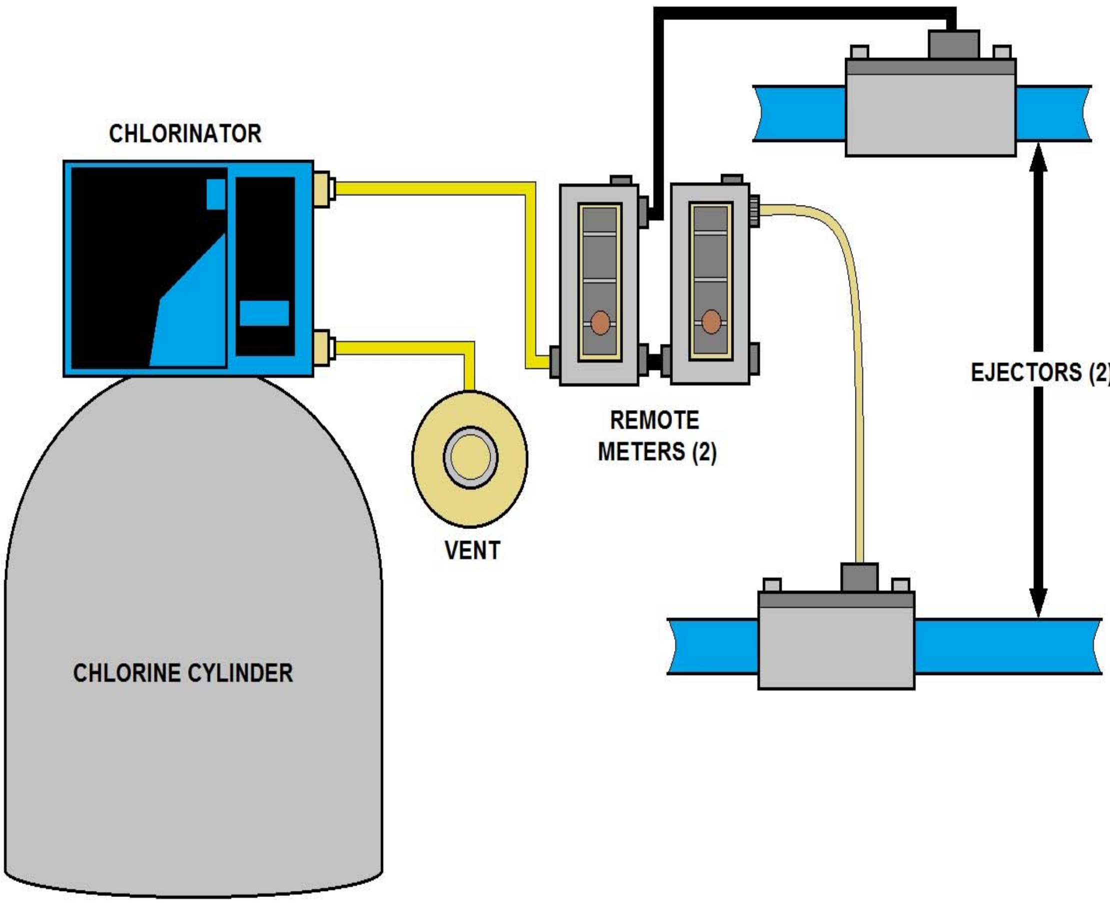
Hydropneumatic Tank Section

Hydropneumatic Tanks Out of Service for Maintenance
Effects on the Water Supply

*Whenever a tank must be taken out of service for maintenance, the operator should insure that the water pressure is maintained by other back-up tanks in the system. If this is not possible, customers should be given as much advance notice as possible, maintenance should be conducted during periods of low water demand, and the maintenance should be conducted as quickly as possible to reduce the time without water service.



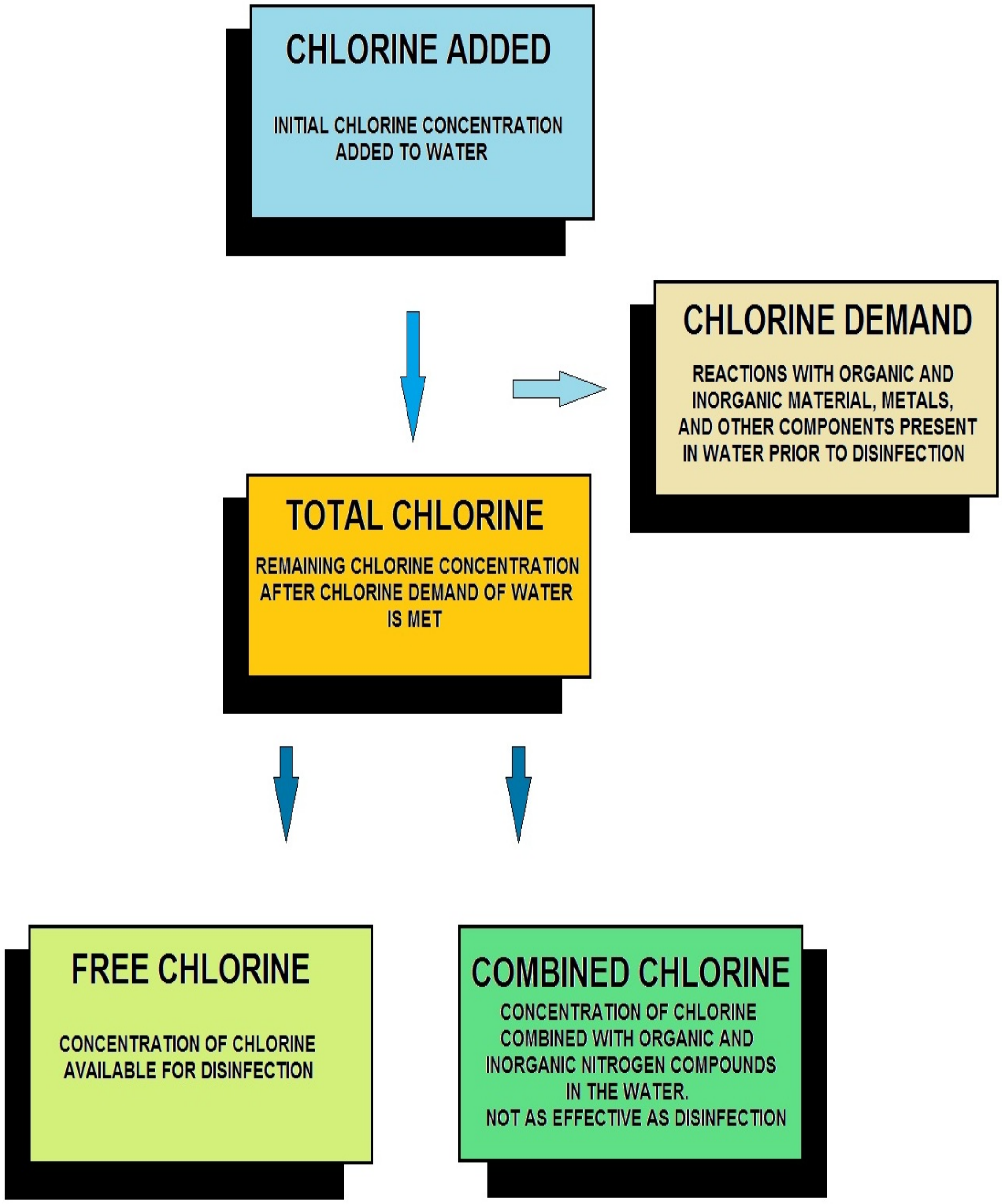
Chlorine Section Chapter 4



Chlorine Exposure Limits

This information is necessary to pass your certification exam.

*** OSHA PEL 1 PPM - IDLH 10 PPM and Fatal Exposure Limit 1,000 PPM**
The current Occupational Safety and Health Administration (**OSHA**) permissible exposure limit (**PEL**) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m(3))) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level. *** IDLH 10 PPM**



CHLORINE DISINFECTION

Modern Water Treatment Disinfectants

Many water suppliers add a disinfectant to drinking water to kill germs such as giardia and e coli. Especially after heavy rainstorms or water main breaks, your water system may add more disinfectant to guarantee that these germs are killed.

***Chlorine.** Some people who use drinking water containing chlorine well in excess of EPA's standard could experience irritating effects to their eyes and nose. Some people who drink water containing chlorine well in excess of EPA's standard could experience stomach discomfort.

***Chloramine.** Some people who use drinking water containing chloramines well in excess of EPA's standard could experience irritating effects to their eyes and nose. Some people who drink water containing chloramines well in excess of EPA's standard could experience stomach discomfort or anemia.

***Chlorine Dioxide.** Some infants and young children who drink water containing chlorine dioxide in excess of EPA's standard could experience nervous system effects. Similar effects may occur in fetuses of pregnant women who drink water containing chlorine dioxide in excess of EPA's standard. Some people may experience anemia.

Chlorine

Today, most of our drinking water supplies are free of the micro-organisms — viruses, bacteria, and protozoa — that cause serious and life-threatening diseases, such as cholera and typhoid fever. This is largely due to the introduction of water treatment, particularly chlorination, at the turn of the century.

Living cells react with chlorine and reduce its concentration while they die. Their organic matter and other substances that are present convert to chlorinated derivatives, some of which are effective killing agents.

*Chlorine present as Cl, HOCl, and OCl^{-} is called ***free available chlorine***, and that which is bound but still effective is ***combined chlorine***. A particularly important group of compounds with combined chlorine is the chloramines formed by reactions with ammonia.

*One especially important feature of disinfection using chlorine is the ease of overdosing to create a "**residual**" concentration. There is a constant danger that safe water leaving the treatment plant may become contaminated later. There may be breaks in water mains, loss of pressure that permits an inward leak, or plumbing errors. This residual concentration of chlorine provides some degree of protection right to the water faucet. With free available chlorine, a typical residual is from 0.1 to 0.5 ppm. Because chlorinated organic compounds are less effective, a typical residual is 2 ppm for combined chlorine.

*There will be no chlorine residual unless there is an excess over the amount that reacts with the organic matter present. However, reaction kinetics complicates interpretation of chlorination data. The correct excess is obtained in a method called **"Break Point Chlorination".**

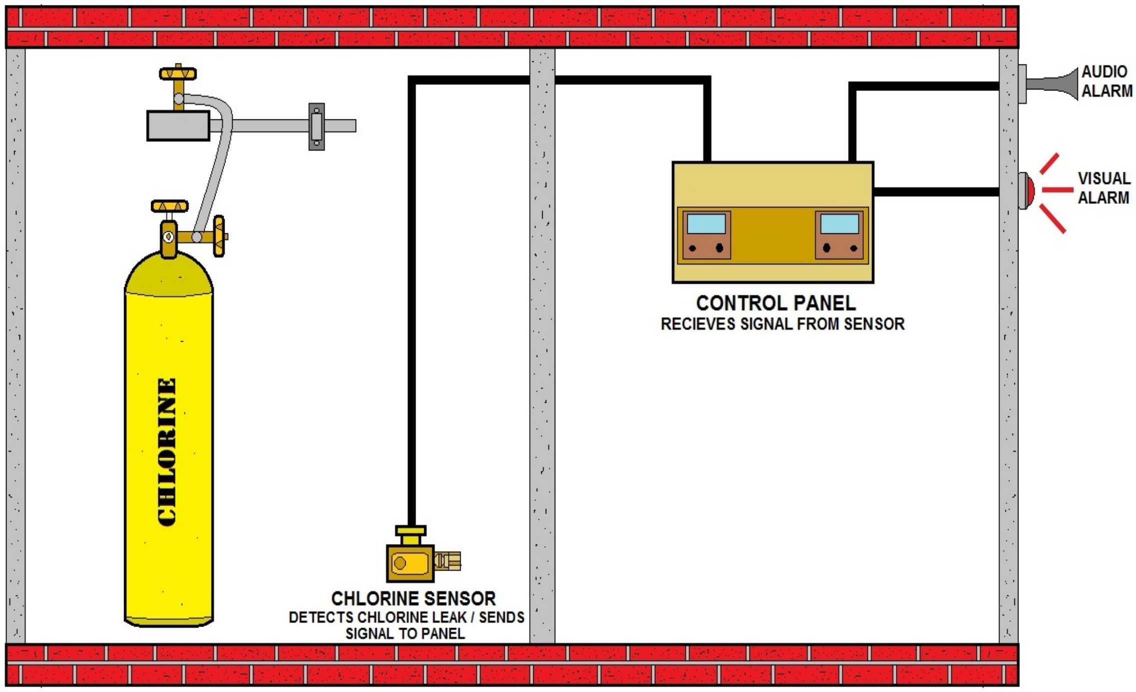
***Chlorine by-products**
Chlorination by-products are the chemicals formed when the chlorine used to kill disease-causing micro-organisms reacts with naturally occurring organic matter (e.g., decay products of vegetation) in the water. *The most common chlorination by-products found in U.S. drinking water supplies are the trihalomethanes (**THMs**).

***The principal trihalomethanes are:**
Chloroform, bromodichloromethane, chlorodibromomethane, and bromoform. Other less common chlorination by-products include the haloacetic acids and haloacetonitriles. The amount of THMs formed in drinking water can be influenced by a number of factors, including the season and the source of the water.

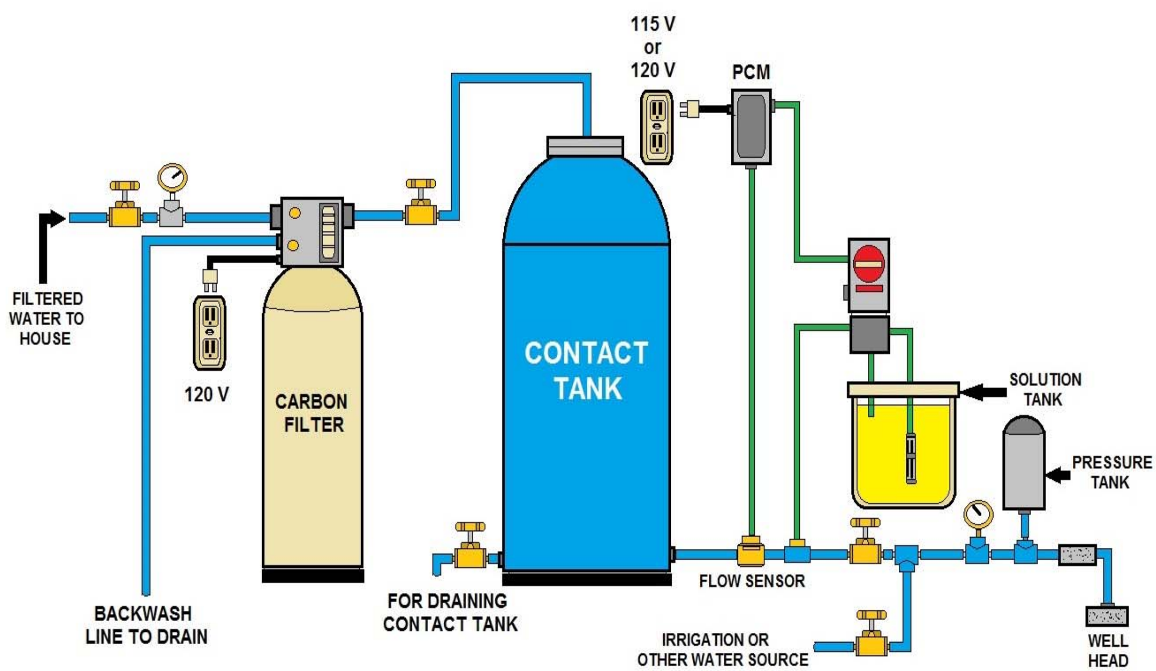
For example, THM concentrations are generally lower in winter than in summer, because concentrations of natural organic matter are lower and *less chlorine is required to disinfect at colder temperatures but longer contact times. THM levels are also low when wells or large lakes are used as the drinking water source, because organic matter concentrations are generally low in these sources.

The opposite — high organic matter concentrations and high THM levels — is true when rivers or other surface waters are used as the source of the drinking water.

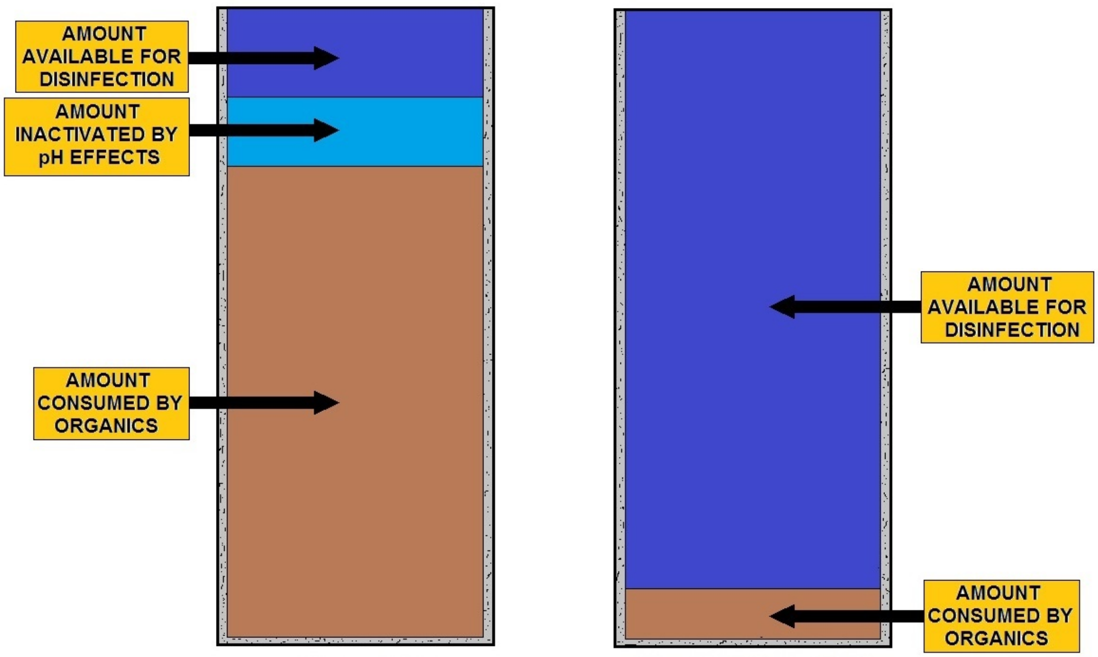
*Chlorine storage room, notice the vents at the bottom and top. The bottom vent will allow the gas to ventilate because Cl_2 gas is heavier than air.



CHLORINE STORAGE ROOM



CHLORINATING WELL WATER



THE DIFFERENCE IN USING CHLORINE AND CHLORINE DIOXIDE AS A DISINFECTANT

BACTERIA / VIRUS	DISINFECTION TIME FOR FECAL CONTAMINANTS IN CHLORINATED WATER
E. COLI (BACTERIUM)	LESS THAN 1 MINUTE OF CONTACT TIME
HEPATITUS A (VIRUS)	APPROXIMATELY 16 MINUTES CONTACT TIME
GIARDIA (PARASITE)	APPROXIMATELY 45 MINUTES CONTACT TIME
CRYPTOSPORIDIUM (PARASITE)	APPROXIMATELY 10.6 DAYS (15,300 minutes)

CHLORINE TIMETABLE FOR PROPER DISINFECTION

Chlorine Gas

Chlorine gas is likely the most widely used oxidizing microbiocide. It has traditionally been the biocide of choice in many cooling water treatment systems. It is a strong oxidizer that is relatively easy to feed and is quite inexpensive. Upon introduction into the water stream, chlorine hydrolyzes into hypochlorous acid (HOCl) and hydrochloric acid (HCl).

This hydrolyzation provides the active toxicant, HOCl, which is pH-dependent. In alkaline cooling systems, it readily dissociates to form the hypochlorite ion (OCl-). This dissociation phenomenon is important to remember when working with systems that will operate at a higher pH. In alkaline conditions, OCl- becomes the predominant species and lacks the biocidal efficacy of the non-dissociated form. Considerably more HOCl is present at a pH of 7.0 than at pH 8.5.

It is also widely known that chlorine is non-selective, making it very sensitive to contamination from either cooling water makeup or from in-plant process leaks. Ammonia, organic acids and organic compounds, sulfides, iron and manganese all easily react with HOCl. The amount of chlorine needed to react with these contamination species is referred to as chlorine demand and it must be satisfied before active HOCl is available to provide a free chlorine residual.

The combination of high chlorine demand in process-contaminated systems and the dissociation process in alkaline systems creates the need for greater chlorine feed to obtain the same microbial efficacy. This results in a higher concentration of HCl in the cooling system. Since HCl removes alkalinity, pH depression and system corrosion could occur. In low pH water the passive metal oxide layers protecting the metal may resolubulize, exposing the surface to corrosion. At free mineral acidity (pH <4.3), many passivating inhibitors become ineffective, and corrosion will proceed rapidly. Increased chloride may also have a negative impact on system corrosion. The chloride ion (Cl^-) can damage or penetrate the passive oxide layer, leading to localized damage of the metal surface.

High chlorine concentrations have also been shown to directly attack traditional organic-based corrosion inhibitors. When these inhibitors are "deactivated," the metal surface would then be susceptible to corrosion. Process Safety Management (PSM) guidelines dictated by the U.S. Occupational Safety and Health Administration (OSHA), discharge problems related to chlorinated organic compounds such as trihalomethane (THM), dezincification of admiralty brass and delignification of cooling tower wood are other significant concerns associated with the use of chlorine.

Pathophysiology
Chlorine is a greenish-yellow, noncombustible gas at room temperature and atmospheric pressure. The intermediate water solubility of chlorine accounts for its effect on the upper airway and the lower respiratory tract.

Exposure to chlorine gas may be prolonged because its moderate water solubility may not cause upper airway symptoms for several minutes. In addition, the density of the gas is greater than that of air, causing it to remain near ground level and increasing exposure time.

The odor threshold for chlorine is approximately 0.3-0.5 parts per million (ppm); however, distinguishing toxic air levels from permissible air levels may be difficult until irritative symptoms are present.

Mechanism of Activity
The mechanisms of the above biological activity are poorly understood and the predominant anatomic site of injury may vary, depending on the chemical species produced. Cellular injury is believed to result from the oxidation of functional groups in cell components, from reactions with tissue water to form hypochlorous and hydrochloric acid, and from the generation of free oxygen radicals.

Although the idea that chlorine causes direct tissue damage by generating free oxygen radicals was once accepted, this idea is now controversial. The cylinders on the right contain chlorine gas.

The gas comes out of the cylinder through a gas regulator. The cylinders are on a scale that operators use to measure the amount used each day. The chains are used to prevent the tanks from falling over. Chlorine gas is stored in vented rooms that have panic bar equipped doors. Operators have the equipment necessary to reduce the impact of a gas leak, but rely on trained emergency response teams to contain leaks.

Solubility Effects
Hydrochloric acid is highly soluble in water. The predominant targets of the acid are the epithelia of the ocular conjunctivae and upper respiratory mucus membranes.

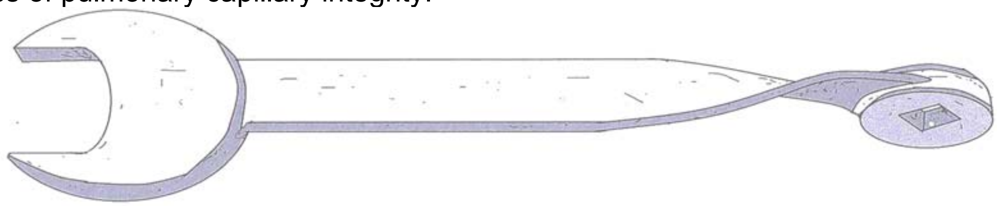
Hypochlorous acid is also highly water soluble with an injury pattern similar to hydrochloric acid. Hypochlorous acid may account for the toxicity of elemental chlorine and hydrochloric acid to the human body.

Early Response to Chlorine Gas
Chlorine gas, when mixed with ammonia, reacts to form chloramine gas. In the presence of water, chloramines decompose to ammonia and hypochlorous acid or hydrochloric acid. The early response to chlorine exposure depends on the (1) concentration of chlorine gas, (2) duration of exposure, (3) water content of the tissues exposed, and (4) individual susceptibility.

Immediate Effects
The immediate effects of chlorine gas toxicity include acute inflammation of the conjunctivae, nose, pharynx, larynx, trachea, and bronchi. Irritation of the airway mucosa leads to local edema secondary to active arterial and capillary hyperemia. Plasma exudation results in filling the alveoli with edema fluid, resulting in pulmonary congestion.

Pathological Findings
Pathologic findings are nonspecific. They include severe pulmonary edema, pneumonia, hyaline membrane formation, multiple pulmonary thromboses, and ulcerative tracheobronchitis.

The hallmark of pulmonary injury associated with chlorine toxicity is pulmonary edema, manifested as hypoxia. Noncardiogenic pulmonary edema is thought to occur when there is a loss of pulmonary capillary integrity.



TWISTED CHLORINE WRENCH

Chlorine is a highly reactive gas. It is a naturally occurring element. Chlorine is produced in very large amounts (23 billion pounds in 1992) by eighteen companies in the United States. US demand for chlorine is expected to increase slightly over the next several years and then decline. The expected decline in US demand is due to environmental concerns for chlorinated organic chemicals. The largest users of chlorine are companies that make ethylene dichloride and other chlorinated solvents, polyvinyl chloride (PVC) resins, chlorofluorocarbons, and propylene oxide. Paper companies use chlorine to bleach paper. Water and wastewater treatment plants use chlorine to reduce water levels of microorganisms that can spread disease to humans.

Exposure to chlorine can occur in the workplace or in the environment following releases to air, water, or land. People who use laundry bleach and swimming pool chemicals containing chlorine products are usually not exposed to chlorine itself. Chlorine is generally found only in industrial settings. Chlorine enters the body breathed in with contaminated air or when consumed with contaminated food or water. It does not remain in the body due to its reactivity.

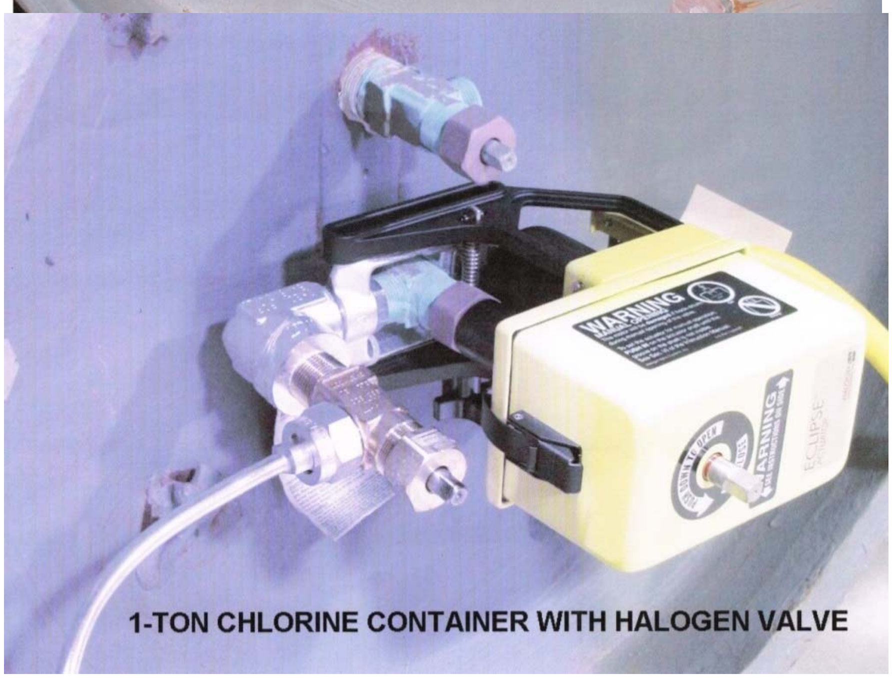
Chlorine gas is greenish yellow in color and very toxic. It is heavier than air and will therefore sink to the ground if released from its container. It is the toxic effect of chlorine gas that makes it a good disinfectant, but it is toxic to more than just waterborne pathogens; it is also toxic to humans. It is a respiratory irritant and it can also irritate skin and mucus membranes. Exposure to high volumes of chlorine gas fumes can cause serious health problems, including death. However, it is important to realize that chlorine gas, once entering the water, changes into hypochlorous acid and hypochlorite ions, and therefore its human toxic properties are not found in the drinking water we consume.

Chlorine gas is sold as a compressed liquid, which is amber in color. Chlorine, as a liquid, is heavier (more dense) than water. If the chlorine liquid is released from its container it will quickly return back to its gas state. Chlorine gas is the least expensive form of chlorine to use.

The typical amount of chlorine gas required for water treatment is 1-16 mg/L of water. Different amounts of chlorine gas are used depending on the quality of water that needs to be treated.

If the water quality is poor, a higher concentration of chlorine gas will be required to disinfect the water if the contact time cannot be increased.

1-TON CHLORINE CONTAINER VALVES



1-TON CHLORINE CONTAINER WITH HALOGEN VALVE

Chlorine’s Appearance and Odor

Chlorine is a greenish-yellow gas with a characteristic pungent odor. It condenses to an amber liquid at approximately -34 degrees C (-29.2 degrees F) or at high pressures. Odor thresholds ranging from 0.08 to part per million (ppm) parts of air have been reported. Prolonged exposures may result in olfactory fatigue.

Reactivity
1. **Conditions Contributing to Instability**: Cylinders of chlorine may burst when exposed to elevated temperatures. Chlorine in solution forms a corrosive material.

2**. Incompatibilities**: Flammable gases and vapors form explosive mixtures with chlorine. Contact between chlorine and many combustible substances (such as gasoline and petroleum products, hydrocarbons, turpentine, alcohols, acetylene, hydrogen, ammonia, and sulfur), reducing agents, and finely divided metals may cause fires and explosions. Contact between chlorine and arsenic, bismuth, boron, calcium, activated carbon, carbon disulfide, glycerol, hydrazine, iodine, methane, oxomonosilane, potassium, propylene, and silicon should be avoided. Chlorine reacts with hydrogen sulfide and water to form hydrochloric acid, and it reacts with carbon monoxide and sulfur dioxide to form phosgene and sulfuryl chloride. Chlorine is also incompatible with moisture, steam, and water.
3. **Hazardous Decomposition Products:** None reported.

CHANGING OUT A 1-TON CHLORINE CONTAINER

4**. Special Precautions:** Chlorine will attack some forms of plastics, rubber, and coatings.

Flammability
Chlorine is a non-combustible gas.
The National Fire Protection Association has assigned a flammability rating of 0 (no fire hazard) to chlorine; however, most combustible materials will burn in chlorine.

1. **Flash point:** Not applicable.

2. **Autoignition temperature**: Not applicable.

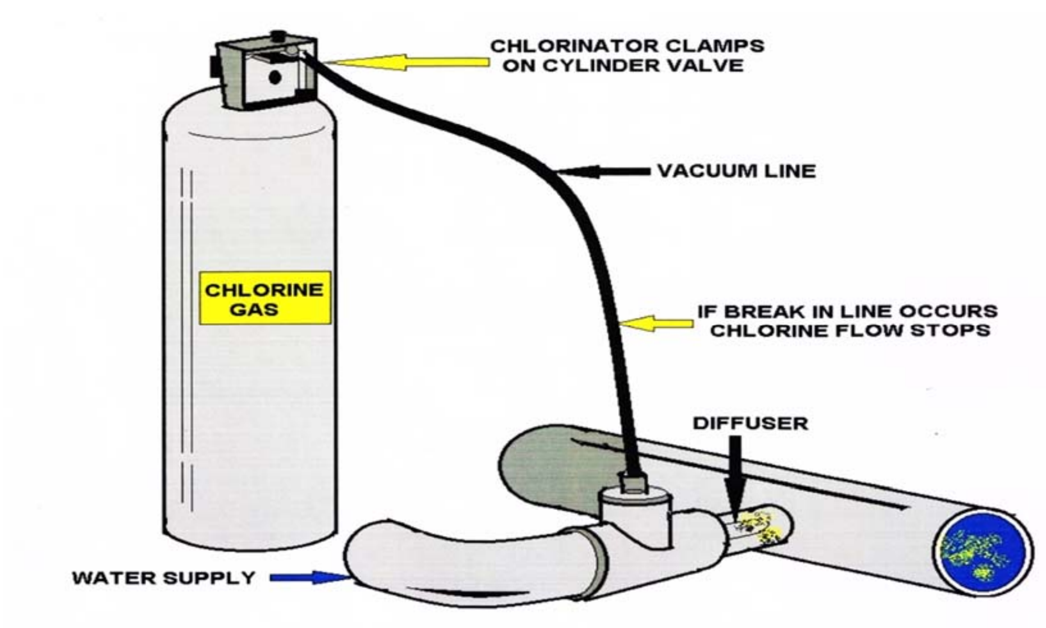
3. **Flammable limits in air:** Not applicable.

4. **Extinguishant:** For small fires use water only; do not use dry chemical or carbon dioxide. Contain and let large fires involving chlorine burn. If fire must be fought, use water spray or fog.

Fires involving chlorine should be fought upwind from the maximum distance possible.

Keep unnecessary people away; isolate the hazard area and deny entry. For a massive fire in a cargo area, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from the area and let the fire burn. Emergency personnel should stay out of low areas and ventilate closed spaces before entering.

Containers of chlorine may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool fire exposed containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Firefighters should wear a full set of protective clothing and self- contained breathing apparatus when fighting fires involving chlorine.



Disinfection Essentials

Selecting the right disinfection weapon requires understanding the factors governing the particular site and the water or wastewater to be treated. In general, the selection of an appropriate disinfection system should be evaluated against the following six criteria:

***Safety*.** How does the disinfectant work and what types of precautions are needed to transport, store, use, and operate the disinfectant system and associated chemicals? If a system will require significant safety protection—such as use of breathing apparatus and protective clothing—as well as high levels of operator training, it may be advisable to explore other, less intensive systems. In addition, while the disinfectant may be relatively safe to use, consideration also has to be made for the effects of both intentional and unintentional releases to the environment.
***Effectiveness*.** How effective is the disinfectant against the pathogens present in the water or wastewater? Since the intent is to reduce the levels of pathogens to acceptable standards, understanding how effective the proposed disinfectant system is in achieving those target levels, as well as the system's ability to reliably achieve the result, will be important to selecting the right system.
***Cost*.** What are the costs associated with the disinfection system, both in terms of capital outlay and ongoing operations and maintenance? Operating costs can vary in terms of the time it takes to service the disinfectant system regularly, and the costs of supplies and components.
Complexity of use. How does the system operate and does it take specialized training to keep the system within tolerances? Since the outflow from the treatment facility may be subject to various standards and regulations, if the system is too complex it may require additional staff time to ensure that it operates within the desired parameters.
Environmental/Adverse Effects. What are some of the potential downsides to the operation of the system as it relates to the distribution system or watershed in which the treated effluent is discharged? While some systems may provide a net-positive environmental benefit through increased oxygenation of the receiving waters, other systems may need to have additional treatment of the disinfected effluent in order to render it benign when released.
***Flow and Water Characteristics*.** Can the system handle fluctuations within the flow or with changing characteristics of the water or wastewater being processed? If a system has a narrow tolerance for the amount of water or wastewater flow, this could impact the effectiveness of the overall system. In addition, if the system cannot adjust for off-site concerns such as dry or wet weather flow rates of the receiving water body, this may also affect the system's appropriateness for your application.

With those criteria in mind, there are primarily four basic disinfection systems currently available—chlorination, ozone gas, ultraviolet radiation, and chemical treatment other than chlorine.

A variety of factors come into play in deciding which type of disinfectant system is right for your operation. The decision to install a system could be the result of local concerns and potential to mitigate health risks, as well as improved community relations. In any event, the operator of an onsite water or wastewater treatment plant needs to consider some of the safeguards that need to be in place as well.

"Typical safeguards include operator training and instrumentation monitoring that will perform a shutdown function if something goes above a certain level," says Schilling. "If they detect [for example] an ozone leak, you can do an interconnect and do a plant shutdown. UV has safeguards where you have monitors that tell you what your dosage is, and if you're over or under your dosage it will perform some kind of warning of whatever you want to do."

State and Local Regulations

State and local regulations vary considerably in their requirements to disinfect wastewater, so the decision of what type of system to use can be affected by the chemical and physical composition of the wastewater stream, the environment to which it will be discharged, and the concerns of the local health department. "It's all over the place," says Bach. "The chemical itself is a pesticide and is regulated by the US EPA.

The states will specify what sort of *E. coli* or *coliform* counts you're going to have on discharge, and the regulations vary all over the map in the states. You've got a lot of things like that throughout the country and it goes down to ultimately the views of local health departments and reflect the local topography, their local population density, and also their experience of whether or not people have gotten sick."

Alternative Disinfectants *More information in the Alternative Section*

Unknown Factors Associated with Alternatives

Scientific investigation of risk associated with alternative disinfectants and alternative disinfection by-products is limited. A decision by water facilities to switch from chlorination could be risky because scientists know so little about DBPs from processes other than chlorination.

Drinking Water Disinfectants At a Glance

Disinfectants	Residual Maintenance	State of Information on By-Product Chemistry	Color Removal	Removal of Common Odors
Chlorine	Good	Adequate	Good	Good
Chloramines	Good	Limited	Unacceptable	Poor
Chlorine dioxide	Unacceptable*	Adequate	Good	Good
Ozone	Unacceptable	Limited	Excellent	Excellent
Ultraviolet radiation	Unacceptable	Nil	N/A	N/A

*In Europe, 50% of water distribution systems use chlorine dioxide as the residual disinfectant

Source: Trussell, R., Control Strategy 1; Alternative Oxidants and Disinfectants, 1991

Chlorine Basics

Chlorine is one of 90 natural elements, the basic building blocks of our planet. To be useful, an element must be relatively abundant or have extremely desirable properties. Chlorine has both characteristics. As a result -- over the course of many decades of careful research and development -- scientists have learned to use chlorine and the products of chlorine chemistry to make drinking water safe, destroy life-threatening germs, produce life-saving drugs and medical equipment, shield police and fire fighters in the line of duty, and ensure a plentiful food supply.

One of the most effective and economical germ-killers, chlorine also destroys and deactivates a wide range of dangerous germs in homes, hospitals, swimming pools, hotels, restaurants, and other public places. Chlorine's powerful disinfectant qualities come from its ability to bond with and destroy the outer surfaces of bacteria and viruses. First used as a germicide to prevent the spread of "child bed fever" in the maternity wards of Vienna General Hospital in Austria in 1846, chlorine has been one of society's most potent weapons against a wide array of life-threatening infections, viruses, and bacteria for 150 years.

When the first men to set foot on the moon returned to earth (Apollo 11 mission: 24.7.69) a hypochlorite solution was chosen as one of the disinfectants for destroying any possible moon germs.

Disinfectant Qualities
Restaurants and meat and poultry processing plants rely on chlorine bleach and other chlorine-based products to kill harmful levels of bacteria such as *Salmonella* and *E. coli* on food preparation surfaces and during food processing. Chlorine is so important in poultry processing that the US Department of Agriculture requires an almost constant chlorine rinse for much of the cutting equipment. In fact, no proven economical alternative to chlorine disinfection exists for use in meat and poultry processing facilities.

Properties
Because it is highly reactive, chlorine is usually found in nature bound with other elements like sodium, potassium, and magnesium. When chlorine is isolated as a free element, chlorine is a greenish yellow gas, which is 2.5 times heavier than air. It turns to a liquid state at -34°C (-29°F), and it becomes a yellowish crystalline solid at -103°C (-153°F). Chemists began experimenting with chlorine and chlorine compounds in the 18th century. They learned that chlorine has an extraordinary ability to extend a chemical bridge between various elements and compounds that would not otherwise react with each other. Chlorine has been especially useful in studying and synthesizing organic compounds -- compounds that have at least one atom of the element carbon in their molecular structure. All living organisms, including humans, are composed of organic compounds.

Chlorine is one of the most abundant chemical elements on Earth. It is ubiquitous in soils, minerals, plants and animals. Seawater is a huge reservoir of dissolved chlorine weathered from the continents and transported to the oceans by Earth's rivers. Chlorine is also one of the most useful chemical elements. Each chemical element has its own set of unique properties and chlorine is known as a very reactive element--so reactive, in fact, that it is usually found combined with other elements in the form of compounds.

More than 3,500 naturally occurring chlorinated organic (associated with living organisms) compounds alone have been identified.

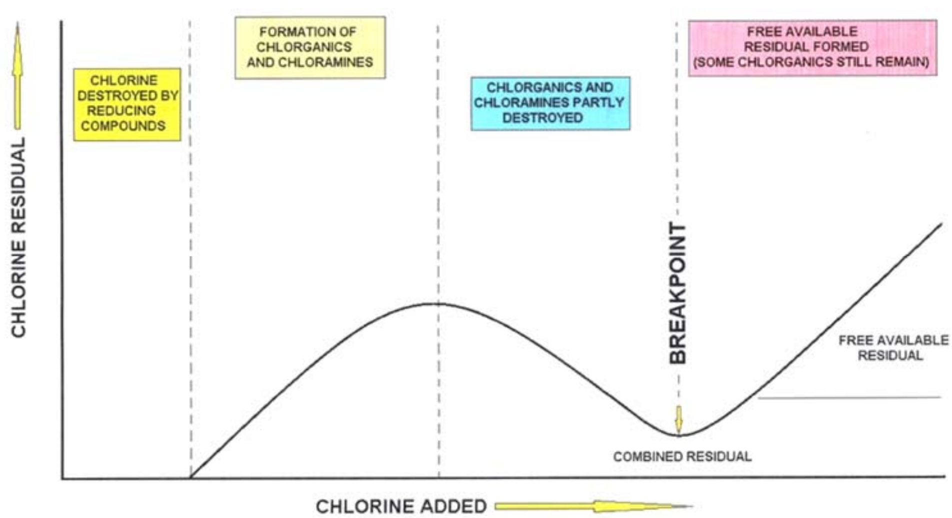
Chlorine's chemical properties have been harnessed innovatively for good use. For example, this element plays a huge role in public health. Chlorine-based disinfectants are capable of removing a wide variety of disease-causing germs from drinking water and wastewater as well as from hospital and food production surfaces. Additionally, chlorine plays an important role in the manufacture of thousands of products we depend upon every day, including such diverse items as cars, computers, pharmaceuticals and military flak jackets. As the ninth largest chemical produced in the U.S. by volume, chlorine is truly a "workhorse chemical."

Released From the Salt of the Earth
Chlorine is produced industrially from the compound sodium chloride, one of the many salts found in geologic deposits formed from the slow evaporation of ancient seawater. When electricity is applied to a brine solution of sodium chloride, chlorine gas (Cl2), caustic soda (NaOH) and hydrogen gas (H_2) are generated according to the following reaction:

Salt + Water → Chlorine gas + Caustic soda + Hydrogen gas

$$2\,NaCl + 2\,H_2O \rightarrow Cl_2 + 2\,NaOH + H_2$$

Co-Products
As the reaction demonstrates, chlorine gas cannot be produced without producing caustic soda, so chlorine and caustic soda are known as "co-products," and their economics are inextricably linked. Caustic soda, also called "alkali," is used to produce a wide range of organic and inorganic chemicals and soaps. In addition, the pulp and paper, alumina and textiles industries use caustic soda in their manufacturing processes. Thus, the "chlor-alkali" industry obtains two very useful chemicals by applying electrical energy to sea salt.



Related Terms and Definitions
Chlorine Gas Feed Room
A chlorine gas feed room, for the purposes of this document, is a room that contains the chlorinator(s) and active cylinder(s) used to apply chlorine gas at a water or wastewater facility.

Chlorine Gas Storage Room
A chlorine gas storage room, for the purposes of this document, is a room other than a chlorine gas feed room, in which full, partial, or empty chlorine gas cylinders or ton containers are stored at a water or wastewater facility.

Gas Chlorinator
A gas chlorinator is a device used to meter and control the application rate of chlorine gas into a liquid. There is the danger of the gas escaping at a water or wastewater treatment facility. The gas chlorinator should be isolated from a water or wastewater treatment plant.

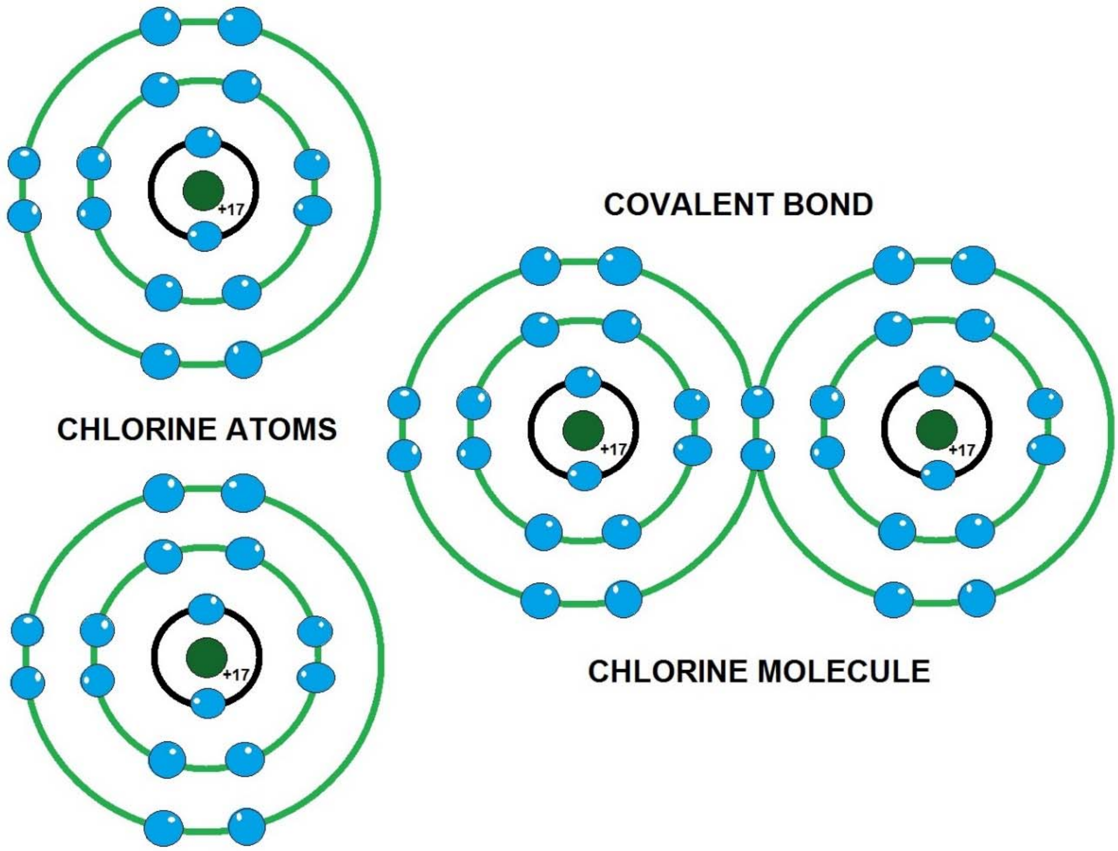
Chlorine Cabinet
A chlorine cabinet is a pre-assembled or factory built unit that contains the equipment used to apply chlorine gas at a water or wastewater treatment facility. It is isolated from a water or wastewater treatment plant.

Chlorine Exposure Limits
*** OSHA PEL**
The current **OSHA** permissible exposure limit (**PEL**) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m$^{(3)}$)) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level [29 CFR 1910.1000, Table Z-1].

*** NIOSH REL**
The National Institute for Occupational Safety and Health (**NIOSH**) has established a recommended exposure limit (**REL**) for chlorine of 0.5 ppm mg/m$^{(3)}$) as a TWA for up to a 10-hour workday and a 40-hour workweek and a short-term exposure limit (**STEL**) of 1 ppm (3 mg/m$^{(3)}$)[NIOSH 1992].

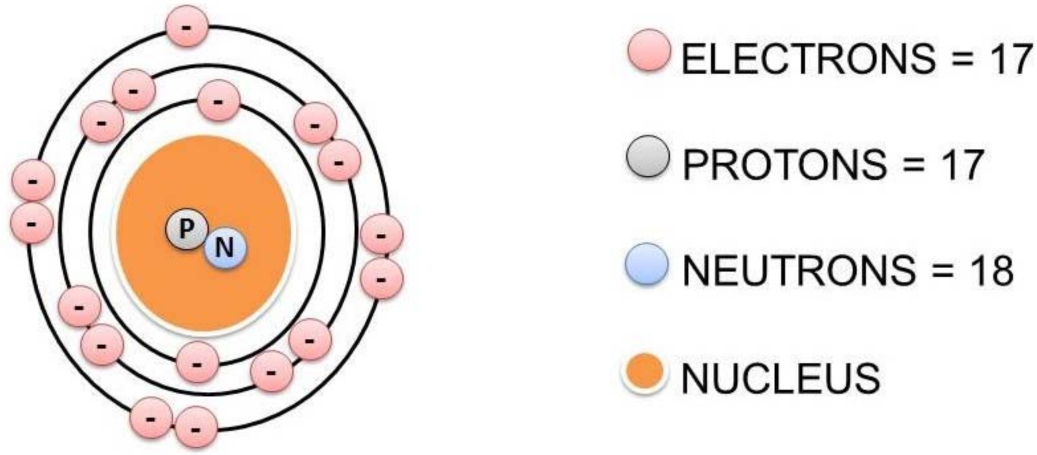
*** ACGIH TLV**
The American Conference of Governmental Industrial Hygienists (**ACGIH**) has assigned chlorine a threshold limit value (**TLV**) of 0.5 ppm (1.5 mg/m$^{(3)}$) as a TWA for a normal 8-hour workday and a 40-hour workweek and a **STEL** of 1 ppm (2.9 mg/m$^{(3)}$) for periods not to exceed 15 minutes. Exposures at the STEL concentration should not be repeated more than four times a day and should be separated by intervals of at least 60 minutes [ACGIH 1994, p. 15].

*** Rationale for Limits**
The NIOSH limits are based on the risk of severe eye, mucous membrane and skin irritation [NIOSH 1992]. The ACGIH limits are based on the risk of eye and mucous membrane irritation [ACGIH 1991, p. 254].



STRUCTURE OF A CHLORINE ATOM

Chlorine's Atomic Structure



Isotopes

Isotope	Half Life
Cl-35	Stable
Cl-36	301000.0 years
Cl-37	Stable
Cl-38	37.2 minutes

Chlorine's Effectiveness
The effectiveness of chlorination depends on the chlorine demand of the water, the concentration of the chlorine solution added, the time that chlorine is in contact with the organism, and water quality. These effects can be summarized in the following manner:

As the concentration of the chlorine increases, the required contact time to disinfect decreases.

Chlorination is more effective as water temperature increases.

Chlorination is less effective as the water's pH increases (becomes more alkaline).

Chlorination is less effective in cloudy (turbid) water.

When chlorine is added to the water supply, part of it combines with other chemicals in water (like iron, manganese, hydrogen sulfide, and ammonia) and is not available for disinfection. The amount of chlorine that reacts with the other chemicals plus the amount required to achieve disinfection is the **chlorine demand** of the water.

The safest way to be sure that the amount of chlorine added is sufficient is to add a little more than is required. This will result in a free chlorine residual that can be measured easily. This chlorine residual must be maintained for several minutes depending on chlorine level and water quality. Table 4 lists the free chlorine residual level needed for different contact times, water temperatures and pH levels.

Kits are available for measuring the chlorine residual by looking for a color change after the test chemical is added. The test is simple and easy for a homeowner to perform. If chlorination is required for the water supply, the chlorine residual should be tested regularly to make sure the system is working properly. The kit should specify that it measures the free chlorine residual and not the total chlorine. Once chlorine has combined with other chemicals it is not effective as a disinfectant.

If a test kit does not distinguish between free chlorine and chlorine combined with other chemicals, the test may result in an overestimation of the chlorine residual.

Oxidation Chemistry

Oxidation chemistry has long been an accepted and effective part of many water treatment programs. Oxidizing chemicals used in today's water treatment programs include: chlorine, chlorine dioxide, bromine, bromine/chlorine releasing compounds, ozone and hydrogen peroxide.

Oxidizing microbicides are often found at the forefront of many cooling water treatment programs. In large volume or once-through cooling systems they are usually the primary biocide and often are the most cost-effective programs available to a plant. When selecting these economical and versatile chemicals, several factors should be considered before a technically sound program is implemented. Environmental and regulatory impact, system pH, process contamination, and equipment capital and maintenance expense all play a role in the decision-making process.

The primary killing mechanism these types of microbicides use is oxidizing protein groups within a microorganism. Proteins are the basic components of essential cellular enzymes that are necessary for life-sustaining cellular processes such as respiration. The destruction of these proteins deprives the cell of its ability to carry out fundamental life functions and quickly kills it.

One oxidant is chlorine dioxide, which appears to provide an additional killing mechanism. Chlorine dioxide is able to diffuse readily through hydrophobic lipid layers of an organism, allowing it to react with cellular amino acids, which directly inhibits protein synthesis. Since amino acids are the basic building blocks of all cellular proteins, destruction of these molecules has a devastating effect on the microorganism.

		MICROBIOLOGICAL SAFETY	CHEMICAL SAFETY	CUSTOMER AESTHETICS	EASE OF MONITORING	ABILITY TO TREAT DIFFICULT WATER	COST OF OPERATING	CAPITAL COSTS	STATE OF COMMERCIAL DEVELOPMENT	SCALE-UP	WASTE PRODUCTION AND ENERGY USE	RELIABILITY
GROUNDWATER	CHLORINE	—	—	—	+	+	+	+	+	+	+	—
	UF ONLY	—	+	+	—	+	●	●	—	—	●	—
	UV ONLY	+	+	+	●	+	+	●	+	+	●	●
	Alternate + Residual (1)	+	●	●	+	+	●	—	+	+	+	+
SURFACE WATER	CHLORINE ONLY	—	—	—	+	—	+	+	+	+	+	+
	Conventional pre-treat + CHLORINE	+	—	—	+	—	●	●	+	+	●	—
	UF ONLY	—	—	●	—	—	●	●	—	—	●	—
	Conventional pre-treat +UF	●	+	+	—	+	—	—	—	—	—	—
	Coventional pre-treat + OZONE + UF	—	●	—	—	+	—	—	—	—	—	—
	MF + UV	●	+	—	●	—	+	●	—	—	●	+
	Conventional pre-treat + UV	●	+	+	●	—	+	●	+	+	●	●
	Conventional pre-treat + OZONE + UV	+	●	+	+	+	—	—	+	+	●	+
	Alternative + Residual (2)	+	●	●	+	+	—	—	+	+	+	+

Conventional pre-treat = Coagulation / Sedimentation
UF - Ultafiltration MF - Microfiltration
+ = Better than average
— = Worse than average
● = Average

(1) UF + Chlorine residual or Conv + UV + Chlorine residual

(2) Conv pre-treat + UF + Chlorine residual or MF + UV + Chlorine residual or Conv pre-treat + UV + Residual

ASSESSMENT TO DETERMINE EFFECTIVE DISINFECTION METHODS

DISINFECTION OF WATER	
DISINFECTANT	**WHAT DISINFECTANT IS USED FOR**
OZONE (O_3)	USED IN DESTROYING BACTERIA, ODORS AND VIRUSES (Scrambles DNA in Viruses to prevent reproduction)
CHLORINE (Cl_2)	USED TO KILL DISEASE-CAUSING PATHOGENS SUCH AS BACTERIA, VIRUSES AND PROTOZOANS
POTASSIUM PERMANGANATE ($KMnO_4$)	USED TO REMOVE IRON AND HYDROGEN SULFIDE, AND ALSO USED IN TREATMENT PLANTS TO CONTROL ZEBRA MUSSEL FORMATIONS
COPPER SULFATE ($CuSO_4$)	USED CONTROL PLANT AND ALGAE GROWTH
CALCIUM HYPOCHLORITE (Ca(ClO)2)	DESTROYS DISEASE-CAUSING ORGANISMS INCLUDING BACTERIA, YEAST, FUNGUS, SPORES AND VIRUSES
CALCIUM HYDROXIDE (Lime) (CaO)	USED FOR pH CONTROL IN WATER TREATMENT TO PREVENT CORROSION OF PIPING

TYPES OF DISINFECTION FOR WATER TREATMENT

	CHLORINE AS A DISINFECTANT	ULTRAVIOLET GERMICIDAL IRRADIATION (UV) AS A DISINFECTANT
DISINFECTION BYPRODUCTS (DBPs)	X	No
CHEMICAL RESIDUE	X	No
NON-CORROSIVE	X	No
COMMUNITY SAFETY RISKS	X	No
EFFECTIVE AGAINST CRYPTOSPORIDIUM AND GIARDIA	X	Yes
WELL-SUITED FOR CHANGING REGULATIONS	X	Yes

CHLORINE vs. UV FOR DISINFECTION

Chlorination Equipment Requirement Section

For all water treatment facilities, chlorine gas under pressure shall not be permitted outside the chlorine room. A chlorine room is where chlorine gas cylinders and/or ton containers are stored. Vacuum regulators shall also be located inside the chlorine room. The chlorinator, which is the mechanical gas proportioning equipment, may or may not be located inside the chlorine room.

For new and upgraded facilities, from the chlorine room, chlorine gas vacuum lines should be run as close to the point of solution application as possible. Injectors should be located to minimize the length of pressurized chlorine solution lines. A gas pressure relief system shall be included in the gas vacuum line between the vacuum regulator(s) and the chlorinator(s) to ensure that pressurized chlorine gas does not enter the gas vacuum lines leaving the chlorine room.

The gas pressure relief system shall vent pressurized gas to the atmosphere at a location that is not hazardous to plant personnel; vent line should be run in such a manner that moisture collecting traps are avoided. The vacuum regulating valve(s) shall have positive shutdown in the event of a break in the downstream vacuum lines.

As an alternative to chlorine gas, it is permissible to use hypochlorite with positive displacement pumping. Anti-siphon valves shall be incorporated in the pump heads or in the discharge piping.

Capacity
The chlorinator shall have the capacity to dose enough chlorine to overcome the demand and maintain the required concentration of the "***free***" or "***combined***" chlorine.

Methods of Control
A chlorine feed system shall be automatic proportional controlled, automatic residual controlled, or compound loop controlled. In the automatic proportional controlled system, the equipment adjusts the chlorine feed rate automatically in accordance with the flow changes to provide a constant pre-established dosage for all rates of flow. In the automatic residual controlled system, the chlorine feeder is used in conjunction with a chlorine residual analyzer which controls the feed rate of the chlorine feeders to maintain a particular residual in the treated water.

In the compound loop control system, the feed rate of the chlorinator is controlled by a flow proportional signal and a residual analyzer signal to maintain particular chlorine residual in the water.

Manual chlorine feed systems may be installed for groundwater systems with constant flow rates.

Standby Provision
As a safeguard against malfunction and/or shut-down, standby chlorination equipment having the capacity to replace the largest unit shall be provided. For uninterrupted chlorination, gas chlorinators shall be equipped with an automatic changeover system. In addition, spare parts shall be available for all chlorinators.

Weigh Scales
Scales for weighing cylinders shall be provided at all plants using chlorine gas to permit an accurate reading of total daily weight of chlorine used. At large plants, scales of the recording and indicating type are recommended. As a minimum, a platform scale shall be provided. Scales shall be of corrosion-resistant material.

Securing Cylinders
All chlorine cylinders shall be securely positioned to safeguard against movement. Tag the cylinder "***empty***" and store upright and chained.

Ton containers may not be stacked.

Chlorine Leak Detection
Automatic chlorine leak detection and related alarm equipment shall be installed at all water treatment plants using chlorine gas. Leak detection shall be provided for the chlorine rooms. Chlorine leak detection equipment should be connected to a remote audible and visual alarm system and checked on a regular basis to verify proper operation.

Leak detection equipment shall not automatically activate the chlorine room ventilation system in such a manner as to discharge chlorine gas. During an emergency, if the chlorine room is unoccupied, the chlorine gas leakage shall be contained within the chlorine room itself in order to facilitate a proper method of clean-up.

Consideration should also be given to the provision of caustic soda solution reaction tanks for absorbing the contents of leaking one-ton cylinders where such cylinders are in use.

Chlorine leak detection equipment may not be required for very small chlorine rooms with an exterior door (e.g., floor area less than 3m^2).

You can use a spray solution of ammonia or a rag soaked with ammonia to detect a small Cl_2 leak. If there is a leak, the ammonia will create a white colored smoke, Ammonium chloride.

Safety Equipment
The facility shall be provided with personnel safety equipment including the following: Respiratory equipment; safety shower, eyewash, gloves, eye protection; protective clothing; cylinder and/or ton repair kits.

Respiratory equipment shall be provided which has been approved under the Occupational Health and Safety Act, General Safety Regulation - Selection of Respiratory Protective Equipment. Equipment shall be in close proximity to the access door(s) of the chlorine room.

Chlorine Room Design Requirements
Where gas chlorination is practiced, the gas cylinders and/or the ton containers up to the vacuum regulators shall be housed in a gas-tight, well illuminated, corrosion resistant and mechanically ventilated enclosure. The chlorinator may or may not be located inside the chlorine room. The chlorine room shall be located at the ground floor level.

Ventilation
Gas chlorine rooms shall have entirely separate exhaust ventilation systems capable of delivering one (1) complete air change per minute during periods of chlorine room occupancy only. The air outlet from the room shall be 150 mm above the floor and the point of discharge located to preclude contamination of air inlets to buildings or areas used by people. The vents to the outside shall have insect screens.

Air inlets should be louvered near the ceiling, the air being of such temperature as to not adversely affect the chlorination equipment. Separate switches for fans and lights shall be outside the room at all entrance or viewing points, and a clear wire-reinforced glass window shall be installed in such a manner as to allow the operator to inspect from the outside of the room.

Heating
Chlorine rooms shall have separate heating systems, if a forced air system is used to heat the building. The hot water heating system for the building will negate the need for a separate heating system for the chlorine room. The heat should be controlled at approximately 15^{o}C.

Cylinders or containers shall be protected to ensure that the chlorine maintains its gaseous state when entering the chlorinator.

Access
All access to the chlorine room shall only be from the exterior of the building. Visual inspection of the chlorination equipment from inside may be provided by the installation of glass window(s) in the walls of the chlorine room. Windows should be at least 0.20 m2 in area, and be made of clear wire reinforced glass. There should also be a ***'panic bar'*** on the inside of the chlorine room door for emergency exit.

Storage of Chlorine Cylinders
If necessary, a separate storage room may be provided to simply store the chlorine gas cylinders, with no connection to the line. The chlorine cylinder storage room shall have access either to the chlorine room or from the plant exterior, and arranged to prevent the uncontrolled release of spilled gas.

The chlorine gas storage room shall have provision for ventilation at thirty air changes per hour. Viewing glass windows and a panic button on the inside of the door should also be provided.

In very large facilities, entry into the chlorine rooms may be through a vestibule from outside.

Scrubbers
For facilities located within residential or densely populated areas, consideration shall be given to provide scrubbers for the chlorine room.

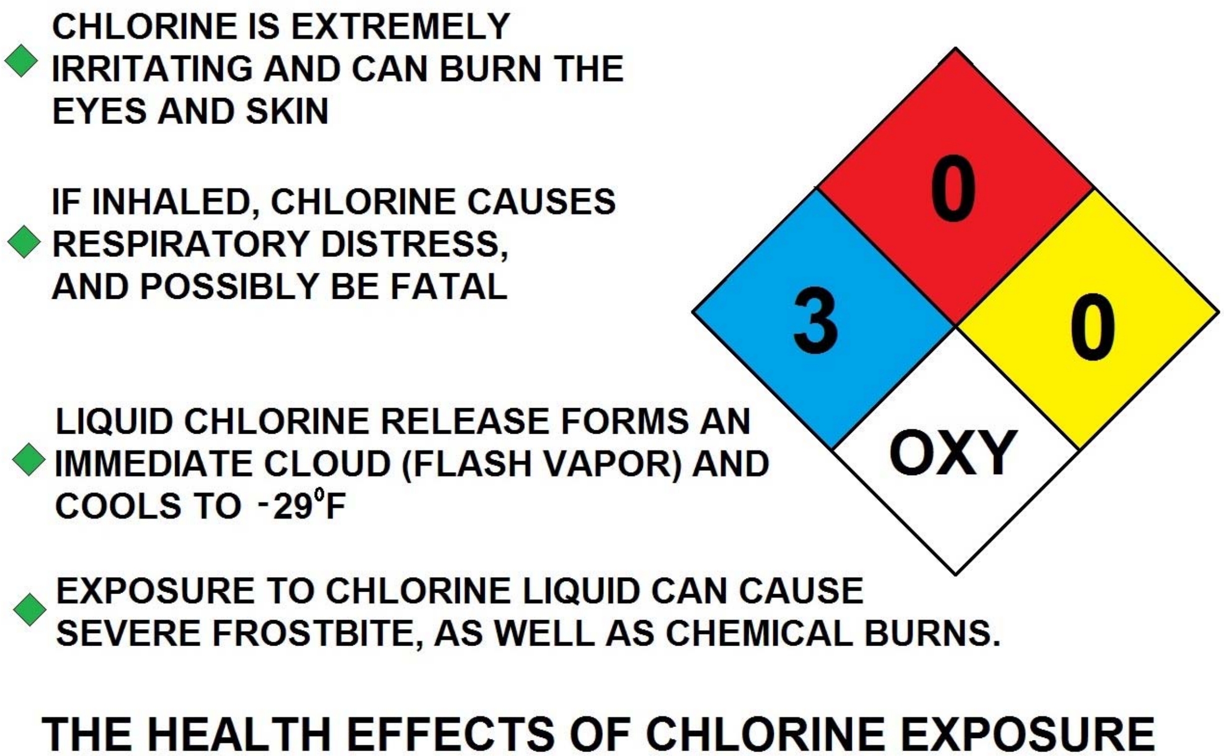
Chlorine Demand
Chlorine combines with a wide variety of materials. These side reactions complicate the use of chlorine for disinfecting purposes. Their demand for chlorine must be satisfied before chlorine becomes available to accomplish disinfection. The amount of chlorine required to react on various water impurities before a residual is obtained. Also, it means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by iodometric method of a sample at a temperature of twenty degrees in conformance with Standard methods.

Chlorine Questions and Answer Review
Downstream from the point of post chlorination, what should the concentration of a free chlorine residual be in a clear well or distribution reservoir? 0.5 mg/L.

True or False. Even brief exposure to 1,000 ppm of Cl2 can be fatal. True

How does one determine the ambient temperature in a chlorine room? Use a regular thermometer because ambient temperature is simply the air temperature of the room.

How is the effectiveness of disinfection determined? From the results of coliform testing.



Chlorine Health Hazard Section

Signs and Symptoms of Exposure

1. Acute exposure: Acute exposure to low levels of chlorine results in eye, nose, and throat irritation, sneezing, excessive salivation, general excitement, and restlessness. Higher concentrations causes difficulty in breathing, violent coughing, nausea, vomiting, cyanosis, dizziness, headache, choking, laryngeal edema, acute tracheobronchitis, chemical pneumonia. Contact with the liquid can result in frostbite burns of the skin and eyes.
2. Chronic exposure: Chronic exposure to low levels of chlorine gas can result in a dermatitis known as chloracne, tooth enamel corrosion, coughing, severe chest pain, sore throat, hemoptysis and increased susceptibility to tuberculosis.

Inhalation

Immediately remove the exposed person upwind from the contaminated area and contact the poison control center. Inhalation can cause coughing, sneezing, shortness of breath, sensation of tightness in the chest, as well as severe restlessness or anxiety, nausea, and vomiting. The nose and throat may become irritated; a stinging and burning sensation may be experienced. Immediate fatalities can occur as a result of suffocation. Delayed fatalities can occur as a result of pulmonary edema (fluid in the lungs). For this reason, rest and immediate attention after inhalation is important. Persons with known cardiovascular or lung problems should not risk chlorine exposure. If breathing has stopped, give artificial respiration; if breathing is difficult, give oxygen if equipment and trained personnel are available. If exposed person is breathing, place in a comfortable position and keep person warm and at rest until medical assistance becomes available.

Eye/Skin Contact

Liquid and concentrated gas could produce severe burns and injury on contact.

Eye

Pour a gentle stream of warm water through the affected eye for at least 15 minutes. Contact the poison control center, emergency room or physician right away as further treatment will be necessary.

Skin

Run a gentle stream of water over the affected area for 15 minutes. A mild soap may be used if available. Contact the poison control center, emergency room or physician right away as further treatment will be necessary.

Chronic

Repeated exposures can result in a loss of ability to detect the odor of chlorine. Long term exposures may cause damage to teeth and inflammation or ulceration of the nasal passages.

Ingestion
Not applicable for gas. Liquid could produce severe burns and injury on contact.

Pre-hospital Management
* Rescue personnel are at low risk of secondary contamination from victims who have been exposed only to gases released from hypochlorite solutions. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to rescuers and may release harmful gases.
* Ingestion of hypochlorite solutions may cause pain in the mouth or throat, dysphagia, stridor, drooling, odynophagia, and vomiting. Hypochlorite irritates the skin and can cause burning pain, inflammation, and blisters. Acute exposure to gases released from hypochlorite solutions can cause coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction and noncardiogenic pulmonary edema may also occur.
* There is no specific antidote for hypochlorite poisoning. Treatment is supportive.

Hot Zone
Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection
Hypochlorite is irritating to the skin and eyes and in some cases may release toxic gases.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response to situations that involve exposure to potentially unsafe levels of chlorine gas.

Skin Protection: Chemical-protective clothing should be worn due to the risk of skin irritation and burns from direct contact with solid hypochlorite or concentrated solutions.

ABC Reminders
Quickly establish a patient airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal
If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone
Victims exposed only to chlorine gas released by hypochlorite who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection
If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders
Quickly establish a patient airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination
Rapid decontamination is critical. Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings. Flush exposed skin and hair with copious amounts of plain tepid water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed or irritated eyes with saline, Ringer's lactate, or D5W for at least 20 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if it can be done without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the support zone.

In Cases of Ingestion, Do Not Induce Emesis or Offer Activated Charcoal.
Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk; if the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Dilultants are contraindicated in the presence of shock, upper airway obstruction, or in the presence of perforation. Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone
As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone
Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders
Quickly establish a patient airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor, if available.

Additional Decontamination
Continue irrigating exposed skin and eyes, as appropriate. In cases of ingestion, do not induce emesis or offer activated charcoal. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk; if the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Dilultants are contraindicated in the presence of

shock, upper airway obstruction, or in the presence of perforation.

Advanced Treatment
In cases of respiratory compromise, secure airway and respiration via endotracheal intubation. Avoid blind nasotracheal intubation or use of an esophageal obturator: only use direct visualization to intubate. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25-0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or who have cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility
Only decontaminated patients or those not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage
Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have ingested hypochlorite, or who show evidence of significant exposure to hypochlorite or chlorine (e.g., severe or persistent cough, dyspnea or chemical burns) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur.

Routes of Exposure
Exposure to chlorine can occur through inhalation, ingestion, and eye or skin contact [Genium 1992].

Emergency Medical Procedures: [NIOSH to Supply]
Rescue: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the Safety Data Sheet (formerly MSDS) required by OSHA's Hazard Communication Standard [29 CFR 1910.1200]).

All workers should be familiar with emergency procedures, the location and proper use of emergency equipment, and methods of protecting themselves during rescue operations.

Chlorine Storage

Chlorine should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's Hazard Communication Standard [29 CFR 1910.1200].

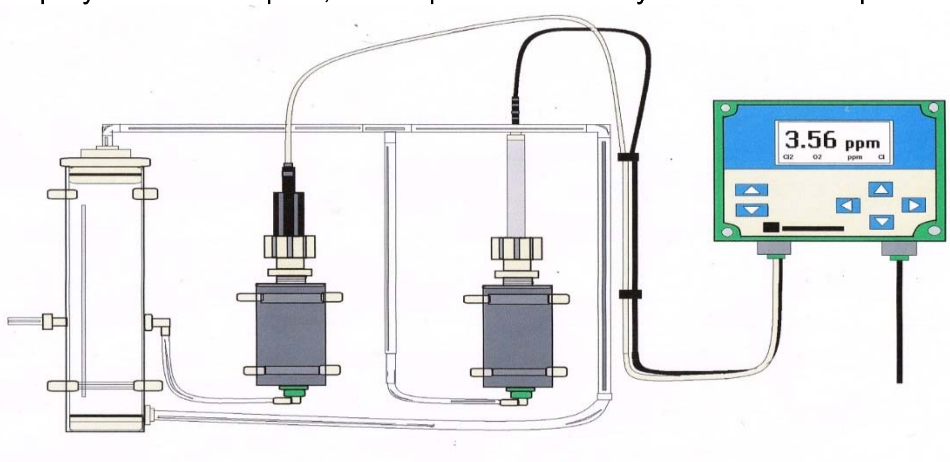
Containers of chlorine should be protected from exposure to weather, extreme temperatures changes, and physical damage, and they should be stored separately from flammable gases and vapors, combustible substances (such as gasoline and petroleum products, hydrocarbons, turpentine, alcohols, acetylene, hydrogen, ammonia, and sulfur), reducing agents, finely divided metals, arsenic, bismuth, boron, calcium, activated carbon, carbon disulfide, glycerol, hydrazine, iodine, methane, oxomonosilane, potassium, propylene, silicon, hydrogen sulfide and water, carbon monoxide and sulfur dioxide, moisture, steam, and water.

Workers handling and operating chlorine containers, cylinders, and tank wagons should receive special training in standard safety procedures for handling compressed corrosive gases. All pipes and containment used for chlorine service should be regularly inspected and tested. Empty containers of chlorine should have secured protective covers on their valves and should be handled appropriately.

Spills and Leaks

In the event of a spill or leak involving chlorine, persons not wearing protective equipment and fully-encapsulating, vapor-protective clothing should be restricted from contaminated areas until cleanup has been completed. The following steps should be undertaken following a spill or leak:

1. Notify safety personnel.
2. Remove all sources of heat and ignition.
3. Keep all combustibles (wood, paper, oil, etc.) away from the leak.
4. Ventilate potentially explosive atmospheres.
5. Evacuate the spill area at least 50 feet in all directions.
6. Find and stop the leak if this can be done without risk; if not, move the leaking container to an isolated area until gas has dispersed. The cylinder may be allowed to empty through a reducing agent such as sodium bisulfide and sodium bicarbonate.
7. Use water spray to reduce vapors; do not put water directly on the leak or spill area.



CHLORINE ANALYZER

Chemical Spill Procedure Example

TOXIC CHEMICAL RELEASE: CHLORINE GAS, AMMONIA, AND LIQUID CHLORINE OR OTHER SUBSTANCE POSING IMMEDIATE HEALTH

DANGER: Evacuate the area. Close all fire doors. Contact the fire department or appropriate emergency response crew immediately. If the substance is liquid and a drain is in the area of the spill, contact the sewer department.

If it is safe for you to clean up the spill:
READ SAFETY DATA SHEET (FORMERLY MSDS) (SDS) FOR SPILLED CHEMICAL.

Read the section STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED.

Read the **WASTE DISPOSAL METHOD** listed.

LOCATE CHEMICAL SPILLS KIT:

Apply gloves and protective eyewear.

Use chemical pads located in the kit to soak up the spill.

Place contaminated pads and gloves in the disposal bag and seal.

IF THE CHEMICAL IS A HAZARDOUS CHEMICAL WASTE, write the name of the chemical on the chemical label, attach the label to the disposal bag and notify a licensed Hazardous Waste Hauler for pick up. All other chemicals can be placed in regular trash.

Follow the methods listed on the SDS for cleaning the contaminated area.

Replace items used from the Chemical Spill Kit.

Evacuation and Emergency Procedures

Leak Procedures
Minor Leak
Note: A minor leak is a small leak which can be discharged to the environment without danger or when the source of the leak can be readily controlled.

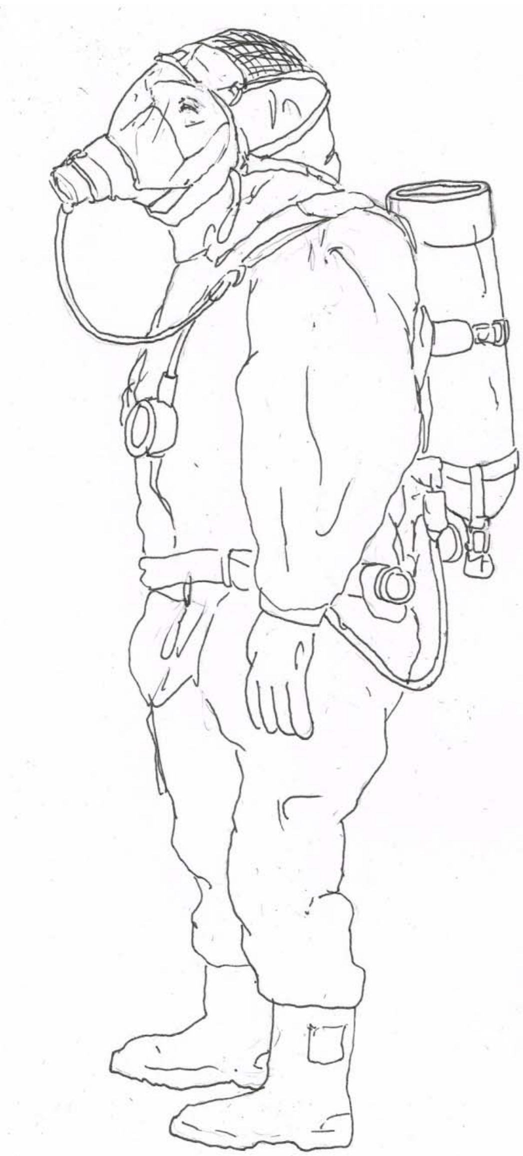
If you determine from outside the chlorine feed room that there is a minor leak, do the following:
1. Notify your supervisor.
2. Have your safety partner don SCBA and be watching you from outside the chlorine room.
3. Equip yourself with a SCBA.
4. Enter chlorine gas room.

Once Inside
5. Turn chlorine cylinder(s) OFF, leave water on.
6. Adjust feed rate to maximum to purge system.
7. Vacate room and remove air pack. Wait for 15 minutes, until chlorine pressure drops to zero or vacuum goes to maximum.
8. Do the Pre-Entry Check, put SCBA back on.
9. Crack open cylinder(s) and shut off right away.
10. Use ammonium hydroxide solution to find the leak.
11. Mark the leak.
12. Purge the system of gas as indicated on page 18, Section C (3), with the water still on.
13. Repair gently, using correct tools.
14. Start-up and re-check for leaks.
15. If no more leaks, place system back into service.

NOTE: If unable to repair the source of the leak, call it a Major Leak, and follow the appropriate emergency steps.

16. **Clean up:**
- remove air pack and recharge;
- air or launder clothes; and
- take a shower.

17. **Document the event completely**. Report the events which may have serious health or safety implications to the State or Federal Occupational Safety and Health Administration and/or Environmental Protection Agency (for Possible Air Violations and Toxic Releases). Also contact the local Fire Department and your Risk Management personnel.



LEVEL "B" SUIT

Major Leak

If you determine from outside the chlorine gas feed or storage room that there is a major leak, you could have a real problem not only for your fellow workers but also for nearby residents and for the plant equipment! Workers can protect themselves with SCBA. Residents may have to be evacuated.

We recommend the following steps, if you discover a Major Leak at your facility.
1. Protect yourself at all times during the emergency, and make sure you will not be overcome by the leaking gas. Stay out of the chlorine gas room. Keep the SCBA ready. Chlorine gas escaping through the ventilation outlet may be collecting outside the chlorine gas room, so be careful outside as well.
2. Isolate the area.
3. Notify your supervisor.
4. Implement the Emergency Response Contingency Plan that has been established for your facility, in consultation with the Safety/Health Committee and/or Risk Management Department.
NOTE: The following steps should be customized as necessary.
5. Notify your Chlorep/Supplier, fire department, police, Spill Report Center, according to your facility's policy.
6. Follow directions given by Chlorep/Supplier.
7. Document the events. Take photographs. Measure the Chlorine in the air.
8. Notify the State or Occupational Safety and Health Administration and/or Environmental Protection Agency (for Possible Air Violations and Toxic Releases). Also contact the local Fire Department and your Risk Management personnel.

Using DPD Method for Chlorine Residuals
N, N – diethyl-p-phenylenediame

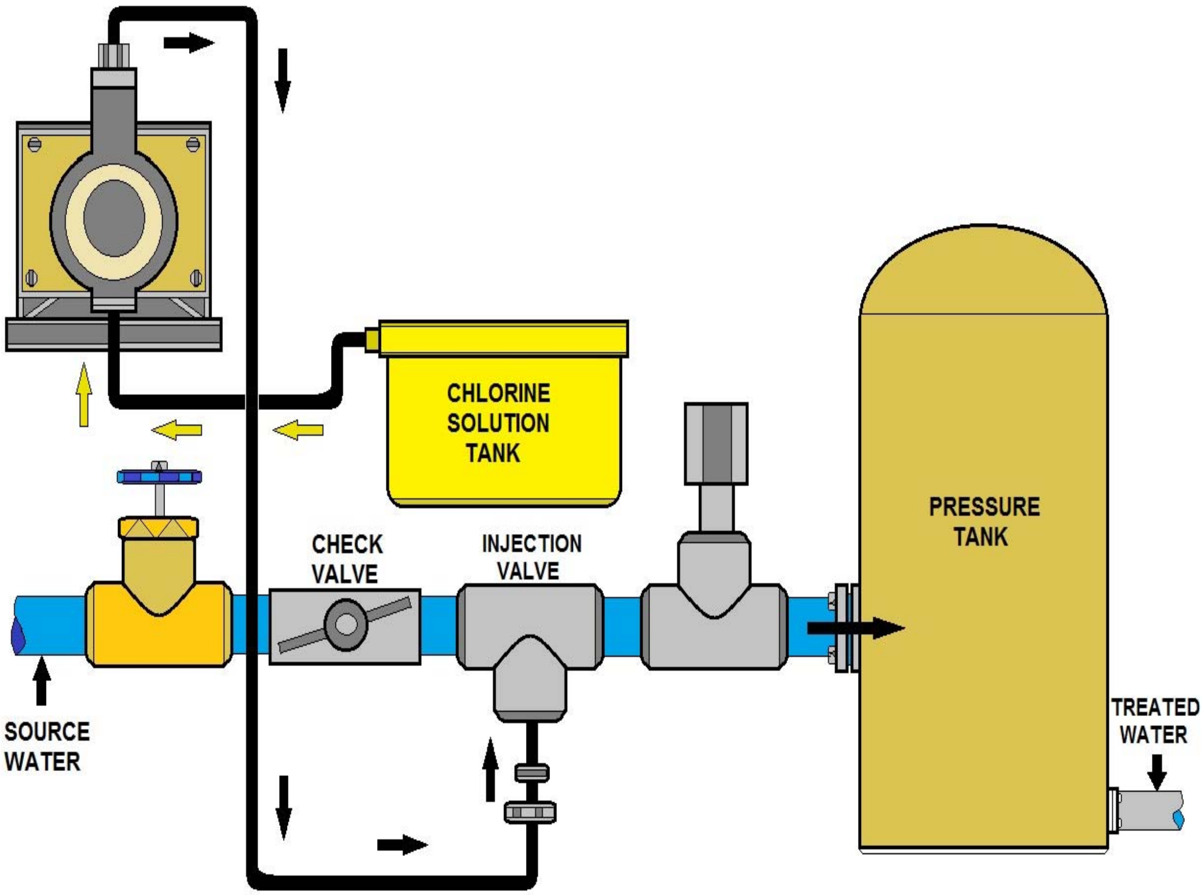
Small portable chlorine measuring kit. The redder the mixture the “hotter” or stronger the chlorine in solution.

Measuring Chlorine Residual **** Know and memorize.***
*****Chlorine residual is the amount of chlorine remaining in water that can be used for disinfection. A convenient, simple and inexpensive way to measure chlorine residual is to use a small portable kit with pre-measured packets of chemicals that are added to water. (Make sure you buy a test kit using the ***DPD method****,* and not the outdated orthotolodine method.)

Chlorine test kits are very useful in adjusting the chlorine dose you apply. You can measure what chlorine levels are being found in your system (especially at the far ends).

*****Free chlorine residuals need to be checked and recorded daily. These results should be kept on file for a health or regulatory agency inspection during a regular field visit.

*****The most accurate method for determining chlorine residuals is to use the laboratory amperometric titration method.



CHLORINATION SYSTEM
(Positive Displacement Type)

Chemical Equations, Oxidation States, and Balancing of Equations

Before we break down chlorine and other chemicals, let's start with this review of basic chemical equations.

Beginning
The common chemical equation could be A + B --> C + D. This is chemical A + chemical B, the two reacting chemicals will go to products C + D etc.

Oxidation
The term "oxidation" originally meant a reaction in which oxygen combines chemically with another substance, but its usage has long been broadened to include any reaction in which electrons are transferred.

Oxidation and reduction always occur simultaneously (redox reactions), and the substance which gains electrons is termed the oxidizing agent. For example, cupric ion is the oxidizing agent in the reaction: Fe (metal) + Cu++ --> Fe++ + Cu (metal); here, two electrons (negative charges) are transferred from the iron atom to the copper atom; thus the iron becomes positively charged (is oxidized) by loss of two electrons, while the copper receives the two electrons and becomes neutral (is reduced).

Electrons may also be displaced within the molecule without being completely transferred away from it. Such partial loss of electrons likewise constitutes oxidation in its broader sense and leads to the application of the term to a large number of processes, which at first sight might not be considered to be oxidation. Reaction of a hydrocarbon with a halogen, for example, CH_4 + 2 Cl --> CH_3Cl + HCl, involves partial oxidation of the methane; halogen addition to a double bond is regarded as an oxidation.

Dehydrogenation is also a form of oxidation; when two hydrogen atoms, each having one electron, are removed from a hydrogen-containing organic compound by a catalytic reaction with air or oxygen, as in oxidation of alcohol to aldehyde.

Oxidation Number
The number of electrons that must be added to or subtracted from an atom in a combined state to convert it to the elemental form; i.e., in barium chloride ($BaCl_2$) the oxidation number of barium is +2 and of chlorine is -1. Many elements can exist in more than one oxidation state.

Now, let us look at some common ions. An ion is the reactive state of the chemical, and is dependent on its place within the periodic table.

Have a look at the "periodic table of the elements". It is arranged in columns of elements, there are 18 columns. You can see column one, H, Li, Na, K, etc. These all become ions as H^+, L_i^+, K^+, etc. The next column, column 2, Be, Mg, Ca etc. become ions Be_2^+, Mg_2^+, Ca_2^+, etc. Column 18, He, Ne, Ar, Kr are inert gases. Column 17, F, Cl, Br, I, ionize to a negative F^-, Cl^-, Br^-, I^-, etc.

What you now need to do is memorize the table of common ions, both positive ions and negative ions.

*Chlorinator Parts

Ejector
Check Valve Assembly
Rate Valve
Diaphragm Assembly
Interconnection Manifold
Rotameter Tube and Float
Pressure Gauge
Gas Supply

***Chlorine measurement devices or Rotameters**

*Safety Information: There is a fusible plug on every chlorine tank. This metal plug will melt at 158° to 165° F. This is to prevent a build-up of excessive pressure and the possibility of cylinder rupture due to fire or high temperatures. * Know and memorize.

Chemistry of Chlorination

Chlorine can be added as sodium hypochlorite, calcium hypochlorite or chlorine gas. When any of these is added to water, chemical reactions occur as these equations show:

$Cl_2 + H_2O \rightarrow HOCl + HCl$
(chlorine gas) (water) (hypochlorous acid) (hydrochloric acid)

$CaOCl + H_2O \rightarrow 2HOCl + Ca(OH)$
(calcium hypochlorite) (water) (hypochlorous acid) (calcium hydroxide)

$NaOCl + H_2O \rightarrow HOCl + Na(OH)$
(sodium hypochlorite) (water) (hypochlorous acid) (sodium hydroxide)

All three forms of chlorine produce hypochlorous acid (HOCl) when added to water. Hypochlorous acid is a weak acid but a strong disinfecting agent. The amount of hypochlorous acid depends on the pH and temperature of the water. Under normal water conditions, hypochlorous acid will also chemically react and break down into a hypochlorite ion.

(OCl^-): $HOCl\ H^+ + OCl^-$ Also expressed $HOCl \rightarrow H^+ + OCl^-$
(hypochlorous acid) (hydrogen) (hypochlorite ion)

The hypochlorite ion is a much weaker disinfecting agent than hypochlorous acid, about 100 times less effective.

Let's now look at how pH and temperature affect the ratio of hypochlorous acid to hypochlorite ions. As the temperature is decreased, the ratio of hypochlorous acid increases. Temperature plays a small part in the acid ratio. Although the ratio of hypochlorous acid is greater at lower temperatures, pathogenic organisms are actually harder to kill. All other things being equal, higher water temperatures and a lower pH are more conducive to chlorine disinfection.

Types of Residual

If water were pure, the measured amount of chlorine in the water should be the same as the amount added. But water is not 100% pure. There are always other substances (interfering agents) such as iron, manganese, turbidity, etc., which will combine chemically with the chlorine.

This is called the ***chlorine demand.*** Naturally, once chlorine molecules are combined with these interfering agents, they are not capable of disinfection. It is free chlorine that is much more effective as a disinfecting agent.

So let's look now at how free, total and combined chlorine are related. When a chlorine residual test is taken, either a total or a free chlorine residual can be read.

Total residual is all chlorine that is available for disinfection.

Total chlorine residual = free + combined chlorine residual.

Free chlorine residual is a much stronger disinfecting agent. Therefore, most water regulating agencies will require that your daily chlorine residual readings be of free chlorine residual.

Break-point chlorination is where the chlorine demand has been satisfied, any additional chlorine will be considered ***free chlorine*.**

Residual Concentration/Contact Time (CT) Requirements

Disinfection to eliminate fecal and coliform bacteria may not be sufficient to adequately reduce pathogens such as Giardia or viruses to desired levels. Use of the ***"CT"*** disinfection concept is recommended to demonstrate satisfactory treatment, since monitoring for very low levels of pathogens in treated water is analytically very difficult.

The CT concept, as developed by the United States Environmental Protection Agency (Federal Register, 40 CFR, Parts 141 and 142, June 29, 1989), uses the combination of disinfectant residual concentration (mg/L) and the effective disinfection contact time (in minutes) to measure effective pathogen reduction. The residual is measured at the end of the process, and the contact time used is the T10 of the process unit (time for 10% of the water to pass).

CT = Concentration (mg/L) x Time (minutes)

The effective reduction in pathogens can be calculated by reference to standard tables of required CTs.

500 pound chlorine gas container and 150 pound gas cylinders. The 1/2 ton is on a scale. Cylinders stand upright and containers on their sides.

Chlorine Exposure Information

This information is necessary to pass your certification exam.

*** OSHA PEL 1 PPM - IDLH 10 PPM and Fatal Exposure Limit 1,000 PPM**
The current Occupational Safety and Health Administration (**OSHA**) permissible exposure limit (**PEL**) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m(3))) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level. *** IDLH 10 PPM**

Physical and chemical properties of chlorine: A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber-colored liquid, a noncombustible gas, and a strong oxidizer. Solid chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air. Atomic number of chlorine is 17. Cl is the elemental symbol and Cl2 is the chemical formula. *Know it.*

Monochloramine, dichloramine, and trichloramine are also known as Combined Available Chlorine.
$Cl2 + NH_4$.

HOCl and OCl-: The **OCL-** is the hypochlorite ion and the both of these two species are known as free available chlorine. These are the two main chemical species formed by chlorine in water and they are known by collectively as hypochlorous acid and the hypochlorite ion. When chlorine gas is added to water, it rapidly hydrolyzes. The chemical equations best describes this reaction is **Cl2 + H2O --> H+ + Cl- + HOCl.** Hypochlorous acid is the most germicidal of the chlorine compounds with the possible exception of chlorine dioxide. *** Know and memorize.**

Yoke-type connectors should be used on a chlorine cylinder's valve, assuming that the threads on the valve may be worn.

The connection from a chlorine cylinder to a chlorinator should be replaced by using a new, approved gasket on the connector. Always follow your manufacturer's instructions.

On a 1 ton container, the chlorine pressure reducing valve should be located downstream of the evaporator when using an evaporator. This is the liquid chlorine supply line and it is going to be made into chlorine gas.

In water treatment, chlorine is added to the effluent before the contact chamber (before the clear well) for complete mixing. One reason for not adding it directly to the chamber is that the chamber has very little mixing due to low velocities.

Here are several safety precautions when using chlorine gas: in addition to protective clothing and goggles, chlorine gas should be used only in a well-ventilated area so that any leaking gas cannot concentrate. Emergency procedures in the case of a large uncontrolled chlorine leak are to: notify local emergency response team, warn and evacuate people in adjacent areas, and be sure that no one enters the leak area without adequate self-contained breathing equipment.

Here are several symptoms of chlorine exposure: burning of eyes, nose, and mouth, coughing, sneezing, choking, nausea and vomiting, headaches and dizziness, fatal pulmonary edema, pneumonia and skin blisters. A little Cl2 will corrode the teeth and then progress to throat cancer.

Approved method for storing a 150 - 200 pound chlorine cylinder: Secure each cylinder in an upright position, attach the protective bonnet over the valve and firmly secure each cylinder. Never store near heat. Always store the empty in an upright, secure position with proper signage.


CHLORINE
DO NOT TAKE INTERNALLY
AVOID CONTACT WITH EYES, MOUTH OR CLOTHING
WARNING
AVOID BREATHING FUMES
FLAMMABLE - KEEP FIRE AWAY
USE ONLY IN WELL VENTILATED AREAS.
USE ONLY WHERE THERE ARE NO OPEN FLAMES OR OTHER SOURCES OF IGNITION
EXTREMELY FLAMMABLE
KEEP AWAY FROM HEAT, SPARKS AND OPEN FLAME
KEEP CONTAINER CLOSED
HAZARD IDENTIFICATION
0
3
0
CODE NUMBERS
4 - SEVERE
3 - SERIOUS
2 - MODERATE
1 - SLIGHT
0 - MINIMAL

Disinfectant Statements

Disinfectant residual: The CT values for disinfection are used to determine the disinfection efficiency based upon time and what other parameter?

Bacteria, Virus, and Intestinal parasites: What types of organisms may transmit waterborne diseases?

Disinfection By-Products (DBPs): The products created due to the reaction of chlorine with organic materials (e.g. leaves, soil) present in raw water during the water treatment process. The EPA has determined that these DBPs can cause cancer.

How is the effectiveness of disinfection determined? *From the results of coliform testing.*

The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites.

What types of source water are required by law to treat water using filtration and disinfection? Groundwater under the direct influence of surface water and surface water sources.

E. Coli, *Escherichia coli*: is a bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

pH is on a scale from 0-14. 7 is considered neutral and acid is on the 0 to 7 side and the base is 7-14. pH is known as the Power of Hydroxyl Ion activity.

*Disinfectant Review Statements

The CT values for disinfection are used to determine the disinfection efficiency based upon time and what other parameter? **Disinfectant residual**

What types of organisms may transmit waterborne diseases? Bacteria, Virus and intestinal parasites.

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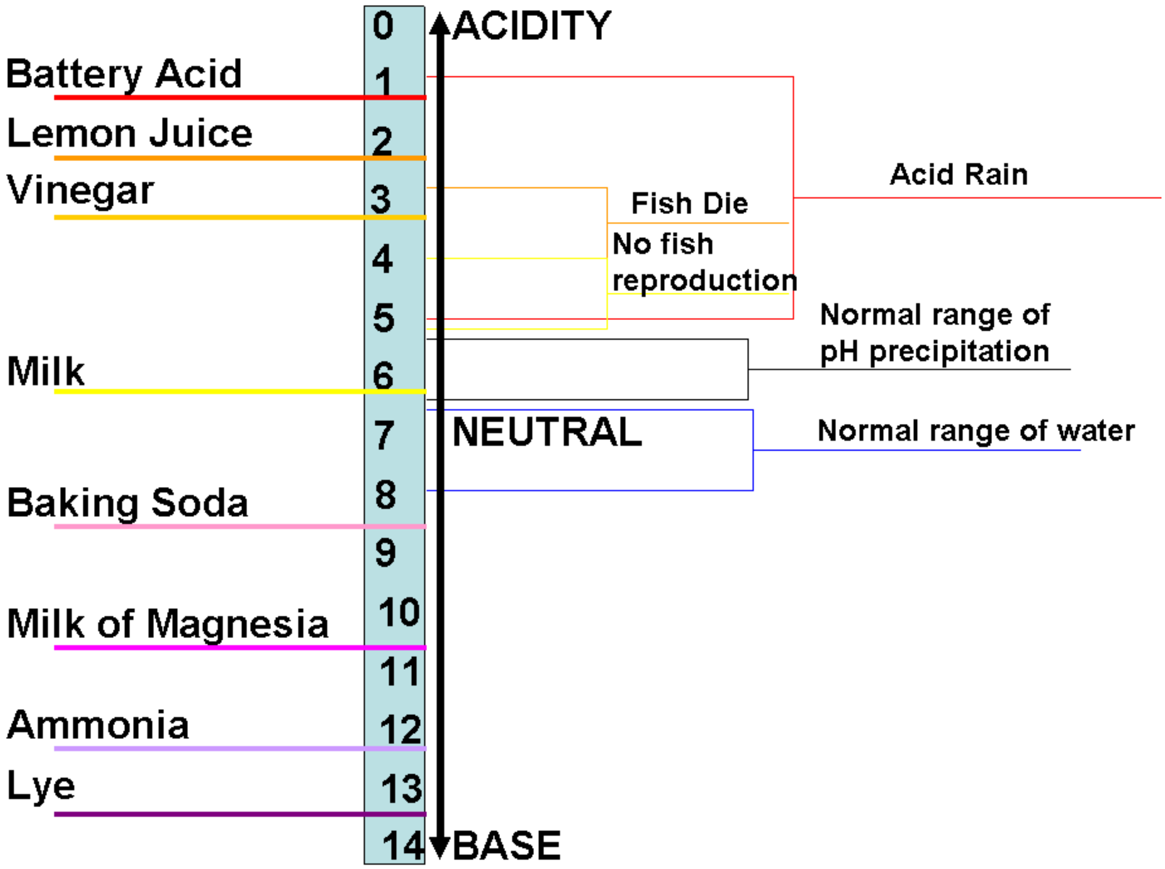
pH is known as the Power of Hydroxyl Ion activity.

***Bac-T Sample Bottle** often referred to as a Standard Sample, 100 mls. Notice the white powder inside the bottle. That is Sodium Thiosulfate, a de-chlorination agent. Be careful not to wash-out this chemical while sampling.

Coliform bacteria are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually the result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can cause disease.

pH Scale



***pH:** A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity.

***pH** = (**Power of Hydroxyl Ion Activity**).

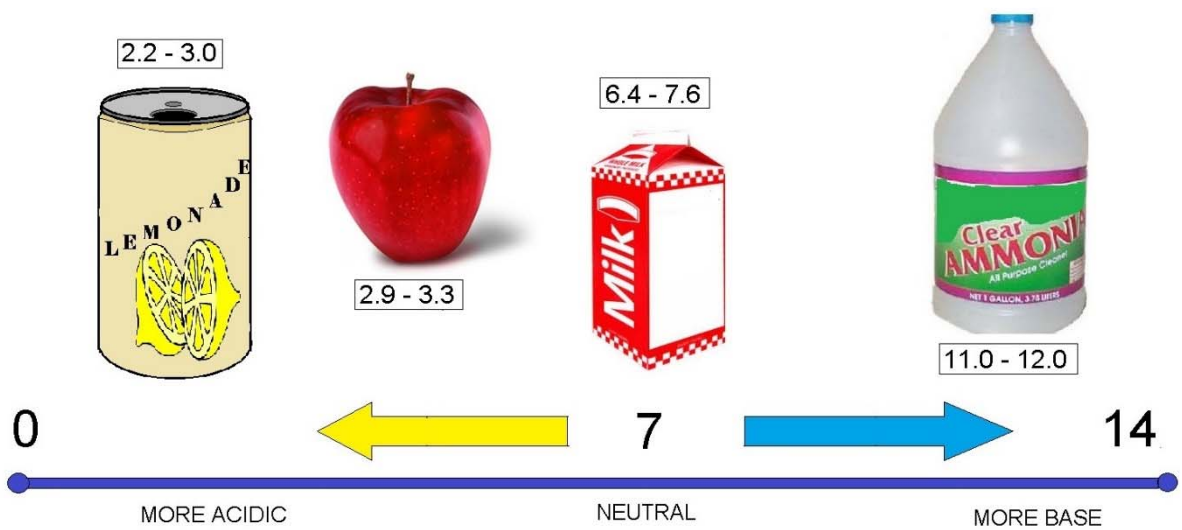
*The acidity of a water sample is measured on a pH scale. This scale ranges from **0** (maximum acidity) to **14** (maximum alkalinity). The middle of the scale, **7**, represents the neutral point. The acidity increases from neutral toward **0**.

*Because the scale is logarithmic, a difference of one pH unit represents a tenfold change. For example, the acidity of a sample with a pH of **5** is ten times greater than that of a sample with a pH of **6**. A difference of 2 units, from **6** to **4**, would mean that the acidity is one hundred times greater, and so on.

Normal rain has a pH of **5.6** – slightly acidic because of the carbon dioxide picked up in the earth's atmosphere by the rain.

CONCENTRATION OF HYDROGEN IONS COMPARED TO DISTILLED H_2O	pH	EXAMPLES OF SOLUTIONS AND THEIR RESPECTIVE pH
1/10,000,000	14	LIQUID DRAIN CLEANER CAUSTIC SODA
1/1,000,000	13	BLEACHES OVEN CLEANERS
1/100,000	12	SOAPY WATER
1/10,000	11	HOUSEHOLD AMMONIA (11.9)
1/1,000	10	MILK OF MAGNESIUM (10.5)
1/100	9	TOOTHPASTE (9.9)
1/10	8	BAKING SODA (8.4) / SEA WATER EGGS
0	7	"PURE" WATER (7)
10	6	URINE (6) / MILK (6.6)
100	5	ACID RAIN (5.6) BLACK COFFEE (5)
1000	4	TOMATO JUICE (4.1)
10,000	3	GRAPEFRUIT & ORANGE JUICE SOFT DRINK
100,000	2	LEMON JUICE (2.3) VINEGAR (2.9)
1,000,000	1	HYDROCHLORIC ACID SECRETED FROM STOMACH LINING (1)
10,000,000	0	BATTERY ACID

pH Scale



pH SCALE

Chlorine Supplement ***Know this section. Answers at rear.***

1. How should the connection from a chlorine cylinder to a chlorinator be replaced?

2. How many turns should a chlorine gas cylinder be initially opened?

3. If the temperature of a full chlorine cylinder is increased by 50°F or 30°C, what is the most likely result?

4. What is meant by the specific gravity of a liquid?

5. Which metals are the only metals that are totally inert to moist chlorine gas?

6. What will be discharged when opening the top valve on a one-ton chlorine cylinder?

7. What are the approved methods for storing a chlorine cylinder?

8. What are normal conditions for a gas chlorination start-up?

9. Name safety precautions when using chlorine gas.

10. What compounds are formed in water when chlorine gas is introduced?

11. Why should roller bearings not be used to rotate a one-ton chlorine cylinder?

12. What are the physical and chemical properties of chlorine?

13. What are the necessary emergency procedures in the case of a large uncontrolled chlorine leak?

14. Name several symptoms of chlorine exposure.

15. 5 lbs. of a 70% concentration sodium hypochlorite solution is added to a tank containing 650 gallons of water. What is the chlorine dosage?

16. As soon as Cl_2 gas enters the throat area, a victim will sense a sudden stricture - nature's way of signaling to prevent passage of the gas to the lungs. At this point, the victim must attempt to do two things. Name them.

17. Positive pressure SCBAs and full face piece SARs can be used in oxygen deficient atmospheres containing less than what percentage of oxygen in the atmosphere?

18. Death is possible from asphyxia, shock, reflex spasm in the larynx, or massive pulmonary edema. Populations at special risk from chlorine exposure are individuals with pulmonary disease, breathing problems, bronchitis, or chronic lung conditions.
A. TRUE
B. FALSE

19. Chlorine gas reacts with water producing a strongly oxidizing solution causing damage to the moist tissue lining of the respiratory tract when the tissue is exposed to chlorine. The respiratory tract is rapidly irritated by exposure to 10-20 ppm of chlorine gas in air, causing acute discomfort that warns of the presence of the toxicant.
A. TRUE
B. FALSE

20. Even brief exposure to 1,000 ppm of Cl_2 can be fatal.
A. TRUE
B. FALSE

21. What are the two main chemical species formed by chlorine in water and what name are they known by collectively?

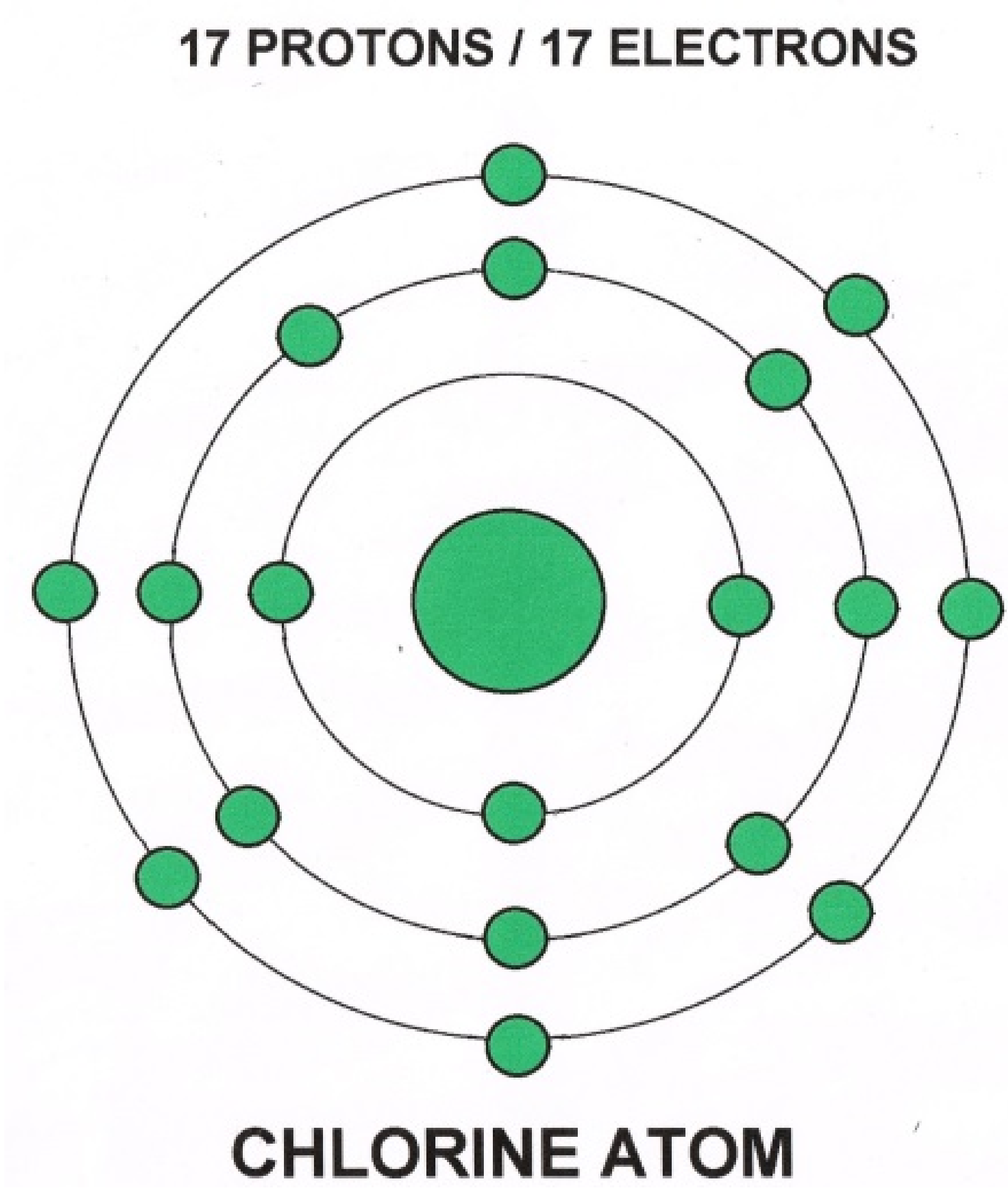
22. When chlorine gas is added to water, it rapidly hydrolyzes according to the reaction:

23. Which chemical reaction equation represents the dissociation of hypochlorous acid?

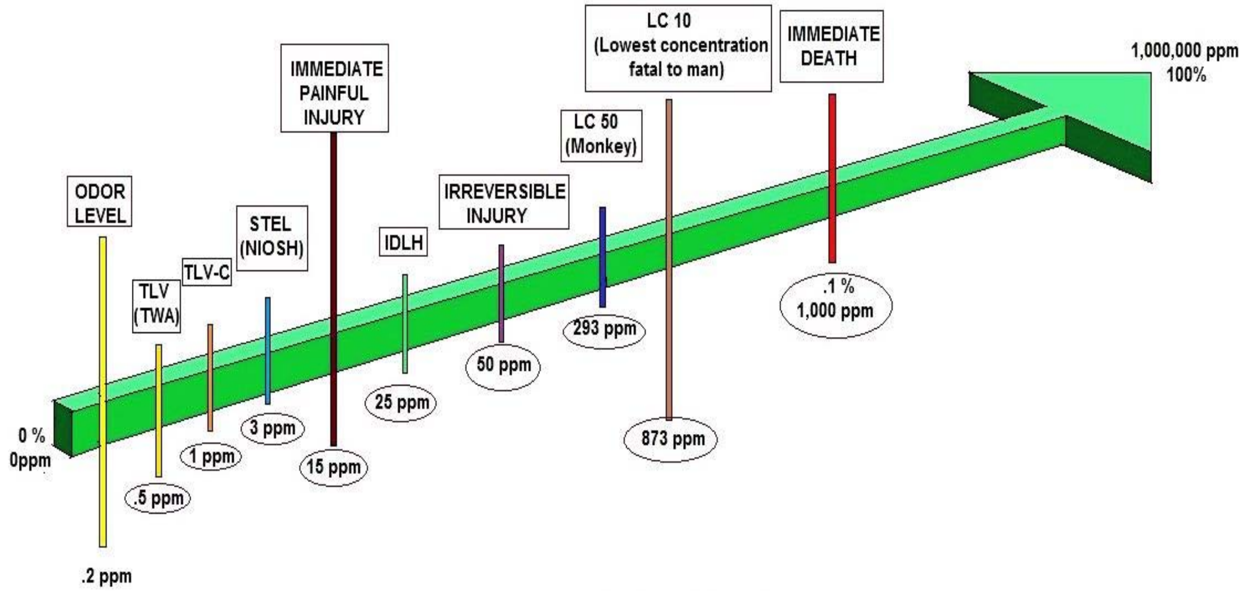
24. This species of chlorine is the most germicidal of ALL chlorine compounds with the possible exception of chlorine dioxide.

Chlorine Answers

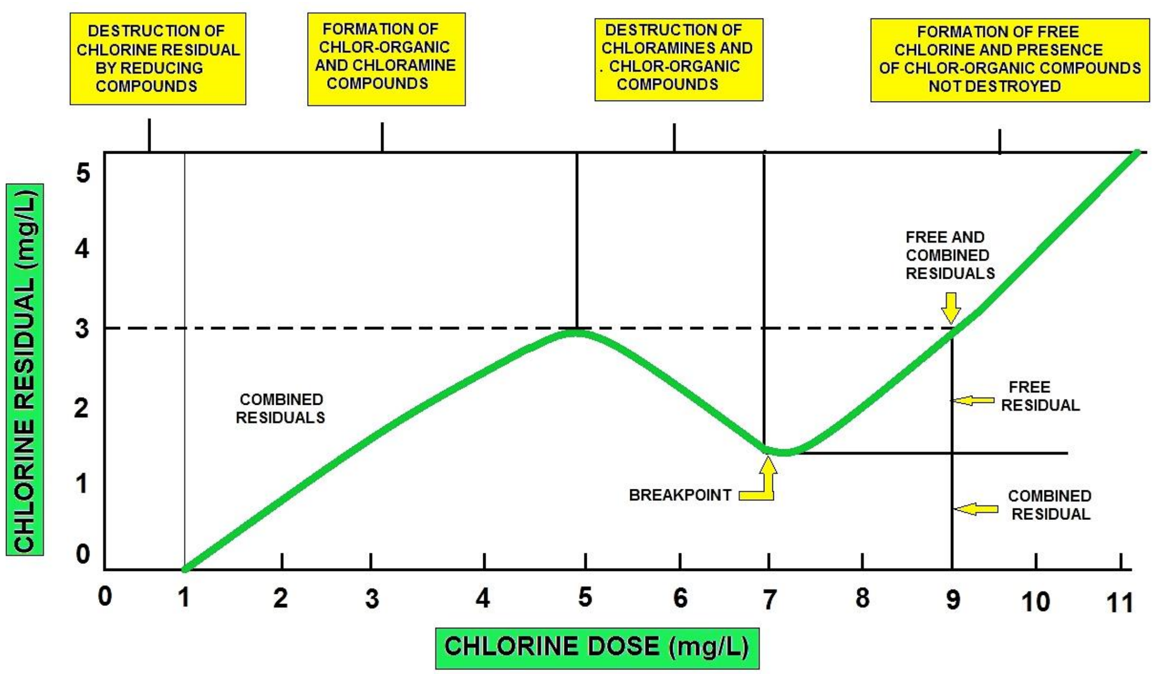
1. Use a new, approved gasket on the connector
2. 1/4 turn to unseat the valve, then open one complete turn
3. The cylinder may rupture
4. The ratio of the density of the liquid to the density of water at 4 degrees C
5. Gold, Platinum, and Tantalum
6. Gas chlorine
7. Secure each cylinder in an upright position. Attach the protective bonnet over the valve. Firmly secure each cylinder.
8. Open chlorine metering orifice slightly. Inspect vacuum lines. Start injector water supply
9. In addition to protective clothing and goggles, chlorine gas should be used only in a well-ventilated area so that any leaking gas cannot concentrate.
10. Chlorine gas forms a mixture of hydrochloric and hypochlorous acids
11. Because it is too easy to roll
12. A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber colored liquid, a noncombustible gas, and a strong oxidizer. Chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air.
13. Notify local emergency response team. Warn and evacuate people in adjacent areas. Be sure that no one enters the leak area without adequate self-contained breathing equipment.
14. Burning of eyes, nose, and mouth; lacrimation and rhinorrhea; Coughing, sneezing, choking, nausea and vomiting; headaches and dizziness; Fatal pulmonary edema; pneumonia; conjunctivitis; keratitis; pharyngitis; burning chest pain; dyspnea; hemoptysis; hypoxemia; dermatitis; and skin blisters.
15. 646 mg/L
16. Get out of the area of the leak, proceeding upwind, and 2) take only very short breaths through the mouth
17. 0.195 or also written 19.5%
18. True
19. True
20. True
21. $HOCl$ and OCl^-; free available chlorine
22. $Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$
23. $HOCl \leftarrow\rightarrow H^+ + OCl^-$
24. Hypochlorous acid


17 PROTONS / 17 ELECTRONS
CHLORINE ATOM

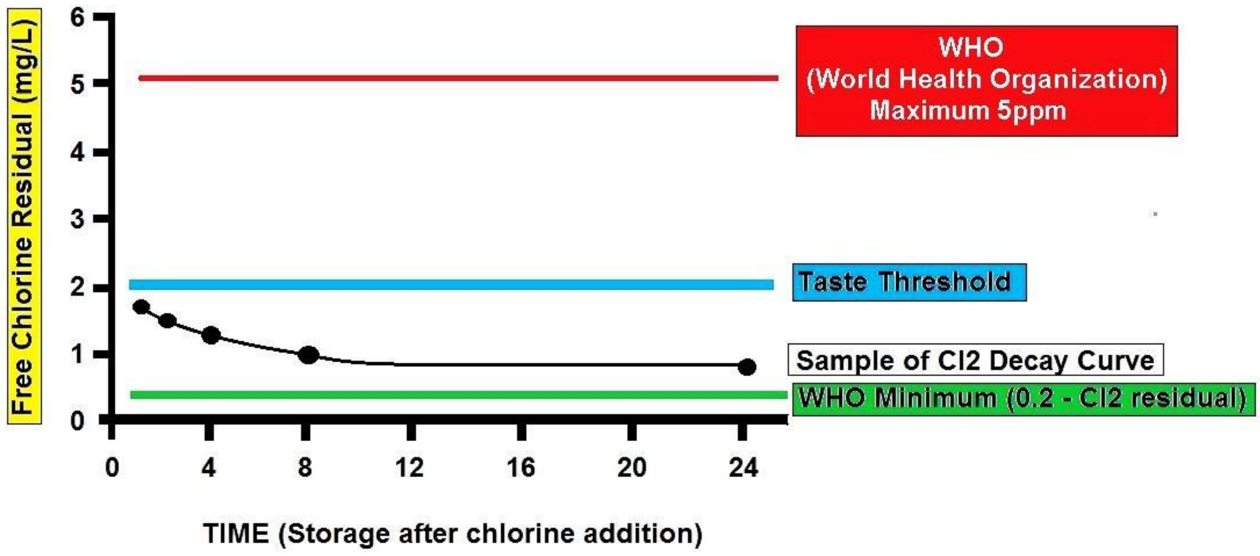
Chlorine Charts



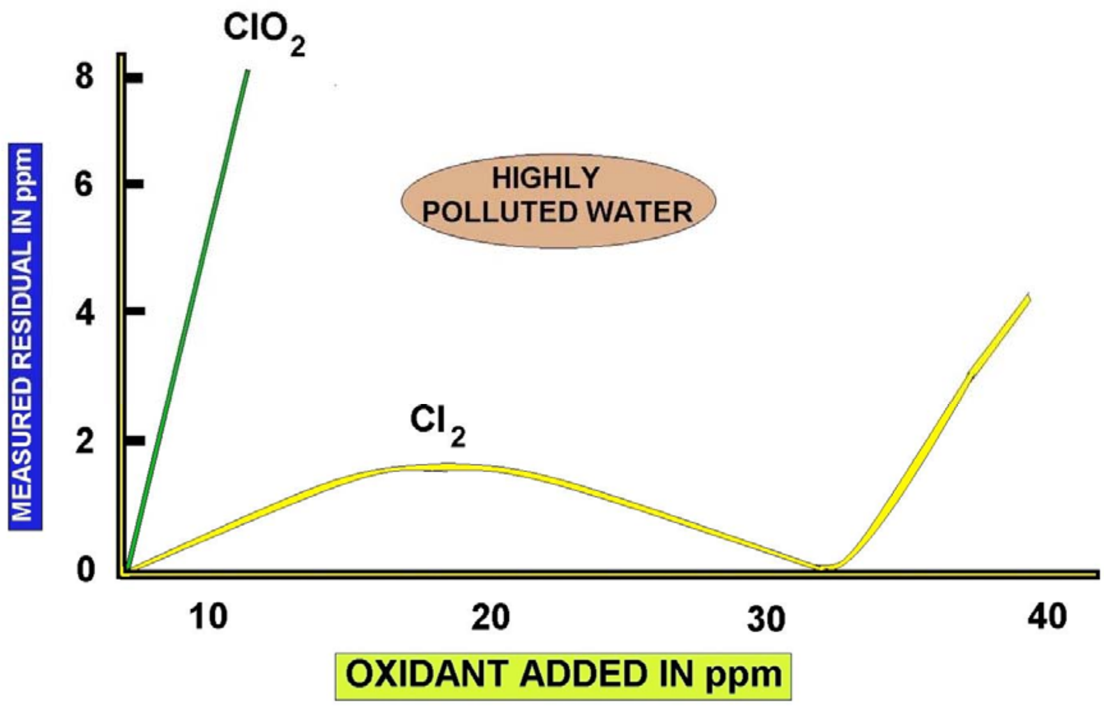
CHLORINE POISON LINES



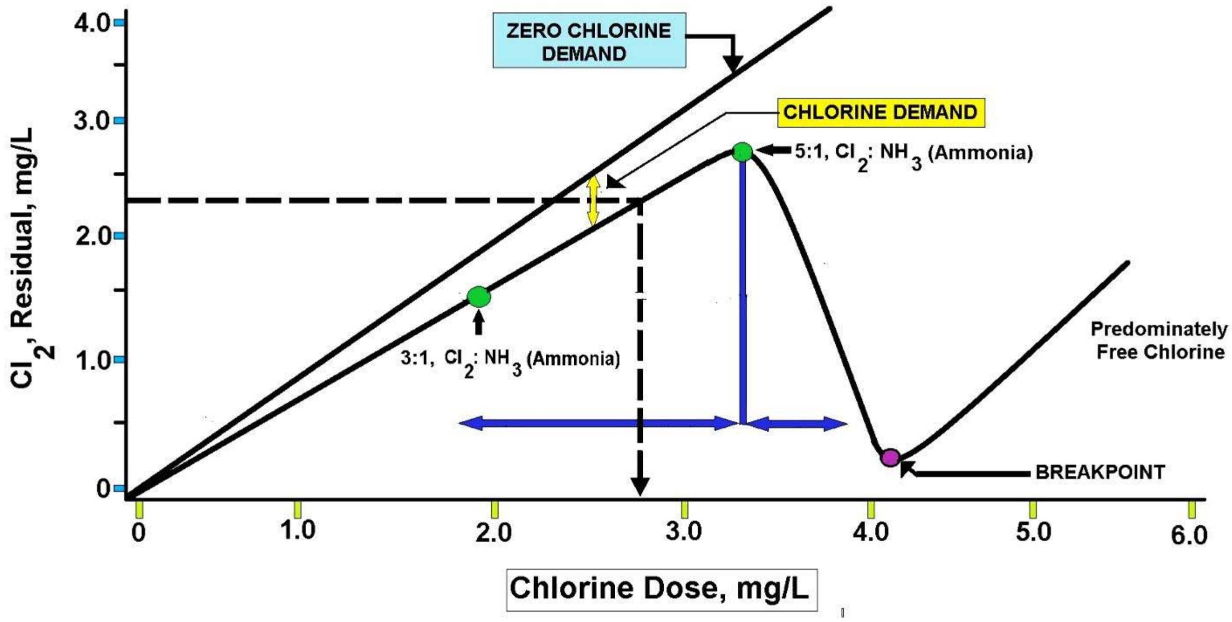
CHLORINE BREAKPOINT



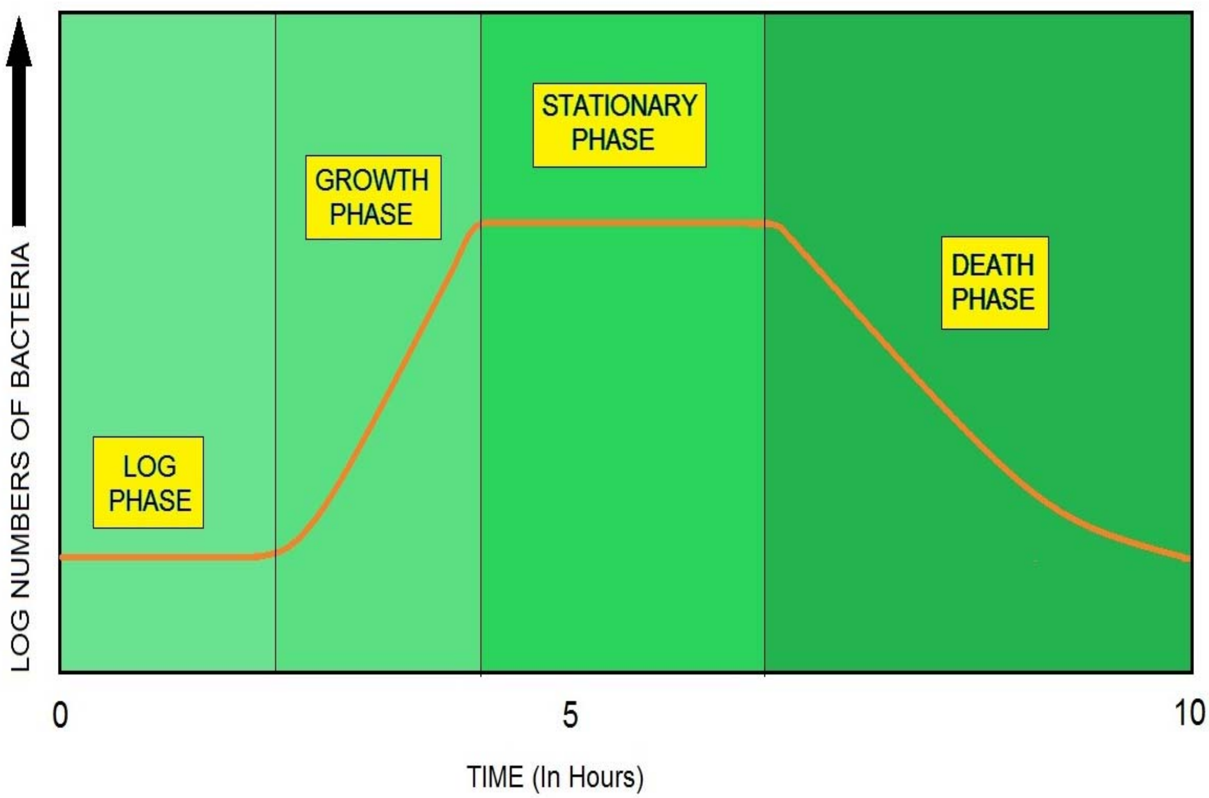
CHLORINE DECAY CURVE

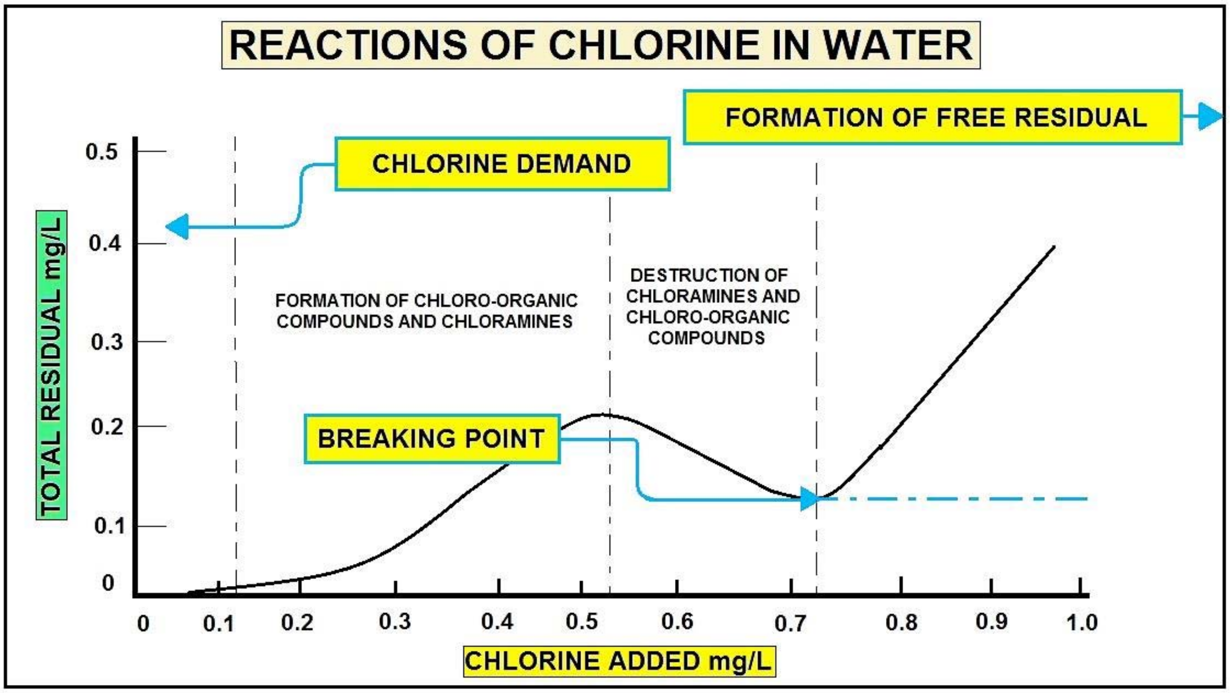


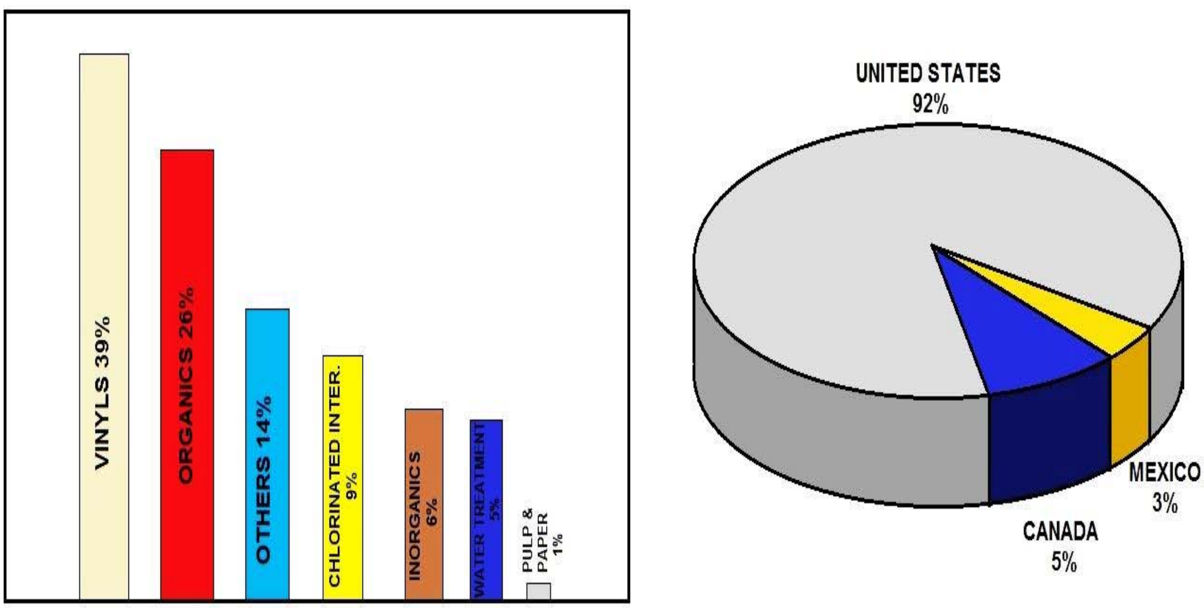
USING CHLORINE DIOXIDE vs CHLORINE



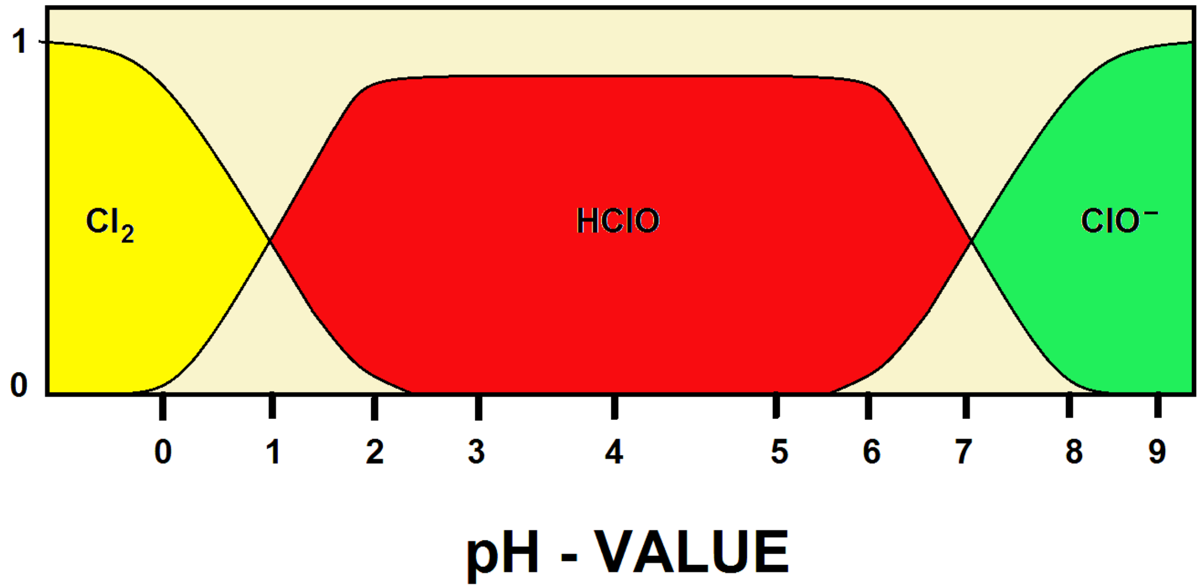
CHLORAMINATION

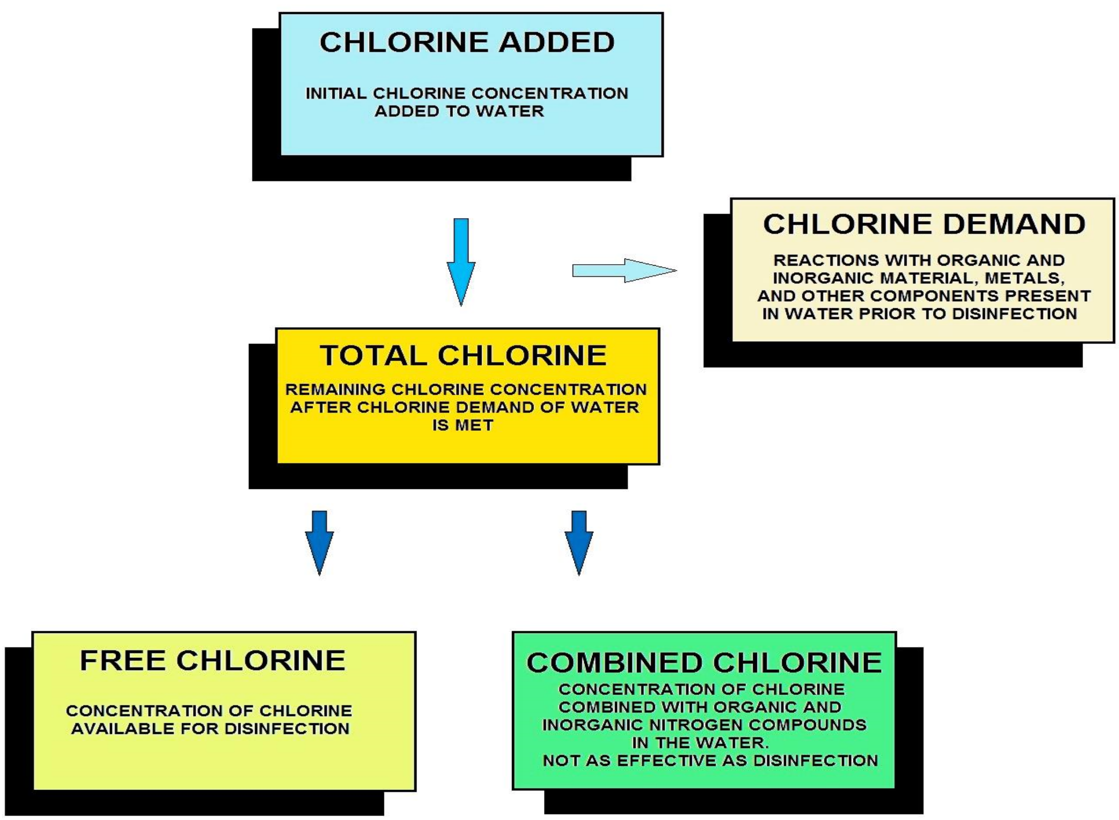




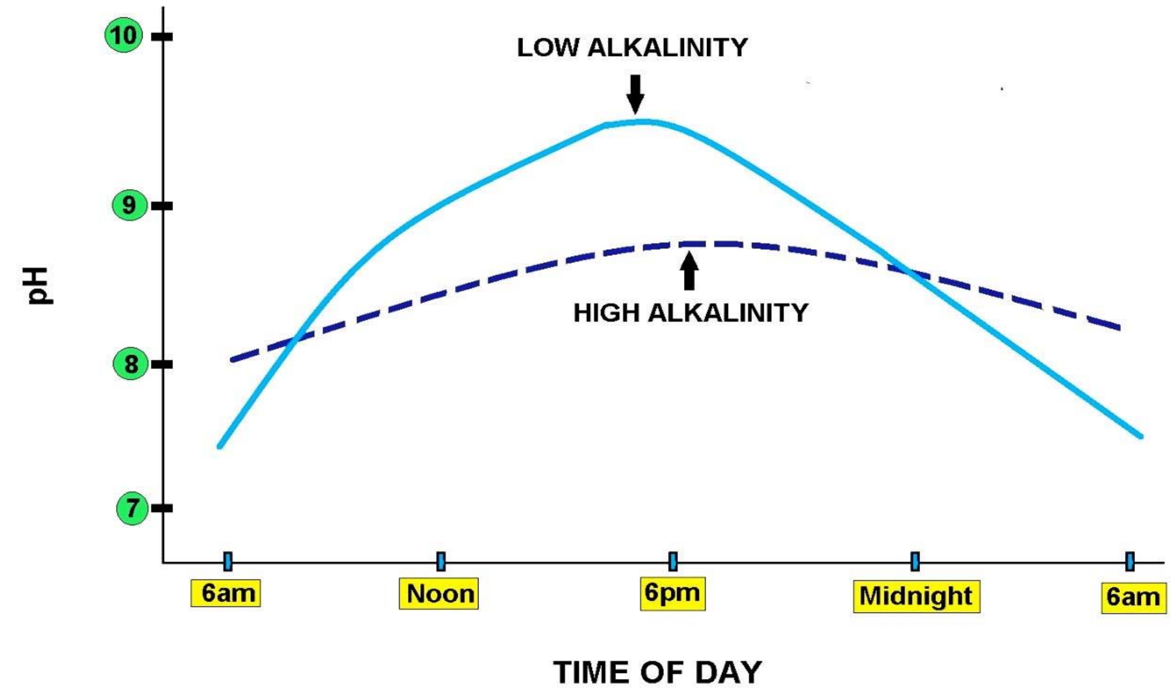


NORTH AMERICA CHLORINE DEMAND COMPARISON

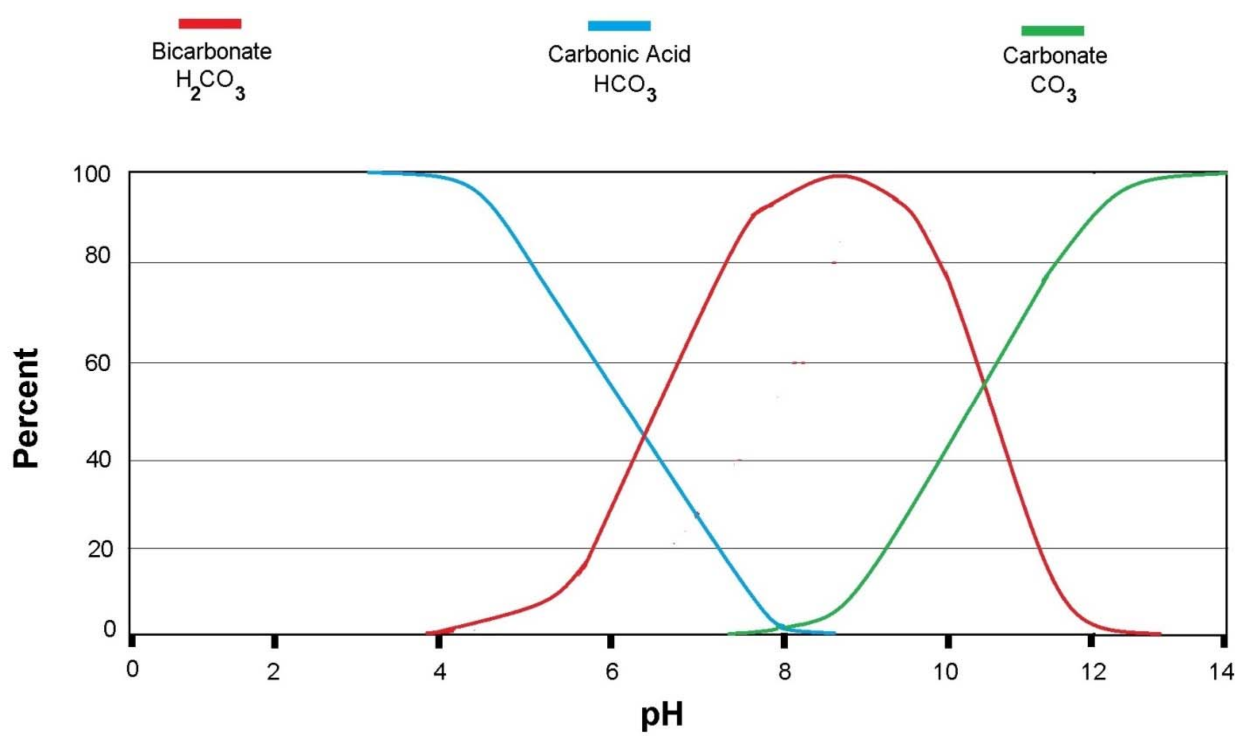




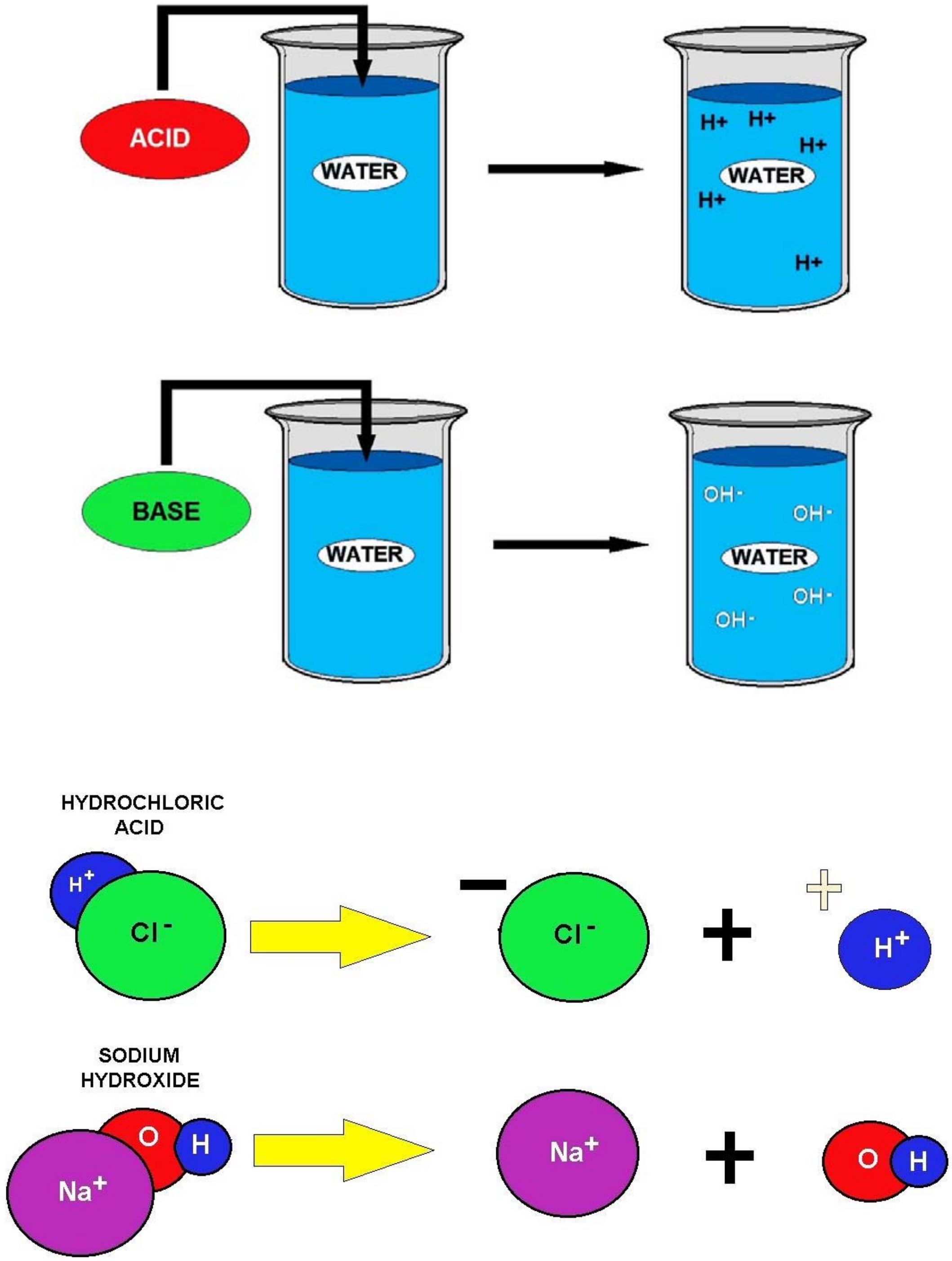
CHLORINE DISINFECTION



ALKALINITY



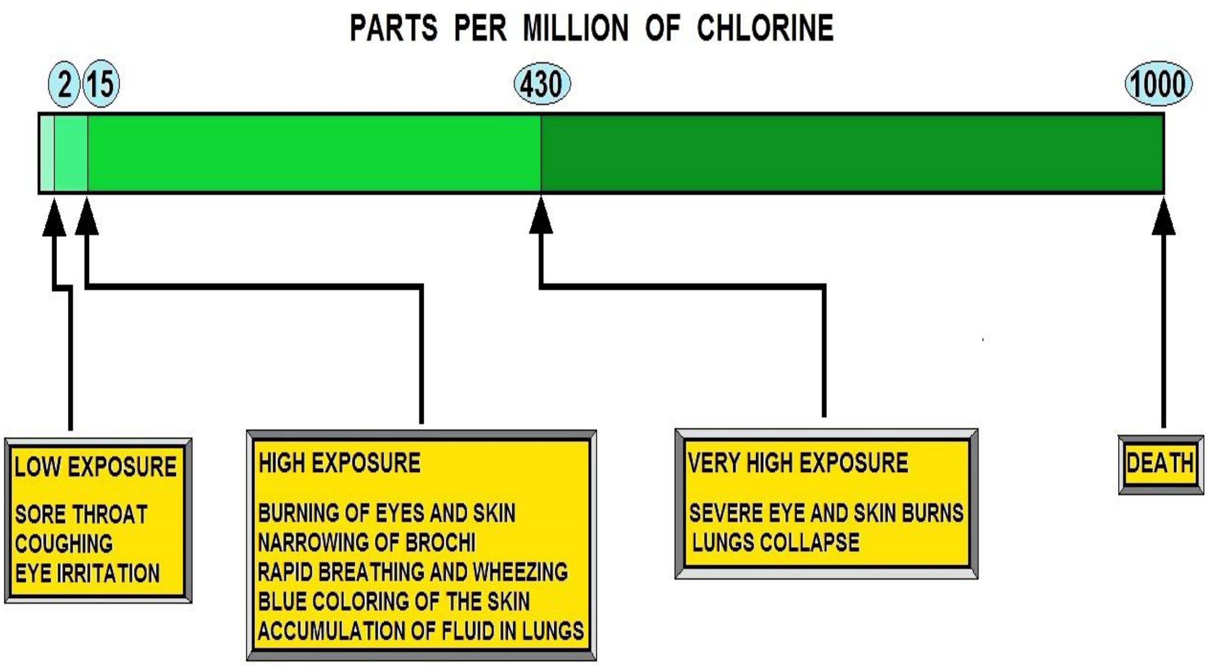
EFFECTS OF ALKALINITY FROM pH



ACIDS AND BASES (comparison)

DENSITY (at 32°F & 1 atm)	0.2006 lbs. / cu.ft.
SPECIFIC GRAVITY (at 32°F & 1 atm)	2.482 (air = 1)
LIQUEFYING POINT (at 1 atm)	-30.1°F
VISCOSITY (at 68°F)	0.01325 centipose
SOLUBILITY IN WATER	60.84 lbs. / 1000 gal.

PROPERTIES OF GASEOUS CHLORINE

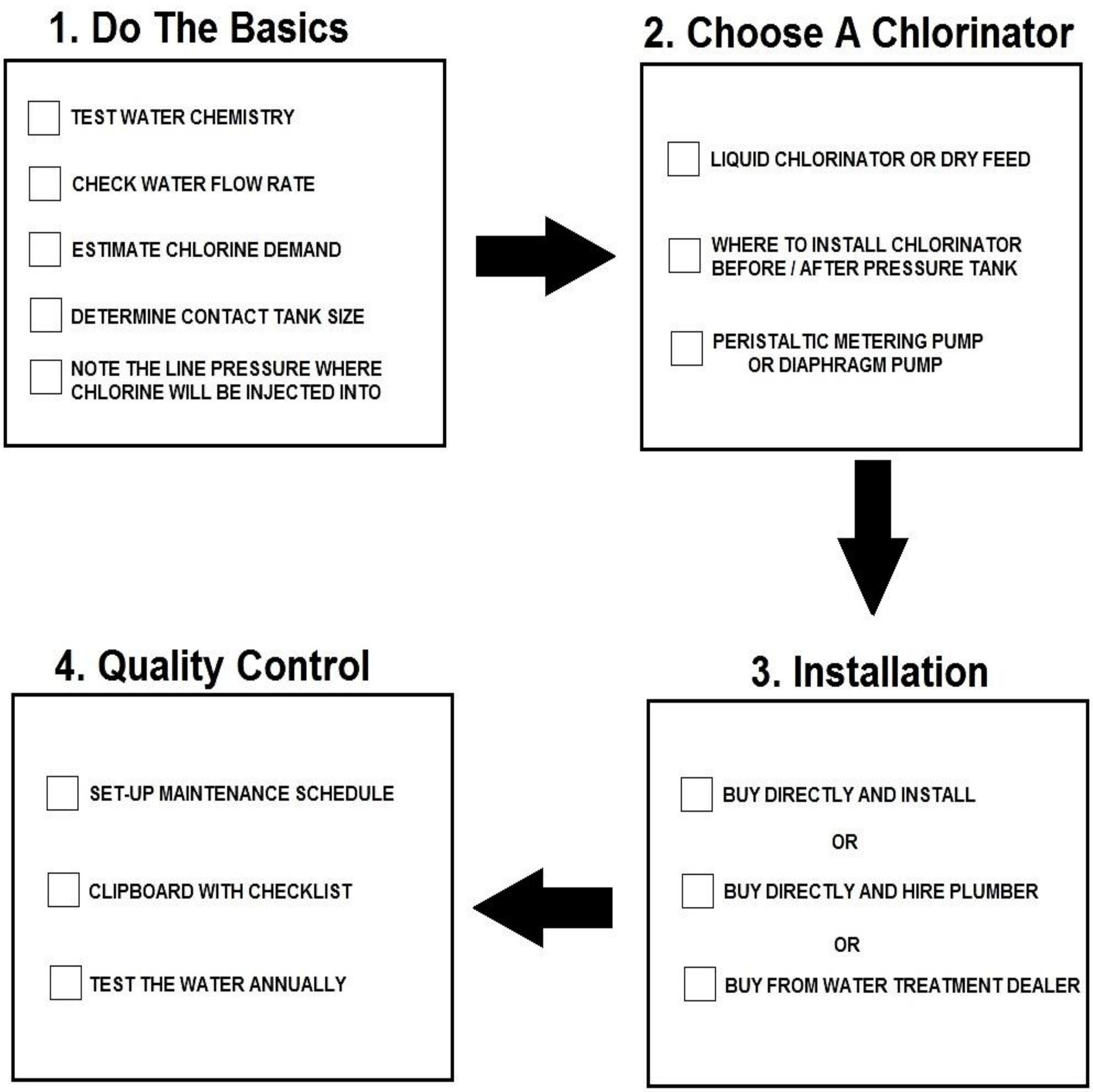


EFFECTS OF CHLORINE GAS ON HEALTH

WATER	BLEACHING POWDER (25 - 35 %) (g)	HIGH STRENGTH CALCIUM HYPOCHLORITE (70 %) (g)	LIQUID BLEACH (5 % SODIUM HYPOCHLORITE) (ml)
1	2.3	1.0	14
1.2	3.0	1.2	17
1.5	3.5	1.5	21
2	5.0	2.0	28
2.5	6.0	2.5	35
3	7.0	3.0	42
4	9.0	4.0	56
5	12	5.0	70
6	14	6.0	84
7	16	7.0	98
8	19	8.0	110
10	23	10	140
12	28	12	170
15	35	15	210
20	50	20	280
30	70	30	420
40	90	40	560
50	120	50	700
60	140	60	840
70	160	70	980
80	190	80	1 100
100	230	100	1 400
120	280	120	1 700
150	350	150	2 100
200	470	200	2 800
250	580	250	3 500
300	700	300	4 200
400	940	400	5 600
500	1 170	500	7 000

(* Approximate dose = 0.7 mg of applied Chlorine per litre of water)

CHLORINE DOSES WITH DIFFERENT TYPES OF CHLORINE



HOW TO DETERMINE A CHLORINATION SYSTEM

HOW TO CALCULATE CHLORINE DOSAGE TO DISINFECT A WELL USING CALCIUM HYPOCHLORITE

EQUIPMENT

- 20 litre bucket
- HSCH Chlorine granules or powder

METHOD

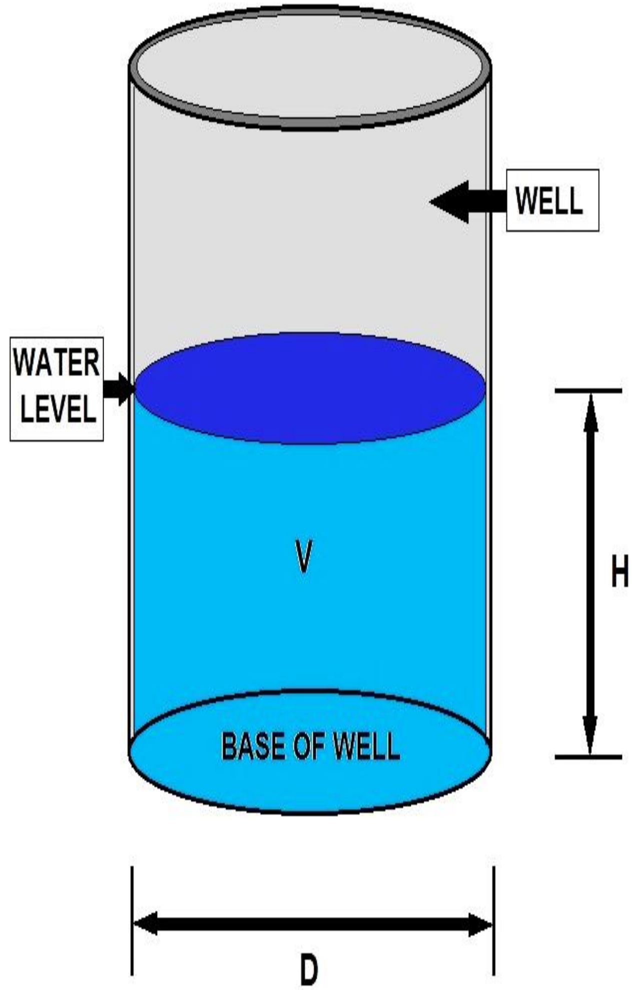
- Calculate the volume of water in the well using formula:

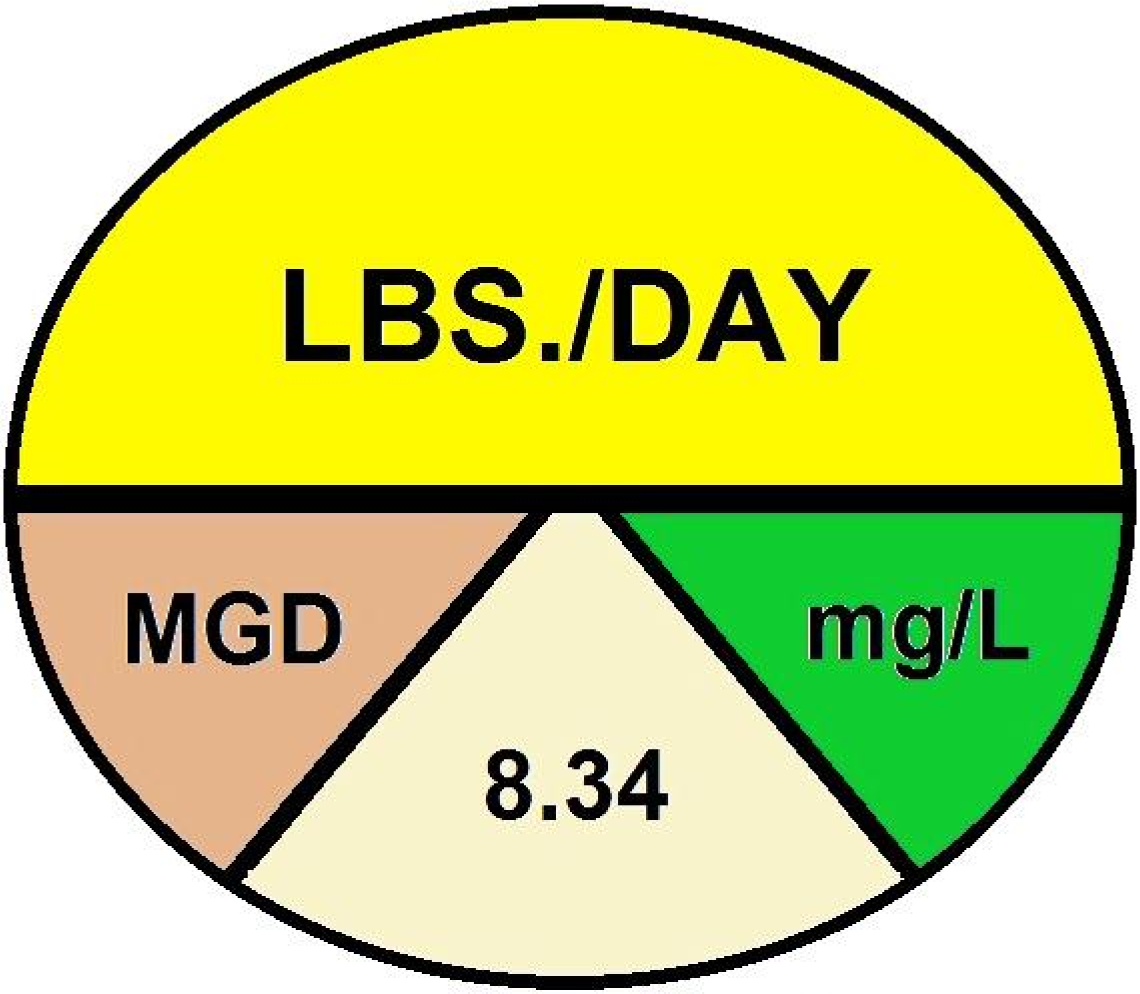
$$V = \frac{\pi D^2 h}{4}$$

WHERE

V = Volume of water
D = Diameter
h = Depth of water
π = 3.142

- Fill bucket with clear water from source
- Add about 300g of HSCH and stir (dissolve)
- For every cubic meter of water, add 10 litres (half bucket) of chlorine solution.
- Double the quantity of HSCH added if the solution is to be used for cleaning well lining or aprons





POUNDS FORMULA WHEEL

A Certified Backflow Tester examining a Double Check Detector check fire line assembly. Notice the water meter which will detect any water usage that may be used in the fire line. All backflow assemblies need to be tested annually and the assemblies need to be 12 inches above the ground or in some cases like the PVB, 12 inches above the highest downstream outlet.

Backflow Statements *Memorize these statements.*

Backflow condition: A continuous positive pressure in a distribution system is essential for preventing what event?

Backflow or cross-connection failure: What might be the source of an organic substance causing taste and odor problems in a water distribution system?

Backflow Prevention: To stop or prevent the occurrence of the unnatural act of reversing the normal direction of the flow of a liquid, gas, or solid substance back into the public potable (drinking) water supply. See Cross-connection control.

Backflow: Minimum water pressure must be maintained to ensure adequate customer service during peak flow periods. However minimum positive pressure must be maintained in mains to protect against backflow or backsiphonage from cross-connections.

Backflow: Name the most common ***CAUSE*** for public water supply contamination. Backflow, or cross-connection.

Backflow: To reverse the natural and normal directional flow of a liquid, gas, or solid substance back into the public potable (drinking) water supply. This is normally an undesirable effect.

Backflow: What does a backsiphonage condition usually cause? Reduced pressure or negative pressure on the service or supply side.

Backflow: What does a double check valve backflow assembly provide effective protection from? Both backpressure and backsiphonage of pollution only.

Backflow: What is equipment that utilizes water for cooling, lubrication, washing or as a solvent always susceptible to? A cross-connection.

Backflow: What is the definition of '***backflow***'? A reverse flow condition that causes water or mixtures of water and other liquids, gases, or substances to flow back into the distribution system.

Backflow: What is the difference between a reduced pressure principle backflow device and a double check backflow device? The RP has a relief valve.

Backflow: What is the maximum time period between having a backflow device tested by a certified backflow tester? 1 year.

Backflow: What must an operator ensure when installing a pressure vacuum breaker backflow device? It must be at least 12 inches about the highest downstream outlet.

Backflow Principles

Atmospheric Pressure

The atmosphere is the entire mass of air that surrounds the earth. While it extends upward for about 500 miles, the section of primary interest is the portion that rests on the earth's surface and extends upward for about 7 1/2 miles. This layer is called the troposphere.

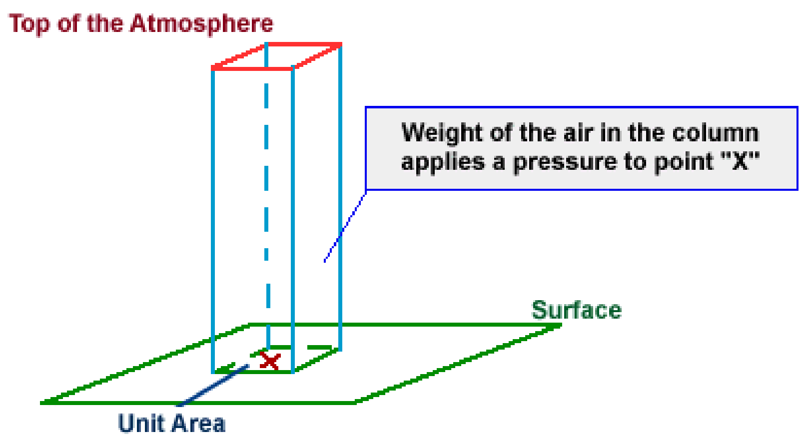
If a column of air 1-inch square extending all the way to the "***top***" of the atmosphere could be weighed, this column of air would weigh approximately 14.7 pounds at sea level. Thus, atmospheric pressure at sea level is approximately 14.7 psi.

As one ascends, the atmospheric pressure decreases by approximately 1.0 psi for every 2,343 feet. However, below sea level, in excavations and depressions, atmospheric pressure increases. Pressures under water differ from those under air only because the weight of the water must be added to the pressure of the air.

Atmospheric pressure can be measured by any of several methods. The common laboratory method uses the mercury column barometer. The height of the mercury column serves as an indicator of atmospheric pressure. At sea level and at a temperature of 0° Celsius (**C**), the height of the mercury column is approximately 30 inches, or 76 centimeters. This represents a pressure of approximately 14.7 psi. The 30-inch column is used as a reference standard.

Another device used to measure atmospheric pressure is the aneroid barometer. The aneroid barometer uses the change in shape of an evacuated metal cell to measure variations in atmospheric pressure. The thin metal of the aneroid cell moves in or out with the variation of pressure on its external surface. This movement is transmitted through a system of levers to a pointer, which indicates the pressure.

The atmospheric pressure does not vary uniformly with altitude. Its changes are more rapid. Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air above that surface. In the diagram below, the pressure at point "**X**" increases as the weight of the air above it increases. The same can be said about decreasing pressure, where the pressure at point "X" decreases if the weight of the air above it also decreases.



Pressure may be referred to using an absolute scale, pounds per square inch absolute (psia), or gauge scale, (psiag). Absolute pressure and gauge pressure are related. Absolute pressure is equal to gauge pressure plus the atmospheric pressure. At sea level, the atmospheric pressure is 14.7 psai.

Absolute pressure is the total pressure. Gauge pressure is simply the pressure read on the gauge. If there is no pressure on the gauge other than atmospheric, the gauge will read zero. Then the absolute pressure would be equal to 14.7 psi, which is the atmospheric pressure.

Vacuum

The term ***vacuum*** indicates that the absolute pressure is less than the atmospheric pressure and that the gauge pressure is negative. A complete or total vacuum would mean a pressure of 0 psia or –14.7 psig. Since it is impossible to produce a total vacuum, the term vacuum, as used in this document, will mean all degrees of partial vacuum. In a partial vacuum, the pressure would range from slightly less than 14.7 psia (0 psig) to slightly greater than 0 psia (-14.7 psig). Backsiphonage results from atmospheric pressure exerted on a liquid forcing it toward a supply system that is under a vacuum.

Water Pressure

*The weight of a cubic foot of water is 62.4 pounds per square foot. The base can be sub-divided into 144-square inches with each subdivision being subjected to a pressure of 0.433 psig.

Suppose you placed another cubic foot of water on top of the first cubic foot. The pressure on the top surface of the first cube which was originally atmospheric, or 0 psig, would now be 0.4333 psig as a result of the additional cubic foot of water. The pressure of the base of the first cubic foot would be increased by the same amount of 0.866 psig or two times the original pressure.

Hydraulics

The word ***hydraulics*** is based on the Greek word for water, and originally covered the study of the physical behavior of water at rest and in motion. Use has broadened its meaning to include the behavior of all liquids, although it is primarily concerned with the motion of liquids. Hydraulics includes the manner in which liquids act in tanks and pipes, deals with their properties, and explores ways to take advantage of these properties. Hydraulics is a branch of engineering concerned mainly with moving liquids. The term is applied commonly to the study of the mechanical properties of water, other liquids, and even gases when the effects of compressibility are small. Hydraulics can be divided into two areas, hydrostatics and hydrokinetics. Hydrostatics, the consideration of liquids at rest, involves problems of buoyancy and flotation, pressure on dams and submerged devices, and hydraulic presses.

Hydrodynamics

The relative incompressibility of liquids is one of its basic principles. Hydrodynamics, the study of liquids in motion, is concerned with such matters as friction and turbulence generated in pipes by flowing liquids, the flow of water over weirs and through nozzles, and the use of hydraulic pressure in machinery.

Development of Hydraulics

Although the modern development of hydraulics is comparatively recent, the ancients were familiar with many hydraulic principles and their applications. The Egyptians and the ancient people of Persia, India, and China conveyed water along channels for irrigation and domestic purposes, using dams and sluice gates to control the flow. The ancient Cretans had an elaborate plumbing system. Archimedes studied the laws of floating and submerged bodies. The Romans constructed aqueducts to carry water to their cities.

Liquids are almost incompressible. For example, if a pressure of 100 pounds per square inch (**psi**) is applied to a given volume of water that is at atmospheric pressure, the volume will decrease by only 0.03 percent. It would take a force of approximately 32 tons to reduce its volume by 10 percent; however, when this force is removed, the water immediately returns to its original volume. Other liquids behave in about the same manner as water.

Another characteristic of a liquid is the tendency to keep its free surface level. If the surface is not level, liquids will flow in the direction which will tend to *make* the surface level.

Liquids at Rest
In studying fluids at rest, we are concerned with the transmission of force and the factors which affect the forces in liquids. Additionally, pressure in and on liquids and factors affecting pressure are of great importance.

Pressure and Force
Pressure is the force that pushes water through pipes. Water pressure determines the flow of water from the tap. If pressure is not sufficient then the flow can reduce to a trickle and it will take a long time to fill a kettle or a cistern. The terms ***force*** **and** ***pressure*** are used extensively in the study of fluid power. It is essential that we distinguish between the terms. Force means a total push or pull. It is the push or pull exerted against the total area of a particular surface and is expressed in pounds or grams.

Pressure means the amount of push or pull (force) applied to each unit area of the surface and is expressed in pounds per square inch (lb/in^2) or grams per square centimeter (gm/cm^2). Pressure maybe exerted in one direction, in several directions, or in all directions.

Computing Force, Pressure, and Area
A formula is used in computing force, pressure, and area in fluid power systems. In this formula, P refers to pressure, F indicates force, and A represents area. Force equals pressure times area. Thus, the formula is written.

Pascal's Law
The foundation of modern hydraulics was established when Pascal discovered that pressure in a fluid acts equally in all directions. This pressure acts at right angles to the containing surfaces. If some type of pressure gauge, with an exposed face, is placed beneath the surface of a liquid at a specific depth and pointed in different directions, the pressure will read the same. Thus, we can say that pressure in a liquid is independent of direction.

Pressure due to the weight of a liquid, at any level, depends on the depth of the fluid from the surface. If the exposed face of the pressure gauges are moved closer to the surface of the liquid, the indicated pressure will be less. When the depth is doubled, the indicated pressure is doubled. Thus the pressure in a liquid is directly proportional to the depth.

Consider a container with vertical sides that is 1-foot-long and 1 foot wide. Let it be filled with water 1 foot deep, providing 1 cubic foot of water. *1 cubic foot of water weighs 62.4 pounds. Using this information and equation, **P = F/A**, we can calculate the pressure on the bottom of the container.

Since there are 144 square inches in 1 square foot, this can be stated as follows: the weight of a column of water 1 foot high, having a cross-sectional area of 1 square inch, is 0.433 pound. If the depth of the column is tripled, the weight of the column will be 3 x 0.433, or 1.299 pounds, and the pressure at the bottom will be 1.299 lb/in^2 (psi), since pressure equals the force divided by the area.

Thus, the pressure at any depth in a liquid is equal to the weight of the column of liquid at that depth divided by the cross-sectional area of the column at that depth. The volume of a liquid that produces the pressure is referred to as the fluid head of the liquid. The pressure of a liquid due to its fluid head is also dependent on the density of the liquid.

Gravity
Gravity is one of the four forces of nature. The strength of the gravitational force between two objects depends on their masses. The more massive the objects are, the stronger the gravitational attraction. When you pour water out of a container, the earth's gravity pulls the water towards the ground. The same thing happens when you put two buckets of water, with a tube between them, at two different heights. You must work to start the flow of water from one bucket to the other, but then gravity takes over and the process will continue on its own.

Gravity, applied forces, and atmospheric pressure are static factors that apply equally to fluids at rest or in motion, while inertia and friction are dynamic factors that apply only to fluids in motion. The mathematical sum of gravity, applied force, and atmospheric pressure is the static pressure obtained at any one point in a fluid at any given time.

Static Pressure
Static pressure exists in addition to any dynamic factors that may also be present at the same time.

Pascal's law states that a pressure set up in a fluid acts equally in all directions and at right angles to the containing surfaces. This covers the situation only for fluids at rest or practically at rest. It is true only for the factors making up static head. Obviously, when velocity becomes a factor it must have a direction, and as previously explained, the force related to the velocity must also have a direction, so that Pascal's law alone does not apply to the dynamic factors of fluid power.

The dynamic factors of inertia and friction are related to the static factors. Velocity head and friction head are obtained at the expense of static head. However, a portion of the velocity head can always be reconverted to static head. Force, which can be produced by pressure or head when dealing with fluids, is necessary to start a body moving if it is at rest, and is present in some form when the motion of the body is arrested. Therefore, whenever a fluid is given velocity, some part of its original static head is used to impart this velocity, which then exists as velocity head.

Volume and Velocity of Flow
The volume of a liquid passing a point in a given time is known as its ***volume of flow*** or flow rate. The volume of flow is usually expressed in gallons per minute (gpm) and is associated with relative pressures of the liquid, such as 5 gpm at 40 psi. The ***velocity of flow*** or velocity of the fluid is defined as the average speed at which the fluid moves past a given point. It is usually expressed in feet per second (fps) or feet per minute (fpm). Velocity of flow is an important consideration in sizing the hydraulic lines. Volume and velocity of flow are often considered together. With other conditions unaltered—that is, with volume of input unchanged—the velocity of flow increases as the cross section or size of the pipe decreases, and the velocity of flow decreases as the cross section increases. For example, the velocity of flow is slow at wide parts of a stream and rapid at narrow parts, yet the volume of water passing each part of the stream is the same.

Bernoulli's Principle
Bernoulli's principle thus says that a rise (fall) in pressure in a flowing fluid must always be accompanied by a decrease (increase) in the speed, and conversely, an increase (decrease) in, the speed of the fluid results in a decrease (increase) in the pressure. This is at the heart of a number of everyday phenomena. As a very trivial example, Bernoulli's principle is responsible for the fact that a shower curtain gets ``***sucked inwards***'' when the water is first turned on. What happens is that the increased water/air velocity inside the curtain (relative to the still air on the other side) causes a pressure drop.

The pressure difference between the outside and inside causes a net force on the shower curtain which sucks it inward. A more useful example is provided by the functioning of a perfume bottle: squeezing the bulb over the fluid creates a low pressure area due to the higher speed of the air, which subsequently draws the fluid up.

Bernoulli’s Principle also tells us why windows tend to explode, rather than implode in hurricanes. The very high speed of the air just outside the window causes the pressure just outside to be much less than the pressure inside, where the air is still.

The difference in force pushes the windows outward, and hence explode. If you know that a hurricane is coming, it is therefore better to open as many windows as possible, to equalize the pressure inside and out. Another example of Bernoulli's principle at work is in the lift of aircraft wings and the motion of ***“curve balls"*** in baseball. In both cases the design is such as to create a speed differential of the flowing air past the object on the top and the bottom - for aircraft wings this comes from the movement of the flaps, and for the baseball it is the presence of ridges. Such a speed differential leads to a pressure difference between the top and bottom of the object, resulting in a net force being exerted, either upwards or downwards.

Cross-Connection Terms

Cross-connection

A cross-connection is any temporary or permanent connection between a public water system or consumer’s potable (i.e., drinking) water system and any source or system containing nonpotable water or other substances. An example is the piping between a public water system or consumer’s potable water system and an auxiliary water system, cooling system, or irrigation system.

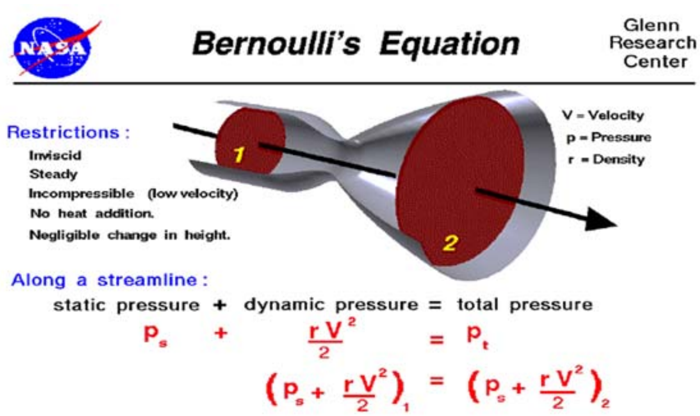
Contaminant: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

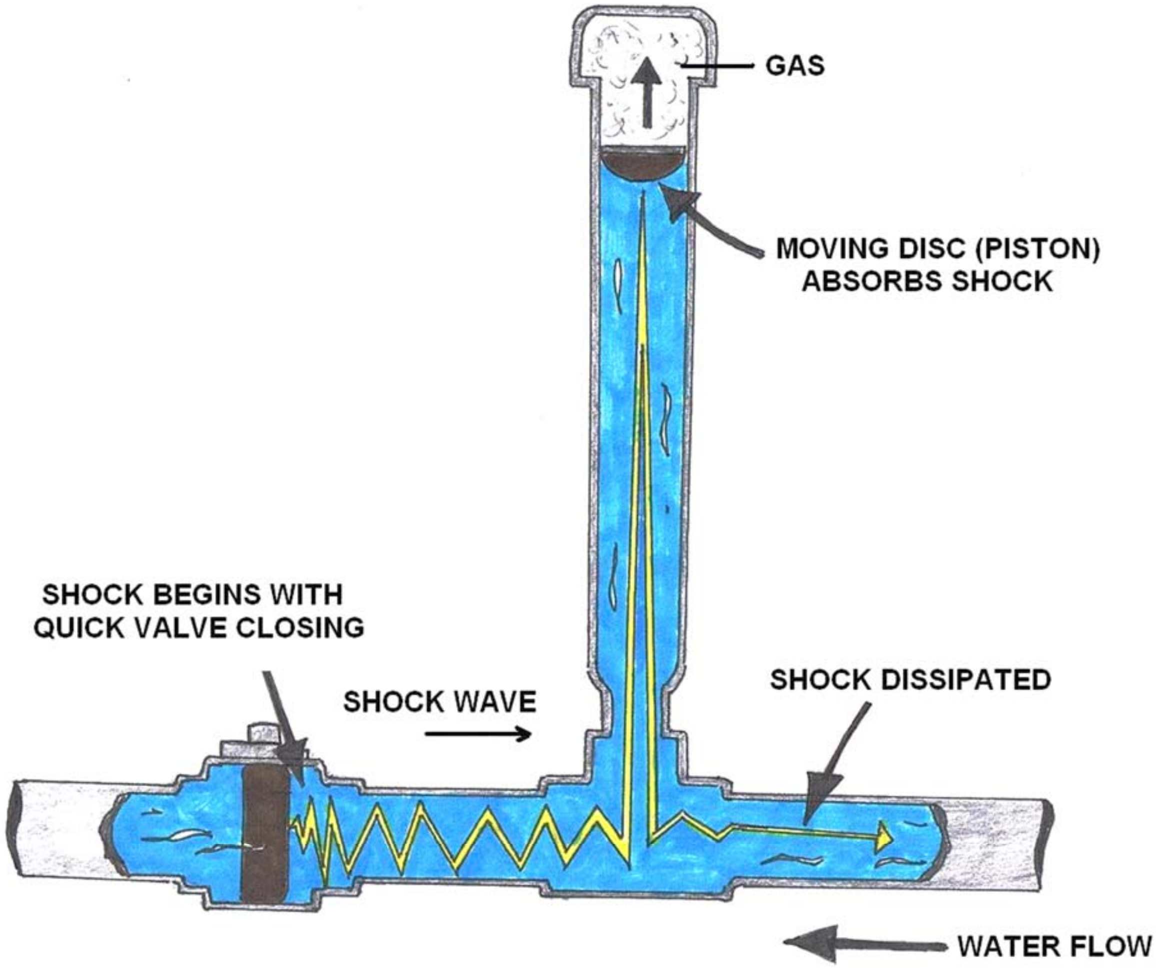
Contamination: To make something bad. To pollute or infect something. To reduce the quality of the potable (drinking) water and create an actual hazard to the water supply by poisoning or through spread of diseases.

***Corrosion**: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers. Corrosion starts on the inside of the pipe working outwards. Caused by electrochemical reactions caused by dissimilar metals.

***Cross-connection failure:** What might be the source of an organic substance causing taste and odor problems in a water distribution system?

Cross-Contamination: The mixing of two unlike qualities of water. For example, the mixing of good water with a polluting substance like a chemical substance.





BASIC FUNCTION OF WATER HAMMER ARRESTER

The following characteristics may reduce or eliminate water hammer:

Reduce the pressure of the water supply to the building by fitting a regulator.

Lower fluid velocities. To keep water hammer low, pipe-sizing charts for some applications recommend flow velocity at or below 5 ft/s (1.5 m/s).

Air valves often remediate low pressures at high points in the pipeline. Though effective, sometimes large numbers of air valves need be installed. These valves also allow air into the system, which is often unwanted.

Shorter branch pipe lengths.

Shorter lengths of straight pipe, i.e. add elbows, expansion loops. Water hammer is related to the speed of sound in the fluid, and elbows reduce the influences of pressure waves.

Arranging the larger piping in loops that supply shorter smaller run-out pipe branches. With looped piping, lower velocity flows from both sides of a loop can serve a branch.

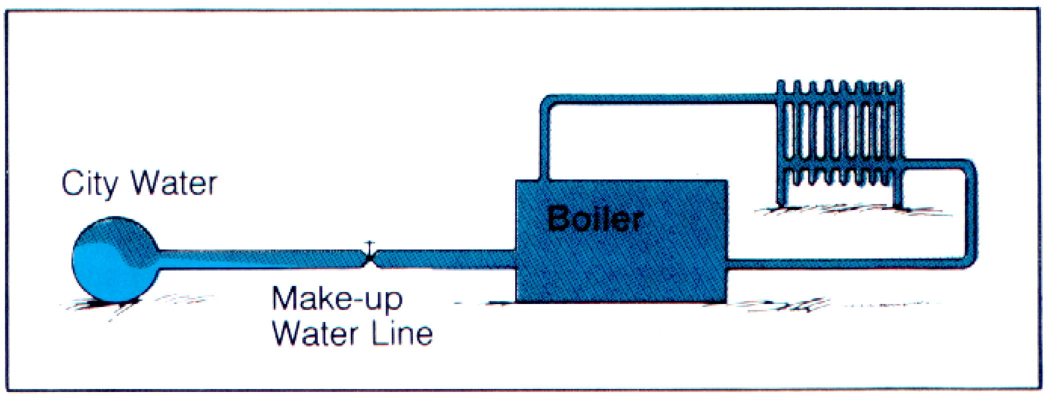
Flywheel on pump.

Pumping station bypass.

Backflow **Memorize this section**

*Backflow is the undesirable reversal of flow of nonpotable water or other substances through a cross-connection and into the piping of a public water system or consumer's potable water system. There are two types of backflow--**backpressure** and **backsiphonage.**

Backsiphonage

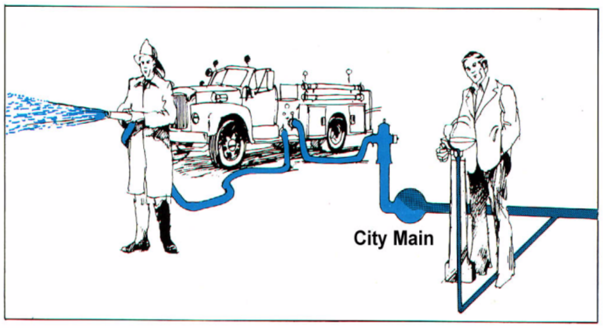


Backpressure

Backsiphonage *Memorize this statement.*

Backsiphonage is backflow caused by a negative pressure (i.e., a vacuum or partial vacuum) in a public water system or consumer's potable water system. The effect is similar to drinking water through a straw.

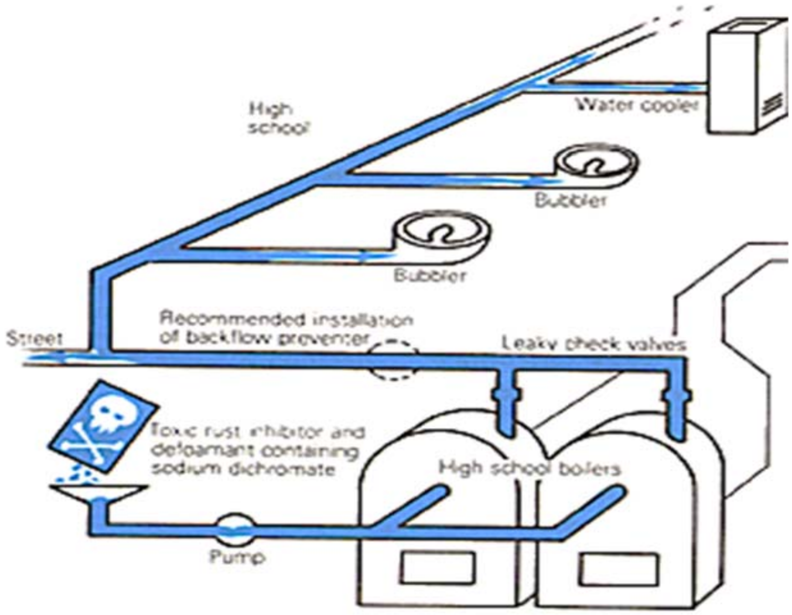
Backsiphonage can occur when there is a stoppage of water supply due to nearby firefighting, a break in a water main, etc.



Backpressure *Memorize this statement.*

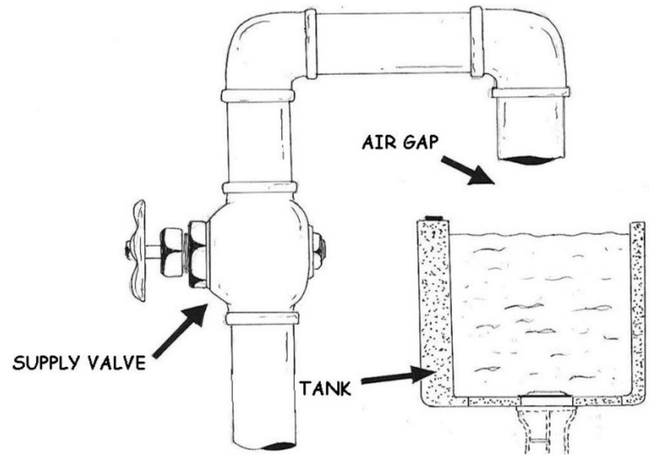
Backpressure is backflow caused by a downstream pressure that is greater than the upstream or supply pressure in a public water system or consumer's potable water system. Backpressure (i.e., downstream pressure that is greater than the potable water supply pressure) can result from an increase in downstream pressure, a reduction in the potable water supply pressure, or a combination of both. Increases in downstream pressure can be created by pumps, temperature increases in boilers, elevation, etc.

Reductions in potable water supply pressure occur whenever the amount of water being used exceeds the amount of water being supplied, such as during water line flushing, firefighting, or breaks in water mains.



Types of Backflow Prevention Methods and Assemblies

***Approved Air Gap Separation (AG)**
An approved air gap is a physical separation between the free flowing discharge end of a potable water supply pipeline, and the overflow rim of an open or non-pressure receiving vessel. These separations must be vertically orientated a distance of at least twice the inside diameter of the inlet pipe, but never less than one inch. An obstruction around or near an air gap may restrict the flow of air into the outlet pipe and nullify the effectiveness of the air gap to prevent backsiphonage. When the air flow is restricted, such as the case of an air gap located near a wall, the air gap separation must be increased. Also, within a building where the air pressure is artificially increased above atmospheric, such as a sports stadium with a flexible roof kept in place by air blowers, the air gap separation must be increased.

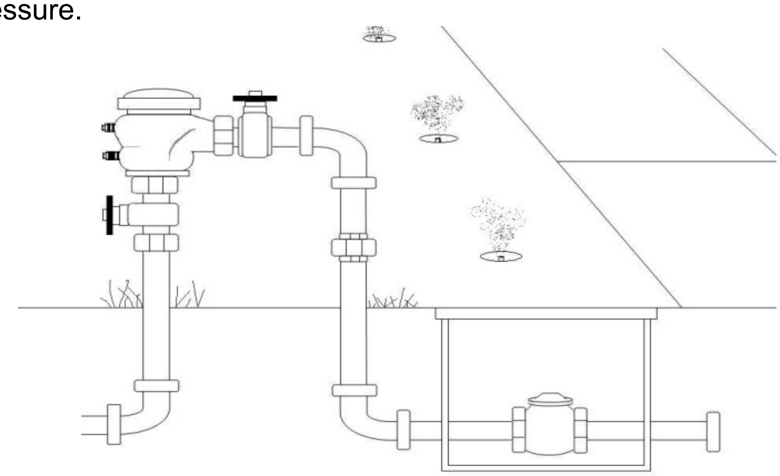


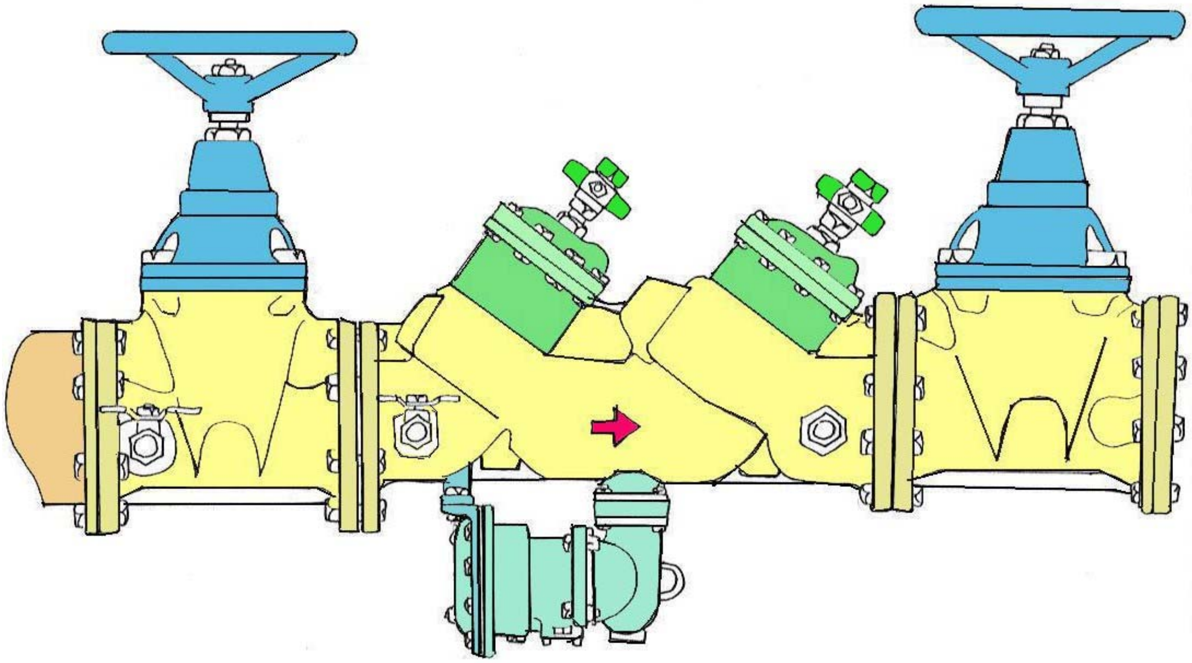
***Air Gap or Vacuum Breaker:** What should a potable water line be equipped with when connected to a chemical feeder for fluoride?

***Air Gap Separation:** A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet.

Pressure Vacuum Breaker Assembly (PVB)

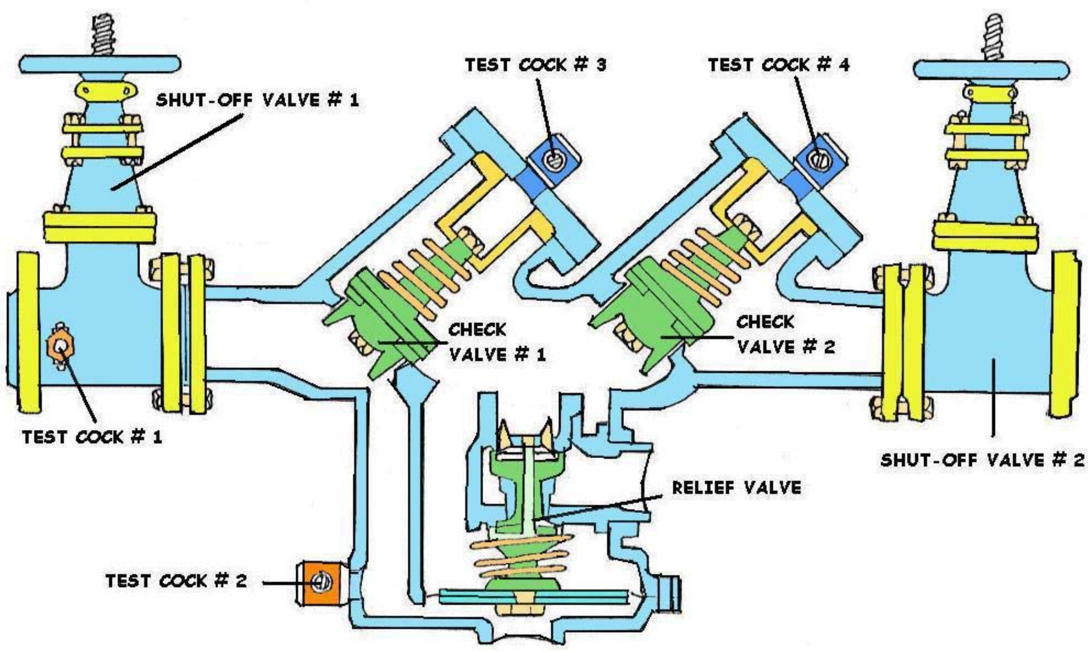
The Pressure Vacuum Breaker Assembly consists of a spring loaded check valve, an independently operating air inlet valve, two resilient seated shutoff valves, and two properly located resilient seated test cocks. It shall be installed as a unit as shipped by the manufacturer. The air inlet valve is internally loaded to the open position, normally by means of a spring, allowing installation of the assembly on the pressure side of a shutoff valve. *A PVB must be 12 inches above the highest downstream outlet and only stops backsiphonage and not backpressure.





REDUCED PRESSURE BACKFLOW ASSEMBLY

REDUCED-PRESSURE BACKFLOW ASSEMBLY



General Backflow Information

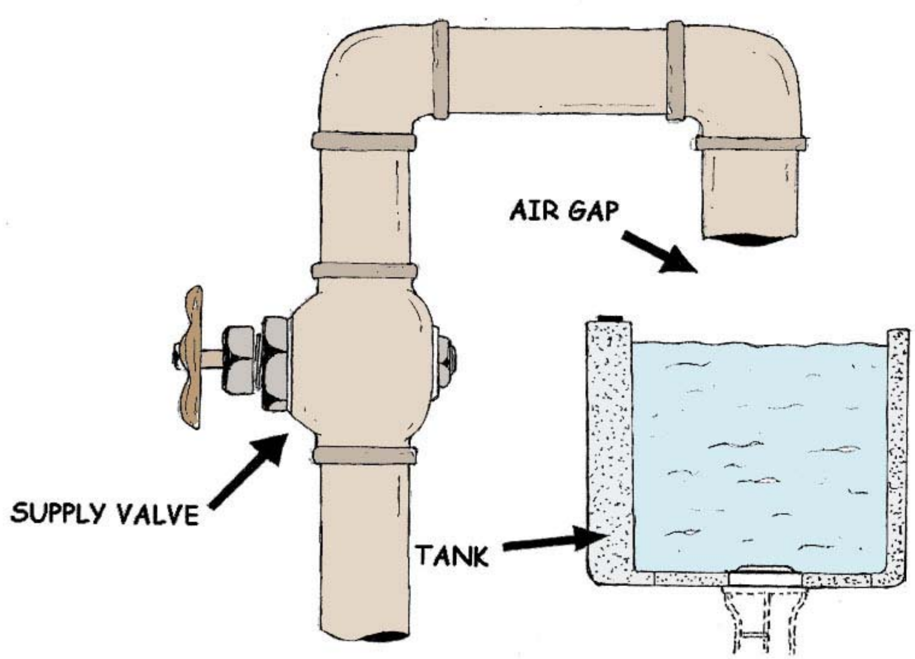
Memorize these statements.

Backflow: The reversal of the normal flow of water caused by either Backpressure or Back-siphonage. Reverse flow condition**.**

Backsiphonage: Negative pressure or zero pressure on the supply side. The flow of water or other liquids, mixtures, or other substances into the distribution pipes of a potable water supply system from any source or sources other than its intended source caused by the sudden reduction of pressure in the potable water supply system.

Backpressure: Higher pressure on the service side than on the supply side. A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public water system.

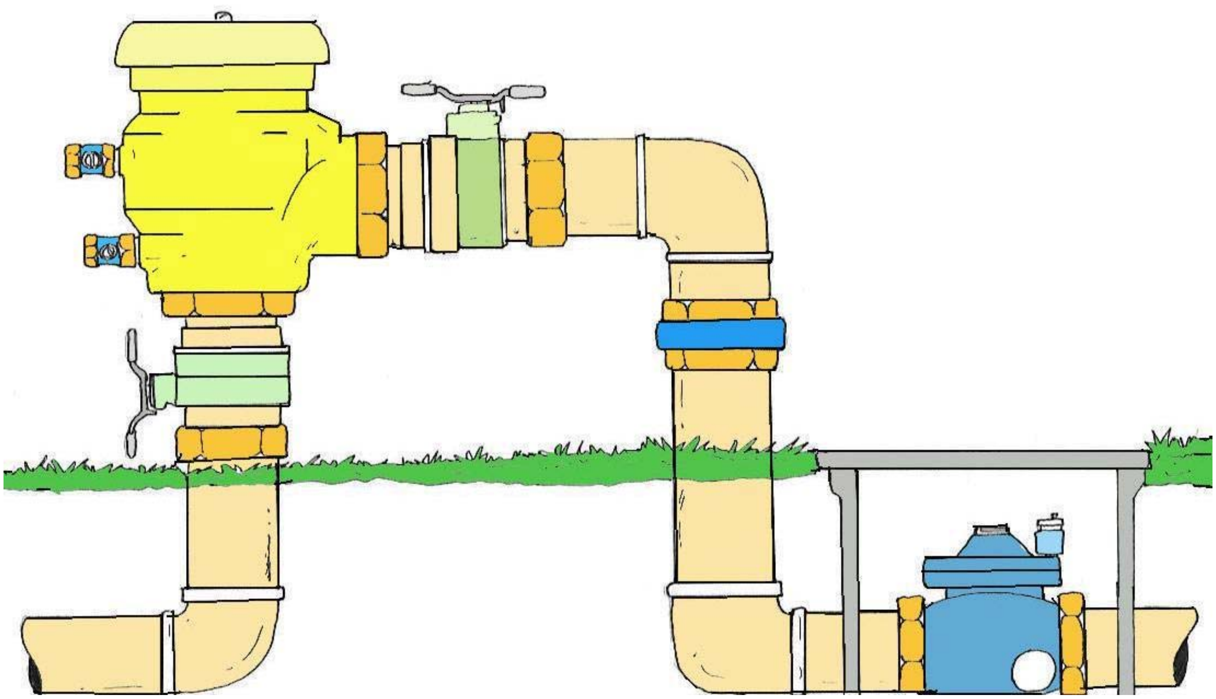
Cross-Connection: A connection between drinking (potable) water and an unapproved water supply.



Air Gap: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet. Minimum 1 inch or twice the diameter whatever is greater.

Biggest Threat: Pesticide tanks are the greatest concerns to our water distribution systems.

PRESSSURE VACUUM BREAKER ASSEMBLY



Memorize these statements.

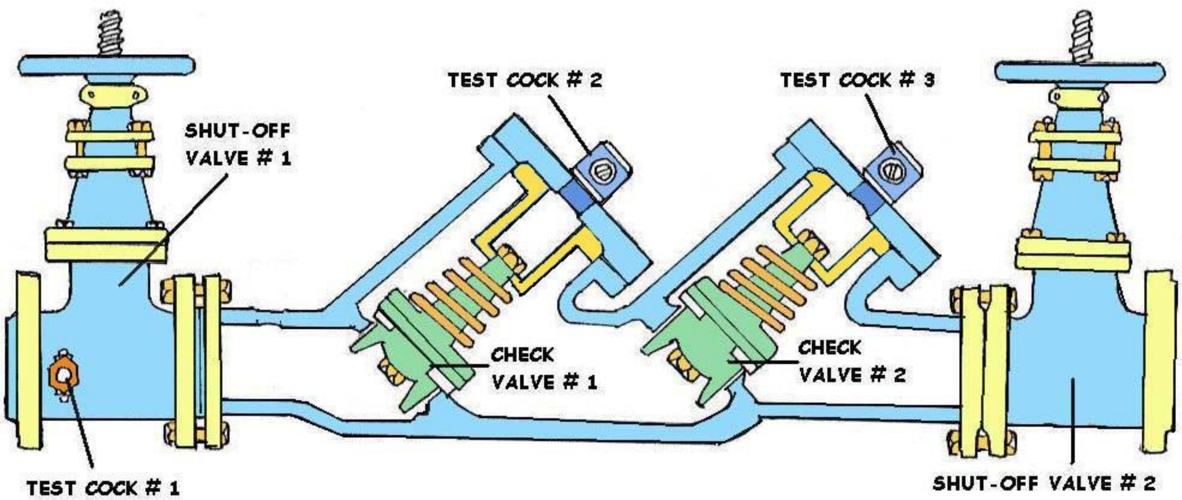
Often referred to as a vacuum breaker.

Primary found on Irrigation systems.

Stops backsiphonage of health related concerns, but not backpressure concerns.

Must be installed 12 inches above the highest downstream outlet. Must be inspected once a year by a certified general tester.

Also review the backflow statements in the glossary.



DOUBLE-CHECK BACKFLOW ASSEMBLY

Memorize these statements.

Double check valve assembly.

Stops backsiphonage and backpressure of pollution concerns only.

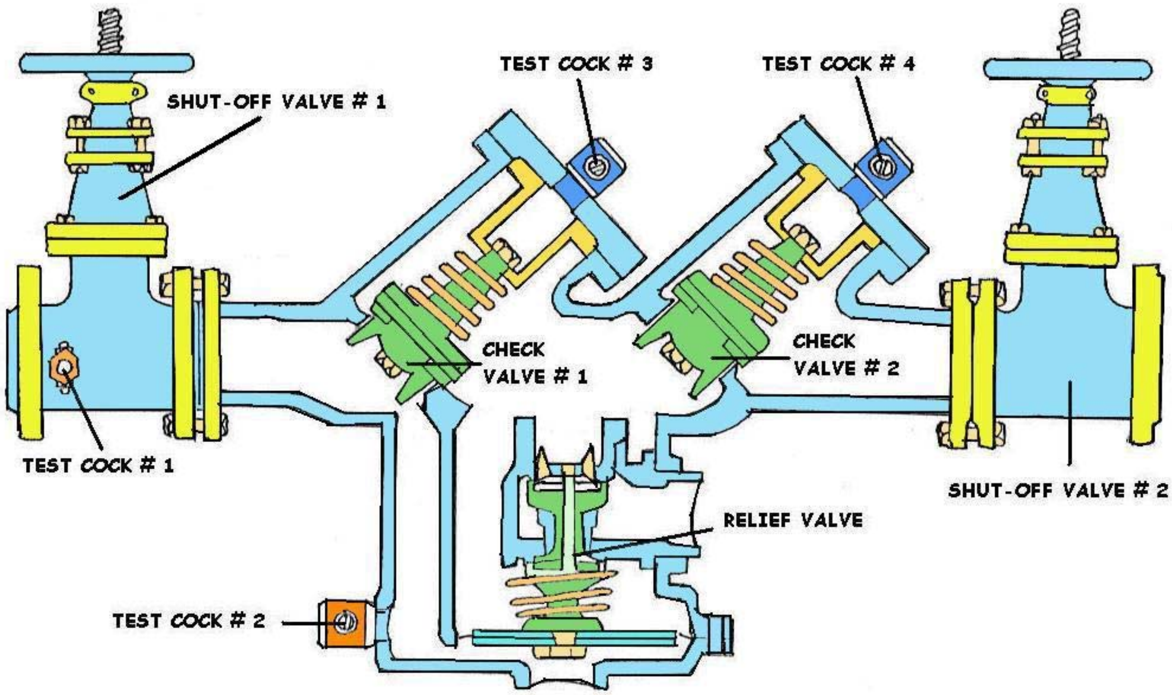
O.S. and Y: Outside screw and yoke valves are commonly found on this assembly.

Needs to be installed 12 inches above the ground and tested once a year by a certified general tester.

Note that this assembly does not have the hydraulic relief valve as with the RP.

Also review the backflow statements in the glossary.

REDUCED-PRESSURE BACKFLOW ASSEMBLY



Memorize these statements.

The RP or Reduced Pressure Principle Backflow Assembly stops backsiphonage and backpressure of health related concerns.

Needs to be tested or inspected once a year by a certified general backflow tester.

Needs to be installed 12 inches above the ground. If backflow occurs and gets past the number 2 check, a pressure differential is created and the hydraulic relief valve will open, allowing the material to dump or open to the atmosphere.

Backflow assemblies need to be installed as close as possible to the water meter, downstream. Not measured in feet but as close as possible.

Also review the backflow statements in the glossary. Please read the entire glossary and Chlorine, Pumps and Safety statements before your exam.

Double Check Valve Assembly (DC)

The Double Check Valve Assembly consists of two internally loaded check valves, either spring loaded or internally weighted, two resilient seated full ported shutoff valves, and four properly located resilient seated test cocks. This assembly shall be installed as a unit as shipped by the manufacturer. *The double check valve assembly is designed to prevent backflow caused by backpressure and backsiphonage from low health or pollutional hazards. *The DC is different from the RP in that it does not have a relief valve. *A DC should only be used on pollutional related concerns not health or contamination concerns.

Reduced Pressure Backflow Assembly (RP)

The reduced pressure principle backflow assembly consists of two independently acting spring loaded check valves separated by a spring loaded differential pressure relief valve, two resilient seated full ported shutoff valves, and four properly located resilient seated test cocks. This assembly shall be installed as a unit shipped by the manufacturer.

During normal operation, the pressure between the two check valves, referred to as the zone of reduced pressure, is maintained at a lower pressure than the supply pressure. If either check valve leaks, the differential pressure relief valve maintains a differential pressure of at least two (2) psi between the supply pressure, and the zone between the two check valves, by discharging water to atmosphere.

The reduced pressure backflow assembly is designed to prevent backflow caused by backpressure and backsiphonage from low to high health hazards.

Why do backflow preventers have to be tested periodically?

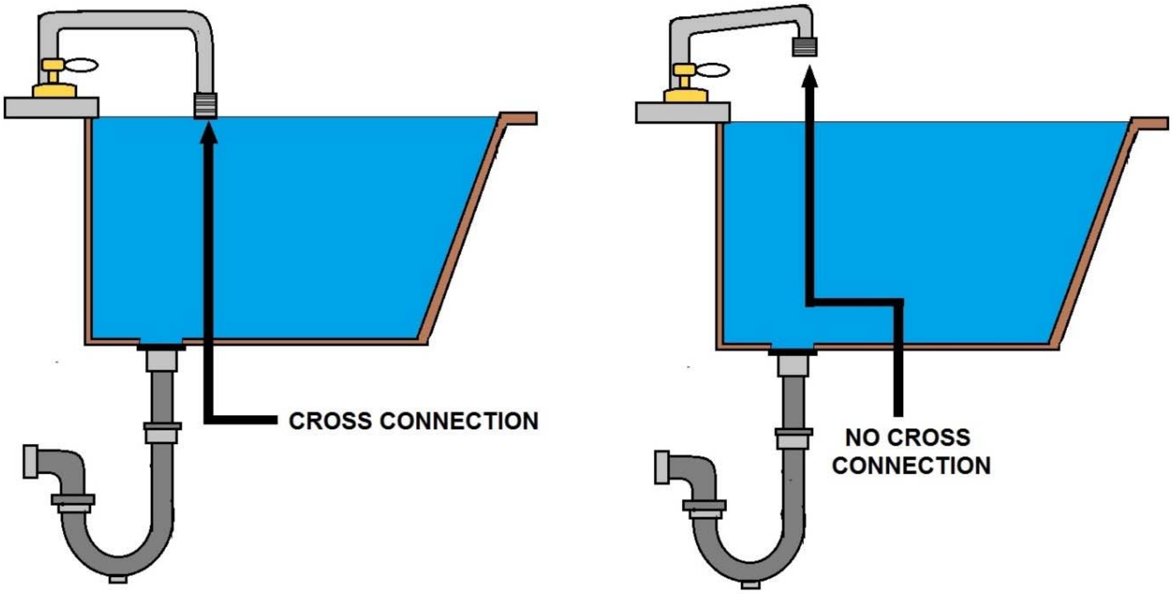
Mechanical backflow preventers have internal seals, springs, and moving parts that are subject to fouling, wear, or fatigue. Also, mechanical backflow preventers and air gaps can be bypassed. Therefore, all backflow preventers have to be tested periodically to ensure that they are functioning properly. A visual check of air gaps is sufficient, but mechanical backflow preventers have to be tested with properly calibrated gauge equipment.

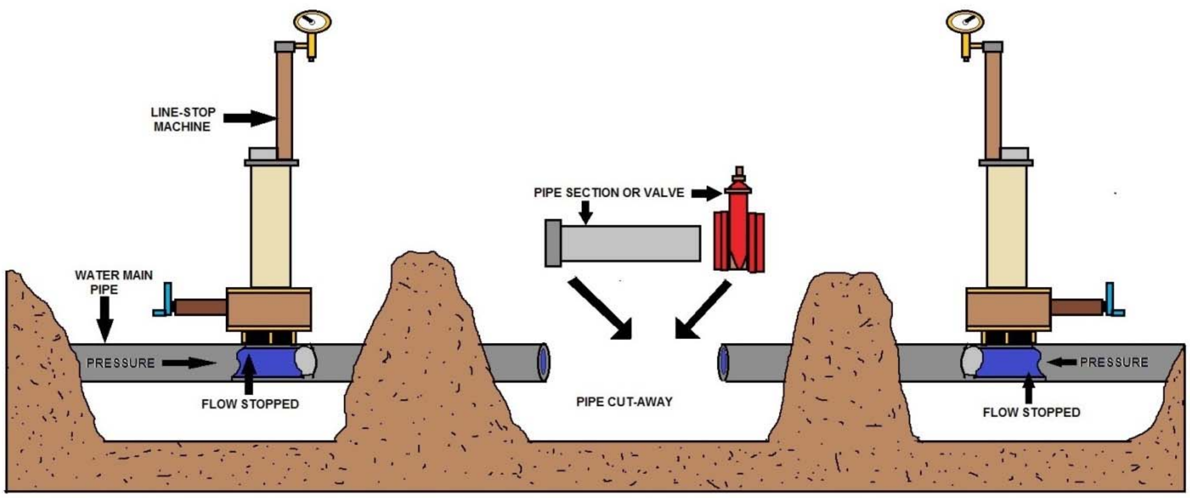
Backflow prevention devices must be tested annually to ensure that they work properly. It is usually the responsibility of the property owner to have this test done and to make sure that a copy of the test report is sent to the Public Works Department or Water Purveyor.

If a device is not tested annually, Public Works or the Water Purveyor will notify the property owner asking them to comply. If the property owner does not voluntarily test their device, the water provider may be forced to turn off water service to that property.

State law requires the Water provider to discontinue water service until testing is complete.

*All backflow assemblies and air gaps need to be checked annually by a certified backflow assembly tester.





INSERTION VALVE

Distribution Valves

The purpose of installing shutoff valves in water mains at various locations within the distribution system is to allow sections of the system to be taken out of service for repairs or maintenance, without significantly curtailing service over large areas.

Valves should be installed at intervals not greater than 5,000 feet in long supply lines and 1,500 feet in main distribution loops or feeders. All branch mains connecting to feeder mains or feeder loops should have valves installed as close to the feeders as practical. In this way, branch mains can be taken out of service without interrupting the supply to other locations.

In the areas of greatest water demand, or when the dependability of the distribution system is particularly important, valve spacing of 500 feet may be appropriate.

At intersections of distribution mains, the number of valves required is normally one less than the number of radiating mains. The valve omitted from the line is usually the one that principally supplies flow to the intersection. Shutoff valves should be installed in standardized locations (that is, the northeast comer of intersections or a certain distance from the center line of streets), so they can be easily found in emergencies.

All buried small- and medium-sized valves should be installed in valve boxes. For large shutoff valves (about 30 inches in diameter and larger), it may be necessary to surround the valve operator or entire valve within a vault or manhole to allow repair or replacement.

*Classification of Valves*** *Know and memorize.***

There are two major classifications of water valves: **Rotary and Linear**. Linear is a fancy word for up and down or blade movement.

Gate Valve *Linear Valve   Our primary Linear valve*
The most common valve in the distribution system. Primarily used for main line shut downs. Should be exercised on annual basis.

Gate valves are used when a straight-line flow of fluid and minimum flow restriction are needed. Gate valves are so-named because the part that either stops or allows flow through the valve acts somewhat like a gate. The gate is usually wedge-shaped. When the valve is wide open the gate is fully drawn up into the valve bonnet. This leaves an opening for flow through the valve the same size as the pipe in which the valve is installed.

Therefore, there is little pressure drop or flow restriction through the valve. Gate valves are not suitable for throttling purposes. The control of flow is difficult because of the valve's design, and the flow of fluid slapping against a partially open gate can cause extensive damage to the valve. Except as specifically authorized, gate valves should not be used for throttling.



Notice the corrosion inside this cast iron main. * Know and memorize.

This corrosion is caused by chemical changes produced by electricity or electrolysis. We call this type of corrosion "tuberculation". It is a protective crust of corrosion products that have built up over a pit caused by the loss of metal due to corrosion or electrolysis. This type of corrosion will decrease the C-Factor (friction loss) and the carrying capacity in a pipe. Crenothrix bacteria or Red-Iron bacteria will live and thrive in the bioslime in this type of tuberculation. Now, for dealing with this bacteria there are two methods: 1) the fast method, super chlorinate and flush forever. Or, 2) replace the line with a nice and new plastic water main.

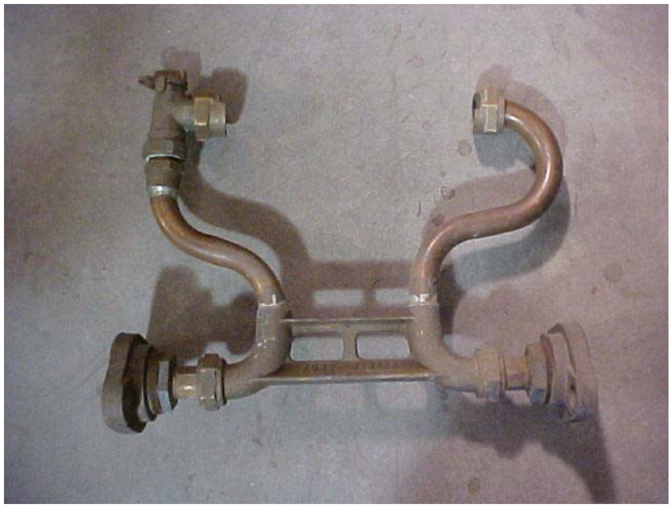
Gate valve storage procedures: Always store a gate valve with the gate up or opened. Not like in this photograph. Sunlight will destroy the rubber. I like to keep the valves covered, open position and clean.

Knife Gate Valve

Always follow standard safety procedures when working on a valve. Install the valve so that the arrows on both sides of the body are in the direction of positive pressure differential.

The preferred orientation is with the stem vertical and the handwheel pointing up. The opposite orientation is not recommended, because fiber and dirt can build-up in the bonnet.

Service connections are used to connect individual buildings or other plumbing systems to the distribution system mains. See the Angle stop.



Water Meter Re-setter, Riser or sometimes referred to as a copper yoke. There is also a cast iron version which are best broken off with two sledge or cocking hammers when it's time to replace or retrofit the service. You almost always replace a yoke stop hot. A Yoke Stop is a type of Angle Stop most of the time.

Common distribution fittings: Single check, Poly Pig, 1 inch repair clamp, 4 inch full circle clamp, T- Bolt and a corp. and saddle. Note from Professor Durbin,

Ductile pipe cement-lined iron pipe. I've seen thousands of dollars of pipe that is dropped or moved with the front bucket of a backhoe and destroyed. This destroys the interior protection of the pipe, causing leaks which will start in a few years. I know that some of you welcome this as job security. These nitwits need job security, but water professionals do not need crappy work to keep them employed. Always protect and store all types of pipe in a pipe rack and covered. This goes for the proper storage of rubbers as well.

Flex Coupling-sometimes referred to as a Dayton-used to join pipes or to "cut-in a valve". You will learn that you can use different sizes to join pipe or even file out the inside diameter to adjust to larger pipes like ACP. This flex coupling only has three bolts. I like four or more for work with larger pipes. Professor Durbin's trick--When working on a water line, I like to turn the valves on slowly to fill the water main as the flex couplings are being tightened. This allows the air to escape and for you to find leaks. It also allows debris in the main to flush out.

Here is a four-way pipe cutting tool used for iron pipe. Be careful not to break the wheels by over tightening. I personally like 4-Ways because of the nice cut. You will learn to recognize the distinct snap of cut pipe. The only drawback to these cutters is cutting a small section out of the main. You may need to make two or three more cuts and break the section out with a cocking hammer. It will easily cut Ductile, galvanized, and even plastic.

Plastic pipe cutters utilize sharper cutting wheels. Rookies like to thread the pipe rather than cut the pipe. It is fun to watch and to tease these rookies about it, especially if they just finished jumping a stop with the valve closed or no ball. Good times for sure in the crazy Distribution field.

Photograph on right-difficult to see- these are pipe crimpers. These will easily and effectively stop flow in copper or plastic pipe in tubing less than 2 inches. The only problem is dealing with the crimp when you are finished. I suggest placing a flex coupling over the crimp in plastic and completely cutting the crimped area out when done in copper pipe**.**

Top photograph-two gate valves blew out-you can see the kickers or thrust blocks in the background. Bottom photograph-a tapping machine and a new gate valve. These tapping machines are very, very expensive.

Slam, Surge and Water Hammer

When a valve is closed* instantaneously *there is a corresponding* instantaneous *pressure rise causing a water hammer. * Know and memorize.

Water hammer (or, more generally, fluid hammer) is a pressure surge or wave caused by the kinetic energy of a fluid in motion when it is forced to stop or change direction suddenly. It depends on the fluid compressibility where there are sudden changes in pressure. For example, if a valve is closed suddenly at an end of a pipeline system a water hammer wave propagates in the pipe. Moving water in a pipe has kinetic energy proportional to the mass of the water in a given volume times the square of the velocity of the water.

The Effects of Water Hammer and Pulsations
Quick closing valves, positive displacement pumps, and vertical pipe runs can create damaging pressure spikes, leading to blown diaphragms, seals and gaskets, and also destroyed meters and gauges.

Liquid for all practical purposes is not compressible--any energy that is applied to it is instantly transmitted. This energy becomes dynamic in nature when a force such as a quick closing valve or a pump applies velocity to the fluid.

Surge (Water Hammer)
Surge, or water hammer, as it is commonly known, is the result of a sudden change in liquid velocity. Water hammer usually occurs when a transfer system is quickly started, stopped or is forced to make a rapid change in direction. Any of these events can lead to catastrophic system component failure. Without question, the primary cause of water hammer in process applications is the quick closing valve, whether manual or automatic. A valve closing in 1.5 seconds (or less, depending upon valve size and system conditions) causes an abrupt stoppage of flow. The pressure spike (acoustic wave) created at rapid valve closure can be high as five (5) times the system working pressure.

For this reason, most pipe-sizing charts recommend keeping the flow velocity at or below 5 ft/s (1.5 m/s). If the pipe is suddenly closed at the outlet (downstream), the mass of water before the closure is still moving forward with some velocity, building up a high pressure and shock waves. In domestic plumbing, this is experienced as a loud bang resembling a hammering noise.

Water hammer can cause pipelines to break or even explode if the pressure is high enough. Air traps or stand pipes (open at the top) are sometimes added as dampers to water systems to provide a cushion to absorb the force of moving water in order to prevent damage to the system. (At some hydroelectric generating stations what appears to be a water tower is actually one of these devices.) The water hammer principle can be used to create a simple water pump called a hydraulic ram.

On the other hand, when a valve in a pipe is closed, the water downstream of the valve will attempt to continue flowing, creating a vacuum that may cause the pipe to collapse or implode. This problem can be particularly acute if the pipe is on a downhill slope. To prevent this, air and vacuum relief valves, or air vents, are installed just downstream of the valve to allow air to enter the line and prevent this vacuum from occurring.

Unrestricted, this pressure spike or wave will rapidly accelerate to the speed of sound in liquid, which can exceed 4000 ft/sec. It is possible to estimate the pressure increase by the following formula.

Water Hammer Formula: P = (0.070) (V) (L) / t + P1

Where P = Increase in pressure
P1 = Inlet Pressure
V = Flow velocity in ft/sec
t = Time in sec.(Valve closing time)
L = Upstream Pipe Length in feet

Here's an example of pressure hammer when closing an EASMT solenoid valve, with a 50 ft long upstream pipe connection:

L = 50 ft
V = 5.0 ft / sec(recommended velocity for PVC piping design)
t = 40 ms(solenoid valve closing time is approx. 40-50 ms)
P1 = 50 psi inlet pressure

therefore, P = 0.07 x 5 x 50 / 0.040 + P1
or P = 437.5 psi + P1

Total Pressure = 437.5 + 50 = 487.5 psi

Pulsation

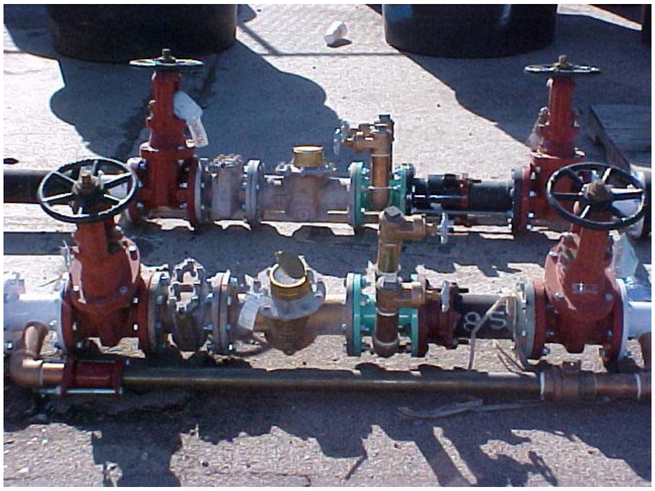
Pulsation generally occurs when a liquid's motive force is generated by reciprocating or peristaltic positive displacement pumps. It is most commonly caused by the acceleration and deceleration of the pumped fluid. This uncontrolled energy appears as pressure spikes. Vibration is the visible example of pulsation and is the culprit that usually leads the way to component failure.

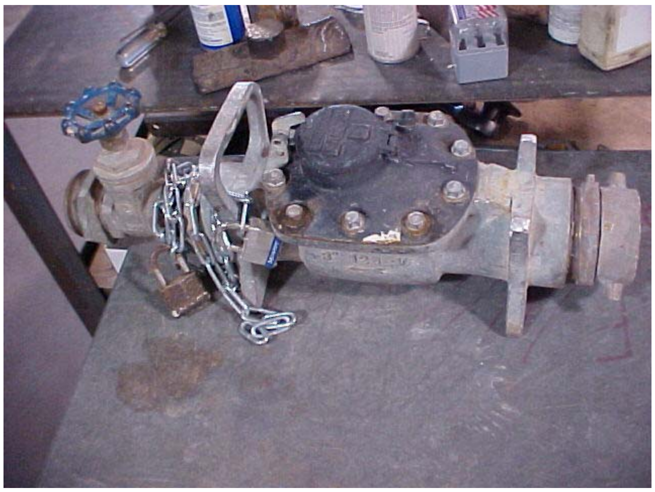
Unlike centrifugal pumps(which produce normally non-damaging high-frequency but low-amplitude pulses), the amplitude is the problem because it's the pressure spike. The peak, instantaneous pressure required to accelerate the liquid in the pipe line can be greater than ten (10) times the steady state flow pressure produced by a centrifugal pump. Damage to seals gauges, diaphragms, valves and joints in piping result from the pressure spikes created by the pulsating flow.

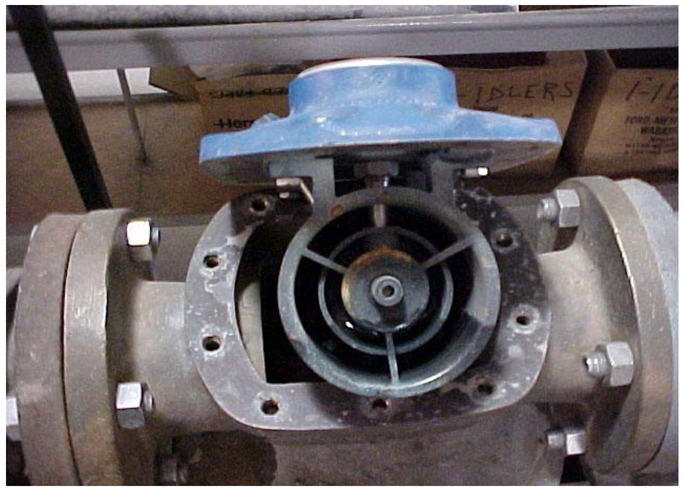
Remedy

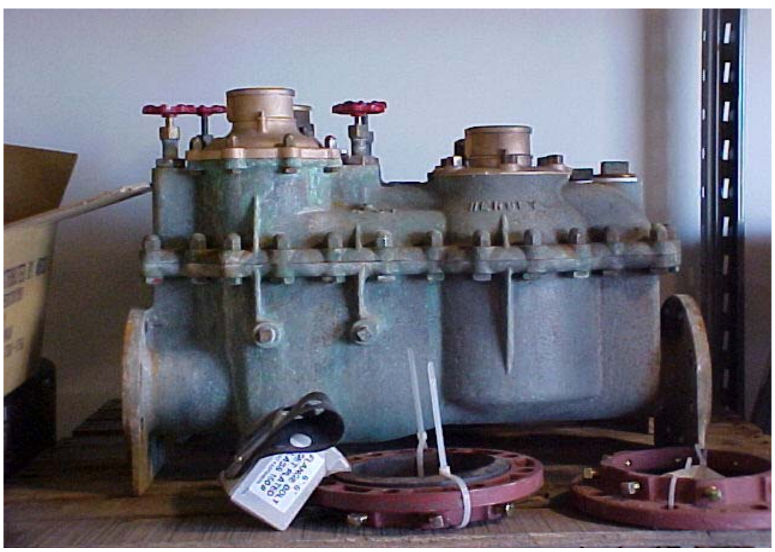
We suggest that you install a pulsation dampener or surge tank. Dampeners provide the most cost efficient and effective choice to prevent the damaging effects of pulsation. A surge suppressor is in design essentially the same as pulsation dampener. The difference primarily lies in sizing and pressurizing. The most current pulsation dampener design is the hydro-pneumatic dampener, consisting of a pressure vessel containing a compressed gas, generally air or Nitrogen separated from the process liquid by a bladder or diaphragm.

**Water Meters record the flow of water in a part of the distribution system.
Bypass, Compound, Turbine or Propeller meters.**







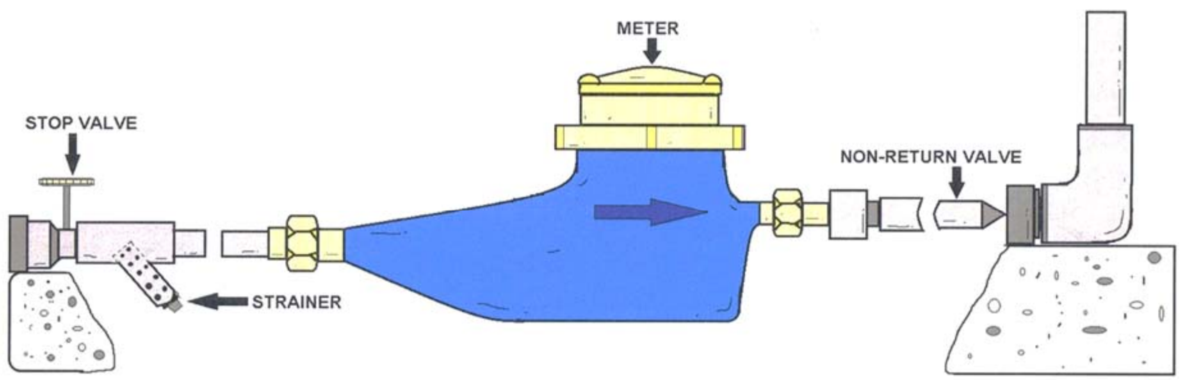


Water Meters

It is important to account for the water produced and supplied. A master meter should be installed on each source, with service meters placed at each point of use. These should be read and recorded periodically. Totals from the master meters should be compared to totals from the service meters to compute the amount of water lost in the distribution system. This information is important in locating and eliminating leaks and unauthorized taps.

Losses of 10 to 20 percent are not uncommon in many distribution systems. Also, it has been shown that a system which is not metered is likely to have a water usage up to three times as great as a metered system.

Un-metered water users tend to water freely and have little incentive to repair plumbing leaks.



WATER METER

Troubleshooting Table for Distribution System

Problem
1. Dirty water complaints
2. Red water complaints
3. No or low water pressure
4. Excessive water **usage**.

Possible Causes
1A. Localized accumulations of debris, solids/**particulates** in distribution mains.
1B. Cross connection between water system and another system carrying non-potable water.
2A. Iron content of water from source is high. Iron precipitates in mains and accumulates.
2B. Cast iron, ductile iron, or steel mains are corroding, causing "rust" in the water.
3A. Source of supply, storage or pumping station interrupted.
3B. System cannot supply **demands.**
3C. Service line, meter, or connections shutoff, or clogged with debris.
3D. Broken or leaking distribution pipes.
3E. Valve in system closed or broken.
4A. More connections have been added to the system.
4B. Excessive leakage (>15% of production)is occurring, meters are not installed or not registering properly.
4C. Illegal connections have been made.

Possible Solutions
1A. Collect and **preserve** samples for **analysis** if needed. Isolate affected part of main and flush.
1B. Collect and preserve samples for analysis if needed. Conduct survey of system for cross connections. Contact State Drinking Water Agency.
2A. Collect and test water samples from water source and location of complaints for iron. If high at both sites, contact regulatory agency, TA provider, consulting engineer or water conditioning company for assistance with iron removal treatment.
2B. Collect and analyze samples for iron and corrosion parameters. Contact State Drinking Water Agency, TA provider, consulting engineer or water conditioning company for assistance with corrosion control treatment.
3A. Check source, storage and pumping stations. Correct or repair as needed.
3B. Check to see if demands are unusually high. If so, try to reduce demand. Contact State Drinking Water Agency, TA provider or consulting engineer.
3C. Investigate and open or unclog service.
3D. Locate and repair break or leak.
3E. Check and open closed isolation and pressure-reducing valves. Repair or contact contractor if valves are broken.
4A. Compare increase in usage over time with new connections added over same period. If correlation evident take action to curtail demand or increase **capacity** if needed. Contact State Drinking Water Agency , TA provider or consulting engineer.
4B. Conduct a water audit to determine the cause. If leakage, contact regulatory agency, and consulting engineer or leak detection contractor.
4C. Conduct survey to identify connections.

Disinfection of Repaired Pipeline Sections

You should recognize that the protection of the public health of its water customers is the primary role of a water provider. Accordingly, the disinfection of all repaired water appurtenances is paramount to the return of the water system to its' normal operation mode. Prior to initiating the disinfection process, a thorough cleaning of all repaired pipes and or reservoirs must be accomplished. The following table indicates the amount of Sodium Hypochlorite and Calcium Hypochlorite that is necessary to disinfect 100,000 gallons of water.

DISINFECTION TABLE
For 100,000 Gallons Of Water

Desired Chlorine Dose in MG/L	Pounds of Liquid Chlorine Required	Gallons of Sodium Hypo Chlorite Required 5% Available Chlorine	10% Available Chlorine	15% Available Chlorine	Pounds of Calcium Hypo Chlorite Required. 65% Available
2	1.7	3.9	2.0	1.3	2.6
10	8.3	19.4	9.9	12.8	12.8
50	42	97	49.6	64	64

Spare Parts Inventory

You should maintain a complete inventory of spare parts for the maintenance and repair of all water transmission and distribution lines. The water lines in the system range in size between ¾ inch and 16 inches in diameter. Additionally, you should maintain spare motor controls, pump ends, and motors for all wells and booster stations. Water system personnel can repair the entire range of water lines without assistance from outside contractors.

*Stand-by warehouse personnel should be available twenty four hours per day to assist in the delivery of spare parts in instances requiring emergency repair.

Preventative maintenance can extend the life of any water pipeline. Pipes can deteriorate on the inside as a result of corrosion and on the outside as a result of aggressive soil and moisture. The Water Department should maintain an intense leak detection program to effectively reduce operating costs and provide revenue savings by reducing lost and unaccounted for water. Leaks can originate in joints and fittings or any corroded portion of a pipeline.

*Additionally, leaks will undermine the pavement and water soak the area around the leaking section of pipeline. When leaks are discovered, they are repaired within twenty four hours after properly locating all underground utilities through the Underground Service Alert or One call Center "***Blue Stake***" procedure.

Types of Pipes Used in the Distribution Field

Several types of pipe are used in water distribution systems, but only the most common types used by operators will be discussed. These piping materials include copper, plastic, galvanized steel, and cast iron. Some of the main characteristics of pipes made from these materials are presented below.

Plastic Pipe (PVC)
Plastic pipe has seen extensive use in current construction. Available in different lengths and sizes, it is lighter than steel or copper and requires no special tools to install. Plastic pipe has several advantages over metal pipe. It is flexible, it has superior resistance to rupture from freezing, it has complete resistance to corrosion and in addition, it can be installed above ground or below ground.

One of the most versatile plastic and polyvinyl resin pipes is the polyvinyl chloride (PVC). PVC pipes are made of tough, strong thermoplastic material that has an excellent combination of physical and chemical properties. Its chemical resistance and design strength make it an excellent material for application in various mechanical systems.

Sometimes polyvinyl chloride is further chlorinated to obtain a stiffer design, a higher level of impact resistance, and a greater resistance to extremes of temperature. A CPVC pipe (a chlorinated blend of PVC) can be used not only in cold-water systems, but also in hot-water systems with temperatures up to 210°F. Economy and ease of installation make plastic pipe popular for use in either water distribution and supply systems or sewer drainage systems.

**Various types and sizes of coupons or tap cut-outs. You will want to date and collect these cut-outs to determine the condition of the pipe or measure the corrosion.*

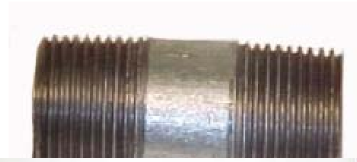
Plastic Pipe (PVC)
This is currently the most common type of pipe used in distribution systems. It is available in diameters of 1/2" and larger, and in lengths of 10', 20', and 40'. A main advantage is its light weight, allowing for easy installation. A disadvantage is its inability to withstand shock loads. Since it is non-metallic, a tracer wire must be installed with the PVC water main so that it can be located after burial.

The National Sanitation Foundation (NSF) currently lists most brands of PVC pipe as being acceptable for potable water use. This information should be stamped on the outside of the pipe, along with working pressure and temperature, diameter and pipe manufacturer.

*PVC pipe will have the highest C Factor of all the above pipes. The higher the C factor the smoother the pipe.

Cast Iron (CIP)

This is another type of piping material that has been in use for a long time. It is found in diameters from 3" to 48". Advantages of this material are its long life, durability, and ability to withstand working pressures up to 350 psi. Disadvantages include the fact that it is heavy, difficult to install, and does not withstand shock loading. Although it is not currently the material of choice, there is still a lot of it in the ground.



Ductile Iron Pipe (DIP)

This was developed to overcome the breakage problems associated with cast iron pipe. It can be purchased in 4" to 45" diameters and lengths of 18' to 20'. Its main advantage is that it is nearly indestructible by internal or external pressures. It is manufactured by injecting magnesium into molten cast iron. It is sometimes protected from highly corrosive soils by wrapping the pipe in plastic sheeting prior to installation. This practice can greatly extend the life of this type of pipe.

Steel Pipe

This pipe is often used in water treatment plants and pump stations. It is available in various diameters and in 20' or 21' lengths. Its main advantage is the ability to form it into a variety of shapes. It also exhibits good yielding and shock resistance. It has a smooth interior surface and can withstand pressures up to 250 psi. A disadvantage is that it is easily corroded by both soil and water. To reduce corrosion problems, steel pipe is usually galvanized or dipped in coal-tar enamel and wrapped with coal-tar impregnated felt. At present, however, coal-tar products are undergoing scrutiny from a health standpoint and it is recommended that the appropriate regulatory agencies be contacted prior to use of this material.

Asbestos Cement Pipe (ACP)

This pipe is manufactured from Portland cement, long fibrous asbestos, and silica. It is available in diameters from 3" to 36" and in 13' lengths. Its main advantages are its ability to withstand corrosion and its excellent hydraulic flow characteristics due to its smoothness.

A major disadvantage is that it is brittle and is easily broken during construction or by shock loading. There is some concern regarding the possible release of asbestos fibers in corrosive water and there has been much debate over the health effects of ingested asbestos. Of greater certainty, however, is the danger posed by inhalation of asbestos fibers. Asbestos is considered a hazardous material, and precautionary measures must be taken to protect water utility workers when cutting, tapping, or otherwise handling this type of pipe.

Galvanized Pipe

Galvanized pipe is commonly used for the water distributing pipes inside a building to supply hot and cold water to the fixtures. This type of pipe is manufactured in 21-ft lengths. *It is **GALVANIZED** (coated with zinc) both inside and outside at the factory to resist corrosion. Pipe sizes are based on nominal INSIDE diameters. Inside diameters vary with the thickness of the pipe. Outside diameters remain constant so that pipe can be threaded for standard fittings.

Copper
Copper is one of the most widely used materials for tubing. This is because it does not rust and is highly resistant to any accumulation of scale particles in the pipe. This tubing is available in three different types:

K, L, and M.
K has the thickest walls, and M, the thinnest walls, with L's thickness in between the other two. The thin walls of copper tubing are soldered to copper fittings. Soldering allows all the tubing and fittings to be set in place before the joints are finished. Generally, faster installation will be the result. Type K copper tubing is available in either rigid (hard temper) or flexible (soft temper) and is primarily used for underground service in the water distribution systems.

Joints and Fittings
Fittings vary according to the type of piping material used. The major types commonly used in water service include elbows, tees, unions, couplings, caps, plugs, nipples, reducers, and adapters. Besides bell-and-spigot joints, cast-iron water pipes and fittings are made with either flanged, mechanical, or screwed joints. The screwed joints are used only on small-diameter pipe.

Tapping Sleeve

*A Gate Valve (shown above) is used to isolate sections of water mains. Not to be used to throttle or regulate the flow.

*A Globe valve should be used to regulate the flow.

Be sure to chlorinate or disinfect all distribution parts such as valves and piping!

Caps
A pipe cap is a fitting with a female (inside) thread. It is used like a plug, except that the pipe cap screws on the male thread of a pipe or nipple.

Couplings

The three common types of couplings are straight coupling, reducer, and eccentric reducer. The **STRAIGHT COUPLING** is for joining two lengths of pipe in a straight run that do not require additional fittings. A run is that portion of a pipe or fitting continuing in a straight line in the direction of flow.

A **REDUCER** is used to join two pipes of different sizes. The **ECCENTRIC REDUCER** (also called a **BELL REDUCER**) has two female (inside) threads of different sizes with centers so designed that when they are joined, the two pieces of pipe will not be in line with each other, but they can be installed to provide optimum drainage of the line.

Elbows (OR ELLS) 90° AND 45°
These fittings (fig. 8-5, close to middle of figure) are used to change the direction of the pipe either 90 or 45 degrees. **REGULAR** elbows have female threads at both outlets. **STREET** elbows change the direction of a pipe in a closed space where it would be impossible or impractical to use an elbow and nipple.

Nipples
A nipple is a short length of pipe (12 in. or less) with a male thread on each end. It is used for extension from a fitting. At times, you may use the **DIELECTRIC** or **INSULATING TYPE** of fittings. These fittings connect underground tanks or hot-water tanks. They are also used with pipes of dissimilar metals. These help slow down corrosion that starts inside the pipe and works to the outside of the pipe. Do not heat or solder dielectric fittings; you may melt the plastic coating on them.

*Zinc is a coating on the outside and inside of pipes to slow corrosion. This process is called **"Galvanization".**

Tees
A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs. A common type of pipe tee is the **STRAIGHT** tee, which has a straight-through portion and a 90-degree takeoff on one side.

All three openings of the straight tee are of the same size. Another common type is the **REDUCING** tee, similar to the straight tee just described, except that one of the threaded openings is of a different size than the other.

Unions
There are two types of pipe unions. The **GROUND JOINT UNION** consists of three pieces, and the **FLANGE UNION** is made in two parts. Both types are used for joining two pipes together and are designed so that they can be disconnected easily. When joined, the two pieces of pipe will not be in line with each other, but they can be installed to provide optimum drainage of the line.

Water Main Installation

Installation of new or replacement pipe sections should be in accordance with good construction practices. The line must be buried a minimum of 30" below the ground surface to prevent freezing. The line must be bedded and backfilled properly insuring protection from weather and surface loadings.

*Also, thrust blocking (***Kickers***) at all bends, tees, and valves is essential to hold the pipe in place and prevent separation of line sections. Thrust blocking is not necessary if the pipe is welded.

*Disinfection of new installations or repaired sections is required prior to placing them in service. This can be accomplished by filling the line with a 25 mg/1 free chlorine solution and allowing it to stand for 24 hours. Valves and fittings used in the waterworks industry are made of cast iron, steel, brass, stainless, and fiberglass.

*Enough gate valves should be placed throughout the system to enable problem areas (leaks, etc.) to be isolated and repaired with minimal service disruption.

*Air relief valves should be installed at high points in the system. Valves should be installed with valve boxes and covers.

Regardless of the type of pipe installed, certain maintenance routines should be performed on the distribution system to maintain water quality and optimal service. These programs should be scheduled and performed on a regular basis.

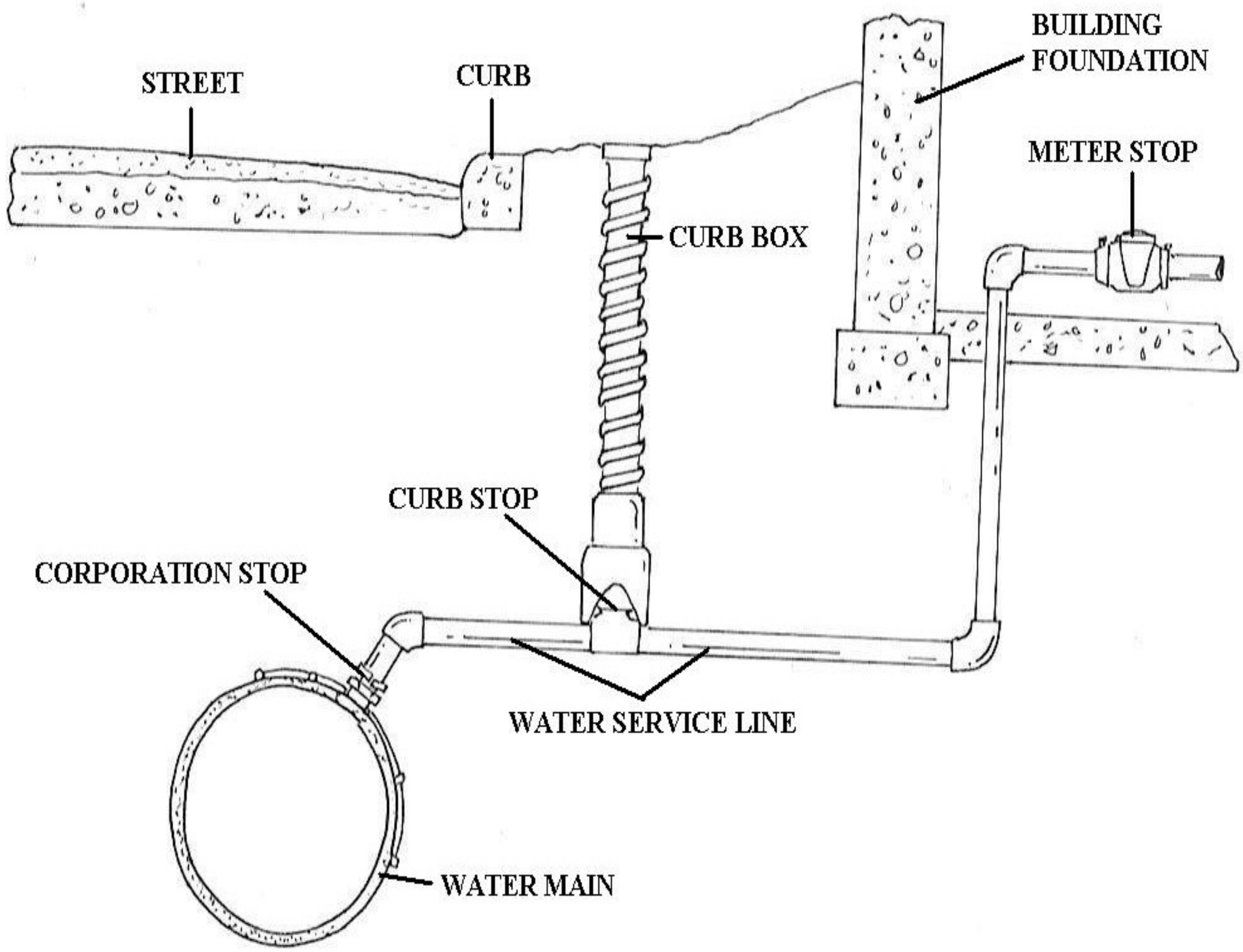
Flushing at blowoffs on dead end lines and at fire hydrants throughout the system should be done at least twice per year. Flushing is needed to remove stagnant water in dead ends and to remove accumulated sediment that results from turbidity, iron, manganese, etc.

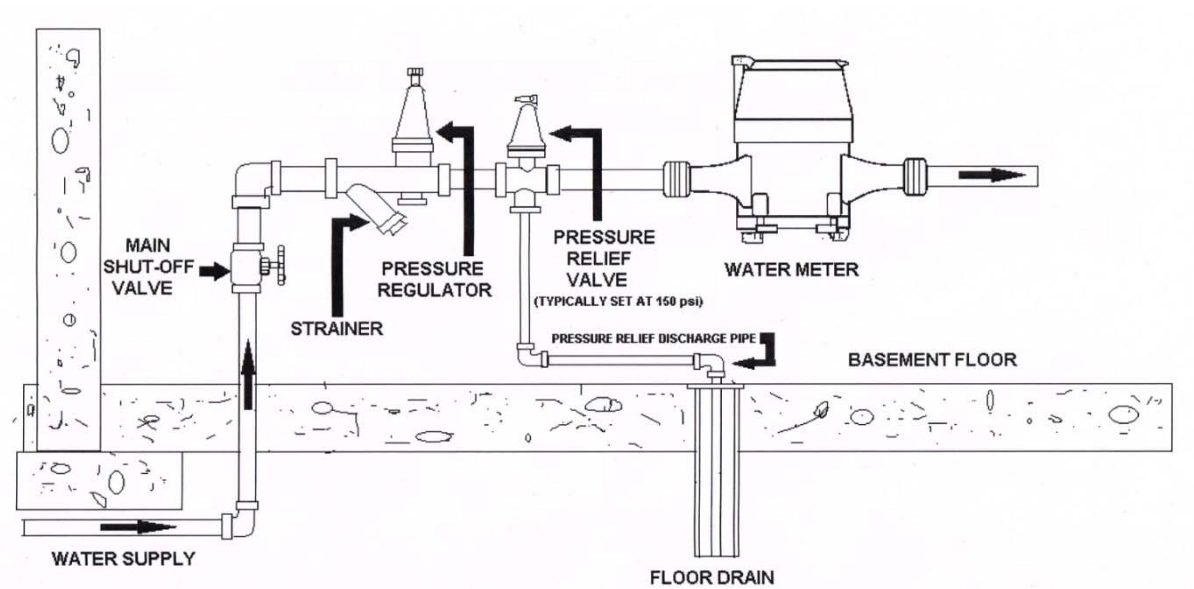
*This should also help minimize customer complaints of water quality. Flushing should always be done from the source to the ends of the system. Affected customers should be notified of this process in advance. To do an adequate job of flushing, the flow should reach a velocity of at least 2.5 feet per second, known as the “minimum cleansing velocity” of the system (at hydrant locations).

These tests are important to determine the adequacy of the distribution system in transmitting water, particularly during days of peak demand. Also, these tests can help determine if pipe capacity is decreasing over time due to internal corrosion or deposits.

Pressure tests should be done at various locations in the distribution system several times per year.

This helps to monitor the performance of the system and alert the operator to problems such as leaks or internal deposits. It is sometimes advantageous to have certain points in the system continuously monitored to provide a constant evaluation of the system.


STREET
CURB
BUILDING
FOUNDATION
METER STOP
CURB BOX
CURB STOP
CORPORATION STOP
WATER SERVICE LINE
WATER MAIN


MAIN
SHUT-OFF
VALVE
STRAINER
PRESSURE
REGULATOR
PRESSURE
RELIEF
VALVE
(TYPICALLY SET AT 150 psi)
WATER METER
PRESSURE RELIEF DISCHARGE PIPE
BASEMENT FLOOR
WATER SUPPLY
FLOOR DRAIN

Distribution and Storage Summary ***Study and memorize these statements.***

Storage Tanks
Safe entry into a confined space requires that all entrants wear a harness and safety line. If an operator is working inside a storage tank and suddenly faints or has a serious problem, there should be two people outside standing by to remove the injured operator.

Climbing safety devices are commonly used on fixed ladders.

During an inspection of your water storage facility, you should inspect the Cathodic protection system including checking the anode's condition and the connections.

Three types of water usage that determines the volume of a storage tank are fire suppression storage, equalization storage, and emergency storage.

Equalization storage is the volume of water needed to supply the system for periods when demand exceeds supply. Generally, a water storage tank's interior coating (paint) protects the interior about 3-5 years.

Standpipes (Storage tanks) should not be located in at a low point in the system, a bottom of a hill.

The concentration of polyphosphates that is used for corrosion control in storage tanks is typically 5 mg/L or less.

External corrosion of steel water storage facilities can be reduced with zinc or aluminum coatings.

All storage facilities should be regularly sampled to determine the quality of water that enters and leaves the facility. One tool or piece of measuring equipment is the Jackson turbidimeter, which is a method to measure cloudiness in water.

The effects of water freezing in storage tanks can be minimized by alternating water levels in the tank. There are 3 types of ice found: sheet, anchor and frazil.

The venting of air is not a major concern when checking water levels in a storage tank.

If an overflow occurs on a storage tank, the operator should first check the altitude-control valve.

Altitude-Control Valve is designed to, 1. Prevent overflows from the storage tank or reservoir, or 2. Maintain a constant water level as long as water pressure in the distribution system is adequate.

The following are common pressure sensing devices: Helical Sensor, Bourdon Tube, and Bellows Sensor.

The most frequent problem that affects a liquid pressure-sensing device is air accumulation at the sensor.

A diaphragm element being used as a level sensor would be used in conjunction with a pressure sensor.

The Strain Gauge is a common measuring device used for a variety of changes such as head. As the pressure in the system changes, the diaphragm expands which changes the length of the wire attached. This change of length of the wire changes the Resistance of the wire, which is then converted to head.

Float mechanisms, diaphragm elements, bubbler tubes, and direct electronic sensors are common types of level sensors.

Distribution system water quality can be adversely affected by improperly constructed or poorly located blowoffs of vacuum/air relief valves. Air relief valves in the distribution system lines must be placed in locations that cannot be flooded. This is to prevent water contamination. The common customer complaint of Milky Water is sometimes solved by the installation of these air relief valves.

When the superintendent is inspecting the plans for a new ground water storage tank, the superintendent should pay attention to the outlet and inlet and be sure that they are on opposite sides of the tank.

Surge tanks are used to control Water Hammer.

A limitation of hydropneumatic tanks is that they do not provide much storage to meet peak demands during power outages and you have very limited time to do repairs on equipment.

The maximum momentary load placed on a water treatment plant, pumping station or distribution system is the Peak Demand.

General & Safety Information ***Memorize***

One of the roles of a distribution system supervisor is to inform the operators of SOPs concerning public relations. This can be accomplished by regular informational staff meetings.

Sprains and strains are the most frequent type of accident(s) encountered by water distribution personnel.

Right to Know Laws state that the employer has the responsibility to provide the employees with information about health hazards and chemical handling.

Uniforms and proper credentials aid meter readers and operators that work close to private property because they help readily identify personnel.

The Building Inspector is responsible for the enforcement of building regulations.

For a dead-end line of over 2,000 feet, the design criteria would dictate a minimum pipe diameter of 8 inches.

Backflow

Any equipment that utilizes water for cooling, lubrication, washing or as a solvent is always susceptible to Cross-connections.

When installing a vacuum breaker backflow device, the operator must make sure that it is 12 inches above the highest discharge outlet. A double check will stop backsiphonage and backpressure of low contamination threats.

The relief valve will open and drain if a pressure differential occurs between the two checks; this best describes the operation of a reduced pressure principal backflow assembly device.

The water utility has the responsibility for insuring that water contamination due to cross connections does not occur.

Pesticide mixing tanks have one of the greatest potential hazards of contamination if a cross connection occurs.

The most likely consequence if a backsiphonage condition causes a cross connection and pressure is then restored to the system is that the distribution system downstream of the cross connection will be contaminated.

An operator can place a screen before a backflow prevention assembly to prevent debris from fouling the assembly.

Cross-Connection: Physical connection between potable and any other source.

Backsiphonage is backflow caused by a negative pressure (i.e., a vacuum or partial vacuum) in a public water system or consumer's potable water system. The effect is similar to drinking water through a straw.

Backpressure : Is a form of backflow caused by a downstream pressure that is greater than the upstream or supply pressure in a public water system or consumer's potable water system.

General Information ***It is good to study the glossary too.***
Chlorine gas is easily detected because of the smell, but can also cause olfactory fatigue, which makes Chlorine gas deadly. Olfactory fatigue means that you lose the ability to smell the odor.

When bumping slip joint pipe, the operator should use a recommended lubricant. Bacterial growth could occur if the wrong lubricant is used.

Negative pressure in parts of the system may occur during periods of high flow or a fire when the waterline's pressure has dropped drastically.

If the desired result of cleaning large pipes is to remove slime and light scale without disturbing heavier encrustation, the best choice for cleaning would be a *Pig.*

Review the Chlorine practice exam too.
Water audits can be performed in order to account for the water in the system. A 24-hour measure of all the water entering the system should be the first step in a water audit.

When you are shutting a large valve, a bypass valve will reduce high pressure that can be present.

If the pH of water from a dead-end line begins to drop, it is most likely an indication that anaerobic conditions are present.

The Hazen-Williams formula is used to determine pipe size.

Thrust Control
Surge tanks are used to control water hammer.

Thrust blocks are commonly known as kickers, not on the test but many of you do not know what is being talked about.

You do not need to use thrust blocks (on exam) if you weld the pipe or use restraining or mechanical joints with restraining lugs.

If a thrust block of another utility is discovered in your path while excavating, you should not alter the existing thrust block in any way.

Maps
Comprehensive maps provide an overall view of the system.

The preferred scale is 500 feet per inch.

Sectional maps show various sections of the comprehensive map in more detail.

Valve and hydrant maps will show valve and hydrants and the number of turns to open the valve, model and installation date.

Plan and profile will show the depth, pipe location and location of both vertically and horizontally.

A Valve Intersection Map or Valve and Hydrant Map would most likely indicate specific information such as the number of turns necessary to open or close a valve.

Motor Statements, Memorize each statement.

Biggest Killer of Electric Motors;
Thermal Overload, usually the number one answer.
Improper Lubrication and Voltage Imbalance will kill a motor.
You can air lock a pump, but not a motor. Cold weather is also not a negative factor in running a motor.

If the overload control on a motor has tripped and the motor has stopped running. An operator should wait for the overload to cool, then try to start the motor again. If the motor does not start, the operator should first check the fuse. Always check equipment before resetting. Always use a time delay fuse.

A Megger is an electrical device used to test the insulation resistance value on a motor or any electrical equipment.

One possible cause for a mechanical noise coming from a motor is an unbalance of the rotating mechanical parts.

One possible result of over greasing a bearing is that it will create extreme friction in the bearing chamber.

If grease comes in contact with the winding of a motor, the winding insulation may deteriorate. Always replace brushes and contacts as a set.

Motors are sized by Amperes or Amps. If a motor is rated for 10 amps the overload protection that should be used is a 10 to 11 amps fuse. 10 percent or also written as .10

Hertz is the term is used to describe the frequency of cycles in an alternating current (AC) circuit. If the motor has 60 Hertz, the maximum speed will be 3600 RPM.

Pump Statements
Cavitation can be caused by a suction line that is clogged or is above the water line.

Centrifugal pumps do not generate suction unless the impeller is submerged in water. If a pump is located above the level of water, a foot valve or check valve must be provided on the suction piping to hold the prime. One disadvantage of a centrifugal pump is that it is not self-priming.

Double suction means water enters from two sides of the impeller casing.

The main purpose of the wear rings in a centrifugal double suction pump is that the wear rings maintain a flow restriction between the impeller discharge and suction areas.

With most lubricants, the viscosity decreases as the temperature increases.

Two pumps of the same size can be operated alternately to equalize wear and distribute lubricant in bearings.

A key and a tight fit is the common method used to secure an impeller to the shaft on double-suction pump.

An Axial Flow pump is also known as a Propeller Pump.

Never run a positive displacement, reciprocating pump or piston pump with the discharge closed.

A Screw Pump always needs to have the screw submersed in liquid in order to work.

As you add stages to a pump, this only increases the pressure, never the volume.

Stuffing Box
That portion of the pump that houses the packing or mechanical seal.

Packing Gland
Very easy to work on and inexpensive, but will leak water. It will leak approximately 20-60 drops per minute.

A possible cause of a scored shaft sleeve is that the packing has broken down or the packing has been over tightened.

Mechanical Seal
A mechanical seal is the best seal to use for a pump operating under high suction head conditions.

Very expensive and difficult to replace.

Should never leak unless there is an abnormal operating condition.

Should last about 5,000 to 20,000 operating hours.

Held in place with spring tension.
Continuous leakage from a mechanical seal on a pump indicates that the mechanical seal needs to be replaced.

Sometimes mechanical seals require cooling water to the seal faces. Use filtered effluent or tap water.

Please review this section and the pump assignment before your exam. So many people fail because they do not take the time to study.

Fire Hydrant Information. Always use a non-rising stem gate valve if you need to use water through a steamer or meter. If the fire hydrant is painted, Blue-1500 GPM or more, Green - 1000-1499 GPM. Dry barrel hydrants are for areas that might freeze.

C-Factor Carrying Capacity of Pipe
The smoother the pipe the greater the C-Factor. Steel pipe has poorest C-Factor.

Remember to review the safety subjects and trenching too.

SCADA
This is a remote method of monitoring pumps and equipment. 130 degrees F is the maximum temperature that transmitting equipment is able to withstand. If the level controller is set with too close a tolerance, frequent turning on and off of a pump could be the cause of a control system. When a pump receives a signal to start, a light will typically be illuminated on the control panel indicating that the pump is running. In order to be sure that the pump is actually pumping water, a positive flow report-back signal should be installed on the control panel.

Telemetering systems must often transmit more than one signal. You can use several types of systems including: Polling, Scanning and Multiplexing.

Valves
The four most common categories of valves encountered in the water distribution system are the slide (linear), rotary, globe, and diaphragm valves.

Rotary and Linear
Only one linear or slide valve, this is the **Gate Valve**. It is used for main line isolation. Never regulate flow with a gate valve and always store this valve in the open position.

Rotary
Globe, used for flow regulation.
Butterfly, full bore opening, operates on a spindle.
Ball, fully on or fully off.

Other Valves
Insertion, valve used to obtain a shutdown on a hot main.
PRV, pressure regulating, rubber diagram.
Bypass can be used to prevent a water hammer.
Corp, service line regulation.

An Insertion Valve (Hydrostop) is used in the water distribution system to isolate sections of mains to permit the making of emergency repairs to be made without interruption of service to a large number of customers, it is a valve used when you are unable to obtain a shut down. The most commonly used valve for isolation is the **Gate valve**.

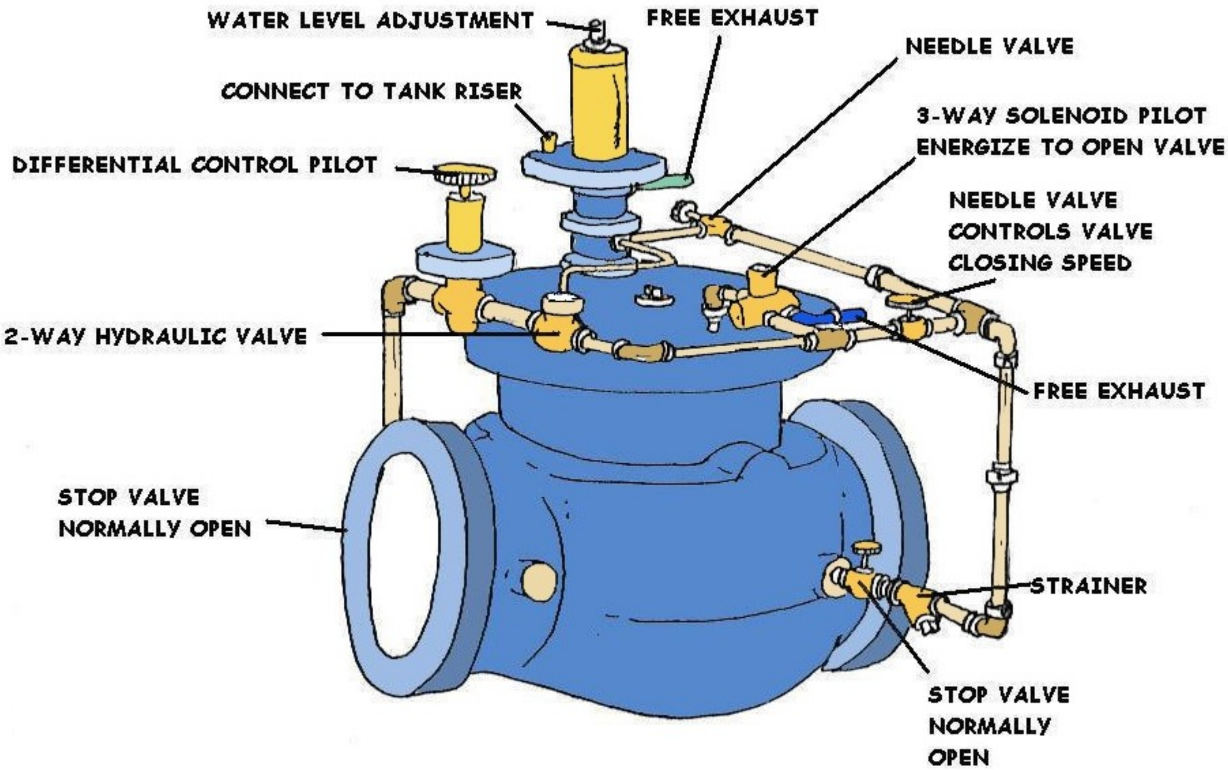
Pressure **R**egulation **V**alves control water pressure and operate by restricting flows. They are used to deliver water from a high pressure to a low-pressure system. The pressure downstream from the valve regulates the amount of flow. Usually, these valves are of the globe design and have a spring-loaded diaphragm that sets the size of the opening.

Backsiphonage is a condition in which the pressure in the distribution system is less than atmospheric pressure. In other words, something is *"sucked"* into the system because the main is under a vacuum.

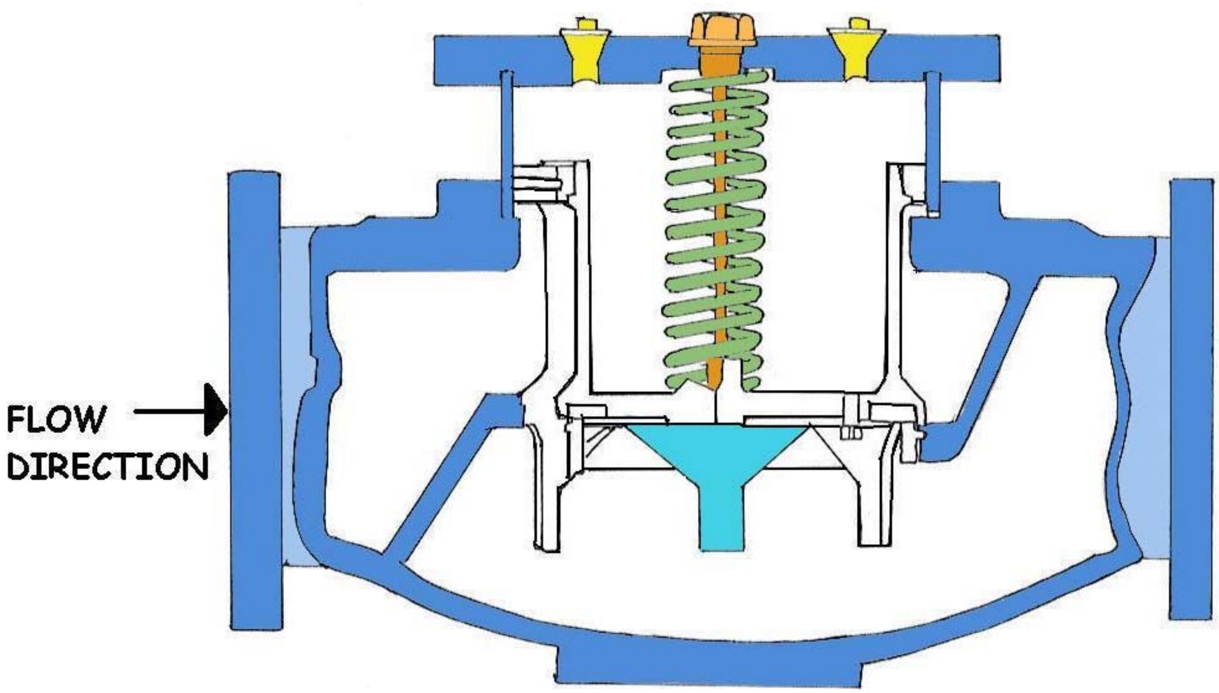
Meters
Three classifications of meters, **Velocity, Displacement and Compound**. The most common Displacement meter is the **Nutating disk**. Compound meters are advantageous for places where there are predominantly low or intermediate flows, only occasionally, high flows.

Inspection of magnetic flow meter instrumentation should include checking for corrosion or insulation deterioration.

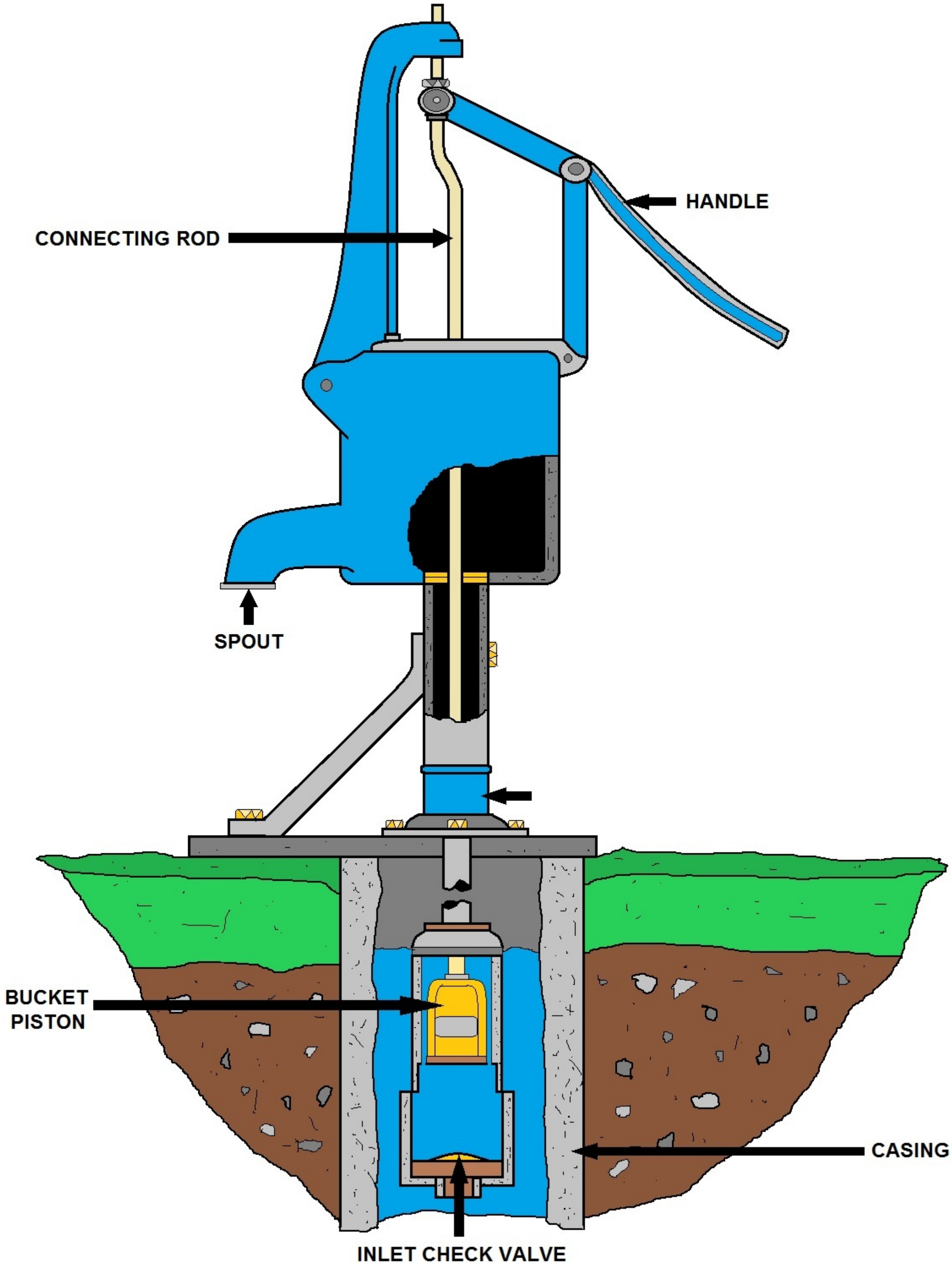
Always replace the caps on a water meter when replacing it. The only negative effect of a meter is head loss. Displacement meters are used to measure flows in lines.

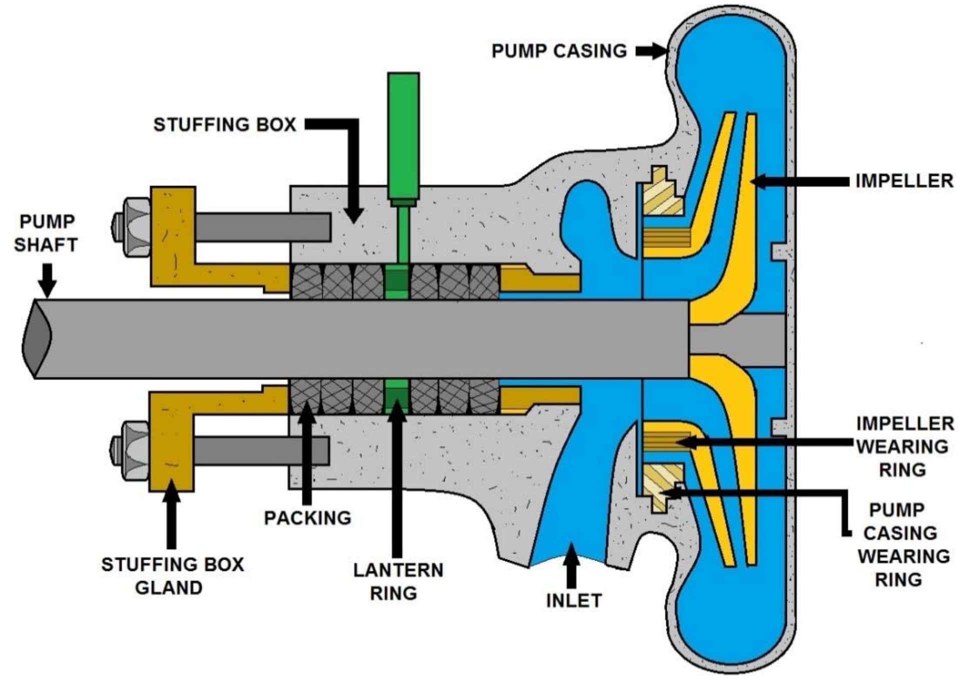


ALTITUDE CONTROL VALVE



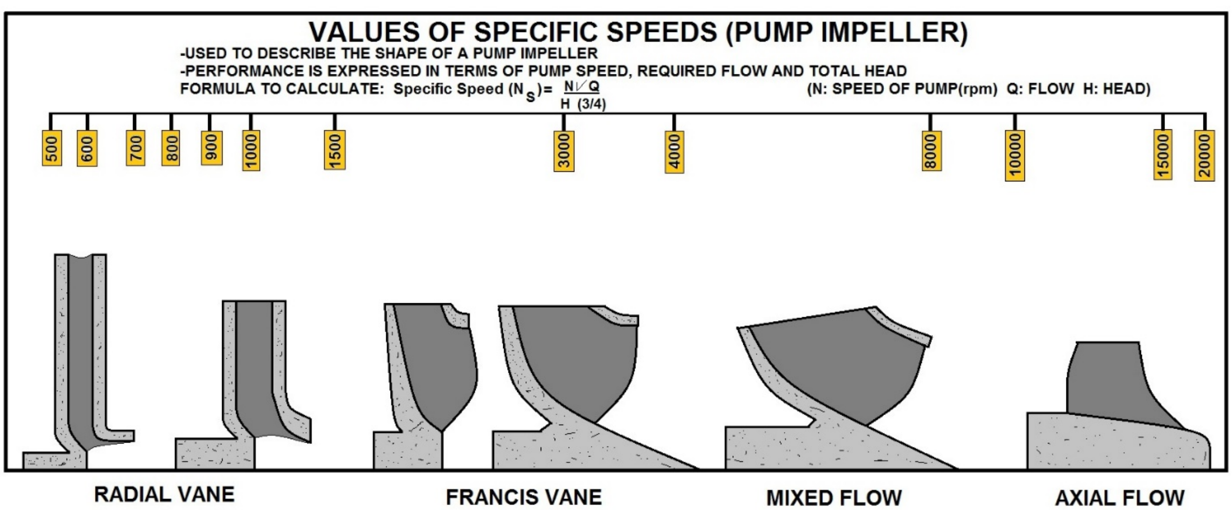
FLANGED GLOBE STYLE PRESSURE REDUCING VALVE


CONNECTING ROD
HANDLE
SPOUT
BUCKET
PISTON
CASING
INLET CHECK VALVE



CENTRIFUGAL PUMP PARTS

A centrifugal pump has two main components:
I. A rotating component comprised of an impeller and a shaft
II. A stationary component comprised of a casing, casing cover, and bearings.



SPECIFIC SPEED

Common Hydraulic Terms

Head
The height of a column or body of fluid above a given point expressed in linear units. Head is often used to indicate gauge pressure. Pressure is equal to the height times the density of the liquid.

Head, Friction
The head required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type, and conditions of conductors and fittings, and the fluid characteristics.

Head, static
The height of a column or body of fluid above a given point.

Hydraulics
Engineering science pertaining to liquid pressure and flow.

Hydrokinetics
Engineering science pertaining to the energy of liquid flow and pressure.

Pascal's Law
A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

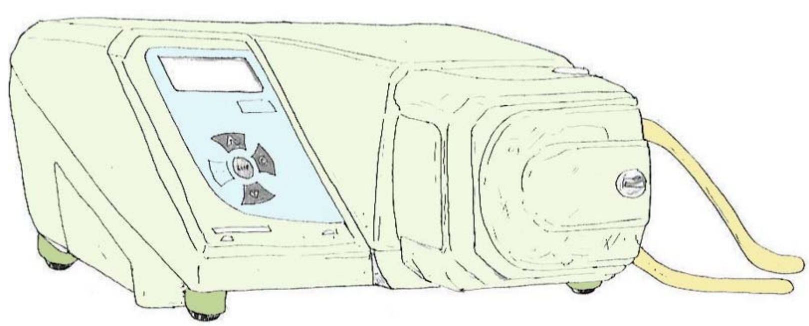
Pressure
The application of continuous force by one body upon another that it is touching; compression. Force per unit area, usually expressed in pounds per square inch (Pascal or bar).

Pressure, Absolute
The pressure above zone absolute, i.e. the sum of atmospheric and gauge pressure. In vacuum related work it is usually expressed in millimeters of mercury. (mmHg).

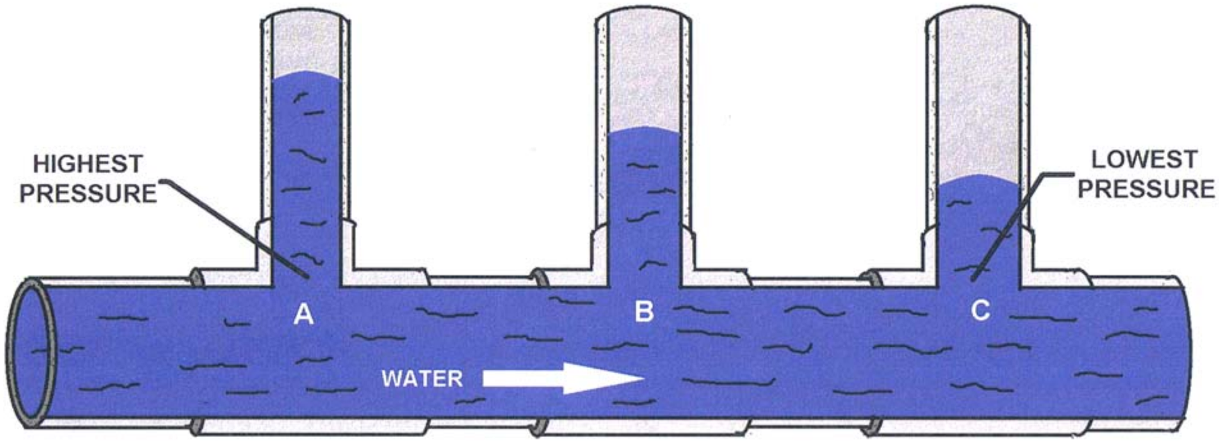
Pressure, Atmospheric
Pressure exported by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute, 1 bar = 14.5psi.)

Pressure, Gauge
Pressure differential above or below ambient atmospheric pressure.

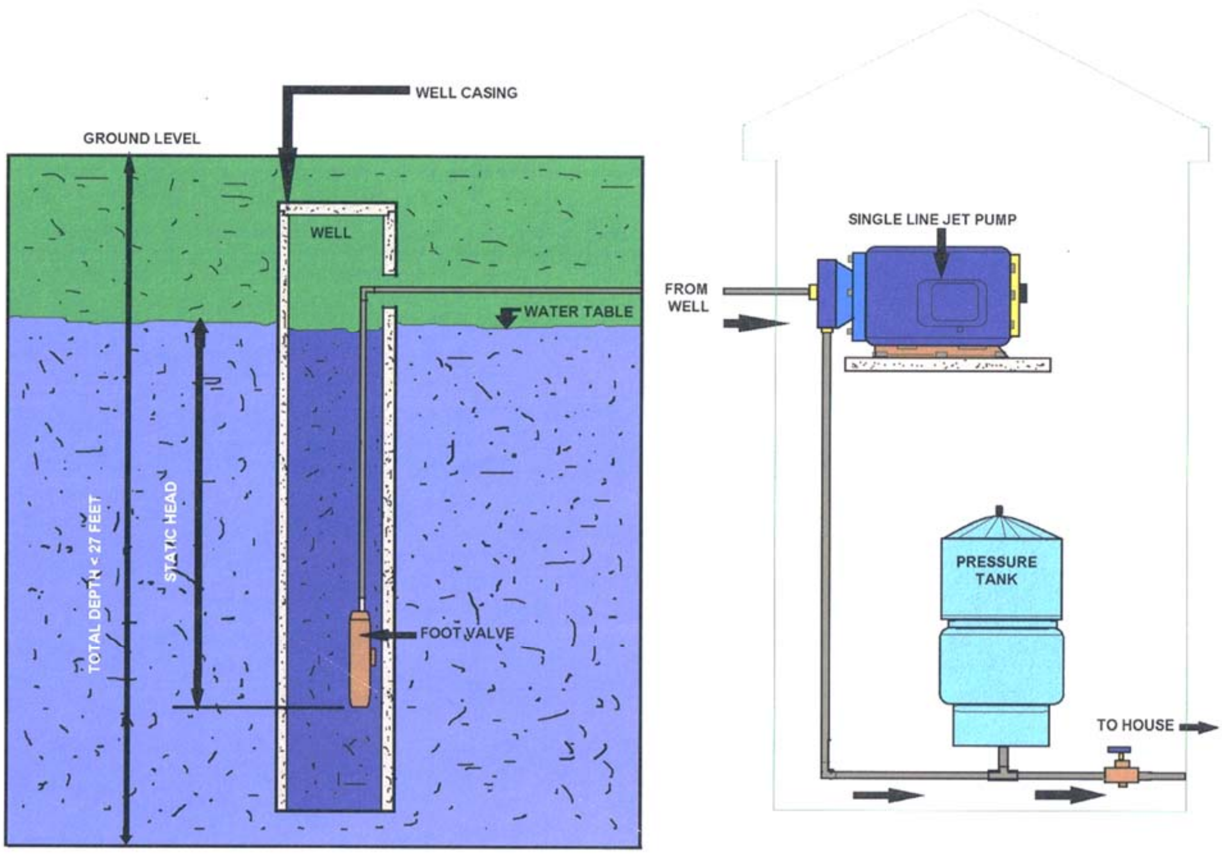
Pressure, Static
The pressure in a fluid at rest.



PERISTALTIC PUMP



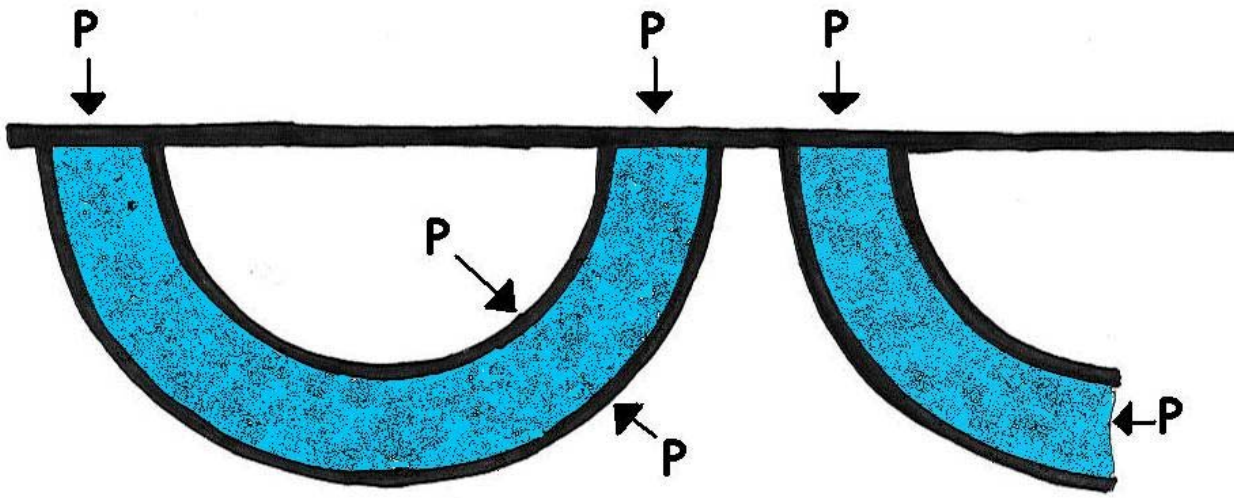
WATER FLOWS FROM HIGHEST PRESSURE ZONE TO LOW ZONE
Pressure at A > Pressure at B > Pressure at C.



SHALLOW WELL WITH SINGLE-LINE JET PUMP
(SUITABLE FOR SHALLOW WELLS LESS THAN 27 FEET DEEP)

Pressure

By a fluid, we have a material in mind like water or air, two very common and important fluids. Water is incompressible, while air is very compressible, but both are fluids. Water has a definite volume; air does not. Water and air have low viscosity; that is, layers of them slide very easily on one another, and they quickly assume their permanent shapes when disturbed by rapid flows. Other fluids, such as molasses, may have high viscosity and take a long time to come to equilibrium, but they are no less fluids. The coefficient of viscosity is the ratio of the shearing force to the velocity gradient. Hydrostatics deals with permanent, time-independent states of fluids, so viscosity does not appear, except as discussed in the Introduction.



EQUALITY OF PRESSURE

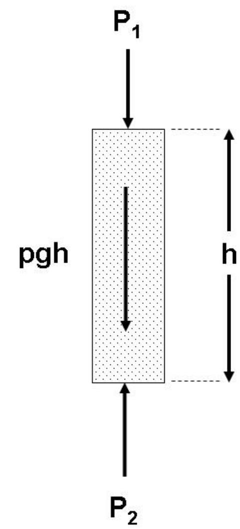
A fluid, therefore, is a substance that cannot exert any permanent forces tangential to a boundary. Any force that it exerts on a boundary must be normal to the boundary. Such a force is proportional to the area on which it is exerted, and is called a pressure.

We can imagine any surface in a fluid as dividing the fluid into parts pressing on each other, as if it were a thin material membrane, and so think of the pressure at any point in the fluid, not just at the boundaries. In order for any small element of the fluid to be in equilibrium, the pressure must be the same in all directions (or the element would move in the direction of least pressure), and if no other forces are acting on the body of the fluid, the pressure must be the same at all neighboring points.

Therefore, in this case the pressure will be the same throughout the fluid, and the same in any direction at a point (Pascal's Principle). Pressure is expressed in units of force per unit area such as dyne/cm^2, N/cm^2 (pascal), pounds/in^2 (psi) or pounds/ft^2 (psf). The axiom that if a certain volume of fluid were somehow made solid, the equilibrium of forces would not be disturbed, is useful in reasoning about forces in fluids.

On earth, fluids are also subject to the force of gravity, which acts vertically downward, and has a magnitude γ = ρg per unit volume, where g is the acceleration of gravity, approximately 981 cm/s^2 or 32.15 ft/s^2, ρ is the density, the mass per unit volume, expressed in g/cm^3, kg/m^3, or $slug/ft^3$, and γ is the specific weight, measured in lb/in^3, or lb/ft^3 (pcf). Gravitation is an example of a body force that disturbs the equality of pressure in a fluid. The presence of the gravitational body force causes the pressure to increase with depth, according to the equation dp = ρg dh, in order to support the water above. We call this relation the barometric equation, for when this equation is integrated, we find the variation of pressure with height or depth. If the fluid is incompressible, the equation can be integrated at once, and the pressure as a function of depth h is p = ρgh + p0.

Free Surface



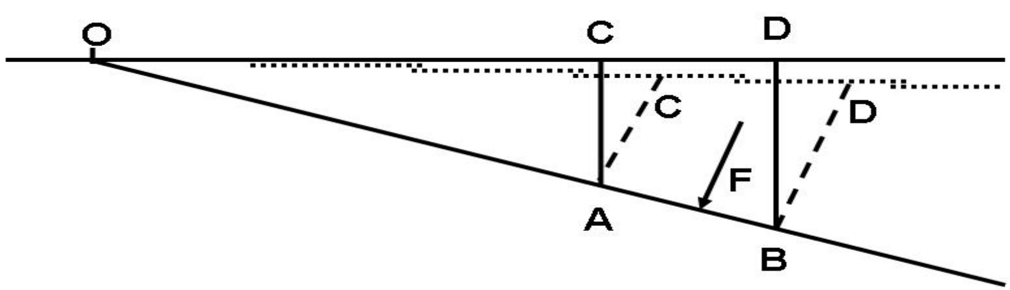
Increase of Pressure with Depth

The density of water is about 1 g/cm^3, or its specific weight is 62.4 pcf. We may ask what depth of water gives the normal sea-level atmospheric pressure of 14.7 psi, or 2117 psf.

This is simply 2117 / 62.4 = 33.9 ft of water. This is the maximum height to which water can be raised by a suction pump, or, more correctly, can be supported by atmospheric pressure. Professor James Thomson (brother of William Thomson, Lord Kelvin) illustrated the equality of pressure by a "curtain-ring" analogy shown in the diagram. A section of the toroid was identified, imagined to be solidified, and its equilibrium was analyzed.

The forces exerted on the curved surfaces have no component along the normal to a plane section, so the pressures at any two points of a plane must be equal, since the fluid represented by the curtain ring was in equilibrium.

The diagram illustrates the equality of pressures in orthogonal directions. This can be extended to any direction whatever, so Pascal's Principle is established. This demonstration is similar to the usual one using a triangular prism and considering the forces on the end and lateral faces separately.



Thrust on a Plane

Pump Definitions *(Larger Glossary in the rear of this manual)*

Fluid: Any substance that can be pumped such as oil, water, refrigerant, or even air.

Gasket: Flat material that is compressed between two flanges to from a seal.

Gland follower: A bushing used to compress the packing in the stuffing box and to control leakoff.

Gland sealing line: A line that directs sealing fluid to the stuffing box.

Horizontal pumps: Pumps in which the Center line of the shaft is horizontal.

Impeller: The part of the pump that increases the speed of the fluid being handled.

Inboard: The end of the pump closest to the motor.

Inter-stage diaphragm: A barrier that separates stages of a multi-stage pump.

Key: A rectangular piece of metal that prevents the impeller from rotating on the shaft.

Keyway: The area on the shaft that accepts the key.

Kinetic energy: Energy associated with motion.

Lantern ring: A metal ring located between rings of packing that distributes gland sealing fluid.

Leak-off: Fluid that leaks from the stuffing box.

Mechanical seal: A mechanical device that seals the pump stuffing box.

Mixed flow pump: A pump that uses both axial-flow and radial-flow components in one impeller.

Multi-stage pumps: Pumps with more than one impeller.

Outboard: The end of the pump farthest from the motor.

Packing: Soft, pliable material that seals the stuffing box.

Positive displacement pumps: Pumps that move fluids by physically displacing the fluid inside the pump.

Radial bearings: Bearings that prevent shaft movement in any direction outward from the center line of the pump.

Radial flow: Flow at 90° to the center line of the shaft.

Retaining nut: A nut that keeps the parts in place.

Rotor: The rotating parts, usually including the impeller, shaft, bearing housings, and all other parts included between the bearing housing and the impeller.

Score: To cause lines, grooves or scratches.

Shaft: A cylindrical bar that transmits power from the driver to the pump impeller.

Shaft sleeve: A replaceable tubular covering on the shaft.

Shroud: The metal covering over the vanes of an impeller.

Slop drain: The drain from the area that collects leak-off from the stuffing box.

Slurry: A thick, viscous fluid, usually containing small particles.

Stages: Impellers in a multi-stage pump.

Stethoscope: A metal device that can amplify and pinpoint pump sounds.

Strainer: A device that retains solid pieces while letting liquids through.

Stuffing box: The area of the pump where the shaft penetrates the casing.

Suction: The place where fluid enters the pump.

Suction eye: The place where fluid enters the pump impeller.

Throat bushing: A bushing at the bottom of the stuffing box that prevents packing from being pushed out of the stuffing box into the suction eye of the impeller.

Thrust: Force, usually along the center line of the pump.

Thrust bearings: Bearings that prevent shaft movement back and forth in the same direction as the center line of the shaft.

Troubleshooting: Locating a problem.

Vanes: The parts of the impeller that push and increase the speed of the fluid in the pump.

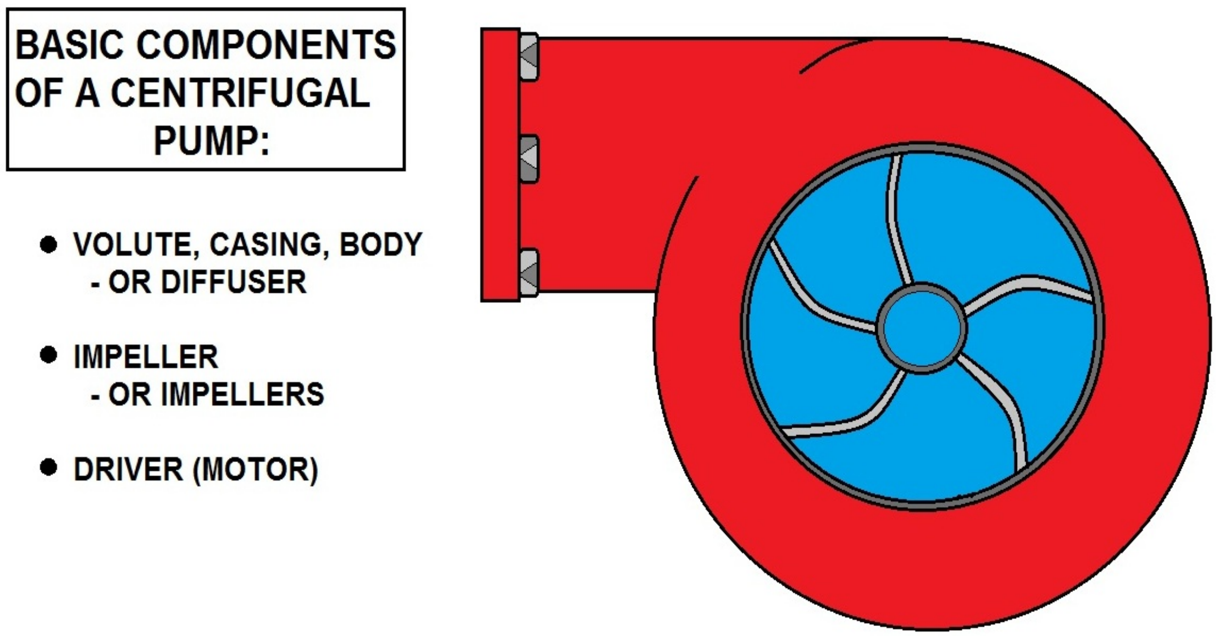
Vertical pumps: Pumps in which the center line of the shaft runs vertically.

Volute: The part of the pump that changes the speed of the fluid into pressure.

Wearing rings: Replaceable rings on the impeller or the casing that wear as the pump operates.

Understanding the Basic Pump

Pumps are used to move or raise fluids. They are not only very useful, but are excellent examples of hydrostatics. Pumps are of two general types, hydrostatic or positive displacement pumps, and pumps depending on dynamic forces, such as centrifugal pumps. Here we will only consider positive displacement pumps, which can be understood purely by hydrostatic considerations. They have a piston (or equivalent) moving in a closely-fitting cylinder and forces are exerted on the fluid by motion of the piston.



BASICS OF A CENTRIFUGAL PUMP

We have already seen an important example of this in the hydraulic lever or hydraulic press, which we have called quasi-static. The simplest pump is the syringe, filled by withdrawing the piston and emptied by pressing it back in, as its port is immersed in the fluid or removed from it.

More complicated pumps have valves allowing them to work repetitively. These are usually check valves that open to allow passage in one direction, and close automatically to prevent reverse flow. There are many kinds of valves, and they are usually the most trouble-prone and complicated part of a pump. The force pump has two check valves in the cylinder, one for supply and the other for delivery. The supply valve opens when the cylinder volume increases, the delivery valve when the cylinder volume decreases.

The lift pump has a supply valve and a valve in the piston that allows the liquid to pass around it when the volume of the cylinder is reduced. The delivery in this case is from the upper part of the cylinder, which the piston does not enter.

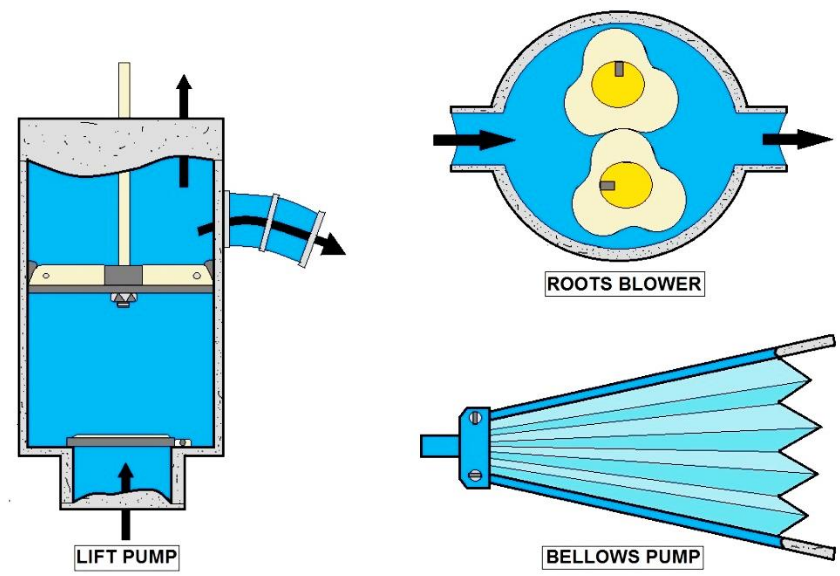
Diaphragm pumps are force pumps in which the oscillating diaphragm takes the place of the piston. The diaphragm may be moved mechanically, or by the pressure of the fluid on one side of the diaphragm.

Some positive displacement pumps are shown below. The force and lift pumps are typically used for water. The force pump has two valves in the cylinder, while the lift pump has one valve in the cylinder and one in the piston. The maximum lift, or "suction," is determined by the atmospheric pressure, and either cylinder must be within this height of the free surface. The force pump, however, can give an arbitrarily large pressure to the discharged fluid, as in the case of a diesel engine injector. A nozzle can be used to convert the pressure to velocity, to produce a jet, as for firefighting. Fire fighting force pumps usually have two cylinders feeding one receiver alternately. The air space in the receiver helps to make the water pressure uniform.

The three pumps below are typically used for air, but would be equally applicable to liquids. The Roots blower has no valves, their place taken by the sliding contact between the rotors and the housing. The Roots blower can either exhaust a receiver or provide air under moderate pressure, in large volumes. The Bellows is a very old device, requiring no accurate machining. The single valve is in one or both sides of the expandable chamber.

Another valve can be placed at the nozzle if required. The valve can be a piece of soft leather held close to holes in the chamber. The bicycle pump uses the valve on the valve stem of the tire or inner tube to hold pressure in the tire. The piston, which is attached to the discharge tube, has a flexible seal that seals when the cylinder is moved to compress the air, but allows air to pass when the movement is reversed.

Diaphragm and vane pumps are not shown, but they act the same way by varying the volume of a chamber, and directing the flow with check valves.



TYPES OF POSITIVE DISPLACEMENT PUMPS

Key Pump Words

NPSH: Net positive suction head - related to how much suction lift a pump can achieve by creating a partial vacuum. Atmospheric pressure then pushes liquid into the pump. A method of calculating if the pump will work or not.

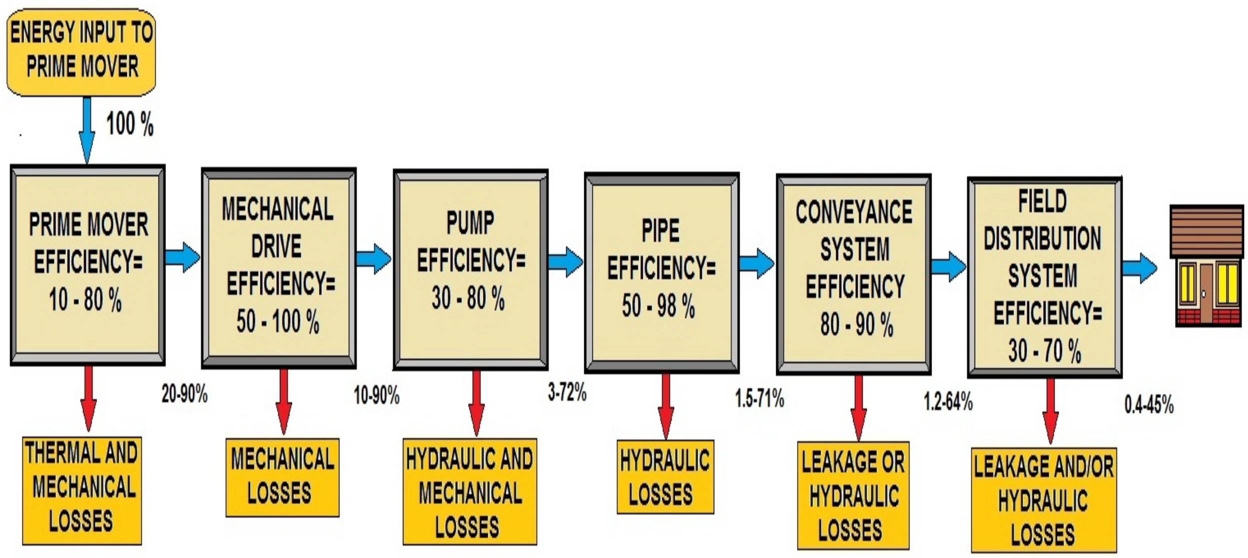
S.G.: Specific gravity. The weight of liquid in comparison to water at approx. 20 deg c (SG = 1).

Specific Speed: A number which is the function of pump flow, head, efficiency etc. Not used in day to day pump selection, but very useful as pumps with similar specific speed will have similar shaped curves, similar efficiency / NPSH / solids handling characteristics.

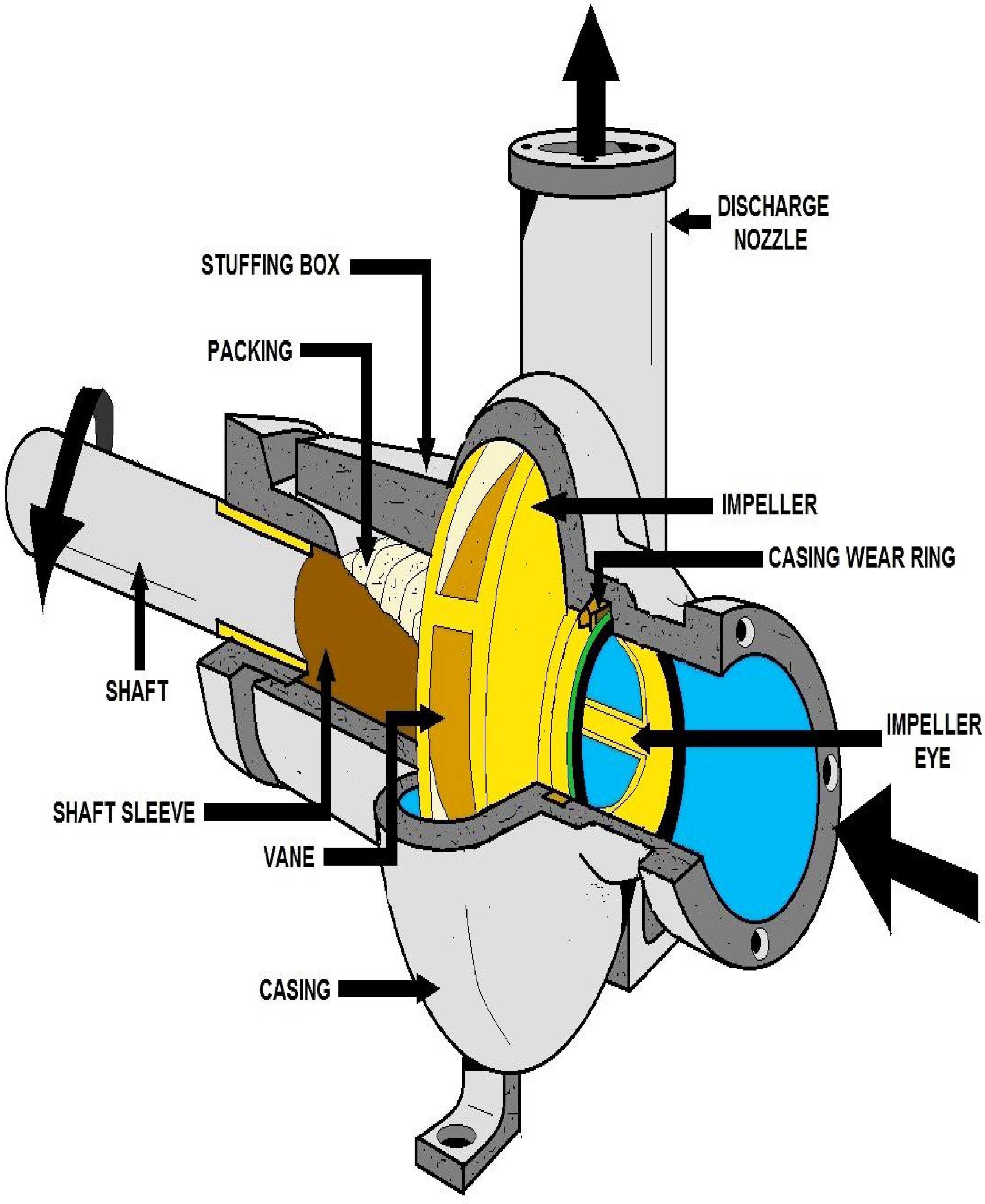
Vapor Pressure: If the vapor pressure of a liquid is greater than the surrounding air pressure, the liquid will boil.

Viscosity: A measure of a liquid's resistance to flow. i.e.: how thick it is. The viscosity determines the type of pump used, the speed it can run at, and with gear pumps, the internal clearances required.

Friction Loss: The amount of pressure / head required to 'force' liquid through pipe and fittings.



PUMPING EFFICIENCY



CENTRIFUGAL PUMP PARTS

Types of Pumps

The family of pumps comprises a large number of types based on application and capabilities. The two major groups of pumps are dynamic and positive displacement.

Dynamic Pumps (Centrifugal Pump)

Centrifugal pumps are classified into three general categories:
Radial flow—a centrifugal pump in which the pressure is developed wholly by centrifugal force.
Mixed flow—a centrifugal pump in which the pressure is developed partly by centrifugal force and partly by the lift of the vanes of the impeller on the liquid.
Axial flow—a centrifugal pump in which the pressure is developed by the propelling or lifting action of the vanes of the impeller on the liquid.

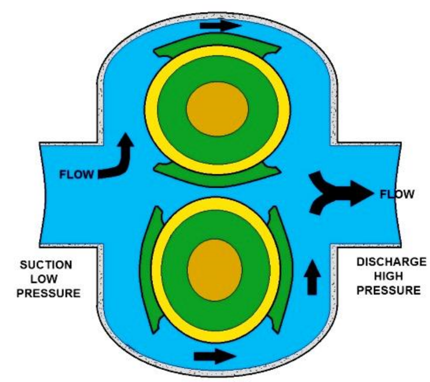
Positive Displacement Pumps

A Positive Displacement Pump has an expanding cavity on the suction side of the pump and a decreasing cavity on the discharge side. Liquid is allowed to flow into the pump as the cavity on the suction side expands and the liquid is forced out of the discharge as the cavity collapses. This principle applies to all types of Positive Displacement Pumps whether the pump is a rotary lobe, gear within a gear, piston, diaphragm, screw, progressing cavity, etc.

A Positive Displacement Pump, unlike a Centrifugal Pump, will produce the same flow at a given RPM no matter what the discharge pressure is. A Positive Displacement Pump cannot be operated against a closed valve on the discharge side of the pump, i.e. it does not have a shut-off head like a Centrifugal Pump does. If a Positive Displacement Pump is allowed to operate against a closed discharge valve it will continue to produce flow which will increase the pressure in the discharge line until either the line bursts or the pump is severely damaged or both.

Types of Positive Displacement Pumps

Single Rotor	Multiple Rotor
Vane	Gear
Piston	Lobe
Flexible Member	Circumferential Piston
Single Screw	Multiple Screw



COMMONLY FOUND POSITIVE DISPLACEMENT PUMP

There are many types of positive displacement pumps. We will look at:
Plunger pumps
Diaphragm pumps
Progressing cavity pumps, and
Screw pumps

Single Rotator

Component	Description
Vane	The vane(s) may be blades, buckets, rollers, or slippers that cooperate with a dam to draw fluid into and out of the pump chamber.
Piston	Fluid is drawn in and out of the pump chamber by a piston(s) reciprocating within a cylinder(s) and operating port valves.
Flexible Member	Pumping and sealing depends on the elasticity of a flexible member(s) that may be a tube, vane, or a liner.
Single Screw	Fluid is carried between rotor screw threads as they mesh with internal threads on the stator.

Multiple Rotator

Component	Description
Gear	Fluid is carried between gear teeth and is expelled by the meshing of the gears that cooperate to provide continuous sealing between the pump inlet and outlet.
Lobe	Fluid is carried between rotor lobes that cooperate to provide continuous sealing between the pump inlet and outlet.
Circumferential piston	Fluid is carried in spaces between piston surfaces not requiring contacts between rotor surfaces.
Multiple Screw	Fluid is carried between rotor screw threads as they mesh.

In the same way, the progressing cavity and the screw are two other types of mechanical action that can be used to provide movement of the liquid through the pump.

Plunger Pump

The plunger pump is a positive displacement pump that uses a plunger or piston to force liquid from the suction side to the discharge side of the pump. It is used for heavy sludge. The movement of the plunger or piston inside the pump creates pressure inside the pump, so you have to be careful that this kind of pump is never operated against any closed discharge valve.

All discharge valves must be open before the pump is started, to prevent any fast build-up of pressure that could damage the pump.

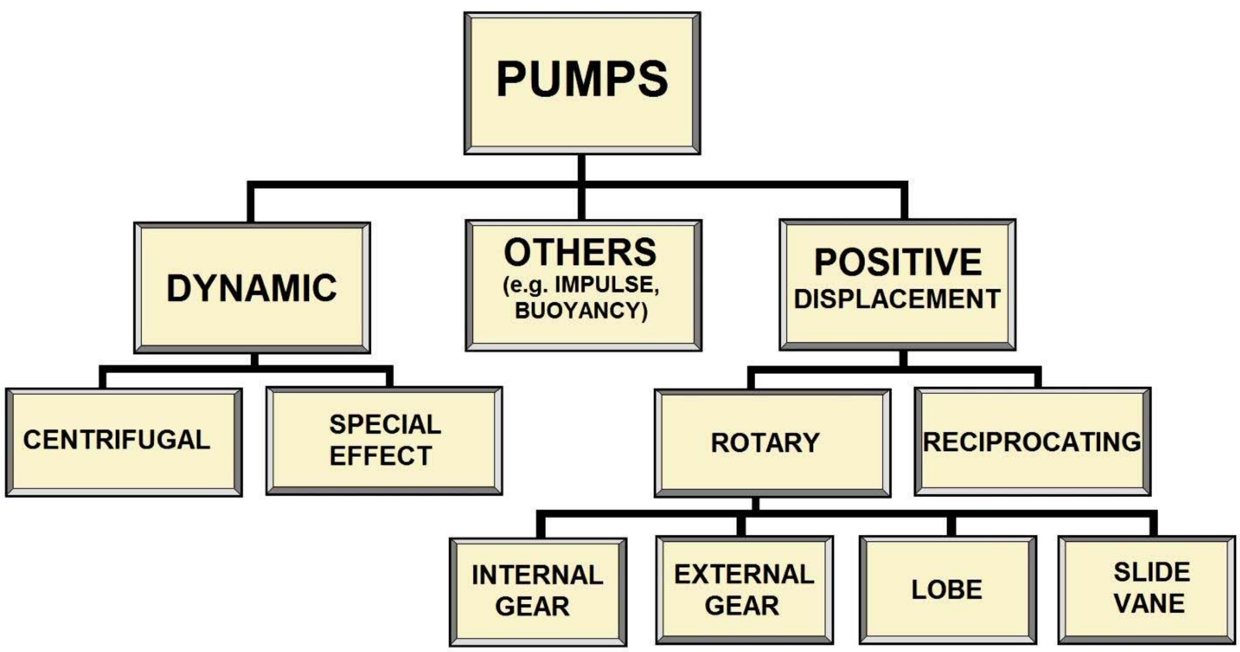
Diaphragm Pumps
In this type of pump, a diaphragm provides the mechanical action used to force liquid from the suction to the discharge side of the pump. The advantage the diaphragm has over the plunger is that the diaphragm pump does not come in contact with moving metal. This can be important when pumping abrasive or corrosive materials.

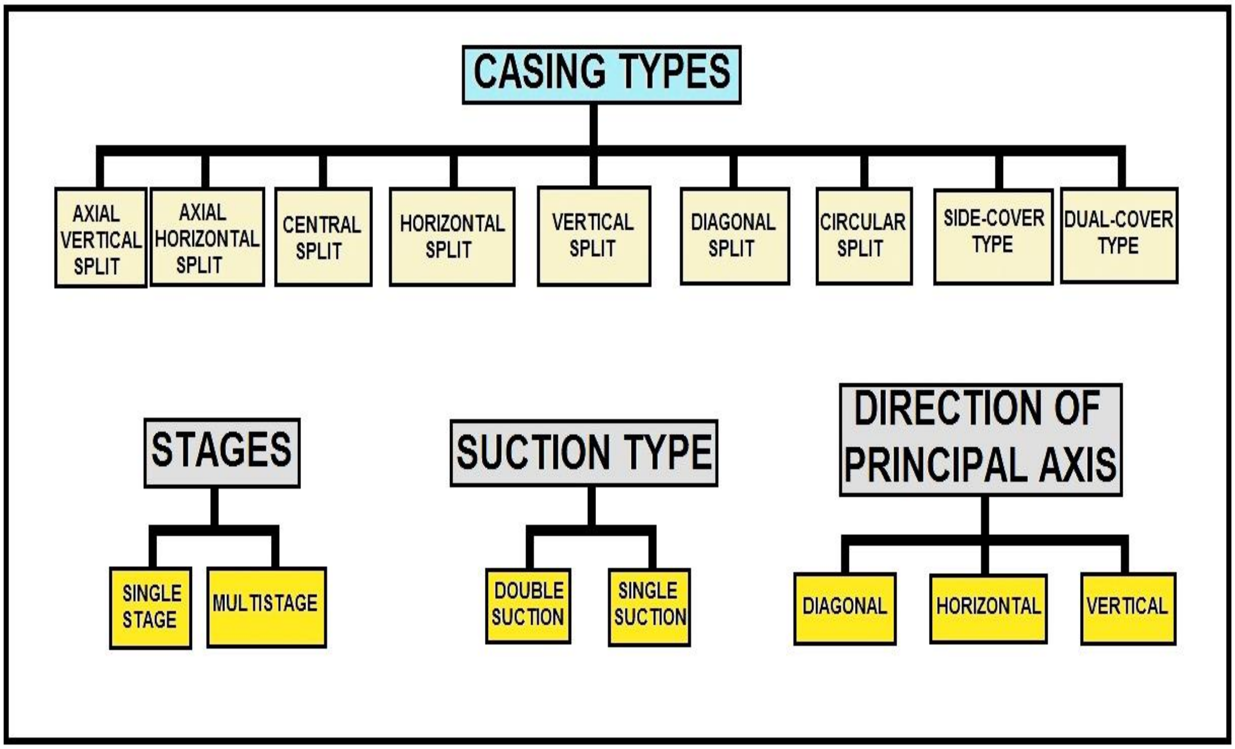
There are three main types of diaphragm pumps available:
1. Diaphragm sludge pump
2. Chemical metering or proportional pump
3. Air-powered double-diaphragm pump

Pump Categories

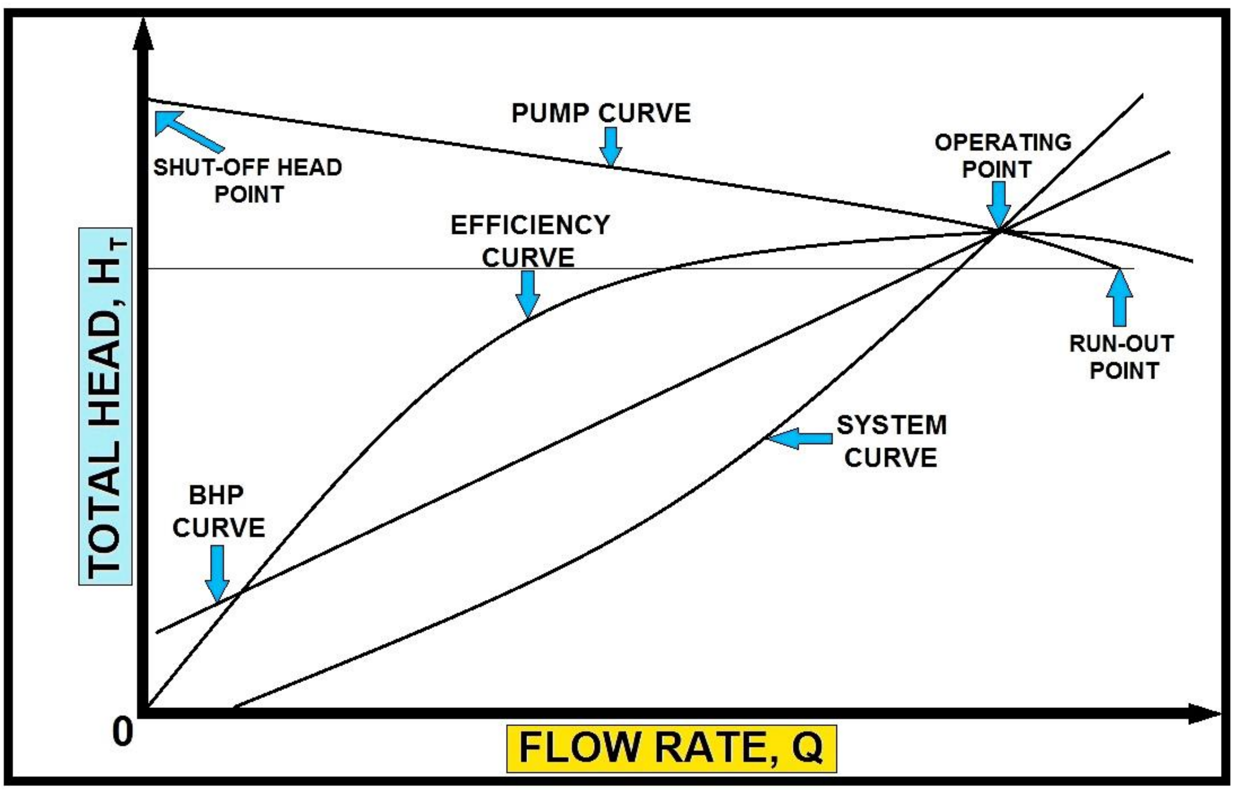
Let's cover the essentials first. The key to the whole operation is, of course, the *pump.* And regardless of what type it is (reciprocating piston, centrifugal, turbine or jet-ejector, for either shallow or deep well applications), its purpose is to move water and generate the delivery force we call pressure. Sometimes — with centrifugal pumps in particular — pressure is not referred to in pounds per square inch but rather as the equivalent in elevation, called head. No matter; head in feet divided by 2.31 equals pressure, so it's simple enough to establish a common figure.

Pumps may be classified on the basis of the application they serve. All pumps may be divided into two major categories: (1) dynamic, in which energy is continuously added to increase the fluid velocities within the machine, and (2) displacement, in which the energy is periodically added by application of force.





PUMP CONFIGURATIONS

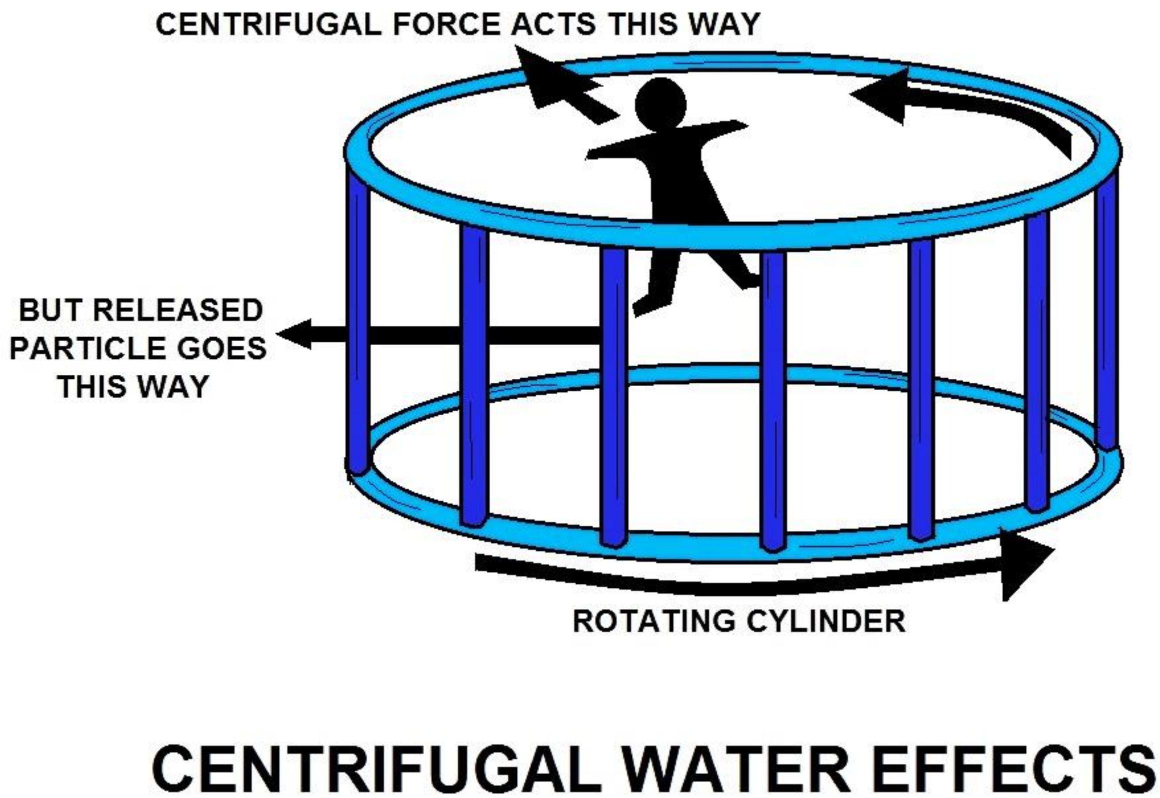


PUMP PERFORMANCE CURVE (CENTRIFUGAL PUMP)

More on the Basic Water Pump

The water pump commonly found in our systems is centrifugal pumps. These pumps work by spinning water around in a circle inside a cylindrical pump housing. The pump makes the water spin by pushing it with an impeller. The blades of this impeller project outward from an axle like the arms of a turnstile and, as the impeller spins, the water spins with it. As the water spins, the pressure near the outer edge of the pump housing becomes much higher than near the center of the impeller.

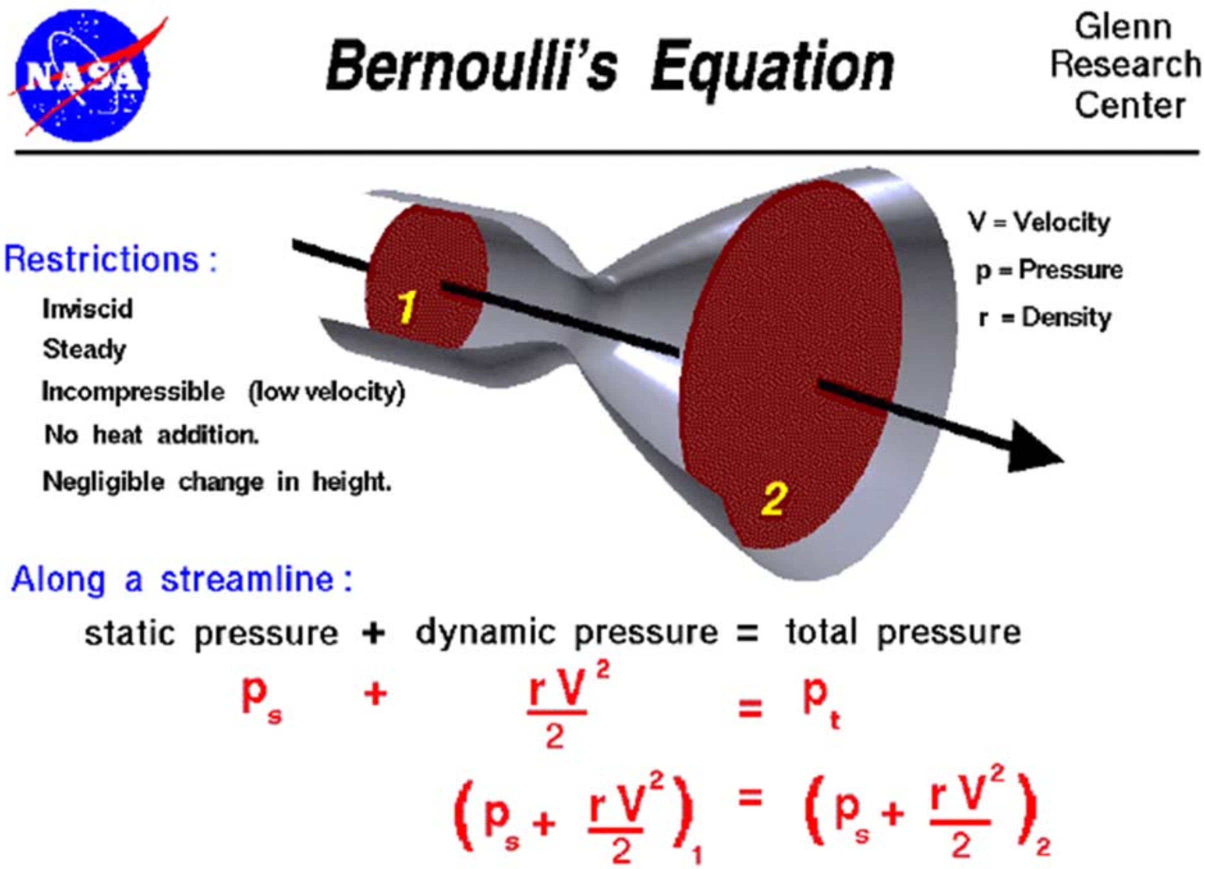
There are many ways to understand this rise in pressure, and here are two:



First, you can view the water between the impeller blades as an object traveling in a circle. Objects do not naturally travel in a circle--they need an inward force to cause them to accelerate inward as they spin. Without such an inward force, an object will travel in a straight line and will not complete the circle. In a centrifugal pump, that inward force is provided by high-pressure water near the outer edge of the pump housing.

The water at the edge of the pump pushes inward on the water between the impeller blades and makes it possible for that water to travel in a circle. The water pressure at the edge of the turning impeller rises until it is able to keep water circling with the impeller blades.

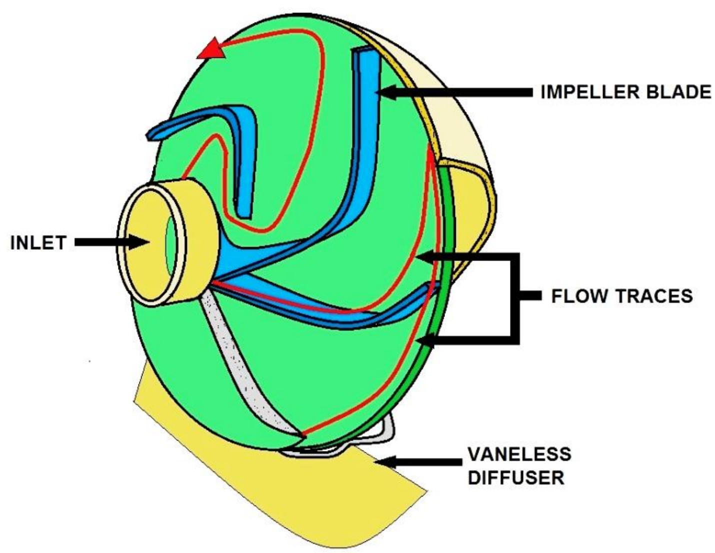
You can also view the water as an incompressible fluid, one that obeys Bernoulli's equation in the appropriate contexts. As water drifts outward between the impeller blades of the pump, it must move faster and faster because its circular path is getting larger and larger. The impeller blades cause the water to move faster and faster. By the time the water has reached the outer edge of the impeller, it is moving quite fast. However, when the water leaves the impeller and arrives at the outer edge of the cylindrical pump housing, it slows down.



Here is where Bernoulli's equation figures in. As the water slows down and its kinetic energy decreases, that water's pressure potential energy increases (***to conserve energy***). Thus, the slowing is accompanied by a pressure rise.

That is why the water pressure at the outer edge of the pump housing is higher than the water pressure near the center of the impeller.

When water is actively flowing through the pump, arriving through a hole near the center of the impeller and leaving through a hole near the outer edge of the pump housing, the pressure rise between center and edge of the pump is not as large.



COMMON PUMP IMPELLER

Types of Water Pumps

The most common type of water pumps used for municipal and domestic water supplies are *variable displacement* pumps. A variable displacement pump will produce at different rates relative to the amount of pressure or lift the pump is working against. *Centrifugal* pumps are variable displacement pumps that are by far used the most. The water production well industry almost exclusively uses *Turbine* pumps, which are a type of centrifugal pump.

The turbine pump utilizes *impellers* enclosed in single or multiple *bowls or stages* to lift water by *centrifugal force*. The impellers may be of either a *semi-open or closed type*. Impellers are rotated by the *pump motor*, which provides the horsepower needed to overcome the pumping head. A more thorough discussion of how these and other pumps work is presented later in this section. The size and number of stages, horsepower of the motor and pumping head are the key components relating to the pump's lifting capacity.

Vertical turbine pumps are commonly used in groundwater wells. These pumps are driven by a shaft rotated by a motor on the surface. The shaft turns the impellers within the pump housing while the water moves up the column.

This type of pumping system is also called a *line-shaft turbine*. The rotating shaft in a line shaft turbine is actually housed within the column pipe that delivers the water to the surface. The size of the column, impeller, and bowls are selected based on the desired pumping rate and lift requirements.

Column pipe sections can be threaded or coupled together while the drive shaft is coupled and suspended within the column by *spider bearings*. The spider bearings provide both a seal at the column pipe joints and keep the shaft aligned within the column. The water passing through the column pipe serves as the lubricant for the bearings. Some vertical turbines are lubricated by oil rather than water. These pumps are essentially the same as water lubricated units; only the drive shaft is enclosed within an *oil tube*.

Food grade oil is supplied to the tube through a gravity feed system during operation. The oil tube is suspended within the column by *spider flanges,* while the line shaft is supported within the oil tube by *brass or redwood bearings*. A continuous supply of oil lubricates the drive shaft as it proceeds downward through the oil tube.

A small hole located at the top of the pump bow unit allows excess oil to enter the well. This results in the formation of an oil film on the water surface within oil-lubricated wells. Careful operation of oil lubricated turbines is needed to ensure that the pumping levels do not drop enough to allow oil to enter the pump.

Both water and oil lubricated turbine pump units can be driven by electric or fuel powered motors. Most installations use an electric motor that is connected to the drive shaft by a keyway and nut. However, where electricity is not readily available, fuel powered engines may be connected to the drive shaft by a right angle drive gear. Also, both oil and water lubricated systems will have a strainer attached to the intake to prevent sediment from entering the pump.

When the line shaft turbine is turned off, water will flow back down the column, turning the impellers in a reverse direction. A pump and shaft can easily be broken if the motor were to turn on during this process.

This is why a *time delay* or *ratchet* assembly is often installed on these motors to either prevent the motor from turning on before reverse rotation stops or simply not allow it to reverse at all.

There are three main types of diaphragm pumps:
In the first type, the diaphragm is sealed with one side in the fluid to be pumped, and the other in air or hydraulic fluid. The diaphragm is flexed, causing the volume of the pump chamber to increase and decrease. A pair of non-return check valves prevents reverse flow of the fluid.

As described above, the second type of diaphragm pump works with volumetric positive displacement, but differs in that the prime mover of the diaphragm is neither oil nor air; but is electro-mechanical, working through a crank or geared motor drive. This method flexes the diaphragm through simple mechanical action, and one side of the diaphragm is open to air. The third type of diaphragm pump has one or more unsealed diaphragms with the fluid to be pumped on both sides. The diaphragm(s) again are flexed, causing the volume to change.

When the volume of a chamber of either type of pump is increased (the diaphragm moving up), the pressure decreases, and fluid is drawn into the chamber. When the chamber pressure later increases from decreased volume (the diaphragm moving down), the fluid previously drawn in is forced out. Finally, the diaphragm moving up once again draws fluid into the chamber, completing the cycle. This action is similar to that of the cylinder in an internal combustion engine.

Cavitation
Cavitation is defined as the phenomenon of formation of vapor bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure. Cavitation is usually divided into two classes of behavior: inertial (or transient) cavitation and non-inertial cavitation. Inertial cavitation is the process where a void or bubble in a liquid rapidly collapses, producing a shock wave.

Such cavitation often occurs in pumps, propellers, impellers, and in the vascular tissues of plants. Non-inertial cavitation is the process in which a bubble in a fluid is forced to oscillate in size or shape due to some form of energy input, such as an acoustic field. Such cavitation is often employed in ultrasonic cleaning baths and can also be observed in pumps, propellers etc.

Cavitation is, in many cases, an undesirable occurrence. In devices such as propellers and pumps, cavitation causes a great deal of noise, damage to components, vibrations, and a loss of efficiency. When the cavitation bubbles collapse, they force liquid energy into very small volumes, thereby creating spots of high temperature and emitting shock waves, the latter of which are a source of noise.

The noise created by cavitation is a particular problem for military submarines, as it increases the chances of being detected by passive sonar. Although the collapse of a cavity is a relatively low-energy event, highly localized collapses can erode metals, such as steel, over time. The pitting caused by the collapse of cavities produces great wear on components and can dramatically shorten a propeller's or pump's lifetime.

After a surface is initially affected by cavitation, it tends to erode at an accelerating pace. The cavitation pits increase the turbulence of the fluid flow and create crevasses that act as nucleation sites for additional cavitation bubbles. The pits also increase the component's surface area and leave behind residual stresses. This makes the surface more prone to stress corrosion.

Understanding the Operation of a Vertical Turbine Pump

Vertical turbine pumps are available in deep well, shallow well, or canned configurations. VHS or VSS motors will be provided to fulfill environmental requirements. Submersible motors are also available. These pumps are also suitable industrial, municipal, commercial and agricultural applications.

Deep well turbine pumps are adapted for use in cased wells or where the water surface is below the practical limits of a centrifugal pump. Turbine pumps are also used with surface water systems. Since the intake for the turbine pump is continuously under water, priming is not a concern. Turbine pump efficiencies are comparable to, or greater than most centrifugal pumps. They are usually more expensive than centrifugal pumps and more difficult to inspect and repair.

The turbine pump has three main parts: (1) the head assembly, (2) the shaft and column assembly and (3) the pump bowl assembly. The head is normally cast iron and designed to be installed on a foundation. It supports the column, shaft, and bowl assemblies, and provides a discharge for the water. It also will support either an electric motor, a right angle gear drive, or a belt drive.

Bowl Assembly
The bowl assembly is the heart of the vertical turbine pump. The impeller and diffuser type casing is designed to deliver the head and capacity that the system requires in the most efficient way. Vertical turbine pumps can be multi-staged, allowing maximum flexibility both in the initial pump selection and in the event that future system modifications require a change in the pump rating. The submerged impellers allow the pump to be started without priming. The discharge head changes the direction of flow from vertical to horizontal, and couples the pump to the system piping, in addition to supporting and aligning the driver.

Drivers
A variety of drivers may be used; however, electric motors are most common. For the purposes of this manual, all types of drivers can be grouped into two categories:
1. Hollow shaft drivers where the pump shaft extends through a tube in the center of the rotor and is connected to the driver by a clutch assembly at the top of the driver.
2. Solid shaft drivers where the rotor shaft is solid and projects below the driver mounting base. This type of driver requires an adjustable flanged coupling for connecting to the pump.

Discharge Head Assembly
The discharge head supports the driver and bowl assembly as well as supplying a discharge connection (the "**NUF**" type discharge connection which will be located on one of the column pipe sections below the discharge head). A shaft sealing arrangement is located in the discharge head to seal the shaft where it leaves the liquid chamber. The shaft seal will usually be either a mechanical seal assembly or stuffing box.

Column Assembly
The shaft and column assembly provides a connection between the head and pump bowls. The line shaft transfers the power from the motor to the impellers and the column carries the water to the surface. The line shaft on a turbine pump may be either water lubricated or oil lubricated.

The oil-lubricated pump has an enclosed shaft into which oil drips, lubricating the bearings. The water-lubricated pump has an open shaft. The bearings are lubricated by the pumped water.

If there is a possibility of fine sand being pumped, select the oil lubricated pump because it will keep the sand out of the bearings. If the water is for domestic or livestock use, it must be free of oil and a water-lubricated pump must be used.

Line shaft bearings are commonly placed on 10-foot centers for water-lubricated pumps operating at speeds under 2,200 RPM and at 5-foot centers for pumps operating at higher speeds. Oil-lubricated bearings are commonly placed on 5-foot centers.

A pump bowl encloses the impeller. Due to its limited diameter, each impeller develops a relatively low head. In most deep well turbine installations, several bowls are stacked in series one above the other. This is called staging. A four-stage bowl assembly contains four impellers, all attached to a common shaft and will operate at four times the discharge head of a single-stage pump.

Impellers used in turbine pumps may be either semi-open or enclosed. The vanes on semi-open impellers are open on the bottom and they rotate with a close tolerance to the bottom of the pump bowl. The tolerance is critical and must be adjusted when the pump is new. During the initial break-in period the line shaft couplings will tighten, therefore, after about 100 hours of operation, the impeller adjustments should be checked. After break-in, the tolerance must be checked and adjusted every three to five years or more often if pumping sand.

Column assembly is of two basic types, either of which may be used:
1. Open lineshaft construction utilizes the fluid being pumped to lubricate the lineshaft bearings.
2. Enclosed lineshaft construction has an enclosing tube around the lineshaft and utilizes oil, grease, or injected liquid (usually clean water) to lubricate the lineshaft bearings.

Column assembly will consist of:
1) column pipe, which connects the bowl assembly to the discharge head,
2) shaft, connecting the bowl shaft to the driver and,
3) may contain bearings, if required, for the particular unit. Column pipe may be either threaded or flanged.
Note: Some units will not require column assembly, having the bowl assembly connected directly to the discharge head instead.

Bowl Assemblies
The bowl consists of:
1) impellers rigidly mounted on the bowl shaft, which rotate and impart energy to the fluid,
2) bowls to contain the increased pressure and direct the fluid,
3) suction bell or case which directs the fluid into the first impeller, and
4) bearings located in the suction bell (or case) and in each bowl.

Both types of impellers may cause inefficient pump operation if they are not properly adjusted. Mechanical damage will result if the semi-open impellers are set too low and the vanes rub against the bottom of the bowls. The adjustment of enclosed impellers is not as critical; however, they must still be checked and adjusted.

Impeller adjustments are made by tightening or loosening a nut on the top of the head assembly. Impeller adjustments are normally made by lowering the impellers to the bottom of the bowls and adjusting them upward. The amount of upward adjustment is determined by how much the line shaft will stretch during pumping. The adjustment must be made based on the lowest possible pumping level in the well. The proper adjustment procedure if often provided by the pump manufacturer.

Basic Operation of a Vertical Turbine

Pre-start

Before starting the pump, the following checks should be made:

1. Rotate the pump shaft by hand to make sure the pump is free and the impellers are correctly positioned.
2. Is the head shaft adjusting nut properly locked into position?
3. Has the driver been properly lubricated in accordance with the instructions furnished with the driver?
4. Has the driver been checked for proper rotation? If not, the pump must be disconnected from the driver before checking. The driver must rotate COUNTER CLOCKWISE when looking down at the top of the driver.
5. Check all connections to the driver and control equipment.
6. Check that all piping connections are tight.
7. Check all anchor bolts for tightness.
8. Check all bolting and tubing connections for tightness (driver mounting bolts, flanged coupling bolts, glad plate bolts, seal piping, etc.).
9. On pumps equipped with stuffing box, make sure the gland nuts are only finger tight — **DO NOT TIGHTEN** packing gland before starting.
10. On pumps equipped with mechanical seals, clean fluid should be put into the seal chamber. With pumps under suction pressure this can be accomplished by bleeding all air and vapor out of the seal chamber and allowing the fluid to enter. With pumps not under suction pressure, the seal chamber should be flushed liberally with clean fluid to provide initial lubrication. Make sure the mechanical seal is properly adjusted and locked into place.

NOTE: After initial start-up, pre-lubrication of the mechanical seal will usually not be required, as enough liquid will remain in the seal chamber for subsequent start-up lubrication.

11. On pumps equipped with enclosed lineshaft, lubricating liquid must be available and should be allowed to run into the enclosing tube in sufficient quantity to thoroughly lubricate all lineshaft bearings.

Initial Start-Up

1. If the discharge line has a valve in it, it should be partially open for initial starting — Min. 10%.
2. Start lubrication liquid flow on enclosed lineshaft units.
3. Start the pump and observe the operation. If there is any difficulty, excess noise or vibration, stop the pump immediately.
4. Open the discharge valve as desired.
5. Check complete pump and driver for leaks, loose connections or improper operation.
6. If possible, the pump should be left running for approximately ½ hour on the initial start-up. This will allow the bearings, packing or seals, and other parts to “run-in” and reduce the possibility of trouble on future starts.

NOTE: If abrasives or debris are present upon startup, the pump should be allowed to run until the pumpage is clean. Stopping the pump when handling large amounts of abrasives (as sometimes present on initial starting) may lock the pump and cause more damage than if the pump is allowed to continue operation.

CAUTION: Every effort should be made to keep abrasives out of lines, sumps, etc. so that abrasives will not enter the pump.

Stuffing Box Adjustment
On the initial starting it is very important that the packing gland not be tightened too much. New packing must be "**run in**" properly to prevent damage to the shaft and shortening of the packing life. The stuffing box must be allowed to leak for proper operation. The proper amount of leakage can be determined by checking the temperature of the leakage; this should be cool or just lukewarm — **NOT HOT**. When adjusting the packing gland, bring both nuts down evenly and in small steps until the leakage is reduced as required. The nuts should only be tightened about ½ turn at a time at 20 to 30 minute intervals to allow the packing to "run in". Under proper operation, a set of packing will last a long time. Occasionally a new ring of packing will need to be added to keep the box full. After adding two or three rings of packing, or when proper adjustment cannot be achieved, the stuffing box should be cleaned completely of all old packing and re-packed.

Lineshaft Lubrication
Open lineshaft bearings are lubricated by the pumped fluid and on close coupled units (less than 30' long), will usually not require pre or post lubrication. Enclosed lineshaft bearings are lubricated by extraneous liquid (usually oil or clean water), which is fed to the tension nut by either a gravity flow system or pressure injection system. The gravity flow system utilizing oil is the most common arrangement. The oil reservoir must be kept filled with a good quality light turbine oil (about 150 SSU at operating temperature) and adjusted to feed 10 to 12 drops per minute plus one (1) drop per 100' of setting. Injection systems are designed for each installation — injection pressure and quantity of lubricating liquid will vary. Refer to packing slip or separate instruction sheet for requirements when unit is designed for injection lubrication.

General Maintenance Section
A periodic inspection is recommended as the best means of preventing breakdown and keeping maintenance costs to a minimum. Maintenance personnel should look over the whole installation with a critical eye each time the pump is inspected — a change in noise level, amplitude or vibration, or performance can be an indication of impending trouble.

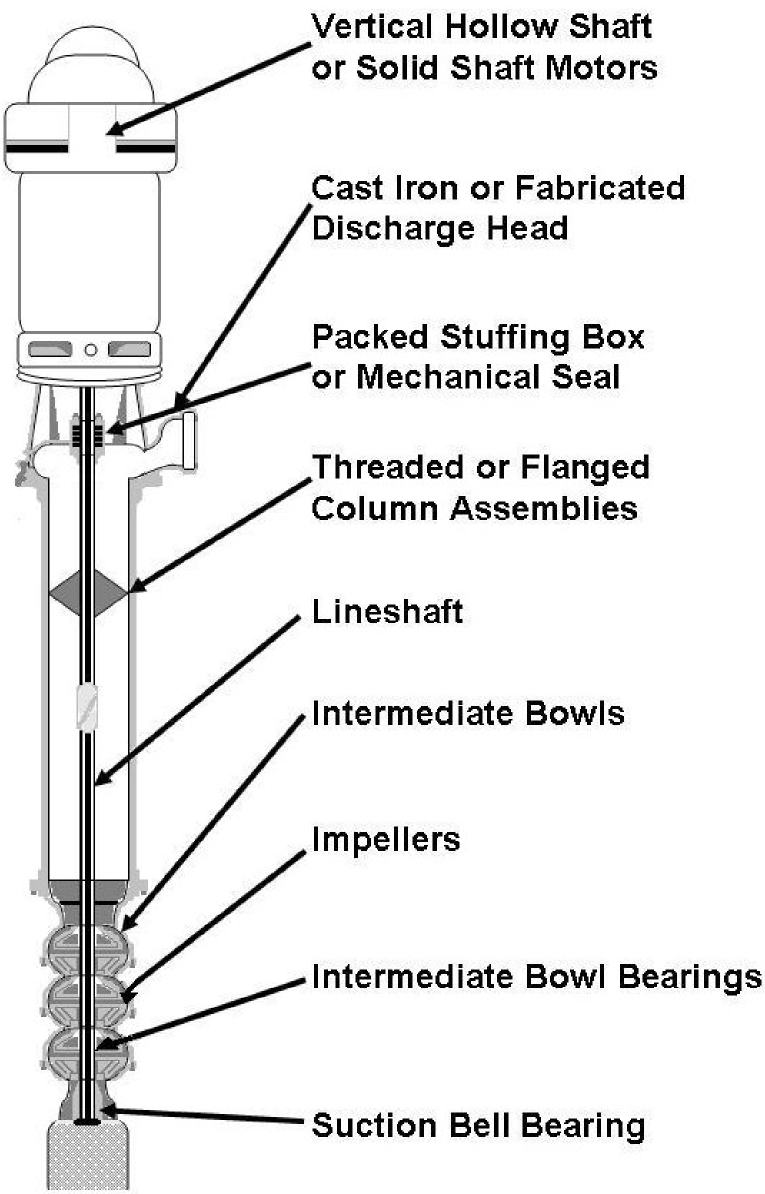
Any deviation in performance or operation from what is expected can be traced to some specific cause. Determination of the cause of any misperformance or improper operation is essential to the correction of the trouble — whether the correction is done by the user, the dealer or reported back to the factory. Variances from initial performance will indicate changing system conditions or wear or impending breakdown of unit.

Deep well turbine pumps must have correct alignment between the pump and the power unit. Correct alignment is made easy by using a head assembly that matches the motor and column/pump assembly. It is very important that the well is straight and plumb.

The pump column assembly must be vertically aligned so that no part touches the well casing. Spacers are usually attached to the pump column to prevent the pump assembly from touching the well casing. If the pump column does touch the well casing, vibration will wear holes in the casing. A pump column out of vertical alignment may also cause excessive bearing wear.

The head assembly must be mounted on a good foundation at least 12 inches above the ground surface. A foundation of concrete provides a permanent and trouble-free installation. The foundation must be large enough to allow the head assembly to be securely fastened. The foundation should have at least 12 inches of bearing surface on all sides of the well.

Common Elements of Vertical Turbines



Closed Pump Impeller

Submersible Pumps

Submersible pumps are in essence very similar to turbine pumps. They both use impellers rotated by a shaft within the bowls to pump water. However, the pump portion is directly connected to the motor.

The pump shaft has a keyway in which the splined motor end shaft inserts. The motor is bolted to the pump housing. The pump's intake is located between the motor and the pump and is normally screened to prevent sediment from entering the pump and damaging the impellers.

The efficient cooling of submersible motors is very important, so these types of pumps are often installed such that flow through the well screen can occur upwards past the motor and into the intake. If the motor end is inserted below the screened interval or below all productive portions of the aquifer, it will not be cooled, resulting in premature motor failure.

Some pumps may have *pump shrouds* installed on them to force all the water to move past the motor to prevent overheating.

The shroud is a piece of pipe that attaches to the pump housing with an open end below the motor. As with turbine pumps, the size of the bowls and impellers, number of stages, and horsepower of the motor are adjusted to achieve the desired production rate within the limitations of the pumping head.

Insertion of motor spline into the pump keyway.

Cut away of a small submersible pump.

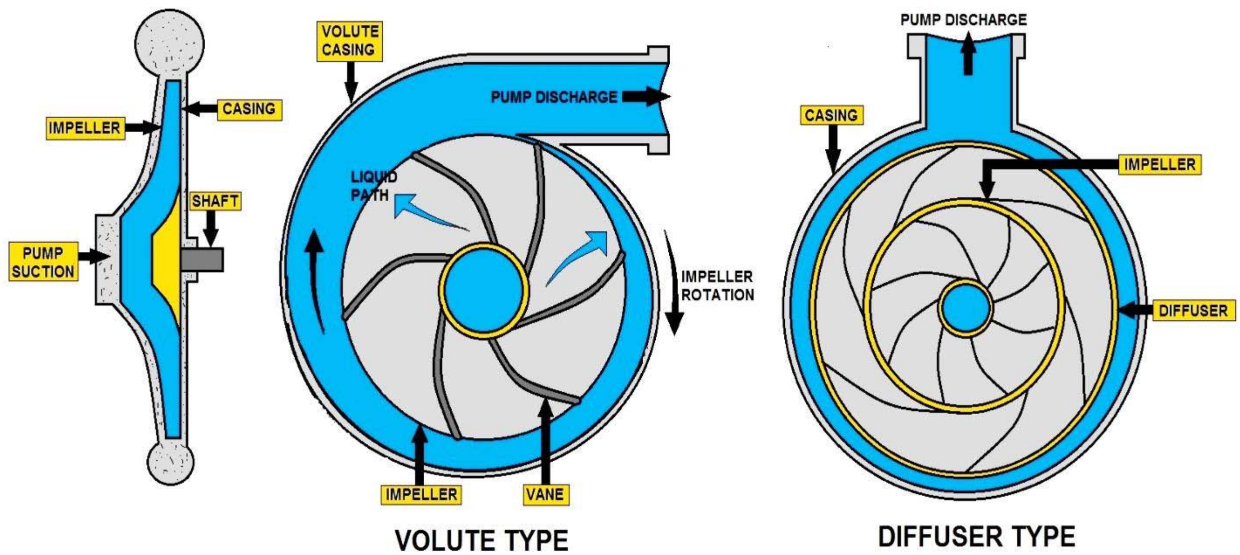
Centrifugal Pump

By definition, a centrifugal pump is a machine. More specifically, it is a machine that imparts energy to a fluid. This energy infusion can cause a liquid to flow, rise to a higher level, or both.

The centrifugal pump is an extremely simple machine. It is a member of a family known as rotary machines and consists of two basic parts: 1) the rotary element or impeller and 2) the stationary element or casing (volute). The figure at the bottom of the page is a cross section of a centrifugal pump and shows the two basic parts.

In operation, a centrifugal pump "*slings*" liquid out of the impeller via centrifugal force. One fact that must always be remembered: A pump does not create pressure, it only provides flow. Pressure is just an indication of the amount of resistance to flow.

Centrifugal pumps may be classified in several ways. For example, they may be either SINGLE STAGE or MULTI-STAGE. A single-stage pump has only one impeller. A multi-stage pump has two or more impellers housed together in one casing.



TYPES OF CENTRIFUGAL PUMPS

As a rule, each impeller acts separately, discharging to the suction of the next stage impeller. This arrangement is called series staging. Centrifugal pumps are also classified as HORIZONTAL or VERTICAL, depending upon the position of the pump shaft.

The impellers used on centrifugal pumps may be classified as SINGLE SUCTION or DOUBLE SUCTION. The single-suction impeller allows liquid to enter the eye from one side only. The double-suction impeller allows liquid to enter the eye from two directions.

Impellers are also classified as CLOSED or OPEN. Closed impellers have side walls that extend from the eye to the outer edge of the vane tips. Open impellers do not have these side walls. Some small pumps with single-suction impellers have only a casing wearing ring and no impeller ring. In this type of pump, the casing wearing ring is fitted into the end plate.

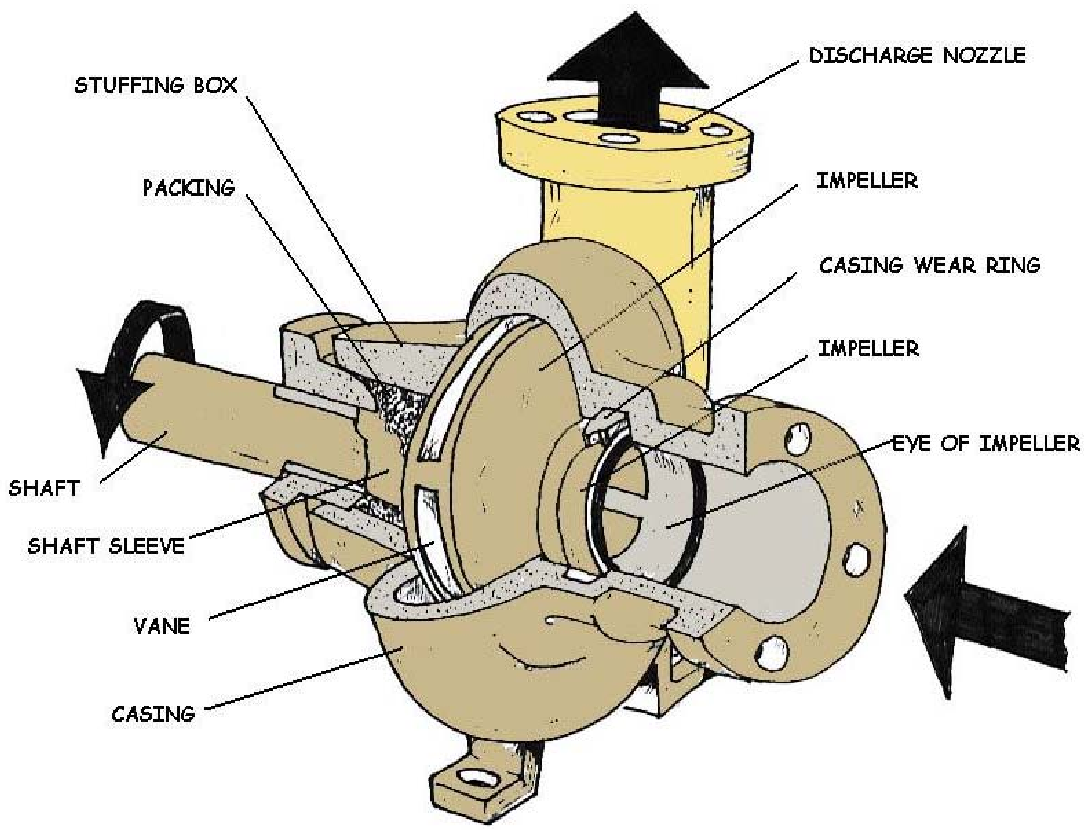
Recirculation lines are installed on some centrifugal pumps to prevent the pumps from overheating and becoming vapor bound, in case the discharge is entirely shut off or the flow of fluid is stopped for extended periods.

Seal piping is installed to cool the shaft and the packing, to lubricate the packing, and to seal the rotating joint between the shaft and the packing against air leakage. A lantern ring spacer is inserted between the rings of the packing in the stuffing box.

Seal piping leads the liquid from the discharge side of the pump to the annular space formed by the lantern ring. The web of the ring is perforated so that the water can flow in either direction along the shaft (between the shaft and the packing).

Water flinger rings are fitted on the shaft between the packing gland and the pump bearing housing. These flingers prevent water in the stuffing box from flowing along the shaft and entering the bearing housing.

Let's look at the components of the centrifugal pump.



Centrifugal Pump

As the impeller rotates, it sucks the liquid into the center of the pump and throws it out under pressure through the outlet. The casing that houses the impeller is referred to as the volute, the impeller fits on the shaft inside. The volute has an inlet and outlet that carries the water as shown above.

NPSH - Net Positive Suction Head

If you accept that a pump creates a partial vacuum and atmospheric pressure forces water into the suction of the pump, then you will find NPSH a simple concept.

NPSH (a) is the Net Positive Suction Head Available, which is calculated as follows:

NPSH (a) = p + s - v - f

Where:
'p'= atmospheric pressure,
's'= static suction (If liquid is below pump, it is shown as a negative value)
'v'= liquid vapor pressure
'f'= friction loss

NPSH (a) must exceed NPSH(r) to allow pump operation without cavitation. (It is advisable to allow approximately 1 meter difference for most installations.) The other important fact to remember is that water will boil at much less than 100 deg C^{O} if the pressure acting on it is less than its vapor pressure, i.e. water at 95 deg C is just hot water at sea level, but at 1500m above sea level it is boiling water and vapor.

The vapor pressure of water at 95 deg C is 84.53 kPa, there was enough atmospheric pressure at sea level to contain the vapor, but once the atmospheric pressure dropped at the higher elevation, the vapor was able to escape. This is why vapor pressure is always considered in NPSH calculations when temperatures exceed 30 to 40 deg C.

NPSH(r) is the Net Positive Suction Head Required by the pump, which is read from the pump performance curve. (Think of NPSH(r) as friction loss caused by the entry to the pump suction.)

Affinity Laws

The Centrifugal Pump is a very capable and flexible machine. Because of this it is unnecessary to design a separate pump for each job. The performance of a centrifugal pump can be varied by changing the impeller diameter or its rotational speed. Either change produces approximately the same results. Reducing impeller diameter is probably the most common change and is usually the most economical. The speed can be altered by changing pulley diameters or by changing the speed of the driver. In some cases both speed and impeller diameter are changed to obtain the desired results.

When the driven speed or impeller diameter of a centrifugal pump changes, operation of the pump changes in accordance with three fundamental laws. These laws are known as the "Laws of Affinity". They state that:
1) Capacity varies directly as the change in speed
2) Head varies as the square of the change in speed
3) Brake horsepower varies as the cube of the change in speed

If, for example, the pump speed were doubled:
1) Capacity will double
2) Head will increase by a factor of 4 (2 to the second power)
3) Brake horsepower will increase by a factor of 8 (2 to the third power)
These principles apply regardless of the direction (up or down) of the speed or change in diameter.

Consider the following example. A pump operating at 1750 RPM, delivers 210 GPM at 75' TDH, and requires 5.2 brake horsepower. What will happen if the speed is increased to 2000 RPM? First we find the speed ratio.

Speed Ratio = 2000/1750 = 1.14

From the laws of Affinity:
1) Capacity varies directly or:
1.14 X 210 GPM = 240 GPM
2) Head varies as the square or:

1.14 X 1.14 X 75 = 97.5' TDH
3) BHP varies as the cube or:

1.14 X 1.14 X 1.14 X 5.2 = 7.72 BHP
Theoretically, the efficiency is the same for both conditions. By calculating several points a new curve can be drawn.

Whether it be a speed change or change in impeller diameter, the Laws of Affinity give results that are approximate. The discrepancy between the calculated values and the actual values obtained in test are due to hydraulic efficiency changes that result from the modification. The Laws of Affinity give reasonably close results when the changes are not more than 50% of the original speed or 15% of the original diameter.

Suction conditions are some of the most important factors affecting centrifugal pump operation. If they are ignored during the design or installation stages of an application, they will probably come back to haunt you.

Suction Lift

A pump cannot pull or "suck" a liquid up its suction pipe because liquids do not exhibit tensile strength. Therefore, they cannot transmit tension or be pulled. When a pump creates a suction, it is simply reducing local pressure by creating a partial vacuum. Atmospheric or some other external pressure acting on the surface of the liquid pushes the liquid up the suction pipe into the pump.

Atmospheric pressure at sea level is called absolute pressure (PSIA) because it is a measurement using absolute zero (a perfect vacuum) as a base. If pressure is measured using atmospheric pressure as a base it is called gauge pressure (PSIG or simply PSI).

Atmospheric pressure, as measured at sea level, is 14.7 PSIA. In feet of head it is:
Head = PSI X 2.31 / Specific Gravity

For Water it is:
Head = 14.7 X 2.31 / 1.0 = 34 Ft

Thus 34 feet is the theoretical maximum suction lift for a pump pumping cold water at sea level. No pump can attain a suction lift of 34 ft; however, well designed ones can reach 25 ft quite easily.

You will note, from the equation above, that specific gravity can have a major effect on suction lift. For example, the theoretical maximum lift for brine (Specific Gravity = 1.2) at sea level is 28 ft.. The realistic maximum is around 20ft. Remember to always factor in specific gravity if the liquid being pumped is anything but clear, cold (68 degrees F) water. In addition to pump design and suction piping, there are two physical properties of the liquid being pumped that affect suction lift.

1) Maximum suction lift is dependent upon the pressure applied to the surface of the liquid at the suction source. Maximum suction lift decreases as pressure decreases.

2) 2) Maximum suction lift is dependent upon the vapor pressure of the liquid being pumped. The vapor pressure of a liquid is the pressure necessary to keep the liquid from vaporizing (boiling) at a given temperature. Vapor pressure increases as liquid temperature increases. Maximum suction lift decreases as vapor pressure rises.

It follows then, that the maximum suction lift of a centrifugal pump varies inversely with altitude. Conversely, maximum suction lift will increase as the external pressure on its source increases (for example: a closed pressure vessel).

Cavitation - Two Main Causes:

A. NPSH (r) EXCEEDS NPSH (a)

Due to low pressure the water vaporizes (boils), and higher pressure implodes into the vapor bubbles as they pass through the pump, causing reduced performance and potentially major damage.

B. Suction or discharge recirculation. The pump is designed for a certain flow range, if there is not enough or too much flow going through the pump, the resulting turbulence and vortexes can reduce performance and damage the pump.

Affinity Laws - Centrifugal Pumps

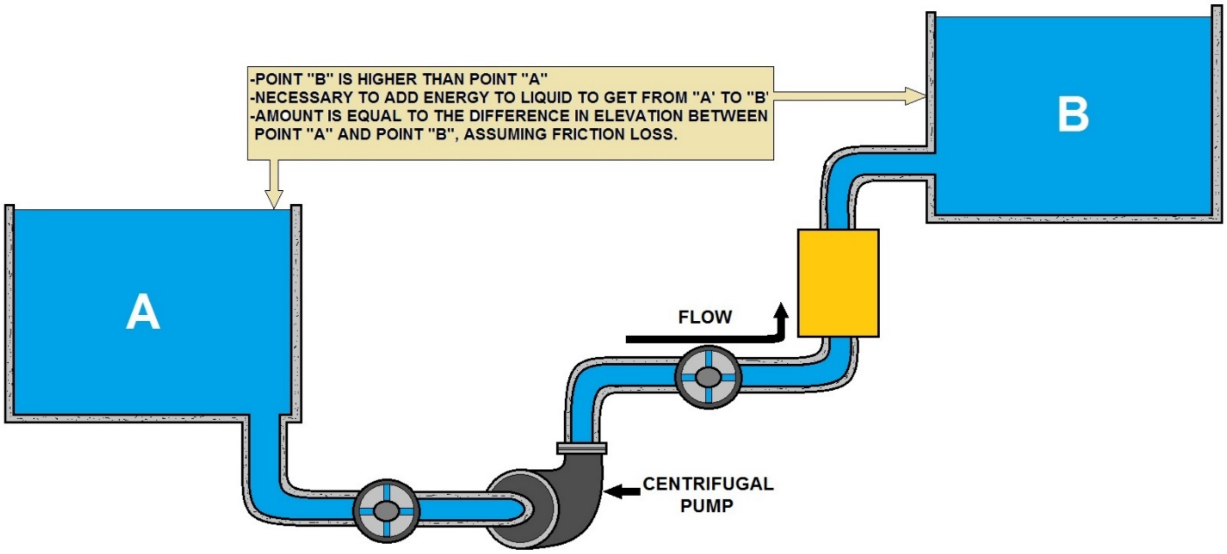
If the speed or impeller diameter of a pump changes, we can calculate the resulting performance change using:

Affinity laws

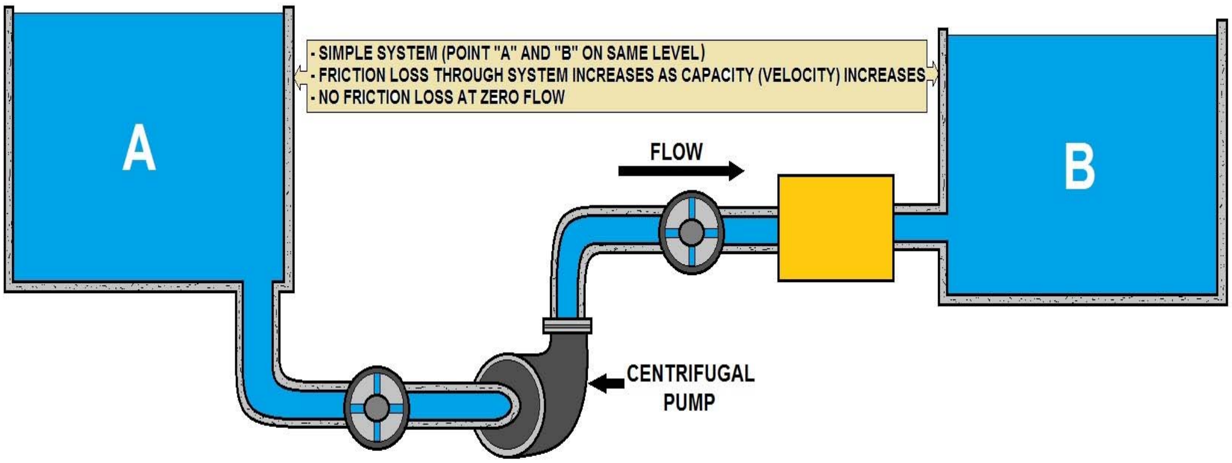
a. The flow changes proportionally to speed
i.e.: double the speed / double the flow
b. The pressure changes by the square of the difference
i.e.: double the speed / multiply the pressure by 4
c. The power changes by the cube of the difference
i.e.: double the speed / multiply the power by 8

Notes:

1. These laws apply to operating points at the same efficiency.
2. Variations in impeller diameter greater than 10% are hard to predict due to the change in relationship between the impeller and the casing. For rough calculations you can adjust a duty point or performance curve to suit a different speed. NPSH (r) is affected by speed / impeller diameter change = **DANGER!**



CENTRIFUGAL PUMP CURVE CHARACTERISITICS



CENTRIFUGAL PUMP CURVE CHARACTERISITICS

Pump Casing

There are many variations of centrifugal pumps. The most common type is an end suction pump. Another type of pump used is the split case. There are many variations of split case, such as; two-stage, single suction, and double suction. Most of these pumps are horizontal.

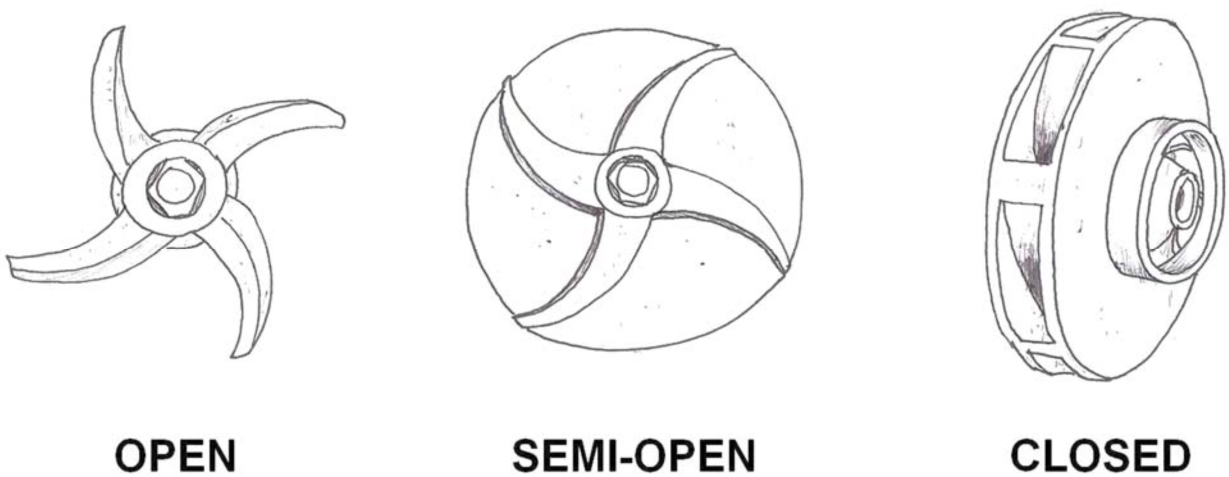
There are variations of vertical centrifugal pumps. The line shaft turbine is really a multistage centrifugal pump.

Impeller

In most centrifugal pumps, the impeller looks like a number of cupped vanes on blades mounted on a disc or shaft. Notice in the picture below how the vanes of the impeller force the water into the outlet of the pipe.

The shape of the vanes of the impeller is important. As the water is being thrown out of the pump, this means you can run centrifugal pumps with the discharged valve closed for a **SHORT** period of time. Remember the motor sends energy along the shaft, and if the water is in the volute too long it will heat up and create steam. Not good!

Impellers are designed in various ways. We will look at:
Closed impellers
Semi-open impellers
Opened impellers, and
Recessed impellers



The impellers all cause a flow from the eye of the impeller to the outside of the impeller. These impellers cause what is called **radial flow**, and they can be referred to as radial flow impellers.

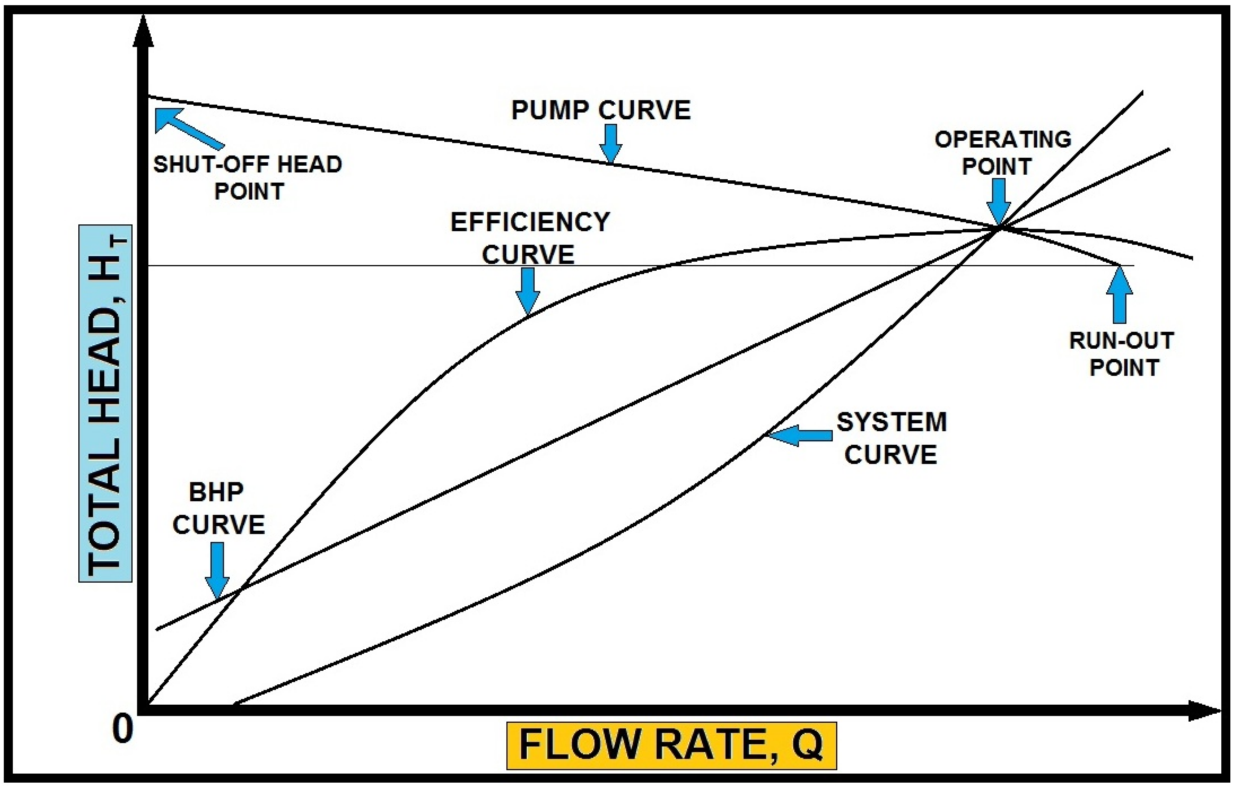
The **critical distance** of the impeller and how it is installed in the casing will determine if it is high volume / low pressure or the type of liquid that could be pumped.

Axial flow impellers look like a propeller and create a flow that is parallel to the shaft.

Pump Performance and Curves

Let's looks at the big picture. Before you make that purchase of the pump and motor you need to know the basics such as:

Total dynamic head, the travel distance.
Capacity, how much water you need to provide.
Efficiency, help determine the impeller size.
HP, how many squirrels you need.
RPM, how fast the squirrels run.



PUMP PERFORMANCE CURVE (CENTRIFUGAL PUMP)

Motor and Pump Calculations

The centrifugal pump pumps the difference between the suction and the discharge heads. There are three kinds of discharge head:
Static head. The height we are pumping to, or the height to the discharge piping outlet that is filling the tank from the top. Note: that if you are filling the tank from the bottom, the static head will be constantly changing.
Pressure head. If we are pumping to a pressurized vessel (like a boiler) we must convert the pressure units (psi. or Kg.) to head units (feet or meters).
System or dynamic head. Caused by friction in the pipes, fittings, and system components. We get this number by making the calculations from published charts.

Suction head is measured the same way.
If the liquid level is above the pump center line, that level is a positive suction head. If the pump is lifting a liquid level from below its center line, it is a negative suction head.
If the pump is pumping liquid from a pressurized vessel, you must convert this pressure to a positive suction head. A vacuum in the tank would be converted to a negative suction head.
Friction in the pipes, fittings, and associated hardware is a negative suction head.
Negative suction heads are added to the pump discharge head, positive suctions heads are subtracted from the pump discharge head.

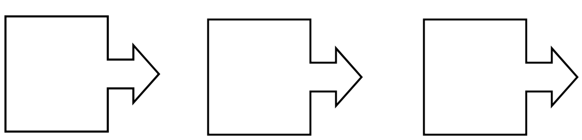
Total Dynamic Head (TDH) is the total height that a fluid is to be pumped, taking into account friction losses in the pipe.

TDH = Static Lift + Static Height + Friction Loss

where:
Static Lift is the height the water will rise before arriving at the pump (also known as the 'suction head').

Static Height is the maximum height reached by the pipe after the pump (also known as the 'discharge head').

Friction Loss is the head equivalent to the energy losses due to viscose drag of fluid flowing in the pipe (both on the suction and discharge sides of the pump). It is calculated via a formula or a chart, taking into account the pipe diameter and roughness and the fluid flow rate, density, and viscosity.



Motor hp **Brake hp** **Water hp**

Horsepower

Work involves the operation of force over a specific distance. The rate of doing work is called power. The rate in which a horse could work was determined to be about 550 ft-lbs/sec or 33,000 ft-lbs/min.

1 hp = 33,000 ft-lbs/min

Motor Horsepower (mhp)

1 hp = 746 watts or .746 Kilowatts

MHP refers to the horsepower supplied in the form of electrical current. The efficiency of most motors range from 80-95%. (Manufactures will list efficiency %)

Brake Horsepower (bhp)

$$\text{Brake hp} = \frac{\text{Water hp}}{\text{Pump Efficiency}}$$

BHP refers to the horsepower supplied to the pump from the motor. As the power moves through the pump, additional horsepower is lost, resulting from slippage and friction of the shaft and other factors.

Water Horsepower

$$\text{Water hp} = \frac{(\text{flow gpm})(\text{total hd})}{3960}$$

Water horsepower refers to the actual horse power available to pump the water.

Horsepower and Specific Gravity

The specific gravity of a liquid is an indication of its density or weight compared to water. The difference in specific gravity, include it when calculating ft-lbs/min pumping requirements.

$$\frac{(\text{ft})(\text{lbs/min})(\text{sp.gr.})}{33{,}000 \text{ ft-lbs/min/hp}} = \text{whp}$$

MHP and Kilowatt requirements

$$1 \text{ hp} = 0.746 \text{ kW} \quad \text{or} \quad \frac{(\text{hp})(746 \text{ watts/hp})}{1000 \text{ watts/kW}}$$

Well Calculations

Well drawdown

Drawdown ft = Pumping water level, ft - Static water level, ft

Well yield

$$\text{Well yield, gpm} = \frac{\text{Flow, gallons}}{\text{Duration of test, min}}$$

Specific yield

$$\text{Specific yield, gpm/ft} = \frac{\text{Well yield, gpm}}{\text{Drawdown, ft}}$$

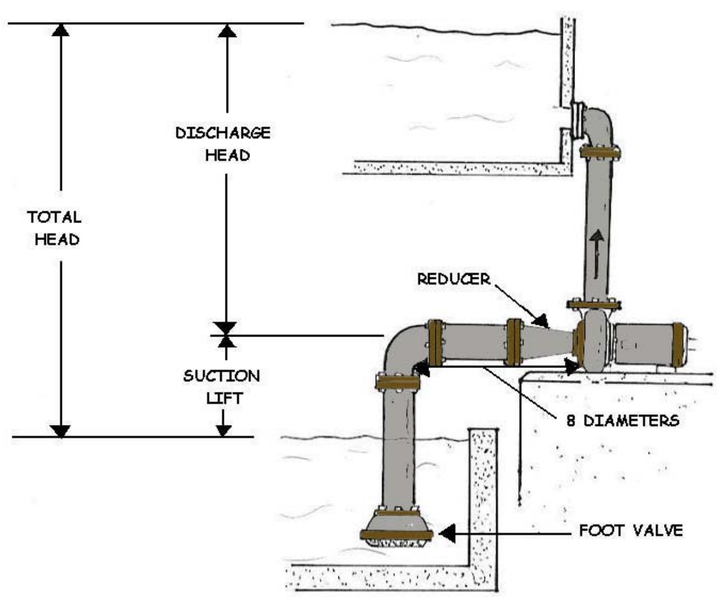
Deep well turbine pump calculations.

Discharge head, ft = (pressure measured) (2.31 ft/psi)

Field head, ft = pumping water + discharge head, ft

Bowl head, ft = field head + column friction

1 psi = 2.31 feet of head
1 foot of head = .433 psi



Example 1

A centrifugal pump is located at an elevation of 722 ft. This pump is used to move water from reservoir **A** to reservoir **B**. The water level in reservoir **A** is 742 ft and the water level in reservoir **B** is 927 ft. Based on these conditions answer the following questions:

If the pump is not running and pressure gauges are installed on the suction and discharge lines, what pressures would the gauges read?

Suction side:

Discharge side:

How can you tell if this is a suction head condition?

Calculate the following head measurements:

SSH:

SDH:

TSH:

Convert the pressure gauge readings to feet:

6 psi:

48 psi:

110 psi:

Calculate the following head in feet to psi:

20 ft:

205 ft:

185 ft:

Motor, Coupling and Bearing Section

We will now refer to the motor, coupling, and bearings. The power source of the pump is usually an electric motor. The motor is connected by a coupling to the pump shaft. The purpose of the bearings is to hold the shaft firmly in place, yet allow it to rotate. The bearing house supports the bearings and provides a reservoir for the lubricant. An impeller is connected to the shaft. The pump assembly can be a vertical or horizontal set-up; the components for both are basically the same.

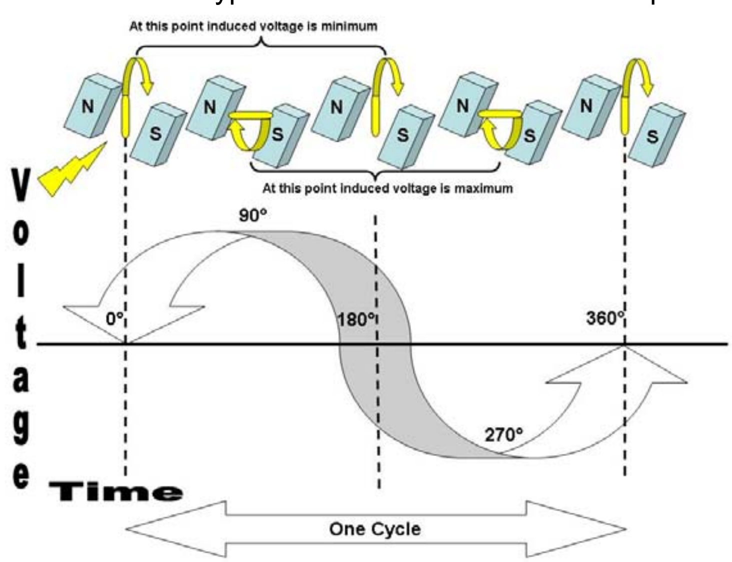
Motors
The purpose of this discussion on pump motors is to identify and describe the main types of motors, starters, enclosures, and motor controls, as well as to provide you with some basic maintenance and troubleshooting information. Although pumps could be driven by diesel or gasoline engines, pumps driven by electric motors are commonly used in our industry.

There are two general categories of electric motors:
D-C motors, or direct current
A-C motors, or alternating current

You can expect most motors at facilities to be A-C type.

D-C Motors
The important characteristic of the D-C motor is that its speed will vary with the amount of current used. There are many different kinds of D-C motors, depending on how they are wound and their speed/torque characteristics.

A-C Motors
There are a number of different types of alternating current motors, such as Synchronous, Induction, wound rotor, and squirrel cage. The synchronous type of A-C motor requires complex control equipment, since they use a combination of A-C and D-C. This also means that the synchronous type of A-C motor is used in large horsepower sizes, usually above 250 HP. The induction type motor uses only alternating current. The squirrel cage motor provides a relatively constant speed. The wound rotor type could be used as a variable speed motor.



Define the Following Terms:

Voltage:

EMF:

Power:

Current:

Resistance:

Conductor:

Phase:

Single Phase:

Three Phase:

Hertz:

Motor Starters

All electric motors, except very small ones such as chemical feed pumps, are equipped with starters, either full voltage or reduced voltage. This is because motors draw a much higher current when they are starting and gaining speed. The purpose of the reduced voltage starter is to prevent the load from coming on until the amperage is low enough.

How do you think keeping the discharge valve closed on a centrifugal pump could reduce the startup load?

Motor Enclosures

Depending on the application, motors may need special protection. Some motors are referred to as open motors.

They allow air to pass through to remove heat generated when current passes through the windings. Other motors use specific enclosures for special environments or safety protection.

Two Types of Totally Enclosed Motors Commonly Used are:

TENV, or totally enclosed non-ventilated motor
TEFC, or totally enclosed fan cooled motor

Totally enclosed motors include dust-proof, water-proof, and explosion-proof motors. An explosion proof enclosure must be provided on any motor where dangerous gases might accumulate.

Motor Controls
All pump motors are provided with some method of control, typically a combination of manual and automatic. Manual pump controls can be located at the central control panel at the pump or at the suction or discharge points of the liquid being pumped.

There are a number of ways in which automatic control of a pump motor can be regulated:
Pressure and vacuum sensors
Preset time intervals
Flow sensors
Level sensors

Two typical level sensors are the float sensor and the bubble regulator. The float sensor is pear-shaped and hangs in the wet well. As the height increases, the float tilts, and the mercury in the glass tube flows toward the end of the tube that has two wires attached to it. When the mercury covers the wires, it closes the circuit.

A low pressure air supply is allowed to escape from a bubbler pipe in the wet well. The back-pressure on the air supply will vary with the liquid level over the pipe.

Sensitive air pressure switches will detect this change and use this information to control pump operation.

Motor Maintenance
Motors should be kept clean, free of moisture, and lubricated properly. Dirt, dust, and grime will plug the ventilating spaces and can actually form an insulating layer over the metal surface of the motor.

What condition would occur if the ventilation becomes blocked?

Moisture

Moisture harms the insulation on the windings to the point where they may no longer provide the required insulation for the voltage applied to the motor. In addition, moisture on windings tend to absorb acid and alkali fumes, causing damage to both insulation and metals. To reduce problems caused by moisture, the most suitable motor enclosure for the existing environment will normally be used. It is recommended to run stand by motors to dry up any condensation which accumulates in the motor.

Motor Lubrication

Friction will cause wear in all moving parts, and lubrication is needed to reduce this friction. It is very important that all your manufacturer's recommended lubrication procedures are strictly followed. You have to be careful not to add too much grease or oil, as this could cause more friction and generate heat.

To grease the motor bearings, this is the usual approach:

Remove the protective plugs and caps from the grease inlet and relief holes.
Pump grease in until fresh starts coming from the relief hole.

If fresh grease does not come out of the relief hole, this could mean that the grease has been pumped into the motor windings. The motor must then be taken apart and cleaned by a qualified service representative.

To change the oil in an oil lubricated motor, this is the usual approach:

Remove all plugs and let the oil drain.
Check for metal shearing.
Replace the oil drain.
Add new oil until it is up to the oil level plug.
Replace the oil level and filter plug.

Never mix oils, since the additives of different oils when combined can cause breakdown of the oil.

Coupling Section

The pump coupling serves two main purposes:

It couples or joins the two shafts together to transfer the rotation from motor to impeller.

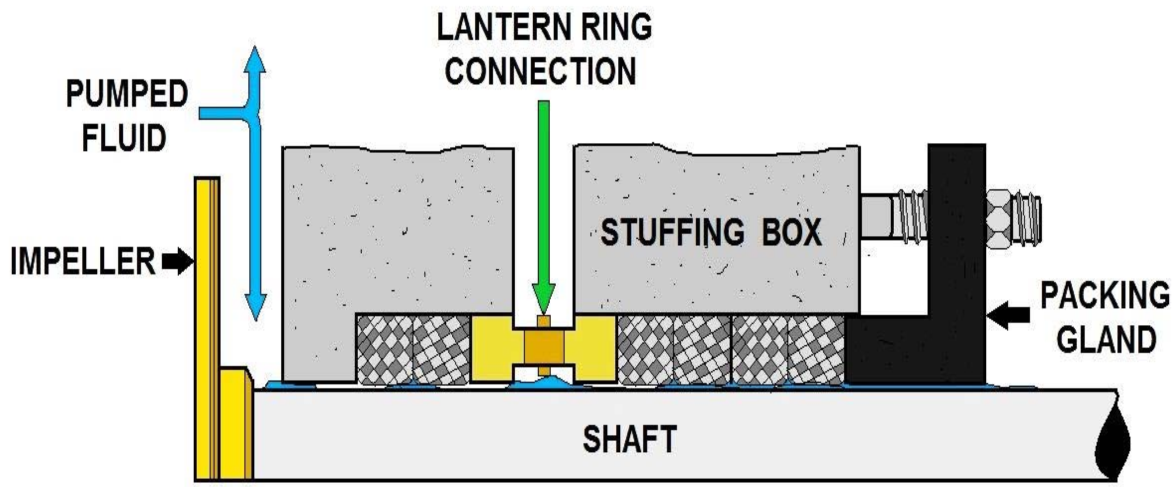
It compensates for small amounts of misalignment between the pump and the motor.

Remember that any coupling is a device in motion. If you have a 4-inch diameter coupling rotating at 1800 rpm, its outer surface is traveling about 20 mph. With that in mind, can you think of safety considerations?

There are three commonly used types of couplings: ***Rigid, Flexible and V-belts.***

Rigid Coupling
Rigid couplings are most commonly used on vertically mounted pumps. The rigid coupling is usually specially keyed or constructed for joining the coupling to the motor shaft and the pump shaft. There are two types of rigid couplings: the flanged coupling, and the split coupling.

Flexible Coupling. The flexible coupling provides the ability to compensate for small shaft misalignments. Shafts should be aligned as close as possible, regardless. The greater the misalignment, the shorter the life of the coupling. Bearing wear and life are also affected by misalignment.

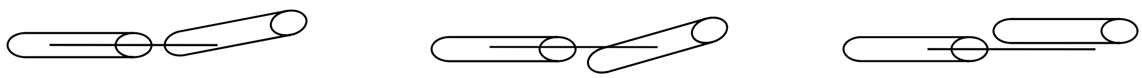


LANTERN RING BETWEEN PACKING FOR COOL / CLEAN FLUID BARRIER

Alignment of Flexible and Rigid Couplings

Both flexible and rigid couplings must be carefully aligned before they are connected. Misalignment will cause excessive heat and vibration, as well as bearing wear. Usually, the noise from the coupling will warn you of shaft misalignment problems.

Three types of shaft alignment problems are shown in the pictures below:



ANGULAR MISALIGNMENT   ANGULAR AND PARALLEL   PARALLEL MISALIGNMENT

Different couplings will require different alignment procedures. We will look at the general procedures for aligning shafts.

Place the coupling on each shaft.
Arrange the units so they appear to be aligned. (Place shims under the legs of one of the units to raise it.)
Check the run-out, or difference between the driver and driven unit, by rotating the shafts by hand.
Turn both units so that the maximum run-out is on top.

Now you can check the units for both parallel and angular alignment. Many techniques are used, such as: straight edge, needle deflection (dial indicators), calipers, tapered wedges, and Laser alignment.

V-Belt Drive Couplings
V-belt drives connect the pump to the motor. A pulley is mounted on the pump and motor shaft. One or more belts are used to connect the two pulleys. Sometimes a separately mounted third pulley is used.

This idler pulley is located off centerline between the two pulleys, just enough to allow tensioning of the belts by moving the idler pulley. An advantage of driving a pump with belts is that various speed ratios can be achieved between the motor and the pump.

Shaft Bearings
There are three types of bearings commonly used: ball bearings, roller bearings, and sleeve bearings. Regardless of the particular type of bearings used within a system--whether it is ball bearings, a sleeve bearing, or a roller bearing--the bearings are designed to carry the loads imposed on the shaft.

Bearings must be lubricated. Without proper lubrication, bearings will overheat and seize.

Proper lubrication means using the correct type and the correct amount of lubrication. Similar to motor bearings, shaft bearings can be lubricated either by oil or by grease.

How can we prevent the water from leaking along the shaft?
A special seal is used to prevent liquid leaking out along the shaft. There are two types of seals commonly used:

Packing seal
Mechanical seal

Packing Seals

Should packing have leakage?

Leakage
During pump operation, a certain amount of leakage around the shafts and casings normally takes place.

This leakage must be controlled for two reasons: (1) to prevent excessive fluid loss from the pump, and (2) to prevent air from entering the area where the pump suction pressure is below atmospheric pressure.

The amount of leakage that can occur without limiting pump efficiency determines the type of shaft sealing selected. Shaft sealing systems are found in every pump. They can vary from simple packing to complicated sealing systems.

Packing is the most common and oldest method of sealing. Leakage is checked by the compression of packing rings that causes the rings to deform and seal around the pump shaft and casing.

The packing is lubricated by liquid moving through a lantern ring in the center of the packing. The sealing slows down the rate of leakage. It does not stop it completely, since a certain amount of leakage is necessary during operation. Mechanical seals are rapidly replacing conventional packing on centrifugal pumps.

Some of the reasons for the use of mechanical seals are as follows:
1. Leaking causes bearing failure by contaminating the oil with water. This is a major problem in engine-mounted water pumps.

2. Properly installed mechanical seals eliminate leakoff on idle (vertical) pumps. This design prevents the leak (water) from bypassing the water flinger and entering the lower bearings. Leakoff causes two types of seal leakage:
a. Water contamination of the engine lubrication oil.
b. Loss of treated fresh water that causes scale buildup in the cooling system.

Centrifugal pumps are versatile and have many uses. This type of pump is commonly used to pump all types of water and wastewater flows, including thin sludge.

Lantern Rings
Lantern rings are used to supply clean water along the shaft. This helps to prevent grit and air from reaching the area. Another component is the slinger ring. The slinger ring is an important part of the pump because it is used to protect the bearings. Other materials can be used to prevent this burier.

Mechanical Seals
Mechanical seals are commonly used to reduce leakage around the pump shaft. There are many types of mechanical seals. The photograph below illustrates the basic components of a mechanical seal. Similar to the packing seal, clean water is fed at a pressure greater than that of the liquid being pumped. There is little or no leakage through the mechanical seal. The wearing surface must be kept extremely clean. Even fingerprints on the wearing surface can introduce enough dirt to cause problems.

Mechanical Seals

Wear Rings
Not all pumps have wear rings. However, when they are included, they are usually replaceable. Wear rings can be located on the suctions side and head side of the volute. Wear rings could be made of the same metal but of different alloys. The wear ring on the head side is usually a harder alloy.

It's called a ***"WEAR RING"*** and what would be the purpose?

Mechanical Seals

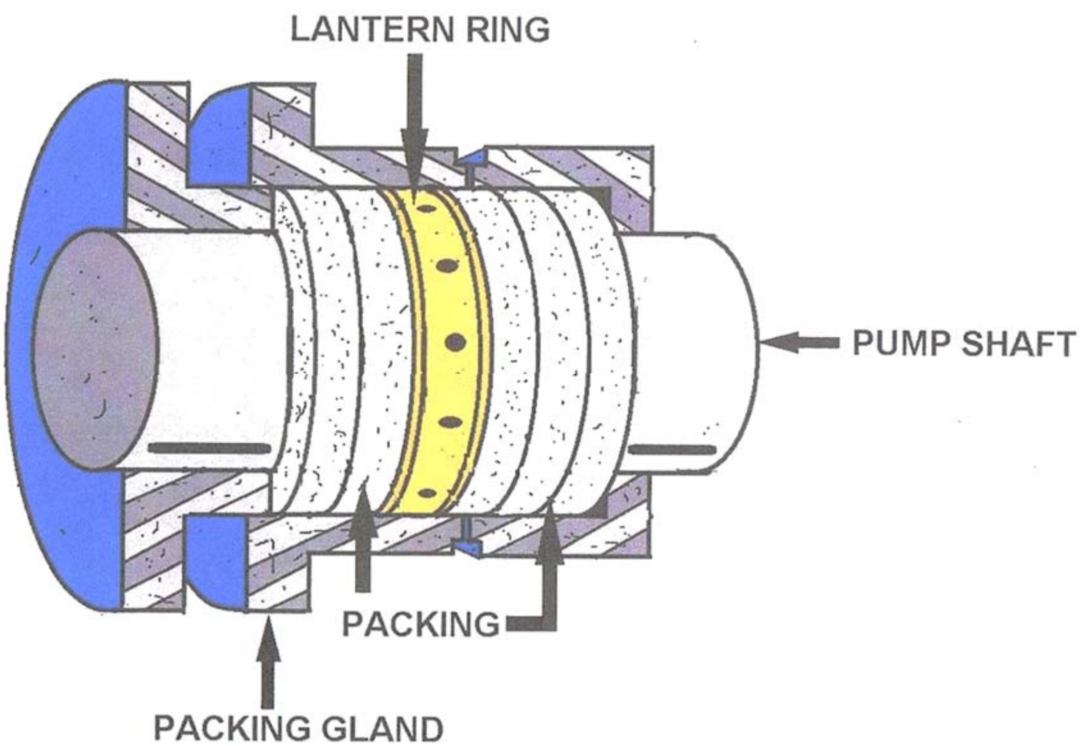
Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on rotary and positive-displacement pumps. Mechanical seals eliminate the problem of excessive stuffing box leakage, which causes failure of pump and motor bearings and motor windings.

Mechanical seals are ideal for pumps that operate in closed systems (such as fuel service and air-conditioning, chilled-water, and various cooling systems). They not only conserve the fluid being pumped, but also improve system operation.

The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for one of the seal faces and ceramic (tungsten carbide) for the other. When the seals wear out, they are simply replaced.

You should replace a mechanical seal whenever the seal is removed from the shaft for any reason, or whenever leakage causes undesirable effects on equipment or surrounding spaces. Do not touch a new seal on the sealing face because body acid and grease or dirt will cause the seal to pit prematurely and leak.

Mechanical shaft seals are positioned on the shaft by stub or step sleeves. Mechanical shaft seals must not be positioned by setscrews. Shaft sleeves are chamfered (beveled) on the outboard ends for easy mechanical seal mounting. Mechanical shaft seals serve to ensure that position liquid pressure is supplied to the seal faces under all conditions of operation. They also ensure adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.



Pump Troubleshooting Section

Some of the operating problems you may encounter with centrifugal pumps as an Operator, together with the probable causes, are discussed in the following paragraphs.

If a centrifugal pump **DOES NOT DELIVER ANY LIQUID**, the trouble may be caused by (1) insufficient priming; (2) insufficient speed of the pump; (3) excessive discharge pressure, such as might be caused by a partially closed valve or some other obstruction in the discharge line; (4) excessive suction lift; (5) clogged impeller passages; (6) the wrong direction of rotation (this may occur after motor overhaul); (7) clogged suction screen (if used); (8) ruptured suction line; or (9) loss of suction pressure.

If a centrifugal pump delivers some liquid but operates at **INSUFFICIENT CAPACITY**, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage into the stuffing boxes in pumps operating at less than atmospheric pressure; (3) insufficient pump speed; (4) excessive suction lift; (5) insufficient liquid on the suction side; (6) clogged impeller passages; (7) excessive discharge pressure; or (8) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump **DOES NOT DEVELOP DESIGN DISCHARGE PRESSURE**, the trouble may be caused by (1) insufficient pump speed; (2) air or gas in the liquid being pumped; (3) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves; or (4) reversed rotation of the impeller (3-phase electric motor-driven pumps).

If a pump **WORKS FOR A WHILE AND THEN FAILS TO DELIVER LIQUID,** the trouble may be caused by (1) air leakage into the suction line; (2) air leakage in the stuffing boxes; (3) clogged water seal passages; (4) insufficient liquid on the suction side; or (5) excessive heat in the liquid being pumped. If a motor-driven centrifugal pump **DRAWS TOO MUCH POWER**, the trouble will probably be indicated by overheating of the motor. The basic causes may be (1) operation of the pump to excess capacity and insufficient discharge pressure; (2) too high viscosity or specific gravity of the liquid being pumped; or (3) misalignment, a bent shaft, excessively tight stuffing box packing, worn wearing rings, or other mechanical defects.

VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure may also cause vibration, as well as noisy operation and fluctuating discharge pressure, particularly in pumps that handle hot or volatile liquids. If the pump fails to build up pressure when the discharge valve is opened and the pump comes up to normal operating speed, proceed as follows:

1. Shut the pump discharge valve.
2. Secure the pump.
3. Open all valves in the pump suction line.
4. Prime the pump (***fill casing with the liquid being pumped***) and be sure that all air is expelled through the air cocks on the pump casing.
5. Restart the pump. If the pump is electrically driven, be sure the pump is rotating in the correct direction.
6. Open the discharge valve to "**load**" the pump. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller may be broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump and continue troubleshooting according to the technical manual for that unit.

Centrifugal Pump Maintenance

When properly installed, maintained and operated, centrifugal pumps are usually trouble-free. Some of the most common corrective maintenance actions that you may be required to perform are discussed in the following sections.

Repacking

Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When operating a centrifugal pump, be sure there is always a slight trickle of water coming out of the stuffing box or seal. How often the packing in a centrifugal pump should be renewed depends on several factors, such as the type of pump, condition of the shaft sleeve, and hours in use.

To ensure the longest possible service from pump packing, make certain the shaft or sleeve is smooth when the packing is removed from a gland. Rapid wear of the packing will be caused by roughness of the shaft sleeve (or shaft where no sleeve is installed). If the shaft is rough, it should be sent to the machine shop for a finishing cut to smooth the surface. If it is very rough, or has deep ridges in it, it will have to be renewed. It is absolutely necessary to use the correct packing. When replacing packing, be sure the packing fits uniformly around the stuffing box. If you have to flatten the packing with a hammer to make it fit, **YOU ARE NOT USING THE RIGHT SIZE.** Pack the box loosely, and set up the packing gland lightly. Allow a liberal leak-off for stuffing boxes that operate above atmospheric pressure.

Next, start the pump. Let it operate for about 30 minutes before you adjust the packing gland for the desired amount of leak-off. This gives the packing time to run-in and swell. You may then begin to adjust the packing gland. Tighten the adjusting nuts one flat at a time. Wait about 30 minutes between adjustments. Be sure to tighten the same amount on both adjusting nuts. If you pull up the packing gland unevenly (or cocked), it will cause the packing to overheat and score the shaft sleeves. Once you have the desired leak-off, check it regularly to make certain that sufficient flow is maintained.

Mechanical Seals

Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on rotary and positive-displacement pumps. Mechanical seals eliminate the problem of excessive stuffing box leakage, which causes failure of pump and motor bearings and motor windings. Mechanical seals are ideal for pumps that operate in closed systems (such as fuel service and air-conditioning, chilled-water, and various cooling systems).

They not only conserve the fluid being pumped, but also improve system operation. The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for one of the seal faces and ceramic (tungsten carbide) for the other. When the seals wear out, they are simply replaced. You should replace a mechanical seal whenever the seal is removed from the shaft for any reason, or whenever leakage causes undesirable effects on equipment or surrounding spaces. Do not touch a new seal on the sealing face because body acid and grease or dirt will cause the seal to pit prematurely and leak.

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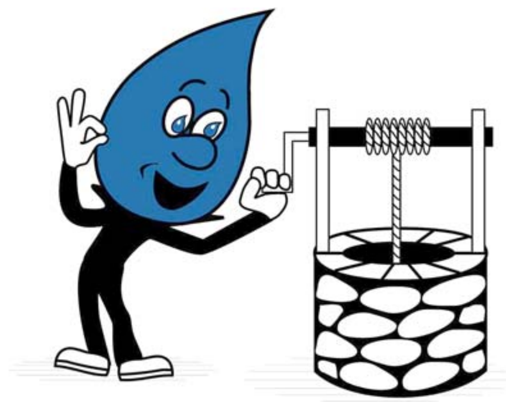
Mechanical shaft seals serve to ensure that liquid pressure is supplied to the seal faces under all conditions of operation. They also ensure adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.

Troubleshooting Table for Well/Pump Problems

1. Well pump will not start.
2. Well pump will not shut off.
3. Well pump starts and stops too frequently (excessive cycle rate).
4. Sand sediment is present in the water.
5. Well pump operates with reduced flow.
6. Well house flooded without recent precipitation.
7. Red or black water complaints.
8. Raw water appears **turbid** or a light tan color following rainfall.
9. **Coliform** tests are positive.

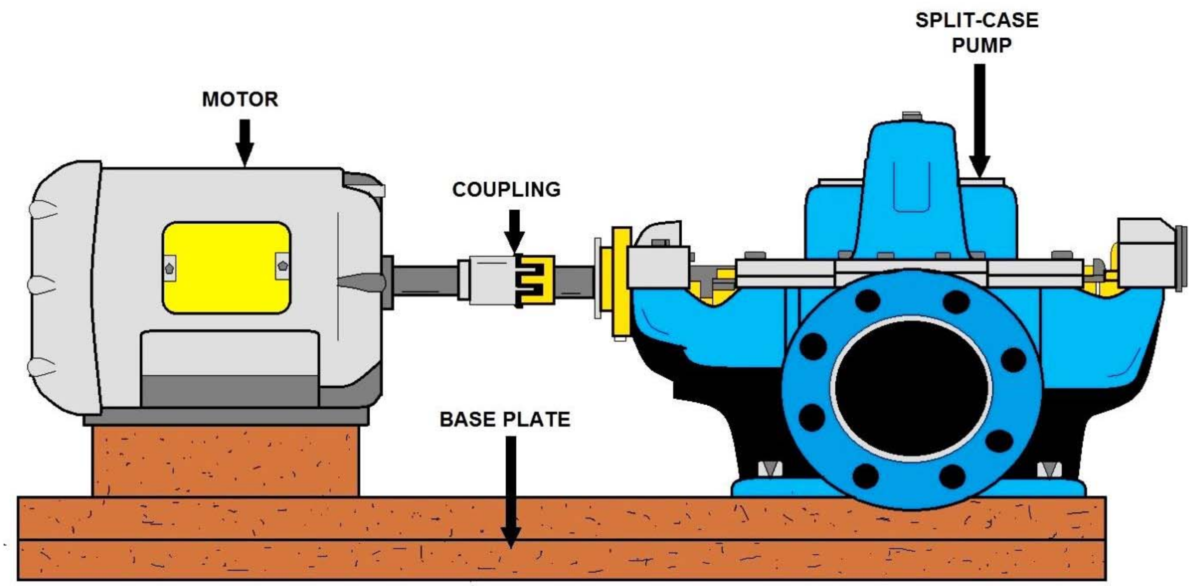
Possible Causes



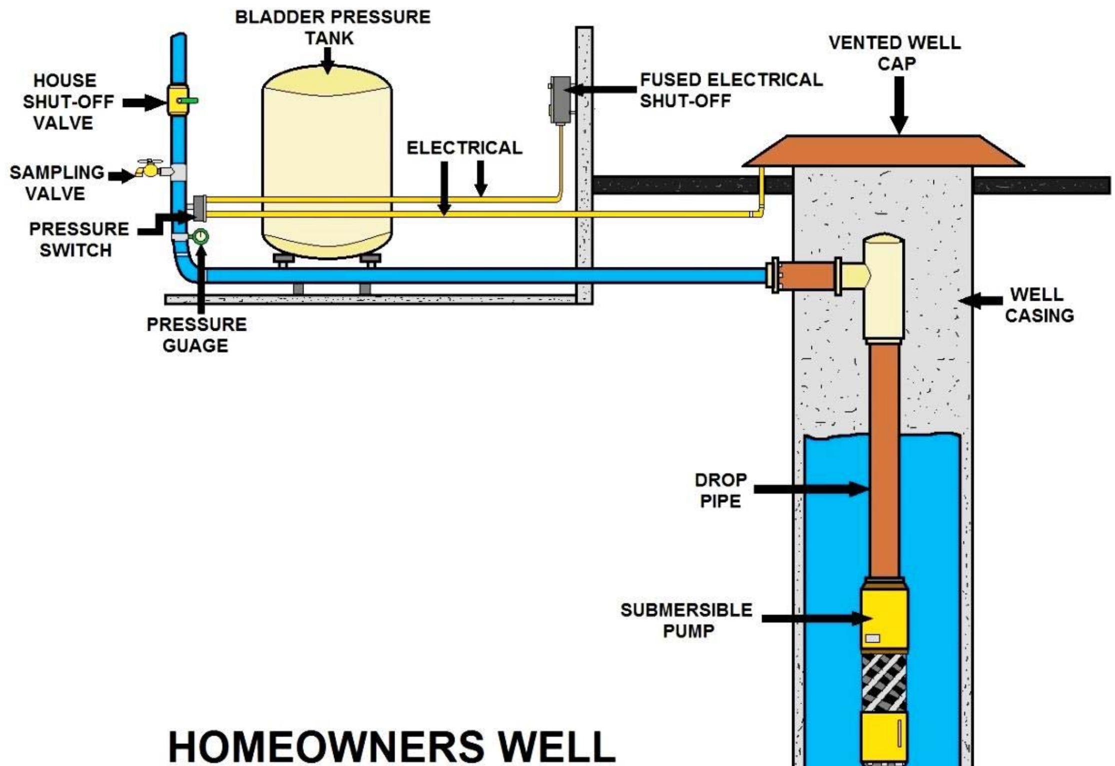
1A. Circuit breaker or overload relay tripped.
1B. Fuse(s) burned out.
1C. No power to switch box.
1D. Short, broken or loose wire.
1E. Low voltage.
1F. Defective motor.
1G. Defective pressure switch.
2A. Defective pressure switch.
2B. Cut-off pressure setting too high.
2C. Float switch or pressure transducer not functioning.
3A. Pressure switch settings too close.
3B. Pump foot valve leaking.
3C. Water-logged hydropneumatic tank.
4A. Problems with well screen or gravel envelope.
5A. Valve on discharge partially closed or line clogged.
5B. Well is over-pumped.
5C. Well screen clogged.
6A. **Check valve** not operating properly.
6B. Leakage occurring in discharge piping or valves.
7A. Water contains excessive **iron** (red brown) and/or **manganese** (black water).
7B. Complainant's hot water needs maintenance.
8A. Surface water entering or **influencing** well.
9A. Sample is invalid.
9B. **Sanitary protection** of well has been **breached.**

Possible Solutions
1A. Reset breaker or manual overload relay.
1B. Check for cause and correct, replace fuse(s).
1C. Check incoming power supply. Contact power company.
1D. Check for shorts and correct, tighten terminals, replace broken wires.
1E. Check incoming line voltage. Contact power company if low.
1F. Contact electrical contractor.
1G. Check voltage of incoming electric supply with pressure switch closed. Contact power company if voltage low. Perform maintenance on switch if voltage normal.
2A. Check switch for proper operation. Replace switch.
2B. Adjust setting.
2C. Check and replace components or cable as needed.
3A. Adjust settings.
3B. Check for **backflow**. Contact well contractor.
3C. Check air volume. Add air if needed. If persistent, check air compressor, relief valve, air lines and connections, and repair if needed.
4A. Contact well contractor.
5A. Open valve, unclog discharge line.
5B. Check **static water level** and compare to past readings. If significantly lower, notify well contractor.
5C. Contact well contractor.
6A. Repair or replace check valve.
6B. Inspect and repair/replace as necessary.
7A. Test for iron and manganese at well. If levels exceed 0.3 mg/L iron or 0.005mg/L manganese, contact regulatory agency, TA provider or water treatment contractor.
7B. Check hot water heater and flush if needed.
8A. Check well for openings that allow surface water to enter. Check area for **sinkholes**, **fractures**, or other physical evidence of surface water **intrusion**. Check water **turbidity**. Notify regulatory agency if >0.5 **NTU**. Check raw water for coliform **bacteria**. Notify regulatory agency immediately if positive.
9A. Check sampling technique, sampling container, and sampling location and tap.
9B. Notify regulatory agency immediately and re-sample for re-testing.

This brush is used to dislodge debris inside well casing.



CLOSED COUPLED PUMP



HOMEOWNERS WELL OR PITLESS ADAPTER

Pump Section Summary and Review Statements

Memorize every one of these statements.

In general, any *Centrifugal* pump can be designed with a multistage configuration. Each stage requires an additional *Impeller* and casing chamber in order to develop increased pressure, which adds to the pressure developed by the preceding stage.

In all centrifugal pumps, there must be a flow restriction between the impeller discharge and suction areas that will prevent excessive circulation of water between the two parts.

When a pump operates under suction, the impeller inlet is actually operating in a vacuum. Air will enter the water stream along the shaft if the packing does not provide an effective seal. It may be impossible to tighten the packing sufficiently to prevent air from entering without causing excessive heat and wear on the packing and shaft or shaft sleeve. To solve this problem, a Lantern Ring is placed inside the Stuffing Box.

A centrifugal pump consists of an impeller fixed on a rotating shaft that is enclosed in a casing, and has an inlet and discharge connection. As the rotating impeller spins the liquid around, force builds up enough pressure to force the water through the discharge outlet.

The foot valve is a special type of check valve located at the bottom end of the suction side of a pump. This valve opens when the pump operates to allow water to enter the suction pipe, but closes when the pump shuts off to prevent water from flowing out of the suction pipe.

A pump engineer will design a system that uses multiple pumps for a parallel operation in the case of the following: To provide for a fluctuating demand, to provide an increased discharge head, to reduce the friction coefficient on a larger pump for greater efficiency.

When multiple water pumps are installed for paralleled operation, the intent of the designer is to provide for a fluctuating demand, or for if one pump is out of service.

If the pump must operate under high suction head, the suction pressure itself will compress the packing rings, regardless of the operator's care. Packing will then require frequent replacement. Most manufacturers recommend using Mechanical Seals for both high and low-suction head conditions as well.

The mechanical seal is designed so that it can be hydraulically balanced. The result is that the wearing force between the machined surfaces does not vary, regardless of the suction head. Most seals have an operating life of 5,000 to 20,000 hours.

The axial-flow pump is often referred to as a Propeller Pump.

On most kilowatt meters, the current kilowatt load is indicated by disk revolutions.

If a single-phase motor is receiving adequate power and the run windings are operable, but the motor will not start, there is a problem with the start winding. A single-phase motor will have a capacitor start motor which has a high starting torque and a high starting current.

As the wear ring inside a centrifugal pump loses tolerance between it and the impeller, the efficiency of the pump will decrease.

Multistage centrifugal pumps can discharge high-pressure water. The pressure increases with the number of stages, but what happens to the capacity/ flow of the pump? The flow will remain the same through each stage.

With remote manual control, the operator is also required to turn a switch or push a button to operate equipment. Control devices which actuate equipment by inducing a magnetic field in the device are commonly known as solenoids.

Mechanical seals consist of two machined and polished surfaces which must contact each other. This contact is maintained by spring pressure.

The speed at which the magnetic field rotates is called the motor's synchronous speed. It is expressed in revolutions per minute. For a motor that operates on an electric power system having a frequency of 60Hz, the maximum synchronous speed is 3,600 rpm, or 60 revolutions per second. In other words, because the electric current changes its flow direction 60 times a second, the rotor can rotate 60 times per second. This speed is achieved by a two-pole motor. A wound-rotor induction motor would be expected to have the lowest demand for starting current.

The purpose of a sump on a vertical turbine pump is used to maintain adequate liquid above the suction level.

Friction Loss is the term used to describe head pressure or energy lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restriction by fittings.

Continuous leakage from a mechanical seal indicates an abnormal condition.

Wearing Rings

A new 8 inch submersible pump and motor with 6 inch column pipe
about to be installed in a high capacity municipal supply well.

The Well Head Assembly

An approved well cap or seal is to be installed at the *wellhead* to prevent any contamination from entering the well through the top once construction is complete. When the well is completed with pumping equipment a well vent is also required.

The well *vent pipe* should be at least ½ inch in diameter, 8 inches above the finished grade, and be turned down, with the opening screened with a minimum 24-mesh durable screen to prevent entry of insects. Only approved well casing material meeting the requirements of the Code may be utilized.

In addition, frost protection should be provided by use of insulation or pump house. Turbine and submersible pumps are normally used. Any pressure, vent, and electric lines to and from the pump should enter the casing only through a watertight seal.

Pumps and pressure tanks may be located in basements and enclosures. However, wells should not be located within vaults or pits, except with a *variance permit*.

If the pump discharge line passes through the well casing underground, an approved *pitless adapter* should be installed. The *well manifold* should include an air relief valve, flow meter, sample port, isolation valve, and a check valve. If the well should need rehabilitation, additional construction, or repair, it must be done in compliance with the State or Local Water Well Construction Codes.

Pump Assignment. **Please practice and memorize these pump related questions and answers. Answers are provided at the rear of this section.**

1. Which steps should be followed to complete the preventive maintenance of a greasing procedure?

2. What should be included on the maintenance of a pneumatically operated diaphragm pump?

3. How does a mechanical seal in a stuffing box receive lubrication?

4. Name one advantage a mechanical seal has over packing in a centrifugal pump.

5. What is the purpose of a check valve installed on the discharge side of a sump pump that is being used in a dry well?

6. A centrifugal pump is making noise and the efficiency of the pump is decreasing. The pump is dismantled and the impeller has pits on all of the vanes. What is a possible cause of the pitting?

7. For which of the following reasons might cavitation occur?

8. What is required to prevent damage to the face of a mechanical seal on a pump?

9. A lift station is equipped with two centrifugal self-priming trash pumps. The bubbler system is air locking and causing the pumps to overheat and shut off. What may be causing this problem?

10. What is used to compare the actual pump efficiency to its expected efficiency?

11. Which condition might cause a positive displacement diaphragm pump to cycle improperly?

12. What is the recommended type of fuse to use in the circuit leading to the electric motor?

13. Which valve would be the best choice to replace a suction side pump valve that is continually clogging?

14. What component might be tested using an Ohmmeter?

15. What describes the proper adjustment of the packing gland in a centrifugal pump?

16. Name one disadvantage of using mechanical seals in a centrifugal pump.

17. How much overload is a heater element on a motor starter usually rated at to drop the circuit?

18. If the voltage of the circuit to be tested is unknown, what should the meter be set on?

19. What is the expected voltage when testing the incoming voltage that is 220 VAC, single phase power?

20. What is the overload protection rating on magnetic starters?

21. What determines the capacity of a progressive pump?

22. What is an essential aspect of priming a pump?

23. What should be done with the motor disconnect switch when shutting down a pump for a long period?

24. What are the two basic types of propeller pumps?

25. What is the most important task when isolating a pump from service?

26. What is the name of a popular method of automatically controlling a pump, valve, chemical feeder, and other devices?

27. What do you call the use of a transmission line with remote signaling to monitor a pumping station?

28. What is a common problem with an electrical probe that is used to measure the level of water?

29. What may be the cause of a control system that is frequently turning a pump on and off?

30. What is the advantage of a double suction pump?

31. What is the maximum number of volts that electrical equipment can be insulated with a lower limit of 1 megaohm?

32. What should be done with a motor that after several years of testing with a Megger indicates low but stable and consistent values?

33. What will employ the use of a magnetic starter?

34. What will cause the deterioration of oil in a transformer?

35. What does continuous leakage from a mechanical seal on a pump indicate?

36. What is a possible cause of a scored shaft sleeve?

37. What does each stage of a multistage centrifugal pump require in order to develop increased pressure adding to the pressure developed by each preceding stage?

38. What is a possible result of over-greasing a bearing?

39. What is another name for an axial-flow pump?

40. What is one disadvantage of a centrifugal pump?

41. What is the common method used to secure an impeller to the shaft on double-suction pump?

42. What is the main purpose of the wear rings in a centrifugal double suction pump?

43. What maintains contact between the two surfaces of a mechanical seal?

44. Which pump is one of the most frequently used as a booster pump in a water distribution system?

45. What happens if grease comes in contact with the windings of a motor?

46. What is the maximum synchronous speed of an electric motor that has a frequency of 60Hz?

Math Pump Drill

Please show your work. Math conversions in rear of Glossary.

47. During a test for well yield, the time required to fill a 600 liter tank was 45.8 sec. Based on this pumping rate, what was the well yield in cubic feet per second?

48. A pump delivers 199 GPM. If the desired chlorine dose is 2.1 mg/L, what should the chlorinator be set at in pounds of chlorine per day?

49. A pump moves a liquid at the rate of 25 gpm. How many pounds per day are pumped if the liquid weighs 74.9 lb/ft^3?

50. A wet well measures 8' x 10' and measures 3' feet in depth between the high and low levels. A pump empties the wet well between the high and low level 9 times per hour, 24 hours a day. Calculate the flow in millions of gallons per day.

51. How much brake horsepower is required to meet the following conditions: 250 gpm, total head = 110 feet. The submersible pump that is being specified is a combined 64% efficient?

52. Calculate the pumping capacity (gpm) of a pump given the following information: -Wet well diameter 10 feet -Water drops 6 feet in 17.75 minutes

Answers for Pump Assignment

1. Run the motor for approximately 30 minutes before reinstalling the drain plug.
2. Periodic inspection of the packing and shaft sleeves
3. Through the seal water supply
4. Mechanical seals do not need routine adjustment
5. To prevent backflow due to back siphoning
6. Cavitation inside the pump
7. Several reasons, If modifications over time change the basic balance of the hydraulic system. If the system is not properly designed. If the wrong pump is used for a particular application.
8. Keep fresh water or filtered effluent on the face of the seal.
9. The bubbler line is plugged or restricted
10. Pump curve
11. Plugged exhaust port
12. Time-delay fuse
13. A plug valve
14. A Coil or relay
15. Tighten gland until there is a flow of 20 to 60 drops of water per minute.
16. Pump must be dismantled to repair
17. 0.1 or 10%
18. Highest range for voltage and work down
19. 110 volts.
20. A ten percent overload
21. The size of the cavity in which the rotor turns
22. Vent the excess air
23. Opened, Locked out, and Tagged.
24. Axial-flow impellers and mixed-flow impellers
25. Draining the volute of the pump
26. Relay logic
27. Telemetering links
28. The probe may be coated by calcium carbonate
29. The level controller may be set with too close a tolerance
30. A reduction in the thrust load that the bearings must carry
31. 1,000 volts
32. Nothing, but the testing should be continued
33. Large three-phase pump
34. Moisture
35. A mechanical seal needs to be replaced
36. The packing has broken down
37. An additional impeller bowl assembly
38. There is extreme friction in the bearing chamber
39. A propeller pump
40. It is not self-priming
41. A key and a tight fit
42. The wear rings maintain a flow restriction between the impeller discharge and suction areas
43. Spring pressure
44. A vertical turbine pump

45. The winding insulation may deteriorate
46. 3600 rpms
47. 0.46 CFS
48. 5
49. 360,360 lb/day
50. 0.39 MGD
51. 10.8 BHP
52. 199 gpm

Math Assignment

It is very important for you to practice the math assignment before coming to your exam review class. Get in a habit of writing the math problem and answer out to show your work. Write the formula and become very familiar with the math.

This is a simple exercise and a good practice review for you to prepare for the operator certification exam.

Long Math Answers for Pump Drill

47. During a test for well yield, the time required to fill a 600 liter tank was 45.8 sec. Based on this pumping rate, what was the well yield in cubic feet per second?

1. $\frac{600 \text{ L}}{1} \cdot \frac{1 \text{ GAL}}{3.785 \text{ L}} = 158.5 \text{ GAL} / 45.8 \text{ SEC.}$

2. $\frac{158.5 \text{ GAL}}{45.8 \text{ SEC}} \cdot \frac{1 \text{ CU FT}}{7.48 \text{ GAL}} = .463 \text{ CFS}$

48. A pump delivers 199 GPM. If the desired chlorine dose is 2.1 mg/L, what should the chlorinator be set at in pounds of chlorine per day?

1. LBS/DAY = FLOW x DOSE x 8.34 LB/GAL.

2. $\frac{199 \text{ GAL}}{1 \text{ MIN}} \cdot \frac{1440 \text{ MIN}}{1 \text{ DAY}} = \frac{286560}{1{,}000{,}000} = .28656 \text{ MGD}$

3. .28656 MGD x 2.1 mg/L x 8.34 lbs/gal = 5.02 lbs/DAY

49. A pump moves a liquid at the rate of 25 gpm. How many pounds per day are pumped if the liquid weighs 74.9 lb/ft^3?

1. $\frac{25 \text{ GAL}}{\text{MIN}} \cdot \frac{1 \text{ CU FT}}{7.48 \text{ GAL}} \cdot \frac{74.9 \text{ lbs}}{1 \text{ CU FT}} \cdot \frac{1440 \text{ MIN}}{1 \text{ DAY}} = 360481.28 \text{ lbs/DAY}$

$\frac{25 \text{ GAL}}{\text{MIN}} \cdot \frac{1440 \text{ MIN}}{1 \text{ DAY}} =$ 2. $\frac{\text{GAL}}{\text{DAY}} \cdot \frac{1 \text{ CU FT}}{7.48 \text{ GAL}} =$ 3. $\frac{\text{CU FT}}{\text{DAY}} \cdot \frac{74.9 \text{ lbs}}{1 \text{ CU FT}} = \frac{\text{lbs}}{\text{DAY}}$

50. A wet well measures 8' x 10' and measures 3' feet in depth between the high and low levels. A pump empties the wet well between the high and low level 9 times per hour, 24 hours a day. Calculate the flow in millions of gallons per day.

1. V = L x W x H

2. 8' x 10' x 3' = 240 CU FT.

3. $240 \text{ CU FT.} \times \frac{7.48 \text{ GAL}}{1 \text{ CU FT.}} = 1795.2 \text{ GAL}$

4. $1795.2 \text{ GAL} \times \frac{9 \text{ TIMES}}{1 \text{ HOUR}} \times \frac{24 \text{ HOURS}}{1 \text{ DAY}} = \frac{387763.2 \text{ GAL}}{1{,}000{,}000 \text{ DAY}} = .388 \text{ MGD}$

51. **How much brake horsepower is required to meet the following conditions: 250 gpm, total head = 110 feet. The submersible pump that is being specified is a combined 64% efficient?**

$$HPB = \frac{(GPM)\ (HEAD\ FT)}{(3960)\ (EFF)} = \frac{(250\ GPM)(110\ FT)}{(3960)\ (.64\%)} = \frac{27500}{2534.4}$$

$$\frac{27500}{2534.4} = 10.85\ BHP$$

52. **Calculate the pumping capacity (gpm) of a pump given the following information: -Wet well diameter 10 feet -Water drops 6 feet in 17.75 minutes**

1. 785 x DIAMETER^2 x DEPTH = V CU FT.

2. $.785 \times 10' \times 10' \times 6' = \underline{471}$ CU FT. $\times \frac{7.48\ GAL}{CU\ FT.} = \underline{3523.08}$ GAL

3. $\frac{3523.08\ GAL}{17.75\ MIN} = \underline{198.483}$ GPM

Safety Section Chapter 7

Excavation & Trenching

This section outlines procedures and guidelines for the protection of employees working in and around excavations and trenches. This section requires compliance with OSHA Standards described in Subpart P (**CFR 1926.650**) for the construction industry. Safety compliance is mandatory to ensure employee protection when working in or around excavations.

The competent person(s) must be trained in accordance with the OSHA Excavation Standard, and all other programs that may apply (examples Hazard Communication, Confined Space, and Respiratory Protection), and must demonstrate a thorough understanding and knowledge of the programs and the hazards associated. All other employees working in and around the excavation must be trained in the recognition of hazards associated with trenching and excavating.

REFERENCES

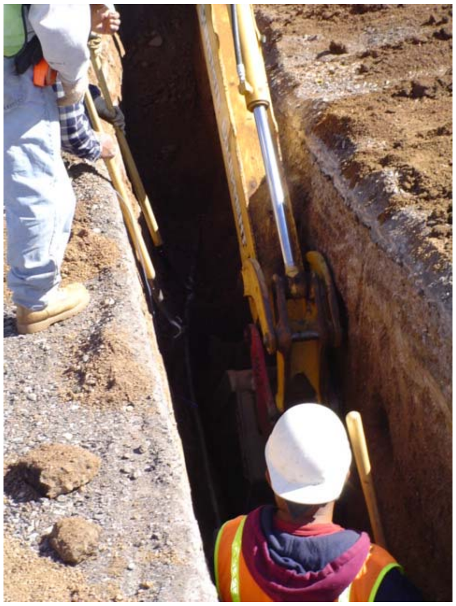
29 CFR 1926.650, Subpart P - Excavations

Excavation Equipment Manufacturer Safety Procedures

Hazards

One of the reasons OSHA requires a competent person on-site during excavation & trenching are the numerous potential hazardous that may be encountered or created. Hazards include:

- **Electrocution**
- **Gas Explosion**
- **Entrapment**
- **Struck by equipment**
- **Suffocation**



Hazard Controls
Before any work is performed and before any employees enter the excavation, a number of items must be checked and ensured:

Before any excavation, underground installations must be determined. This can be accomplished by either contacting the local utility companies or the local "**one-call'** center for the area. All under-ground utility locations must be documented on the proper forms. All overhead hazards (**surface encumbrances**) that create a hazard to employees must be removed or supported to eliminate the hazard.

If the excavation is to be over 20 feet deep, it must be designed by a registered professional engineer who is registered in the state where work will be performed.

Adequate protective systems will be utilized to protect employees. This can be accomplished through sloping, shoring, or shielding.

The worksite must be analyzed in order to design adequate protection systems and prevent cave-ins.

There must also be an excavation safety plan developed to protect employees.

Workers must be supplied with and wear any personal protective equipment deemed necessary to assure their protection.

*All spoil piles will be stored a minimum of **two (2) feet from** the sides of the excavation. The spoil pile must not block the safe means of egress.

If a trench or excavation is 4 feet or deeper, stairways, ramps, or ladders will be used as a safe means of access and egress. For trenches, the employee must not have to travel any more than 25 feet of lateral travel to reach the stairway, ramp, or ladder.

No employee will work in an excavation where water is accumulating unless adequate measures are used to protect the employees.

A competent person will inspect all excavations and trenches daily, prior to employee exposure or entry, and after any rainfall, soil change, or any other time needed during the shift. The competent person must take prompt measures to eliminate any and all hazards.

Excavations and trenches 4 feet or deeper that have the potential for toxic substances or hazardous atmospheres will be tested at least daily. If the atmosphere is inadequate, protective systems will be utilized.

If work is in or around traffic, employees must be supplied with and wear orange reflective vests. Signs and barricades must be utilized to ensure the safety of employees, vehicular traffic, and pedestrians.

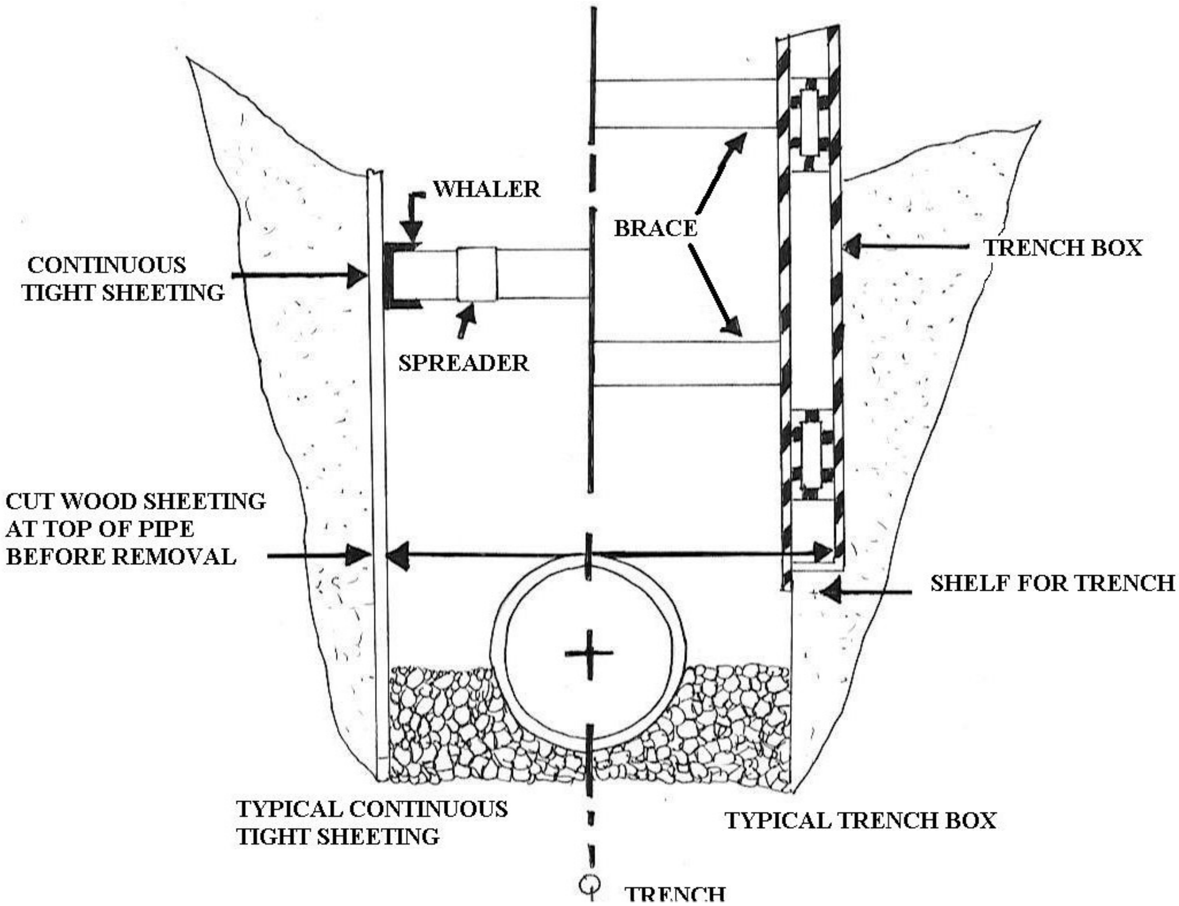
Competent Person Responsibilities
The OSHA Standards require that the competent person must be capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and have authorization to take prompt corrective measures to eliminate them and, if necessary, to stop the work.

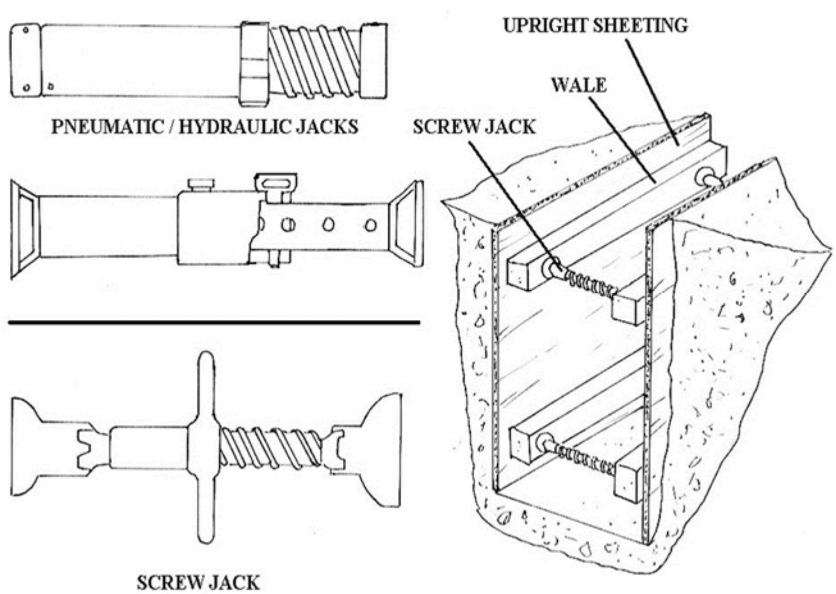
A competent person is required to:
- ✓ Have a complete understanding of the applicable safety standards and any other data provided.
- ✓ Assure the proper locations of underground installations or utilities, and that the proper utility companies have been contacted.
- ✓ Conduct soil classification tests and reclassify soil after any condition changes.
- ✓ Determine adequate protective systems (sloping, shoring, or shielding systems) for employee protection.
- ✓ Conduct all air monitoring for potential hazardous atmospheres.
- ✓ Conduct daily and periodic inspections of excavations and trenches.
- ✓ Approve design of structural ramps, if used.

Excavation Safety Plan
An excavation safety plan is required in written form. This plan is to be developed to the level necessary to ensure complete compliance with the OSHA Excavation Safety Standard and state and local safety standards.

Excavation safety plan factors:
- ✓ Utilization of the local one-call system
- ✓ Determination of locations of all underground utilities
- ✓ Consideration of confined space atmosphere potential
- ✓ Proper soil protection systems and personal protective equipment and clothing
- ✓ Determination of soil composition and classification
- ✓ Determination of surface and subsurface water

- ✓ Depth of excavation and length of time it will remain open
- ✓ Proper adherence to all OSHA Standards, this excavation and trenching safety program, and any other coinciding safety programs.





Confined Spaces are

-large enough to allow entry of any body part, and

-limited or restricted entry or exit, and

-not designed for continuous employee occupancy

Permit Required Confined Spaces are confined spaces that have any of the following
-potential hazardous atmosphere
-material inside that may engulf or trap you
-internal design that could trap or asphyxiate you
-any other serious safety or health hazard

Entry Permits are required before you enter any
"**Permit Required Confined Space**"

Hazards include
Fire & Explosion
Engulfment
Asphyxiation
Entrapment
Slips & Falls
Electric Shock
Noise & Vibration
Chemical Exposure
Toxic Atmospheres
Thermal / Chemical Burns

Engineering Controls
Ventilation
Locked Access
Lighting

Administrative Controls
Controlled Access
Hazard Assessments
Entry Permits & Procedures
Signs & Lockout Tagout
Training

Smart Safety Rules

Know what you are getting into.

Know how to get out in an emergency.

Know the hazards & how they are controlled.

Only authorized & trained personnel may enter a Confined Space or act as an attendant.

No smoking in Confined Space or near entrance or exit area.

Attendant must be present at all times.

Constant visual or voice communication must be maintained between the attendant and entrants.

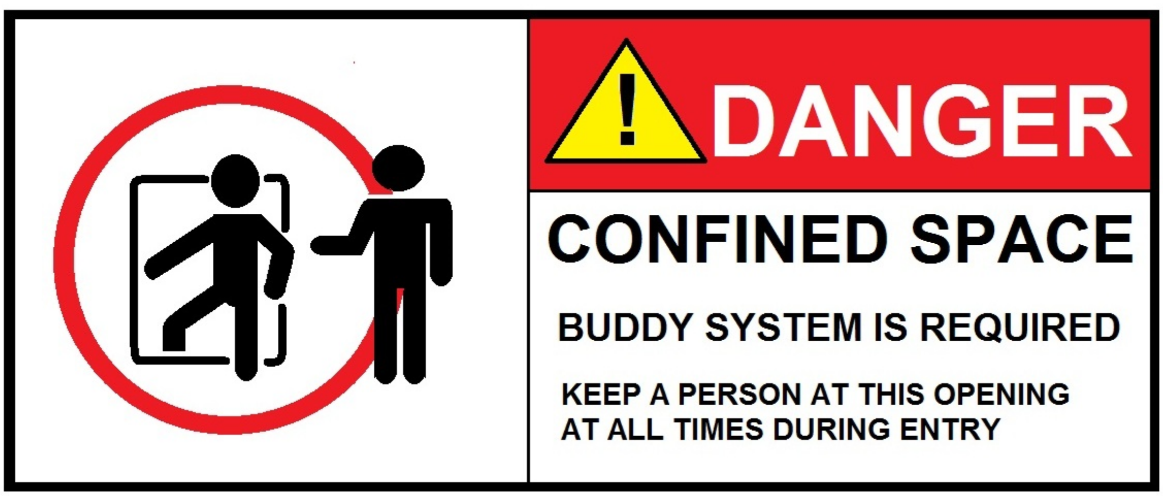
No bottom or side entry will be made, or work conducted below, the level any hanging material or material which could cause engulfment.

Air and oxygen Monitoring is required before entering a Permit-Required Confined Space.

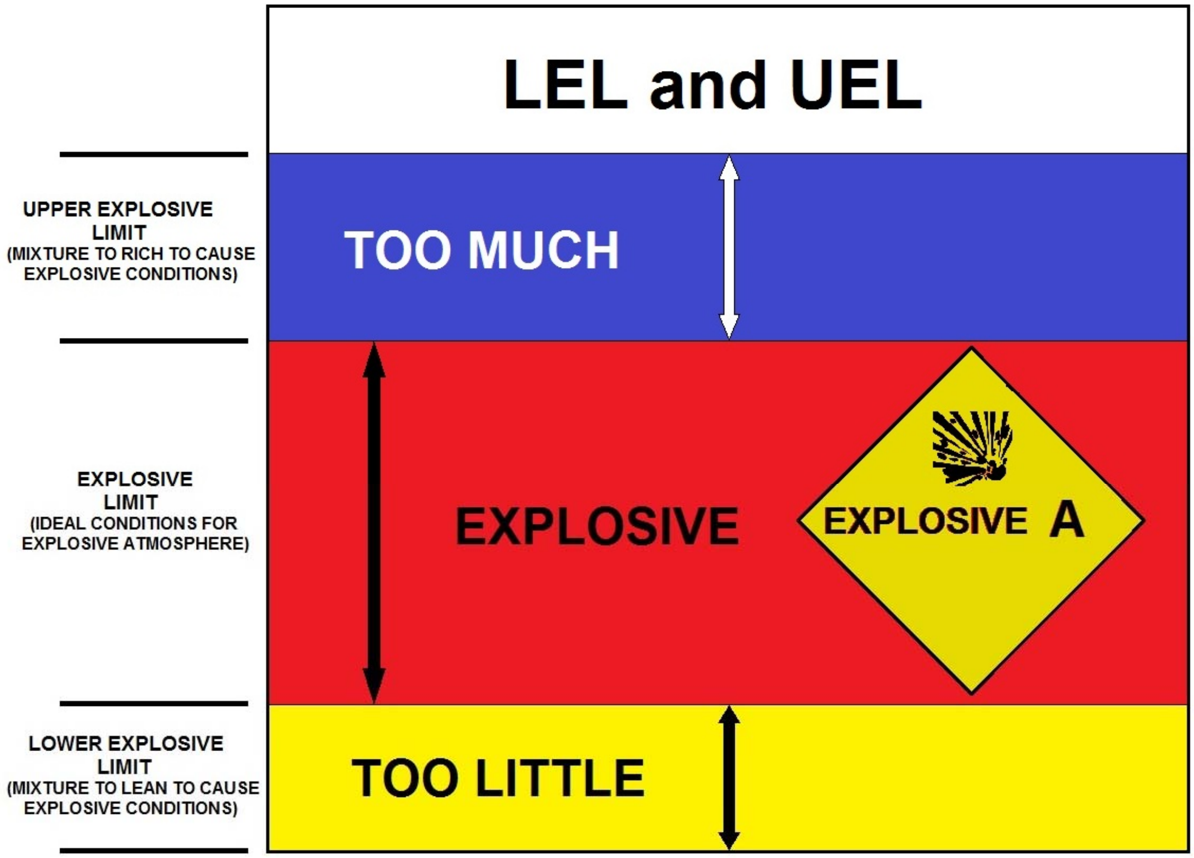
Ventilation & oxygen monitoring is required when welding is performed.

COMMON HAZARDOUS GASES THAT MAY BE PRESENT IN CONFINED SPACE					
SUBSTANCE *	8-HOUR TIME-WEIGHTED AVERAGE (TWA)	15-MINUTE SHORT-TERM EXPOSURE LIMIT (STEL)	CEILING LIMIT (Never To Be Exceeded)	IMMEDIATELY DANGEROUS TO LIFE AND HEALTH (IDLH)	RECOMMENDED ALARM SETTINGS (Low / High)
AMMONIA	25 ppm	35 ppm	—	300 ppm	13 ppm / 25 ppm
CARBON MONOXIDE	25 ppm	100 ppm	—	1200 ppm	13 ppm / 25 ppm
CHLORINE	0.5 ppm	1 ppm	—	10 ppm	0.25 ppm / 0.5 ppm
HYDROGEN SULFIDE	—	—	10 ppm	100 ppm	5 ppm / 10 ppm
METHANE	1000 ppm	—	—	—	500 ppm / 1000 ppm
NITROGEN DIOXIDE	—	—	1 ppm	20 ppm	0.5 ppm / 1 ppm
SULFUR DIOXIDE	2 ppm	5 ppm	—	100 ppm	1 ppm / 2 ppm
OXYGEN	—	—	—	—	20.5 % of Atmosphere
LOWER EXPLOSIVE LIMIT (LEL)	—	—	—	—	5 % LEL

EXAMPLE OF A CHART OF CONFINED SPACE GASES



EXAMPLE OF A CONFINED SPACE ENTRY DANGER SIGN



UNDERSTANDING UPPER (UEL) & LOWER (LEL) EXPLOSIVE LIMITS

Safety Review Statements *Memorize these statements for your exam.*

What is the definition of “stable rock” regarding a trench excavation? This is natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed.

What is the maximum allowable slope and height/depth ratio for type B soils in excavations less than 20 ft (6.09 m)? The slope is 45 degrees and height/depth ratio 1:1.

What is the maximum distance between horizontal cross braces for each zone in a trench? 4 feet apart.

What does the term "relative compaction" refer to? The level of compaction obtained compared to the level possible under ideal conditions.

What is the maximum distance between ladders and how far above the excavation should ladders be in trenches 4 ft or more in depth? Spacing between ladders should be no more than 25 ft laterally to the nearest means of egress and extend a minimum of 36 in (10.98 m) above the landing.

What is this classification of material that includes granular soils such as gravel, sand and loamy sand, submerged soil, and soil from which water is freely seeping? Type C soils.

When a trench is dug for a new line or replacement of an old line, it should be dug and backfilled in such a manner to support the pipe. What is used to determine the width of the trench? Narrow as possible for safety and to increase pipe sidewall support.

When backfilling around a flexible pipe, what could happen if the load above the pipe is too great? The pipe could deflect and collapse.

When uprights are installed during the shoring activity, the operator must place them at required intervals along the trench wall. Where should the uprights be placed? At the top of the trench and within two feet of the bottom.

Why are hydraulic shores usually not used on jobs exceeding five (5) days in length? There is a possibility of the hydraulic pressure bleeding off during this length of time.

If a trench is more than five feet deep where must the spoil be placed? At least 2 feet from the trench and only on one side of the trench.

What is the minimum compaction height of backfill when laying piping in Class A or Class B bedding? 12 inches.

What could possibly happen when groundwater is removed from a construction site or trench? Subsidence of ground and/or adjacent structures.

What is the maximum depth of the cut below the bottom of a shield when used for earth excavation? Earth excavation to a depth of 2 ft (0.61 m) below the shield is permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench.

What the definition of a “trench” excavation? This is a narrow excavation (in relation to its length) made below the surface of the ground.

Which fluid is recommended for use in hydraulic shoring equipment? Hydraulic shoring fluid.

When should atmospheric monitoring in a confined space be performed? Continuously from pre-entry to exit.

Below what maximum percentage is an atmosphere considered oxygen deficient? 19.5% or sometimes written .195.

The detailed plan for emergency response to an injury or other emergency within the confined space should be described in detail in what kind of program? The water system's Confined Space Entry Program.

What does entry into a confined space require? A confined space entry permit.

What is the definition of a hazardous atmosphere? An atmosphere that is explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful that may cause death, illness, or injury.

What type of Confined Space Entry permit is required when operations may cause a source of ignition to a material or substance or create a work induced hazard by ignition within any confined space? Two different permits, Confined space entry Permitted Entry, Hot Work permit type is required.

Which type of confined space has the characteristic of containing or has the potential to contain a hazardous atmosphere? Type 2 confined space or permit required confined space.

What is the definition of an "Energy Isolating Device"? A mechanical device that physically prevents the transmission or release of energy.

The following are all listed as forms of hazardous energy under OSHA 29 CFR 1910.147: Electrical energy in a pump station; hydraulic pressure in a pipeline, known as static **Head**; Mechanical energy in a surge-relief valve; but not magnetic energy in a motor coil.

Two poor souls trying to get killed in a thirty foot deep trench without any trench protection.

Safety Review Practice *Exam Answers at rear.*

1. What is the maximum depth of the cut below the bottom of a shield when used for earth excavation?

2. What is the maximum distance between ladders and how far above the excavation should ladders be in trenches 4 ft or more in depth?

3. What is the maximum allowable slope and height/depth ratio for type B soils in excavations less than 20 ft ?

4. The detailed plan for emergency response to an injury or other emergency within the confined space should be described in detail in what kind of program?

5. What type of Confined Space Entry permit is required when operations may cause a source of ignition to a material or substance or create a work induced hazard by ignition within any confined space?

6. What critical safety advantage does hydraulic shoring have over timber shoring?

7. What is the definition of “stable rock” regarding a trench excavation?

8. What is the definition of a hazardous atmosphere?

9. What is the definition of an "Energy Isolating Device"?

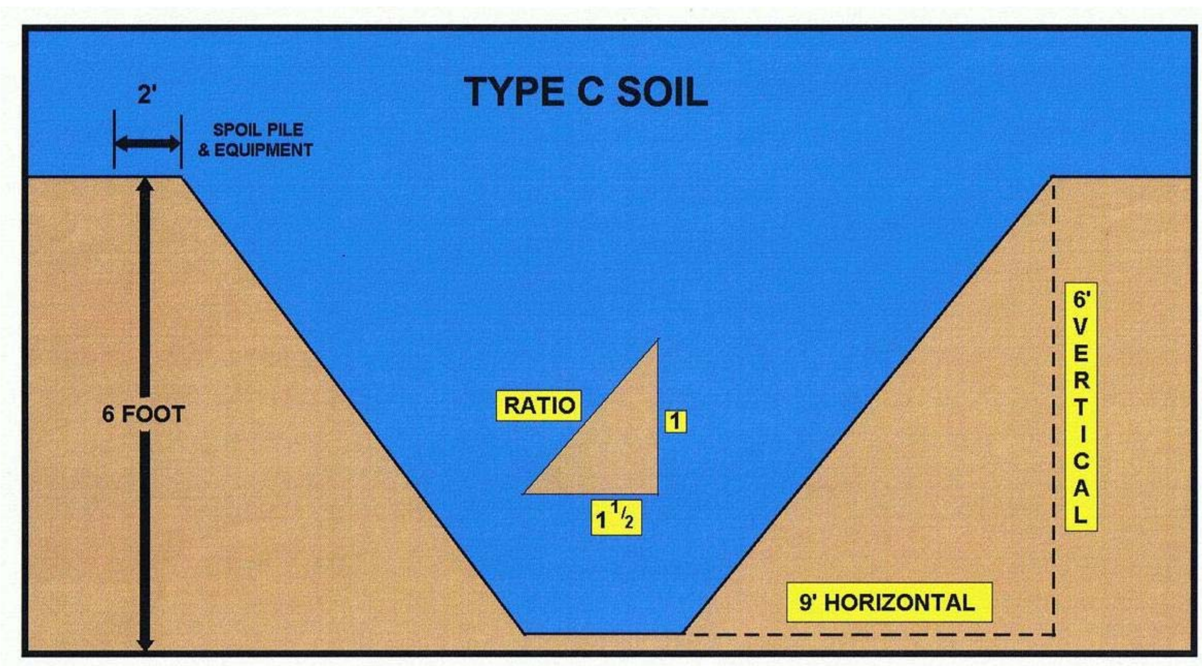
10. What is the classification of material that includes granular soils such as gravel, sand and loamy sand, submerged soil, soil from which water is freely seeping?

11. What the definition of a “trench” excavation?

12. How should the presence of a confined space be identified to an employee?

Safety Review Answers

1. Earth excavation to a depth of 2 ft below the shield is permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench
2. Spacing between ladders should be no more than 25 ft laterally to the nearest means of egress and extend a minimum of 36 in above the landing.
3. The slope is 45 degrees and height/depth ratio 1:1
4. The water system's Confined Space Entry Program
5. Confined space entry Permitted Entry, Hot Work permit type is required
6. Are light enough to be installed by one worker and workers do not have to enter the trench to install or remove hydraulic shoring
7. This is natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed
8. An atmosphere that is explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful that may cause death, illness, or injury
9. A mechanical device that physically prevents the transmission or release of energy
10. Type C soils
11. This is a narrow excavation (in relation to its length) made below the surface of the ground
12. By clearly posting the appropriate signage at all entries to a confined space



First General Practice Exam ***Answers at rear.***

1. What is the general definition of an ion? An ______________ with a positive or negative charge.

2. A continuous positive pressure in a distribution system is essential for preventing what event?

3. ____________________ water pressure must be maintained to ensure adequate customer service during peak flow periods. However, minimum positive pressure must be maintained in mains to protect against backflow or backsiphonage from cross-connections.

4. Name the most common ***CAUSE*** for public water supply contamination. _________________ or cross-connection.

5. What does a backsiphonage condition usually cause? _______________ pressure or negative pressure on the service or supply side.

6. What does a double check valve backflow assembly provide effective protection from? Both backpressure and backsiphonage of _____________________.

7. What is equipment that utilizes water for cooling, lubrication, washing or as a solvent always susceptible to?

8. What is the difference between a reduced pressure principle backflow device and a double check backflow device? The RP has a ________________________________.

9. What is the maximum time period between having a backflow device tested by a certified backflow tester? ___________ year.

10. What is the regulatory definition of a cross-connection in a water supply? A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the ______________________ through backflow.

11. , What is the name of a type of valve that reduces the differential pressure across a closed disk making the main valve easier to open and close?

12. As soon as CL2 gas enters the throat area, a victim will sense a sudden stricture in this area- Nature's way of signaling to prevent passage of the gas to the lungs. At this point, the victim must attempt to do two things: get out of the area of the leak, proceeding upwind, and to take only very short breaths through the mouth. Normal breathing will cause ______________, which must be prevented if possible.

13. Chlorine gas causes suffocation, constriction of the chest, tightness in the throat, and edema of the ___________________.

14. _________________ available chlorine is very effective in killing bacteria.

15. How should an operator store an empty chlorine cylinder? _____________, tagged as empty.

16. If a chlorine leak occurs, where will chlorine gas accumulate? Near the ________________ of the tank.

17. What effect does chlorine gas have on the sense of smell? It produces olfactory ______________.

18. What is the primary safety concern when using chlorine gas as opposed to calcium hypochlorite or sodium hypochlorite? The potential for a _______________ leak.

19. What may occur due to chronic exposure to low concentrations of chlorine gas? Chronic exposure may cause corrosion of the ___________________.

20. What is the process called that changes water vapor to tiny droplets or ice crystals?

21. What is the unit of measurement for sound?

22. What happens if grease comes in contact with the winding of a motor? The winding insulation may deteriorate.

23. What is the most common type of valve used in isolating a small or medium sized section of a distribution system?

24. What is a possible result of over greasing a bearing? There is extreme ______________ in the bearing chamber causing heat and scoring of the shaft.

25. What is meant by the term "***peak demand***?" The ______________ momentary load placed on a water treatment plant, pumping station or distribution system.

26. What is the range of the pH scale? between ______________ - 14.

27. What does a Bellows-type sensor reacts to a change in? ______________________.

28. Centrifugal pumps do not generate suction unless the impeller is submerged in water. If a pump is located above the level of water what must be provided on the suction piping to hold the prime? What causes pump cavitation? A suction line may be ___________ or the pump is above the waterline. You have over-pumped the well.

29. What does continuous leakage from a mechanical seal on a pump indicate? The mechanical seal needs to be ____________________.

30. What is a possible cause of a scored shaft sleeve? The _______________ has broken down

31. What is one disadvantage of a centrifugal pump? It is not ______________________.

32. What is the best seal to use for a pump operating under high suction head conditions? A ______ seal.

33. What is the common method used to secure an impeller to the shaft on double-suction pump? A _________________and a tight fit.

34. What is the main purpose of the wear rings in a centrifugal double suction pump? The wear rings maintain a flow ________________ between the impeller discharge and suction areas.

35. What is the purpose of the foot valve on a pump? It keeps the pump ______________.

36. At which type of facility is a remote operator allowed to operate? Any Grade 1 or Grade 2 _____________.

37. At which type of facility is an on-site operator mandatory? All grade __ and Grade __ facilities.

38. How close must a certified operator of a facility live to a facility to legally operate the facility as a remote operator? Within 200 miles by ______________ travel.

39. Systems with what types of source water are required by law to treat using filtration and disinfection? _______________ under the direct influence of surface water and surface water sources.

40. The quality of water in a storage facility could degrade due to excessive water age caused by low demand and short-circuiting within the distribution storage reservoir. Which of the following is not a reason for water quality degradation? The water quality _____________ program is not in compliance.

41. What is the definition of an "***on-site operation***?" An operator who visits a facility at least _______ to ensure that it is operating properly.

42. What is the definition of an "***on-site representative***?" On-site representative means a person located at a facility that monitors the daily operation at the facility and maintains contact with the _______________ operator regarding the facility.

43. What is the frequency that a remote operator must inspect a grade 1 or grade 2 water treatment plant or distributes groundwater? As often as necessary but no less then _____________________.

44. What is the objective of a vulnerability assessment? To determine ________________ in the distribution or water system.

45. How far from the edge of a hole must you place the spoil from an excavation?

46. Before beginning an excavation, who should be contacted to assist in determining the location of all underground utilities in the work area? An "***Underground Service Alert***" center, "***One Call Center***" or _____________________________, all three of these are the same.

47. This type of chemical classification may weaken, burn, or destroy a person's skin or eyes and can be either acidic or ___________________.

48. How should a supervisor warn an operator about the presence of a confined space? By clearly posting the appropriate _______________ at all entries to a confined space.

49. List the correct order for placing shoring equipment in a trench. Starting at the top move to the bottom of the trench and _____________________ to remove it.

50. How frequently should ladders and climbing devices be inspected by a qualified individual?

51. What is the name of a map that provides detailed drawings of the distribution system's zones?

52. What maintains contact between the two surfaces of a mechanical seal?

53. What does the work "***stationing***" on a plan drawing refer to? It is a representation of a location from a starting point or reference.

54. Generally, how long will a water storage tank's interior coating (paint) protect the interior? _______________ years.

55. What is the name of the valve that is specifically designed for connecting a new water main to an existing main that is under pressure?

56. Define the term “***Water Hammer***.” A ____________________ in a pipeline resulting from the rapid increase or decrease in water flow.

57. Water hammer exerts tremendous force on a system and can be highly ___________________.

58. How should a water meter that is removed from service for repair be handled? ______________ the meter to retain water.

59. Name the three main classifications of water meters. Compound, Displacement, and __________.

60. Peak day demand is the greatest amount of water used for any one _____________ in a calendar year.

61. What negative effect does a water meter have on a service? _______________ loss may occur.

62. Name the 4 broad categories of water quality. Physical, __________________, biological, radiological.

63. What are disease causing organisms such as bacteria and viruses called?

64. What does a positive bacteriological sample indicate? The _________________ of bacteriological contamination.

65. What is the name of the area from which surface runoff is carried away by a single drainage system?

66. What is an advantage of a “***wet tap***” vs. a “***dry tap***?” You do not need to ________________ the water line down.

67.What is the most likely type of symptom one could expect upon exposure to a very small percentage of chlorine in the air? A ___________________sensation in the eyes and throat.

68. What must an operator ensure when installing a pressure vacuum breaker backflow device? It must be at least ____________________ inches about the highest downstream outlet.

Answers to first general practice exam

1. Atom
2. Backflow Event
3. Minimum
4. Backflow
5. Reduced
6. Pollution
7. Cross-Connection
8. Relief Valve
9. 1
10. PWS
11. Bypass Valve
12. Coughing
13. Lungs
14. Free
15. Upright
16. Bottom
17. Fatigue
18. Gas
19. Teeth
20. Condensation
21. Decibels
22. Deteriorate
23. Gate
24. Friction
25. Maximum
26. Zero
27. Pressure
28. Clogged
29. Replaced
30. Packing
31. Self-Priming
32. Mechanical
33. Key
34. Restriction
35. Primed
36. Facility ***Depends on your State***
37. 3&4 ***Depends on your State***
38. Ground
39. Groundwater
40. Sampling
41. Daily ***Depends on your State***
42. Remote ***Depends on your State***
43. Monthly ***Depends on your State***
44. Weakness
45. 2 feet
46. Bluestake
47. Basic, Alkaline or corrosive
48. Signage
49. Reverse
50. Once a year
51. Sectional Maps
52. Spring Pressure

53. Stationing
54. 3-5 years
55. Tapping Valve
56. Pressure Surge
57. Destructive
58. Seal
59. Velocity
60. Day
61. Head
62. Chemical
63. Pathogens
64. Presence
65. Watershed
66. Down or turn off
67. Burning
68. 12 Inches

Second General Practice Exam

Answers in Rear of this assignment. You can find the answers in the Sacramento and AWWA manual.

1. In general, any ___________pump can be designed with a multistage configuration. Each stage requires an additional __________ and casing chamber in order to develop increased pressure, which adds to the pressure developed by the preceding stage.
AWWA Chap. 12, Page 360 Topic GK
A. Submersible, Diffuser
B. Centrifugal, Impeller
C. Displacement, Volute
D. Centrifugal, Foot valve
E. None of the above

The axial-flow pump is often referred to as a ________________.
AWWA Chap. 12, P. 360 Topic GK
A. Propeller Pump
B. Submersible Pump
C. Hydraulic pump
D. None of the above

3. In all centrifugal pumps, there must be a flow restriction between the __________ discharge and _____________ areas that will prevent excessive circulation of water between the two parts. AWWA Chap. 12, page 380 Topic GK
A. Wear ring & Foot valve
B. Impeller & Suction
C. Lantern Ring & Shaft Sleeve
D. Packing rings & Shaft

4. This type of valve is designed to, 1. Prevent overflows from the storage tank or reservoir, or 2. Maintain a constant water level as long as water pressure in the distribution system is adequate. SAC. Sec 2.31 Topic WS
A. Double Check
B. PVB
C. Air Relief
D. Ball
E. Altitude-Control Valve

5. When a pump operates under suction, the impeller inlet is actually operating in a vacuum. Air will enter the water stream along the shaft if the packing does not provide an effective seal. It may be impossible to tighten the packing sufficiently to prevent air from entering without causing excessive heat and wear on the packing and shaft or shaft sleeve. To solve this problem, a _______ is placed in the Stuffing Box. AWWA Chap. 12 p. 382 Topic PM
A. Lantern Ring
B. Packing Gland
C. Sanitary seal
D. Wye
E. None of the above

6. If the pump must operate under high suction head, the suction pressure itself will compress the packing rings regardless of the operator's care. Packing will then require frequent replacement. Most manufactures recommend using ______________ for low-suction head conditions as well. AWWA Chap 12 page 382 Topic GK
A. Mechanical Seals
B. Graphite
C. Vibration devices
D. Flow controls
E. All of the above

7. The mechanical seal is designed so that it can be hydraulically balanced. The result is that the wearing force between the machined surfaces does not vary regardless of the suction head. Most seals have an operating life of _____________. AWWA Chap 12 page 383 Topic GK
A. 5,000 to 20,000 hours
B. 50,000
C. 75,000
D. 1 million hours

8. The speed at which the magnetic field rotates is called the motor's synchronous speed. It is expressed in revolutions per minute. For a motor that operates on an electric power system having a frequency of 60Hz, the maximum synchronous speed is 3,600 rpm, or 60 revolution per second. In other words, because the electric current changes its flow direction 60 times a second, the rotor can rotate 60 times per second. This speed is achieved by?
AWWA Chap. 13, Page 400, Topic GK
A. The Starting Current
B. Squirrel cage
C. A two-pole motor
D. A three phase stator
E. All of the above

9. ____________ is a condition in which the pressure in the distribution system is less than atmospheric pressure. In other words, something is "sucked" into the system because the main is under a vacuum. AWWA Chap 11 page 315 Topic GK
A. Backsiphonage
B. Backpressure

10. Float mechanisms, diaphragm elements, bubbler tubes, and direct electronic sensors are?
AWWA Chap. 14 page 437
A. Types of valves
B. Methods of telemetry
C. Common types of level sensors
D. Out dated methods of measuring flows
E. All of the above

Which of the following is a correct statement concerning a single phase motor.
AWWA Chap 13 page 402 Topic GK
A. If it is a split-phase motor, the motor will not have windings.
B. A repulsion-induction motor is very simple and less expensive than other single phase motors.
C. Will have a capacitor start motor has a high starting torque and a high starting current.
D. All of the above
E. None of the above

12. A chlorine demand test from a well water sample produces a result of 1.2 mg/L. The water supplier would like to maintain a chlorine residual of 0.2 mg/L throughout the system. What should be the chlorine dose in mg/L from either a chlorinator or a hypochlorinator?
SAC. Sec. 6.710 Example 11 Topic MA
A. 1.2
B. 0.2
C. 1.0
D. 1.4

13. The vacuum created by a chlorine ejector moves through this device. This device prevents water from back feeding or entering the vacuum-regulator portion of the chlorinator.
SAC. Sec. 6.400 Topic GK
A. Rate valve
B. The ejector
C. Interconnection manifold
D. Check valve assembly
E. Rotameter

14. A section of an old 8-inch water main has been replaced and a 350-fot section of pipe needs to be disinfected. An initial chlorine dose of 400 mg/l is expected to maintain a chlorine residual of over 300 mg/L during the three-hour disinfection period. How many gallons of 5.25 percent sodium hypochlorite solution will be needed? SAC. Sec. 6.701 Ex. 9 Topic MA
A. 7 Gallons
B. 9 Gallons
C. 923 Gallons
D. 3.08 Gallons
E. None of the above

15. A trench four feet wide, 1,100 feet long and six feet deep is to be excavated for a water main. How many cubic feet of soil have to be excavated for this water main?
SAC. Sec. A.133 Example 18 Topic MA
A. 978
B. 27
C. 26,400
D. 11,000
E. None of the above

16. Water from a well is being treated by a hypochlorinator. If the hypochlorinator is set at a pumping rate of 50 gallons per day (GPD) and uses a 3 percent available hypochlorite solution, what is the chlorine dose rate in mg/L if the pump delivers 350 GPM?
SAC. Sec. 6.712 Example 15 Topic MA
A. 12.5
B. 0.5
C. 8.34
D. 3
E. None of the above

17. A 50,000 gallon storage tank is to be disinfected with a chlorine solution of 50 mg/L. How many pounds of chlorine (gas) will be needed? SAC. Sec. 5.82 Topic MA
A. 21
B. 8.34
C. .05
D. None of the above

18. Estimate the C Factor for a 10-inch water main. When the flow is 800 GPFM, the drop in pressure head elevation between two pressure gages 500 feet apart is two (2) feet?
SAC. Sec. A.132 Example 10 Topic MA
A. 132
B. 193.75
C. 251
D. None of the above

19. A hypochlorite solution for a hypochlorinator is being prepared in a 55-gallon drum. If 10 gallons of 5 percent hypochlorite is added to the drum, how much water should be added to the drum to produce a 1.3 percent hypochlorite solution?
SAC. Sec 6.712 Example 18 Topic MA
A. 1.3 Gallons
B. 13 Gallons
C. 3 Gallons
D. None of the Above

20. A deep-well turbine pump delivers 250 GPM against typical operating heads. If the desired chlorine dose is 2.5 mg/L, what should be the chlorine feed rate in pounds per day?
SAC. Sec. A.134 Example 27 Topic MA
A. 7.5 lbs/day
B. 2.5 lbs./day
C. 0.30 lbs./day
D. 17.5 lbs./day
E. None of the above

21. An underground rectangular water storage tank must be drained and cleaned. The tank is 30 feet long and 10 feet wide. The groundwater is 5 feet above the bottom of the tank. What is the force of the water pressure lifting upward on the bottom of the tank?
SAC. Sec. A132 Example 9 Topic MA
A. 300
B. 62.4
C. 3,600
D. 93,600

22. A 6 inch diameter water main is to be flushed at a 4 ft/sec before disinfection. What should be the reading on the flowmeter in gallons per minute? SAC. Sec.5.81 Topic MA
A. 352
B. 144
C. .785
D. 50

23. One of the roles of a distribution system supervisor is to inform the operators of SOPs concerning public relations. This can be accomplished by? AWWA Chap. 16 P. 522   Topic MG
Installing two way radios in each truck
A. Regular informational staff meetings
B. Giving exams
C. Publishing the procedures and posting in the crew room

24. Uniforms and proper credentials aid meter readers and operators that work close to private property because they help? AWWA Chap. 16 P. 517-518 Topic MG
A. Readily identify personnel
B. Cash pay checks
C. Alter behavior
D. All of the above

25. Which of the following is responsible for the enforcement of building regulations?
SAC. Sec. 5.31 Topic MG
A. The Crew Leader
B. The Building Inspector
C. The Supervisor
D. Depends if anyone is around
E. None of the above

26. A water storage facility should be able to provide water for the ____________ and _____ demands. SAC. Sec 2.0 Topic WS
A. Typical, Fire
B. Average, Peak
C. Fire, Peak
D. Maximum, Minimum
E. None of the above

27. What is the peak demand?   SAC. Sec 2.0 Topic WS
A. The maximum momentary load placed on a water treatment plant, pumping station or distribution system.
B. The total demand for water during the period of time divided by the number of days in that time period.
C. None of the above

28. Surge tanks are used to control? Sac. Sec 2.15 Topic WS
A. Water Hammer
B. Chlorine Demand
C. Backpressure
D. Backwash
E. CAFO

29. On most kilowatt meters, the current kilowatt load is indicated by?
AWWA Chap. 14 P. 440-441 Topic IN
A. The Primary or Binder dial
B. Current load dial
C. Disk revolutions
D. None of the above

30. This special type of check valve is located at the bottom end of the suction on a pump. This valve opens when the pump operates to allow water to enter the suction pipe but closes when the pump shuts off to prevent water from flowing out of the suction pipe?
SAC. Sec 2.33 Topic PM
A. Prime Valve
B. Foot
C. Impeller

31. Distribution system water quality can be adversely affected by improperly constructed or poorly located blowoffs of vacuum/air relief valves. Air relief valves in the distribution system lines must be placed in locations that cannot be flooded. This is to prevent water contamination. What customer complaint is sometimes solved by the installation of air relief valves?
SAC. Sec. 4.515 Topic WQ
A. Taste and odors
B. Milky water
C. MIB
D. Constipation
E. None of the above

32. What does HPC mean?
A. Halogenated Particle Count
B. Heterotrophic plate count
C. Hard Particle Count
D. Heterotrophic Particle Count
E. None of the above

33. Which of the following pumps is consisting of an impeller fixed on a rotating shaft that is enclosed in a casing, and having an inlet and discharge connection. As the rotating impeller spins the liquid around, force builds up enough pressure to force the water through the discharge outlet? SAC. Sec. 2.33 Topic PM
A. Booster
B. Centrifugal
C. Submersible
D. Rotator
E. None of the above

34. What is a limitation of hydropneumatic tanks? SAC. Sec 2.14 Topic WS
A. Do not provide much storage during average demands
B. Do not provide much storage to meet peak demands during power outages
C. Very limited time to do repairs on equipment
D. Both B & C
E. None of the above

35. Why would a pump engineer design a system that would use multiple pumps for a parallel operation? AWWA Appendix D Page 552 Topic DG
A. To provide for a fluctuating demand
B. To provide an increased discharge head
C. To reduce the friction coefficient on a larger pump for greater efficiency
D. All of the above

36. When the superintendent is inspecting the plans for a new ground water storage tank, the superintendent should pay attention to the inlet and outlet of this tank. What design factor should be noticed? SAC. Sec. 3.43 Topic DG
A. The outlet and inlet should be on opposite sides of the tank
B. The inlet must be twice the size of the outlet
C. The outlet must be twice the size of the inlet
D. The outlet and inlet should be on the top
E. CMOM

37. Water quality in a storage facility could degrade due to excessive water age caused by low demands for water and short-circuiting within the distribution storage reservoir. Which of the following are not other reasons for water quality degradation? SAC. Sec 2.35 Topic WQ
A. Sampling program
B. Poor design
C. Inadequate maintenance
D. Improperly applied coating and linings
E. None of the above

38. Transmitting equipment requires installation where temperature will not exceed ?
AWWA Chap. 14 Page 465 Topic IN
A. 100 degrees F.
B. 100 degrees C.
C. 130 degrees C.
D. 130 degrees F.
E. None of the above

39. For a dead-end line of over 2,000 feet, the design criteria would dictate a minimum pipe diameter of ________ inches. SAC. Sec. 3.2 Topic DG
A. 4
B. 8
C. 6
D. 12
E. None of the above

40. A diaphragm element being used as a level sensor would be used in conjunction with ?
AWWA Chap. 14 Page 437 Topic IN
A. Pressure Sensor
B. Manometer
C. Rotometer
D. Redwood plug
E. HTH

41. Inspection of magnetic flow meter instrumentation should include?
AWWA Chap. 14 P. 464-465 Topic IN
A. Checking EMF on the hemisphere transducer
B. Checking for corrosion or insulation deterioration
C. Placing a bucket of water for your feet
D. Polarity multiplexing

42. The most frequent problem that affects a liquid pressure-sensing device is?
AWWA Chap. 14 Page 464 Topic IN
A. Air accumulation at the sensor
B. Greenhouse effect
C. Freezing
D. Sensing solenoid failure
E. CAFO

43. Which of the following is **NOT** a pressure sensing device?
AWWA Chap. 14 Page 435 Topic IN
A. Helical Sensor
B. Bourdon Tube
C. Campos Gauge
D. Bellows Sensor

44. Telemetering systems must often transmit more than one signal. Which of the following is **NOT** a means for transmitting multiple signals?
AWWA Chap. 14 P. 452-453 Topic IN
A. Pulse-duration modulation
B. Polling
C. Scanning
D. Multiplexing
E. None of the above

45. The Strain Gauge is a common measuring device used for a variety of changes such as head. As the pressure in the system changes, the diaphragm expands which changes the length of the wire attached. This change of length of the wire changes the ________of the wire, which is then converted to head. AWWA Chap. 14 Page 435 Topic IN
A. Resistance
B. Voltage
C. Current
D. None of the above

46. Any equipment that utilizes water for cooling, lubrication, washing or as a solvent is always susceptible to ? AWWA Chap. 11 Page 316 Topic CC
A. Cross connections
B. An operator falling in to it
C. Garden hoses and backpressure
D. All of the above

47. When installing a vacuum breaker backflow device, the operator must make sure that?
AWWA Chap. 11 P. 336-337 Topic CC
A. It is 12 inches above the lowest discharge outlet
B. It is 2 inches above the air gap
C. It is 12 inches above the highest discharge outlet
D. It is made of brass

48. Which of the following statements is true concerning a double check backflow assembly?
AWWA Chap. 11 P. 334-336 Topic CC
A. A Double Check is approved for high contamination/pollution and backpressure
B. A double check will stop backsiphonage
C. A double check has a relief valve
D. A double check is redundant

49. Which of the following statements best describe the operation of a reduced pressure principal backflow assembly device? AWWA Chap. 11 P. 332-334 Topic CC
A. The relief valve will open and drain if a pressure differential occurs between the two checks
B. The spring loaded diaphragm is below the second check valve
C. The air relief will open at 15 PSI
D. All of the above

50. Which of the following has the greatest potential hazard of contamination if a cross connection occurs? AWWA Chap. 11 P. 328-329 Topic CC
A. Sugar machine
B. Commercial food processors
C. Swimming pools
D. Pesticide mixing tanks

51. What is the most likely consequence if a backsiphonage condition causes a cross connection and pressure is then restored to the system?
AWWA Chap. 11 P. 322-324 Topic CC
A. Probably dirty water
B. There will be no contamination
C. Backpressure
D. The distribution system downstream of the cross connection will be contaminated

52. A common abbreviation on plan and profile drawings is "PI". What does this stand for?
AWWA Chap. 15 P. 489-490 Topic ML
A. Point of Increase
B. Point of Tap
C. Point of Instruction
D. Point of Intersection
E. None of the above

53. Galvanized pipes are unsuitable for most services because?
AWWA Chap. 9 P. 257-258 Topic TS
A. Easily bent
B. Improper threads
C. Galvanic corrosion
D. Palatability problems

54. If valve and hydrant maps are to be effective, the maps must?
AWWA Chap. 15 Page 484 Topic ML
A. Provide measurements to appurtenances from permanent references/tie and measure
B. Show as-builds
C. Have the Operator's name on the each valve
D. Show the size the stem
E. None of the above

55. An effective cross-connection control program should focus on two major sources of problems. These will include? AWWA Chap. 11 P. 345-346 Topic CC
A. Firefighting equipment/Pollutional sources
B. Garden Hoses/ Air Gaps
C. Customer plumbing problems/Auxiliary water sources
D. All of the above

56. What is the name of a map that an operator would use on a day to day basis that provides detailed drawings of distribution zones, but do not show all the system components?
AWWA Chap. 15 P. 480-481 Topic ML
A. Leak survey maps
B. Sectional Maps
C. Comprehensive maps
D. Supervisor's Map
E. None of the above

57. Intersection indexes can be prepared by? AWWA Chap. 15 Page 487 Topic ML
A. Alphabetizing street names
B. Assigning numbers to each intersection
C. scada
D. SCATA
E. CMOM

58. What is the advantage of a "**Wet Tap**" over a "**Dry Tap**" ?
AWWA Chap. 9 P. 263-264 Topic TS
A. You have more chances of contamination
B. You do not need a shut down for a corp/saddle installation
C. A ball peen hammer is all you need
D. The installation time is increased.

59. Why would an operator place a screen before a backflow prevention assembly?
AWWA Chap. 11 P. 331-334 Topic PM
A. Prevent debris from fouling the assembly
B. Prevent small animals from entering the assembly
C. To allow the passage of air
D. To keep insects out of the air relief

60. A single-phase motor is receiving adequate power and the run windings are operable, but the motor will not start, what could be the problem? AWWA Chap. 13 P. 401-402 Topic PP
A. The switch is closed
B. There is a problem with the stator
C. There is a problem with the start winding
D. There is a problem with the Rotor Monitor

61. Who has the responsibility for insuring that water contamination due to cross connections does not occur? AWWA Chap. 11 P. 315 Topic GK
A. DEQ
B. The Health Dept.
C. Federal Government
D. The water utility
E. All of the above

62. Pigs traveling at speeds of 10 fps will likely result in ? AWWA Chap. 8 P. 222-224 Topic PM
A. Excessive wearing of the pig
B. SOCs and BOD reduction
C. Leaks in the water line
D. Complete removal of the tubercles
E. MIB

63. When cleaning or swabbing a water line, the velocity should be?
SAC. Sec. 5.707 Topic PM
A. 2-4 fps
B. 10-20 fps
C. 20 PPM
D. 5 gallons per minute

64. Of the following answers, which is an acceptable way to launch pigs?
AWWA Chap. 8 P. 222-224 Topic PM
A. Using a fire hydrant
B. Using a taping tool
C. Tying the pig up, and having an Operator 1 using a backhoe
D. Using a high pressure air compressor, or PTO

65. Mechanical seals consist of two machined and polished surfaces which must contact each other. This contact is maintained by ? AWWA Chap. 12 P. 382-383 Topic PP
A. Spring pressure
B. Water pressure
C. Operator II
D. None of the Above

66. What is the main reason for having an updated comprehensive map of the entire water distribution system? AWWA Chap. 15 Page 478 Topic ML
A. To help identify and record sections that need improvement or development
B. To show all of the other utilities and their locations
C. To help develop a per capita use plan
D. To make work for the Valveman

67. Valve and hydrant maps using an intersection method of indexing will typically have a scale of? AWWA Chap. 487 Topic ML
A. 1 mile per inch
B. 1/25
C. 20-30 feet per inch
D. 1/2
E. None of the above

68. Water audits can be performed in order to account for the water in the system. What should be the first step in a water audit? AWWA Chap. 8 P. 232-233 Topic PM
A. Measure flow in to each quarter-section
B. Pump test
C. A 24 hour measure of all the water entering the system
D. Dye test

69. Which of the following types of motors would be expected to have the lowest demand for starting current? AWWA Chap. 13 P. 403-404 Topic PP
A. Wound-rotor induction motor
B. Squirrel Cage induction motor
C. Rotor Synch motor
D. None of the Above

70. The purpose of a sump on a vertical turbine pump is used to maintain adequate?
AWWA Chap. 12 Page 366 Topic PP
A. Liquid above the suction level
B. Pressure for the foot valve
C. Backpressure
D. Cavitation diffusion

71. This term is used to describe head pressure or energy lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restrictions by fittings. SAC. Sec 3.1 Topic TS
A. C Factor
B. Friction Losses
C. Pressure
D. Pressure Head
E. None of the above

72. Continuous leakage from a mechanical seal indicates ?
AWWA Chap. 12 P. 382-383 Topic PP
A. An abnormal condition
B. A normal condition
C. Packing needs to be tightened
D. Mechanical gland needs to be replaced
E. All of the above

73. When you are shutting a large valve, which of the following valves will reduce high pressure that can be present? AWWA Chap. 3 Page 65 Topic VH
A. Gate valve
B. Bypass valve
C. Binder device
D. Inserting Valve

74. What is the most likely choice for the result of grease coming in to contact with the windings for a motor? AWWA Chap. 13 P. 416-417 Topic PP
A. The winding insulation may deteriorate
B. The overloads will trip
C. There will be a phase monitor problem
D. The torque converter will fail
E. None of the above

75. If the pH of water from a dead-end line begins to drop, it is most likely an indication that?
SAC. Sec. 4.511 Topic WQ
Anaerobic conditions are present
The main is being flushed regularly
There is a redwood plug in the main
None of the above

76. An electric motor that has a frequency of 60Hz will have a maximum synchronous speed of ?
AWWA Chap. 13 P. 400 Topic PP
A. 600 rpms
B. 3600 rpms
C. 3000 rpms
D. None of the Above

77. As the wear ring inside a centrifugal pump loses tolerance between the impeller and wear ring, the efficiency of the pump will ? AWWA Chap. 12 P. 380-381 Topic PP
A. Remain the same
B. Fluctuates with the velocity of water
C. Increases
D. Decreases
E. None of the above

78. Multistage centrifugal pumps can discharge high pressure water. The pressure increases with the number of stages but what happens to the capacity/ flow of the pump?
AWWA Chap. 12 P. 360 Topic PP
A. The flow is decreased by 25% for each stage
B. The flow will remain the same through each stage
C. The flow will double with each stage
D. The flow is cut in half

79. What is the function of speed controls on valve actuators? AWWA Chap. 3 P 79 Topic VH
A. A SCADA function
B. To prevent a water hammer
C. To prevent backflow
D. A measuring device
E. All of the above

80. Dry-barrel fire hydrants with unplugged drains should be inspected?
AWWA Chap. 6 P. 170-171 Topic VH
A. Twice a year
B. Prior to installation
C. By placing a stethoscope on the stem
D. With the gate valve closed and pressure induced through an outlet nozzle
E. None of the above

81. With remote manual control, the operator is also required to turn a switch or push a button to operate equipment, Control devices which actuate equipment by inducing a ___________in the device are commonly known as ___________. AWWA Chap. 15 P. 455 Topic IN
A. Electric charge, SCADA
B. Magnetic field, Solenoids
C. Electric charge, Full Duplexing switches
D. EMF, Helical Sensors
E. Pressure change, Diaphragms

82. Thrust protection from thrust blocks should ?
AWWA Chap. 4 P. 123 Topic DG
A. To kick the pipe in place
B. Partially cradle the protected pipe and to equally distribute the force
C. Be part all thread and 500 pounds of cement
D. Not poured in trenches near fire hydrants
E. None of the above

83. Cement-mortar linings of a water mains have been effectively used on nearly all pipe diameters. However, the most cost effective use of this procedure is generally for water lines of________ or greater. SAC. Sec. 5.708 Topic VH
A. 8 Inches
B. 12 Inches
C. 18 Inches
D. 48 Inches
E. None of the above

84. What design criteria of water distribution systems is based upon the Hazen-Williams formula? AWWA Chap. 1 Page 14 Topic DG
A. Pipe Size
B. Fire control capacities
C. Pressure head requirements
D. Never heard of this guy, all of the above
E. None of the above

85. Which of the following problems may occur during periods of high flow or a fire when the waterline's pressure has dropped drastically? SAC. Sec. 3.1 Topic DG
A. Negative pressure in parts of the system
B. Water hammer
C. Low velocity throughout the system
D. All of the above

86. This type of valve which controls water pressure operates by restricting flows. They are used to deliver water from a high pressure to a low pressure system. The pressure downstream from the valve regulates the amount of flow. Usually, these valves are of the globe design and have a spring-loaded diaphragm that sets the size of the opening. SAC. Sec 3.670 Topic VH
A. Pressure Regulation Valve
B. A Butterfly Valve
C. Reduced Pressure
D. Bypass Valve
E. Check Valve

87. What is the intent of a designer when multiple water pumps are installed for paralleled operation? AWWA Appendix D. Page 552 Topic DG
A. To increase the discharge head
B. To provide for a fluctuating demand/or for if one pump is out of service
C. To increase the water force
D. To help build the kingdom/spend the budget

88. During an inspection of your water storage facility, how should you inspect the Cathodic protection system? AWWA Chap. 7 Page 201-202 Topic WS
A. Check the anode's condition and the connections
B. Check the system with a Megger
C. Check the dielectric converter
D. Check the voltage level
E. None of the above

89. The concentration of polyphosphates that is used for corrosion control in storage tanks is typically _______ or less. SAC. Sec. 2.42 Topic WS
A. 5 mg/L
B. 15 mg/L
C. 20 mg/L
D. 50 PPM

90. The most accurate method of measuring chlorine residual concentrations is?
SAC. Sec. 6.50 Topic DS
A. The Walker method
B. Combined residual analysis
C. The DPD procedure
D. Amperometric titration
E. CMOM

91. According to the manual, external corrosion of steel water storage facilities can be reduced with coating of ? SAC. Sec. 2.42 Topic WS
A. Zinc or aluminum coatings
B. Lead coatings
C. Petroleum coatings
D. Latex coatings

92. All storage facilities should be regularly sampled to determine the quality of water which enters and leaves the facility. One tool or piece of measuring equipment is the Jackson turbidimeter. What is the function of this device? SAC. Sec 2.34 Topic WQ
A. A visual method to measure cloudiness in water
B. An instrumental method based on deflected light
C. Both 1 & 2
D. None of the above

93. The effects of water freezing in storage tanks can be minimized by ?
AWWA Chap. 7 P. 204-205 Topic WS
A. Adding drinking water antifreeze
B. Adding solar heaters
C. Alternating water levels in the tank
D. Adding slaked lime
E. All of the above

94. Which of the following is a not a major concern when checking water levels in a storage tank?
SAC. Sec. 2.30 Topic WS
A. The venting of air
B. Excessive water demands
C. Stale water
D. Backsiphonage

95. If an overflows occurs on a storage tank, the operator should first check?
SAC. Sec. 2.31 Topic WS
A. Bac-t samples
B. Backpressure
C. The altitude-control valve
D. Pump velocity

96. What is most frequent type of accident(s) encountered by water distribution personnel?
SAC. Table 7.2 Topic SA
A. Sprains and strains
B. An Operator 1 running a tamper over a foot
C. Slips and falls
D. Sunburns and hangovers
E. ERGO

97. If a thrust block of another utility is discovered in your path while excavation, you should?
SAC. Sec. 7.594 Topic SA
A. Call the Engineer and place all thread on the thrust block
B. Be careful and alter the thrust block so that you can do the work
C. Do not alter the existing thrust block in any way
D. Do your work and pour concrete
E. File a NPDES

98. Right to Know Laws state that the employer has the responsibility to provide the employees with information about? SAC. Sec. 7.18 Topic SA
CDLs
A. The information about health hazards and chemical handling
B. The amount of each chemical to use in each application
C. The method of disposal for the product
D. None of the above

99. Safe entry into a confined space requires that ?
SAC. Sec. 7.20 Topic SA
A. All entrants be First aid trained and able to hold their breaths
B. All entrants wear watches to remind them of the time limit
C. All entrants wear a harness and safety line
D. A rescue squad is standing by.
E. All of the above

100. If an operator is working inside a storage tank and suddenly faints or has a serious problem, there should be?
SAC. Sec. 7.35 Topic SA
A. Smelling salts available
B. Two handheld radios
C. Two people outside standing by to remove the injured operator
D. LOTO
E. None of the above

Answer Key

1. B
2. A
3. B
4. E
5. A
6. A
7. A
8. C
9. A
10. C
11. C
12. D
13. D
14. A
15. C
16. D
17. A
18. A
19. D
20. A
21. D
22. A
23. B
24. A
25. B
26. B
27. A
28. A
29. C
30. B
31. B
32. B
33. B
34. D
35. A
36. A
37. A
38. D
39. B
40. A
41. B
42. A
43. C
44. A
45. A
46. A
47. C
48. B
49. A
50. D
51. D
52. D
53. C
54. A
55. C
56. B
57. B
58. B
59. A
60. C
61. D
62. A
63. A
64. A
65. A
66. A
67. C
68. C
69. A
70. A
71. B
72. A
73. B
74. A
75. A
76. B
77. D
78. B
79. B
80. D
81. B
82. B
83. C
84. A
85. A
86. A
87. B
88. A
89. A
90. D
91. A
92. A
93. C
94. A
95. C
96. A
97. C
98. B
99. C
100. C

Math Exercise Section Exam #1

Volume in Cubic Feet

Cube Formula
V= (L) (W) (D)
Volume= Length X Width X Depth

Cylinder Formula
V= (.785) (D^2) (d)

Build it, Fill it, and Dose it.

1. Convert 10 cubic feet to gallons of water.

There is 7.48 gallons in one cubic foot.

2. A tank weighs 800 pounds, how many gallons are in the tank?

3. Convert a flow rate of 953 gallons per minute to million gallons per day.
There is 1440 minutes in a day.

4. Convert a flow rate of 610 gallons per minute to millions of gallons per day.

5. Convert a flow of 550 gallons per minute to gallons per second,

6. Now, convert this number to liters per second.

7. A tank is 6’ X 15’ x 7’ and can hold a maximum of ____________ gallons of water.
V= (L) (W) (D) X 7.48 =

8. A tank is 25’ X 75’ X 10’. What is the volume of water in gallons?
V= (L) (W) (D) X 7.48 =

9. In Liters?
V= (L) (W) (D) X 7.48 =_________ X 3.785

10. A tank holds 67,320 gallons of water. The length is 60’ and the width is 15’. How deep is the tank?

Gallons______ ÷ 7.48 = _______ 60 X 15 =

11. The diameter of a tank is 60’ and the depth is 25’. How many gallons does it hold?

Cylinder Formula
V= (.785) (D^2) (d)

.785 X 60’ X 60’ X 25’ X 7.48 =

Cubic Feet Information
There is no universally agreed symbol but the following are used:
cubic feet, cubic foot, cubic ft
cu ft, cu feet, cu foot
ft^3, $feet^3$, $foot^3$
$feet^3$, $foot^3$, ft^3
feet/-3, foot/-3, ft/-3

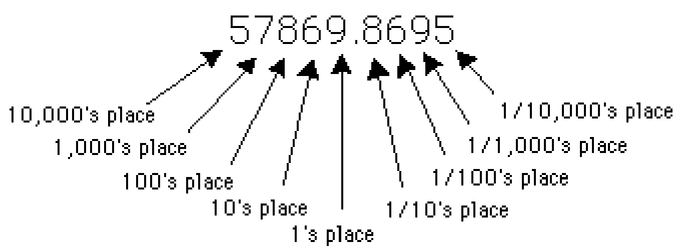
Water Treatment Production Math Numbering System
In water treatment, we express our production numbers in Million Gallon numbers. Example 2,000,000 or 2 million gallons would be expressed as 2 MG or 2 MGD.
Hints. A million has six zeros; you can always divide your final number by 1,000,000 or move the decimal point to the left six places. Example 528,462 would be expressed .56 MGD.

12. The diameter of a tank is 15 Centimeters or cm and the depth is 25 cm, what is the volume in liters?

2.54cm = 1 inch, 12 inches = 1 foot
15 cm ÷ 2.54 cm ÷ 12 inches = .492 feet

.785 X .492’ X .492’ X _____’ =______ X 7.48 = _______ X 3.785 L =

Percentage and Fractions
Let's look again at the sequence of numbers 1000, 100, 10, 1, and continue the pattern to get new terms by dividing previous terms by 10:
.1 = 1/10
.01 = 1/100
.001 = 1/1000



So just as the digits to the left of the decimal represent 1's, 10's, 100's, and so forth, digits to the right of the decimal point represent 1/10's, 1/100's, 1/1000's, and so forth.

Let’s express 5% as a decimal. 5 ÷ 100 = 0.05 or you can move the decimal point to the left two places.

Changing a fraction to a decimal:
Divide the numerator by the denominator
A. 5/10 (five tenths) = five divided by ten:

```
    .5
   -----
10 ) 5.0
     5 0
    ----
```
So 5/10 (five tenths) = .5 (five tenths).

B. How about 1/2 (one half) or 1 divided by 2 ?

```
     .5
    -----
  2 ) 1.0
      1 0
      ----
```

So 1/2 (one half) = .5 (five tenths)

Notice that equivalent fractions convert to the same decimal representation.

8/12 is a good example. 8 ÷ 12 =.66666666 or rounded off to .667

How about 6/12 or 6 inches? .5 or half a foot

Flow and Velocity

This depends on measuring the average velocity of flow and the cross-sectional area of the channel and calculating the flow from:

$Q(m^3/s) = A(m^2) \times V(m/s)$

Or

Q = A X V

Q CFM = Cubic Ft, Inches, Yards of time, Sec, Min, Hrs, Days

A = Area, squared Length X Width

V f/m = Inch, Ft, Yards, Per Time, Sec, Min, Ft or Speed

13. A channel is 3 feet wide and has water flowing to a depth of 2.5 feet. If the velocity through the channel is 2 fps or feet per second, what is the cfs flow rate through the channel?

Q = A X V

Q = 7.5 sq. ft. X 2 fps What is Q?

A= 3' X 2.5' = 7.5

V= 2 fps

14. A channel is 40 inches wide and has water flowing to a depth of 1.5 ft. If the velocity of the water is 2.3 fps, what is the cfs flow in the channel? Q = A X V
First we must convert 40 inches to feet.
40 ÷ 12" = 3.333 feet

A = 3.333' X 1.5' = 4.999 or round up to 5
V = 2.3 fps
We can round this answer up.

15. The flow through a 6 inch diameter pipe is moving at a velocity of 3 ft/sec. What is the cfs flow rate through the pipeline?

Q =
A = .785 X .5' X .5' =
V = 3 fps

16. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?

Q = ______ cfs X 60 sec/min X 7.48 = ___________ gpm
A = .785 X .667' X .667'
V = 3.4 fps

17. A 6 inch diameter pipe delivers 280 gpm. What is the velocity of flow in the pipe in ft/sec?

Take the water out of the pipe. 280 gpm ÷ 7.48 ÷ 60 sec/min = ________ cfs
Q =
A = .785 X .5’ X .5’ =
V =

18. A new section of 12 inch diameter pipe is to be disinfected before it is placed in service. If the length is 2000 feet, how many gallons of 5% NaOCl will be need for a dosage of 200 mg/L?

Cylinder Formula
V= (.785) (D^2) (d)
.785 X 1’ X 1’ X 2000’ = _______ cuft X 7.48 = ______ ÷ 1,000,000 = ___________MG

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal if 100% concentrate. If not, divide the lbs/day by the given %

0.0117436 MG X 200 mg/L X 8.34 =_________ lbs/day ÷ .05 =

19. A section of 6 inch diameter pipe is to be filled with water. The length of the pipe is 1320 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 3 mg/L?

.785 X .5’ X .5’ X 1320’ X 7.48 =_____________ Make it MGD

Pounds per day formula = Flow X Dose X 8.34 X 45.4 Grams per pound

20. Determine the chlorinator setting in pounds per 24 hour period to treat a flow of 3.4 MGD with a chlorine dose of 3.35 mg/L.

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

21. To correct an odor problem, you use chlorine continuously at a dosage of 15 mg/L and a flow rate of 85 GPM. Approximately how much will odor control cost annually if chlorine is $0.17 per pound?

85 gpm X 1440 min/day = _____________ gpd ÷ 1,000,000 = __________ MGD

______ MGD X 15 mg/L X 8.34 lbs/gal X $0.17 per pound X 365 days/year =

22. A wet well measures 8 feet by 10 feet and 3 feet in depth between the high and low levels. A pump empties the wet well between the high and low levels 9 times per hour, 24 hours a day. Neglecting inflow during the pumping cycle, calculate the flow into the pump station in millions of gallons per day (MGD).

Build it, fill it and do what it says, hint: X 9 X 24

Crazy Math Section

The metric system is known for its simplicity. All units of measurement in the metric system are based on decimals—that is, units that increase or decrease by multiples of ten. A series of Greek decimal prefixes is used to express units of ten or greater; a similar series of Latin decimal prefixes is used to express fractions. For example, *deca* equals ten, *hecto* equals one hundred, *kilo* equals one thousand, *mega* equals one million, *giga* equals one billion, and *tera* equals one trillion. For units below one, *deci* equals one-tenth, *centi* equals one-hundredth, *milli* equals one-thousandth, *micro* equals one-millionth, *nano* equals one-billionth, and *pico* equals one-trillionth.

23. How many grams equal 3,500 mg?

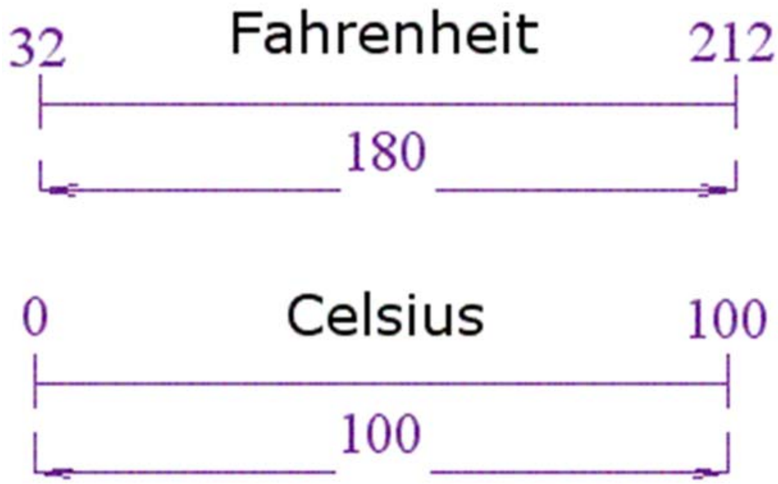
Just simply divide by 1,000.

Remember this "King Henry died by drinking Chocolate Milk".

Kilo- Heca- Deca- Centi - Mili

Temperature

There are two main temperature scales. The **Fahrenheit Scale** (used in the US), and the **Celsius Scale** (part of the Metric System, used in most other Countries)
They both measure the same thing (temperature!), just using different numbers.
If you freeze water, it measures 0° in Celsius, but 32° in Fahrenheit
If you boil water, it measures 100° in Celsius, but 212° in Fahrenheit
The difference between freezing and boiling is 100° in Celsius, but 180° in Fahrenheit.



Conversion Method
Looking at the diagram, notice:
The scales start at a different number (32 vs. 0), so we will need to add or subtract 32
The scales rise at a different rate (180 vs. 100), so we will also need to multiply
And this is how it works out:

To convert from Celsius to Fahrenheit, first multiply by 180/100, then add 32

To convert from Fahrenheit to Celsius, first subtract 32, then multiply by 100/180

Note: 180/100 can be simplified to **9/5**, and likewise 100/180=**5/9**.
$^0F = (^0C \times 9/5) + 32$ 9/5 =1.8

$^0C = (^0F - 32) \times 5/9$ 5/9 = .555

24. Convert 20 degrees Celsius to degrees Fahrenheit.

$20^o \times 1.8 + 32 = F$

25. Convert 4 degrees Celsius to degrees Fahrenheit.

Water Treatment Filters

26. A 19 foot wide by 31 foot long rapid sand filter treats a flow of 2,050 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.

GPM ÷ Square Feet

27. A 26 foot wide by 36 foot wide long rapid sand filter treats a flow of 2,500 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.

Chemical Dose

28. A pond has a surface area of 51,500 square feet and the desired dose of a chemical is 6.5 lbs per acre. How many pounds of the chemical will be needed?

43,560 Square feet in an acre

51,500 ÷ 43,560 = _______ X 6.5 =

29. A pond having a volume of 6.85 acre feet equals how many millions of gallons?

Q=AV Review

30. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the GPM flow rate through the pipe?
Q = 1.18 CFS x 60 Seconds x 7.48 GAL/CU.FT = 532 GPM
A = .785 X .667 X .667 X 1 = .349 Sq. Ft.
V= 3.4 Feet per second

31. An 6 inch diameter pipe delivers 280 GPM. What is the velocity of flow in the pipe in Ft/Sec?
280 GPM ÷ 60 seconds in a minute ÷ 7.48 gallons in a cu. ft. = .623 CFS

Q = .623
A = .785 X.5 X .5 =.196 Sq. Ft.
V = 3.17 Ft/Second

32. Calculate the total dosage in pounds of a chemical. Assume the sewer is completely filled with the concentration. Pipe diameter: 18 inches, Pipe length: 420 feet, Dose: 120 mg/L.

Figure out the volume first.

.785 X 1.5' X 1.5' X 420' X 7.48 =___________ convert to MG

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

More Math Review, No answers provided, you can find the answers in the Sacramento manual.

1. A 17-inch water main is flushed at a velocity of 4.4 ft/sec. What should the reading on the flow meter be in cubic feet per second?

2. Convert a flow rate of 389 gallons per minute to millions of gallons per day.

3. A chlorine demand test from a well water sample produces a result of 1.12 mg/L. The water supplier maintains a chlorine residual of 0.24 mg/L throughout the system. What is the chlorine dose in mg/L from the chlorinator?

4. The net weight of a tank of water is 857 lbs. How many gallons does it contain?

5. A rectangular concrete channel is 4-feet wide contains 2 feet of water. The water is flowing at a velocity of 1.5 feet per second. What is the flow rate in CFS?

6. A pressure gauge on a fire hydrant reads 53 psi. What is the head on the fire hydrant in feet?

7. Estimate the chlorine demand for water in milligrams per liter if the chlorine dosage is 3.63 mg/L and the chlorine residual is 0.42 mg/L.

8. Calculate the volume of a cube with the following dimensions: L=24 inches W=15 inches H=18 inches.

9. Convert 20 °Celsius to Fahrenheit.

10. A chlorinator feeds 51.33 pounds of chlorine per day to a flow of 0.831 MGD. What is the chlorine dose in mg/L?

Learn to convert your answers into metric values.

Third General Practice Exam Section ***No Answers Provided***

1. What is true about a double check valve backflow assembly?

2. Which statement best describes the operation of a reduced pressure principal backflow assembly?

3. What disease is ***NOT*** transmitted by water?

4. What distribution valves is ***NOT*** classified as a rotary valve?

5. What types of motors would be expected to have the lowest demand for a starting current?

6. This statement is ***NOT*** correct about a pressure tap.

7. Explain the procedures concerning a confined space safety procedure.

8. What statement is correct about a single phase motor?

9. Explain statements concerning confined space entry.

10. What best describes a double suction pump?

11. What pump is one of the most frequently used as a booster pump in a water distribution system?

12. What procedures should an operator perform before doing work on any piece of electrical equipment?

13. What items may be used in a pump stuffing box to prevent air from entering without causing excessive heat and wear on the shaft sleeve?

14. Identify different types of three-phase motor.

15. Identify different types of pressure sensing devices.

16. This device has the greatest potential to cause contamination if a cross connection occurs.

17. What device is used to prevent backflow on a service connection?

18. What chemical is used to de-chlorinate a water sample that is analyzed for bacteria?

19. What chemical reaction equations represents the dissociation of hypochlorous acid?

20. When shutting a large valve, what will help to reduce high pressure?

21. What type of valve is used where the valve is not buried and an operator will need to know from an inspection whether the valve is open or closed?

22. What type of gauge is used most widely in modern instrumentation?

Final Math Project ***No answers provided*.**

1. What is the flow through a main in cubic feet per second if a 6-inch water main is flushed at a velocity of five feet per second?

2. An 8-inch diameter water main is to be flushed at a rate of 4.25 ft/sec before disinfection. What is the reading on a flowmeter in gallons per minute?

3. A deep-well turbine pump delivers 255.5 GPM. If the desired chlorine dose is 2.22 mg/L, what is the chlorine feed rate in pounds per day?

4. A pump delivers approximately 199 GPM. If the desired chlorine dose is 2.1 mg/L, what should the chlorinator be set at in pounds of chlorine per day?

A water flow of 560 GPM is pumped against a total head of 120 feet by a pump with an efficiency of 75%. What is the pump horsepower?

6. Calculate the chlorine dose in milligrams per liter if 625 gallons of 2.5 percent sodium hypochlorite solution were used to treat three million gallons of water.

7. Determine the leak rate in GPD/mi-in from a section of pipe if the leak rate during a test period was 71 GPD. The section of pipe is one-fifth of a mile (0.2-mile) in length and 13 inches in diameter.

8. Doubling the diameter of a well increases its yield by approximately what percentage?

9. Estimate the C Factor for a 10-inch water main when the flow is 800 GPFM, and the drop in pressure head elevation between two pressure gauges 500 feet apart is two (2) feet.

Water Quality Exam Review

Answers in rear of this exercise.

1. Disease causing bacteria are known as:
A. Coliforms
B. Noncoliforms
C. Nonpathogenic
D. Pathogenic
E. None of the above

2. Coliform bacteria are reported in organisms per:
A. liter
B. 100 milliliters
C. milliliter
D. plate
E. None of the above

3. The primary health risk associated with synthetic organic compounds (SOCs) is:
A. Acute respiratory diseases
B. Cancer
C. "Baby blue" syndrome
D. Reduced IQ levels in children
E. None of the above

4. The primary source(s) of synthetic organic compound (SOC) contamination in water supplies is (are):
A. Industrial solvents and agricultural pesticides
B. Mammalian fecal contamination of surface water
C. Agricultural fertilizers and natural mineral deposits
D. Disinfection by-products
E. None of the above

5. Normally, the pH of surface water and of ground water ranges from:
A. 9.0 to 10.5
B. 6.8 to 8.5
C. 1.5 to 4.0
D. No answers apply

6. One indication of corrosive water is a high concentration of:
A. Algae odors
B. Carbon dioxide
C. Carbonates
D. Total dissolved solids
E. None of the above

7. A cross-connection can best be described as:
A. A loose connection between any two water pipes.
B. A piping mistake, like when the pump inlet is connected to the outlet or vice- versa.
C. A situation which rarely happens.
D. A physical connection between a potable water supply and any other source of water of unknown, or unsafe quality.
E. None of the above

8. A chlorine taste is reported by two or more customers in a given section of town some distance from the plant. If you are required to handle all complaints and you receive this complaint, how should it be handled?
A. Inform the plant manager that a chlorine taste problem exists and that they may need to cut down on chlorine.
B. Disregard, as they will get accustomed to the taste in a short time anyway.
C. Inform the customers that the chlorine taste is good for them.
D. Inform the plant manager that a chlorine taste problem exists and that they may need to add more chlorine.
E. None of the above

9. Which of the following best describes chlorine demand?
A. The difference between the amount of chlorine added and turbidity
B. The difference between the amount of chlorine added and pH
C. The difference between the total chlorine residual and the free chlorine residual
D. The difference between the amount of chlorine added and the amount of residual chlorine after a given contact time
E. None of the above

10. Fusible plugs on chlorine cylinders are designed to melt at:
A. 80º F
B. 102º F
C. 135º F
D. 158º F
E. None of the above

11. How is the water disinfected before it is delivered to the public through a water distribution system?
A. Chlorination
B. Filtration
C. Fluoridation
D. Reduction
E. None of the above

12. What is the purpose of a check valve?
A. To be a double check method for the meter flow of water
B. To act as a back-up system for air-vac valves
C. To prevent the reverse flow of water in a pipeline
D. To have an accounting system that checks all of the valves that a water system purchases
E. None of the above

13. What affects the flow of water in a pipeline?
A. C factor, capillary action, and piezometric surfaces
B. Weir level, tees, and tuberculation
C. Pipe size, elbows, crosses, and tees
D. Elbows, C factor, and runoff
E. None of the above

14. A coupon test installation in a distribution system is used to:
A. Determine the system's water quality
B. Determine the rate of scaling or corrosion
C. Calculate the daily treatment changes
D. Assist in calculating hydrant flows
E. None of the above

15. In a distribution system, which type of valve is usually used for isolation of a section?
A. Check
B. Gate
C. Globe
D. Needle
E. None of the above

16. If the speed of a centrifugal pump is increased and the head remains the same, the gallons per minute output will:
A. Decrease
B. Increase
C. Remain the same
D. Increase slightly, then decrease
E. None of the above

17. The most rapid damage to a centrifugal pump is from:
A. Cavitation
B. Excessive head pressure
C. High velocity
D. Sand
E. None of the above

18. Which of the following is the most important reason to keep daily records of operational data?
A. Maintain records for customer billing
B. Document the need for an increased budget
C. Provide insurance data
D. Document that safe drinking water has been delivered to customers
E. None of the above

19. What is the difference between a maximum contaminant level (MCL) and a secondary maximum contaminant level (SMCL)?
A. MCLs relate to health effects, while SMCLs relate to aesthetic concerns
B. MCL violations automatically trigger acute violations while violations of SMCLs do not
C. MCL violation levels may not be superseded by the state, while SMCL violation levels may
D. MCLs relate to known effects of contaminants, while SMCLs relate to suspected effects of contaminants

20. A 4-log removal means _____ percent removal/inactivation:
A. 99.9
B. 99.99
C. 99.999
D. 100.0
E. None of the above

21. What is the definition of a hazardous atmosphere?
A. An atmosphere that is explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful that may cause death, illness, or injury
B. An atmosphere that is only explosive and oxygen-deficient which may cause death to persons exposed to it
C. An atmosphere that contains less than 22% oxygen and otherwise harmful which may cause death, illness, or injury to persons exposed to it
D. An atmosphere that employees shall not be permitted to work in which contain more than 19.5% but less than 23.5% oxygen that will cause death
E. None of the above

22. How often should safety training be conducted to ensure a safe workplace for operators?
A. After an accident
B. Continuous and ongoing
C. When employees have time
D. Whenever needed
E. None of the above

23. A grab sample represents:
A. The quality of the water at the time the sample was taken
B. Approximately 2 L of water
C. A time-proportional sample
D. A flow-proportional sample

24. American Water Works Association (AWWA) recommends that all storage structures be completely inspected every:
A. 3 to 5 years
B. Annually
C. 4 to 8 years, depending on water quality
D. Time the exterior requires painting
E. None of the above

25. Reverse osmosis is a(n):
A. Membrane process
B. Air stripping procedure
C. Type of chemical oxidation
D. Backflow prevention procedure

Answers
1. D, 2.C, 3.B, 4. A, 5. B, 6. B, 7.D, 8. D, 9.C, 10. D, 11.A, 12.C, 13.C, 14.B, 15. B, 16.C, 17.A, 18. D, 19. A, 20. B, 21.A, 22.B, 23.A, 24.A, 25. A

Practice Exam #4

Groundwater exercise, answers in rear of this section.

1. Which source of water has the greatest natural protection from bacterial contamination?
A. Shallow well
B. Deep well in gravel
C. Surface water
D. Spring
E. None of the above

2. Which of the following should an operator investigate first when well pump and control problems occur?
A. Depth of supply
B. Piping
C. Electricity
D. Water leaks
E. None of the above

3. The pumping water level is best defined as the distance from the top of the well to the:
A. Intake screen of the pump
B. Location where the main flow of water enters a well
C. Water after the pump has been operating for a period of time
D. Water level from the start of a pump test to the end of the test
E. None of the above

4. A submersible pump would be a good choice in a well which:
A. Is straight and plumb
B. May not be straight and plumb
C. Brackish
D. Perched
E. None of the above

5. The cone of depression forms around:
A. A well during pumping
B. Bacteriological samples during incubation
C. Pump impellers cavitating
D. An air line
E. None of the above

6. A submersible pump is a:
A. Positive displacement pump
B. A double check valve assembly
C. A centrifugal pump
D. An Archimedes screw
E. None of the above

7. Turbine pumps are often used in large wells because they:
A. Use little energy
B. Can pump a wide range of flows
C. Require no lubrication
D. Use a submerged motor and wiring
E. None of the above

8. In a well, the difference between the pumping level and the static level is called:
A. The static level
B. The yield
C. The drawdown
D. None of the above

9. Chlorine should be stored in a separate room from the well pump in order to:
A. Reduce piping run length
B. Ensure complete disinfection
C. Prevent corrosion and enhance safety
D. Save on annual chemical costs
E. None of the above

10. The basic types of pumps used for pumping ground water wells are:
A. Positive displacement and diaphragm pumps
B. Vertical turbine, line-shaft turbine and submersible pumps
C. Sewage ejector and screw pumps
D. Split-case, frame-mounted pumps and close-coupled vertically mounted pumps
E. None of the above

11. A vent fan for a chlorinator in a well house should be located:
A. Near the pump
B. In the roof
C. Near the roof
D. Above the light switch
E. None of the above

12. Well screens serve mainly to:
A. Aid chlorination
B. Prevent fine sand and soil particles from entering the pump
C. Exclude bacteria
D. Prevent artesian conditions
E. None of the above

13. Turbine pumps are often used in large wells because they:
A. Use lots of energy
B. Can pump a wide range of flow
C. Require lots of lubrication
D. Use a submerged motor and wiring
E. None of the above

14. A multiple well supply system with varying quality sources would benefit by having:
A. Cross-connections sources
B. Chlorination
C. Storage to allow blending sources
D. No answers apply
E. None of the above

15. To increase efficiency of a well you might:
A. Place and develop a gravel pack
B. Reduce specific capacity
C. Increase motor size
D. Reduce iron content
E. None of the above

16. Iron (**Fe**) and manganese (**Mn**) are more likely to be a problem in:
A. Ground level tanks
B. Surface water supplies
C. Ground water
D. The mid-west
E. None of the above

17. Well pits for pumps are considered hazardous because they are:
A. Prone to cause accidents when employees climb in and out of the pit
B. Prone to cause condensate problems of the electrical equipment
C. Subject to collecting toxic gases
D. Subject to flooding
E. None of the above

18. A sanitary seal on a well is used to:
A. Neutralize pressures
B. Prevent contamination
C. Color code the capacity
D. Prevent air from entering the casing
E. None of the above

19. You are chlorinating a well supply and the chlorine demand jumps from 0.9 mg/L to 3.0 mg/L. This is an indication that:
A. More water is being pumped
B. Pollution was recently introduced
C. A weak chlorine solution is being fed and you need more of it.
D. The reagent in your test kit is out-of-date.
E. None of the above

20. When the static level of the ground water is 50 feet below the ground surface, the most suitable type of pump is a(n):
A. Air lift pump
B. Gear pump
C. Horizontal centrifugal pump
D. Turbine pump

21. The drawdown in a well is measured from:
A. The motor base to the tip of the pump strainer
B. The static water level to the tip of the pump strainer
C. The static water level to the pumping water level
D. No answers apply

22. Which of the following well types is most protected from surface contamination?
A. Artesian well
B. Infiltration gallery
C. Rock well
D. Shallow well
E. None of the above

23. The yield of a well could be affected by several factors, including:
A. Depth into the aquifer
B. Composition of the aquifer
C. Temperature of the water
D. All of the above
E. None of the above

24. Ground water generally requires less treatment than surface water for:
A. Radionucides
B. Industrial solvents
C. Microorganisms
D. Iron and manganese
E. None of the above

25. What is a cone of depression?
A. The drop in water level between the static water level and the pumping water level
B. The distance between the original static water level and the level the water in a well reaches after the pumping stops
C. A cone- or funnel-shaped well
D. A depression in the free water surface in an aquifer as it flows toward a well during pumping
E. None of the above

Answers
1. B, 2.C, 3.A, 4.A, 5.A, 6.C, 7.B,8.C,9.C, 10.B, 11.C, 12.B, 13.B, 14.C, 15.A, 16. C, 17.C, 18.B, 19.B, 20.D, 21.C, 22.A, 23.D, 24.C, 25.D

Memorize these for your exam.

Chemical Name	Common Name	Chemical Formula
Aluminum sulfate	Alum, liquid	$AL_2(SO_4)3 . 14(H_2O)$
Ammonia		NH_3
Ammonium		NH_4
Calcium Hypochlorite	HTH	$Ca(OCl)_2 . 4H_2O$
Calcium hydroxide	Slaked Lime	$Ca(OH)_2$
Carbon	Activated Carbon	C
Carbon dioxide		CO_2
Carbonic acid		H_2CO_3
Chlorine gas		Cl2
Chlorine Dioxide		ClO_2
Hydrofluorsilicic acid		H_2SiF_6
Hydrochloric acid	Muriatic acid	HCl
Hydrogen sulfide		H_2S
Hypochlorus acid		HOCL
Monochloramine		NH_2Cl
Potassium permanganate		$KMnO_4$ Strong Oxidizer
Sodium fluoride		NaF
Sodium fluorsilicate		Na_2SiF_6
Sodium hydroxide	Lye	NaOH
Sodium hypochlorite		NaOCl
Sodium Metaphosphate	Hexametaphosphate	Could Cut the Operator
Sodium sulfate		Na_2SO_4
Sulfuric acid		H_2SO_4

Cl,

Cl_2,

17, Atomic Number

10 PPM, IDLH

Fatal exposure limit,

DPD,

0.2 Mg/L

Small amount of Cl_2 exposure. Olfactory fatigue too

Halogenated Organics and THMS,

Carbon,

PAC,

GAC,

HTH storage,

O_3,

UV,

NH_3,

Cl_2NH_3,

Too much Fluoride will,

Specific gravity,

Acid to Water,

Memorize theses…
pH, the power of hydroxyl ion activity measured by the reciprocal of the hydrogen ion on a logarithmic scale from 0-14.

Logarithmic: The power to which a base, such as 10, must be raised to produce a given number. If $n^x = a$, the logarithm of *a,* with *n* as the base, is *x;* symbolically, $\log_n a = x$. For example, $10^3 = 1{,}000$; therefore, $\log_{10} 1{,}000 = 3$.

Precision: The extent to which a given set of measurements of the same sample agree with their mean.

Accuracy: The extent to which a given measurement agrees with the standard value for that measurement.

Math Conversion Factors and Practical Exercise

1 PSI = 2.31 Feet of Water
1 Foot of Water = .433 PSI
1.13 Feet of Water = 1 Inch of Mercury
454 Grams = 1 Pound
2.54 CM =Inch
1 Gallon of Water = 8.34 Pounds
1 mg/L = 1 PPM
17.1 mg/L = 1 Grain/Gallon
1% = 10,000 mg/L
694 Gallons per Minute = MGD
1.55 Cubic Feet per Second = 1 MGD
60 Seconds = 1 Minute
1440 Minutes = 1 Day
.746 kW = 1 Horsepower

LENGTH
12 Inches = 1 Foot
3 Feet = 1 Yard
5,280 Feet = 1 Mile

AREA
144 Square Inches = 1 Square Foot
43,560 Square Feet = 1 Acre

VOLUME
1000 Milliliters = 1 Liter
3.785 Liters = 1 Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of Water
62.38 Pounds = 1 Cubic Foot of Water

Dimensions

SQUARE: Area (sq.ft) = Length X Width
Volume (cu.ft.) = Length (ft) X Width (ft) X Height (ft)

CIRCLE: Area (sq.ft) = 3.14 X Radius (ft) X Radius (ft)

CYLINDER: Volume (Cu. ft) = 3.14 X Radius (ft) X Radius (ft) X Depth (ft)

PIPE VOLUME: .785 X Diameter ^{2} X Length = ? To obtain gallons multiply by 7.48

SPHERE: $\frac{(3.14)\ (\text{Diameter})^3}{(6)}$

Circumference = 3.14 X Diameter

General Conversions

Flowrate

Multiply	—>	to get
to get	**<—**	**Divide**
cc/min	1	mL/min
cfm (ft^3/min)	28.31	L/min
cfm (ft^3/min)	1.699	m^3/hr
cfh (ft^3/hr)	472	mL/min
cfh (ft^3/hr)	0.125	GPM
GPH	63.1	mL/min
GPH	0.134	cfh
GPM	0.227	m^3/hr
GPM	3.785	L/min
oz/min	29.57	mL/min

POUNDS PER DAY= Flow (MG) X Concentration (mg/L) X 8.34
***AKA* Solids Applied Formula** = Flow X Dose X 8.34

PERCENT EFFICIENCY = $\frac{\text{In – Out}}{\text{In}}$ X 100

TEMPERATURE: $^0F = (^0C \times 9/5) + 32$ 9/5 =1.8
$^0C = (^0F - 32) \times 5/9$ 5/9 = .555

CONCENTRATION: Conc. (A) X Volume (A) = Conc. (B) X Volume (B)

FLOW RATE (Q): Q = A X V (**Q**uantity = **A**rea X **V**elocity)

FLOW RATE (gpm): Flow Rate (gpm) = $\frac{2.83 \text{ (Diameter, in)}^2 \text{ (Distance, in)}}{\text{Height, in}}$

% SLOPE = $\frac{\text{Rise (feet)}}{\text{Run (feet)}}$ X 100

ACTUAL LEAKAGE = $\frac{\text{Leak Rate (GPD)}}{\text{Length (mi.) X Diameter (in)}}$

VELOCITY = $\frac{\text{Distance (ft)}}{\text{Time (Sec)}}$

N = Manning's Coefficient of Roughness
R = Hydraulic Radius (ft.)
S = Slope of Sewer (ft/ft.)

HYDRAULIC RADIUS (ft) = $\frac{\text{Cross Sectional Area of Flow (ft)}}{\text{Wetted pipe Perimeter (ft)}}$

WATER HORSEPOWER = $\frac{\text{Flow (gpm) X Head (ft)}}{3960}$

BRAKE HORSEPOWER = $\frac{\text{Flow (gpm) X Head (ft)}}{\text{X Pump Efficiency}}$

MOTOR HORSEPOWER = $\frac{\text{Flow (gpm) X Head (ft)}}{\text{X Pump Eff. X Motor Eff.}}$

MEAN OR AVERAGE = $\frac{\text{Sum of the Values}}{\text{Number of Values}}$

TOTAL HEAD (ft) = Suction Lift (ft) X Discharge Head (ft)

SURFACE LOADING RATE (gal/min/sq.ft) = $\frac{\text{Flow Rate (gpm)}}{\text{Surface Area (sq. ft)}}$

MIXTURE STRENGTH (%) = $\frac{\text{(Volume 1, gal) (Strength 1, \%) + (Volume 2, gal) (Strength 2,\%)}}{\text{(Volume 1, gal) + (Volume 2, gal)}}$

INJURY FREQUENCY RATE = $\frac{\text{(Number of Injuries) 1,000,000}}{\text{Number of hours worked per year}}$

DETENTION TIME (hrs) = $\frac{\text{Volume of Basin (gals) X 24 hrs}}{\text{Flow (GPD)}}$

SLOPE = $\frac{\text{Rise (ft)}}{\text{Run (ft)}}$ **SLOPE (%)** = $\frac{\text{Rise (ft) X 100}}{\text{Run (ft)}}$

POPULATION EQUIVALENT (PE):

1 PE = .17 Pounds of BOD per Day
1 PE = .20 Pounds of Solids per Day
1 PE = 100 Gallons per Day

LEAKAGE (GPD/inch) = $\frac{\text{Leakage of Water per Day (GPD)}}{\text{Sewer Diameter (inch)}}$

CHLORINE DEMAND (mg/L) = Chlorine Dose (mg/L) – Chlorine Residual (mg/L)

MANNING'S FORMULA

τQ = Allowable time for decrease in pressure from 3.5 PSI to 2.5 PSI
τq = As below

$\tau Q = (0.022)\ (d_1^2 L_1)/Q$ $\tau q = \frac{[\ 0.085]}{q}\ [(d_1^2 L1)/(d_1 L_1)]$

Q = 2.0 cfm air loss
θ = .0030 cfm air loss per square foot of internal pipe surface
δ = Pipe diameter (inches)
L = Pipe Length (feet)

$V = \frac{1.486}{\nu} R^{2/3} S^{1/2}$

V = Velocity (ft./sec.)
ν = Pipe Roughness
R = Hydraulic Radius (ft)
S= Slope (ft/ft)

HYDRAULIC RADIUS (ft) = $\frac{\text{Flow Area (ft. 2)}}{\text{Wetted Perimeter (ft.)}}$

WIDTH OF TRENCH (ft) = Base (ft) + (2 Sides) X $\frac{\text{Depth (ft 2)}}{\text{Slope}}$

Formula/Conversion Table

Acid Feed Rate = $\frac{\text{(Waste Flow) (Waste Normality)}}{\text{Acid Normality}}$

Alkalinity = $\frac{\text{(mL of Titrant) (Acid Normality) (50,000)}}{\text{mL of Sample}}$

Amperage = Voltage ÷ Ohms

Area of Circle = (0.785)(Diameter^2) OR (π)(Radius^2)

Area of Rectangle = (Length)(Width)

Area of Triangle = $\frac{\text{(Base) (Height)}}{2}$

C Factor Slope = Energy loss, ft. ÷ Distance, ft.

C Factor Calculation = Flow, GPM ÷ [193.75 (Diameter, ft.)$^{2.63}$(Slope)$^{0.54}$]

Chemical Feed Pump Setting, % Stroke = $\frac{\text{(Desired Flow) (100\%)}}{\text{Maximum Flow}}$

Chemical Feed Pump Setting, mL/min =
$\frac{\text{(Flow, MGD) Dose, mg/L) (3.785L/gal) (1,000,000 gal/MG)}}{\text{(Liquid, mg/mL) (24 hr / day) (60 min/hr)}}$

Chlorine Demand (mg/L) = Chlorine dose (mg/L) – Chlorine residual (mg/L)

Circumference of Circle = (3.141)(Diameter)

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

Detention Time = $\frac{\text{Volume}}{\text{Flow}}$

Digested Sludge Remaining, % = $\frac{\text{(Raw Dry Solids) (Ash Solids) (100\%)}}{\text{(Digested Dry Solids) (Digested Ash Solids)}}$

Discharge = $\frac{\text{Volume}}{\text{Time}}$

Dosage, lbs/day = (mg/L)(8.34)(MGD)

Dry Polymer (lbs.) = (gal. of solution)(8.34 lbs/gal)(% polymer solution)

Efficiency, % = $\frac{(\text{In} - \text{Out})(100\%)}{\text{In}}$

Feed rate, lbs/day = $\frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34\ \text{lbs/gals})}{(\text{Available fluoride ion})(\text{Purity})}$

Feed rate, gal/min (Saturator) = $\frac{(\text{Plant capacity, gal/min.})(\text{Dosage, mg/L})}{18{,}000\ \text{mg/L}}$

Filter Backwash Rate = $\frac{\text{Flow}}{\text{Filter Area}}$

Filter Yield, lbs/hr/sq ft = $\frac{(\text{Solids Loading, lbs/day})(\text{Recovery, \% / 100\%})}{(\text{Filter operation, hr/day})(\text{Area, ft}^2)}$

Flow, cu. ft./sec. = (Area, Sq. Ft.)(Velocity, ft./sec.)

Gallons/Capita/Day = $\frac{\text{Gallons / day}}{\text{Population}}$

Hardness = $\frac{(\text{mL of Titrant})(1{,}000)}{\text{mL of Sample}}$

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

Horsepower (motor) = $\frac{(\text{Flow, gpm})(\text{Head, ft})}{(3960)(\text{Pump, Eff})(\text{Motor, Eff})}$

Horsepower (water) = $\frac{(\text{Flow, gpm})(\text{Head, ft})}{(3960)}$

Hydraulic Loading Rate = $\frac{\text{Flow}}{\text{Area}}$

Leakage (actual) = Leak rate (GPD) ÷ [Length (mi.) x Diameter (in.)]

Mean = Sum of values ÷ total number of values

Mean Cell Residence Time (MCRT) = $\frac{\text{Suspended Solids in Aeration System, lbs}}{\text{SS Wasted, lbs / day + SS lost, lbs / day}}$

Organic Loading Rate = $\frac{\text{Organic Load, lbs BOD / day}}{\text{Volume}}$

Oxygen Uptake = $\frac{\text{Oxygen Usage}}{\text{Time}}$

Pounds per day = (Flow, MGD) (Dose, mg/L) (8.34)

Population Equivalent = $\frac{\text{(Flow MGD) (BOD, mg/L) (8.34 lbs / gal)}}{\text{Lbs BOD / day / person}}$

RAS Suspended Solids, mg/l = $\frac{1{,}000{,}000}{\text{SVI}}$

RAS Flow, MGD = $\frac{\text{(Infl. Flow, MGD) (MLSS, mg/l)}}{\text{RAS Susp. Sol., mg/l – MLSS, mg/l}}$

RAS Flow % = $\frac{\text{(RAS Flow, MGD) (100 \%)}}{\text{Infl. Flow, MGD}}$

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

Slope = $\frac{\text{Drop or Rise}}{\text{Run or Distance}}$

Sludge Age = $\frac{\text{Mixed Liquor Solids, lbs}}{\text{Primary Effluent Solids, lbs / day}}$

Sludge Index = $\frac{\text{\% Settleable Solids}}{\text{\% Suspended Solids}}$

Sludge Volume Index = $\frac{\text{(Settleable Solids, \%) (10,000)}}{\text{MLSS, mg/L}}$

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

Solids Applied, lbs/day = (Flow, MGD)(Concentration, mg/L)(8.34 lbs/gal)

Solids Concentration = $\frac{\text{Weight}}{\text{Volume}}$

Solids Loading, lbs/day/sq ft = $\frac{\text{Solids Applied, lbs / day}}{\text{Surface Area, sq ft}}$

Surface Loading Rate = $\frac{\text{Flow}}{\text{Rate}}$

Total suspended solids (TSS), mg/L =
(Dry weight, mg)(1,000 mL/L) ÷ (Sample vol., mL)

Velocity = $\frac{\text{Flow}}{\text{Area}}$ **O R** $\frac{\text{Distance}}{\text{Time}}$

Volatile Solids, % = $\frac{(\text{Dry Solids} - \text{Ash Solids})(100\%)}{\text{Dry Solids}}$

Volume of Cone = (1/3)(0.785)(Diameter^2)(Height)

Volume of Cylinder = (0.785)(Diameter^2)(Height) OR (π)(r^2)(h)

Volume of Rectangle = (Length)(Width)(Height)

Volume of Sphere = [(π)(diameter^3)] ÷ 6

Waste Milliequivalent = (mL) (Normality)

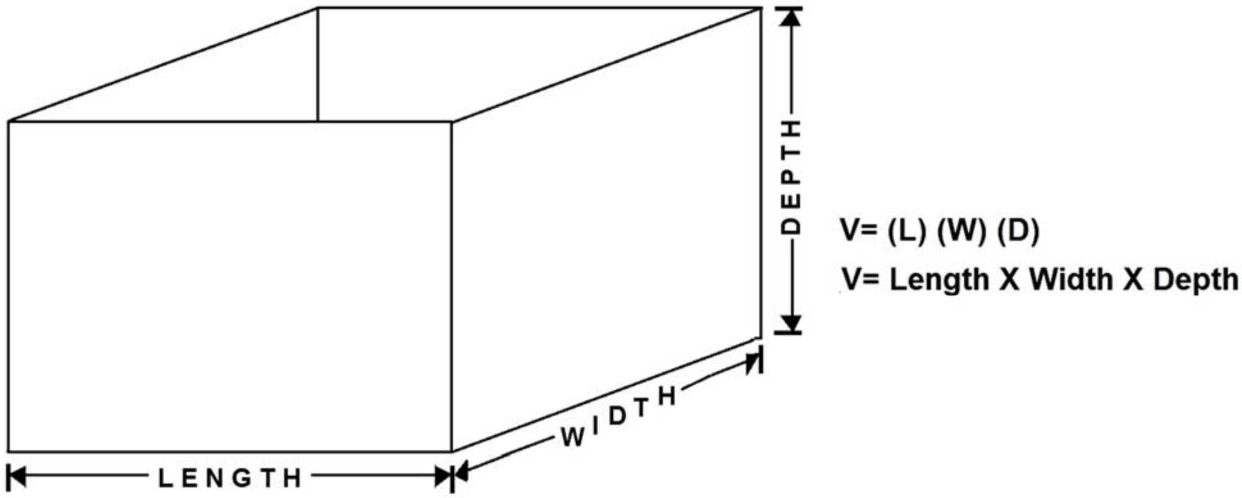
Waste Normality = $\frac{(\text{Titrant Volume})(\text{Titrant Normality})}{\text{Sample Volume}}$

Weir Overflow Rate = $\frac{\text{Flow}}{\text{Weir Length}}$

Conversion Factors

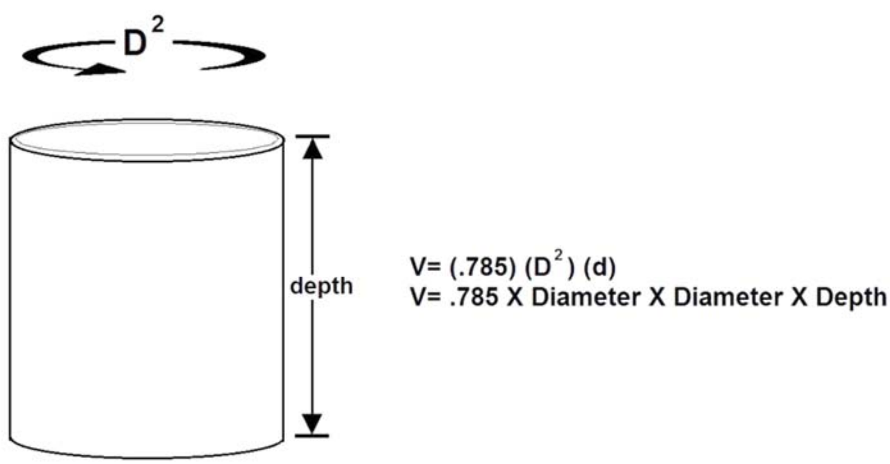
1 acre = 43,560 square feet
1 cubic foot = 7.48 gallons
1 foot = 0.305 meters
1 gallon = 3.785 liters
1 gallon = 8.34 pounds
1 grain per gallon = 17.1 mg/L
1 horsepower = 0.746 kilowatts
1 million gallons per day = 694.45 gallons per minute
1 pound = 0.454 kilograms
1 pound per square inch = 2.31 feet of water
1% = 10,000 mg/L
Degrees Celsius = (Degrees Fahrenheit - 32) (5/9)
Degrees Fahrenheit = (Degrees Celsius * 9/5) + 32
64.7 grains = 1 cubic foot
1,000 meters = 1 kilometer
1,000 grams = 1 kilogram
1,000 milliliters = 1 liter
144 square inches = 1 square foot
1.55 cubic feet per second = 1 MGD
1 meter = 3.28 feet
π = 3.141

Math Review Section- Practice Exam



CALCULATING THE VOLUME OF A CUBE

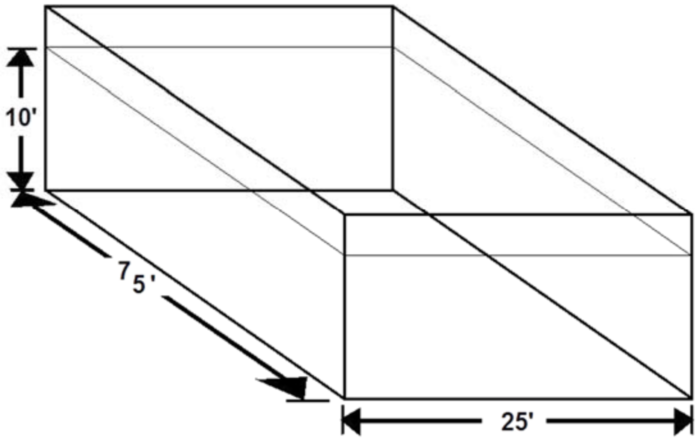
Cube Formula
V= (L) (W) (D)
Volume= Length X Width X Depth



CALCULATING THE VOLUME OF A CYLINDER

Cylinder Formula
V= (.785) (D^2) (d)

Build it, Fill it and Dose it.



A TANK IS 25' x 75' x 10', WHAT IS THE VOLUME OF WATER IN GALLONS

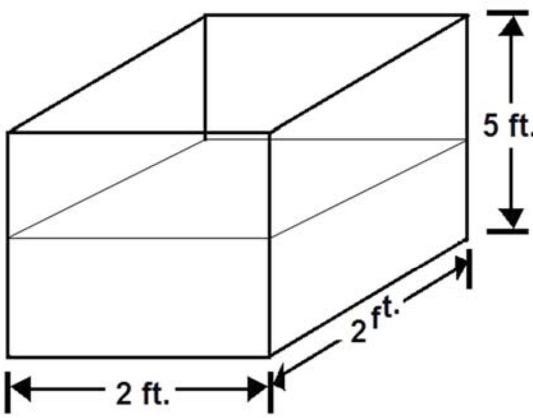
V= (L) (W) (D)

(25) (75) (10) (7.48)

25' x 75' x 10' x 7.48 = 46750 gallons

1. Convert 10 cubic feet to gallons of water.

There is 7.48 gallons in one cubic foot.



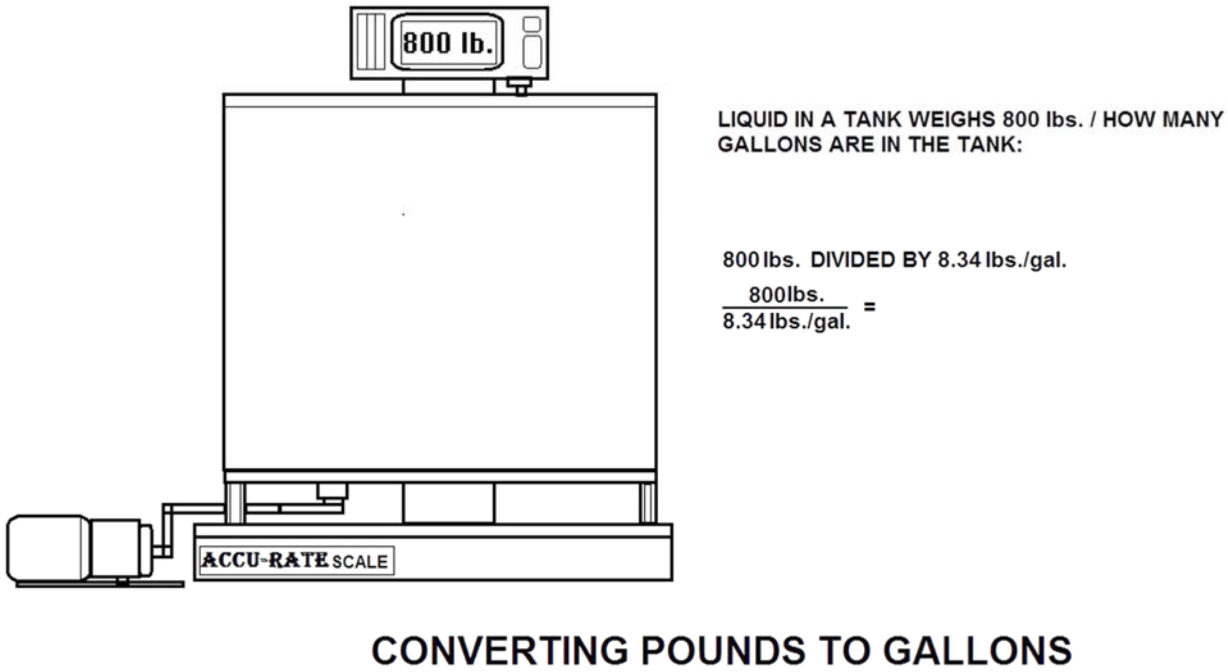
Convert 10 cu.ft. to gallons of water :

$(10\ ft.^3)\ (7.48)$

Multiply $10\ ft.^3$ X 7.48 = gallons

CONVERTING CUBIC FEET TO GALLONS OF WATER

2. The liquid in a tank weighs 800 pounds, how many gallons are in the tank?

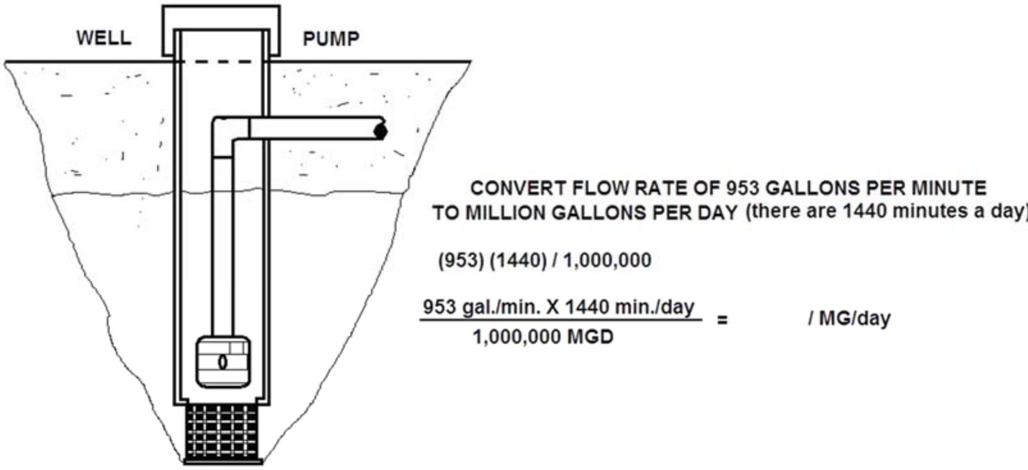


Practice Questions, no answers provided

A1. Convert 75 cubic feet to gallons of water.

B1. The liquid in a tank weighs 50 pounds, how many gallons are in the tank?

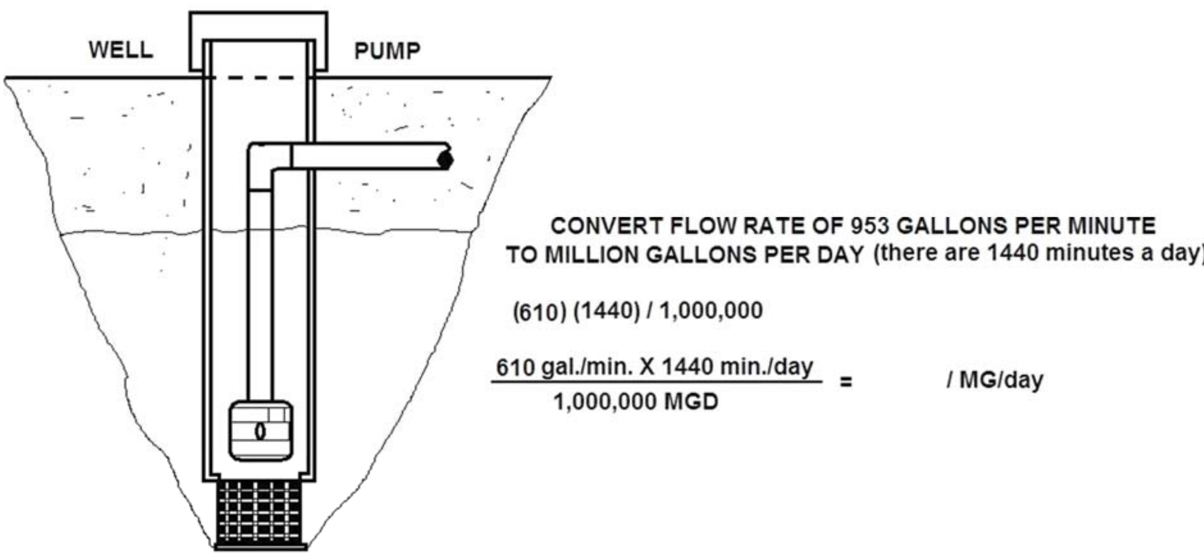
3. Convert a flow rate of 953 gallons per minute to million gallons per day.
There is 1440 minutes in a day.



CONVERTING GALLONS PER MINUTE TO MILLION GALLONS PER DAY

4. Convert a flow rate of 610 gallons per minute to millions of gallons per day.

$$1\ \text{MG} = \frac{100{,}000\ \text{Gallons}}{24\ \text{Hours (fill time)}}$$



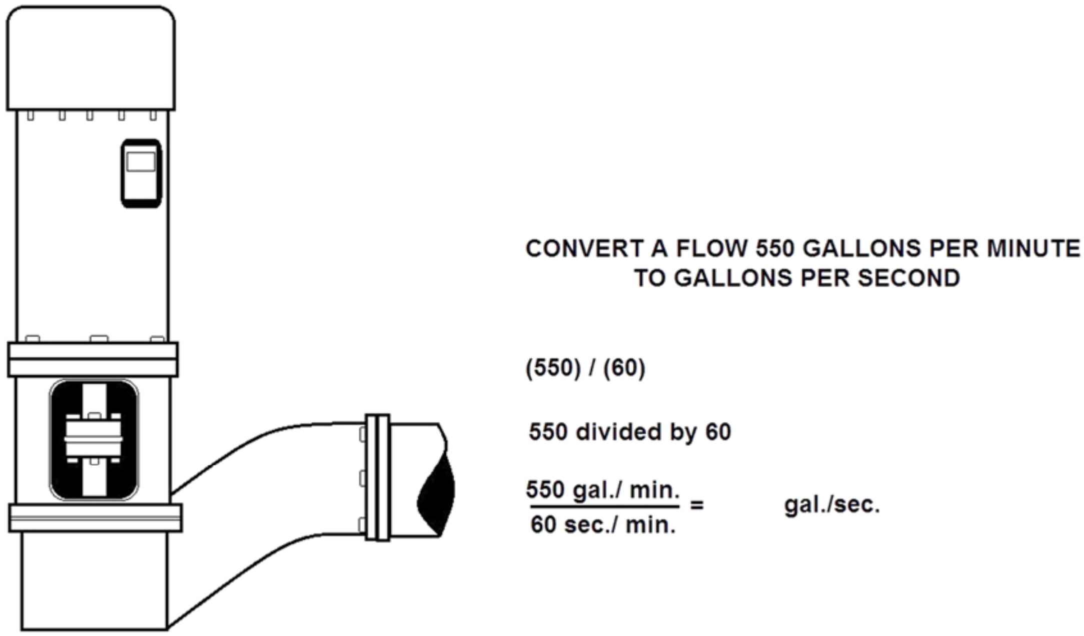
CONVERTING GALLONS PER MINUTE TO MILLION GALLONS PER DAY

Practice Questions, no answers provided

A2. Convert a flow rate of 14,750 gallons per minute to million gallons per day.

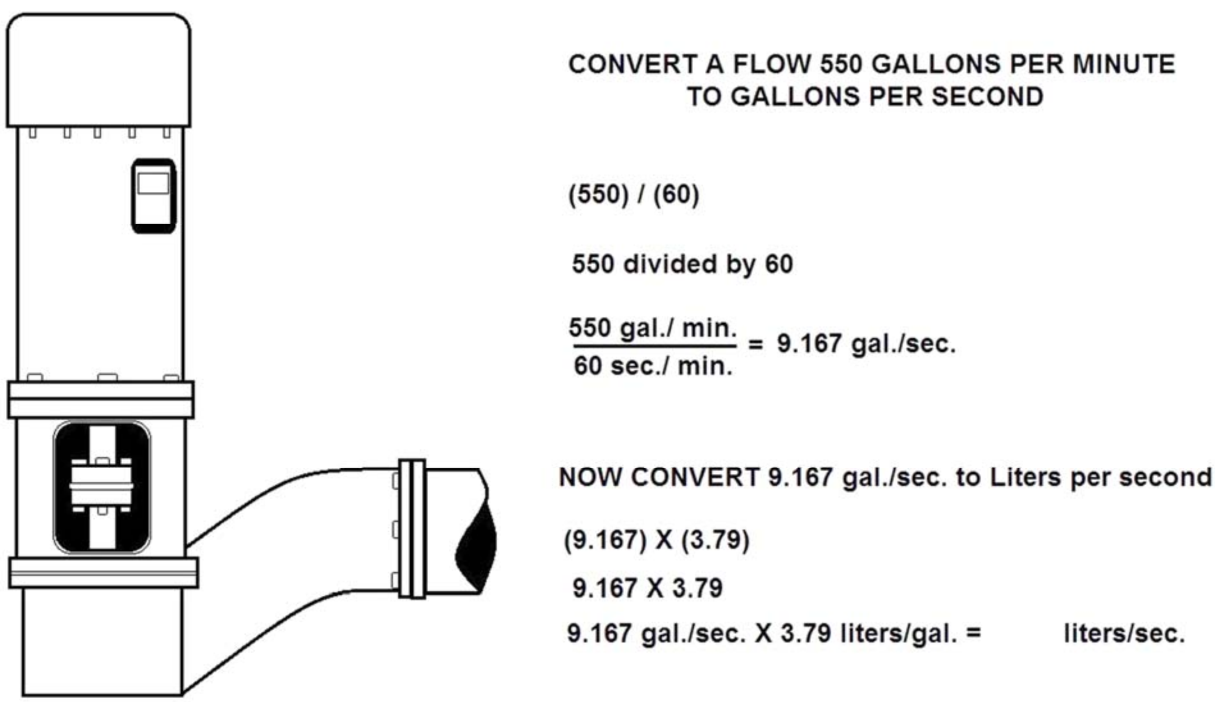
B2. Convert a flow rate of 5880 gallons per minute to millions of gallons per day.

5. Convert a flow of 550 gallons per minute to gallons per second.



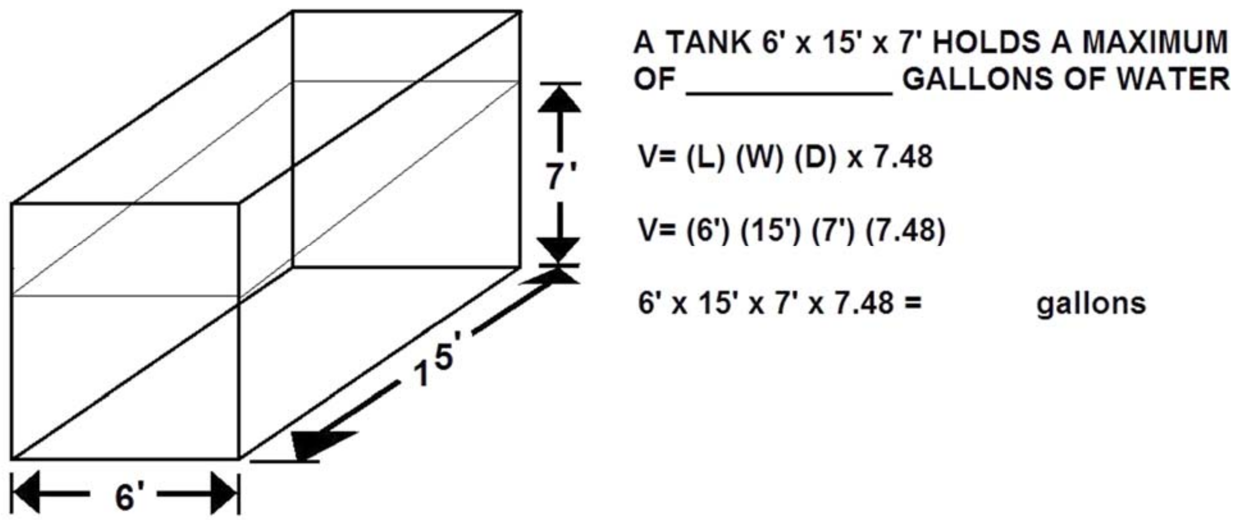
CONVERTING GALLONS PER MINUTE TO GALLONS PER SECOND

6. Now, convert this number to liters per second.



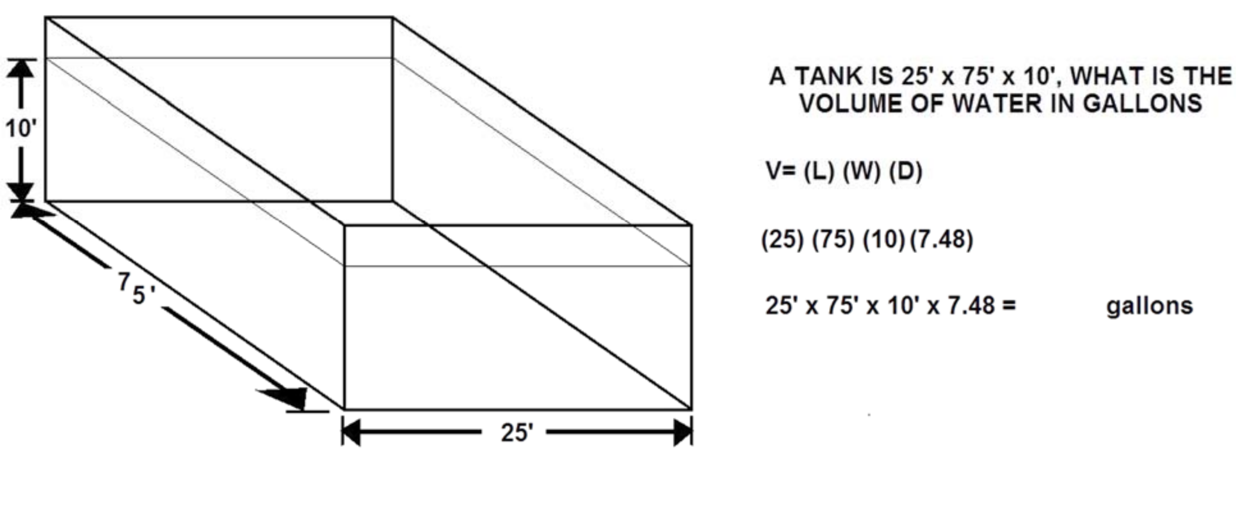
7. A tank is 6’ X 15’ x 7’ and can hold a maximum of ____________ gallons of water.

V= (L) (W) (D) X 7.48 =



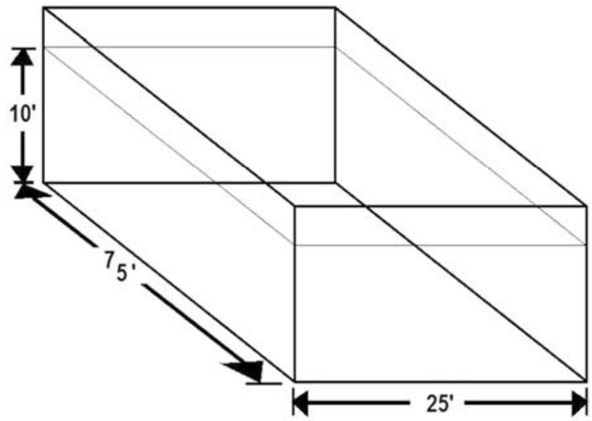
8. A tank is 25’ X 75’ X 10’ what is the volume of water in gallons?

V= (L) (W) (D) X 7.48 =



9. In Liters?

V= (L) (W) (D) X 7.48 =_________ X 3.785



A TANK IS 25' x 75' x 10', WHAT IS THE VOLUME OF WATER IN LITERS

V= (L) (W) (D)

(25) (75) (10) (7.48)

25' x 75' x 10' x 7.48 = 46750 gallons

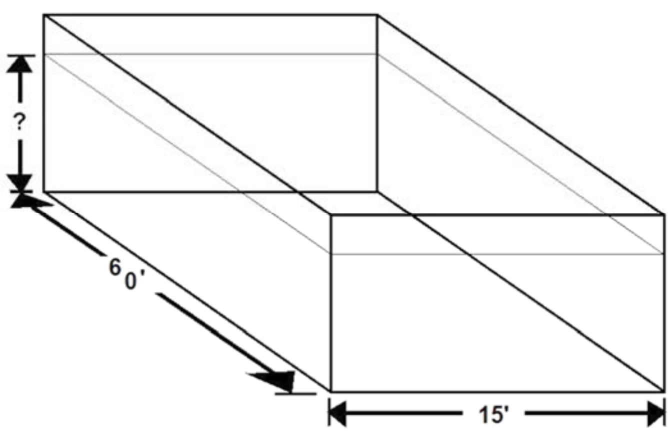
1 GALLON = 3.79 LITERS

V= (L) (W) (D) X 7.48= 46750 gallons X 3.79

V= Liters

10. A tank holds 67,320 gallons of water. The length is 60' and the width is 15'. How deep is the tank?

Gallons______ ÷ 7.48 = _______ 60 X 15 =



A TANK HOLDS 67,320 GALLONS OF WATER. THE LENGTH IS 60' AND THE WIDTH IS 15'. HOW DEEP IS THE TANK?

Gallons 67,320 / 7.48 = 9000 gal.

60' X 15' = 900 ft.

$\frac{\text{9000 gal.}}{\text{900 ft.}}$ = ft.

Practice Questions, no answers provided

A3. Convert a flow of 733 gallons per minute to gallons per second.

B3. Now, convert this number to liters per second.

C3. A tank is 20' X 20' x 40' and can hold a maximum of ____________ gallons of water.

D3. In Liters?

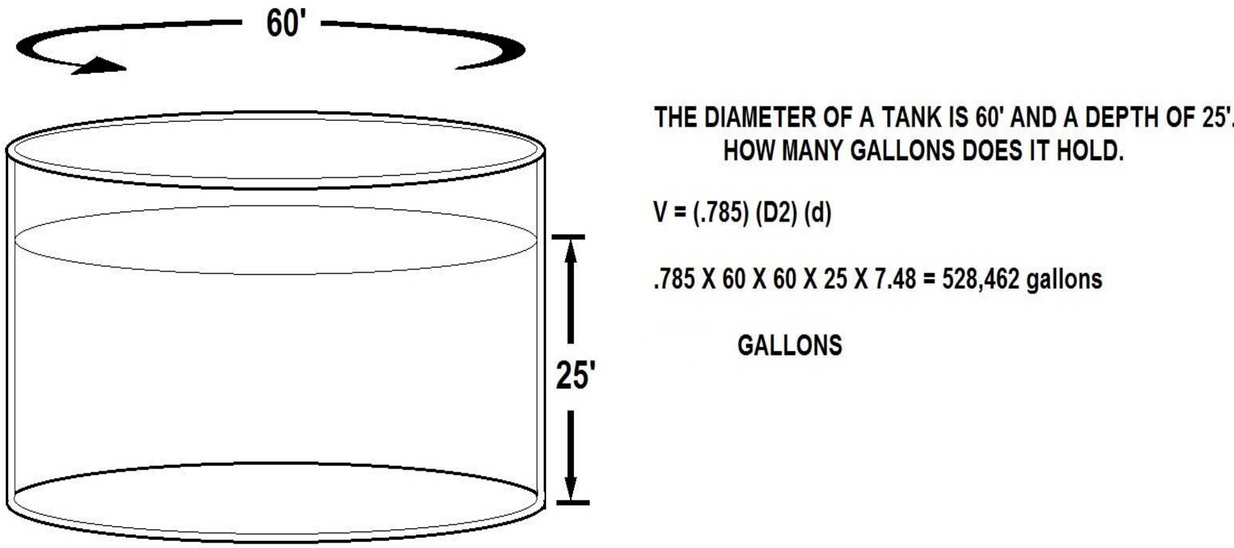
V= (L) (W) (D) X 7.48 =_________ X 3.785

E3. A tank holds 85,000 gallons of water. The length is 75' and the width is 14'. How deep is the tank?

11. The diameter of a tank is 60’ and the depth is 25’. How many gallons does it hold?

Cylinder Formula
V= (.785) (D^2) (d)

.785 X 60’ X 60’ X 25’ X 7.48 =



Practice Questions, no answers provided

A4. The diameter of a tank is 30’ and the depth is 5’. How many gallons does it hold?

B4. The diameter of a tank is 160’ and the depth is 30’. How many gallons does it hold?

C4. The diameter of a tank is 33’ and the depth is 20’. How many gallons does it hold?

D4. The diameter of a tank is 5’ and the depth is .5’. How many gallons does it hold?

Cubic Feet Information
There is no universally agreed symbol but the following are used:

cubic feet, cubic foot, cubic ft
cu ft, cu feet, cu foot
ft_3, feet 3, foot 3
feet3, foot3, ft_3
feet/-3, foot/-3, ft/-3

Water/Wastewater Treatment Production Math Numbering System

In water/wastewater treatment, we express our production numbers in Million Gallon numbers. Example 2,000,000 or 2 million gallons would be expressed as 2 MG or 2 MGD.

$$1 \text{ MG} = \frac{100{,}000 \text{ Gallons}}{24 \text{ Hours (fill time)}}$$

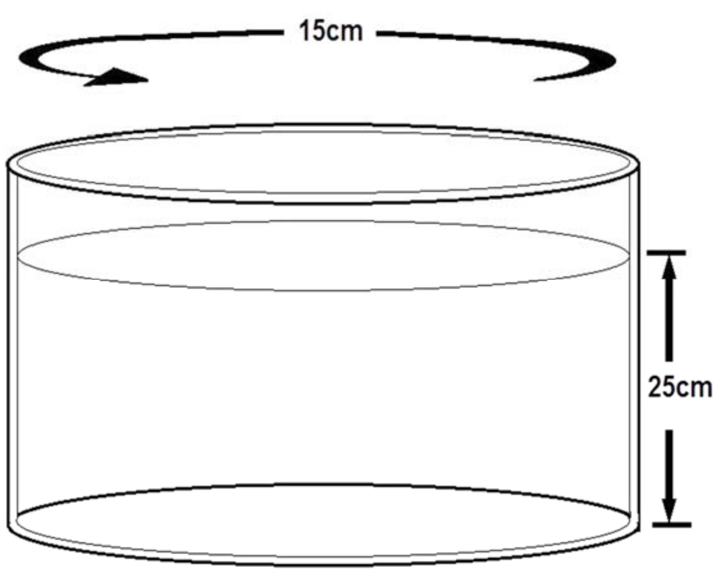
FILL TIME= 2.4 Hours

Hint. A million has six zeroes; you can always divide your final number by 1,000,000 or move the decimal point to the left six places. Example 528,462 would be expressed .56 MGD.

12. The diameter of a tank is 15 Centimeters or cm and the depth is 25 cm, what is the volume in liters?

2.54cm = 1 inch, 12 inches = 1 foot
15 cm ÷ 2.54 cm ÷ 12 inches = .492 feet

.785 X .492' X .492' X _____' =______ X 7.48 = _______ X 3.785 L =



THE DIAMETER OF A TANK IS 15 Centimeters OR cm, WHAT IS THE VOLUME IN Liters.

2.54cm = 1 inch , 12 inches = 1 foot

15cm / 2.54cm / 12 inches = .492 feet

25cm / 2.54 / 12 inches = .82 feet

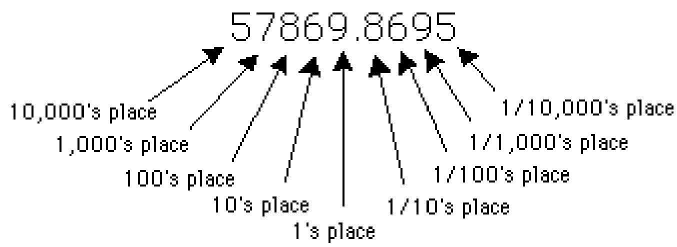
.785 X .492' X .492' X .82 X 7.48 = 1.17

1.17 X 3.785 Liters = Liters

Percentage and Fractions

Let's look again at the sequence of numbers 1000, 100, 10, 1, and continue the pattern to get new terms by dividing previous terms by 10:

.1 = 1/10
.01 = 1/100
.001 = 1/1000



So just as the digits to the left of the decimal represent 1's, 10's, 100's, and so forth, digits to the right of the decimal point represent 1/10's, 1/100's, 1/1000's, and so forth.

Let’s express 5% as a decimal. 5 ÷ 100 = 0.05 or you can move the decimal point to the left two places.

Changing a fraction to a decimal:
Divide the numerator by the denominator

A. 5/10 (five tenths) = five divided by ten:

```
      .5
    -----
 10 ) 5.0
      5 0
    ----
```

So 5/10 (five tenths) = .5 (five tenths).

B. How about 1/2 (one half) or 1 divided by 2 ?

```
     .5
    -----
  2 ) 1.0
      1 0
      ----
```

So 1/2 (one half) = .5 (five tenths)
Notice that equivalent fractions convert to the same decimal representation.

8/12 is a good example. 8 ÷ 12 =.66666666 or rounded off to .667

How about 6/12 or 6 inches? .5 or half a foot

Flow and Velocity

This depends on measuring the average velocity of flow and the cross-sectional area of the channel and calculating the flow from:

$$Q(m^3/s) = A(m^2) \times V(m/s)$$

Or

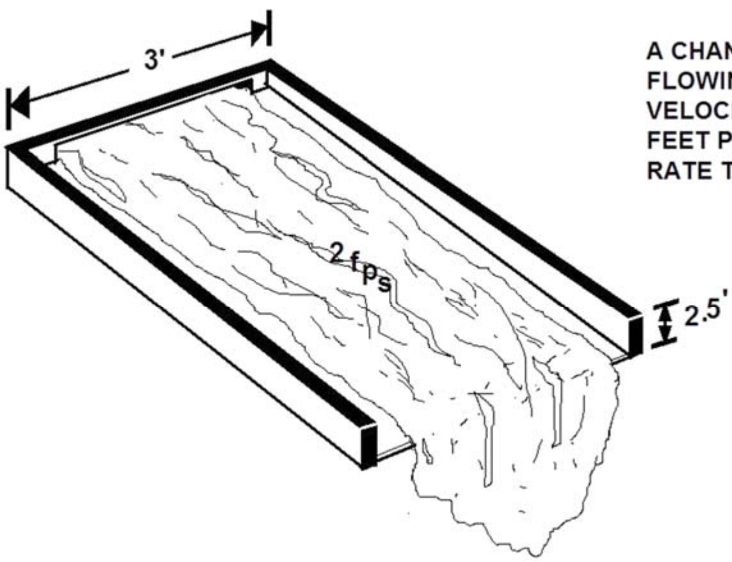
$$Q = A \times V$$

Q CFM = Cubic Ft, Inches, Yards of time, Sec, Min, Hrs, Days
A = Area, squared Length X Width
V f/m = Inch, Ft, Yards, Per Time, Sec, Min, Ft or Speed

13. A channel is 3 feet wide and has water flowing to a depth of 2.5 feet. If the velocity through the channel is 2 fps or feet per second, what is the cfs flow rate through the channel?
Q = A X V

Q = 7.5 sq. ft. X 2 fps *What is Q?*

A= 3' X 2.5' = 7.5
V= 2 fps



A CHANNEL IS 3 FEET WIDE AND HAS WATER FLOWING TO A DEPTH OF 2.5 FEET. IF THE VELOCITY THROUGH THE CHANNEL IS 2 fps OR FEET PER SECOND,WHAT IS THE cfs FLOW RATE THROUGH THE CHANNEL.

Q = A X V

A = 3ft. X 2.5ft

A = 7.5 ft^2

V = 2ft./sec.

Q = 7.5 ft.^{2} X 2ft./sec.

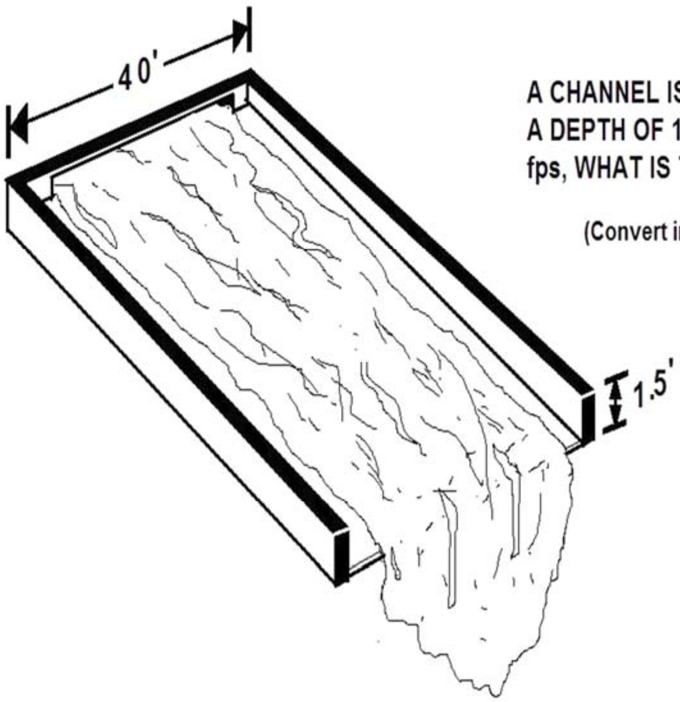
Q = /sec.

14. A channel is 40 inches wide and has water flowing to a depth of 1.5 ft. If the velocity of the water is 2.3 fps, what is the cfs flow in the channel? Q = A X V
First we must convert 40 inches to feet.

40 ÷ 12" = 3.333 feet

A = 3.333' X 1.5' = 4.999 or round up to 5
V = 2.3 fps

We can round this answer up.



A CHANNEL IS 40 INCHES WIDE AND HAS WATER FLOWING TO A DEPTH OF 1.5 FEET. IF THE VELOCITY OF THE WATER IS 2.3 fps, WHAT IS THE cfs FLOW IN THE CHANNEL.

(Convert inches to feet first by dividing by 12 to get feet)

Q = A X V

A = (40/12 = 3.33ft.) X (1.5ft)

A = 4.995 (Round to 5)

V = 2.3 ft/sec.

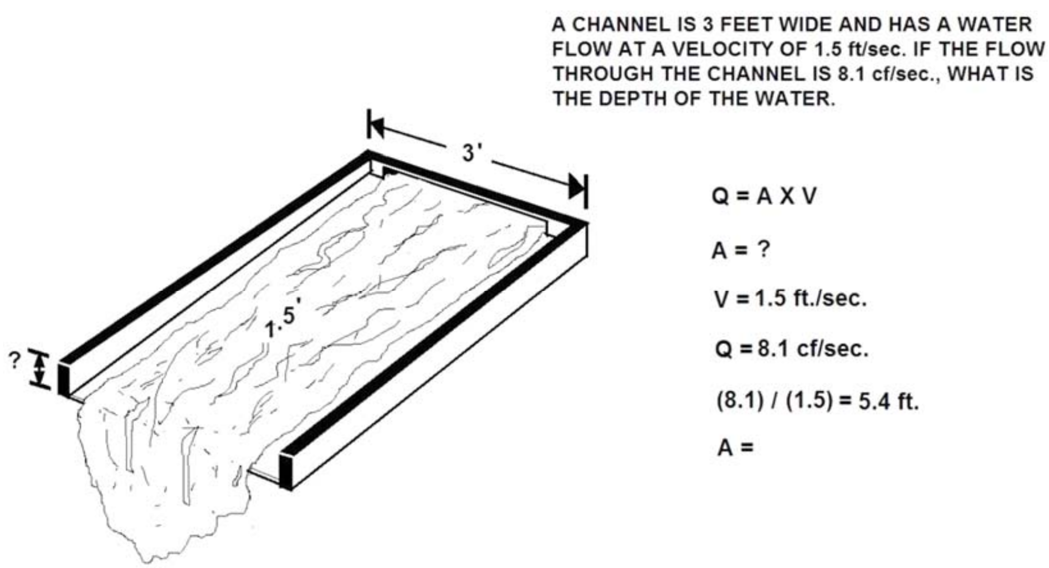
Q = 2.3 ft/sec. X 5ft

Q = cf/sec.

15. A channel is 3 feet wide and has a water flow at a velocity of 1.5 fps. If the flow through the channel is 8.1 cfs, what is the depth of the water?

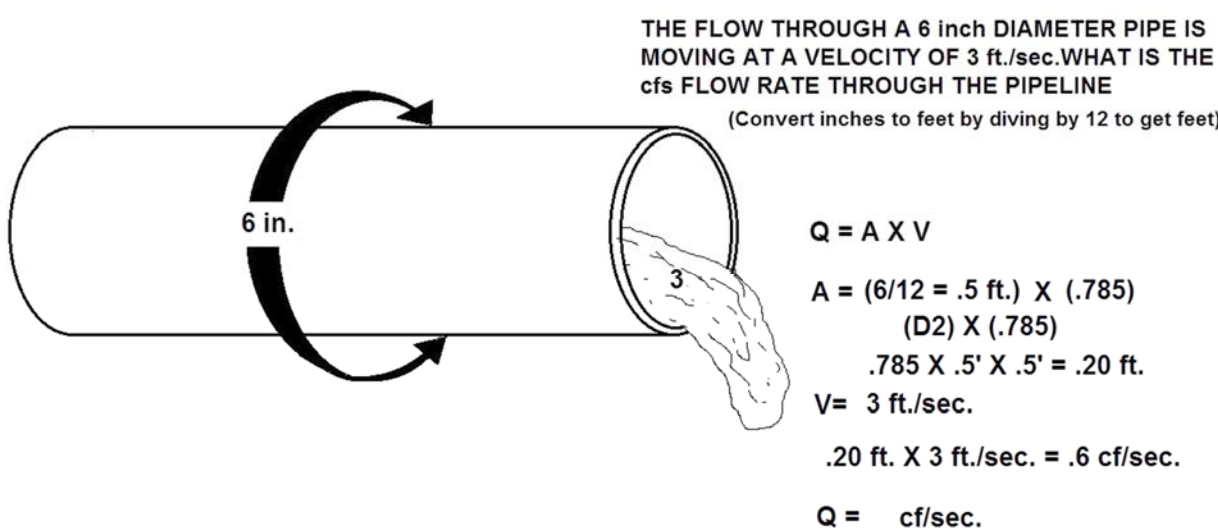
Q = 8.1 cfs
V = 1.5 fps
A = ?

8.1 ÷1.5 = _______ Total Area

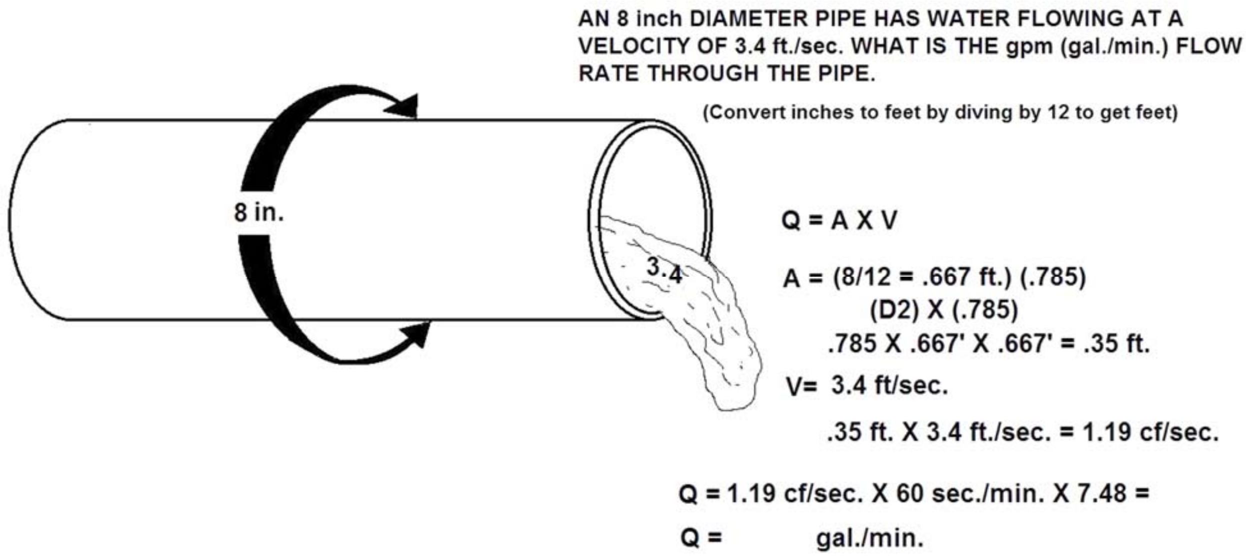


16. The flow through a 6 inch diameter pipe is moving at a velocity of 3 ft/sec. What is the cfs flow rate through the pipeline?

Q =
A = .785 X .5' X .5' =
V = 3 fps



17. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?
Q = ______ cfs X 60 sec/min X 7.48 = ___________ gpm
A = .785 X .667' X .667'
V = 3.4 fps



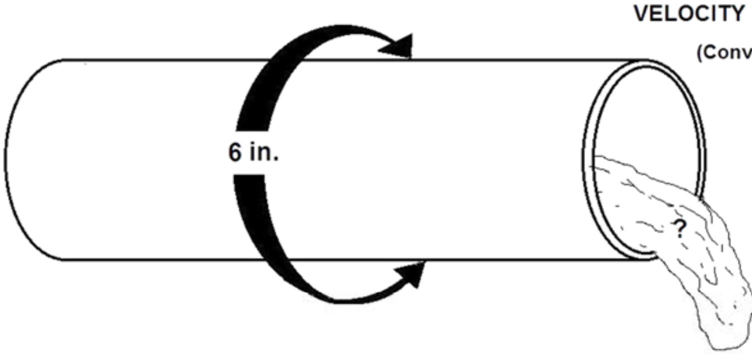
18. A 6 inch diameter pipe delivers 280 gpm. What is the velocity of flow in the pipe in ft/sec?

Take the water out of the pipe. 280 gpm ÷ 7.48 ÷ 60 sec/min = ________ cfs

Q =
A = .785 X .5' X .5' =
V =

A 6 inch PIPE DELIVERS 280 gal./min. WHAT IS THE VELOCITY IN THE PIPE IN ft./sec.

(Convert inches to feet by diving by 12 to get feet)



Q = A X V

A = (6/12 = .5 ft.) (.785)
(D2) (.785)
.785 X .5' X .5' = .20 ft.

V = ?

Q = 280 gal./min.

(Take the water out of the pipe)

Q = (280 gal./min.) / (7.48) / (60 sec./min.) = .623 cf/sec.

(Divide the Q by the A to get the V)

(.623 cf/sec.) / (.20 ft.) =

V = ft./sec.

19. A new section of 12 inch diameter pipe is to be disinfected before it is placed in service. If the length is 2000 feet, how many gallons of 5% NaOCl will be needed for a dosage of 200 mg/L?

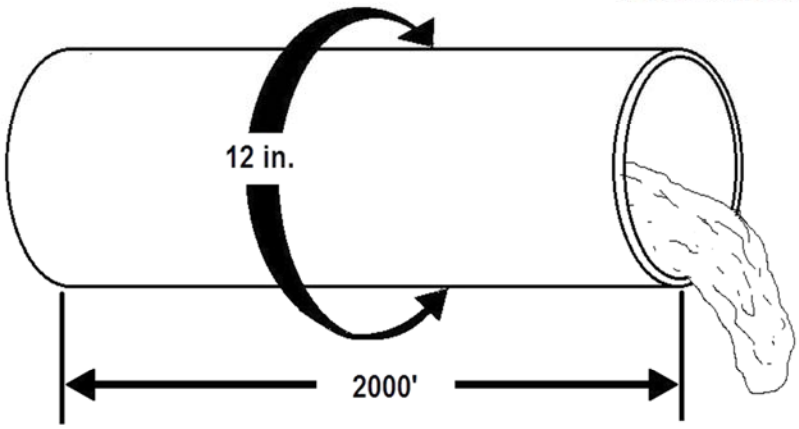
Cylinder Formula
V= (.785) (D^2) (d)

.785 X 1’ X 1’ X 2000’ = _______ cu.ft. X 7.48 = ______ ÷ 1,000,000 = ___________MG

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal if 100% concentrate. If not, divide the lbs/day by the given %

0.0117436 MG X 200 mg/L X 8.34 =_________ lbs/day ÷ .05 =

A NEW SECTION OF 12 inch DIAMETER PIPE IS TO BE DISINFECTED BEFORE IT IS PLACED IN SERVICE. IF THE LENGTH IS 2000 ft., HOW MANY GALLONS OF 5% NaOCl WILL BE NEEDED FOR A DOSAGE OF 200 mg/L.



CYLINDER FORMULA

V = (.785) (D2) (d)

.785 X 1.0 X 1.0 X 2000 = 1570'

1570' X 7.48 X = 11,743.6

11,743.6 / 1,000,000 MG = 0.012 MGD

0.012 X 200 X 8.34 = 19.59 lbs./day

19.59 lbs. / 0.05 % = 391.8 gallons

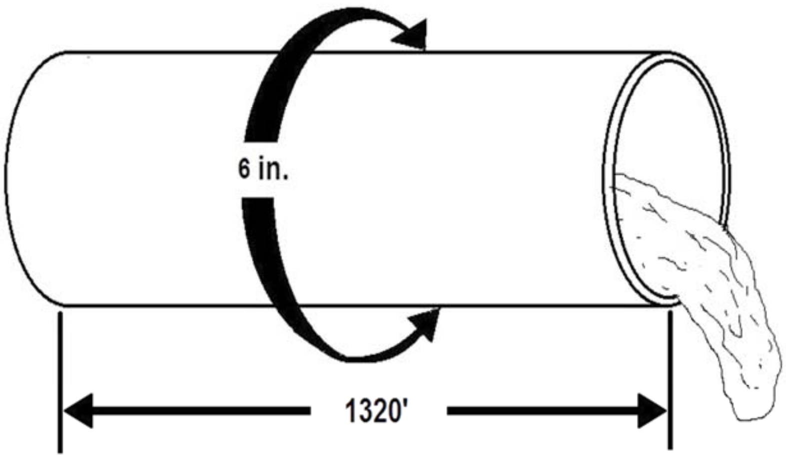
V = gallons

20. A section of 6 inch diameter pipe is to be filled with water. The length of the pipe is 1320 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 3 mg/L?

.785 X .5’ X .5’ X 1320’ X 7.48 =_____________ Make it MGD

Pounds per day formula = Flow X Dose X 8.34 X .454 Grams per pound

A SECTION OF 6 inch PIPE IS TO BE FILLED WITH WATER. THE LENGTH OF THE PIPE IS 1320 ft. LONG. HOW MANY KILOGRAMS OF CHLORINE WILL BE NEEDED FOR A CHLORINE DOSE OF 3 mg/L.



CYLINDER FORMULA

V = (.785) (D2) (d)

.785 X .5 X .5 X 1320 = 259.05

259.05 X 7.48 X = 1937.694

1937.694 / 1,000,000 MG = 0.002

0.002 X 3 mg/L X 8.34 = 0.050 lbs/day

0.050 lbs. X .454 gram = 0.023 Kg/day

Kg/day

Math Answers

1. 46750
2. 800 ÷ 8.34 = 95.92 gallons
3. 1372320 or 1.3 MGD
4. 610 X 1441 = 878400 or 0.87 MGD
5. 550 ÷ 60 = 9.167 gpm
6. 9.167 X 3.785 = 34.697 Liters
7. 630 Area 4712.4 gallons
8. 18,750 cu. ft. X 7.48 = 140250 gallons
9. 177182.5
10. 10 feet deep
11. 528462 or .5 MG
12. 1.166 Gallons X 3.785 = 4.4131 Liters
13. 15 cfs
14. 11.5 cfs
15. 5.4
16. .58875 or .6 cfs
17. 534.7 or 533 gpm
18. 3.115 or 3.2 ft/sec
19. 46.9 gal
20. .02 kg

Practice Questions, no answers provided

A5. A channel is 5 feet wide and has water flowing to a depth of 2 feet. If the velocity through the channel is 2 fps or feet per second, what is the cfs flow rate through the channel?

$$Q = A \times V$$

B5. A channel is 36 inches wide and has water flowing to a depth of 2.5 ft. If the velocity of the water is 2.0 fps, what is the cfs flow in the channel?

$$Q = A \times V$$

C5. A channel is 2 feet wide and has a water flow at a velocity of 3.5 fps. If the flow through the channel is 5.5 cfs, what is the depth of the water?

D5. The flow through a 8 inch diameter pipe is moving at a velocity of 5 ft/sec. What is the cfs flow rate through the pipeline?

E5. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?

F5. A 6 inch diameter pipe delivers 55 gpm. What is the velocity of flow in the pipe in ft/sec?

G5. A new section of 18 inch diameter pipe is to be disinfected before it is placed in service. If the length is 5000 feet, how many gallons of 5% NaOCl will be needed for a dosage of 200 mg/L?

Cylinder Formula
$V = (.785)(D^2)(d)$

H5. A section of 18 inch diameter pipe is to be filled with water. The length of the pipe is 1200 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 2 mg/L?

Pounds per day formula = Flow X Dose X 8.34 X .454 Grams per pound

Chlorine Dose Example

$$\text{DOSE, mg/L} = \frac{(332)\ \text{lbs. / day}}{(5.27)\ \text{MGD} \times 8.34\ \text{lbs./mg/L/MG}}$$

$$\text{DOSE, mg/L} = (7.6)\ \text{mg/L}$$

DOSE CALCULATION EXAMPLE

Chlorine Residual Formula

$$\text{Dose, mg / L} = \text{Demand, mg / L} + \text{Residual, mg / L}$$

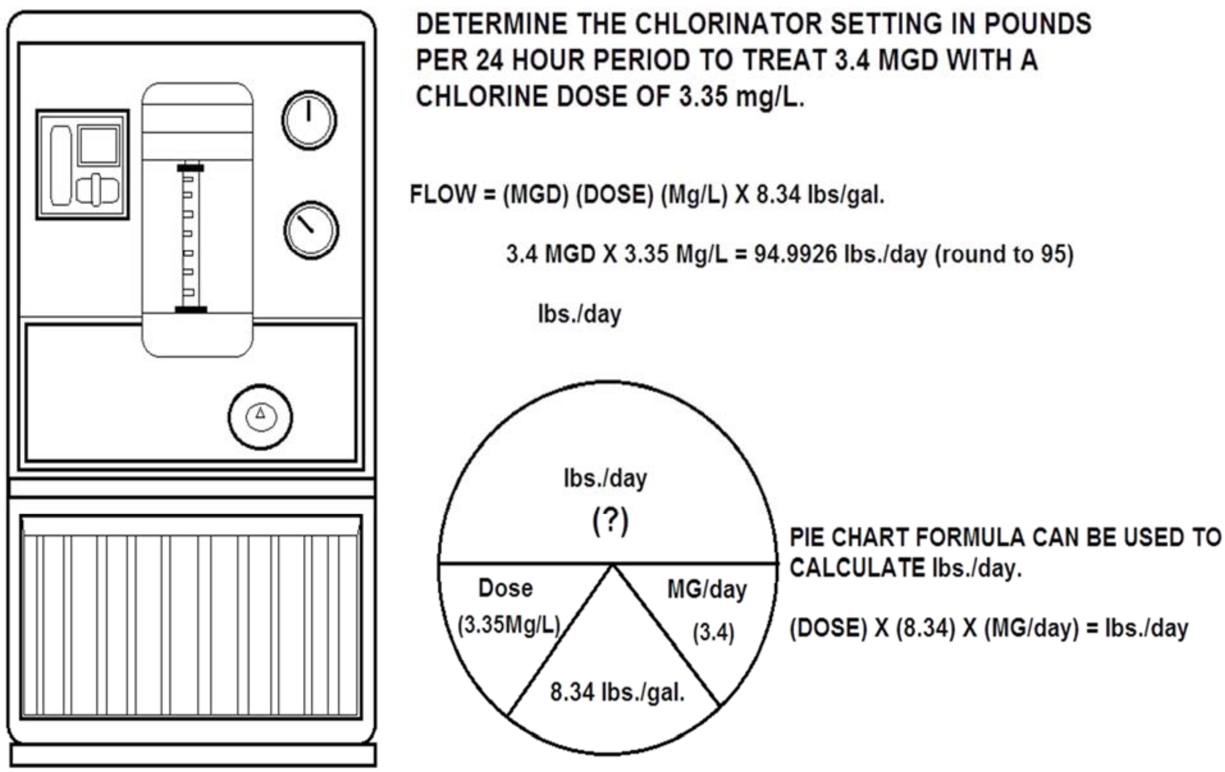
How To Calculate Chlorine Dose

$$(\text{mg / L } Cl_2)\ (\text{MGD flow})\ (8.34\ \text{lbs. / gal.}) = \text{lbs. / day } Cl_2$$

Formula To Convert : mg/L TO lbs./day

21. Determine the chlorinator setting in pounds per 24 hour period to treat a flow of 3.4 MGD with a chlorine dose of 3.35 mg/L? Answer in rear of this section.

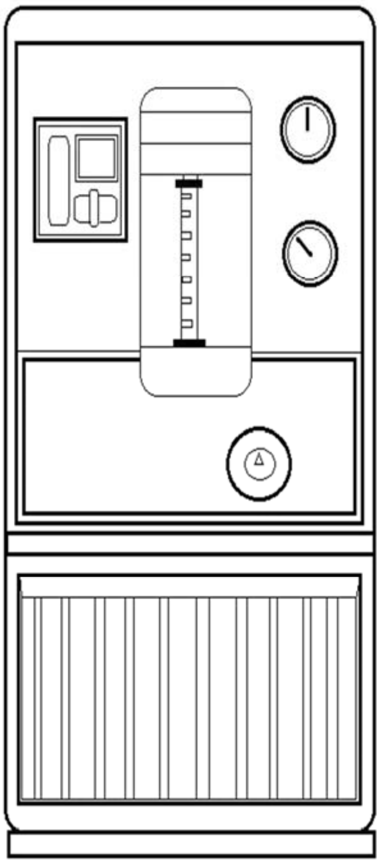
Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal



22. To correct an odor problem, you use chlorine continuously at a dosage of 15 mg/L and a flow rate of 85 GPM. Approximately how much will odor control cost annually if chlorine is $0.17 per pound?

85 gpm X 1440 min/day = _____________ gpd ÷ 1,000,000 = __________ MGD

______ MGD X 15 mg/L X 8.34 lbs/gal X $0.17 per pound X 365 days/year =



TO CORRECT AN ODOR PROBLEM, YOU USE CHLORINE CONTINUOUSLY AT A DOSAGE OF 15 mg/L AND A FLOW RATE OF 85 GPM. APPROXIMATELY HOW MUCH WILL ODOR CONTROL COST ANNUALLY IF CHLORINE IS $0.17 PER POUND.

CONVERT GPM TO gal/day.: 85 GPM X 1440 min./day = 122,400 gal./day.

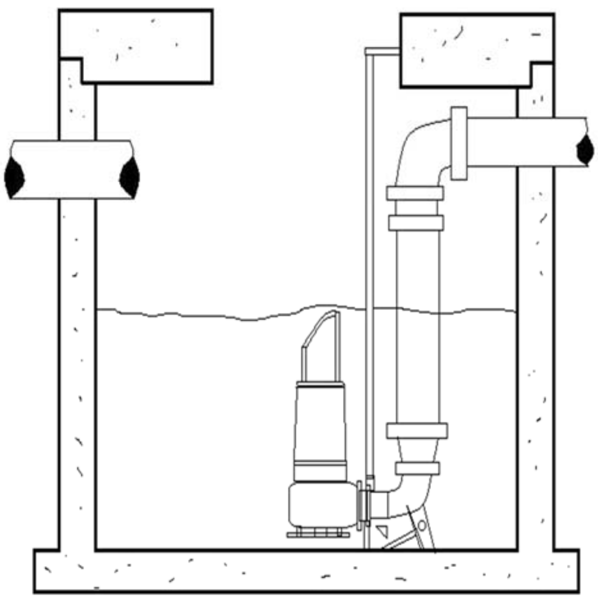
NOW CONVERT TO MGD: 122,400 divided by 1,000,000 = .1224 MGD.

.1224 MGD X 15 mg/L X 8.34 lbs./gal. X $ 0.17 per/Lb. X 365 days/year =

COST =

23. A wet well measures 8 feet by 10 feet and 3 feet in depth between the high and low levels. A pump empties the wet well between the high and low levels 9 times per hour, 24 hours a day. Neglecting inflow during the pumping cycle, calculate the flow into the pump station in millions of gallons per day (MGD).

Build it, fill it, and do what it says, hint: X 9 X 24



A WET WELL MEASURES 8 feet BY 10 feet AND 3 feet IN DEPTH BETWEEN THE HIGH AND LOW LEVELS. A PUMP EMPTIES THE WET WELL BETWEEN THE HIGH AND LOW LEVELS 9 TIMES PER HOUR, 24 HOURS A DAY. NEGLECTING INFLOW DURING PUMP CYCLE, CALCULATE THE FLOW INTO THE PUMP STATION IN MILLION OF GALLONS PER DAY (MGD).
(Build it / Fill it / and Do What it says, hint: X 9 X 24)

(L) (W) (d) = (8) X (10) X (3) = 240 ft3
(CONVERT TO GALLONS: X 7.48)

240 ft3 X 7.48 = 1795.2 gals.

DETERMINE HOW MANY CYCLES IN 24 hrs.:
9 times hour X 24 hrs./day = 216 times/day.

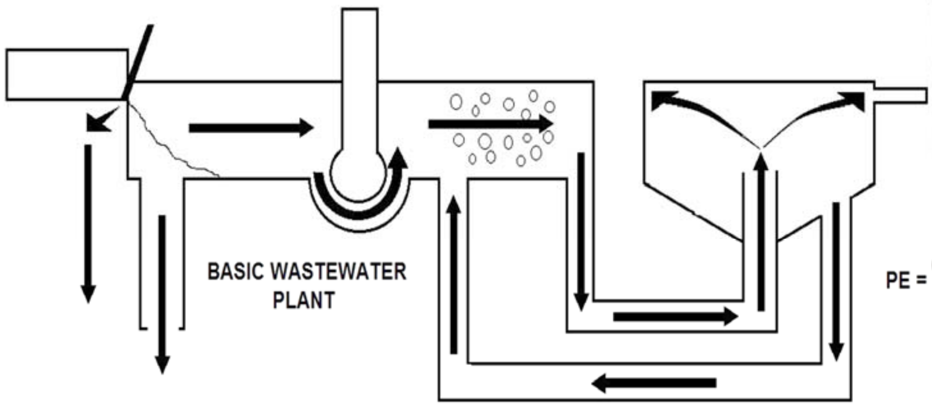
1795.2 gals. X 216 times/day = 387763.2 gals./day

CONVERT THIS TO MGD BY DIVIDING BY 1,000,000.

387763.2 gals./day / 1,000,000 = .388 MGD

INFLOW =   MGD

24. A sewage treatment plant has a flow of 0.7 MGD and a BOD of 225 mg/L. On the basis of a national average of 0.2 lbs BOD per capita per day, what is the approximate population equivalent of the plant?



A SEWAGE TREATMENT PLANT HAS A FLOW OF 0.7 MGD AND A BOD OF 225 mg/L. ON THE BASIS OFA NATIONAL AVERAGE OF 0.2 lbs. BOD PER CAPITA PER DAY, WHAT IS THE APPROXIMATE POPULATION EQUIVALENT OF THE PLANT?

$$PE = \frac{\text{(FLOW/MGD) (BOD mg/L) (8.34)}}{\text{lbs. day/per person}}$$

$$\frac{\text{(0.7 /MGD) (225 mg/L) (8.34)}}{\text{0.2 lbs. day/per person}}$$

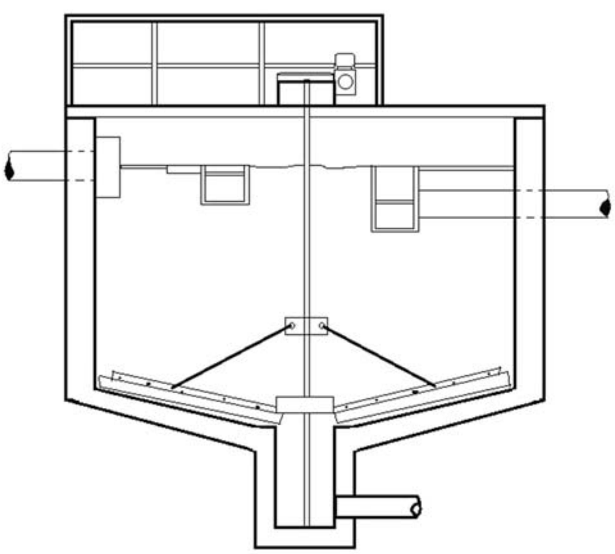
$$\frac{1313.55}{0.2} =$$

25. What is the detention time of a clarifier with a 250,000 gallon capacity if it receives a flow of 3.0 MGD?

DT= Volume in Gallons X 24 Divided by MGD

.25 MG X 24 hrs ÷ 3.0 MGD =________ Hours of DT

Always convert gallons to MG



WHAT IS THE DETENTION TIME OF A CLARIFIER WITH A 250,000 GALLON CAPACITY IF IT RECEIVES A FLOW OF 3.0 MGD.

DT = VOLUME IN GALLONS X 24 DIVIDED BY MDG

CONVERT GALLONS TO MG/DAY. BY DIVIDING BY 1,000,000.

250,000 gal. / 1,000,000 = .25 MGD.

.25 MGD X 24 hrs./day divided BY 3.0 MGD = 2.0

DT = hours.

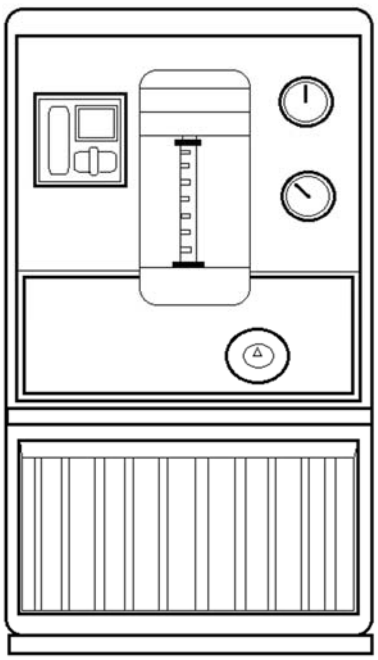
Answers

21. 94.9 lbs/day
22. $950.12
23. .388 or .39 MGD
24. 6567.75
25. 2 hrs

Practice Questions

A6. Determine the chlorinator setting in pounds per 24 hour period to treat a flow of 5.4 MGD with a chlorine dose of 2.35 mg/L?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

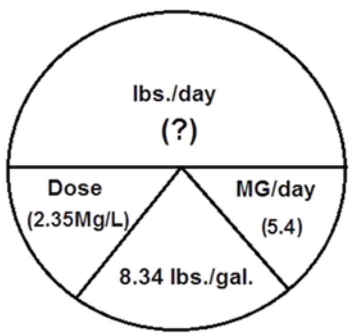


DETERMINE THE CHLORINATOR SETTING IN POUNDS PER 24 HOUR PERIOD TO TREAT 5.4 MGD WITH A CHLORINE DOSE OF 2.35 mg/L.

FLOW = (MGD) (DOSE) (Mg/L) X 8.34 lbs/gal.

5.4 MGD X 2.35 Mg/L = 105.83 lbs./day (round to 106)

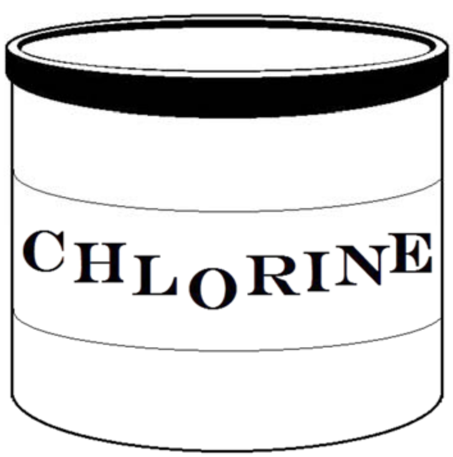
106 lbs./day



PIE CHART FORMULA CAN BE USED TO CALCULATE lbs./day.

(DOSE) X (8.34) X (MG/day) = lbs./day

B6. To correct an odor problem, you use chlorine continuously at a dosage of 15 mg/L and a flow rate of 7 GPM. Approximately how much will odor control cost annually if chlorine is $0.15 per pound?



TO CORRECT AN ODOR PROBLEM, YOU USE CHLORINE CONTINUOUSLY AT A DOSAGE OF 15 mg/L AND A FLOW RATE OF 7 GPM. APPROXIMATELY HOW MUCH WILL ODOR CONTROL COST ANNUALLY IF CHLORINE IS $0.15 PER POUND?

FIRST CONVERT gal./min TO MGD

(7gal./min.) (1440 min./day) = 10,080 gal./day

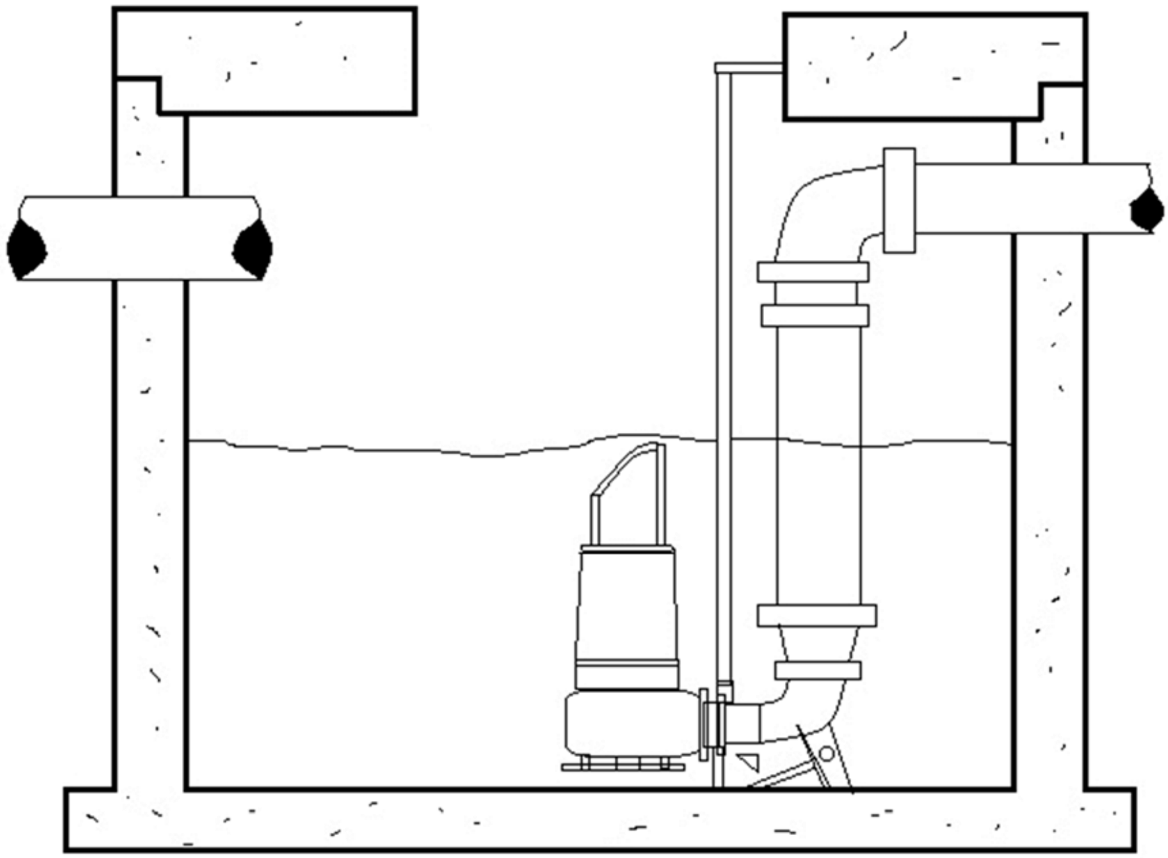
DIVIDE gal./day BY 1,000,000 TO GET MGD

10,080 / 1,000,000 = 0.010 MGD

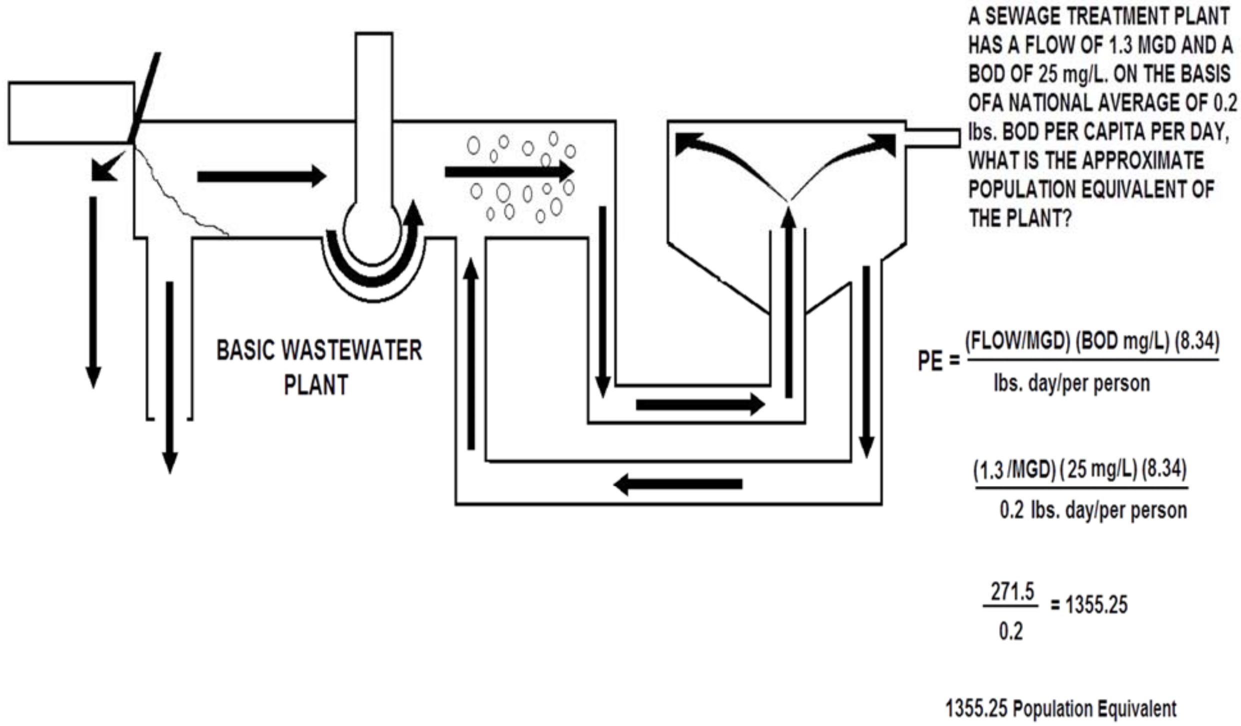
(0.010 MGD) (15 mg/L) (8.34 lbs./gal.) ($0.15/lb.) (365 days/year)= $68.49

$ 68.49 ANNUAL COST

C6. A wet well measures 12 feet by 15 feet and 11 feet in depth between the high and low levels. A pump empties the wet well between the high and low levels 9 times per hour, 24 hours a day. Neglecting inflow during the pumping cycle, calculate the flow into the pump station in millions of gallons per day (MGD).

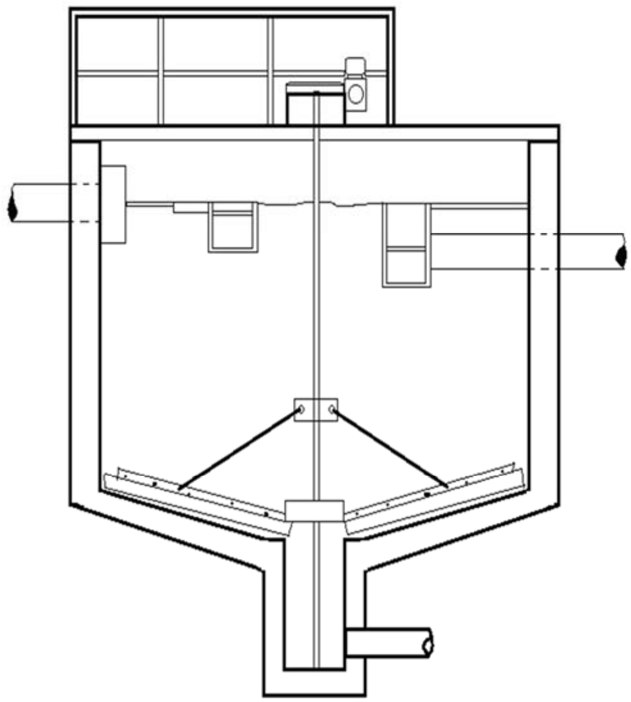


D6. A sewage treatment plant has a flow of 1.3 MGD and a BOD of 25 mg/L. On the basis of a national average of 0.2 lbs BOD per capita per day, what is the approximate population equivalent of the plant?



E6. What is the detention time of a clarifier with a 750,000 gallon capacity if it receives a flow of 10.0 MGD?

DT= Volume in Gallons X 24 Divided by MGD



WHAT IS THE DETENTION TIME OF A CLARIFIER WITH A 750,000 GALLON CAPACITY IF IT RECEIVES A FLOW OF 10.0 MGD.

DT = VOLUME IN GALLONS X 24 DIVIDED BY MDG

CONVERT GALLONS TO MG/DAY. BY DIVIDING BY 1,000,000.

750,000 gal. / 1,000,000 = .75 MGD.

.75 MGD X 24 hrs./day divided BY 10.0 MGD = 1.8

DT = 1.8 hours.

Metric Math Section

The metric system is known for its simplicity. All units of measurement in the metric system are based on decimals—that is, units that increase or decrease by multiples of ten. A series of Greek decimal prefixes is used to express units of ten or greater; a similar series of Latin decimal prefixes is used to express fractions. For example, deca equals ten, hecto equals one hundred, kilo equals one thousand, mega equals one million, giga equals one billion, and tera equals one trillion.

For units below one, deci equals one-tenth, centi equals one-hundredth, milli equals one-thousandth, micro equals one-millionth, nano equals one-billionth, and pico equals one-trillionth.

1 ppm = 1 pound per million pounds / or

120,000 Gallons of Water = 1,000,000 pounds

1 ppm = 1 pound per 120,000 Gallons of Water

Milligrams Per liter

(Parts Per Million)

1 Gram (weight) = 1,000 milligrams (and)

1 Liter of Water Weighs 1,000 GRAMS (so)

1 Liter of Water = 1,000,000 milligrams (1,000 X 1,000) (so)

1 Milligram in one Liter of Water = 1 milligram per liter (or)

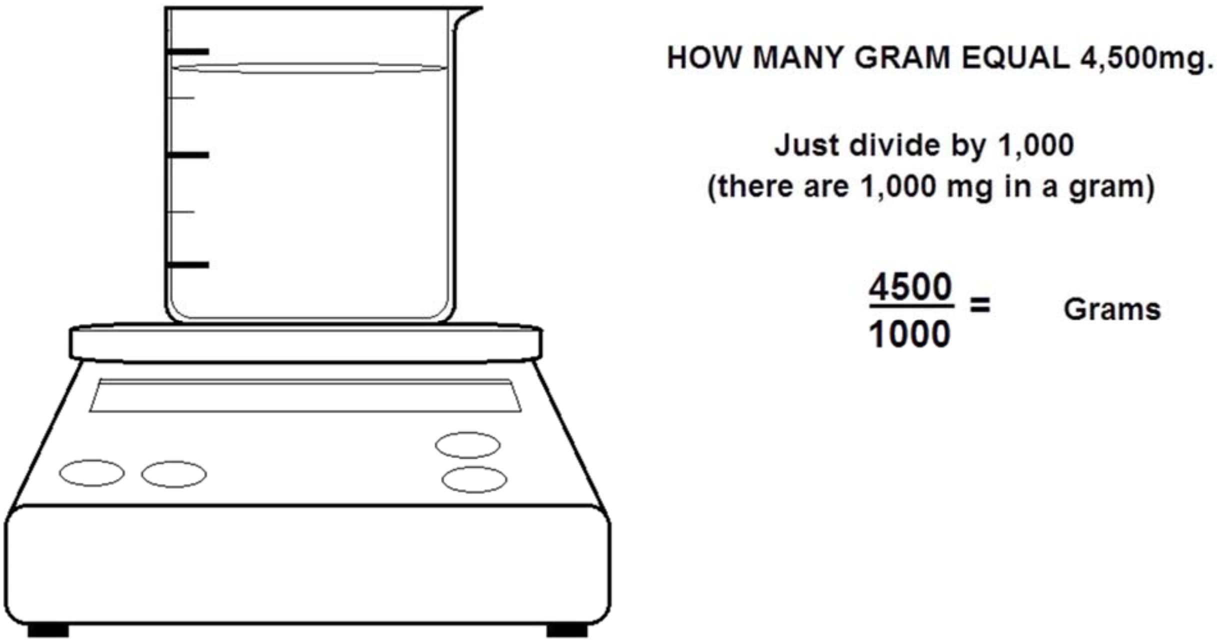
One Part in a Million Parts

Milligrams Per Liter

(Refers to a Weight Ratio)

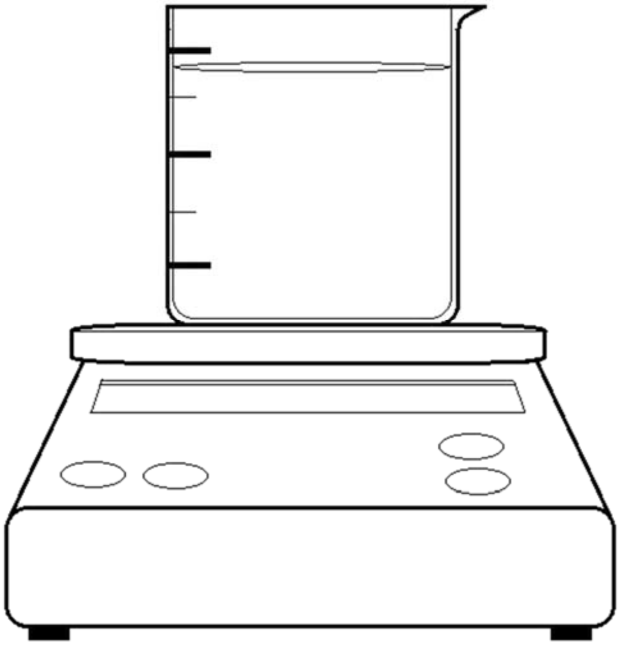
26. How many grams equal 4,500 mg?

Just simply divide by 1,000.



Practice Questions

A7. How many grams equal 7,500 mg?

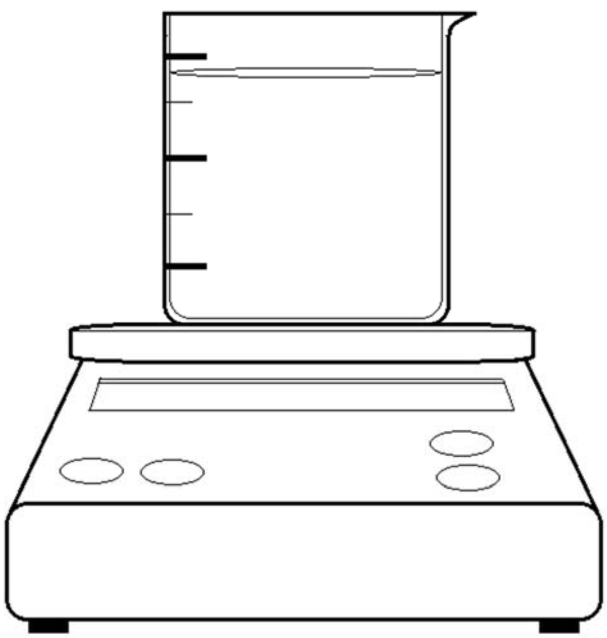


HOW MANY GRAM EQUAL 7,500mg.

Just divide by 1,000
(there are 1,000 mg in a gram)

$$\frac{7500}{1000} = 7.5 \text{ Grams}$$

B7. How many grams equal 12,500 mg?



HOW MANY GRAM EQUAL 12,500mg.

Just divide by 1,000
(there are 1,000 mg in a gram)

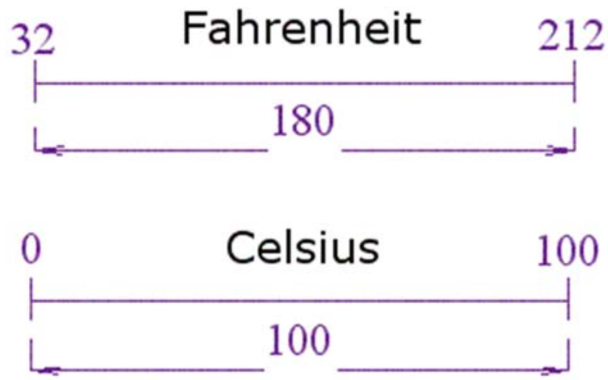
$$\frac{12500}{1000} = 12.5 \text{ Grams}$$

Temperature

There are two main temperature scales. The Fahrenheit Scale (used in the US), and the Celsius Scale (part of the Metric System, used in most other Countries)

They both measure the same thing (temperature!), just using different numbers.

If you freeze water, it measures 0° in Celsius, but 32° in Fahrenheit
If you boil water, it measures 100° in Celsius, but 212° in Fahrenheit
The difference between freezing and boiling is 100° in Celsius, but 180° in Fahrenheit.



Conversion Method
Looking at the diagram, notice:

The scales start at a different number (32 vs. 0), so we will need to add or subtract 32
The scales rise at a different rate (180 vs. 100), so we will also need to multiply
And this is how it works out:

To convert from Celsius to Fahrenheit, first multiply by 180/100, then add 32

To convert from Fahrenheit to Celsius, first subtract 32, then multiply by 100/180

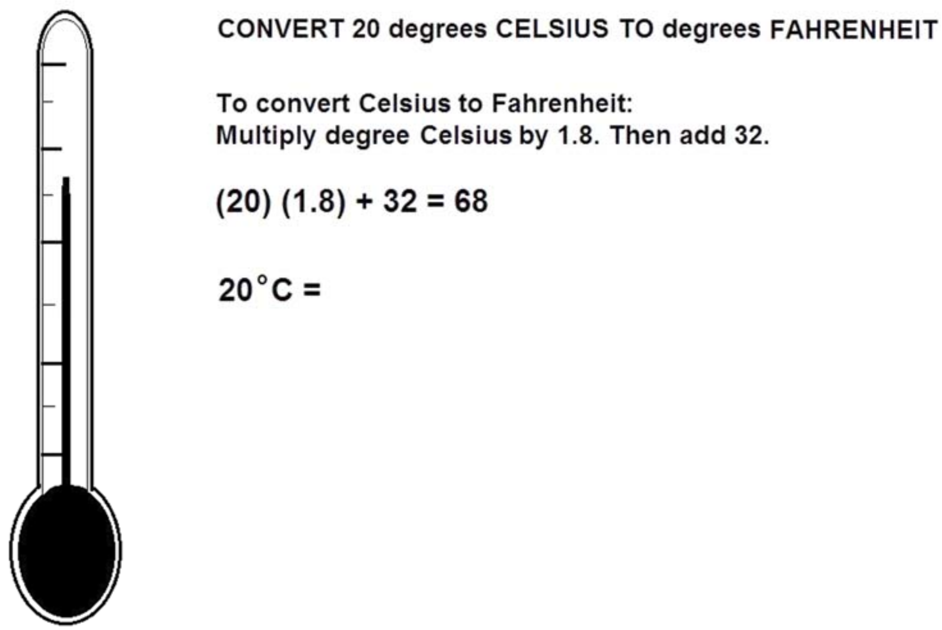
Note: 180/100 can be simplified to 9/5, and likewise 100/180=5/9.

$^{0}F = (0C\ X\ 9/5) + 32$ $\quad 9/5 = 1.8$

$^{0}C = (0F - 32)\ X\ 5/9$ $\quad 5/9 = .555$

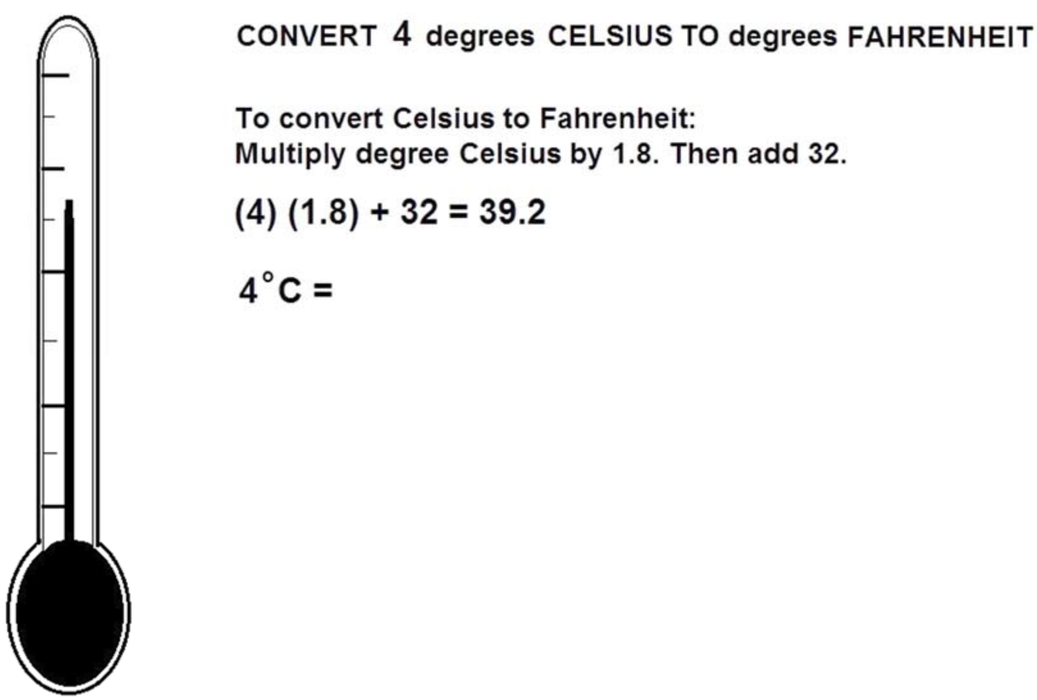
27. Convert 20 degrees Celsius to degrees Fahrenheit.

$20^{\circ} \times 1.8 + 32 = F$



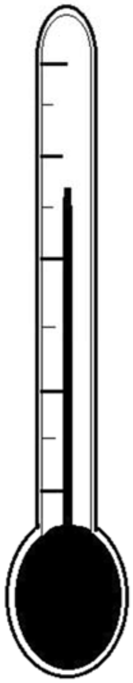
28. Convert 4 degrees Celsius to degrees Fahrenheit.

$4^{\circ} \times 1.8 + 32 = F$



Practice Questions

A8. Convert 22 degrees Celsius to degrees Fahrenheit.



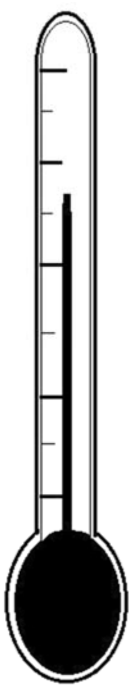
CONVERT 22 degrees CELSIUS TO degrees FAHRENHEIT

To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

$(22)\ (1.8) + 32 = 71.6$

$22^{\circ}C = 71.6^{\circ}F$

B8. Convert 2 degrees Celsius to degrees Fahrenheit.



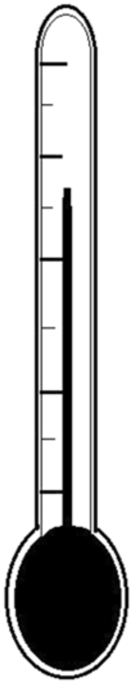
CONVERT 2 degrees CELSIUS TO degrees FAHRENHEIT

To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

$(2)\ (1.8) + 32 = 35.6$

$2^{\circ}C = 35.6^{\circ}F$

C8. Convert 82 degrees Fahrenheit to degrees Celsius.



CONVERT 82 degrees FAHRENHEIT TO degrees CELSIUS

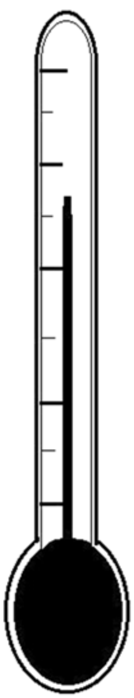
To convert Fahrenheit to Celsius :

First subtract by 32 then multiply by .555

82 - 32 (.555) = 27.75

82°F = 27.75°C

D8. Convert 33 degrees Fahrenheit to degrees Celsius.



CONVERT 33 degrees FAHRENHEIT TO degrees CELSIUS

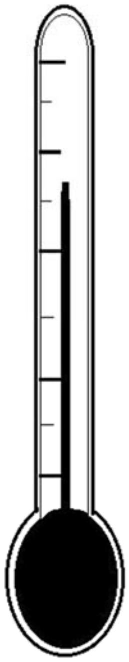
To convert Fahrenheit to Calsius :

First subtract by 32 then multiply by .555

33 - 32 (.555) = .555

33°F = .555°C

E8. Convert 72 degrees Fahrenheit to degrees Celsius.



CONVERT 72 degrees FAHRENHEIT TO degrees CELCIUS

To convert Fahrenheit to Celcius:

First subtract by 32 then multiply by .555

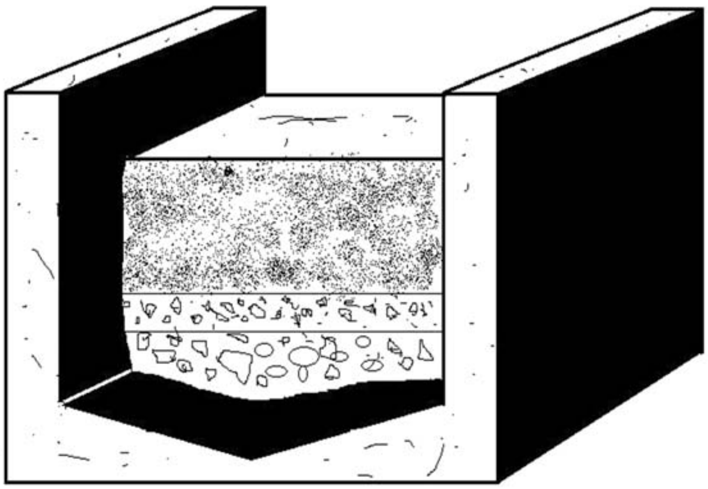
72 - 32 (.555) = 22.2

$72^{\circ}F = 22.2^{\circ}C$

Water Treatment Filters

29. A 19 foot wide by 31 foot long rapid sand filter treats a flow of 2,050 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.

GPM ÷ Square Feet



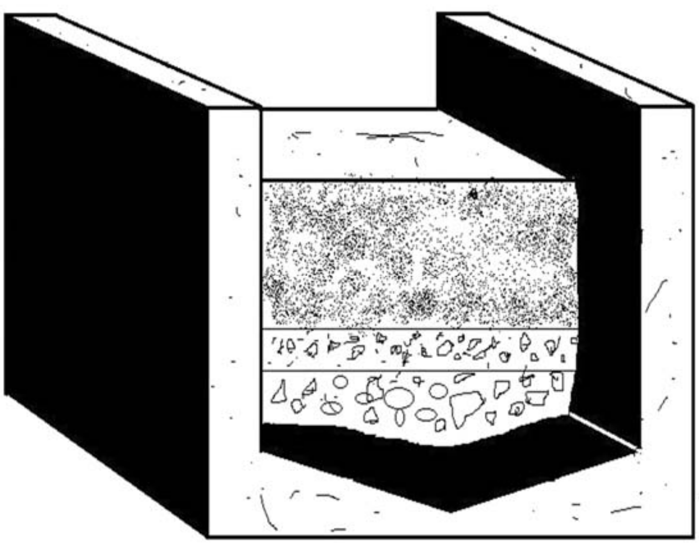
A 19 FOOT WIDE BY 31 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 2,050 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

Determine Square Feet:
(W) (H)
(19) (31) = 598 ft^2

$$\frac{2050 \text{ gal/min}}{598 \text{ ft}^2} =$$

30. A 26 foot wide by 36 foot wide long rapid sand filter treats a flow of 2,500 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.



A 26 FOOT WIDE BY 36 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 2,500 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

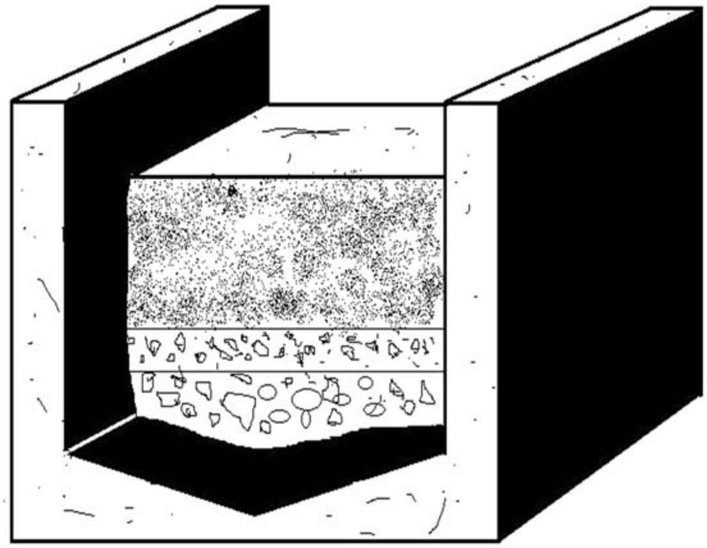
GPM divided by Square Feet

Determine Square Feet:
(W) (H)
(26) (36) = 936 ft^2

$$\frac{2500 \text{ gal/min}}{936 \text{ ft}^2} =$$

Practice Questions

A9. A 25 foot wide by 25 foot long rapid sand filter treats a flow of 300 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.



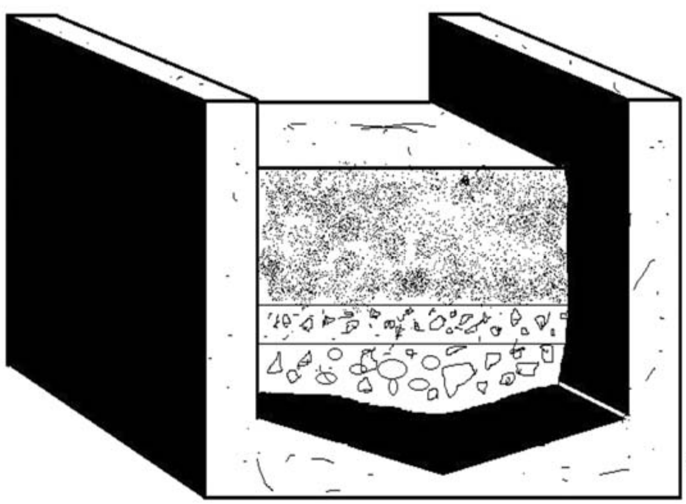
A 25 FOOT WIDE BY 25 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 300 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

Determine Square Feet:
(W) (H)
$(25)\ (25) = 625\ ft^2$

$$\frac{300\ gal/min}{625\ ft^2} = .48\ gal/min./ft^2$$

B9. A 30 foot wide by 30 foot wide long rapid sand filter treats a flow of 1,500 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.



A 30 FOOT WIDE BY 30 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 1,500 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

Determine Square Feet:
(W) (H)
$(30)\ (30) = 900\ ft^2$

$$\frac{1500\ gal/min}{900\ ft^2} = 1.67\ gal/min./ft^2$$

Chemical Dose

31. A pond has a surface area of 51,500 square feet and the desired dose of a chemical is 6.5 lbs per acre. How many pounds of the chemical will be needed?

43,560 Square feet in an acre

51,500 ÷ 43,560 = _______ X 6.5 =

32. A pond having a volume of 6.85 acre feet equals how many millions of gallons?

Practice Questions, no answers provided

A10. A pond has a surface area of 75,000 square feet and the desired dose of a chemical is 5.5 lbs per acre. How many pounds of the chemical will be needed?

B10. A pond having a volume of 13,000 acre feet equals how many millions of gallons?

33. Alum is added in a treatment plant process at a concentration of 10.5 mg/L. What should the setting on the feeder be in pounds per day if the plant is treating 3.5 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

$$GPD = \frac{GALLONS}{MINUTE} \times \frac{60\ MINUTES}{HOUR} \times \frac{24\ HOURS}{DAY}$$

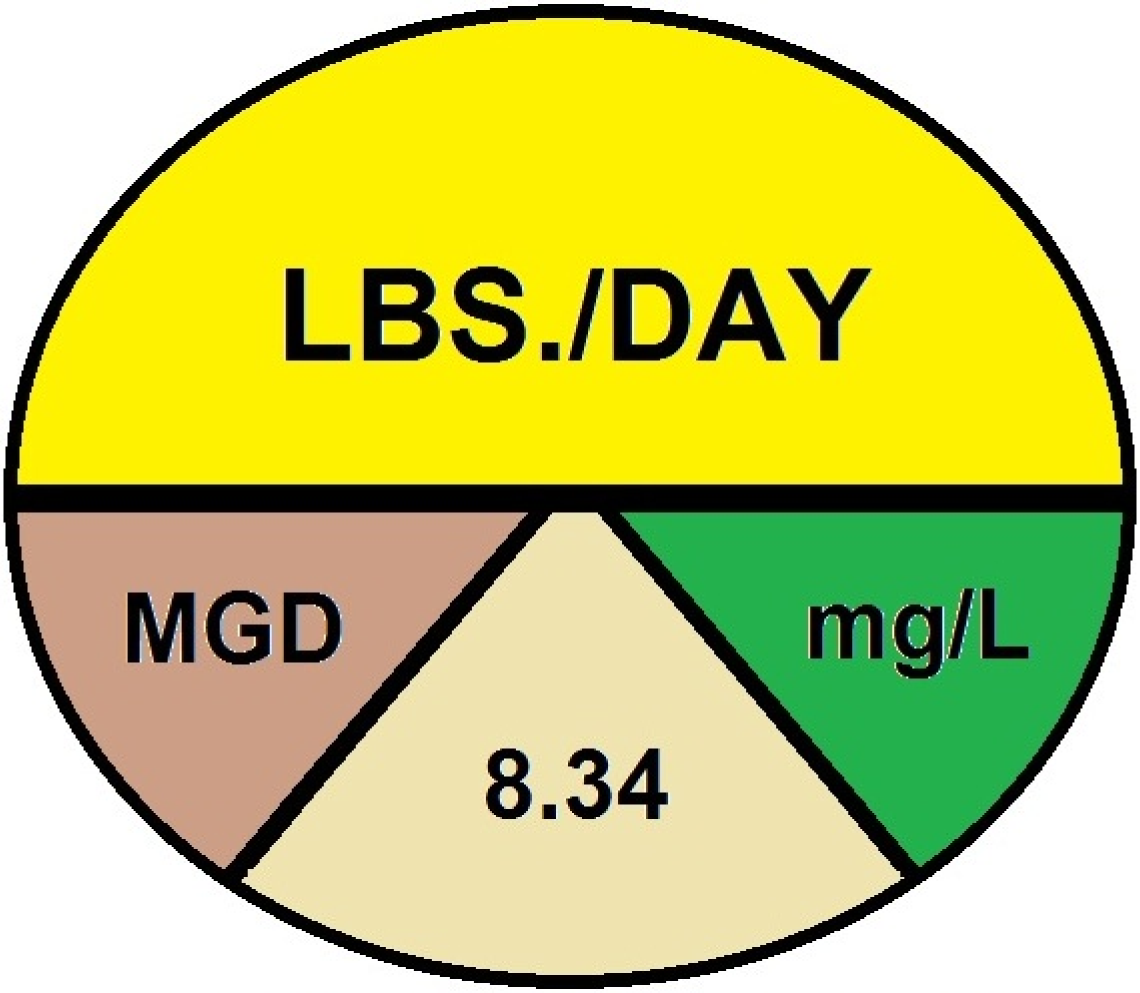
$$GT = \frac{CHLORINE\ \%\ \times\ 10{,}000}{1\ PPM}$$

$$\frac{GPD}{GT} = \text{GALLONS OF CHLORINE PER 24 HOURS}$$

GPD= Gallon Per Day
GT= Gallons Treated

$$(mg / L\ Cl_2)\ (MGD\ flow)\ (8.34\ lbs. / gal.) = lbs. / day\ Cl_2$$

Formula To Convert : mg/L TO lbs./day



POUNDS FORMULA WHEEL

Practice Questions, no answers provided

A11. Alum is added in a treatment plant process at a concentration of 4.5 mg/L. What should the setting on the feeder be in pounds per day if the plant is treating 23.5 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

Q=AV Review

34. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the GPM flow rate through the pipe?
Q = 1.18 CFS x 60 Seconds x 7.48 GAL/CU.FT = 532 GPM
A = .785 X .667 X .667 X 1 = .349 Sq. Ft.
V= 3.4 Feet per second

35. A 6 inch diameter pipe delivers 280 GPM. What is the velocity of flow in the pipe in Ft/Sec?
280 GPM ÷ 60 seconds in a minute ÷ 7.48 gallons in a cu.ft. = .623 CFS

Q = .623
A = .785 X.5 X .5 =.196 Sq. Ft.
V = 3.17 Ft/Second

Practice Questions, no answers provided

A12. An 36 inch diameter pipe has water flowing at a velocity of 1.4 fps. What is the GPM flow rate through the pipe?

B12. An 18 inch diameter pipe delivers 80 GPM. What is the velocity of flow in the pipe in Ft/Sec?

Collection Math Section

36. A 24-inch sewer carries an average daily flow of 5 MGD. If the average daily flow per person from the area served is 110 GPCD (gallons per capita per day), approximately how many people discharge into the wastewater collection system?

5,000,000 divided by 110 =

37. Using a dose rate of 5 mg/L, how many pounds of chlorine per day should be used if the flow rate is 1.2 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

38. What capacity blower will be required to ventilate a manhole which is 3.5 feet in diameter and 17 feet deep? The air exchange rate is 16 air changes per hour.
.785 X 3.5’ X 3.5’ X 17’ X 16 = ____________ CFH

39. Approximately how many feet of drop are in 455 feet of 8-inch sewer with a 0.0475 ft/ft. slope?

SLOPE = Rise (ft) / Run (ft)

SLOPE (%) = Rise (ft) / Run (ft) X 100

455' X 0.0475 =

40. How much brake horsepower is required to meet the following conditions: 250 gpm, total head = 110 feet? The submersible pump that is being specified is a combined 64% efficient?

(250 X 110) ÷ (3960 X .64)

41. How wide is a trench at ground surface if a sewer trench is 2 feet wide at the bottom, 10 feet deep, and the sides have been sloped at a 4/5 horizontal to 1 vertical (3/4:1) ratio?

(3/4:1) or 3 ÷ 4 = .75 X every foot of depth

Short Math Answers

1. 46750
2. 800 ÷ 8.34 = 95.92 gallons
3. 1372320 or 1.3 MGD
4. 610 X 1441 = 878400 or 0.87 MGD
5. 550 ÷ 60 = 9.167 gpm
6. 9.167 X 3.785 = 34.697 Liters
7. 630 Area 4712.4 gallons
8. 18,750 cu. ft. X 7.48 = 140250 gallons
9. 177182.5
10. 10 feet deep
11. 528462 or .5 MG
12. 1.166 Gallons X 3.785 = 4.4131 Liters
13. 15 cfs
14. 11.5 cfs
15. 5.4
16. .58875 or .6 cfs
17. 534.7 or 533 gpm
18. 3.115 or 3.2 ft/sec
19. 46.9 gal
20. .02 kg
21. 94.9 lbs/day
22. $950.12
23. .388 or .39 MGD
24. 6567.75
25. 2 hrs
26. 4.5 grams
27. 68° F
28. 39.2°F
29. 3.43 gpm/sq.ft.
30. 2.67 gpm/sq.ft.
31. 7.68 lbs
32. 2.231 MG
33. 306.495
34. 532 gpm
35. 3.2 fps
36. 45454.5 people
37. 50.04 lbs
38. 2615.6 cfh
39. 21.61 ft
40. 10.85 bhp
41. 17 ft

Glossary

Excellent operator certification study tool. Please study this section before your exam.

0.2 mg/L: Should be the target value for the free chlorine residual in the distribution system.
10 ppm: The IDLH for Cl2 gas according to the NIOSH manual.
Absence of Oxygen: The complete absence of oxygen in water described as Anaerobic.
Accuracy: How closely an instrument measures the true or actual value.
Acid and a Base is Mixed: When an acid and a base are mixed an explosive reaction occurs and decomposition products are created under certain conditions.
Acid Rain: A result of airborne pollutants.
Acid: Slowly add the acid to water while stirring. An operator should not mix acid and water or acid to a strong base.
Activated Charcoal: A treatment technique that is not included in the grading of a water facility.
Air Gap or Vacuum Breaker: A potable water line should be equipped with an air gap or vacuum breaker when connected to a chemical feeder for fluoride.
Air Gap: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet. Minimum 1 inch or twice the diameter whatever is greater.
Air Hood: The most suitable protection when working with a chemical that produces dangerous fumes.
Alternative Disinfectants: Disinfectants - other than chlorination (halogens) - used to treat water, e.g. ozone, ultraviolet radiation, chlorine dioxide, and chloramine. There is limited experience and scientific knowledge about the by-products and risks associated with the use of alternatives.
Aluminum Sulfate: The chemical name for Alum. The molecular formula of Alum is $Al_2(SO_4)3\sim14H_2O$. It is a cationic polymer.
Ammonia: A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water. Most ammonia in water is present as the ammonium ion rather than as ammonia.
Anaerobic: An abnormal condition in which color and odor problems are most likely to occur.
Anaerobic conditions: When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with Reduction in the stratified waters.
Aquifer: An underground geologic formation capable of storing significant amounts of water. Is a permeable layer of the subsurface that allows the movement of groundwater.
As: The chemical symbol of Arsenic.
Atom: The general definition of an ion is an atom with a positive or negative charge. Electron is the name of a negatively charged atomic particle.
Backflow 12 inches: The required distance above ground that a double check backflow or RP assembly needs to be installed.
Backflow or Cross-connection Failure: Might be the source of an organic substance causing taste and odor problems in a water distribution system.
Backflow Prevention: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquid, gases, or solid substances back in to the public potable (drinking) water supply. Continuous positive pressure in a distribution system is essential for preventing a backflow event. See Cross-connection control.
Backflow: A double check valve backflow assembly provides effective protection from both backpressure and backsiphonage of pollution only. Needs to be tested on an annual basis, needs to be installed 12 inches above the ground.
Backflow: The definition of '***backflow*** 'is a reverse flow condition that causes water or mixtures of water and other liquids, gases, or substances to flow back into the distribution system. To reverse the natural and normal directional flow of a liquid, gases, or solid substances back in to the public potable (drinking) water supply. This is normally an undesirable effect. The difference between a reduced pressure principle backflow device and a double check backflow device is that RP has a relief valve.1 year is the maximum time period between having a backflow device tested by a certified backflow

tester. An operator must ensure when installing a pressure vacuum breaker backflow device that it must be at least 12 inches above the highest downstream outlet. This is different than 12 inches above the ground. Backsiphonage condition usually causes reduced pressure or negative pressure on the service or supply side. Equipment that utilizes water for cooling, lubrication, washing or as a solvent always susceptible to a cross-connection. Minimum water pressure must be maintained to ensure adequate customer service during peak flow periods. However minimum positive pressure must be maintained in mains to protect against backflow or backsiphonage from cross-connections.
Backsiphonage: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point.
Back-up Disinfection units: If a chlorination system goes out of operation you are required to have back-up.
Backwash: A surface wash system should be activated prior to the start of the backwash.
Backwashing: Backwash the filters more frequently can be used to increase water production if an increase in raw water turbidity and coagulation feed rate creates additional loading on the filter.
Bacteria: Small, one-celled animals too small to be seen by the naked eye. Bacteria are found everywhere, including on and in the human body. Humans would be unable to live without the bacteria that inhabit the intestines and assist in digesting food. Only a small percentage of bacteria cause disease in normal, healthy humans. Iron bacteria is undesirable in a water distribution system because the bacteria may cause red water and slime. Examples include; Salmonella, Shigella, Bacillus, Vibri Cholera and Cholera.
Battery: A source of direct current (**DC**) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.
Benching: A method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near vertical surfaces between levels.
Breakpoint Chlorination: The process of chlorinating the water with significant quantities of chlorine to oxidize all contaminants and organic wastes and leave all remaining chlorine as free chlorine.
Bromine: This chemical disinfectant has been used only on a very limited scale for water treatment because of its handling difficulties. This chemical causes skin burns on contact, and a residual is difficult to obtain.
Bromine: Has a limited use for water treatment because of its handling difficulties. This is one of the chemical disinfectants (***HALOGEN***) that kills bacteria and algae.
Buffer: Chemical that resists pH change, e.g. sodium bicarbonate.
Bypass Valve: The name of a type of valve that reduces the differential pressure across a closed disk making the main valve easier to open and close.
Ca: The chemical symbol for calcium.
Cadmium: A contaminant that is usually not found naturally in water or in very small amounts.
Calcium Hardness: A measure of the calcium salts dissolved in water.
Calcium Ion: Divalent because it has a valence of +2.
Calcium, Magnesium, and Iron: The three elements that cause hardness in water.
$CaOCl2.4H_2O$: The molecular formula of Calcium hypochlorite.
Capillary Fringe: The material immediately above the water table may contain water by capillary pressure in the small void spaces.
Carbon Dioxide Gas: The pH will decrease and alkalinity will change as measured by the Langelier index after pumping carbon dioxide gas into water.
Carbonate, Bicarbonate and Hydroxide: Chemicals that are responsible for the alkalinity of water.
Cathodic Protection: An operator should protect against corrosion of the anode and/or the cathode by painting the copper cathode.
Cathodic Protection: Cathodic protection interrupts corrosion by supplying an electrical current to overcome the corrosion-producing mechanism.
Cathodic Protection: Guards against stray current corrosion.
Caustic Soda: Also known as sodium hydroxide and is used to raise pH.
Ceiling Area: The specific gravity of ammonia gas is 0.60. If released, this gas will accumulate first at the ceiling are. Cl2 gas will settle on the floor.

Centrifugal Force: That force when a ball is whirled on a string pulls the ball outward. On a centrifugal pump, it is that force which throws water from a spinning impeller.
Centrifugal Pump: A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.
Check Valve: It allows water to flow in only one direction.
Chelation: A chemical process used to control scale formation in which a chelating agent "captures" scale-causing ions and holds them in solution.
Chemical Oxidizer: $KMnO_4$ is used for taste and odor control because it is a strong oxidizer which eliminates many organic compounds.
Chemical Reaction Rate: In general, when the temperature decreases, the chemical reaction rate also decreases. The opposite is true for when the temperature increases.
Chloramination: Treating drinking water by applying chlorine before or after ammonia. This creates a persistent disinfectant residual called chloramines.
Chloramines: A group of chlorine and ammonia compounds formed when chlorine combines with organic wastes in the water. Chloramines are not effective as disinfectants and are responsible for eye and skin irritation as well as strong chlorine odors (***also known as Combined Chlorine).***
Chlorination: The process in water treatment of adding chlorine (gas or solid hypochlorite) for purposes of disinfection.
Chlorine Demand: Amount of chlorine required to react on various water impurities before a residual is obtained. Also, means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by iodometric method of a sample at a temperature of twenty degrees in conformance with Standard methods.
Chlorine Feeding: Chlorine may be delivered by vacuum-controlled solution feed chlorinators. The chlorine gas is controlled, metered, introduced into a stream of injector water and then conducted as a solution to the point of application.
Chlorine, Free: Chlorine available to kill bacteria or algae. The amount of chlorine available for sanitization after the chlorine demand has been met. Also known as chlorine residual.
Chlorine: A chemical used to disinfect water. Chlorine is extremely reactive, and when it comes in contact with microorganisms in water killing them. Chlorine is added to swimming pools to keep the water safe for swimming. Chlorine is available as solid tablets for swimming pools. Some public water system's drinking water treatment plants use chlorine in a gas form because of the large volumes required. Chlorine is very effective against algae, bacteria and viruses. Protozoa are resistant to chlorine because they have thick coats. Protozoa are removed from drinking water by filtration.
Cl2 0.2 mg/L: If you are disinfecting to preserve water potability, the minimum concentration of free Cl2 residual in the distribution system.
Cl2 10 mg/L: Small water storage tanks are commonly disinfected with a solution containing a Cl2 concentration of 50 mg/L. After 24 hours the minimum Cl2 concentration should be 10 mg/L.
CL2 A Fusible Plug: Is considered a safety device on a Cl2 cylinder.
Cl2 Chronic Exposure Corrosion of the Teeth: May occur due to chronic exposure to low concentrations of Cl2 gas. After long exposure, throat cancer will occur.
Cl2 Cylinder is Increased: If the temperature of a full Cl2 cylinder is increased by 50^o F or 30^o C, a rupture may occur.
Cl2 Demand: Cl2 combines with a wide variety of materials. These side reactions complicate the use of Cl2 for disinfecting purposes. Their demand for Cl2 must be satisfied before Cl2 becomes available to accomplish disinfection.
Cl2 Expands in Volume: Happens to Cl2 when the temperature of a Cl2 cylinder increases.
Cl2 Free Concentration: If you are disinfecting to preserve water potability, the minimum concentration of free chlorine residual in the distribution system should be 0.2 mg/l.
Cl2 Gas Exposure: Chlorine gas causes suffocation, constriction of the chest, tightness in the throat, and edema of the lungs. As little as 2.5 mg per liter (approximately 0.085 percent by volume) in the atmosphere causes death in minutes, but less than 0.0001 percent by volume may be tolerated for several hours. Chlorine gas reacts with water producing a strongly oxidizing solution causing damage to the moist tissue lining the respiratory tract when the tissue is exposed to chlorine. The respiratory tract is rapidly irritated by exposure to 10-20 ppm of chlorine gas in air,

causing acute discomfort that warns of the presence of the toxicant. Death is possible from asphyxia, shock, reflex spasm in the larynx, or massive pulmonary edema. Populations at special risk from chlorine exposure are individuals with pulmonary disease, breathing problems, bronchitis, or chronic lung conditions.

Cl2 Gas IDLH: As soon as Cl2 gas enters the throat area, a victim will sense a sudden stricture in this area—nature's way of signaling to prevent passage of the gas to the lungs. The victim must attempt to get out of the area of the leak, proceeding upwind, and to take only very short breaths through the mouth. Normal breathing will cause coughing, which must be prevented if possible. Chlorine gas causes suffocation, constriction of the chest, tightness in the throat, and edema of the lungs. As little as 2.5 mg per liter in the atmosphere causes death in minutes, but less than 0.01 percent by volume may be tolerated for several hours.

Cl2 Gas Safety: Gas leak is the primary safety concern when using chlorine gas as opposed to calcium hypochlorite or sodium hypochlorite.

Cl2 Gas will Accumulate: If a Cl2 leak occurs, the Cl2 gas will accumulate on the floor.

Cl2 Gaskets: Replace according to manufacturer's recommendations should be done with the gaskets when making a new connection on a chlorine feed system.

Cl2 General Statements: If an operator cannot open the valve on a Cl2 cylinder because it is too tight, first loosen the packing gland around the valve, and tap the valve gently with your hand. 17 is the atomic number of Cl2. 200 mg/l is the generally acceptable concentration of Cl2 solution that should be prepared to wash the inside of a storage facility. A device that has a transparent tube with a tapered bore containing a ball and is often used to measure the rate of a gas or liquid is called a Rotameter. After Cl2 gas is manufactured, it primarily transported and packaged as a liquefied gas under pressure in steel containers. As soon as CL2 gas enters the throat area, a victim will sense a sudden stricture in this area- Nature's way of signaling to prevent passage of the gas to the lungs. At this point, the victim must attempt to do two things: get out of the area of the leak, proceeding upwind, and to take only very short breaths through the mouth. Normal breathing will cause coughing, which must be prevented if possible. Before entering a Cl2 room to check on a leak don a self-contained breathing apparatus and check to see that the ventilation system is working. Be sure that no one enters the leak area without an adequate self-contained breathing apparatus. Breakpoint chlorination means adding Cl2 to the water until the Cl2 demand is satisfied. Chronic exposure to low concentrations of Cl2 gas may cause corrosion of the teeth. Cl2 combines with a wide variety of materials. These side reactions complicate the use of Cl2 for disinfecting purposes. Their demand for Cl2 must be satisfied before Cl2 becomes available to accomplish disinfection. Cl2 combines with water to form both hypochlorous and hydrochloric acids. Cl2 gas is highly corrosive in moist conditions. The only metals that are totally inert to moist Cl2 gas are Gold, Platinum, and Tantalum. Cl2 as with H_2S gas produces olfactory fatigue. Cl2 gas reacts with water producing a strongly oxidizing solution causing damage to the moist tissue lining the respiratory tract when the tissue is exposed to Cl2. The respiratory tract is rapidly irritated by exposure to 10-20 ppm of Cl2 gas in air, causing acute discomfort that warns of the presence of the toxicant. Cl2 gas should only be used under a fume hood. Determine the ambient temperature in a Cl2 room by using a regular thermometer because ambient temperature is simply the air temperature of the room. Downstream from the point of post chlorination, the concentration of a free Cl2 residual should be 0.5 mg/L in a clear well or distribution reservoir. Even brief exposure to 1,000 ppm of Cl2 can be fatal. Free available Cl2 is very effective in killing bacteria. If an operator places water on a leaking Cl2 cylinder, corrosion will occur and the leak will get larger. Store an empty Cl2 cylinder upright, tagged as empty. The Cl2 storage ventilation equipment be checked on a daily basis. The CT values for disinfection are used to determine the disinfection efficiency based upon time and concentration of the disinfectant residual. The effectiveness of disinfection determined from the results of coliform testing. The first step when removing a hypochlorinator from service is to turn off the water supply pump. The fusible plug on a 150-pound Cl2 cylinder is designed to soften and melt at high temperatures. The physical and chemical properties of Cl2 are: A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber colored liquid. A noncombustible gas, and a strong oxidizer, Cl2 is about 1.5 times heavier than water and gaseous Cl2 is about 2.5 times heavier than air. The purpose of an evaporator is to convert liquid Cl2 to gaseous Cl2 for use by gas chlorinators. The purpose of the bottom valve on a 1-ton Cl2 cylinder is to remove liquid Cl2.The purpose of the ejector on a hypochlorinator, is that the ejector draws in additional water for dilution of the hypochlorinate solution. The water temperature decreases from 70°F (21°C) to 40°F (4°C). Allow a longer contact time to maintain good disinfection of the water. When Cl2 is inhaled in high concentrations it causes emphysema and damage to the pulmonary blood vessels. When determining a Cl2 use rate, the scale or meter should be read at the same time each day. When hypochlorite is brought into contact with an organic material, the organic material decomposes releasing heat very rapidly. Where other factors are constant, the disinfecting action may be represented by: **Kill = C x T**.

Clear Well: A large underground storage facility sometimes made of concrete. A clear well or a plant storage reservoir is usually filled when demand is low.

ClO_2: The molecular formula of Chlorine dioxide.

Coagulation: The best pH range for coagulation is between a pH of 5 and 7. Mixing is an important part of the coagulation process you want to complete the coagulation process as quickly as possible.

Coliform Bacteria: Bacteria that are normally found in the intestines of warm-blooded animals. Coliform bacteria are present in high numbers in animal feces. They are an indicator of potential contamination of water. Adequate and appropriate disinfection effectively destroys coliform bacteria.

Coliform Testing: The effectiveness of disinfection is usually determined by Coliform bacteria testing. A positive sample is a bad thing and indicates that you have bacteria contamination.

Colloidal Suspensions: Because both iron and manganese react with dissolved oxygen to form insoluble compounds they are not found in high concentrations in waters containing dissolved oxygen except as colloidal suspensions of the oxide.

Colorimetric Measurement: A means of measuring and unknown chemical concentration in water by measuring a sample's color intensity.

Combined Chlorine: The reaction product of chlorine with ammonia or other pollutants, also known as chloramines.

Community Water System: A water system which supplies drinking water to 25 or more of the same people year-round in their residences.

Competent Person: One who is capable of identifying existing and predictable hazards in the surroundings or working conditions, which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Compliance Cycle: A 9-calendar year time-frame during which a public water system is required to monitor. Each compliance cycle consists of 3 compliance periods.

Compliance Period: A 3-calendar year time-frame within a compliance cycle.

Composite Sample: A water sample that is a combination of a group of samples collected at various intervals during the day.

Condensation: The process that changes water vapor to tiny droplets or ice crystals.

Contact Time, pH and Low Turbidity: Factors which are important in providing good disinfection using chlorine.

Contact Time: If the water temperature decreases from 70°F (21°C) to 40°F (4°C). The operator needs to increase the detention time to maintain good disinfection of the water.

Contains the Element Carbon: A simple definition of an organic compound.

Contaminant: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

Contamination: To make something bad; to pollute or infect something. To reduce the quality of the potable (drinking) water and create an actual hazard to the water supply by poisoning or through spread of diseases.

Control Taste and Odor Problems: $KMnO^4$ Potassium permanganate is a strong oxidizer is commonly used to control taste and odor problems.

Copper: The chemical name for the symbol Cu.

Corrosion: The gradual decomposition or destruction of a material as it chemically reacts with water and is often referred to as corrosion. The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

Corrosivity: The Langelier Index measures corrosivity.
Coupon: Placed to measure corrosion damage in the water mains.
Cross-connection: A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow. Might be the source of an organic substance causing taste and odor problems in a water distribution system.
Cross-contamination: The mixing of two unlike qualities of water. For example, the mixing of good water with a polluting substance like a chemical substance.
Cryptosporidium: A disease-causing parasite, resistant to chlorine disinfection. It may be found in fecal matter or contaminated drinking water.
Diaphragm: Valves can be used to maintain a constant downstream pressure in a water distribution system, regardless of fluctuating demand. An integral component of these valves is a rubber diaphragm. Commonly found in a PRV.
Dangerous Chemicals: The most suitable protection when working with a chemical that produces dangerous fumes is to work under an air hood.
CWS: Community Water System.
Decibels: The unit of measurement for sound.
Decompose: To decay or rot.
Decomposition of Organic Material: The decomposition of organic material in water produces taste and odors.
Demineralization Process: Mineral concentration of the feed water is the most important consideration in the selection of a demineralization process. Acid feed is the most common method of scale control in a membrane demineralization treatment system.
Dental Caries Prevention in Children: Is the main reason that fluoride is added to a water supply.
Depolarization: The removal of hydrogen from a cathode.
Desiccant: When shutting down equipment which may be damaged by moisture, the unit may be protected by sealing it in a tight container. This container should contain a desiccant.
Detection Lag: The period of time between the moment of change in a chlorinator control system and the moment when the change is sensed by the chlorine residual indicator.
Detention Time: The minimum detention time range recommended for flocculation is 5 – 20 minutes for direct filtration and up to 30 minutes for conventional filtration.
Diatomaceous Earth: A fine silica material containing the skeletal remains of algae.
Direct Current: A source of direct current (**DC**) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.
Disinfect: To kill and inhibit growth of harmful bacterial and viruses in drinking water.
Disinfectant Residual: The CT values for disinfection are used to determine the disinfection efficiency based upon time and disinfectant residual.
Disinfection by-products (DBPs): The products created due to the reaction of chlorine with organic materials (e.g. leaves, soil) present in raw water during the water treatment process. The EPA has determined that these DBPs can cause cancer.
Disinfection: The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites. The effectiveness of disinfection determined by the results of coliform testing. Types of source water are required by law to treat water using filtration and disinfection are groundwater under the direct influence of surface water. Surface water sources.
Dissolved Oxygen: Can be added to zones within a lake or reservoir that would normally become anaerobic during periods of thermal stratification.
Distillation, Reverse Osmosis and Freezing: Processes can be used to remove minerals from the water.
Distribution 8 inches: The minimum pipe diameter for a dead end line exceeding 2,000 feet in length should be 8 inches.
Double Suction Pump: One advantage of a double suction pump is a reduction in the thrust load that the bearings must carry.
Dry Acid: A granular chemical used to lower pH and or total alkalinity.
E. Coli, *Escherichia coli* : A bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water

contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.
Eccentric Valve: The plug on an eccentric valve contacts the valve seat when the valve is closed.
Effectiveness of Chlorination: The factors which influence the effectiveness of chlorination the most are pH, Turbidity and Temperature.
Effectiveness of the Chlorine Decreases: Will occur during disinfection in source water with excessive turbidity.
Electrical Problem: Moisture will cause the deterioration of oil in a transformer.
Electrical Resistance: Resistance of electrical equipment is affected by many variables including the thickness of the insulation and its total mass area.
Electrical: An operator using a voltage meter to test electrical equipment should first, make sure the main switch is off and the voltage tester is rated to handle the voltage expected in the circuit. If grease comes in contact with the winding of a motor the winding insulation may deteriorate. If the overload control on a motor has tripped and the motor has stopped running. An operator needs to wait for the overload to cool, then tries to start the motor again. If the motor does not start, the operator should first check the fuse.
Electricity: Rubber may be used to prevent the flow of electricity through a wire.
Electron: The name of a negatively charged atomic particle.
Elementary Business Plan: Technical Capacity, Managerial Capacity, and Financial Capacity make up the elementary business plan. To become a new public water system, an owner shall file an elementary business plan for review and approval by the Department.
Emergency Response Team: Get out of the area and notify your local emergency response team is the first should be done first in case of a large uncontrolled chlorine leak.
Enhanced Coagulation: The process of joining together particles in water to help remove organic matter.
Enterovirus: A virus whose presence may indicate contaminated water; a virus that may infect the gastrointestinal tract of humans.
F: The chemical symbol of Fluorine.
Faucet with an Aerator: When collecting a water sample from a distribution system, a faucet with an aerator should not be used as a sample location.
Fecal Coliform: A group of bacteria that may indicate the presence of human or animal fecal matter in water.
Filtration: A series of processes that physically removes particles from water. A water treatment step used to remove turbidity, dissolved organics, odor, taste and color.
Filter Clogging: An inability to meet demand may occur when filters are clogging.
Filtration Methods: The conventional type of water treatment filtration method includes coagulation, flocculation, sedimentation, and filtration. Direct filtration method is similar to conventional except that the sedimentation step is omitted. Slow sand filtration process does not require pretreatment, has a flow of 0.1 gallons per minute per square foot of filter surface area, and is simple to operate and maintain. Diatomaceous earth method uses a thin layer of fine siliceous material on a porous plate. This type of filtration medium is only used for water with low turbidity. Sedimentation, adsorption, and biological action treatment methods are filtration processes that involves a number of interrelated removal mechanisms. Demineralization is primarily used to remove total dissolved solids from industrial wastewater, municipal water, and seawater.
Finished Water: Treated drinking water that meets minimum state and federal drinking water regulations.
Flocculation: The process of bringing together destabilized or coagulated particles to form larger masses that can be settled and/or filtered out of the water being treated.
Floc Shearing: Likely to happen to large floc particles when they reach the flocculation process.
Flocculation Basin: A compartmentalized basin with a reduction of speed in each compartment. This set-up or basin will give the best overall results.
Flood Rim: The point of an object where the water would run over the edge of something and begin to cause a flood.
Flow must be Measured: A recorder that measures flow is most likely to be located in a central location.

Fluoride Feeding System: Always review fluoride feeding system designs and specifications to determine whether locations for monitoring readouts and dosage controls are convenient to the operation center and easy to read and correct.
Fluoride: High levels of fluoride may stain the teeth of humans. This is called Mottling. This chemical must not be overfed due to a possible exposure to a high concentration of the chemical. The most important safety considerations to know about fluoride chemicals is that all fluoride chemicals are extremely corrosive**.** These are the substances is most commonly used to furnish fluoride ions to water: Sodium fluoride, Sodium silicofluoride and Hydrofluosilicic acid.
Flux: The term flux describes the rate of water flow through a semipermeable membrane. The water flux decreases through a semipermeable membrane means that the mineral concentration of the water is increasing.
Formation of Tubercles: This condition is of the most concern regarding corrosive water effects on a water system. It is the creation of mounds of rust inside the water lines.
Free Chlorine Residual gives the best Disinfection: Is the reason for chlorinating past the breakpoint is to provide protection in case of backflow.
Free Chlorine Residual: Regardless of whether pre-chlorination is practiced or not, a free chlorine residual of at least 10 mg/L should be maintained in the clear well or distribution reservoir immediately downstream from the point of post-chlorination.
Free Chlorine: In disinfection, chlorine is used in the form of free chlorine or as hypochlorite ion.
Frequency must a Remote Operator inspect a Grade 1 or grade 2 Water Treatment Plant: Monthly or as necessary a remote operator inspect a grade 1 or grade 2 water treatment plant or distribution system that produces and distributes groundwater.
Gate Valve: Most common type of valve used in isolating a small or medium sized section of a distribution system and is the only linear valve used in water distribution. All the other valves are in the rotary classification.
Giardia Lamblia: A pathogenic parasite, which may be found in, contaminated water.
Giardiasis, Hepatitis, or Typhoid: Diseases that may be transmitted through the contamination of a water supply but not AIDS.
GIS - Graphic Information System: Detailed information about the physical locations of structures such as pipes, valves, and manholes within geographic areas with the use of satellites.
Globe Valve: The main difference between a globe valve and a gate valve is that a globe valve is designed as a controlling device.
Good Contact Time, pH and Low Turbidity: These are factors that are important in providing good disinfection when using chlorine.
Grab Sample: Is a type of sample that should be collected to analyze for coliform bacteria, pH and Temperature. A snap shot of a certain location and time.
Gt : Represents (Detention time) x (mixing intensity) in flocculation.
H_2SO_4: The molecular formula of Sulfuric acid.
Hard Water: Hard water causes a buildup of scale in household hot water heaters.
Hazards of Polymers: Slippery and difficult to clean-up are the most common hazards associated with the use of polymers in a water treatment plant.
Head: The measure of the pressure of water expressed in feet of height of water. 1 PSI = 2.31 feet of water or 1 foot of head equals about a half a pound of pressure or .433 PSI. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).
Head Loss: A negative effect that a water meter has on a service.
Headworks: The facility at the "**head**" of the water source where water is first treated and routed into the distribution system.
Health Advisory: An EPA document that provides guidance and information on contaminants that can affect human health and that may occur in drinking water, but which EPA does not currently regulate in drinking water.
Heat Damage to Air Compressor: An air compressor generates heat during the compression cycle. And is the most common type of damage caused by heat generated during operation.
Hertz: Is the term is used to describe the frequency of cycles in an alternating current (AC) circuit.

Heterotrophic Plate Count Bacteria: A broad group of bacteria including non-pathogens, pathogens, and opportunistic pathogens; they may be an indicator of poor general biological quality of drinking water. Often referred to as **HPC**.
HF: The molecular formula of Hydrofluoric acid.
High Turbidity Causing an Increased Chlorine Demand: May occur or be caused by the inadequate disinfection of water.
Hydrochloric and Hypochlorous Acids: The compounds that are formed in water when chlorine gas is introduced.
Hydrogen Sulfide or Chlorine: These chemicals can cause olfactory fatigue.
Hydrophobic: Does not mix readily with water.
Hypochlorite and Organic Material: Heat and a possible fire may happen when hypochlorite is brought into contact with an organic material.
Hypochlorous and Hydrochloric Acids: Chlorine combines with water to form hypochlorous and hydrochloric acids, HOCL and HCL or free available chlorine.
If a facility is re-graded to a higher grade, how long does the facility have to hire or train an operator with the applicable class and grade? 12 months.
Impeller: A rotating set of vanes designed to impart rotation to a mass fluid.
Impervious: Not allowing, or allowing only with great difficulty, the movement of water.
Infectious Pathogens/Microbes/Germs: Are considered disease-producing bacteria, viruses and other microorganisms.
Initial monitoring year: An initial monitoring year is the calendar year designated by the Department within a compliance period in which a public water system conducts initial monitoring at a point of entry.
Inorganic Contaminants: Mineral-based compounds such as metals, nitrates, and asbestos. These contaminants are naturally-occurring in some water, but can also get into water through farming, chemical manufacturing, and other human activities. EPA has set legal limits on 15 inorganic contaminants.
Insoluble Compounds: Types of compounds cannot be dissolved. When iron or manganese reacts with dissolved oxygen (**DO**) insoluble compound are formed.
Intake Facilities: One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for Cathodic protection.
Ion Exchange: Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. The hardness of the source water affects the amount of water an ion exchange softener may treat before the bed requires regeneration.
Iron and Manganese: In water can be usually detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the reservoir bottom sediments. The presence of iron and manganese in water promote the growth of Iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and Manganese in water may be detected by observing the color of the of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.
Iron Bacteria: Perhaps the most troublesome consequence of iron and manganese in the water is they promote the growth of a group of microorganism known as Iron Bacteria.
Iron Fouling: You should look for an orange color on the resin and backwash water when checking an ion exchange unit for iron fouling
Iron: The elements iron and manganese are undesirable in water because they cause stains and promote the growth of iron bacteria.
Kill=C x T: Where other factors are constant, the disinfecting action may be represented by: Kill=C x T.
Kinetic Energy: The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head.

Langelier Index: A measurement of Corrosivity. The water is becoming corrosive in the distribution system causing rusty water if the Langelier index indicates that the pH has decreased from the equilibrium point. Mathematically derived factor obtained from the values of calcium hardness, total alkalinity, and pH at a given temperature. A Langelier index of zero indicates perfect water balance (i.e., neither corroding nor scaling).
Leaching: A chemical reaction between water and metals that allows for removal of soluble materials.
Lead and Copper: Initial tap water monitoring for lead and copper must be conducted during 2 consecutive 6-month periods.
Lime Soda Softening: In a lime soda softening process, the pH of the water is raised to 11.0. In a lime softening process, excess lime is frequently added to remove Calcium and Magnesium Bicarbonate. The minimum hardness which can be achieved by the lime-soda ash process is 30 to 40 mg/L as calcium carbonate. The hardness due to noncarbonate hardness is most likely to determine the choice between lime softening and ion exchange to remove hardness.
Lime: A chemical that may be added to water to reduce the corrosivity. When an operator adds lime to water, Calcium and magnesium become less soluble.
Lines: Lines in the distribution system should be flushed on a regular basis. The flushing should be done at night and the water pressure in the distribution system must be at least 25 PSI.
LOTO: In a good lock-out/tag out program, if a piece of equipment is locked out, the key to the lock-out device the key should be held by the person who is working on the equipment. The tag is an identification device and the lock is a physical restraint.
Magnesium Hardness: Measure of the magnesium salts dissolved in water – it is not a factor in water balance.
Magnetic Starter: A type of motor starter should be used in an integrated circuit to control flow automatically.
Marble and Langelier Tests: Used to measure or determine the corrosiveness of a water source.
Maximum Contaminant Level Goal (MCLG): The level of a contaminant at which there would be no risk to human health. This goal is not always economically or technologically feasible, and the goal is not legally enforceable.
Maximum Contaminant Levels (MCLs): The maximum allowable level of a contaminant that federal or state regulations allow in a public water system. If the MCL is exceeded, the water system must treat the water so that it meets the MCL.
MCL for Turbidity: Turbidity is undesirable because it causes health hazards. An MCL for turbidity was established by the EPA because turbidity does not allow for proper disinfection.
Measure Corrosion Damage: A coupon is a strip of metal and is placed to measure corrosion damage in the distribution system in a water main.
Mechanical Seal: A mechanical device used to control leakage from the stuffing box of a pump. Usually made of two flat surfaces, one of which rotates on the shaft. The two flat surfaces are of such tolerances as to prevent the passage of water between them. Held in place with spring pressure.
Medium Water System: More than 3,300 persons and 50,000 or fewer persons.
Megger: Used to test the insulation resistance on a motor.
M-Endo Broth: The media shall be brought to the boiling point when preparing M-Endo broth to be used in the membrane filter test for total coliform.
Methane: Classified as an organic compound.
mg/L: Milligrams per liter.
Microbe, Microbial: Any minute, simple, single-celled form of life, especially one that causes disease.
Microbial Contaminants: Microscopic organisms present in untreated water that can cause waterborne diseases.
Microbiological: Type of analysis in which a composite sample unacceptable.
mL: milliliter
Moisture and Potassium Permanganate: The combination of moisture and potassium permanganate produces heat.
Moisture: If a material is hygroscopic it must it be protected from water.

Motor 3600 rpms: The maximum synchronous speed of an electric motor that has a frequency of 60 Hz.
Motor Overload Control: The overload control on a motor has tripped and the motor has stopped running. An operator waits for the overload to cool, then tries to start the motor again. If the motor does not start, the operator should check first the Motor overload control.
Motor: If a motor is rated for 10 amps the overload relays that should be used are 10 to 11 amps. A possible cause for a mechanical noise coming from a motor is there is an unbalance of a rotating mechanical part. And a possible result of over greasing a bearing is that there will be extreme friction in the bearing chamber.
Mottling: High levels of fluoride may stain the teeth of humans.
MSDS: A safety document must an employer provide to an operator upon request.
Mud Balls in Filter Media: A possible result of an ineffective or inadequate filter backwash.
Muriatic Acid: An acid used to reduce pH and alkalinity. Also used to remove stain and scale.
NaOCl: The molecular formula of Sodium hypochlorite.
NaOH: The molecular formula of Sodium hydroxide.
New Public Water System: Depending upon your state rule; Community water systems and non-transient non-community water systems that begin operations on or after October 1, 1999 must comply with Article 6, Capacity Development Requirements for a New Public Water System.
NH_3: The molecular formula of Ammonia.
NH_4^+: The molecular formula of the Ammonium ion.
Nitrate and nitrite are prohibited: The Department will not grant a nitrate or nitrite waiver.
Nitrates: A dissolved form of nitrogen found in fertilizers and sewage by-products that may leach into groundwater and other water sources. Nitrates may also occur naturally in some waters. Over time, nitrates can accumulate in aquifers and contaminate groundwater.
Nitrogen and Phosphorus: Pairs of elements and major plant nutrients that cause algae to grow.
NO_3^-: The molecular formula of the Nitrate ion.
Non-Carbonate Hardness: The portion of the total hardness in excess of the alkalinity.
Noncarbonate Ions: Water contains Noncarbonate ions if it cannot be softened to a desired level through the use of lime only.
Non-point source pollution: Air pollution may leave contaminants on highway surfaces. This nonpoint source pollution adversely impacts reservoir water and groundwater quality.
Non-Transient, Non-Community Water System: A water system which supplies water to 25 or more of the same people at least six months per year in places other than their residences. Some examples are schools, factories, office buildings, and hospitals which have their own water systems.
Normality: The number of equivalent weights of solute per liter of solution.
Notification and Safety of the Public: The most important concern to an owner/operator if a toxic substance contaminates a drinking water.
NTNCWS: Non-transient non-community water system.
NTU (nephelometric turbidity unit)**:** A measure of the clarity or cloudiness of water.
O_3: The molecular formula of ozone.
Oligotrophic: A reservoir that is nutrient-poor and contains little plant or animal life.
Organic Precursors: Natural or man-made compounds with chemical structures based upon carbon that, upon combination with chlorine, leading to trihalomethane formation.
Osmosis: The process by which water moves across a semi permeable membrane from a low concentration solute to a high concentration solute to satisfy the pressure differences caused by the solute.
Over range Protection Devices: Mechanical dampers, snubbers and an air cushion chamber are examples of surging and over range protection devices.
Oxidizing: The process of breaking down organic wastes into simpler elemental forms or by products. Also used to separate combined chlorine and convert it into free chlorine.
Oxygen Deficient Environment: Name one of the most dangerous threats to an operator upon entering a manhole.
Ozone does not provide a Residual in the Distribution System: One of the major drawbacks to using ozone as a disinfectant.

Ozone, Chlorine Dioxide or Chloramine O_3, ClO_2, or NH_4Cl2: These chemicals may be used as alternative disinfectants.
PAC: A disadvantage of using PAC is it is very abrasive and requires careful maintenance of equipment. One precautions should be taken in storing PAC is that bags of carbon should not be stored near bags of HTH. Removes tastes and odors by adsorption only. Powered activated carbon frequently used for taste and odor control because PAC is non-specific and removes a broad range of compounds. Jar tests and threshold odor number testing determines the application rate for powdered activated carbon. Powdered activated carbon, or PAC, commonly used for in a water treatment plant for taste and odor control. Powdered activated carbon may be used with some success in removing the precursors of THMs
Packing: Material, usually of woven fiber, placed in rings around the shaft of a pump and used to control the leakage from the stuffing box.
Pathogens: Disease-causing pathogens; waterborne pathogens A pathogen is a bacterium, virus or parasite that causes or is capable of causing disease. Pathogens may contaminate water and cause waterborne disease.
Pb: The chemical symbol of Lead.
pCi/L: Picocuries per liter. A curie is the amount of radiation released by a set amount of a certain compound. A picocurie is one quadrillionth of a curie.
Peak Demand: The maximum momentary load placed on a water treatment plant, pumping station or distribution system.
Permeate: The term for water which has passed through the membrane of a reverse osmosis unit.
pH of Saturation: The ideal pH for perfect water balance in relation to a particular total alkalinity level and a particular calcium hardness level, at a particular temperature. The pH where the Langelier Index equals zero.
pH (*Power of Hydroxyl Ion Activity*): A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. Alkalinity and pH tell an operator with regards to coagulation how to determine the best chemical coagulant to be used. The definition of an acidic solution is a solution that contains a significant number of H+ ions. An operator should calibrate the instrument with a known buffer solution before using a pH meter. Rinse the electrodes with distilled water should be done with the electrodes after measuring the pH of a sample with a pH meter. pH Temperature and Chlorine dosage are the factors that influence the effectiveness of chlorination the most.
Phenolphthalein /Total Alkalinity: The relationship between the alkalinity constituent's bicarbonate, carbonate, and hydroxide can be based on the P and T alkalinity measurement.
Phosphate, Nitrate, and Organic Nitrogen: Nutrients in a domestic water supply reservoir may cause water quality problems if they occur in moderate or large quantities.
Pipeline Appurtenance: Pressure reducers, bends, valves, regulators (which are a type of valve), etc.
Pneumatic systems are not reliable over transmission lines greater than 1000 feet: Is the primary characteristic which limits the use of a pneumatic data transmission system.
Point of Entry: POE.
Pollution: The duration of exposure to the contaminant affects the dose of a toxic contaminant in a water supply.
Pollution: To make something unclean or impure. See Contaminated.
Polyphosphates: Chemicals that may be added to remove low levels of iron and manganese.
Potable: Good water which is safe for drinking or cooking purposes. **Non-Potable:** A liquid or water that is not approved for drinking.
Potential Energy: The energy that a body has by virtue of its position or state enabling it to do work.
PPM: Abbreviation for parts per million.
Pre-chlorination: The addition of chlorine to the water prior to any other plant treatment processes.
Perikinesis: The aggregation resulting from random thermal motion of fluid molecules.
Pressure Head: The height to which liquid can be raised by a given pressure.

Pressure Measurement: Bourdon tube, Bellows gauge and Diaphragm are commonly used to measure pressure in waterworks systems.
Pressure: A Bellows-type sensor reacts to a change in pressure.
Prevention: To take action; to stop something before it happens.
Proton, Neutron, Electron: The 3 fundamental particles of an atom.
Public Notification: An advisory that EPA requires a water system to distribute to affected consumers when the system has violated MCLs or other regulations. The notice advises consumers what precautions, if any, they should take to protect their health.
Public Water System (PWS): Any water system which provides water to at least 25 people for at least 60 days annually. There are more than 170,000 PWSs providing water from wells, rivers and other sources to about 250 million Americans. The others drink water from private wells. There are differing standards for PWSs of different sizes and types.
Pump 5,000 to 20,000 hours: The typical operating life of a mechanical seal.
Pump Discharge Valve Off: A reciprocating pump or piston pump should never be operated with the discharge closed.
Pump: A key and a tight fit is the common method used to secure an impeller to the shaft on double-suction pump. A mechanical seal is the best seal to use for a pump operating under high suction head conditions. A possible cause of a scored shaft sleeve is that the packing has broken down or the packing is too tight or over tightened. A reciprocating pump or piston pump should not be operated with the discharge valve in the closed position. An air compressor generates heat during the compression cycle. The most common type of damage caused by heat generated during operation: the lubricating oil tends to break down quickly requiring frequent replacement. Cavitation is caused by a suction line may be clogged or is above the water line. Centrifugal pumps do not generate suction unless the impeller is submerged in water. If a pump is located above the level of water a foot valve must be provided on the suction piping to hold the prime. Continuous leakage from a mechanical seal on a pump indicates that the mechanical seal needs to be replaced. One disadvantage of a centrifugal pump is that it is not self-priming. The main purpose of the wear rings in a centrifugal double suction pump is that the wear rings maintain a flow restriction between the impeller discharge and suction areas. The purpose of the foot valve on a pump is that it keeps the air relief opened. The viscosity decreases with most lubricants as the temperature increases. Two pumps of the same size can be operated alternately to equalize wear and distribute lubricant in bearings.
PWS: 3 types of public water systems. Community water system, non-transient non-community water system, transient non community water system.
Raw Water: Water that has not been treated in any way; it is generally considered to be unsafe to drink.
Recorder: A recorder that measures flow is most likely to be located anywhere in the plant where a flow must be measured and in a central location.
Reagent: A substance used in a chemical reaction to measure, detect, examine, or produce other substances
Red Water and Slime: Iron bacteria are undesirable in a water distribution system because of red water and slime complaints.
Relay Logic: The name of a popular method of automatically controlling a pump, valve, chemical feeder, and other devices.
Reservoir: An impoundment used to store water.
Residual Disinfection/Protection: A required level of disinfectant that remains in treated water to ensure disinfection protection and prevent recontamination throughout the distribution system (i.e., pipes).
Rotameter: The name of transparent tube with a tapered bore containing a ball is often used to measure the rate of flow of a gas or liquid.
Rules: The objective of a vulnerability assessment is to determine weakness in the distribution or water system.
Runoff: Surface water sources such as a river or lake are primarily the result of natural processes of runoff.
Safe Yield: A possible consequence when the “safe yield” of a well is exceeded and water continues to be pumped from a well is land subsidence around the well will occur.

Safety: 2 Feet: The distance from the edge of a hole must you place the spoil from an excavation.
Safety Statements: A supervisor should warn an operator about the presence of a confined space by clearly posting the appropriate signage at all entries to a confined space. Before beginning an excavation, an “Underground Service Alert” center should be contacted to assist in determining the location of all underground utilities in the work area. Corrosive-This type of chemical classification may weaken, burn, or destroy a person’s skin or eyes and can be either acidic or basic. Ladders and climbing devices by inspected by a qualified individual once a year. The correct order for placing shorting equipment in a trench is starting at the top move to the bottom of the trench and reverse to remove it.
Salts are Absent: A strange characteristic that is unique to water vapor in the atmosphere.
Sample: The water that is analyzed for the presence of EPA-regulated drinking water contaminants. Depending on the regulation, the EPA requires water systems and states to take samples from source water, from water leaving the treatment facility, or from the taps of selected consumers.
Sand, Anthracite and Garnet: Mixed media filters are composed of these three materials.
Sanitary Survey: Persons trained in public health engineering and the epidemiology of waterborne diseases should conduct the sanitary survey. The importance of a detailed sanitary survey of a new water source cannot be overemphasized. An on-site review of the water sources, facilities, equipment, operation, and maintenance of a public water systems for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water. The purpose of a non-regulatory sanitary survey is to identify possible biological and chemical pollutants which might affect a water supply.
Sanitizer: A disinfectant or chemical which disinfects (kills bacteria), kills algae and oxidizes organic matter.
Saturation Index: See Langelier's Index.
Saturator: A device which produces a fluoride solution for the fluoride process. Crystal-grade types of sodium fluoride should be fed with a saturator. Overfeeding must be prevented to protect public health when using a fluoridation system.
SCADA: A remote method of monitoring pumps and equipment. 130 degrees F is the maximum temperature that transmitting equipment is able to with stand. If the level controller may be set with too close a tolerance 45 could be the cause of a control system that is frequently turning a pump on and off.
Scale: Crust of calcium carbonate, the result of unbalanced water. Hard insoluble minerals deposited (usually calcium bicarbonate) which forms on pool and spa surfaces and clog filters, heaters and pumps. Scale is caused by high calcium hardness and/or high pH. The regular use of stain prevention chemicals can prevent scale.
Scroll and Basket: Are the two basic types of centrifuges used in water treatment.
Secondary Drinking Water Standards: Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.
Sectional Map: The name of a map that provides detailed drawings of the distribution system’s zones. Sometimes we call these quarter-sections.
Sedimentation Basin: This location is where the thickest and greatest concentration of sludge will be found. Twice a year sedimentation tanks should be drained and cleaned if the sludge buildup interferes with the treatment process.
Sedimentation: The process of suspended solid particles settling out (going to the bottom of the vessel) in water.
Sensor: A float and cable system are commonly found instruments that may be used as a sensor to control the level of liquid in a tank or basin.
Shock: Also known as super chlorination or break point chlorination. Ridding a water of organic waste through oxidization by the addition of significant quantities of a halogen.
Shroud: The front and/or back of an impeller.
Single Phase Power: Is the type of power is used for lighting systems, small motors, appliances, portable power tools and in homes.
Sludge Basins: After cleaning sludge basins and before returning the tanks into service the tanks should be inspected, repaired if necessary, and disinfected.

Sludge Reduction: Organic polymers are used to reduce the quantity of sludge. If a plant produces a large volume of sludge, the sludge could be dewatered, thickened, or conditioned to decrease the volume of sludge. Turbidity of source water, dosage, and type of coagulant used are the most important factors which determine the amount of sludge produced in a treatment of water.
Small Water System: 3,300 or fewer persons.
SOC: A common way for a synthetic organic chemical such as dioxin to be introduced to a surface water supply is from an industrial discharge, agricultural drainage, or a spill.
Soda Ash: Chemical used to raise pH and total alkalinity (sodium carbonate). Chemical often used to soften water.
Sodium Bicarbonate: Commonly used to increase alkalinity of water and stabilize pH.
Sodium Bisulfate: Chemical used to lower pH and total alkalinity (dry acid).
Sodium Hydroxide: Also known as caustic soda, a by-product chlorine generation and often used to raise pH.
Softening Water: When the water has a low alkalinity it is advantageous to use soda ash instead of caustic soda for softening water.
Softening: The process that removes the ions which cause hardness in water.
Solar Drying Beds or Lagoons: Shallow, small-volume storage ponds where sludge is concentrated and stored for an extended periods.
Solar Drying Beds, Centrifuges and Filter Presses: Are procedures used in the dewatering of sludge.
Solid, Liquid, Vapor: 3 forms of matter.
SPADNS: The lab reagent called SPADNS solution is used in performing the Fluoride test.
Split Flow Control System: This type of control system is to control the flow to each filter influent which is divided by a weir.
Spray Bottle of Ammonia: An operator should use ammonia to test for a chlorine leak around a valve or pipe. You will see white smoke if there is a leak.
Spring Pressure: What maintains contact between the two surfaces of a mechanical seal.
Standpipe: A water tank that is taller than it is wide. Should not be found in low point.
Stationing: The word stationing on a plan drawing refers to a representation of a location from a starting point or reference. A stone line or benchmark.
Sterilized Glassware: The only type of glassware that should be used in testing for coliform bacteria.
Storage Tanks: Three types of water usage that determine the volume of a storage tank are fire suppression storage, equalization storage, and emergency storage. Equalization storage is the volume of water needed to supply the system for periods when demand exceeds supply. Generally, a water storage tank's interior coating (paint) protect the interior about 3-5 years.
Stuffing Box: That portion of the pump that houses the packing or mechanical seal.
Sulfate: Will readily dissolve in water to form an anion.
Sum of all the Atomic Weights of the Elements in a Molecule: The molecular weight of a compound.
Supernatant: The liquid layer which forms above the sludge in a settling basin.
Surface Water Sources: Surface water sources such as a river or lake are primarily the result of Runoff.
Surface Water: Water that is open to the atmosphere and subject to surface runoff; generally, lakes, streams, rivers.
Susceptibility Waiver: A waiver that is granted based upon the results of a vulnerability assessment.
Tapping Valve: The name of the valve that is specifically designed for connecting a new water main to an existing main that is under pressure.
Taste and Odor Problems in the Water: May happen if sludge and other debris are allowed to accumulate in a water treatment plant.
Taste and Odors: The primary purpose to use potassium permanganate in water treatment is to control taste and odors. Anaerobic water undesirable for drinking water purposes because of color and odor problems are more likely to occur under these conditions.

TCE, *trichloroethylene*: A solvent and degreaser used for many purposes; for example dry cleaning, it is a common groundwater contaminant.
TDS-Total Dissolved Solids: An expression for the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular (colloidal sol) suspended form. Generally the operational definition is that the solids (often abbreviated TDS) must be small enough to survive filtration through a sieve size of two micrometers. Total dissolved solids are normally only discussed for freshwater systems, since salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is generally considered not as a primary pollutant (e.g. it is not deemed to be associated with health effects), but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants.
TDS: Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. This process is ideal as long as the water does not contain a large amount of TDS. When determining the total dissolved solids, a sample should be filtered before being poured into an evaporating dish and dried. Demineralization may be necessary in a treatment process if the water has a very high value Total Dissolved Solids.
Telemetering: The use of a transmission line with remote signaling to monitor a pumping station or motors. Can be used to accomplish accurate and reliable remote monitoring and control over a long distribution system.
Temperature: This test should be performed immediately in the field, a grab sample.
The rate decreases: In general, when the temperature decreases, the chemical reaction rate decreases also.
Thickening, Conditioning, and Dewatering: Common processes that are utilized to reduce the volume of sludge.
Three-phase Motor: The incoming leads for a three-phase motor all have power.
Three-Phase Pumps: Large three-phase pumps employs the use of a magnetic starter.
Time for Turbidity Breakthrough and Maximum Head Loss: Are the two factors which determine whether or not a change in filter media size should be made.
Titration: Method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.
Titration: The common method of standardization of a solution determination in the lab.
Total Alkalinity: A measure of the acid-neutralizing capacity of water that indicates its buffering ability, i.e. measure of its resistance to a change in pH. Generally, the higher the total alkalinity, the greater the resistance to pH change.
Total Dissolved Solids (**TDS**)**:** The accumulated total of all solids that might be dissolved in water. See TDS.
Toxic substance contaminates a drinking water: Public Safety is the most important concern should an owner/operator allow a toxic substance to contaminate a drinking water.
Transient, Non-Community Water System: A water system which provides water in a place such as a gas station or campground where people do not remain for long periods of time. These systems do not have to test or treat their water for contaminants which pose long-term health risks because fewer than 25 people drink the water over a long period. They still must test their water for microbes and several chemicals. A Transient Non-community Water System: Is not required to sample for VOC's.
Treated Water: Disinfected and/or filtered water served to water system customers. It must meet or surpass all drinking water standards to be considered safe to drink.
Trihalomethanes (THM): Four separate compounds including chloroform, dichlorobromom-ethane, dibromochloromethane, and bromoform. The most common class of disinfection by-products created when chemical disinfectants react with organic matter in water during the disinfection process. *See Disinfectant Byproducts.*
Tubercles: The creation of this condition is of the most concern regarding corrosive water effects on a water system. Tubercles are formed due to joining dissimilar metals, causing electro-chemical reactions. Like iron to copper pipe. We have all seen these little rust mounds inside cast iron pipe.

Turbidimeter: Monitoring the filter effluent turbidity on a continuous basis with an in-line instrument is a recommended practice. Turbidimeter is best suited to perform this measurement.
Turbidity Interferes with Disinfection: The primary reason turbidity of water be minimized.
Turbidity: One physical characteristic of water. A measure of the cloudiness of water caused by suspended particles. The cloudy appearance of water caused by the presence of tiny particles. High levels of turbidity may interfere with proper water treatment and monitoring. If high quality raw water is low in turbidity, there will be a reduction in water treatment costs. Turbidity is undesirable because it causes health hazards. An MCL for turbidity established by the EPA because turbidity interferes with disinfection. This characteristic of water changes the most rapidly after a heavy rainfall. The following conditions may cause an inaccurate measure of turbidity; the temperature variation of a sample, a scratched or unclean sample tube in the nephelometer and selecting an incorrect wavelength of a light path
U.S. Environmental Protection Agency: In the United States, this agency responsible for setting drinking water standards and for ensuring their enforcement. This agency sets federal regulations which all state and local agencies must enforce.
Under Pressure in Steel Containers: After chlorine gas is manufactured, it is primarily transported in steel containers.
Unit Filter Run Volume (UFRV): One of the most popular ways to compare filter runs. This technique is the best way to compare water treatment filter runs.
Valve 20 or 30 Feet Per Inch: The typical scale of a Valve and Hydrant map using an intersection method of indexing.
Valves: A gate valve should be operated in any position between fully open and fully closed.
Vane: That portion of an impeller that throws the water toward the volute.
Velocity Head: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.
Venturi: If water flows through a pipeline at a high velocity, the pressure in the pipeline is reduced. Velocities can be increased to a point that a partial vacuum is created.
VOC waiver that a public water system using groundwater could receive: The longest term VOC waiver that a public water system using groundwater could receive is 9 years.
VOC's: The reporting limit for all regulated VOC's is 0.0005 mg/L.
Volatile Organic Chemical: VOC.
Voltage: 1,000 volts is the maximum number of volts that electrical equipment can be insulated with a lower limit of 1 megaohm.
Volute: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharge by the impeller.
Vulnerability Assessment: An evaluation of drinking water source quality and its vulnerability to contamination by pathogens and toxic chemicals.
Waivers: Monitoring waivers for nitrate and nitrite are prohibited.
Water Hammer: A surge in a pipeline resulting from the rapid increase or decrease in water flow. Water hammer exerts tremendous force on a system and can be highly destructive.
Water Level: The probe may be coated by calcium carbonate is a common problem with an electrical probe that is used to measure the level of water.
Water Meter: A water meter that is removed from service for repair should be handled by sealing the meter to retain water.
Water Meter: Head loss may occur with the use of a water meter. The three main classifications of water meters. Compound, Displacement, Velocity. Peak day demand is the greatest amount of water used for any one day in a calendar year.
Water Purveyor: The individual or organization responsible to help provide, supply, and furnish quality water to a community.
Water Quality: The 4 broad categories of water quality are: Physical, chemical, biological, radiological. Pathogens are disease causing organisms such as bacteria and viruses. A positive bacteriological sample indicates the presence of bacteriological contamination. Source water monitoring for lead and copper be performed when a public water system exceeds an action level for lead of copper.

Water Vapor: A characteristic unique to water vapor in the atmosphere is does not contain salts.
Waterborne Disease: A disease, caused by a virus, bacterium, protozoan, or other microorganism, capable of being transmitted by water (e.g., typhoid fever, cholera, amoebic dysentery, gastroenteritis).
Watershed: An area that drains all of its water to a particular water course or body of water. The land area from which water drains into a stream, river or reservoir.

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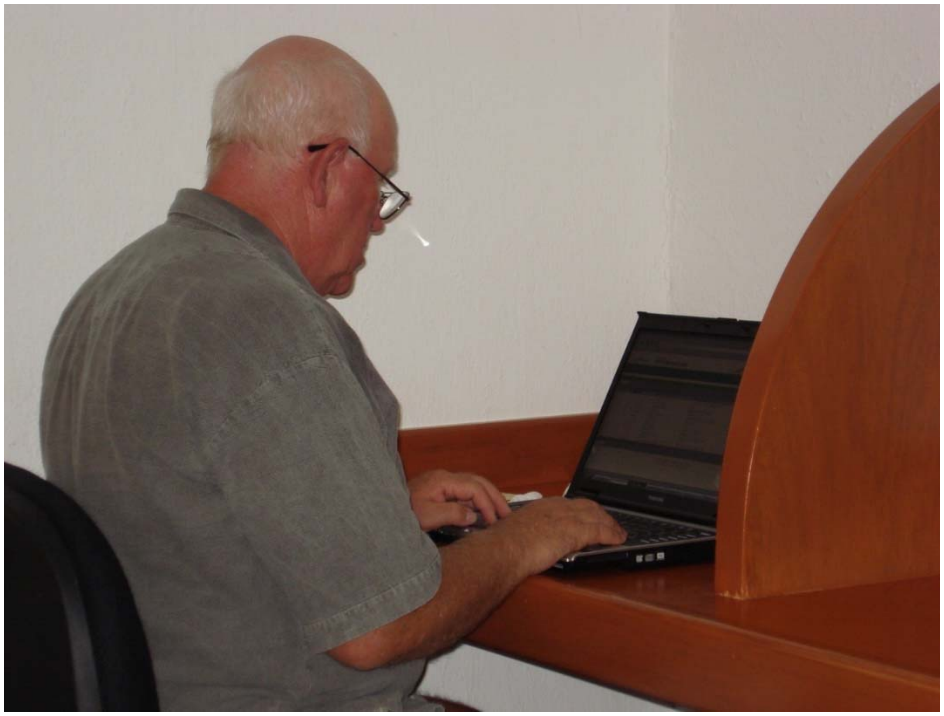

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