COLLECTIONS
CERTIFICATION REVIEW COURSE

Technical Learning College

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

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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Do not solely depend on TLC's Approval list for it may be outdated.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 $50 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 /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.

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.

Important Information about this Manual

This manual has been prepared to educate employees in the general awareness of dealing with complex wastewater collection procedures and requirements for safely handling hazardous and toxic materials. The scope of the problem is quite large, requiring a major effort to bring it under control. Employee health and safety, as well as that of the public, depend upon careful application of safe sewer collection procedures.

This manual will cover general laws, regulations, required procedures and generally accepted policies relating to wastewater collection systems. It should be noted, however, that the regulation of wastewater and other hazardous materials is an ongoing process and subject to change over time. For this reason, a list of resources is provided to assist in obtaining the most up-to-date information on various subjects.

This manual is not a guidance document for employees who are involved with pollution control or wastewater treatment. It is not designed to meet the requirements of the United States Environmental Protection Agency (EPA) or Department of Labor-Occupational Safety and Health Administration (**OSHA**) or state environmental or health departments.

This course manual will provide general educational training guidance of Wastewater Collection. This document is not a detailed wastewater collection or treatment textbook or a comprehensive source book on occupational safety and health.

Technical Learning College or Technical Learning Consultants, Inc. makes no warranty, guarantee, or representation as to the absolute correctness or appropriateness of the information in this manual and assumes no responsibility in connection with the implementation of this information.

It cannot be assumed that this manual contains all measures and concepts required for specific conditions or circumstances. This document should be used for educational guidance and is not considered a legal document.

Individuals who are responsible for the collection of wastewater or the health and safety of workers at wastewater sewer facilities should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with OSHA, EPA, and other appropriate federal, state, health, and local agencies.

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Course Description

Collections Certification Preparation and Review CEU Training Course
This CEU course is designed for the inhancement of Wastewater Collection Operators, Pretreatment / Industrial Wastewater Operators and Wastewater Treatment Operators in knowledge of geneal collection system operation and mainatance.

This CEU course will review various wastewater collection methods and related subjects. This course is general in nature and not state specific but will contain different wastewater collection methods, rules, policies, electricity, pump, safety, operator certification, and Lift Station information. You will not need any other materials for this course. Review of the dangers of trenching and excavation and related safety fundamentals.

This course will cover the basic requirements of OSHA's Competent Person 29 CFR 1926.650 Subpart F and other related federal safety rules. The Competent Person Program, as it is called, will require formal training and on-the-job experience.

This continuing education course will present basic and complex math principles and formulas for wastewater collections 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.

Target Audience
The target audience for this course is the person interested in working in a wastewater treatment or collection's facility and/or wishing to maintain CEUs for certification license or to learn how to do the job safely and effectively, and/or to meet education needs for promotion. This is not a comprehensive wastewater treatment or collections manual.

Course Objective
To provide ten hours of continuing education training in effective and efficient wastewater collection methods, cleaning, rules, and generally accepted collection related safety practices.

Upon Completion of this Course….
The student will understand and identify several effective and efficient wastewater collection methods, various cleaning techniques, federal collection rules; CMOM, NPDES, CWA and various collection related safety practices; confined space and competent person rules (OSHA) and will be awarded ten contact hours upon successful course completion.

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 Collections 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.

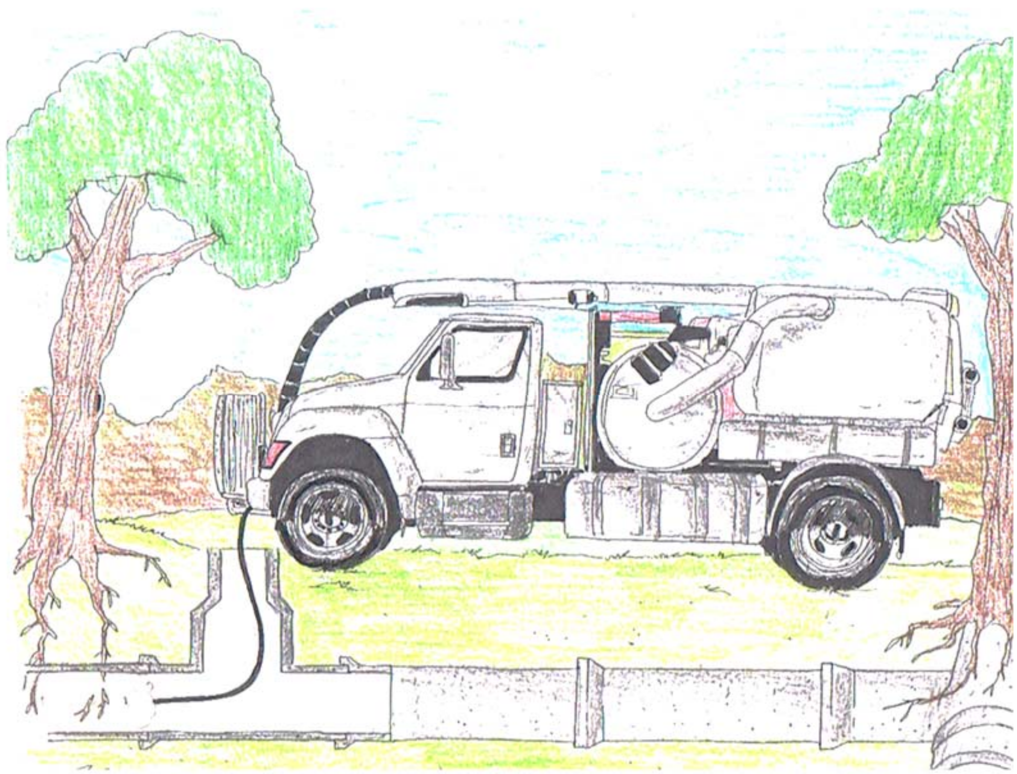
Required Texts
The Collections Certification Preparation and Review CEU training course will not require any other materials. This course comes complete. No other materials are needed.

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.

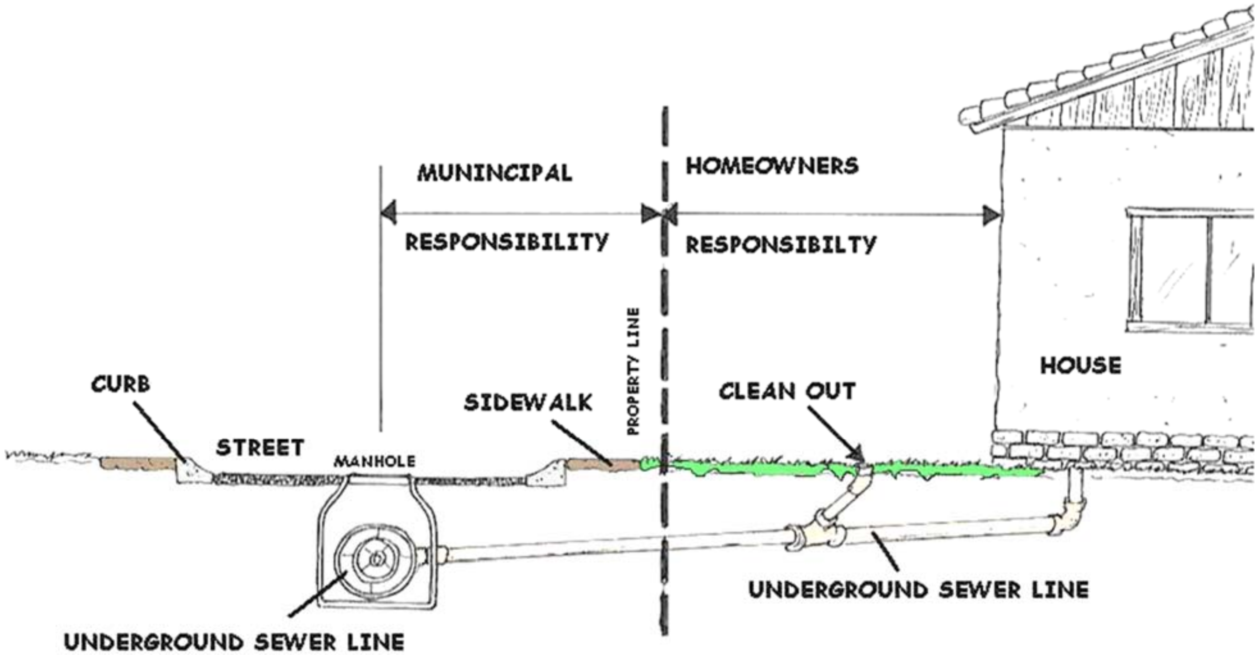
ADA Compliance
TLC will make reasonable accommodations for persons with documented disabilities. Students should notify TLC and their instructors of any special needs. Course content may vary from this outline to meet the needs of this particular group.

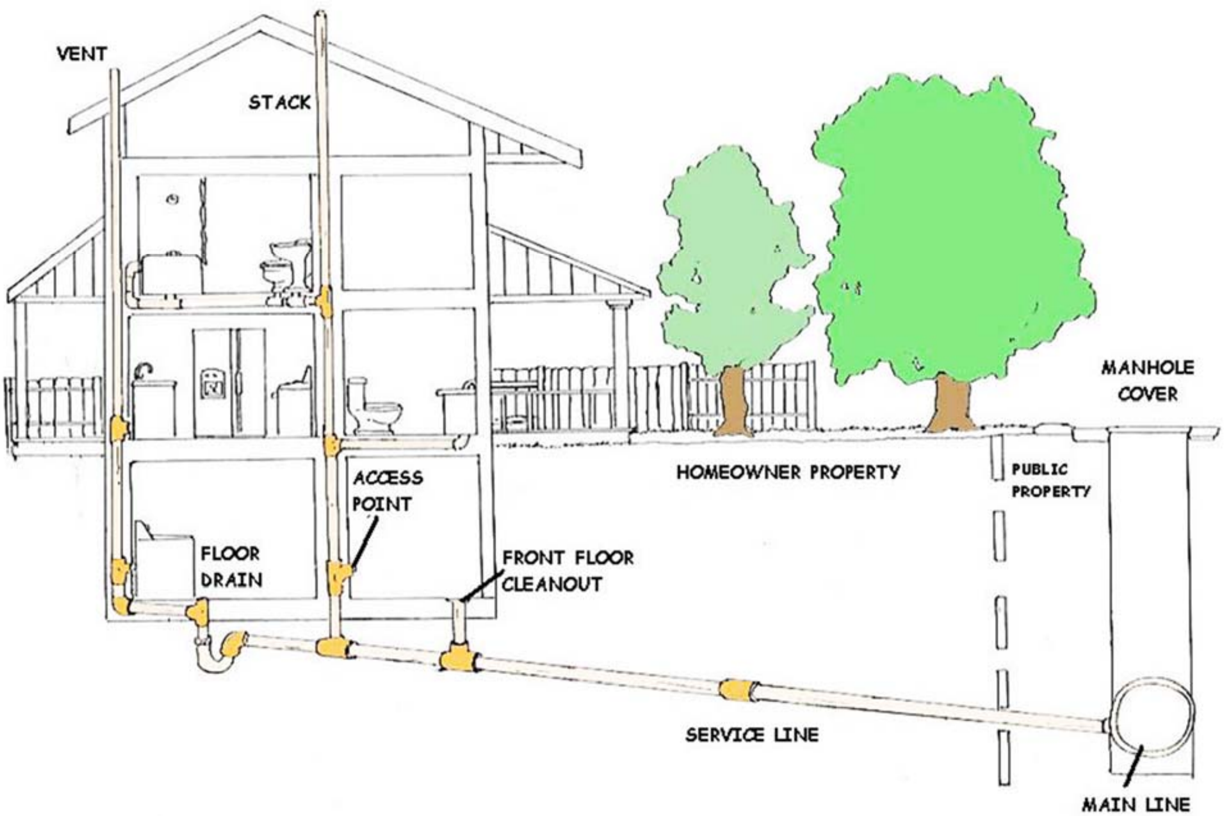
Educational Mission
The educational mission of TLC is:

- ✓ *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 collections system operators in the safe and effective maintenance and operation of various wastewater collection systems and related daily operations in order to understand and pass operator certification requirements*.


MUNINCIPAL
RESPONSIBILITY
HOMEOWNERS
RESPONSIBILTY
PROPERTY LINE
HOUSE
CURB
STREET
MANHOLE
SIDEWALK
CLEAN OUT
UNDERGROUND SEWER LINE
UNDERGROUND SEWER LINE


VENT
STACK
MANHOLE
COVER
ACCESS
POINT
HOMEOWNER PROPERTY
PUBLIC
PROPERTY
FLOOR
DRAIN
FRONT FLOOR
CLEANOUT
SERVICE LINE
MAIN LINE

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Safety Section Chapter 5

This course contains general EPA's CWA federal rule requirements. Please be aware that each state implements wastewater/safety/environmental /building regulations that may be more stringent than EPA's regulations.

Check with your state environmental/health agency for more information. These rules change frequently and are often difficult to interpret and follow. Be careful to not be in non-compliance and do not follow this course for proper compliance.

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 vulnerabilit*y**. 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.

(a) 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*"?

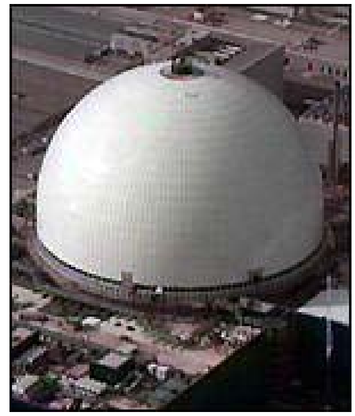
Ever thought about the access Trash Collection or Delivery Vehicles have and the potential for Terrorist to use these trucks for a bomb or to sneak into your facility?

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 of exam.

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

Wastewater Collection Rules and Regulations
Chapter 2

Clean Water Act Summary
33 U.S.C. s/s 1251 et seq. (1977)

The Clean Water Act is a 1977 amendment to the Federal Water Pollution Control Act of 1972, which set the basic structure for regulating discharges of pollutants to waters of the United States.

The law gave the EPA the authority to set effluent standards on an industry basis (technology-based) and continued the requirements to set water quality standards for all contaminants in surface waters. The CWA makes it unlawful for any person to discharge any pollutant from a point source into navigable waters unless a permit (NPDES) is obtained under the Act.

The 1977 amendments focused on toxic pollutants. In 1987, the CWA was reauthorized and again focused on toxic substances, authorized citizen suit provisions, and funded sewage treatment plants (POTW's) under the Construction Grants Program.

The CWA provides for the delegation by the EPA of many permitting, administrative, and enforcement aspects of the law to state governments. In states with the authority to implement CWA programs, the EPA still retains overseer responsibilities.

In 1972, Congress enacted the first comprehensive national clean water legislation in response to growing public concern for serious and widespread water pollution. The Clean Water Act is the primary federal law that protects our nation's waters, including lakes, rivers, aquifers, and coastal areas.

Lake Erie was dying. The Potomac River was clogged with blue-green algae blooms that were a nuisance and a threat to public health. Many of the nation's rivers were little more than open sewers and sewage frequently washed up on shore. Fish kills were a common sight. Wetlands were disappearing at a rapid rate.

Today, the quality of our waters has improved dramatically as a result of a cooperative effort by federal, state, tribal and local governments to implement the pollution control programs established in 1972 by the Clean Water Act.

The Clean Water Act's primary objective is to restore and maintain the integrity of the nation's waters. This objective translates into two fundamental national goals: eliminate the discharge of pollutants into the nation's waters, and achieve water quality levels that are fishable and swimmable.

The Clean Water Act focuses on improving the quality of the nation's waters. It provides a comprehensive framework of standards, technical tools, and financial assistance to address the many causes of pollution and poor water quality, including municipal and industrial wastewater discharges, polluted runoff from urban and rural areas, and habitat destruction.

For example, the Clean Water Act requires major industries to meet performance standards to ensure pollution control; charges states and tribes with setting specific water quality criteria appropriate for their waters and developing pollution control programs to meet them; provides funding to states and communities to help them meet their clean water infrastructure needs; protects valuable wetlands and other aquatic habitats through a permitting process that ensures development and other activities are conducted in an environmentally sound manner.

After 25 years, the Act continues to provide a clear path for clean water and a solid foundation for an effective national water program.

In 1972:
Only a third of the nation's waters were safe for fishing and swimming. Wetlands losses were estimated at about 460,000 acres annually.

Agricultural runoff resulted in the erosion of 2.25 billion tons of soil and the deposit of large amounts of phosphorus and nitrogen into many waters. Sewage treatment plants served only 85 million people.

Today:
Two-thirds of the nation's waters are safe for fishing and swimming.

The rate of annual wetlands losses is estimated at about 70,000-90,000 acres according to recent studies.

The amount of soil lost due to agricultural runoff has been cut by one billion tons annually, and phosphorus and nitrogen levels in water sources are down. Modern wastewater treatment facilities serve 173 million people.

The Future:
All Americans will enjoy clean water that is safe for fishing and swimming. We will achieve a net gain of wetlands by preventing additional losses and restoring hundreds of thousands of acres of wetlands.

Soil erosion and runoff of phosphorus and nitrogen into watersheds will be minimized, helping to sustain the nation's farming economy and aquatic systems. The nation's waters will be free of effects of sewage discharges.

*Large sewer main with damage caused by Hydrogen Sulfide Gas; once H_2SO_4 touches water, it creates Sulfuric Acid which will destroy concrete pipes.

Sanitary Sewer Overflows (SSOs)

Overview
Properly designed, operated, and maintained sanitary sewer systems are meant to collect and transport all of the sewage that flows into them to a publicly owned treatment works (POTW). However, occasional unintentional discharges of raw sewage from municipal sanitary sewers occur in almost every system. These types of discharges are called sanitary sewer overflows (SSOs).

SSOs have a variety of causes, including but not limited to severe weather, improper system operation and maintenance, and vandalism. The EPA estimates that there are at least 40,000 SSOs each year. The untreated sewage from these overflows can contaminate our waters, causing serious water quality problems. It can also back-up into basements, causing property damage and threatening public health.

Sanitary Sewer Overflows Rule
"In accordance with the memorandum of January 20, 2001, from the Assistant to the President and Chief of Staff, entitled *"Regulatory Review Plan*," published in the Federal Register on January 24, 2001, 66 FR 7701, EPA has withdrawn this document from the Office of the Federal Register to give the Administrator an opportunity to review it."

Currently, there are requirements for SSOs: discharges to waters of the United States from municipal sanitary sewer systems are prohibited, unless authorized by a NPDES permit. Permits authorizing discharges from such systems must contain technology-based effluent limitations, based upon secondary treatment and appropriate water quality-based effluent limitations.

Currently, NPDES permits for municipal treatment plants should require record keeping and reporting of overflows that result in a discharge. However, the EPA realizes that even municipal collection systems operated in an exemplary fashion may experience unauthorized discharges under exceptional circumstances.

Therefore, NPDES permits may provide a framework for evaluating specific circumstances of overflows which result in a discharge. In narrowly-prescribed circumstances, an overflow may be excused, either through the exercise of enforcement discretion or through establishment of an affirmative defense.

The EPA and the individual states continue to address SSO problems with compliance assistance and enforcement actions, in accordance with the *Compliance and Enforcement Strategy Addressing Combined Sewer Overflows and Sanitary Sewer Overflows* (issued April 27, 2000). This Strategy calls for each EPA Region to develop an enforcement response plan that includes an inventory of SSO violations. This enforcement response plan also will describe how 20% of the priority systems with SSO violations will be addressed each year.

Downstream of a nonfunctional Combined Sewer Overflow (CSO) Control Facility.

Combined Sewer Overflows

Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a water body.

During periods of heavy rainfall or snowmelt, however, the wastewater volume in a combined sewer system can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies.

These overflows, called combined sewer overflows (CSOs), contain not only storm water but also untreated human and industrial waste, toxic materials, and debris. They are a major water pollution concern for the approximately 772 cities in the U.S. that have combined sewer systems.

CSOs may be thought of as a type of "urban wet weather" discharge. This means that, like sanitary sewer overflows (SSOs) and storm water discharges, they are discharges from a municipality's wastewater conveyance infrastructure that are caused by precipitation events such as rainfall or heavy snowmelt. The EPA's CSO Control Policy, published April 19, 1994, is the national framework for control of CSOs.

The Policy provides guidance on how communities with combined sewer systems can meet Clean Water Act goals in as flexible and cost-effective a manner as possible. EPA's Report to Congress on implementation of the CSO Control Policy assesses the progress made by EPA, states, and municipalities in implementing and enforcing the CSO Control Policy.

What are the Elements of a Proper MOM Program?
Utility Specific
The complexity and expense associated with a utility's MOM program is specific to the size and complexity of the Publicly Owned Treatment Works (POTW) and related infrastructure. Factors such as population growth rate and soil/groundwater conditions also dictate the level of investment which should be made.

Purposeful
When MOM programs are present and properly maintained, they support customer service and protect system assets, public health, and water quality.

Goal-Oriented
Proper MOM programs have goals directed toward their individual purposes. Progress toward these goals is measurable, and the goals are attainable.

Uses Performance Measures
Performance measures should be established for each MOM program in conjunction with the program goal. These measures are quantifiable, and used in determining progress to, or beyond, the program goal.

Periodically Evaluated
An evaluation of the progress toward reaching the goals, or a reassessment of the goals, should be made periodically and based upon the quantified performance measures.

Available In Writing
The effectiveness of a MOM program quickly breaks down unless it is available in writing. Personnel turnover and lapses in communication between staff and management can change otherwise proper MOM programs to improper ones. Written MOM programs are useful only if they are made readily available to all personnel and clearly documented.

Implemented by Trained Personnel
Appropriate safety, equipment, technical, and program training is essential for implementing MOM programs properly.

What MOM programs should be audited?
MOM activity at a utility involves its entire wastewater infrastructure. Common utility management activities and operations and maintenance activities associated with sewer systems and pretreatment are listed in the Self-Audit Review Document.

If a utility owns treatment works or a pond system, then activities associated with the management, operation, and maintenance of these facilities should also be included in the audit. A helpful guide for this part is the NPDES Compliance Inspection Manual. Instruction for obtaining this manual is provided in a list of references.

What are the Elements of a Proper Self-Audit?

Initial Assessment

Begin by performing a general assessment of the utility, and prioritizing the order of programs to be audited. The NPDES Compliance Inspection Manual and Guidance may be useful references in making this assessment.

Develop the Audit Plan

Identify the MOM programs present and/or needed at the utility, establish performance measures, and develop a schedule for auditing the programs.

Conduct the Audit

Evaluate each MOM program against the defined elements of a proper program. This can be accomplished by reviewing the program's records and resources, conducting a field evaluation, and comparing the program understanding of both personnel and management.

Identify Deficiencies

Define any programs needed, or improvements to programs needed, and any infrastructure deficiencies found. Identify any un-permitted discharges which have occurred in the past five years.

Develop Improvement Plan

Define the utility's plan/schedule to remediate the necessary improvements. This plan should include any short-term or long-term program improvements, and any short-term or long-term capital improvements which need addressing.

Prepare the Self-Audit Report

Generate a report of the audit results, including any deficiencies found and the corresponding improvement plan, which is useful for the utility. This report should be capable of serving the utility as a reference when conducting any needed remedial measures, and as a reference to compare current performance with future self-audit results.

Are there federal grants or other compliance assistance resources available to conduct a Self-Audit?

Currently, there are no funds available for the specific purpose of conducting a MOM Programs Self-Audit. However, the Office of Wastewater Management offers a number of financial resources to assist qualified utilities in making improvements to their programs.

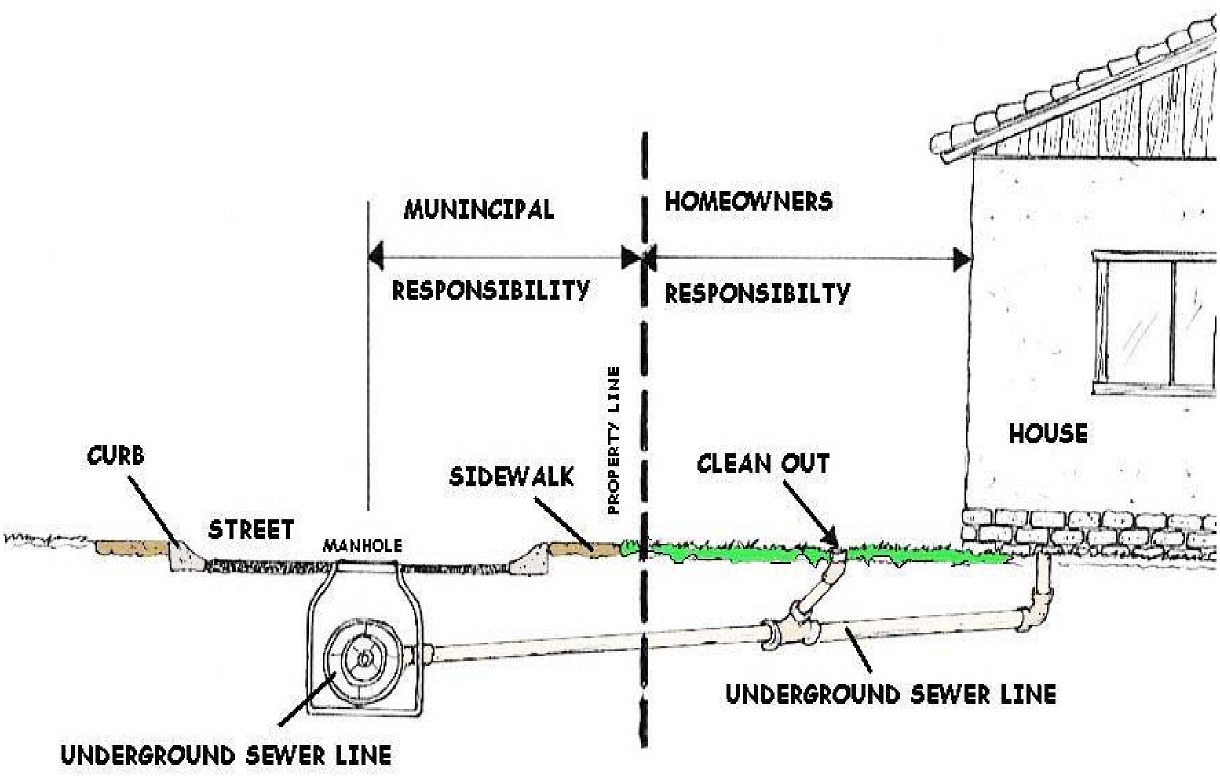
Small publicly-owned wastewater treatment plants which discharge less than 5 million gallons per day are also eligible for the Wastewater Treatment Plant Operator On-Site Assistance

Wastewater Collection System

Every house, restaurant, business, and industry produces waste. Wastewater collection protects public health and the environment by removing this infectious waste and recycling the water. A network of interconnected pipes accepts the flow from each building's sewer connection and delivers it to the treatment facilities. In addition to what homes and businesses flush down the drain, the system also collects excess groundwater, infiltration liquids, and inflow water. Wastewater collection is therefore a comprehensive liquid waste removal system.

The fluid waste distributed through this system is about 98% water. The waste floats on, is carried along by, and goes into suspension or solution in water. Possible waste includes anything that can be flushed down the drain--human excretion, body fluids, paper products, soaps and detergents, foods, fats, oil, grease, paints, chemicals, hazardous materials, solvents, disposable and flushable items; the list is almost infinite. This mixture of water and wastes is called ***"wastewater."*** In the past, it was known as *"sewage,"* but this term is now falling out of favor because it refers specifically to domestic sanitary wastewater, like toilet flushing, which represents only a portion of the entire fluid waste content.

"Wastewater" is a more accurate description and has become the standard term for this fluid waste because it encompasses the total slurry of wastes in water that is gathered from homes and businesses.



Types of Sewer Systems

Centralized sewer systems are generally broken out into three different categories: sanitary sewers, storm sewers, and combined sewers.

Sanitary sewers carry wastewater or sewage from homes and businesses to treatment plants. Underground sanitary sewer pipes can clog or break, causing unintentional *"overflows"* of raw sewage that flood basements and streets. Storm sewers are designed to quickly get rainwater off the streets during rain events. Chemicals, trash and debris from lawns, parking lots, and streets are washed by the rain into the storm sewer drains. Most storm sewers do not connect with a treatment plant, but instead drain directly into nearby rivers, lakes, or oceans. Combined sewers carry both wastewater and storm water in the same pipe. Most of the time, combined sewers transport the wastewater and storm water to a treatment plant.

However, when there is too much rain, combined sewer systems cannot handle the extra volume and designed "overflows" of raw sewage into streams and rivers occur. The great majority of sewer systems have separated, not combined, sanitary and storm water pipes.

According to a recent Clean Water Needs Survey conducted by the USEPA, by the year 2016, the U.S. will have to invest more than $10 billion to upgrade existing wastewater collection systems, over $20 billion for new sewer construction, and nearly $44 billion to improve sewer overflows, to effectively serve the projected population. As the infrastructure in the United States and other parts of the world ages, increasing importance is being placed on rehabilitating wastewater collection systems. Cracks, settling, tree root intrusion, and other disturbances that develop over time deteriorate pipelines and other conveyance structures that comprise wastewater collection systems, including stormwater, sanitary, and combined sewers.

Leaking, overflowing, and insufficient wastewater collection systems can release untreated wastewater into receiving waters. Outdated pump stations, undersized to carry sewage from newly developed subdivisions or commercial areas, can also create a potential overflow hazard, adversely affecting human health and degrading the water quality of receiving waters.

The maintenance of the sewer system is therefore a continuous, never-ending cycle. As sections of the system age, problems such as corroded concrete pipe, cracked tile, lost joint integrity, grease, and heavy root intrusion must be constantly monitored and repaired.

Technology has improved collection system maintenance with such tools as television camera assisted line inspection equipment, jet-cleaning trucks, and improvements in pump design.

Because of the increasing complexity of wastewater collection systems, collection system maintenance is evolving into a highly skilled trade. Collection system operators are charged with protecting public health and the environment, and therefore must have documented proof of their certifications in the respective wastewater management systems. These professionals ensure that the system pipes remain clear and open. They eliminate obstructions and are constantly striving to improve flow characteristics. They keep the wastewater moving underground, unseen and unheard. Because this wastewater collection system and the professionals who maintain it operate at such a high level of efficiency, problems are very infrequent. So much so that the public often takes the wastewater collection system for granted. In truth, these operators must work hard to keep it functioning properly.

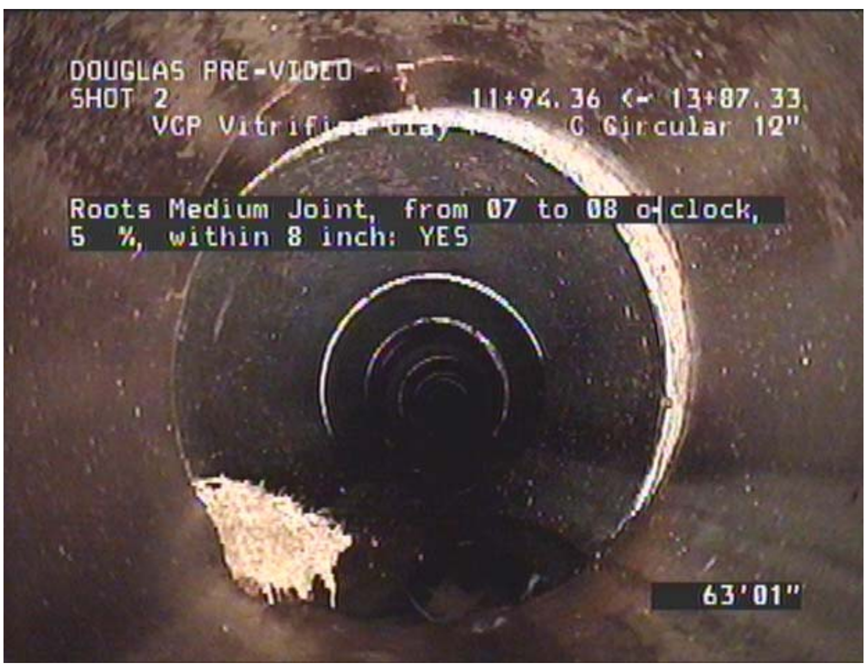
Characteristics of Domestic Wastewater
Mostly water -- 99.95% pure water
What is the 0.05%?
Large Solids -- rags, wigs, sticks, shoes, etc.
Small Solids -- grit (sand, garbage, etc.)
Suspended Solids -- bacteria, feces are 30 - 60% by weight bacteria
Dissolved Material
Organic (Biochemical Oxygen Demand, BOD)
Ammonia (Nitrogenous Oxygen Demand, NOD)
Inorganic (Metals and nutrients like nitrogen and phosphorus)
Other Organic (not decomposable)
Pathogens

Sewer Main
In a centralized wastewater treatment system, the sewer to which sewer connections are made from individual residences.

Trunk Lines
Sewer pipes measuring more than 12 inches in diameter and having a capacity of 1 to 10 million gallons per day. Trunk lines connect smaller sewer pipes, or collectors, to the largest transport pipes or interceptors.

Collectors
Small sewer pipes measuring twelve inches or less in diameter.

Root sewer blockage
Photograph of sewers courtesy of Propipe.



Root sewer blockage
Photographs of sewers courtesy of Propipe.

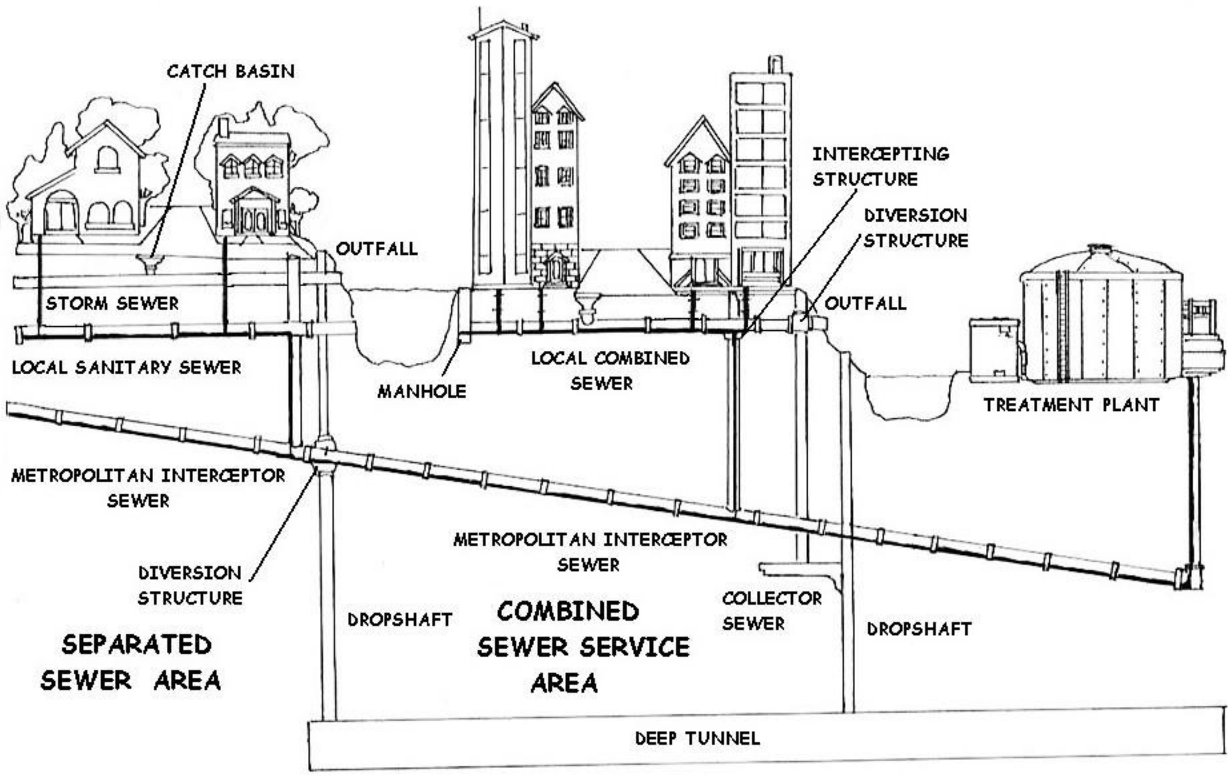
The Hydraulic Sewer Cleaning Truck above is 38 feet long and 9 feet wide. The attached tank has a capacity of 1500 gallons and can hold 10 cubic yards of debris. The truck is equipped with a high pressure cleaning head that can move 800 feet down a sanitary line at 2500 PSI.

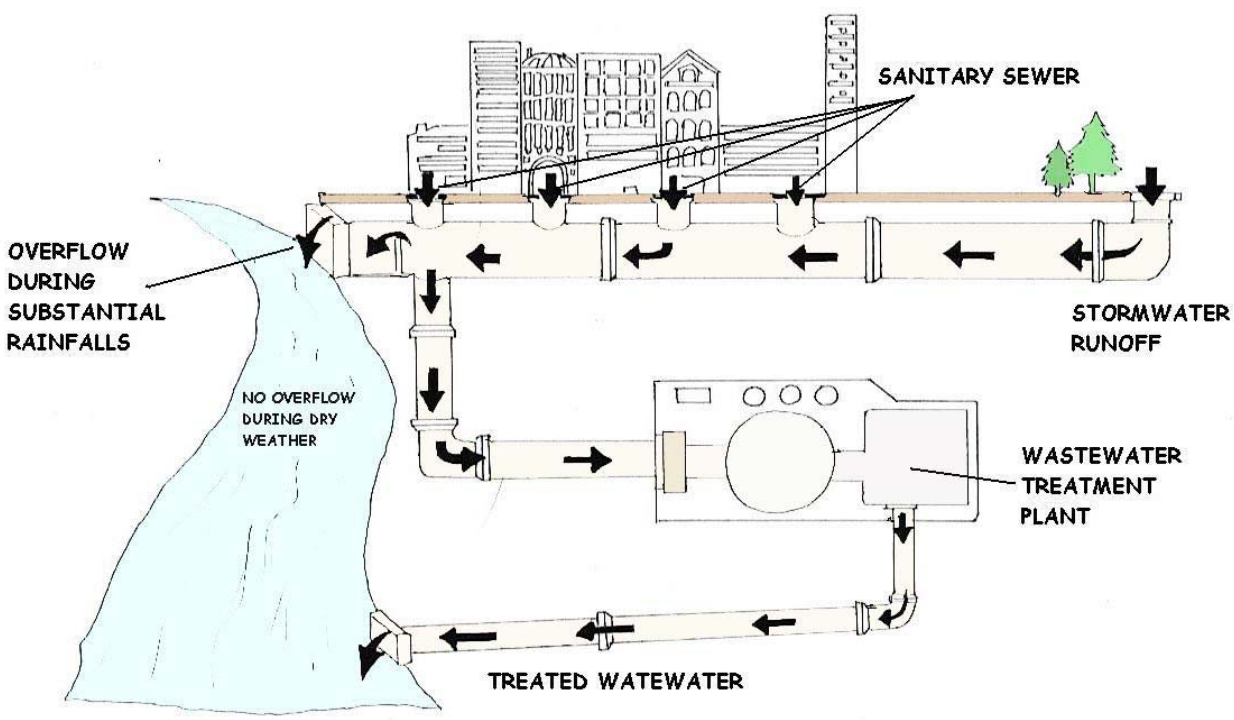
*Out of sight, out of mind—that's your sanitary sewer collection system. Until there comes that inevitable emergency call due to a stoppage, then you have upset residents with sewage backed up in their toilets.

A very economical and quick method of determining if a new sewer line is straight and unobstructed is called *"Lamping"* and can be done with a mirror and a bright source of light, for example a headlight at night or sunlight.

*Video inspection coupled with a good cleaning program can be a highly effective maintenance tool. By cleaning and root sawing your lines, restrictions caused by debris, roots and grease buildup can be prevented—thus drastically reducing the number of emergency backups and surcharge calls.

*Sewage collection systems that have video inspection closed circuit television (CCTV) and cleaning programs, report drastic reductions in the number of emergency calls because the system was cleaned and potential trouble spots were located prior to problems occurring.


CATCH BASIN
OUTFALL
STORM SEWER
LOCAL SANITARY SEWER
MANHOLE
LOCAL COMBINED SEWER
INTERCEPTING STRUCTURE
DIVERSION STRUCTURE
OUTFALL
TREATMENT PLANT
METROPOLITAN INTERCEPTOR SEWER
DIVERSION STRUCTURE
METROPOLITAN INTERCEPTOR SEWER
DROPSHAFT
COMBINED SEWER SERVICE AREA
COLLECTOR SEWER
DROPSHAFT
SEPARATED SEWER AREA
DEEP TUNNEL


SANITARY SEWER
OVERFLOW DURING SUBSTANTIAL RAINFALLS
STORMWATER RUNOFF
NO OVERFLOW DURING DRY WEATHER
WASTEWATER TREATMENT PLANT
TREATED WATEWATER

Gravity Sanitary Sewers

A sanitary sewer has two main functions:
To convey the designed peak discharge.
Transport solids so that the deposits are kept at a minimum.

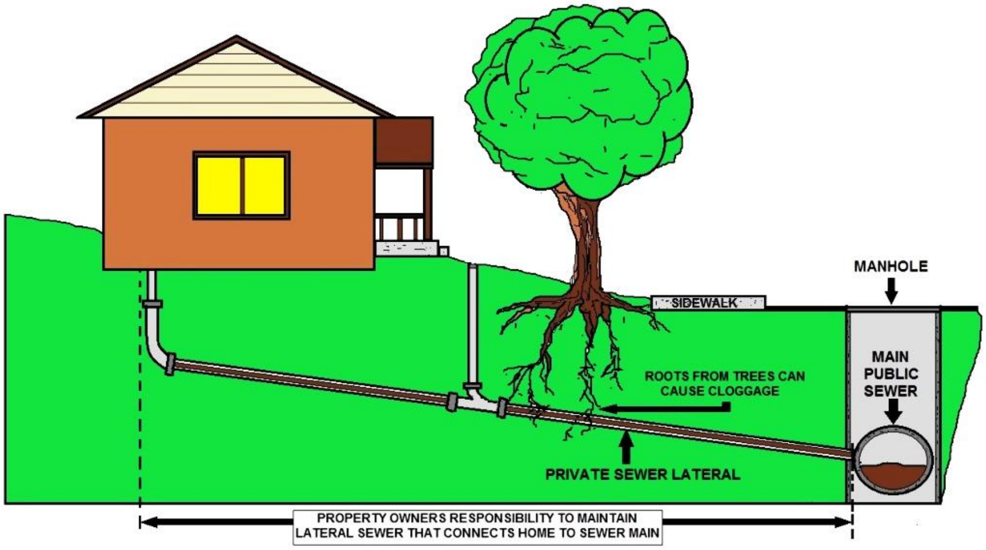


DIAGRAM OF SEWER LATERAL

Sanitary sewers are designed to transport the wastewater by utilizing the potential energy provided by the natural elevation of the earth resulting in a downstream flow. This energy, if not designed properly, can cause losses due to free falls, turbulent junctions and sharp bends. Sewer systems are designed to maintain proper flow velocities with minimum head loss. However, higher elevations in the system may find it necessary to dissipate excess potential energy. Design flows are based on the quantity of wastewater to be transported. Flow is determined largely by population served, density of population, and water consumption. Sanitary sewers should be designed for peak flow of population. Stormwater inflow is highly discouraged and should be designed separate from the sanitary system.

Gravity-flow sanitary sewers are usually designed to follow the topography of the land and to flow full or nearly full at peak rates of flow and partly full at lesser flows. Most of the time the flow surface is exposed to the atmosphere within the sewer and it functions as an open channel. At extreme peak flows the wastewater will surcharge back into the manholes. This surcharge produces low pressure in the sewer system. In order to design a sewer system, many factors are considered. The purpose of this topic is to aid in the understanding of flow velocities and design depths of flow. The ultimate goal for our industry is to protect the health of the customers we serve. This is achieved by prevention of sewer manhole overflows.

Flow Measurements
Most sewers are designed with the capacity to flow half full, for less than 15 inches in diameter; larger sewers are designed to flow at three-fourths flow. The velocity is based on calculated peak flow, which is commonly considered to be twice the average daily flow.

Accepted standards dictate that the minimum design velocity should not be less than 0.60 m/sec (2 fps) or generally greater than 3.5 m/sec (10 fps) at peak flow. A velocity in excess of 3.5 m/sec (10 fps) can be tolerated a proper consideration of pipe material, abrasive characteristics of the wastewater, turbulence, and thrust at changes of direction. The minimum velocity is necessary to prevent the deposition of solids.

Various Sewer Flow Measuring Devices
The use of a dye at the manhole to determine the velocity is done as follows:

Insert dye upstream and begin timing until the dye is first seen at the downstream manhole (t_1); and Total the travel time, the insertion time from the time the dye is no longer seen at the downstream manhole (t_2).

Once this is complete, add (t_1 + t_2) then divide it by 2. This will give you the total average time for the dye. In order to calculate the velocity, the travel time is divided by the distance between manholes (note that the time needs to be converted to seconds):

Distance, ft
Velocity, ft/sec = ―――――――
Average time, sec

There are devices available to measure flow measurements, they all are based on the principle of the cross-sectional area of the flow in a sewer line. This is done by using the table below. Once this has been determined, then the following equations can be used:

Q, cubic feet of flow = Area, sq. ft multiplied by Velocity, ft/sec

d/D	Factor	d/D	Factor	d/D	Factor	d/D	Factor
0.0013		0.0811		0.2074		0.3527	
0.0037		0.0885		0.2167		0.3627	
0.0069		0.0961		0.2260		0.3727	
0.0105		0.1039		0.2355		0.3827	
0.0174		0.1118		0.2350		0.3927	
0.0192		0.1199		0.2545		0.4027	
0.0242		0.1281		0.2642		0.4127	
0.0294		0.1365		0.2739		0.4227	
0.0350		0.1449		0.2836		0.4327	
0.0409		0.1535		0.2934		0.4426	
0.0470		0.1623		0.3032		0.4526	
0.0534		0.1711		0.3130		0.4625	
0.0600		0.1800		0.3229		0.4724	
0.0668		0.1890		0.3328		0.4822	
0.0739		0.1982		0.3428		0.4920	

This table works as followed:

To determine the cross-sectional flow for a 12 inch sewer main with a flow depth of 5 inches you would first:

d or depth 5 inches divided by **D** or diameter 12 inches equals 0.42 **d/D.** using the table above find the correct factor for 0.42 d/D.

The factor equals 0.3130, now calculate the cross-sectional area using the following formula:

$$\text{Pipe Cross-sectional Area, sq. ft} = \frac{(\text{Factor})(\text{Diameter, in})^2}{144 \text{ sq. in/sq. ft}}$$

$$\frac{(0.3130)(12 \text{ in})^2}{144 \text{ sq. in/sq./ft}}$$

$$= 0.0313 \text{ sq. ft}$$

Once the Velocity and the cross-sectional area have been determined, the calculation for flow rate is used. This formula is as followed:

Q, cubic feet per second = (Area, sq. ft} (Velocity, ft/sec)

Once this calculation is made, cubic feet can be converted to gallons by multiplying it by 7.48 gal/cubic feet can be converted to minutes, hours, or days by multiplying the gallons with the time.

Infiltration/Inflow

***What is Infiltration/Inflow (I/I)?**
Infiltration occurs when groundwater enters the sewer system through cracks, holes, faulty connections, or other openings. Inflow occurs when surface water such as storm water enters the sewer system through roof downspout connections, holes in manhole covers, illegal plumbing connections, or other defects.

The sanitary sewer collection system and treatment plants have a maximum flow capacity of wastewater that can be handled. I/I, which is essentially clean water, takes up this capacity and can result in sewer overflows into streets and waterways, sewer backups in homes, and unnecessary costs for treatment of this water. It can even lead to unnecessary expansion of the treatment plants to handle the extra capacity. These costs get passed on to the consumer.

***I/I (Infiltration and Inflow)**
Infiltration is water (typically groundwater) entering the sewer underground through cracks or openings in joints.
Inflow is water (typically stormwater or surface runoff) that enters the sewer from grates or unsealed manholes exposed to the surface.

Determining I/I
Flow monitoring and flow modeling provide measurements and data used to determine estimates of I/I. Flow meters are placed at varying locations throughout the sewer collection system to take measurements and identify general I/I source areas. Measurements taken before and after a precipitation event indicate the extent that I/I is increasing total flow. Both infiltration and inflow increase with precipitation. Infiltration increases when groundwater rises from precipitation, and inflow is mainly stormwater and rainwater. Rainfall monitoring is also performed to correlate this data.

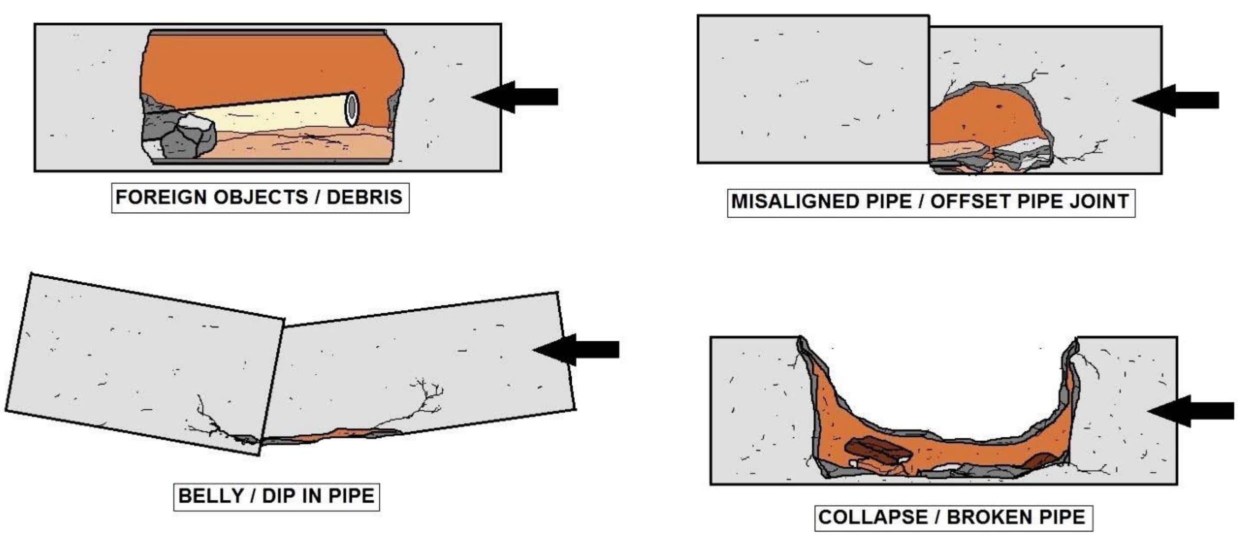
Identifying sources of I/I
A Sewer System Evaluation Survey (SSES) involves inspection of the sewer system using several methods to identify sources of I/I: Visual inspection - accessible pipes, gutter and plumbing connections and manholes are visually inspected for faults.

Smoke testing – smoke is pumped into sewer pipes. Its reappearance aboveground indicates points of I/I. These points can be on public property such as along street cracks or around manholes, or on private property such as along house foundations or in yards where sewer pipes lay underground.

TV inspection – camera equipment is used to do internal pipe inspections. The City should have one 2-3-person crew that performs TV inspection.

Dye testing – Dye is used at suspected I/I sources. The source is confirmed if the dye appears in the sewer system.

Sources of I/I are also sometimes identified when sewer backups or overflows bring attention to that part of the system. The purpose of the SSES is to reduce these incidences by finding sources before they cause a problem.



COMMON CAUSES OF SEWER LATERAL BLOCKAGES

Tree Roots vs. Sanitary Sewer Lines

***Root Growth in Pipes**
Roots require oxygen to grow, they do not grow in pipes that are full of water or where high ground water conditions prevail. Roots thrive in the warm, moist, nutrient rich atmosphere above the water surface inside sanitary sewers. The flow of warm water inside the sanitary sewer service pipe causes water vapor to escape to the cold soil surrounding the pipe. Tree roots are attracted to the water vapor leaving the pipe and they follow the vapor trail to the source of the moisture, which are usually cracks or loose joints in the sewer pipe.

Upon reaching the crack or pipe joint, tree roots will penetrate the opening to reach the nutrients and moisture inside the pipe. This phenomenon continues in winter even though trees appear to be dormant.

Problems Caused by Roots Inside Sewers
Once inside the pipe, roots will continue to grow, and if not disturbed, they will completely fill the pipe with multiple hair-like root masses at each point of entry. The root mass inside the pipe becomes matted with grease, tissue paper, and other debris discharged from the residence or business. Homeowners will notice the first signs of a slow flowing drainage system by hearing gurgling noises from toilet bowls and observing wet areas around floor drains after completing the laundry. A complete blockage will occur if no remedial action is taken to remove the roots/blockage. As roots continue to grow, they expand and exert considerable pressure at the crack or joint where they entered the pipe. The force exerted by the root growth will break the pipe and may result in total collapse of the pipe. Severe root intrusion and pipes that are structurally damaged will require replacement.

Tree Roots in Sewer
Tree roots growing inside sewer pipes are generally the most expensive sewer maintenance item experienced by City residents. Roots from trees growing on private property and on parkways throughout the City are responsible for many of the sanitary sewer service backups and damaged sewer pipes. Homeowners should be aware of the location of their sewer service and refrain from planting certain types of trees and hedges near the sewer lines. The replacement cost of a sanitary sewer service line as a result of damage from tree roots may be very expensive.

Pipes Susceptible to Root Damage
Some pipe material is more resistant to root intrusion than others. Clay tile pipe that was commonly installed by developers and private contractors until the late 1980's is easily penetrated and damaged by tree roots. Concrete pipe and PVC pipe may also allow root intrusions, but to a lesser extent than clay tile pipe. PVC pipe is more resistant to root intrusion because it usually has fewer joints. The tightly fitting PVC joints are less likely to leak as a result of settlement of backfill around the pipe.

Root Spread

During drought conditions and in winter, tree roots travel long distances in search of moisture. As a general rule, tree roots will extend up to 2.5 times the height of the tree, and some species of trees may have roots extending five to seven times the height of the tree.

Root Growth Control

*The common method of removing roots from sanitary sewer service pipes involves the use of augers, root saws, and high pressure flushers. These tools are useful in releasing blockages in an emergency, however, cutting and tearing of roots encourages new growth. The effect is the same as pruning a hedge to promote faster, thicker, and stronger re-growth. Roots removed by auguring are normally just a small fraction of the roots inside the pipe.

*To augment the cutting and auguring methods, there are products available commercially that will kill the roots inside the pipe without harming the tree. The use of products such as copper sulfate and sodium hydroxide are not recommended because of negative environmental impacts on the downstream receiving water. Also, these products may kill the roots but they do not inhibit re-growth.

The more modern method used throughout Canada and the United States for controlling root growth involves the use of an herbicide mixed with water and a foaming agent. The foam mixture is pumped into the sewer pipe to kill any roots that come into contact with the mixture. New root growth will be inhibited from three to five years after the treatment, according to the manufacturers.

FlexKid is an accessory for Ripper tools designed to clear roots and other blockages from sewer pipes. The unit readily passes through pipes and around or over typical obstructions like offset joints, hand taps and debris. Available for pipes 18 inches and larger, it features durable cable and easy attachment to the rear of any root-cutting motor. It is designed for quick setup and quick size changes in field. No underground (in-manhole) assembly is required, and no manhole modification is necessary.

The Knocker is a chain cleaner designed to use in conjunction with The Ripper.

Smoking out Sewer Leaks

*An overview of smoke testing, an important part of successful **I & I** studies.*
By Paul Tashian, Superior Signal Company, Inc.

Used extensively for over 40 years, smoke testing has proven to be a vital ingredient of successful inflow and infiltration (I&I) studies. It is as important now as it has ever been as growing municipalities increase demands on aging, often deteriorating collection systems. In addition, programs such as the EPA's new CMOM (capacity, management, operations, and maintenance) emphasize a focus on proactive, preventive maintenance practices. Smoke testing is an effective method of documenting sources of inflow and should be part of any CMOM program.

Just as a doctor would require the aid of several instruments to evaluate the status of one's health, various test methods should be used in performing a complete sanitary sewer evaluation survey (SSES). In addition to smoke testing, these could include dyed water testing, manhole inspection, TV inspection, flow monitoring, and more. Specializing in sanitary sewer evaluation surveys, Wade & Associates of Lawrence Kansas states a reduction of 30 to 50% in peak flows can be expected as a result of implementing these types of programs.

Smoke testing is a relatively simple process, which consists of blowing smoke mixed with larger volumes of air into the sanitary sewer line, usually induced through the manhole. The smoke travels the path of least resistance and quickly shows up at sites that allow surface water inflow. Smoke will identify broken manholes, illegal connections (including roof drains, sump pumps, yard drains and more), uncapped lines, and will even show cracked mains and laterals providing there is a passageway for the smoke to travel to the surface.

Although video inspection and other techniques are certainly important components of an I&I survey, research has shown that approximately 65% of all extraneous stormwater inflow enters the system from somewhere other than the main line (see private sector diagram). Smoke testing is an excellent method of inspecting both the mainlines, laterals and more.

Smoke travels throughout the system, identifying problems in ALL connected lines even sections of line that were not known to exist, or thought to be independent or unconnected. Best results are obtained during dry weather, which allows smoke better opportunity to travel to the surface.

Needed Equipment

Blowers; Most engineering specifications for smoke testing identify the use of a blower able to provide 1750 cfm (cubic feet of air per minute), however in today's world it seems to be the mindset that bigger is better. New smoke blowers on the market can deliver over 3000 cfm, but is this really needed?

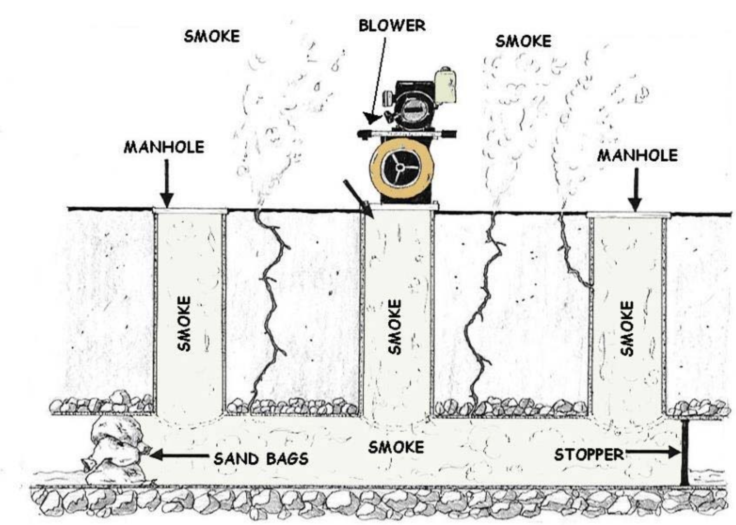
Once the manhole area is filled, the smoke only needs to travel sections of generally 8 or 10-inch pipe. Moving the air very quickly is useless if the blower does not have the static pressure to push that air/smoke through the lines. If you've used high CFM blowers and found that smoke frequently backs up to the surface, this may be your problem.

Blowers

There are two types of blowers available for smoke testing sewers: squirrel cage and direct drive propeller. In general, squirrel cage blowers are usually larger in size, but can provide more static pressure in relation to CFM. The output of the squirrel cage type is usually adjustable by alternating pulleys and belts to meet the demands of the job.

Propeller style blowers are usually more compact and generally offer approx. 3,200 CFM. Other than reducing the engine throttle, the output is not adjustable since the fan blade is attached directly to the engine shaft. If purchasing a smoke blower you should ask the manufacturer if the CFM and static pressure output they are quoting is the specification of the propeller itself (uninstalled/free air), or if it is the actual performance when installed in the blower assembly. These two numbers can vary significantly.

Smoke Types; There are two types of smoke currently offered for smoke testing sewers, classic smoke candles and smoke fluids.



Smoke candles were first used for testing sewers when the process began its popularity back in 1961, and continue to be the most widely used. They are used by simply placing a smoke candle on the fresh air intake side of the blower. Once ignited, the exiting smoke is drawn in with the fresh air and blown down into the manhole and throughout the system. Smoke candles are available in various sizes that can be used singularly or in combination to meet any need. This type of smoke is formed by a chemical reaction, creating a smoke which contains a high content of atmospheric moisture. It is very visible even at low concentrations, and extremely effective at finding leaks.

Another available source of smoke is a smoke fluid system. Although they have just recently been more aggressively marketed, smoke fluids became available for sewer testing shortly after smoke candles, some 30 years ago.

They can certainly be used effectively, but it is important to understand how they work. This system involves injecting a smoke fluid (usually a petroleum based product) into the hot exhaust stream of the engine where it is heated within the muffler (or heating chamber) and exhausted into the air intake side of the blower. One gallon of smoke fluid is generally less expensive than one dozen smoke candles; however smoke fluids do not consistently provide the same quality of smoke.

When using smoke fluid, it is important to understand that as fluid is injected into the heating chamber (or muffler) it immediately begins to cool the unit. The heating chamber will eventually reach a point where it is not hot enough to completely convert all the fluid to smoke, thus creating thin/wet smoke.

This can actually happen quickly depending on the rate of fluid flow. If the smoke has become thin it can be especially difficult to see at greater distances. Blocking off sections of line is usually a good idea with any type of smoke, but becomes almost a necessity when using smoke fluid. Some manufactures have taken steps to address this issue, and now offer better flow control, fluid distribution, and most importantly *insulated heating chambers* to help maintain necessary temperatures.

Safety
Maybe one of the more talked about, yet least understood aspects of smoke testing is the use and safety of these products. As manufacturers have become more competitive, some marketing programs and advertisements have implied danger in the use of competitive types of smoke products. Laboratory reports, scientific studies, and even Material Safety Data Sheets can be quite confusing to most of us who are not trained or qualified to make scientific judgments on this data. Having this information delivered to us in the form of advertising can be dangerous, as most of us tend to believe what we read.

An author of an associated industry publication once stated… "*Do not use smoke bombs, as they give off a toxic gas*". Although the author quotes no scientific literature to support this statement, competitive propaganda has made such implications. It is interesting to note that the same exact statement could be made for smoke fluids. Smoke from fluid is created in the exhaust system of the engine, which contains carbon monoxide. Is carbon monoxide not a toxic gas?

Other statements that have been made include warnings to wear a respirator while smoke testing. While certain manufacturers have issued this warning about competitive products, they do not qualify the statement, nor do they mention the fact that the same thing could be said of their own product. The fact is that a respirator should be worn whenever a person would be exposed to **ANY** substance in quantities that exceeded OSHA limits.

The bottom line on safety is that it is important to use common sense. All smokes, candles and fluids can be used safely and effectively when used as directed.

*****When planning to smoke test, it is important to develop a proactive public notice program. Ads in local papers, door hangers, mailers, as well as door to door inquiries are recommended. It is helpful to educate the public as to why the test is being performed and the positive benefits to the community. In addition, it should instruct residents on what to do and who to call if smoke should enter their homes.

It is also important to notify local police and fire departments daily, as to where and when smoke testing will be taking place. Reducing stormwater inflow into collection systems means reduced chances of overflows, less emergency maintenance and less money spent on treatment. If these are goals of your organization, consider smoke testing as a fairly easy, inexpensive, and effective way of achieving your objectives.

Paul Tashian is employed by Superior Signal Company Inc., a manufacturer of all types of smoke testing equipment, and a major contributor to the original development of smoke testing practices. Paul can be reached at (732) 251-0800, or ptashian@superiorsignal.com. Also, thanks to Wade & Associates (a company specializing in sanitary sewer evaluation surveys) for offering reference material, and providing artwork and photographs used in this article. For information on Wade's services call (785) 841-1774, or visit www.wadeinc.com.

Manholes

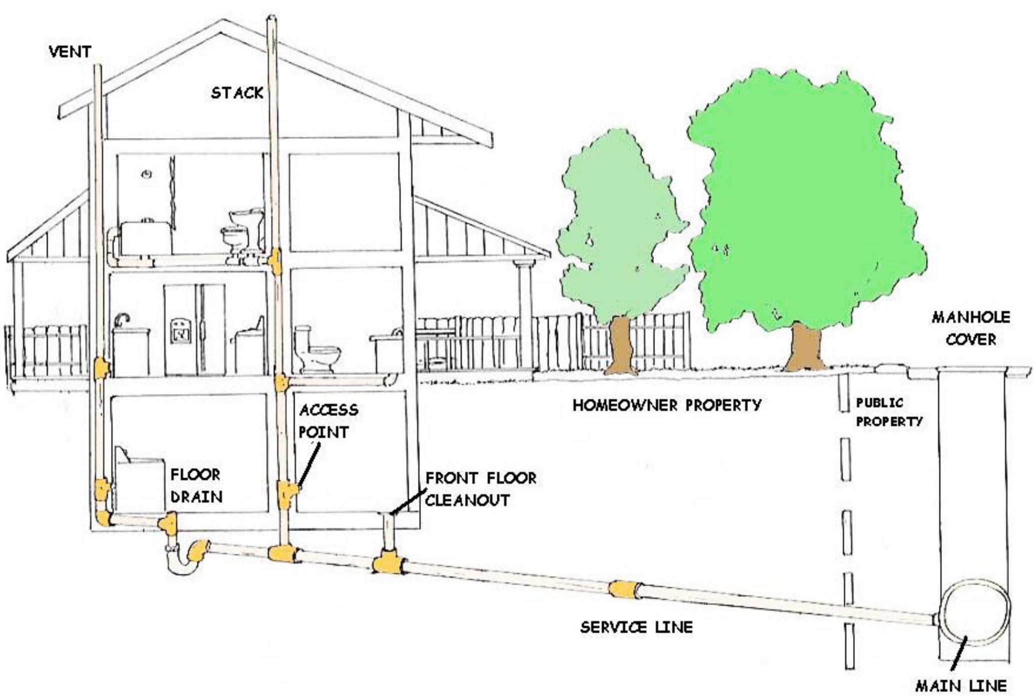
When designing a wastewater system, the design engineer begins by first determining the types and quantities of sewage to be handled. This is accomplished through a careful study of the area to be served. The design engineer bases his design on the average daily use of water per person in the area to be served. A typical value is 100 gallons per person per day. But, the use of water is not constant.

Use is greater in the summer than in the winter and greater during the morning and evening than it is in the middle of the day or at night. Therefore, the average daily flow (based on the average utilization) is multiplied by a peak flow factor to obtain the design flow.

Typical peak flow factors range from 4 to 6 for small areas down to 1.5 to 2.5 for larger areas. An allowance for unavoidable infiltration of surface and subsurface water into the lines is sometimes added to the peak flow to obtain the design flow. A typical infiltration allowance is 500 gallons per inch of pipe diameter per mile of sewer per day. From the types of sewage and the estimated design flow, the engineer can then tentatively select the types, sizes, slopes, and distances below grade of the piping to be used for the system.

Upon acceptance of the preliminary designs, final design may begin. During this phase, adjustments to the preliminary design should be made as necessary, based upon additional surveys, soil analysis, or other design factors. The final designs should include a general map of the area that shows the locations of all sewer lines and structures.

They also should include detailed plans and profiles of the sewers showing ground elevations, pipe sizes and slopes, and the locations of any appurtenances and structures, such as manholes and lift stations. Construction plans and details should also be included for those appurtenances and structures.



Joints

Lead and Oakum Joint, Compression Joint, and No-Hub Joint
These types of joints are used to connect cast-iron soil pipes (CISP) and fittings. In lead and oakum joints, oakum (made of hemp impregnated with bituminous compound and loosely twisted or spun into a rope or yarn) is packed into the hub completely around the joint, and melted lead is poured over it.

In compression joints, an assembly tool is used to force the spigot end of the pipe or fitting into the lubricated gasket inside the hub. A no-hub joint uses a gasket on the end of one pipe and a stainless steel shield and clamp assembly on the end of the other pipe.

Mortar and Bituminous Joints
This type of joint is common to vitrified clay and concrete pipes and fittings. Mortar joints may be made of grout (a mixture of cement, sand, and water).

The use of *Speed Seal Joints* (rubber rings) in joining vitrified clay pipe has become widespread. Speed seal joints eliminate the use of oakum and mortar joints for sewer mains. This type of seal is made a part of the vitrified pipe joint when manufactured. It is made of polyvinyl chloride and is called a plastisol joint connection

Smoke testing is accomplished by forcing a non-toxic smoke into the sewer system and looking for locations where it is improperly exiting.

These locations are considered illegal connections in that they allow stormwater directly or indirectly to enter the sanitary sewer system.

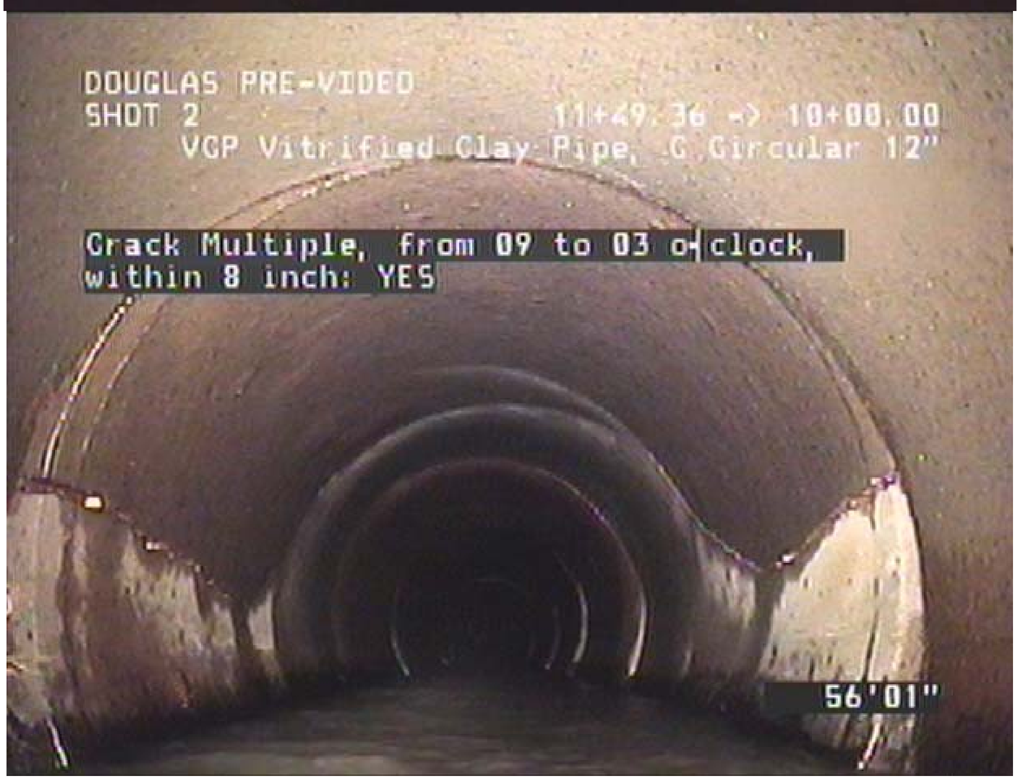
Typical illegal connections found are roof drains tied directly into the system, abandoned customer sewer lines that were not properly capped, as well as an occasional broken sewer line.

The sewer vacuum truck utilizes both a high pressure stream of water and a vacuum system to clean and remove built up debris from sewer lines. These versatile vehicles are also used to clean lift station wet wells, stormwater catch basins, and to perform excavations to locate broken water or sewer lines. It reduces repair times and costs by over 50%.

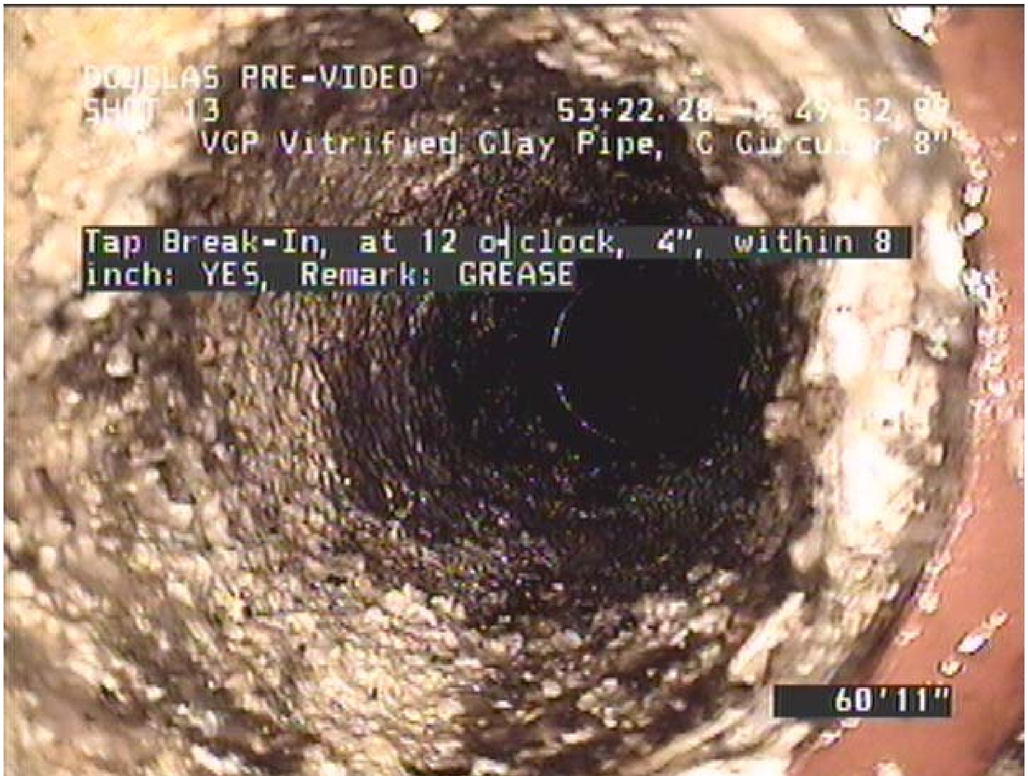
Various Jetter or hydraulic cleaning attachments.

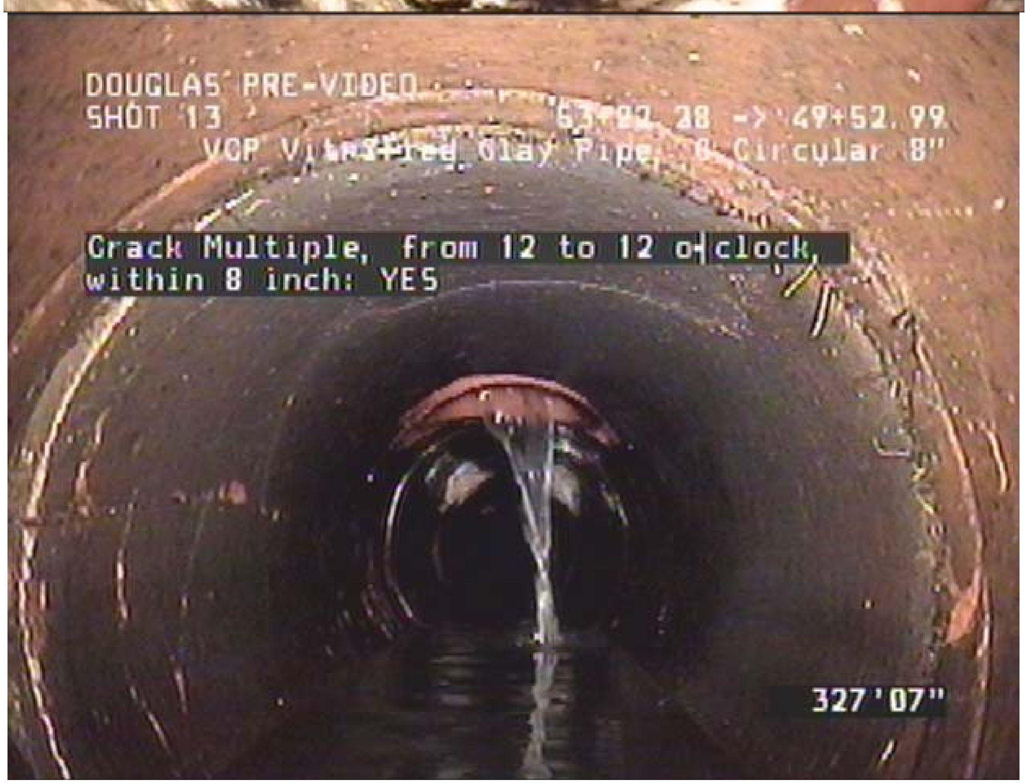
*A remotely controlled TV camera on the bottom is utilized by crews to identify and video tape problem areas within the system. By using this equipment, staff can determine what the cause of the problem is, what materials will be needed for repair, and where the problem area is. Repairs can be made quickly without digging up large areas to find and correct a problem as was done in the past.

*There are many reasons for inspecting sewer lines with a closed circuit television (CCTV). All of the following are valid reasons; Locate sources of inflow and infiltration, locate buried manholes, and locate illegal sewer taps such as industrial or storm drains.

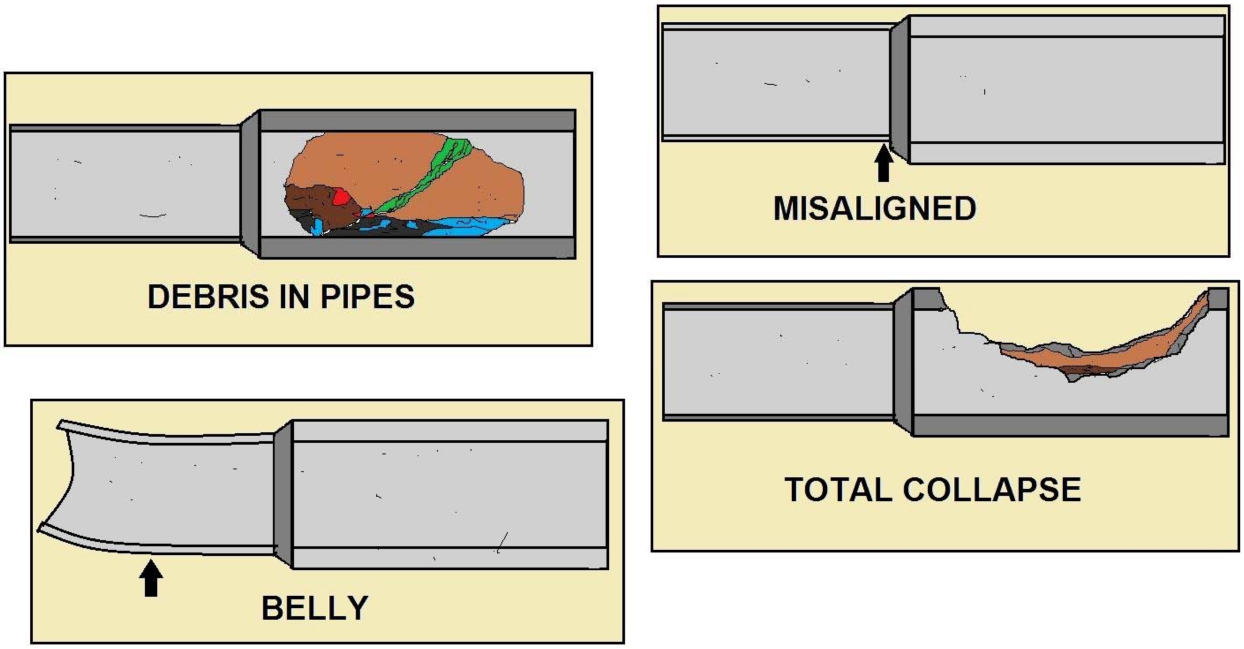


Examples of pipe corrosion.
Photographs courtesy of Propipe.

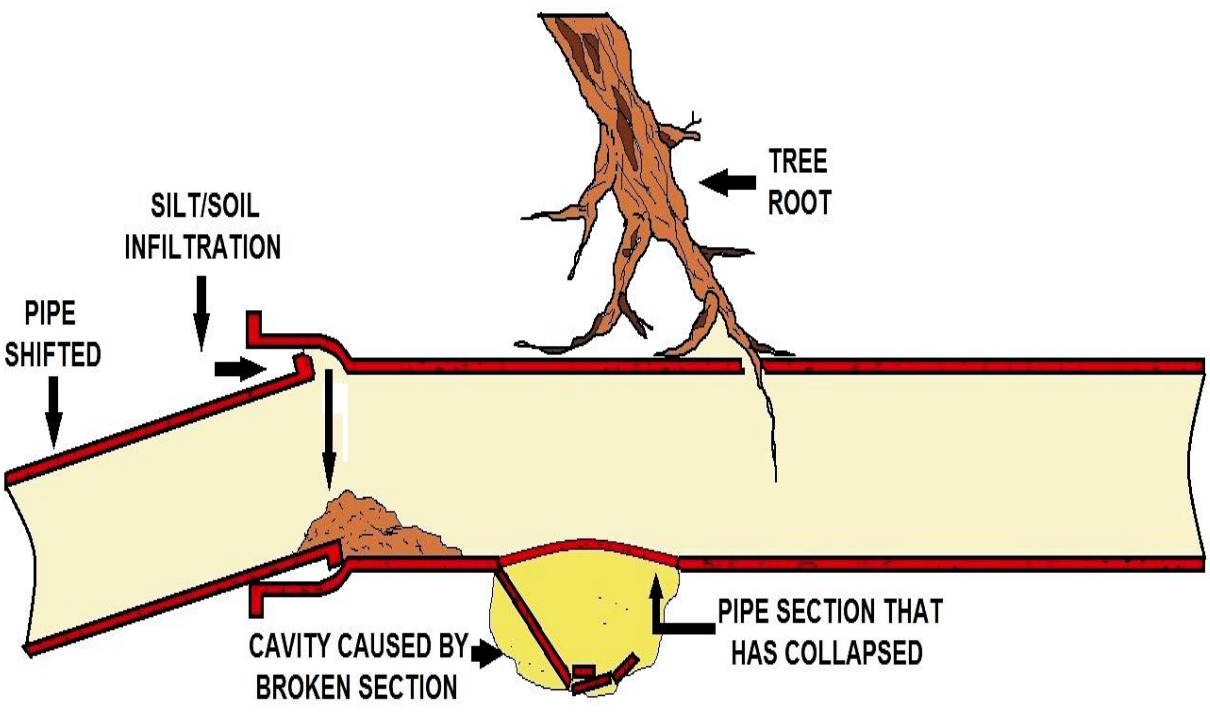




Photographs courtesy of Propipe.



DAMAGED SEWER PIPE EXAMPLES



BROKEN SEWER PIPE

Low Pressure System Description and Operation

Applications
Vacuum collection and transportation systems can provide significant capital and ongoing operating cost advantages over conventional gravity systems particularly in flat terrain, high water table, or hard rock areas. Vacuum sewer systems are installed at shallow depths, significantly reducing excavation, shoring and restoration requirements, and minimizing the disruption to the community. The alignment of vacuum mains is extremely flexible, without the need for manholes at changes in grade or direction.

Vacuum sewer mains can skip over and around other services or obstacles and can be used to achieve uphill flow. Turbulent velocities of 5 to 6m/sec are developed as the sewage and air passes through the interface valve. This disintegrates solids and reduces the risks of sewer blockages in a correctly designed and constructed vacuum system.

No electricity is required at the interface valve, enabling the system to be installed in virtually any location. Fractures in gravity systems may go undetected for a long time. A leak in a vacuum main will raise an alarm within minutes of the break. The mains have to be repaired for sewage transport to continue, ensuring up to date maintenance and eliminating deterioration and infiltration.

Due to the shallow depth of the installation, additional connections can be quickly and simply made by a small construction crew, thus reducing the disruption and restoration work normally required for conventional gravity sewers. Vacuum collection and transport systems have many applications in industry for collecting all forms of liquid waste, including toxic and radioactive fluids. Collection pipes may be installed above ground, overhead or in utility ducts.

The versatility of the vacuum sewer system can be employed in a variety of locations and situations, such as:

- ✓ Rural community sewerage schemes
- ✓ Industrial redevelopments
- ✓ Camping and caravan sites
- ✓ New residential and industrial developments
- ✓ Existing towns (especially where narrow streets or congested service corridors occur)
- ✓ Diversion of small sea outfalls
- ✓ Hospital effluent collection
- ✓ Airports/Shopping centers
- ✓ Railway services
- ✓ Replacement of failed gravity systems
- ✓ Petrol-chemical industry
- ✓ Food processing plants
- ✓ Roof drainage
- ✓ Retrofitting factories for the management of segregated wastestreams.
- ✓ Collection of toxic and radioactive waste
- ✓ Condensate collection systems
- ✓ Factory sewerage
- ✓ Leachate from landfills
- ✓ Spillage around tank farms
- ✓ Collecting used oil and fluids
- ✓ River and lakeside communities
- ✓ Quayside redevelopments
- ✓ Arctic communities

Vacuum Interface Valves

There is an interface between the vacuum within the vacuum mains and maintains the atmospheric pressure within the vacuum interface chamber. When sewage is entering the system from a source and the sewage level in the chamber rises, it pressurizes air in the 2.5-inch or 63mm sensor line. This air pressure is transmitted by a hose to the controller/sensor unit which opens the valve and the wastewater is rapidly drawn into the vacuum main. Suction of the sewer creates a vortex in the sump and air is drawn into the sewer with the sewage.

As the valve opens, a pneumatic timer in the controller/sensor unit starts a pre-set time cycle. The timer holds the valve open for sufficient time to draw all the sewage out of the sump and allows a designated amount of air to enter the system.

The Iseki interface valve is capable of serving at least four equivalent tenements, and multiple valve chambers may be installed to serve higher flow rates. No electricity is required at the valve chamber. The vacuum valve is automatically operated by the pressure generated with the rising sewage level and the pneumatic timer, and actuated by the vacuum in the sewer.

Differential air pressure is the driving force in vacuum sewer systems. The vacuum sewer lines are under a vacuum of 16"-20" Hg (-0.5 to -0.7 bar) created by vacuum pumps located at the vacuum station. The pressure differential between the atmospheric pressure and the vacuum in the sewer lines of 7 to 10 psi (0.5 - 0.7 bar) provides the energy required to open the vacuum interface valves and to transport the sewage.

Sewage flows by gravity from homes into a collection sump. When 10 gallons (40 liters) accumulates in the sump, the vacuum interface valve located above the sump automatically opens and differential air pressure propels the sewage through the valve and into the vacuum main.

Sewage flows through the vacuum lines and into the collection tank at the vacuum station. Sewage pumps transfer the sewage from the collection tank to the wastewater treatment facility or nearby gravity manhole. There are no electrical connections required at the home. Power is necessary only at the vacuum station.

Valve Pit Package
The Valve Pit Package connects the homes to the vacuum sewer system. Raw sewage flows by gravity from up to four homes into a sealed fiberglass sump. Located above the sewage sump and surrounded by a fiberglass valve pit is a 3" (90 mm) vacuum interface valve which is pneumatically controlled and operated. Vacuum from the sewer line opens the valve and outside air from a breather pipe closes it.

Sewage level sensing is remarkably simple. As the sewage level rises, air trapped in the empty 2" (50 mm) diameter sensor pipe pushes on a diaphragm in the valve's controller/sensor unit, signaling the valve to open. When ten gallons of sewage accumulates in the sump the valve automatically opens.

The differential air pressure propels the sewage at velocities of 15-18 feet per second (4.5 - 5.5 m/s), disintegrating solids while being transported to the vacuum station. The valve stays open for four to six seconds during this cycle.

Atmospheric air used for transport enters through the 4" (100 mm) screened air intake on the gravity line. There are no odors at this air inlet due to the small volumes of sewage (10 gallons - 40 liters) and short detention times in the sump. The valve is 3" and designed for handling nominal 3" (75 mm) solids. Homes connected to vacuum sewers don't require any special plumbing fixtures. Typically one valve pit package serves two homes. Install the valve pit package in the street, if desired. With the optional traffic cast iron cover the valve pit package has a water loading rating.

Vacuum Lines
Vacuum sewer lines are installed in narrow trenches in a saw tooth profile for grade and uphill transport. Vacuum lines follow grade for downhill transport. Vacuum lines are slightly sloped (0.2%) towards the collection station. Unlike gravity sewers that must be laid at a minimum slope to obtain a 2 ft./sec. (0.6 m/s) scouring velocity, vacuum has a flatter slope since a high scouring velocity is a feature of vacuum sewage transport.

Line Sizes
The vacuum service line from the valve to the main in the street is 3" diameter (90 mm). The vacuum mains are 4", 6", 8" and 10" diameter (110 mm to 250 mm) schedule 40 or SDR 21 gasketed PVC pipe. PE pipe can also be used. In general, a potential vacuum loss is associated with every lift. This limits the length of each vacuum line to about 2 to 3 miles (3 to 5 km) in flat terrain. Elevation changes can extend or reduce this range. Longer distances are possible depending on local topography.

Vacuum Station
The vacuum station is similar in function to a lift station in a gravity sewer system. Sewage pumps transfer the sewage from the collection tank through a force main to the treatment plant. Unlike a lift station, the vacuum station has two vacuum pumps that create vacuum in the sewer lines and an enclosed collection tank.

Vacuum Pumps
The vacuum pumps maintain the system vacuum in the 16" to 20" mercury vacuum (-0.5 to -0.7 bar) operating range. Vacuum pumps typically run 2 to 3 hours each per day (4 to 6 hours total) and don't need to run continuously since the vacuum interface valves are normally closed.

As sewage enters the system, driven by air at atmospheric pressure, the system vacuum will slowly decrease from 20" to 16" Hg. The vacuum pumps are sized to increase the system vacuum from 16" to 20" Hg in three minutes or less. Typical vacuum pump sizes are 10, 15, and 25 horsepower (7.5, 11 and 18.6 kw). Busch rotary vane vacuum pumps are standard. The two non-clog sewage pumps are each sized for peak flow.

The collection tank is steel or fiberglass and is sized according to flow, with typical sizes ranging from 1,000 to 4,000 gallons (3.8 to 15 cubic meters). The incoming vacuum lines connect individually to the collection tank, effectively dividing the system into zones. A stand-by generator keeps the vacuum sewer system in operation during extended power outages. An automatic telephone dialer alerts the operator to alarm conditions.

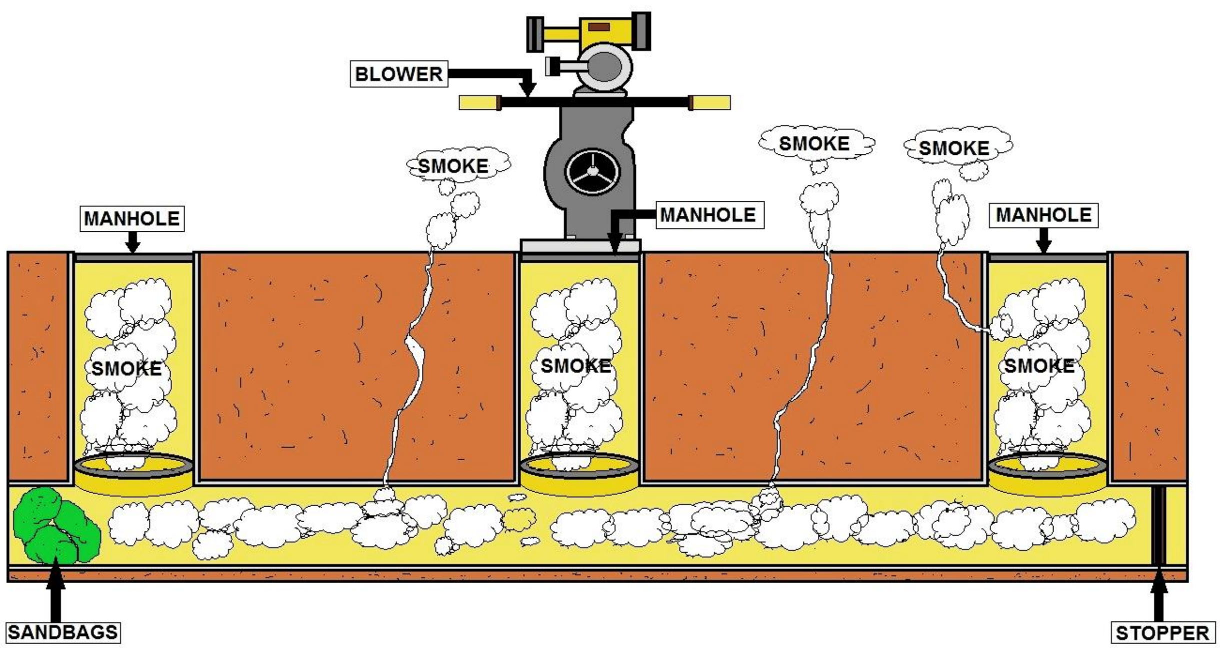
Review

Pressure Sewers
Instead of relying on gravity, pressure sewers utilize the force supplied by pumps, which deliver the wastewater to the system from each property. Since pressure sewers do not rely on gravity, the system's network of piping can be laid in very shallow trenches that follow the contour of the land.

There are two kinds of pressure sewer systems, based upon the type of pump used to provide the pressure. Systems that use a septic tank/effluent pump combination are referred to as STEP pressure sewers. Like the small diameter gravity system, STEP pressure sewers utilize septic tanks to settle out the solids; this allows for the use of piping that is extremely narrow in diameter. The effluent pump delivers the wastewater to the sewer pipes and provides the necessary pressure to move it through the system. The other type of pressure sewer uses a grinder pump.

Wastewater from each property goes to a tank containing a pump with grinder blades that shred the solids into tiny particles. Both solids and liquids are then pumped into the sewer system. Because the effluent contains a mixture of solids as well as liquids, the diameter of the pipes must be slightly larger. However, grinder pumps eliminate the need to periodically pump the septic tanks for all the properties connected to the system.

Both the STEP and grinder systems are installed with high water alarms. Because of the addition of the pumps, pressure sewers tend to require more operation and maintenance than small diameter gravity sewers. Operators can usually be hired on a part time basis, as long as someone is on call at all times. Operators will need training on both the plumbing and electrical aspects of the system.



SMOKE TEST IN SEWER MAIN

Wastewater Collection Highlights, **Memorize this section for the exam.**

A person shall not bypass untreated sewage from a sewage treatment plant.

A person shall not install or maintain a connection between any part of a sewage treatment facility and a potable water supply so that sewage or wastewater contaminates a potable or public water supply.

The definition of '*sewage*' is the untreated wastes from toilets, baths, sinks, lavatories, laundries, and other plumbing fixtures in places of human habitation, employment, or recreation.

The wastewater in a gravity collection system is conveyed by all of the following**:** An Interceptor sewer, Lift Stations, and Combined Sewer.

I & I Information: Exfiltration is a concern to wastewater collection operators because it may pollute ground water supplies. Exfiltration can be a source of pollution to the surrounding area. Smoke testing methods can detect the location of the exfiltration. Exfiltration can occur at joints and cracks and overflows at manholes which can expose the public to diseases.

If the collection system is inspecting lines for inflow problems, operators may find many sources of inflow from houses and buildings which increase flows during periods of wet weather. To eliminate these problems the collection system needs to have in place a sewer use ordinance.

The collection system operators have determined that a section of the sewer line is cracked. The direct problem that occurs is infiltration and exfiltration. Many times one problem can create another one. Root intrusion problems are often related to a cracked sewer line.

Flammable gas meters are calibrated to activate alarms when 10% or .10 of the lower explosion limit is reached.

In large-diameter sewer construction projects, the final inspection should include a *'walk through'* inspection to verify that all construction tools and debris have been removed from the line.

Lateral and main sewers should generally be buried approximately six (6) feet deep.

Lamping is a procedure to establish that a section of pipe is straight and open. A bright source of light and proper staffing of personnel for the operation must be present before lamping a section of pipe. Lamping is a very economical and quick method of determining if a new sewer line is straight and unobstructed. The best technique to use when lamping a sewer line is to hold the light steady in the center of the opening, check for an open and straight pipe, and rotate the light around the inside of the pipe to check for other problems.

Before excavating a section of sewer for replacement, upstream and downstream manholes should be inspected to determine the volume of flow.

Gunite is commonly used in repairing concrete sewer lines, brick sewers, and manholes. This material is used because of its high density and corrosion resistant qualities.

All the following items should be examined when inspecting manholes: Inside surfaces and joints for cracks or breaks, elevation of the lid, and listen for noises that indicate infiltration from cracked or broken pipes.

Manufacturers specify that a vitrified clay pipe is 2,200 pounds per foot; this expression means the pipe will support this load without cracking.

Operators may encounter problems in gaining access to sewer lines which are located in easements. The public should be informed of the agency's (collection system) right to perform inspection and maintenance activities. These rules can be found in local sewer-use ordinances.

Proper tools, equipment, and materials to do the job must be on the repair crew's truck before they drive to the job site. The following equipment is needed when installing a cleanout: Round point, square point and narrow cut shovels, couplings, bushings and plastic plugs, Drill hammer, cold chisel and wonder bar.

Records can become a problem when storage is needed to house volumes of paperwork.

An information management system must meet the needs of the collection system supervisor and the utility personnel. The most common of these requirements are: schedule preventative maintenance on pumps, equipment and vehicles; track and measure of workforce productivity and development of unit costs and measurement of resource allocation.

The most valuable tools for future planning of collection system needs are collection system records.

Microfilming printed records is used to consolidate records into a form that will use less storage than normal paper records fill and are also record of the past and a basis for future plans. Old school technology.

Area Maps are used at almost every system in the country. These maps of the system show the operator the entire collection system.

Smoke testing sewer lines can be helpful in finding cracks and lost manholes. This type of inspection can also find illegal connections to the sewer. Before smoking an area for locating leaks and improper connections, the supervisor should notify the public of the testing. Local Fire and Police should also be notified before smoke testing a sewer line. If the collection system crew is smoke testing a line, the operators should be told where to check for smoke coming from the buildings and grounds.

House vents are the only location from which smoke should be emerging. When smoke testing a line for illegal connections and other problems, a non-toxic, no residual effect type smoke bombs should be used.

The operator has smoke tested a section of line and found there is no smoke coming from a customer's vent pipe. Dye testing the lateral line is the most appropriate action to perform on the service line to confirm the sewer connection. The best way to apply sewer test dye when a plumbing fixture is used is to dissolve the dye in water, turn on the water, and pour into the flow.

If the collection system crew needs to dig or excavate a trench to remove a broken tap and main line, the first procedure is to notify or request all the buried utilities to be identified or call the One Call center.

The operator has repaired a break in an 8-inch sewer main. The trench is now ready for backfilling, but first the operator must bed the new section of pipe. Bedding the new section 6 to 12 inches above the top of the pipe is the proper method of bedding a sewer line for proper backfilling.

The purpose of the scouring velocity in a sewer line is to prevent the deposit and buildup of solids.

Rise over Run equals the Slope: The slope of gravity sewer line is critical to maintain flow and self-cleaning of the pipe. Gravity sewer lines should be designed to follow the slope of the land provided minimum slope is maintained. The elevation of the invert is typically represented on collection system maps. The invert is located on the inside bottom of the sewer pipe.

The Specific Gravity of a liquid refers to the relative weight of a liquid compared to the weight of water at 4°C.

A Rodenticide is a type of chemical which can be used to control rats.

A Rotameter is a device which measures the flow of gases or liquids through a tapered calibrated glass tube. Inside the tube, a ball or float rises as the flow of gas or liquid flows through the tube.

Compounds containing sulfur that have an extremely offensive skunk-like odor are called Mercaptans.

Concrete will not hold up in corrosive environments.

If the CCTV operator announces that the line has a "Right Offset", the operator then knows that the line has a misalignment problem.

Scenario The collection system CCTV has indicated that there are many protruding taps in a section of line. The protruding taps can be repaired by the following methods: Remove section of line containing the tap and install a factory made wye, or cut away the protruding tap with a mechanical cutting system.

There are many reasons for inspecting sewer lines with a closed circuit television (**CCTV**). All of the following are valid reasons: 1. Locate sources of inflow and infiltration. 2. Locate buried manholes, and 3. Locate illegal sewer taps such as industrial or storm drains.

Cleaning sewers with a high velocity cleaner should be done before performing a CCTV inspection.

A Polaroid or an instant camera is a typical piece of equipment found in the CCTV unit and provides operators with a picture record for log entries of conditions of trouble spots in the lines.

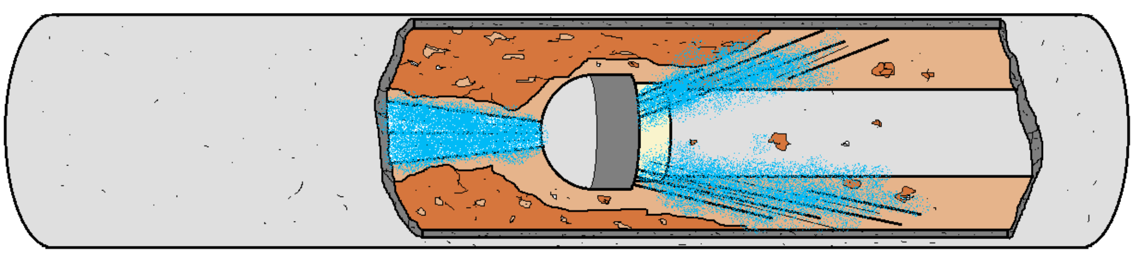
Two-way clean outs are often used on house laterals. These fittings are typically a Tee fitting with a Baffle inside to better accommodate sewer-cleaning equipment.

Pressure sewers or low-pressure or vacuum systems may be installed instead of gravity sewers in areas where the slope is not practical to maintain gravity. The grinder pump is a critical component found in the low-pressure collection system.

There are fewer stoppages and less infiltration and inflow with low-pressure collection systems and there can be major cost savings. Vacuum collection systems are being used as an alternative to a gravity system. A Lift station is not a component of a vacuum system.

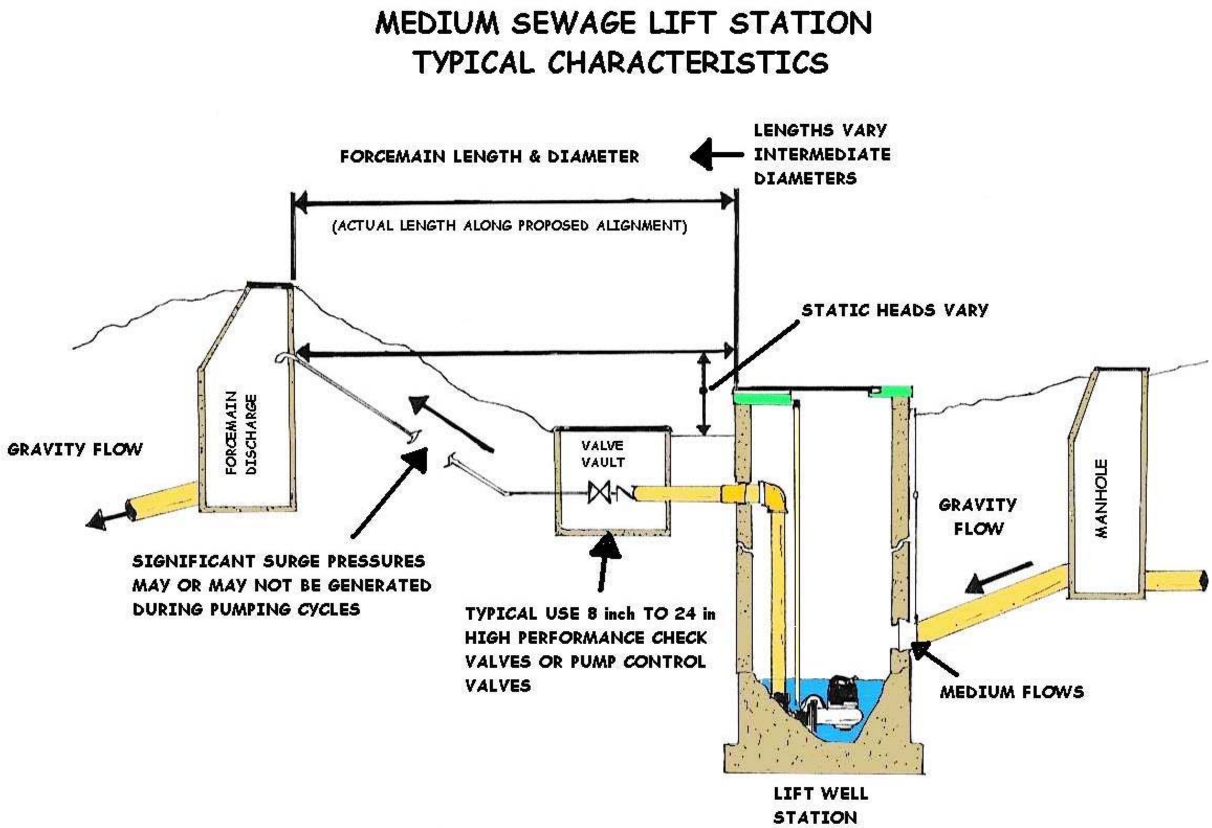
Wastewater flow in collection systems is expected to be lowest at 4 a.m.

Zinc and iron salts can be used to control hydrogen sulfide by precipitation.



PRESSURE WASHER SEWER JETTER

Pumps and Lift Stations



Lift Station: A facility in a sewer system consisting of a receiving chamber, pumping equipment, and associated drive and control devices which collect and lift wastewater to a higher elevation when the continuance of the sewer at reasonable slopes would involve excessive trench depths; or that collects and raises wastewater through the use of force mains from areas too low to drain into available sewers. There should not be an odor coming from a Lift Station.

Pumping Station: A relatively large sewage pumping installation designed not only to lift sewage to a higher elevation, but also to convey it through force mains to gravity flow points located relatively long distances from the pumping station.

Lift Stations – Wet Well/Dry Well

Sewer pipes are generally gravity driven. Wastewater flows slowly downhill until it reaches a certain low point. Then, pump or "lift" stations push the wastewater back uphill to a high point where gravity can once again take over the process.

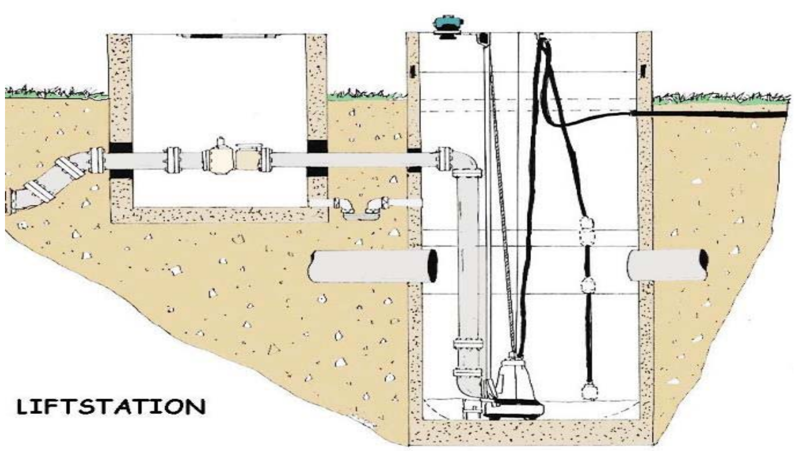
Lift stations are used in sanitary sewer systems where water is accumulated in wet wells and then pumped to a higher elevation. They are generally designed to operate continuously to keep sewerage from backing up through the system. That means that most lift stations have a backup electrical supply in the event that normal power is disrupted.

Most Wastewater Collection systems will have installed radio/WIFI telemetry, or SCADA systems. The telemetry system is used to monitor and control pump stations via computer at the WW Collections facility.

This type of system gives up to the minute pump station status such as wet well level, pump performance, electrical power conditions, etc. This allows wastewater technicians to prevent wastewater spills and protect public health. Using telemetry, Operators have the ability to identify potential problems instantaneously and take the proper steps to rectify the situation before it becomes a public health risk.

A Lift Station typically contains 4 main Components:

- A wet well - usually 15+ ft. in depth and 8ft. in diameter - that houses two submersible pumps (there are some stations with up to 5 submersibles) of varying horsepower, discharging piping and floats that operate the pumps and keep a set level in the well.
- A dry well that houses the piping and valves that prevent backflow in the station, and camlock connection used to bypass the submersibles in an emergency.
- An electrical panel houses control for the submersible pumps. It also houses the telemetry used to monitor and control the station remotely.
- A “Log Book” or “Station Book” which contains the records and maps of the Lift Station’s area.



Pumping and Lift Station Chapter Highlights *Memorize these for your exam.*

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 in 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. It 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.

A pump engineer will design a system that would use multiple pumps for a parallel operation in case of the following: to provide for a fluctuating demand, to provide an increased discharge head, and to reduce the friction coefficient on a larger pump for greater efficiency.

The intent of a designer when multiple water pumps are installed for paralleled operation 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 manufactures recommend using Mechanical Seals for 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 that has a capacitor start motor will also have a high starting torque and a high starting current.

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. A two-pole motor achieves this speed.

The winding insulation may deteriorate and is most likely the result of grease coming into contact with the windings for a motor.

An electric motor that has a frequency of 60Hz will have a maximum synchronous speed of 3600 rpms.

As the wear ring inside a centrifugal pump loses tolerance between the impeller and wear ring, 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.

Wound-rotor induction motor has 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 restrictions by fittings.

Continuous leakage from a mechanical seal indicates an abnormal condition.

A qualified operator is testing an electrical circuit for proper voltage. The incoming voltage is 220 VAC, single-phase power. The operator places one of the tester leads on LI and the other on the neutral wire. The expected voltage when testing these two wires should be 110 volts.

Electric motors burn out for many reasons, but 70% of motor failures can be controlled by the operator and proper maintenance. The following are causes of motor insulation failure: Overloading the motor, single phasing three--phase motors, and contamination of the windings area.

Molded-case circuit breakers typically require little maintenance. Inspect for evidence of overheating; manually tripping the circuit breaker periodically and checking connections for tightness are recommended maintenance on these circuit breakers.

Replacing the entire contact set when surface is badly pitted and eroded with badly feathered and lifting edges is the recommended practice for maintaining the stationary and movable contacts in a motor starter.

The greatest cause of failure in electric motors is thermal overload.

The operator is testing a coil from a control relay using an ohmmeter. The power to the coil must be off when using the ohmmeter to check out this type of component.

A circuit is tested with an Ohmmeter and is found to be defective. The most likely reading is Infinity.

Most failures at a lift station can be avoided by proper preventive maintenance.

The operator has just installed a repaired motor in a pumping station. The motor is started but it never comes up to speed. The following are possible reasons for the malfunction: incorrect power supply; motor is overloaded and/or incorrectly wired.

Enclosed electrode controls are sometimes used in lift stations to control pumps.

If an operator was to respond to an odor complaint at a lift station. The operator would go to the station and finds the source of the problem and corrects the situation. Notify the person who complained about the situation.

The pneumatic ejector at a small lift station is cycling too often. The flow into the tank is low but the ejector pumps frequently; a discharge valve stuck open may be the possible cause for this problem.

Check valves are installed on the discharge side of sump pumps in dry wells to prevent flooding of the dry well by backflow due to back siphoning.

Many pumps are outfitted with mechanical seals to prevent water from leaking out of the pump. The seal faces must be protected. Keeping fresh water on the faces of the seal is an important maintenance task to be performed by the operator to prevent damage to the seal faces.

Relief valves on the discharge side of pumps are used in order to prevent injuries or severe damage to piston pumps.

Submersible pumps are commonly used in lift stations. Preventive maintenance is important to ensure that motor windings are not burned. A Megger is used to determine if moisture is entering the motor through the pump.

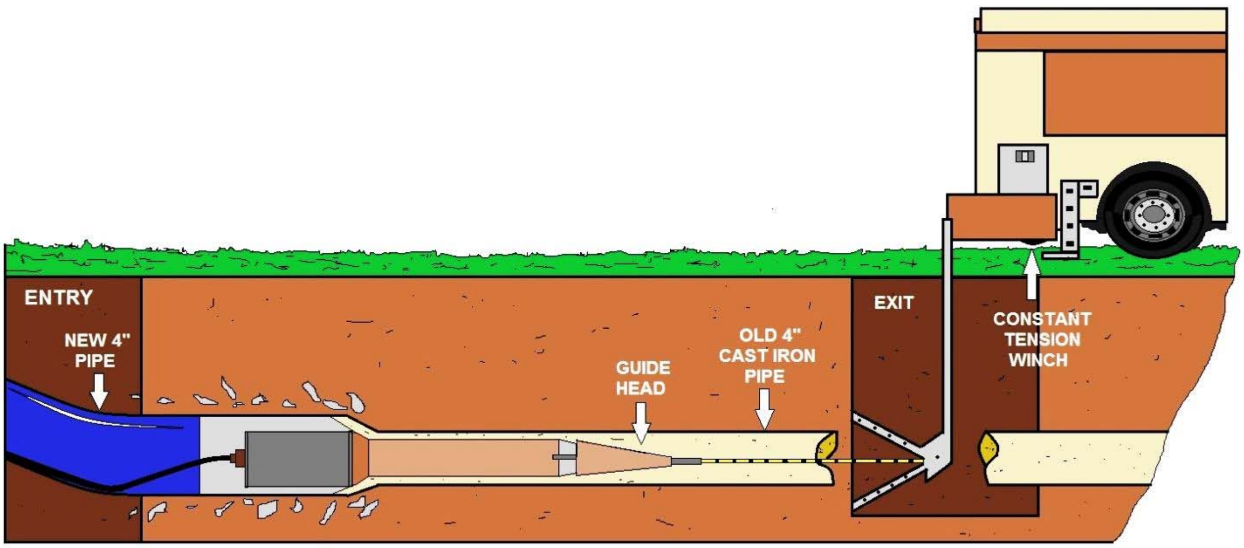
The following are considered standard practices when installing packing rings in a pump: Stagger the joints of rings to avoid having tow joints at the same position. Cut packing rings so they are all the correct length. Packing rings should be of materials recommended by the pump manufacturer.

When the operator changes the grease in the bearings of a motor, the operator should run the motor for 30 minutes and then install the drain plug.

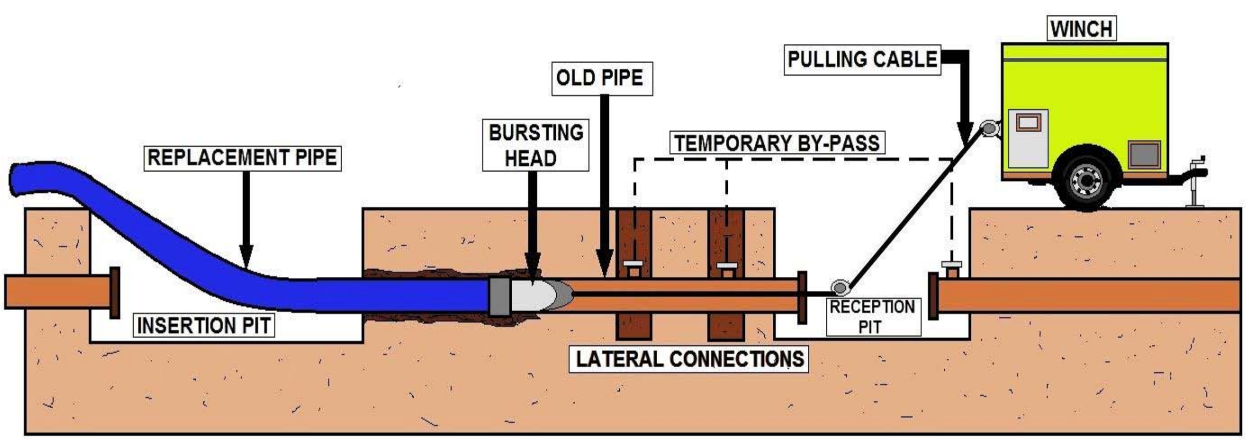
The operator has noticed the centrifugal pump is making noise and the efficiency of the pump is lowering. The pump is dismantled and the impeller has pits on all the vanes. This is usually caused by pump cavitation. Cavitation inside the pump is a possible cause of the pits.

The operator removes a submersible pump from a wet well. The pump is an oil-filed motor. The inspection plug is opened and a small amount of fluid is poured into a beaker. The fluid is an emulsion of oil and water. Mechanical seals that may be leaking could be the probable cause.

The term *Ambient Temperature* means the surrounding temperature.



TRENCHLESS SEWER REPAIR



TRENCHLESS PIPE REPLACEMENT

Grease Chapter 3

A grease interceptor used in a commercial food service operation.

Most stoppages in the sewer are caused by grease. It is best to have a strong Ordinance that prevents restaurants from dumping grease into the system; also a process of back charging the restaurants that do clog the sewers as payment for cleaning.

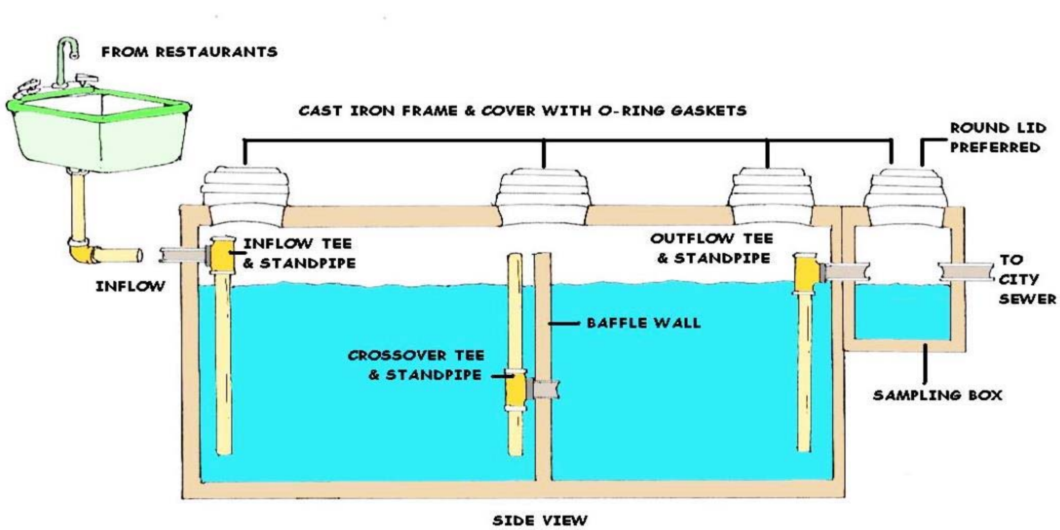
Grease

If left unmanaged, grease can cause interference in wastewater collection, transmission, and treatment systems. Blockages due to grease build-up are a common cause of sanitary sewer overflows, and grease accumulation at treatment facilities can lead to pass-through of contaminants.

Proactive municipal governments have a grease ordinance which provides them legal authority to require that grease generators have devices to catch the grease before it enters the public wastewater system. These devices are often referred to as "grease traps."

Grease build-up inside a sewer causing interference with flow.

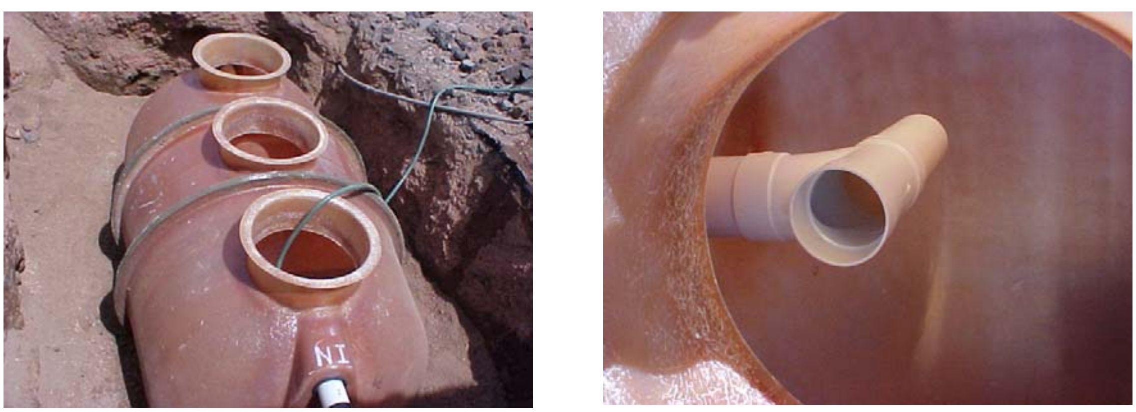
Proactive municipal governments also have in place an inspection and enforcement program to ensure grease generators clean the traps on an appropriate schedule and in a proper manner. Failure to do so incurs a penalty levied by the municipality, so there is incentive to correct problems before they result in sanitary sewer overflows, interference, or pass-through. Proactive municipalities often have public education programs to ensure non-commercial contributions of grease to the wastewater system are minimized.



Grease Trap
The trap prevents excess grease from getting into the sewer system from existing plumbing lines within facilities. Traps are small and are usually installed inside a facility. Generally, they range in size from 20 gallons per minute (**gpm**) to 50 gpm.

In-floor Grease trap being removed and replaced with a grease interceptor.

Grease Interceptors
High-volume or new establishments use grease interceptors which are larger than the traps and are installed underground, outside of a facility. Grease is actually "intercepted" in these concrete or Fiberglass tanks before it reaches the city sewer main. Grease interceptors should be accessible by three manhole covers, and a sample box. Interceptors and traps cause the flow of water to slow down, allowing the grease to naturally float to the top of the tank for easy removal.



New fiberglass three compartment grease interceptor. You will need to fill the interceptor with water before connecting it to the sewer main.

Other types of devices
A grease trap may be approved in lieu of an interceptor for full service food service facilities only in very limited circumstances when space is not available. Grease traps may also be approved by the Industrial Pretreatment Program for facilities such as delicatessens and small bakeries that produce small quantities of oil, grease, or fat. Refer to the International Plumbing Code for requirements related to grease traps, such as installation of flow-control devices, flow rates, and other structural requirements.

Please Note: flow restrictors are required for grease traps because they increase retention time and efficiency. Automatic grease skimming devices collect small volumes of water and remove grease into a side container at preset times each day. Usually, special approval from the Industrial Pretreatment Staff or the POTW is required to install one of these devices in lieu of a grease interceptor.

Magic Grease "Bugs" and Bacterial Additives
Manufacturers of bacterial additives claim that their products remove grease and enhance the performance of grease traps and interceptors. Such additives cannot be substituted for a grease removal device and regular inspection and maintenance. If you decide to use an additive, make sure the product you select is not an emulsifier, which simply keeps grease in suspension temporarily and allows it to flow to the sewer system.

Obtaining necessary permits
• Building departments prefer in-ground installations that drain by gravity to the sanitary sewer. Avoid pumps and other mechanical devices in your connection to the sewer if possible.
• Size your interceptor or grease trap in accordance with the International Plumbing Code, IAPMO, or local plumbing ordnance.

Chain Cutter
This tool is attached to the flush truck. When water pressure is applied, the 3 chains at the head spin at tremendous speeds. These spinning chains will cut roots, grease build-up, and even a protruding tap.

This is a sewer line that has a large amount of grease buildup that will be cut out. Grease gets into the sewer line by pouring grease, left over from cooking, down the kitchen sink.

Hydrogen Sulfide Gas

This Chapter provides answers to basic questions about hydrogen sulfide gas. It will explain what hydrogen sulfide gas is, where it is found, how it can affect your health, and what you can do to prevent or reduce exposure to it.

Hydrogen sulfide gas is also known as “sewer gas” because it is often produced by the decay of waste material. Hydrogen sulfide gas has a strong odor at low levels. At higher levels, your nose can become overwhelmed by the gas and you cannot smell it. At these higher levels, hydrogen sulfide gas can make you sick and even kill you.

Hydrogen Sulfide Gas
If you wait for a warning, it may be too late
*Hydrogen sulfide is a powerful and deadly gas which smells like rotten eggs at low concentrations and has a sweet smell at high concentrations. But workers should not rely on the smell as a warning. At high concentrations H_2S may overcome one's sense of smell. The result could be instant death. Long exposure to low concentrations will also deaden the sense of smell.

What it is
*H^2S is explosive - it will ignite and explode when subjected to a spark or an ordinary flame - in any concentration from 4% to 44% of the air. It is also soluble in water and oil, so it may flow for a considerable distance from its origin before escaping above ground or in an entirely unexpected place. Because the vapor (gas) is heavier than air, it may travel for a long way until ignited and then flash back towards the source. Hydrogen sulfide is found in large amounts in the wastewater collection system.

H_2S Sources
H_2S is easily found widely in our industry and a good manager will warn operators of its dangers or of their exposure. It is formed by the decomposition of organic materials, so it is found in sewers and cesspools.

Health Effects of H_2S Acute Exposure
Most importantly, H_2S will kill you. The extent of acute poisoning danger depends on the concentration of H_2S in the atmosphere. When you breathe in H_2S, it goes directly through your lungs and into your bloodstream. To protect itself, your body "oxidizes" (breaks down) the H_2S as rapidly as possible into a harmless compound. If you breathe in so much H_2S that your body can't oxidize all of it, the H_2S builds up in the blood and you become poisoned. The nervous centers in your brain which control breathing are paralyzed. Your lungs stop working and you asphyxiate--just as though someone had come up and put their hands around your neck and strangled you. A worker can be overcome by H_2S and lose consciousness in a few seconds. Luckily, if he is rescued in time and is given artificial respiration within a few minutes, the worker may recover. Either artificial mouth-to-mouth or an oxygen supply system of resuscitation will work if it is done in time, because, with an adequate source of oxygen and no further H_2S intake, the body will quickly break down the H_2S still in the blood.

This is acute poisoning. It can occur with no warning at all, since even the sense of smell may be overcome, and it can be fatal within a few seconds. Although acute poisoning is deadly if it is not caught in time, when caught and treated it is reversible; this is why rescue attempts with proper safety equipment are so important. Recent evidence has shown irreversible brain damage from acute high doses.

Chronic Effects

H_2S can also cause a wide range of sub-acute and chronic effects. At very low concentrations of 10-100 ppm. headache, dizziness, nausea and vomiting may develop, together with irritation of the eyes and respiratory tract (the lungs and trachea and bronchi, or air pipes from the nose and mouth to the lungs). The eyes become red, sore, inflamed, and sensitive to light. Respiratory system effects include cough, pain in the nose and throat, and painful breathing.

Chronic Poisoning

If exposure at low levels continues, the worker may develop a state of chronic poisoning. In addition to eye and respiratory tract irritation, there will be a slowed pulse rate, fatigue, insomnia, digestive disturbances, and cold sweats. More dangerous, if exposure at the level of 100 ppm (which results in eye and respiratory tract irritation and drowsiness after 15 minutes) lasts for several hours, it may result in death within the next 48 hours. Symptoms of chronic exposures at low levels are conjunctivitis (eye infections), headache, attack of dizziness, diarrhea, and loss of weight.

Chronic hydrogen sulfide intoxication is marked by headaches, eye disorders, chronic bronchitis, and a grey-green line on the gums. Reports of nervous system disorders including paralysis, meningitis, and neurological problems have been reported, but not confirmed.

A study of workers and community residents of a California Wastewater Treatment facility forum complained of headaches, nausea, vomiting, depression, personality changes, nosebleeds and breathing difficulties. When compared to a non-exposed group of people, the exposed people showed abnormalities of color discrimination, hand-eye coordination, balance, and mood disturbances. In rats, exposure to hydrogen sulfide has caused teratogenic effects.

How Much is Safe?

*The OSHA Permissible Exposure Limit (PEL) for a ceiling concentration is 20 ppm hydrogen sulfide, a level which may not ever be exceeded. The acceptable maximum peak, for 10 minutes only, once during an 8 hour day if there is no other measurable exposure, is 50 ppm. There is no time-weighted average because H_2S is so fast-acting that no fluctuations above 20 ppm are safe; only one peak per day is allowed.

This level is too high and recent recommendations are that it be lowered to 10 ppm. You should remember, however, that H_2S is an invisible gas, floating freely and unpredictably, and a reading even below a 10 ppm Permissible Exposure Limit (PEL) may not guarantee your safety. There are no particular medical exams for exposure to H_2S.

- **If you work with H_2S make sure that...**
  Your employer has trained you in the hazards of H_2S.
  Your employer has appropriate rescue equipment onsite.

Hydrogen Sulfide Highlights, memorize this section for the exam.

Hydrogen sulfide or H_2S problems are very common in the collection and wastewater system. There are many chemicals used to help or treat this problem. Salts of zinc, lime, hydrogen peroxide, chlorine and magnesium hydroxide are used in the treatment of hydrogen sulfide problems.

Hydrogen sulfide production in collection systems can cause a number of problems, including the following: Corrosion of the pipes and manholes, creation of hazardous atmospheres and foul odors.

The best method of controlling hydrogen sulfide is to eliminate its habitat or growth area by keeping sewers cleaner, this will harbor fewer slime bacteria.

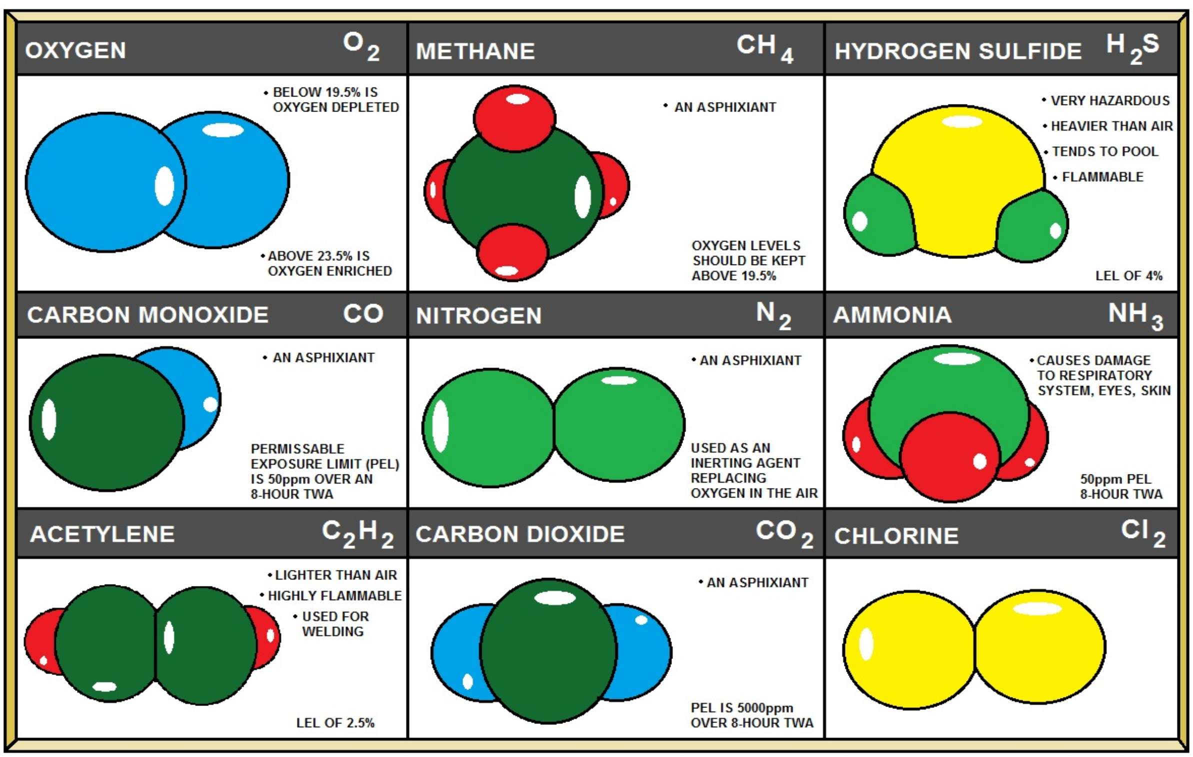
Statements regarding the reduction of hydrogen sulfide: Salts of zinc and iron may precipitate sulfides, lime treatments can also kill bacteria that produces hydrogen sulfide, but this creates a sludge disposal problem. Chlorination is effective at reducing the bacteria which produce hydrogen sulfide.

Hydrogen sulfide conditions occur in the sewer system because of the lack of oxygen.

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

The effects of Sulfuric acid (H_2SO_4) created by Hydrogen Sulfide gas (H_2S) and water.



COMMON GASES THAT CAN BE FOUND IN CONFINED SPACE

Wastewater Collection Quiz #1

1. Your collection system requires a new sewer main line. Who would be the best source of information for instructions on how to lay and join new sewer pipes?

2. In many sewer installations low pressure air testing is necessary to determine the tightness of the pipe. In instances where ground water levels are higher that the sewer lines the new pipes are usually tested around_______ to _______ psi above any outside water pressure on the pipe.

3. A good manager will establish a good record keeping system to help in analyzing many problems that occur. Records such as outside services versus in-house personnel costs could result in saving money by hiring personnel to handle jobs typically farmed out. For the purposes of budgeting and justifying the costs the manager will:

4. Managers and supervisors maintain a personnel file on each employee. These files contain information about the employee. What information should be found in the employee file?

5. Sewer lines made of __________ types of pipe should be tested with a mandrel to measure for ___________ and joint offsets.

6. What is the one most important reason for having a wastewater collection system?

7. Many public agencies are having a difficult time stretching their financial resources to meet all the demands they face from both internal and external sources. What is the best thing a collection system operator can do to help in meeting these challenges?

8. An operator should have a good understanding of the terms used in wastewater collection systems. What description best explains the term "*combined wastewater"*?

9. A term used often in a collection system is the term "*grade ring*". What best describes a grade ring as used in the collection system?

10. Two words are used to describe a collection system; they are the words '*sanitary*' and '*wastewater*'. What is the correct definition of the term *'sanitary collection system'*?

11. Ideally wastewater collection systems are designed and constructed to provide a minimum velocity of _____ ft per second to ensure the waste in maintained in suspension.

12. A ball is traveling down a 12 inch sewer line and you see it at your manhole at 1:52:00 p.m.. Your partner, at the next manhole 350 feet away, said the ball went past her at 1:55:02 p.m. The estimated surface velocity in the sewer is:

13. Which types of pipe materials would be suitable for use in a wastewater collection system?

14. Channel corrections are usually required for___________ and _____________ in older manholes to reduce the causes of turbulent flows and restrictions to flow in the incoming lines.

15. The co-efficient value used to represent the channel or pipe roughness in Manning's formula for computing flows in gravity sewers is called the:

The type of waste that can generally be consumed by bacteria and other small organisms is called:

What is the name given to a chamber, connected to the flow in the main channel by a small inlet, where the liquid level is measured to determine the flow in the main channel?

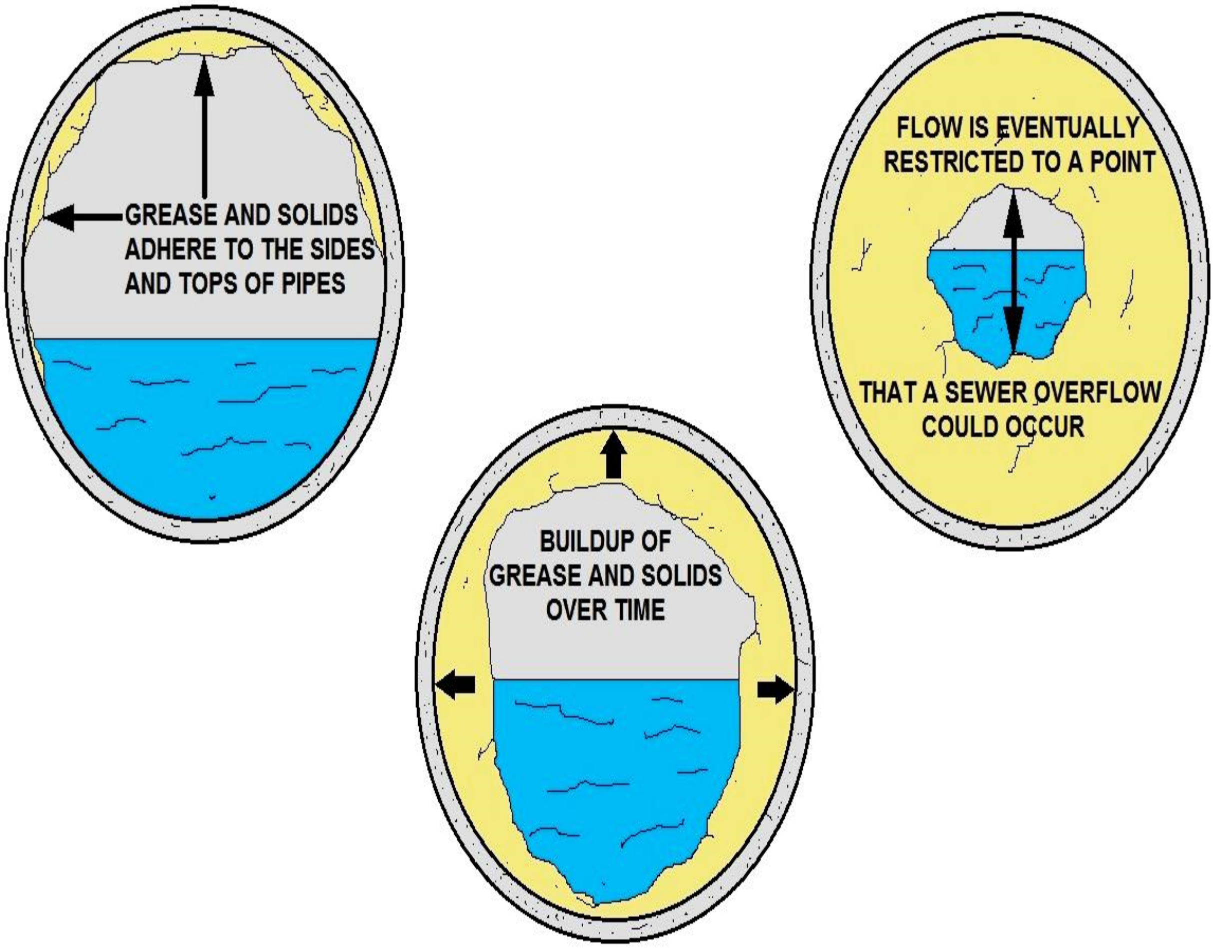
The primary purpose of lubrication in the maintenance of equipment is to reduce the _________ and _________ between two surfaces.

One important point to remember when using a portable centrifugal trash pump is to:

20. The two terms that are frequently used to describe the incoming and outgoing conductors of circuit breakers, motor starters and other devices are called?

Answers to Quiz#1

1. Manufacturer.
2. 3, 5
3. Plot the costs to ease understanding the need for personnel.
4. Accident reports, Attendance analysis and Performance evaluations.
5. Flexible, deflection.
6. Prevent disease.
7. Provide good collection system maintenance, operation and inspection.
8. A mixture of surface runoff and industrial wastewater and a mix of domestic wastewater and storm water.
9. A precast concrete ring of various heights to raise the manhole cover.
10. A collection system used only for domestic waste.
11. 2
12. 1.9 ft/sec.
13. Asbestos cement pipe, Clay, Ductile Iron, Polyethylene and CPVC. Not uncoated black iron pipe.
14. Tee intersections, basin channels.
15. "R" factor and "N" factor.
16. Inorganic waste.
17. Stilling well.
18. Friction, heat.
19. Always locate the pump as close as possible to the water surface being pumped.
20. Line side, load side



EFFECTS OF GREASE AND SOLIDS ON SEWER FLOW

Collection System Operator Review Exam # 2

1. Why are hydraulic shores usually not used on jobs exceeding five (5) days in length?

2. What does the term "relative compaction" refer to?

3. 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?

4. When backfilling around a flexible pipe, what could happen if the load above the pipe is too great?

5. 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?

6. What fluid is recommended for use in hydraulic shoring equipment?

7. What is the proper method for bedding a sewer line?

8. If a trench is more than five feet deep where must the spoil be placed?

9. What is the maximum distance between horizontal cross braces for each zone in a trench?

10. What is the minimum compaction height of backfill when laying piping in Class A or Class B bedding?

11. Why should upstream and downstream manholes be inspected prior to excavating a section of sewer for replacement?

12. Which type of pipe is recommended when crossing another underground utility?

13. What could possibly happen when groundwater is removed from a construction site or trench?

14. What do you call a confined space that has 18% oxygen?

15. Below what maximum percentage is an atmosphere considered oxygen deficient?

16. When should atmospheric monitoring in a confined space be performed?

17. What does entry into a confined space require?

18. Even brief exposure to 1,000 ppm of Cl2 gas can be fatal.
A. TRUE
B. FALSE

19. 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

20. 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.
A. TRUE
B. FALSE

21. 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.
A. TRUE
B. FALSE

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

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

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

25. What term represents the temperature at which oil vaporizes enough to keep burning?

26. Which is not listed as a form of hazardous energy under OSHA 29 CFR 1910.147?

27. What is olfactory fatigue?

28. What is the recommended type of fuse to use in the circuit leading to the electric motor?

29. What are major reasons for motor failure?

30. What type of lubrication do most mechanical seals require?

31. How are elevations typically represented on a collection system map?

32. What does the term "*scouring velocity*" refer to?

33. What is the purpose of lamping a new collection system?

34. When smoke testing a line, what types of smoke bombs should be used?

35. Describe a close-coupled pump.

36. During a CCTV inspection of a sewer line, roots intruding a joint are observed. What does it mean if the audio states there are "roots at joint / 5"?

37. What can and cannot result from the blockage of a sewer system?

38. What should be considered if a collection system area is very large and travel time is excessive?

39. What procedure is recommended for maintaining the stationary and movable contacts in a motor starter?

40. What is the greatest cause of failure in an electric motor?

41. What should be observed before filling a water truck to clean sewers?

42. What is ambient temperature?

43. Identify statements concerning pipe repair.

44. What is the appropriate procedure used to repair a sewer line damaged by root intrusion?

45. What should a collection system crew member do before performing system maintenance in driveways, easements and front yards?

46. What should be done prior to resetting a tripped circuit breaker?

47. Identify one disadvantage of using mechanical seals in a centrifugal pump.

48. How can most failures of a lift station be avoided?

49. When would the use of dyes be most appropriate for sewer inspection?

50. When a lift station pump discharges into the force main a positive pressure develops in the force main. Which piece of equipment is used to prevent the discharged wastewater from flowing back into the wet well when the pump shuts off?

51. What is an acceptable method to prevent a cross-connection when filling a water tank truck or Vactor from a fire hydrant?

52. Which conditions might cause a positive displacement diaphragm pump to cycle improperly?

53. Besides the location of the tap, what else should be included on a service line location card?

54. What is meant by the invert of a pipe?

55. Acrylonitrile butadiene styrene (ABS) pipe will be softened and eroded by which type of product?

56. Which pieces of lift station equipment would be expected to be found in a dry well?

57. Which piece of equipment is used to aid in testing for insulation resistance in a submersible pump motor?

58. What is the definition of anaerobic?

59. Identify statements regarding the reduction of hydrogen sulfide.

60. Identify components of a gravity collection system.

61. Why is exfiltration of concern to wastewater collection operators?

62. What two important factors need to be considered for the protection of an operator of a collection system?

63. What is one of the problems associated with using a packer to seal a large diameter sewer line?

64. What should be done after joining a length of pipe?

65. What are normal conditions for a gas chlorination start-up for a 150 pound cylinder?

66. What are the physical and chemical properties of chlorine? And the Atomic Number?

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

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

69. How many turns should a 150 pound chlorine gas cylinder be initially opened?

70. 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. Name them.

71. Name several symptoms of chlorine gas exposure.

72. What is the first step to ensure adequate hearing protection for employees?

73. Why would it be advantageous to rod a sewer line from an upstream position?

74. When would a pressure sewer be preferred to a gravity sewer?

75. What is the main purpose for using an instant camera while televising a line?

76. What type of equipment can be used to remove sand and grit debris in a sewer collection line that is 24" in diameter or less?

77. Which equipment or process would be the best suited for cutting roots, removing hardened grease and for scraping and dislodging certain types of materials found in sewers?

78. What would be the appropriate course of action if very low flows were observed at a downstream manhole during a flushing operation?

79. What chemical can be used to remove sulfides by precipitation?

80. What is a problem with using an odor masking agent?

81. What type of pipe materials would not hold up in corrosive environments?

82. What is a true statement concerning the selection of chemicals for the removal of grease and detergents?

83. What could be expected in a sewer line that enters a larger sewer line below the water level?

84. What is a piezometer?

85. What information does a *station book* contain?

86. What method of controlling hydrogen sulfide by chemical treatment is considered the least expensive?

87. If the voltage of the circuit to be tested is unknown, what should the meter be set on?

88. What is one of the cleaning methods for a CCTV lens which becomes greasy and the unit is far from a manhole?

89. What is true concerning the discharge of water from a piston pump?

90. What should be done when testing a control circuit with a Megger?

91. What item does not need to be examined when inspecting a manhole?

92. Which valve would be the best choice to replace a suction side pump valve that is continually clogging?

93. If a manhole has been covered due to construction, landscaping, or other activities, what action should be taken?

94. What is considered a standard practice when installing packing rings in a pump?

95. Which device is used in order to prevent injuries or severe damage to piston pumps?

96. When using a hydraulic pressure cleaner, what should always be placed in the downstream manhole?

97. Where should the drop line be placed inside a manhole?

98. What precaution should be taken when applying treatment to control hydrogen sulfide production and anaerobic bacteria? Think about the Treatment Plant.

99. Describe the proper adjustment of the packing gland in a centrifugal pump.

100. What component might be tested using an Ohmmeter?

101. What is used to compare the actual pump efficiency to its expected efficiency?

102. What is the overload protection rating on magnetic motor starters?

103. Which condition would prevent smoke from exiting from a connected sewer?

104. An electrical circuit is being tested for proper voltage. The incoming voltage is 220 VAC, single phase power. The operator places one of the tester leads on L1 and the other on the neural wire. What is the expected voltage when testing these two wires?

105. What is the most likely Ohmmeter reading of a circuit found to be defective?

106. How far are offset stakes set from the actual sewer line?

107. Approximately what concentration of hydrogen peroxide should be used to control hydrogen sulfide?

108. How much overload is a heater element on a motor starter usually rated at to drop the circuit?

109. What is a hydro-brake?

Hints, study areas that you may not use in your system. Define Lamping, Control Points, Kites, Balling, and Smoke procedures.

Example, what type of smoke bomb should you use?

Who should you notify before smoking a section of pipe? What will smoke testing discover?

Math Section **Conversions can be found in the rear of this section.**

110. 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?
Please write out your answers and show your work

111. 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?

112. 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. Also figure in CFM.

113. Approximately how many feet of drop are in 455 feet of 8-inch sewer with a 0.0475 ft/ft. slope?

114. 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?

115. 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?

116. A float arrives in a manhole 550 feet down stream three minutes and thirty seconds from its release point. What is the velocity in ft/sec.?

117. A new sewer line plan calls out a 0.6% slope of the line. An elevation reading of 108.8 feet at the manhole discharge and an elevation of 106.2 feet at a distance of 200 feet from the manhole are recorded. What is the existing slope of the line that has been installed?

118. A triangular pile of spoil is 12 feet high and 12 feet wide at the base. The pile is 60' long. If the dump truck hauls 9 cubic yards of dirt, how many truck loads will it take to remove all of the spoil?

119. A red dye is poured into an upstream manhole connected to a 12 inch sewer. The dye first appears in a manhole 400 feet downstream 3 minutes later. After 3 minutes and 40 seconds the dye disappears. Estimate the flow velocity in feet per second.

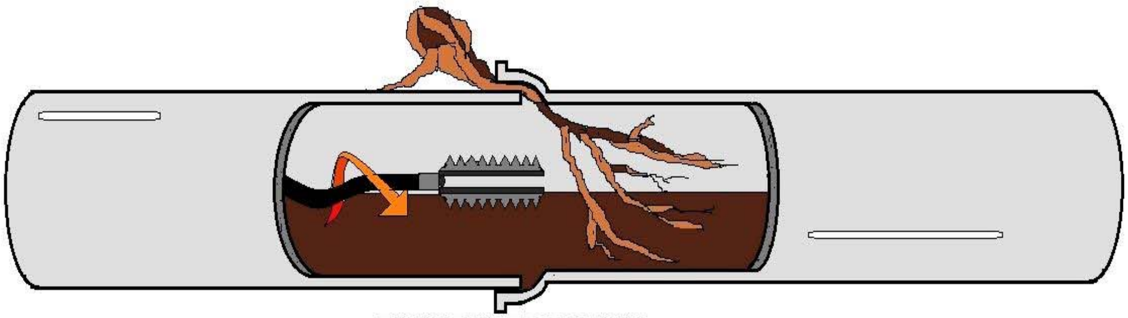
120. Calculate the total dosage in pounds of a chemical. Assume the sewer is completely filled with the concentration. Pipe diameter: 18 inches, Pipe length: 420 feet, Dose: 120 mg/L.

Answers to Quiz# 2

1. There is a possibility of the hydraulic pressure bleeding off during this length of time.
2. The level of compaction obtained compared to the level possible under ideal conditions.
3. At the top of the trench and within two feet of the bottom.
4. The pipe could deflect and collapse.
5. Narrow as possible for safety and to increase pipe sidewall support.
6. Hydraulic shoring fluid.
7. Bed the new section 6 to 12 inches above the top of the pipe.
8. At least 2 feet from the trench and only on one side of the trench.
9. 4 feet apart.
10. 12 inches.
11. To determine the volume of flow.
12. Ductile iron pipe (DIP)
13. Subsidence of ground and/or adjacent structures.
14. Oxygen deficient.
15. 19.5%.
16. Continuously from pre-entry to exit.
17. A confined space entry permit.
18. True.
19. True.
20. True.
21. True.
22. Gold, Platinum, and Tantalum.
23. Use a new, approved gasket on the connector.
24. Gas chlorine.
25. Fire point.
26. Magnetic energy in a motor coil.
27. Loss of smell.
28. Time-delay fuse.
29. Overloading the motor, Voltage imbalance, Short-cycling but not air-locking the motor.
30. Tap water.
31. The elevation of the invert.
32. The flow required to prevent the deposition and buildup of solids.
33. Test for obstructions and straightness.
34. Non-toxic smoke bombs.
35. No coupling between the motor and pump.
36. Severity code of the root system.
37. Increased annual flows.
38. Place Satellite yards in the system.
39. Replace entire contact set when surface is badly pitted and eroded.
40. Thermal overload.
41. There should be an air gap between the discharge line and the top of the water level to prevent a cross connection.
42. The surrounding temperature.
43. Replacement sections of pipe can be joined with band couplings. Pipe can be heavy and awkward at times. Replacement pipe sections may be of different materials.
44. Kill and remove roots, seal with a root inhibiting grout.
45. Inform the property owner of any inconvenience.

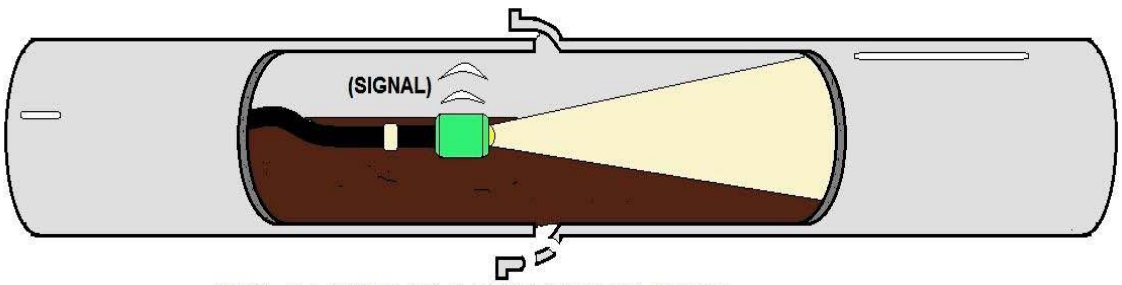
46. Inspect the electrical equipment for problems
47. Pump must be dismantled to repair.
48. Implementing proper preventive maintenance.
49. When smoke testing information is incomplete.
50. Swing check valve.
51. Utilizing an Air gap installation.
52. Plugged exhaust port.
53. Pipe size, type and cleanout location.
54. Inner bottom of the pipe.
55. Petroleum products.
56. Electric controls, Motors and Pumps. You would not find Float switches.
57. Megger.
58. Absence of dissolved molecular oxygen.
59. Salts of zinc and iron may precipitate sulfides. Lime treatments can kill bacteria which produce hydrogen sulfide, but create a sludge disposal problem. Chlorination is effective at reducing the bacteria which produce hydrogen sulfide. Chemical treatment is not the preferred treatment method for reducing hydrogen sulfide.
60. Main sewers, Manholes, Lateral sewers and Lift stations. Vacuum interface pumps are not part of a gravity system but are part of a low-pressure system.
61. It may pollute regional groundwater.
62. Personal hygiene and protective equipment for the head, hands and body.
63. Excessive pressure may damage the line.
64. Check the alignment and grade of the pipe.
65. Open chlorine metering orifice slightly. Inspect vacuum lines. Start injector water supply. Chlorine gas valve open at the chlorinator is not a normal condition for start-up.
66. 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.
67. Chlorine gas forms a mixture of hydrochloric and hypochlorous acids.
68. Because it is too easy to roll.
69. 1/4 turn to unseat the valve, then open one complete turn.
70. 1) Get out of the area of the leak, proceeding upwind, and 2) take only very short breaths through the mouth.
71. 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.
72. Ensure that engineered controls are used on equipment whenever possible and provide hearing protection.
73. If a high head of water developed at the stoppage.
74. If the slope is inadequate to maintain flow in a gravity sewer.
75. Provides operators with a picture record, for log entries, of conditions of trouble spots in the lines.
76. High velocity cleaning truck or a trailer mounted hydro jet. Bucket machines and scrapers used with other hydraulic cleaning devices.
77. Rodding the line.
78. Discontinue filling the manhole and make arrangements for extensive cleaning.

79. You can use the following: Ferrous sulfate ($FeSO_4$), Ferrous chloride ($FeCl_2$) and Ferric chloride ($FeCl_3$).
80. They do not eliminate the source of the odor problem.
81. Concrete.
82. Chemicals may be very effective under specific conditions, but may not work in all conditions.
83. An air seal will form causing odor problems.
84. An instrument used to measure the pressure head in a pipe, tank, or soil.
85. ID numbers and maps of the station.
86. Aeration.
87. Highest range for voltage and work down.
88. Pull the camera back into the puddle to rinse the lens.
89. The discharge valve should always remain open.
90. First, turn off circuit breaker.
91. Inadequate sewer use ordinances.
92. Plug valve
93. Bring the entry up to grade.
94. Stagger the joints of rings to avoid having tow joints at the same position. Cut packing rings so they are all the correct length. Packing rings should be of materials recommended by the pump manufacturer. Install 2 rings on the inside of the lantern ring and 2 rings on the outside, or an equal number on each side of the lantern ring.
95. Relief valve on discharge side of pump.
96. Debris or sand traps.
97. As close to the flow line as possible.
98. Excessive chlorine can kill the aerobic organisms in the secondary treatment plant.
99. Tighten gland until there is a flow of 20 to 60 drops of water per minute.
100. A Coil or relay.
101. A Pump curve.
102. A ten percent overload.
103. A trap in the line. A grade defect in the service line. A faulty plumbing O-ring would not prevent smoke from exiting.
104. 110 volts.
105. Infinity.
106. 5 ft. - 10 ft.
107. 0.4.
108. 0.1.
109. A vortex flow regulator.
110. 45,000 persons.
111. 50 pounds.
112. 44 CFM.
113. 21.6 ft.
114. 10.8 BHP.
115. 18 feet.
116. 2.6 ft/min.
117. 1.3% slope.
118. 18 truckloads.
119. 2.0 ft/sec.
120. 5.55 lbs.



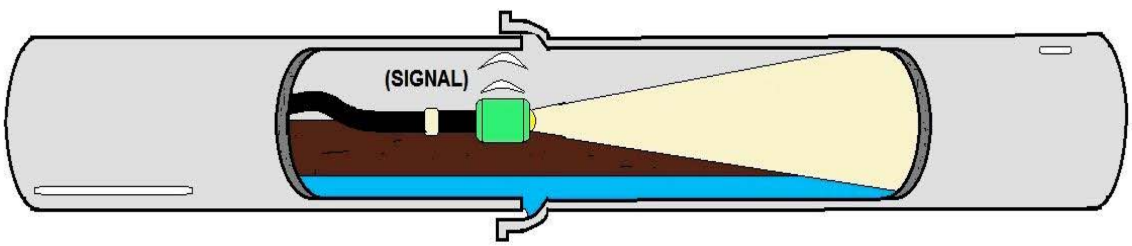
ROOT INTRUSION

(CLEANED WITH A CABLE FITTED WITH A ROOT-CUTTING BLADE)



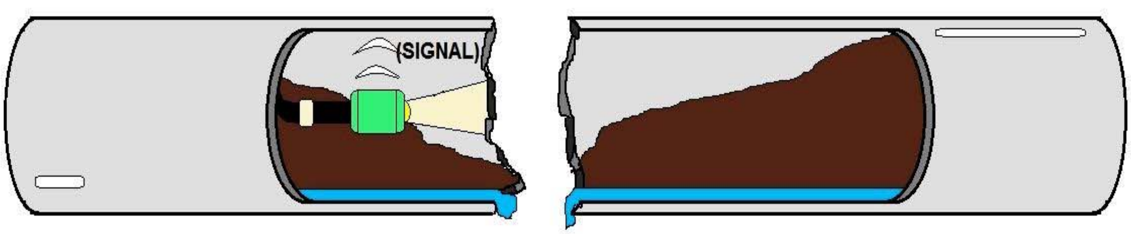
MIS-ALIGNED / CRACKED PIPE

(A CAMERA IS USED TO SHOW THE LOCATION OF THE PROBLEM VIA A SIGNAL)



PIPE WITH A BELLY

(A CAMERA IS USED TO SHOW THE LOCATION OF THE PROBLEM VIA A SIGNAL)



PIPE THAT HAS BEEN CRUSHED

(A CAMERA IS USED TO SHOW THE LOCATION OF THE PROBLEM VIA A SIGNAL)

PROBLEMS IN SEWER PIPING

Practice Exam #3 **No answers given. Look in Glossary for Answers.**

1. Vacuum collection systems are also being used as an alternative to a gravity system. What are some of the components of a vacuum system?

2. Which unit is used to prevent the passage of gases and odors from the main sewer system into the building's wastewater plumbing system?

3. When working in tight quarters where vertical lifts are required, which type of buckets are installed on cranes for excavation?

4. Batter boards can be used to control the laying of sewer pipe after the trench has been excavated. The only problem using this procedure would be:

5. Vertical lateral sewer cleanouts at the terminals of lateral branch sewers are constructed with a long radius 1/4 bend of the same diameter and preferably of the same material and jointing as the sewer pipe. When using a "combo" fitting what does the combination consist of?

6. A manhole that is located reasonably close to the discharge of a hospital, venereal disease treatment center, clinical laboratory, surgical facility or a veterinarian's office needs work done inside. It may be advisable to first:

7. Proper tools, equipment and materials to do the job must be on the repair crew's truck before they drive to the job site. What is required when installing a clean-out?

8. Manholes are sometimes buried or paved over when streets are repaved. Usually this problem is discovered by a preventive maintenance crew. What type of locators can be used to find the manhole?

9. Once the location of a manhole is established and preparations for the raising of the manhole are made, where is the casting placed?

10. Motors and pumps are used in lift stations. What device allows low-power electrical signals to operate the ON/OFF switch for high power equipment?

11. Pump curves list several items on the axis lines such as capacity, TDH and RPM. The Net Positive Suction Head is expressed in what measuring unit?

12. Sump pumps are installed in case the dry well becomes flooded. Sometimes the check valve fails due to debris. What should the operator install to protect the sump pump?

13. Single-phase conditions causes unbalanced currents to circulate in the rotor causing increases in internal motor heating. What should the operator consider to correct this problem?

14. If a motor is operated in a clean, dry environment and within its specified nameplate load and operating characteristics, there is no reason why the motor should not operate for years without major maintenance. What would happen if dust contaminates the motor?

15. A piece of pipe is 23 feet long and is to be cut into 4 equal pieces. Each piece will be ________ feet _________inches long?

16. What was the average daily flow for a lift station given the following flow totalizer readings?
8:00 a.m. Monday, August 11 113,428,731 gallons
8:00 a.m. Monday, August 18 121,987,566 gallons

17. How many feet of drop are in 400 feet of 8-inch sewer with a 0.045ft/ft slope?

18. Estimate the velocity of wastewater flowing in a 12-inch sewer. A red dye is poured into an upstream manhole. Three minutes later, the dye first appears in a manhole 400 ft downstream. The dye disappears 3 minutes and 40 seconds after the dye is poured into the upstream manhole.

19. The operator wants to repair a broken line using a sloped wall trench to avoid shoring. The walls need to be 3/4 horizontal to 1 vertical. If the trench is to be 12 feet deep and 2 feet wide at the bottom, how wide should the trench be at the top (ground level)?

20. A sewer has failed and 155 feet of 8-inch pipe must be replaced. How many 5-foot sections of pipe will be required?

21. Determine the force against each plug if a pipe is 18 inches in diameter and the test pressure is 5 psi. SAC-V1 Sec. A.12 Sec F#19

22. A 24-inch sewer carries an average daily flow of 5 MGD. If the average daily flow per person from the area served is 100 GPCD (gallons per capita or person per day), how many people discharge into the wastewater collection system?

23. When laying piping in Class A or Class B bedding, the backfill should be compacted to a minimum height of:

24. The construction crew is laying new sewer pipe with the help of a fixed beam laser to set grade and line. Once the laser is set into the manhole or end of the pipe, the operator should check the beam for:

25. The collection system crew has completed laying the new extension of the sewer main. What should be placed at the end of the newly constructed sewer line?

26. Overload protection devices on magnetic starters should generally be rated at:

27. Which of the following could possibly happen when groundwater is removed from a construction site or trench?

28. Pipe composed of Acrylonitrile Butadiene Styrene (ABS) is very resistant to most conditions found in collection systems. However, ABS pipe will be softened and eroded by:

29. Construction of a sewer line with concrete pipe will commonly include joining the pipes with:

30. When selecting a lubricant for the machinery the operator must know about the qualities of the oil being used. The *"Pour Point"* of the oil is the temperature at which the oil:

31. A megger or insulation tester is used to check the insulation value of motor windings and feeder lines. When testing a control circuit with a megger the operator should:

32. The operator takes voltage readings on a three-phase motor in a lift station. The operator finds that there is an imbalance or unbalance in the electric system. What is the result of having an imbalance to the motor?

33. A good oil lubricant has the correct viscosity for a specific piece of equipment. Oil can vaporize enough to ignite when near a flame. Which term represents the temperature at which oil vaporizes enough to keep burning?

34. Motors fail for many reasons. What are causes for a three phase motor failure?

35. Total static head refers to:

36. Continuation of the air flow is important; stoppage could cause odorous and toxic release of hydrogen sulfide. Name the appurtenance that prevents this?

37. Which of the following defines the word "hydrophilic"?

38. The most common cause of odors associated with collection systems is the production of hydrogen sulfide. When a smaller sewer line joins a larger sewer line this will cause?

39. When a CCTV lens become greasy, if debris accumulates, blurring or blocking the image, and the unit is far from either manhole, one clearing procedure might be:

40. Smoke testing a sewer requires the plugging of lines to contain the smoke. However, high flow conditions may prevent plugging a line. Under these conditions the operator can use the smoke test if he:

41. The best method of detecting a cracked pipe or joint in a sewer line is:

42. The operator is inspecting manholes on a routine inspection. The operator notices the lid and cover have been compressed by the traffic that drives over the manhole. What is a probable result of this compression of the manhole?

43. The operators are inspecting a sewer line with smoke. Although one of the houses does not have any smoke coming from the vent, it is still connected to the sewer line. What could be the cause for this deception?

44. Design-related deficiencies can be a problem after the collection system has operated for a period. What could cause joints to pull apart once the system is in service?

45. When a lift station is lifting the wastewater from a low elevation to a higher elevation, the discharge side of the pump is pressurized. The discharge line of the pump may have high and low sections. What type of valve would be used to prevent the discharge from air locking at the high point in the discharge line?

46. An operator who is wanting to compare the efficiency of a pump to its expected efficiency should utilize:

47. The CCTV is being used in a section of line which is flowing two thirds full. The high flow is submerging the camera lens. If the operator plugs off the upstream line, which of the following is a precaution which must be taken to prevent damage?

48. The wastewater plant is experiencing an increase in production. It is suggested that a smoke test be used for determining:

49. CCTV inspection is important for the operator attempting to locate problems in the system. Information the CCTV can give includes.

50. The supervisor of the collection system crew purchased an air blower for smoke testing the sewer lines. A Squirrel cage blower with a gasoline engine and belt drive is used. What air capacity should the operator expect from the unit?

51. Water hammer can be very damaging to piping and valves in force mains. The effect of water hammer can be reduced by:

52. A lift station pump is lifting the wastewater up to a gravity sewer line. If the operator wants to know the height or elevation of the lift, what calculations would tell the operator the height of the lift?

53. Lift stations are sometimes outfitted with aeration equipment. This helps keep the wastewater fresh during periods of low flow. The operator should not over-aerate the wastewater in the wet well if the force main has:

54. Lift stations require preventive maintenance on several components within the system. One piece of equipment that is over looked is gate valves. Which of the following prevents excessive leaking in the valve?

55. Maps are typically formatted in a grid system. The grid system has a set of axis which run north/south. Which of the following is the axis which is considered the east/west axis?

56. Property maps are used as the basis of the collection system map. What is the advantage of a computerized mapping system?

57. In the collection system an ideal map would be one drawn for your specific needs. Common types of maps that we use have information such as the major components of the system, trunk lines, pumping stations, and treatment plants. This type of map is known as a:

58. The operator is looking at a set of maps of the collection system. The abbreviations VCP and CIP appear on sewer lines on the maps. These abbreviations are standard for:

59. A good manager will establish a good record keeping system to help in analyzing many problems that occur. Records such as outside services versus in-house personnel costs could result in saving money by hiring personnel to handle jobs typically farmed out. For the purposes of budgeting and justifying the costs the manager will:

60. A question considered unacceptable to ask during an employment interview would be?

61. Supervisors are responsible for the efficient use of time and materials used in the collection system. To accomplish the tasks needed to be performed in the system efficiently the supervisor must give the staff:

62. Supervisors have many personal contacts with the public in the course of the year. Many of these contacts are at the customer's residence. All of the following are qualities the supervisor should have to make the contacts as pleasant and positive for both parties:

63. The manager has hired a new employee. The manager should hire the individual for a 90-120-day period before permanent position is given to the employee. What is this time period called?

64. What is an essential part of an administrator's management information system?

65. Dual check valves installed on the discharge line of a sump pump in a dry well are used primarily to?

66. Most mechanical seals require lubrication with:

67. Operators often disagree on the pros and cons of mechanical seals or packing in centrifugal pumps. Many operators want to use mechanical seals instead of packing. What is a disadvantage of using mechanical seals in a centrifugal pump?

68. Which condition might cause a positive displacement diaphragm pump to cycle improperly?

69. The pneumatic ejector in a small lift station is filling properly. The incoming wastewater is surcharged in the sewer lines. The operator has operated the compressor and everything seems fine except the wastewater will not flow into the receiving tank. What is a possible cause?

70. Piston pumps are used in high-pressure cleaners and in other pieces of equipment that can produce high-pressure. There are many factors which govern pump capacity. All of the following are the factors that govern capacity:

71. The operator has a number of submersible pumps in the collection system. One of the main problems with this type of pump is moisture entering the motor. Which piece of equipment is used to aid the operator in testing for moisture in the motor?

72. The operator uses a screw pump in one of the wet wells in the system. These types of pumps can operate in a no-flow condition to maximum rate when the following conditions exists.

73. Analysis of records can be accomplished in the form of tables, charts, and graphs. This type of report can often show or illustrate the need for budgeting money. The best way to do this would be to:

74. Most reports require input using programs that are not word processors. The term *"spreadsheet"* refers to:

75. Permitted confined space (Type II) entry by any personnel requires a confined space entry permit. What is absolutely needed prior to personnel entry?

76. Data processing helps the supervisor transform bits of information that are independent in nature into useful knowledge. All of the following essential factors must be involved to make the information effective except:

77. An operating plan is an essential element of an effective administration. It consists of a detailed written plan which should include:

78. The common use of atmospheric monitoring equipment has decreased the hazards of working in collection systems. What is true concerning confined space entry and atmospheric monitoring equipment?

79. When working in manholes near medical centers, clinical labs, and hospitals, the operator may want to disinfect the wastewater in the manhole before work begins. What is a proper method of disinfection?

80. The collection system has many dangers including infectious disease transmission. The presence of rats in a large collection system poses a threat to the operator by transmission of which disease?

81. After leaving a manhole, the operator should be aware of the dangers that may still exist. What is a recommended procedure for the operator performing work in a manhole?

82. During the early morning hours, you are called out to a broken 36 inch sewer line. In preparation for repair, what is the first task at hand?

83. The operator in the collection system has a plugged 18-inch sewer line. The operator on the job should notify which of the following agencies before clearing the line?

84. The collection system operator has adopted *"balling"* as a preventive maintenance practice. The procedure has advantages and disadvantages compared to other methods of cleaning. What is an advantage to the collection system preventive maintenance program?

85. The collection system crew is cleaning sewer lines and is using drinking water from a fire hydrant in town. The tank truck must be filled up frequently for the hydraulic jetter. When filling the tank truck the operators must not cause a cross connection. What is an acceptable device to prevent cross connections?

86. When attempting to repair a sewer line damaged by root intrusion, what would be the best procedure to fix this?

87. The best choice for the installation of an inside drop joint is:

88. Channel corrections are made to relieve flow problems such as the tee-shaped channel. When flow runs directly into the main channel flow it is called:

89. Repairing a sewer line which crosses another utility excavation poses special problems due to the possibility of:

90. As a supervisor you must always look out for the safety of the operational staff. When working in a manhole the operators should always wear the following safety equipment:

91. The collection system crew wants to install a clean-out at the end of a sewer line. Which connections should be placed at the end of the line to accommodate the cleaning equipment?

92. The collection system crew is installing a new tap on the main sewer line. After the tap has been made and the cleanout is installed the crew must fill the trench. What is the proper method of backfilling the trench?

93. The crew is repairing a broken line in the collection system. The line is an eight-inch PVC main and it will take 4 hours to repair the break. What is an acceptable method of handling the wastewater flow until repairs can be completed?

94. Inspection of the manholes in the system has revealed that two of the manholes have settled after construction. The lids and covers need to be raised to make grade. What is another possible problem caused by the settling of the manholes?

95. When installing a drop line inside a manhole the operator should place the drop line:

96. When performing sewer rehabilitation, the operator must know how to perform excavation carefully and safely. Shoring requirements change according to the soil stability in the trench. Identify some classifications of soil stability in a trench.

97. Sewer repair of a cracked bell and spigot is an important duty of the collection system operator. When repairing the cracked pipeline the operator should always remove all loose dirt from the area around the repaired line. The reason for this is to:

98. If a manhole has been covered due to construction, landscaping, or other activities, which of the following actions should be taken?

99. When placing the spoil away from the trench, the operator is making the area safe for the operator in the trench. Falling tools, dirt, etc. fall into the hole and can injure the operator. What is another reason for placing the spoil away from the trench?

100. The collection system crew is digging a trench to repair a broken line. At all times the jobsite must have someone who is in charge and accepts responsibility for the project. If a change in soil dictates a change in shoring, who would be the proper person for making an authorized change?

101. What is the definition of "*Sewage*"?

What type of cross-connection must be installed between a public water system and a wastewater treatment plant?

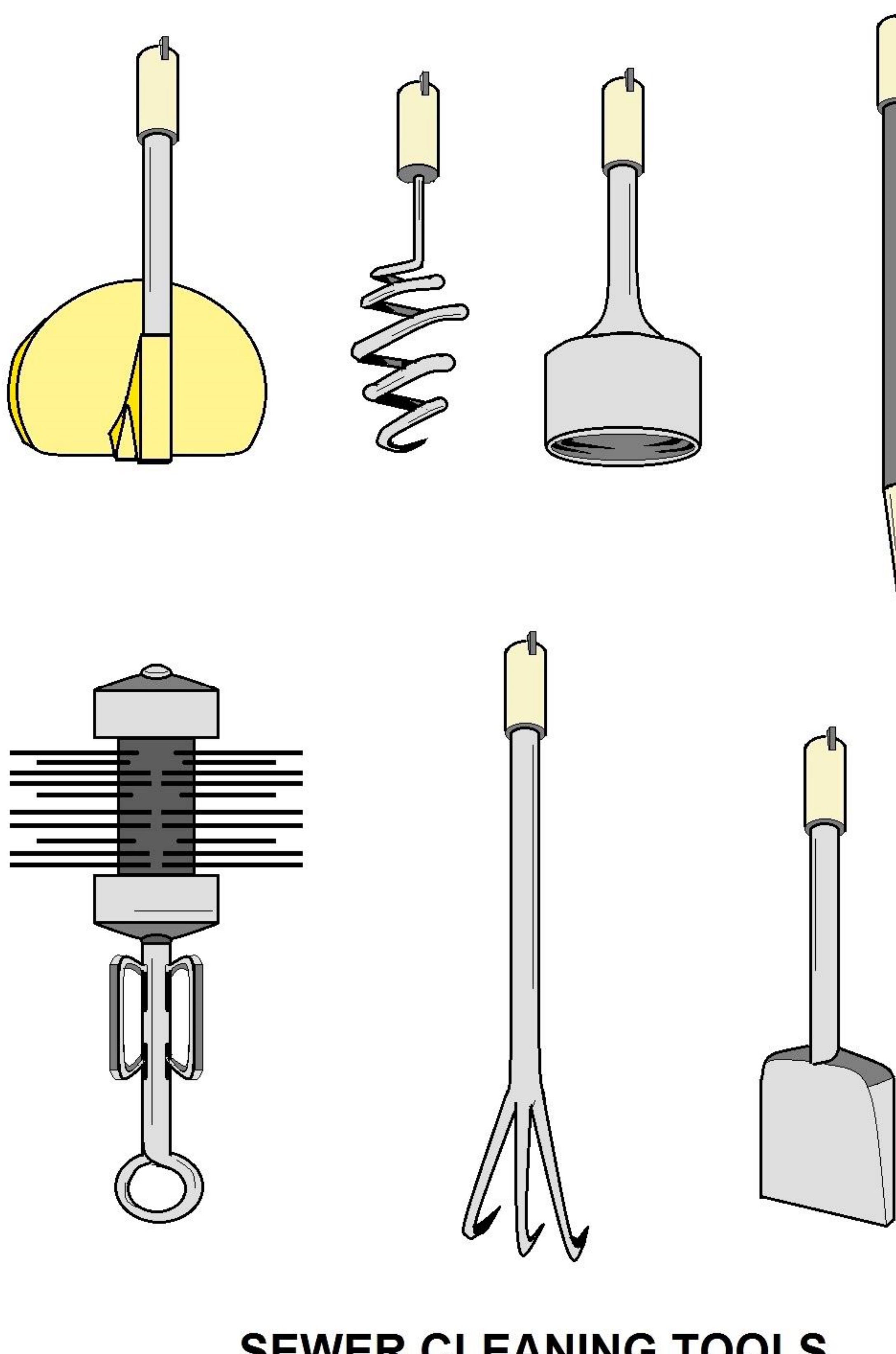
What precaution must be performed while handling sulfur dioxide?

What should an operator do before startup to avoid injury on equipment with rotating parts?

Which sampling method is preferred to calculate the efficiency of a wastewater treatment process?

What is the reason a wastewater treatment plant provides secondary treatment?

A septic sludge in a primary clarifier may result in foul odors, bubbles of gas at the surface, and floating clumps of solids. T/F



SEWER CLEANING TOOLS

Wastewater Collection #4 Assignment

Here is an excellent practice exam. I would review these areas before your examination.

Only one answer per question. Answers can be found in the glossary.
1. Vacuum collection systems are being used as an alternative to a gravity system. Which of the following is not a component of a vacuum system?
A. Vacuum pumps
B. Grinder Pump
C. Gravity sewers
D. Vacuum interface unit
E. None of the above

2. Pressure sewers may be installed instead of gravity sewers in areas where the:
A. Slope is not practical to maintain gravity
B. Population is below 10,000
C. Biological Oxygen Demand tends to be low
D. None of the above

3. What is the purpose of the scouring velocity in a sewer line?
A. Too maintain fluctuating flows
B. Prevent the deposit and buildup of solids
C. Increase dissolved oxygen
D. Compensate for slope irregularities

4. Lateral and main sewers should generally be buried approximately:
A. Depth does not matter
B. Below all other utilities
C. Below sea level
D. Three feet deep
E. Six feet deep

5. Manufacturers specify that a vitrified clay pipe is 2,200 pounds per foot, this means the pipe will:
A. Support this load without cracking
B. Will need heavy equipment to install
C. Carries extreme flow rates
D. None of the above

6. The advance warning area, from the first sign to the start of the next should be:
A. At least one block for urban streets
B. 150 feet for most highway conditions
C. Not necessary
D. Only used on highways

Answers can be found in the glossary or/and in the statements. Please memorize and study before your exam.

7. Proper tools, equipment and materials to do the job must be on the repair crew's truck before they drive to the job site. Which of the following is **NOT** needed when installing a cleanout?
A. Invert and hydro-brake flow regulator
B. Round point, square point and narrow cut shovels
C. Couplings, bushings and plastic plugs

8. Which of the following pipes would not hold up in corrosive environments?
A. PVC
B. Clay pipe
C. Concrete
D. Stainless steel

9. Which chemical can be used to control hydrogen sulfide by precipitation?
A. Zinc and iron salts
B. Chlorine
C. Ammonia anhydrous
D. Sand stone
E. Sodium

10. Hydrogen sulfide conditions occur in the sewer system because of the lack of:
A. Microorganisms
B. High velocity
C. Oxygen
D. Industrial flow
E. All of the above

11. Compounds containing sulfur that have an extremely offensive skunk-like odor are called:
A. Halogen
B. Disinfectant
C. Mercaptans
D. Hydrogen
E. All of the above

12. Atmospheric monitors continuously sample the atmosphere for which of the following levels:
A. Toxicity
B. Oxygen
C. Flammability
D. All of the above

13. An atmospheric analyzer will have an audible and visible alarm that will warn when the flammable gases exceed _______%.
A. 19.5%
B. 50%
C. 80%
D. 10%

Answers can be found in the glossary or/and in the statements.

14. The slope of gravity sewer lines is critical to maintain flow and self-cleaning of the pipe. Gravity sewer lines should be designed:
A. To follow the slope of the land provided minimum slope is maintained
B. As deep as possible to prevent odors
C. To always maintain a slope of >5%
D. With varying slopes every four hundred feet to prevent settling

15. When a trench is dug for a new line or replacement of an old line, the trench should be dug and backfilled in such a manner to support the pipe. A rule of thumb as to the width of the trench is that the trench should be:
A. As wide as possible for pedestrian safety
B. As wide as a thumb
C. Narrow as possible for safety and to increase pipe sidewall support
D. Four times the width of the pipe being laid to provide maximum sidewall support for the pipe

16. Two-way clean outs are often used on house laterals. These fittings are typically a Tee fitting with a ___________ inside to better accommodate sewer-cleaning equipment.
A. Single swing check valve
B. Double check valve
C. Perforated section in the fitting
D. Baffle

17. Low-pressure collection systems can be a cost savings. Which of the following is true about a low-pressure collection system?
A. There are fewer stoppages and less infiltration and inflow
B. There is a loss of BOD and slope of pipe
C. There is a decrease in use of electricity
D. There is no need for lift stations or flow meters

18. A _________is a type of chemical which can be used to:
A. Rodenticide, Control rats
B. TPH, Reduce grease build-up
C. Pesticide, Mask odors
D. Rodenticide, Remove roots

19. A circuit is tested with an Ohmmeter and is found to be defective. The most likely reading is:
A. 10
B. 100
C. 1,000
D. Infinity

20. What is the recommended practice for maintaining the stationary and movable contacts in a motor starter?
A. Replace entire contact set when surface is badly pitted and eroded with badly feathered and lifting edges
B. Leave them alone; contacts never need care
C. Sand the contacts with emery cloth when oxidation appears
D. Monthly spray the contacts with a cleaning lubricant (like “***WD-40***”)

21. Hydrogen sulfide problems are very common in the collection system. There are many chemicals used to help or treat this problem. Which of the following chemicals is NOT used in the treatment of hydrogen sulfide problems?
A. Lime
B. Hydrogen peroxide
C. Chlorine
D. Hydrochloric acid

22. Molded-case circuit breakers typically require little maintenance. Which of the following is NOT recommended maintenance on these circuit breakers?
A. Lubricate the mechanism with a high grade machine oil
B. Inspect for evidence of over-heating
C. Manually trip the circuit breaker periodically
D. Check connections for tightness

23. The greatest cause of failure in electric motors is:
A. Old age
B. Thermal overload
C. Rotor failure
D. Foreign contaminants in the motor
E. All of the above

24. The operator has just changed the grease in the bearings of a motor. Which of the following steps should be followed to complete the preventive maintenance of the greasing procedure?
A. Run the motor for 30 minutes then install drain plug
B. Apply 30 PSI of grease to the zerk fittings and close drain plug
C. Heat the grease prior to starting the motor
D. Fill the remaining portion of the cavity with kerosene

25. The operator is testing a coil from a control relay using an ohmmeter. Which of the following is true when using the ohmmeter to check out this type of component?
A. Spray the coil with a little water
B. The power to coil must be off
C. Full voltage must be placed on the coil
D. Ohm meters are not capable of testing coils

26. Electric motors burn out for many reasons, but 70% of motor failures can be controlled by the operator and proper maintenance. Which of the following is NOT a cause of motor insulation failure?
A. Overloading the motor
B. Cold weather of <10 degrees C
C. Single phasing three phase motors
D. Contamination of the windings

27. The operator has just installed a repaired motor in a pumping station. The motor is started but it never comes up to speed. Which of the following is NOT a possible reason for the malfunction?
A. Discharge check valve is closed
B. Incorrect power supply
C. Motor is overloaded
D. Incorrectly wired

28. A qualified operator is testing an electrical circuit for proper voltage. The incoming voltage is 220 VAC, single-phase power. The operator places one of the tester leads on LI and the other on the neutral wire. What is the expected voltage when testing these two wires?
A. 110 volts
B. 220 volts
C. 12 volts
D. 0 volts

29. Hydrogen sulfide production in collection systems can cause a number of problems including all of the following **EXCEPT**:
A. Corrosion
B. Hazardous atmosphere
C. Cavitation
D. Foul odors
E. None of the above

30. Wastewater flow in collection systems would be expected to be lowest at:
A. 11p.m
B. 4 a.m.
C. 12 a.m.
D. 5 p.m.
E. All of the above

31. Why is exfiltration a concern to wastewater collection operators?
A. It may overload the treatment plant
B. It may pollute ground water supplies
C. It may result in odor problems in treatment plants
D. Exfiltration is not a concern for the collection operator
E. All of the above

32. The wastewater in a gravity collection system is conveyed by all of the following EXCEPT:
A. An Interceptor sewer
B. An Infiltration gallery
C. Lift Stations
D. Combined Sewer
E. All of the above

33. Which of the following statements regarding the reduction of hydrogen sulfide is NOT true?
A. Salts of zinc and iron may precipitate sulfides
B. Chemical treatment is the preferred treatment method for reducing hydrogen sulfide
C. Lime treatments can kill bacteria which produce hydrogen sulfide, but create a sludge disposal problem
D. Chlorination is effective at reducing the bacteria which produce hydrogen sulfide
E. None of the above

34. Which of the following devices measures the flow of gases or liquids through a tapered calibrated glass tube? Inside the tube, a ball or float rises as the flow of gas or liquid flows through the tube.
A. Magnetic flow meter.
B. Ball float meter
C. Orifice meter.
D. Rotameter.

35. A critical component found in the low-pressure collection system is:
A. A grinder pump.
B. A vacuum interface unit.
C. Large diameter pipe to prevent stoppages.
D. Inverted siphons at various crossings.

36. When looking at the nameplate of a motor the term Ambient Temperature appears on the nameplate. Which of the following defines Ambient Temperature?
A. The surrounding temperature
B. The inside temperature
C. The surface temperature
D. The bearing temperature

37. The Specific Gravity of a liquid refers to the relative weight of a liquid compared to the weight of:
A. Water at 4 degrees C
B. Water at 20 degrees C
C. Mercury at 20 degrees C
D. Gravitational pull of the earth at 68 degrees F

38. The best method of controlling hydrogen sulfide is to eliminate its habitat or growth area by:
A. Using Colilert
B. Keep the pH in the collection system low
C. Regularly add chlorine or other chemicals to the collection system
D. Keeping sewers cleaner, which will harbor fewer slime bacteria

39. Smoke testing sewer lines can be helpful in finding cracks and lost manholes. This type of inspection can also find:
A. Areas of low oxygen concentrations
B. Illegal connections to the sewer
C. The percent of slope in the section of pipe
D. Sections of pipe with improper slopes

40. What must be done before performing a CCTV inspection?
A. Clean sewers with a high velocity cleaner
B. Perform a preliminary inspection using lamps
C. Block the sewer and divert the flow to avoid short-circuiting of the instruments
D. Notify other utilities of the inspection
E. All of the above

41. Operators may encounter problems in gaining access to sewer lines which are located in easements. The public should be informed of the agency's (collection system) right to perform inspection and maintenance activities. These rules can be found in:
A. State Department of Health Rules
B. Local sewer-use ordinances
C. USEPA's rules and regulations
D. Highway and Traffic Control Department's rules
E. None of the above

42. If the CCTV operator announces that the line has a "*Right Offset*", the operator then knows that the line has:
A. A misalignment problem
B. A Y-connection at that point
C. A protruding tap connection
D. A grease build-up on the right side of the pipe
E. All of the above

43. The collection system operators have determined that a section of the sewer line is cracked. The direct problem that occurs is infiltration and exfiltration. Many times one problem can create another one. Which of the following problems is related to a cracked sewer line?
A. Odor problems
B. Increase in velocity through the pipe
C. Root intrusion
D. Sharp increase in hydrogen sulfide
E. None of the above

44. All the following items should be examined when inspecting manholes except:
A. Inadequate sewer use ordinances
B. Inside surfaces and joints for cracks or breaks
C. Elevation of the lid
D. Noises that indicate infiltration from cracked or broken pipes
E. All of the above

45. A very economical and quick method of determining if a new sewer line is straight and unobstructed is:
A. Lamping
B. Hydro-dynamic testing
C. Exfiltration and infiltration testing
D. Sighting manholes using a laser survey instrument

46. The collection system is inspecting lines for inflow problems. The operators find many sources of inflow from houses and buildings which increase flows during periods of wet weather. To eliminate these problems the collection system needs to have in place a:
A. Sewer use ordinance
B. Way to write citations for each homeowner
C. Legal staff to inform violators
D. Mandatory trial for all offenders

47. There are many reasons for inspecting sewer lines with a closed circuit television (CCTV). All of the following are valid reasons EXCEPT:
A. Locate sources of inflow and infiltration, Locate buried manholes
B. Locate illegal sewer taps such as industrial or storm drains.
C. Locate high BOD loading in the sewer line
D. All of the above

48. The operator is smoke testing a line for illegal connections and other problems. Which of the following types of smoke bombs should be used?
A. Military smoke bombs which have colored smoke and tear gas
B. Non-toxic, no residual effect type smoke bombs
C. Military smoke bombs used for signaling
D. Railroad signaling flare used in public right-of-ways

49. The operator has smoke tested a section of line and found there is no smoke coming from a customer's vent pipe. Which of the following tests is appropriate to perform on the service line to confirm the sewer connection?
A. Dye test in the lateral line
B. Hydrostatic testing of the lateral
C. Snake the line to see where it goes
D. Lamping the sewer lateral line

50. If the collection system is subject to a large amount of inflow and infiltration, which of the following can occur if the line is surcharged?
A. Pressure in the pipe can cause the pipe to rupture.
B. Exfiltration can occur at joints and cracks
C. Overflows at manholes which can expose the public to diseases
D. All of the above

51. The collection system crew is smoke testing a line and the operators are told where to check for smoke coming from the buildings and grounds. Which of the following is the only location from which smoke should be emerging?
A. Yard clean out
B. Out of the back of the camera truck
C. Gutters or roof drains
D. House vents

52. A Polaroid or an instant camera is a typical piece of equipment found in the CCTV unit. What is the main purpose for the instant camera while televising a line?
A. Provide additional lighting for the CCIV
B. Used only when the CCTV is malfunctioning
C. Both A and B
D. Provides operators with a picture record, for log entries, of conditions of trouble spots in the lines

53. The best way to apply sewer test dye when a plumbing fixture is used is to:
A. Deliver the dye with a peristaltic pump
B. Deliver the dye in powder form using a dye injector
C. Dissolve the dye in water, turn on the water and pour into the flow
D. Dump a canister in the toilet

54. Exfiltration can be a source of pollution to the surrounding area. Which of the following methods of inspection can detect the location of the exfiltration?
A. Smoke testing
B. Deflection testing
C. Pressure testing
D. Lamp testing

55. The best technique to use when lamping a sewer line is to:
A. Hold the light steady in the center of the opening, to check for an open and straight pipe
B. Rotate the light around the inside of the pipe to check for other problems.
C. Both A and B
D. Pull the light through the sewer line

56. Lamping is a procedure to establish that a section of pipe is straight and open. What items must an operator consider before lamping a section of pipe?
A. Elevation of the manhole inverts
B. A bright source of light and proper staffing of personnel for the operation
C. Sources of inflow by deliberate connections and surface drainage
D. Cable strain relief and float lines

57. Most failures at a lift station can be avoided by:
A. Properly cleaned sewers
B. Proper preventive maintenance
C. Properly constructed sewers
D. All of the above

58. Before smoking an area for locating leaks and improper connections, the supervisor should notify the public of the testing. Which of the following should also be notified before smoke testing a sewer line?
A. Local hospital
B. Local Fire and Police
C. State Health Department
D. State Department of Environmental Quality

59. Enclosed electrode controls are sometimes used in lift stations to:
A. Control pumps
B. Measure pH
C. Adjust the incoming wastewater flow
D. Operate air compressors

60. The operator is responding to an odor complaint at a lift station. The operator goes to the station and finds the source of the problem and corrects the situation. What is the final step in responding to the complaint?
A. Notify Department of Environmental Quality
B. Write a public statement
C. Notify the person who complained about the situation
D. Provide the notification to local newspapers
E. Contact OSHA

61. Check valves are installed on the discharge side of sump pumps in dry wells to prevent flooding of the dry well by:
A. Solids and grease accumulation on the pump shaft
B. Net Positive Suction Head Loss due to cavitation
C. Pump discharge pipe manifold isolation gate valves
D. Backflow due to back siphoning
E. Removing the static head allowing the pumps to run easier

62. The distance between two manholes on a map is measured as 15/16 of an inch. Scale for the map is 1 inch equals 800 feet. Estimate the actual distance between the two manholes.
B. A. 750 feet
620 feet
C. 550 feet
D. None of the above

63. Determine the force against each plug if a pipe is 18 inches in diameter and the test pressure is 5 psi.
A. 1,270 lbs
B. 1,021 lbs
C. 1,482 lbs
D. 1,342 lbs
E. All of the above

64. An 8-inch sewer 400 feet long is given a water leak test. The downstream manhole is plugged where the line enters the manhole. There are no service lines connected to the test line. At 9:00 a.m., the 36-inch upstream manhole was filled to the bottom of the cone. By 5:00 p.m., the water had dropped 4.0 feet. Calculate the leakage in terms of gallons per day per inch of sewer diameter per mile of sewer.
A. 1,047 GPD/in/mi
B. 1,120 GPD/in/mi
C. 1,234 GPD/in/mi
D. None of the above

65. What is the slope on an 8-inch sewer that is 400 feet long if the invert elevation of the upstream manhole is 428.31 feet and the invert elevation of the down-stream manhole is 423.89 feet?
A. 0.011 ft/ft
B. 0.07 ft/ft
C. 0.036 ft/ft
D. 0.042 ft/ft

66. How many feet of drop are in 400 feet of 8-inch sewer with a 0.045 ft/ft. slope?
A. 18.0 ft
B. 19.0 ft
C. 20.0 ft
D. 21.0 ft

67. If the total fall in a ditch is 14 feet in 1,000 feet, what is the grade in ft/ft?
A. 0.026 ft/ft
B. 0.021ft/ft
C. 0.014 ft/ft
D. 0.032 ft/ft

68. Area Maps are used at almost every system in the country. These maps of the system show the operator:
A. Every fire hydrant
B. Individual streets on each page
C. The entire collection system
D. Very specific information of the system

69. How are elevations typically represented on collection system maps?
A. The elevation of the invert
B. The elevation of the street center line
C. The elevation of the service tap

70. On maps used to show the collection system there is a method of telling the distance between two points such as manholes. If the manhole number 1 is located at station 3+50 and manhole two is 7+25, how many feet apart are the two manholes?
A. 375 feet
B. 1,075 feet
C. 10.75 feet
D. 3.75 feet

71. Which of the following is **NOT** considered a standard practice when installing packing rings in a pump?
A. Stagger the joints of rings to avoid having two joints at the same position
B. Install 2 rings on the inside of the lantern ring and 2 rings on the outside, or an equal number on each side of the lantern ring
C. Cut packing rings into different pieces
D. Packing rings should be of materials recommended by the pump manufacturer

72. Many pumps are outfitted with mechanical seals to prevent water from leaking out of the pump. The seal faces must be protected. Which of the following is an important maintenance task to be performed by the operator to prevent damage to the seal faces?
A. Keep fresh water on the faces of the seal
B. Maintain clockwise rotation on the seals
C. Apply grease to each face monthly
D. Clean the faces with a fine grit emery cloth

73. Which of the following devices are used in order to prevent injuries or severe damage to piston pumps?
A. Big rubber parts and soft metal
B. Relief valve on discharge side of pump
C. Check valve on discharge side of pump

74. Submersible pumps are commonly used in lift stations. Preventive maintenance is important to ensure motor windings are not burned. Which of the following devices is used to determine if moisture is entering the motor through the pump?
A. Megger
B. Amp meter
C. Hydrometer
D. Water test kit
E. Moisture Index tester

75. The operator has noticed the centrifugal pump is making noise and the efficiency of the pump is lowering. The pump is dismantled and the impeller has pits on all the vanes.
Which of the following is the possible cause of the pits?
A. Cavitation inside the pump
B. Low static pressure in the system
C. High strength of the wastewater
D. High velocity through the pump

76. The pneumatic ejector at a small lift station is cycling too often. The flow into the tank is low but the ejector pumps frequently. Which of the following is a possible cause for this problem?
A. Intake valve is stuck closed
B. Discharge valve is stuck open
C. The spillway into the tank is clogged
D. The electrical control circuit is receiving a high voltage
E. All of the above

77. Calculate the *wetted perimeter* of a 24-inch sewer with a slope of 0.004 ft per ft if the pipe is flowing half full.
0.785 ft
37.68 ft
1.57 ft
3.14 ft

78. In large-diameter sewer construction projects, the ___________should include a ‘walk through’ inspection to verify that all construction tools and debris have been removed from the line.
A. Preliminary survey
B. Final inspection
C. Weekly examination
D. Daily audit

79. The operator removes a submersible pump from a wet well. The pump is an oil-filled motor. The inspection plug is opened and a small amount of fluid is poured into a beaker. The fluid is an emulsion of oil and water. *What is the probable cause*?
A. Bearings are failing
B. Mechanical seals are leaking
C. Packing is leaking water
D. Oil is breaking down due to heat
E. Pump shaft key way is leaking

80. An information management system must meet the needs of the collection system supervisor and the utility personnel. The most common of these requirements are:
A. Schedule preventative maintenance on pumps, equipment and vehicles
B. Tracking and measurement of workforce productivity
C. Development of unit costs and measurement of resource allocation
D. All of the above

81. Records can become a problem when storage is needed to house volumes of paperwork. Which of the following is used to consolidate records into a form that will use less storage area?
A. Store records in lift stations and other wasted space
B. Microfilming printed records
C. Type all records and store in wooden crates
D. All records are destroyed at the end of each year of operation. For security purposes.
E. All of the above

82. The most valuable tools for future planning of collection system needs are:
A. Testimony from collection system personnel
B. Collection system records
C. Reading the newspaper
D. Conferences with other collection system managers

83. Records of maintenance and operations are used for two basic reasons. The two basic needs that records fulfill are:
A. Justify the need of for another manager and vehicles
B. Manpower needs and salary structure for those needs
C. Record of the past and a basis for future plans
D. Fulfill the State requirements for adequate system of accounting and budget

84. Upon entering a confined space, your oxygen meter indicates an oxygen concentration of 22.9%. The appropriate course of action is:
A. Evacuate the area immediately
B. Continue working there is sufficient oxygen
C. Check oxygen meter for defective readings it should never go above 22.5%
D. Assume the meter is inaccurate, it been awhile since calibration

85. A confined space is defined as an area where existing ventilation is inadequate to remove contaminants or provide a sufficient air supply. What other criteria defines a confined space?
A. Areas that are difficult to enter or evacuate
B. Areas which are totally enclosed
C. Underground areas
D. A storeroom

86. If the operator is confronted by an unsafe or discourteous driver while driving a treatment plant vehicle, he should:
A. Swallow his pride and handle the situation with manners
B. Use the emergency lights to warn the other driver
C. Hit the other vehicle with a slight tap
D. Report the incident to local police
E. View it as a personal assault and take action

87. The use of a SCBA is important to operators who are expected to work in confined spaces. Which of the following is prohibited when using a SCBA?
A. Near-sighted operator
B. Facial Hair
C. Operator experiencing a sore thumb
D. Jewelry or metal necklaces

88. Flammable gas meters are calibrated to activate alarms when:
A. 10% of the lower explosion limit is reached
B. The upper explosion level is reached
C. The lower explosion level is reached
D. 15% of the upper explosion limit is reached

89. Which of the following gases would present the greatest explosion hazard to a collection system worker? Each gas is flammable and has an identical LEL and UEL.
A. Gas #1 with a specific gravity of 2.5
B. Gas #2 with a specific gravity of 0.1
C. Gas #3 with a specific gravity of 1.0
D. Gas #4 with a specific gravity of 1.2

90. The collection system CCTV has indicated that there are many protruding taps in a section of lines. The protruding taps can be repaired by which of the following methods?
A. Installing a pipe cutter on a rodding machine
B. Remove section of line containing the tap and install a factory made wye
C. Cut away the protruding tap with a mechanical cutting system
D. Both answers B and C

91. The operator has repaired a break in an 8-inch sewer main. The trench is now ready for backfilling, but first the operator must bed the new section of pipe. Which of the following is the proper method of bedding a sewer line?
A. Bed the new section 6 to 12 inches above the top of the pipe
B. Bed the pipe to the center line of the new section of pipe
C. Bed the pipe to the top of the pipe
D. Bed only to the bottom of the sewer line

92. Before excavating a section of sewer for replacement, upstream and downstream manholes should be inspected:
A. To determine the volume of flow
B. To release explosive gases from the sewer
C. For venomous insects or snakes
D. To monitor soil stability

93. Hydraulic shores are used due to their ease of installation and removal. However, they are usually not used on jobs for a time period greater than five (5) days, because of the following reason or reasons.
A. The unit weighs about 70 pounds and can only spot brace trenches 22 to 48 inches
B. Installation requires more than one person in order to connect the high-pressure hoses
C. There is a possibility of the hydraulic pressure bleeding off during a time period longer than five (5) days
D. All of the above

94. Which of the following fluids is recommended for use in hydraulic shoring equipment?
A. Hydraulic shoring fluid
B. Ultra-pure water
C. Mineral oil
D. Ninety weight oil (gear lube)

95. An alternative to screw jacks as a shoring brace is:
A. Stringer jacks
B. Cyclone spreaders
C. Air shores
D. Pneumatic brace supports

96. When purchasing a specific type of shoring for the collection system, the operator should consider price and quality of the material. The type of shoring purchased for an agency is governed by:
A. Soil conditions in the area
B. Amount of insurance held by the agency
C. The manpower available to install the shoring
D. Local fire and police ordinances

97. The operator is installing air shores. The carbon dioxide tank is used to fill the cylinders which reinforce the trench walls. The cylinders are pressurized to 300 PSI. Now what is the next step in using this type of shoring equipment?
A. Pressurize the system to 3000 PSI after testing the shores at 300 PSI
B. Seal the air connections with a special epoxy resin
C. Insert a metal pin behind the collar to form a mechanical lock
D. Continue to fill the cylinder with pure nitrogen gas to stabilize the carbon dioxide

98. The collection system crew is going to dig a trench to remove a broken tap and main line. The trench is going to be 7 feet deep and requires shoring. The type and placement of the shoring is governed by:
A. DEQ
B. OSHA
C. Fire and police departments
D. Local plumbing inspector

99. The operator has installed a screw jack between the solid sheeting materials for shoring a trench. To ensure safe conditions in the trench the operator needs to perform which additional task on the screw jacks?
A. Use a double lock nut on the screw jack
B. Place spacers in between the cylinder and jack
C. Drive nails into the base of the jack and timbers
Spot-weld the screw and cylinder together
E. Use a removable epoxy on the jack screw to prevent turning

100. Which of the following materials is commonly used in repairing concrete sewer lines, brick sewers, and manholes? This material is used because of its high density and corrosion resistant qualities.
A. Polymers, both cationic and anionic
B. Poly-Urethane
C. Gunite
D. Polymers, anionic only

Collections Key Final Review

No Answers Provided

1. How many GPM is needed to fill a 1-million-gallon tank in ten hours?

2. How many gallons per minute to fill a 100,000-gallon tank in 1 hour?

3. If you had to purchase 8 boxes of chlorine at 16.33 a box, how much would it cost?

4. What is 2 million gallons a day expressed in gpm?

5. What is the oldest method of cleaning sewers?

6. Should the floor in a wet well or lift station be tilted?

7. How many drops of water per minute are allowed from a packing gland?

8. What to do if entering a lift station and the power is off?

9. Study up on packing and mechanical seals.

10. Study up on Safety Management.

11. Study up on Recordkeeping needs and purposes.

12. What is a voltage meter used for?

13. Study up on Hydrogen Sulfide.

14. Study up on NPDES and Pass-through.

15. Study up on manholes and ventilation.

Memorize these for your exam.

Chemical Name	Common Name	Chemical Formula
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		$H2CO_3$
Chlorine gas		Cl_2
Chlorine Dioxide		ClO_2
Ferric chloride	Iron chloride	$FeCl_3$
Ferric hydroxide		$Fe(OH)_3$
Ferric sulfate	Iron sulfate	$Fe_2(SO_4)3$
Ferrous hydroxide		$Fe(OH)_3$
Hydrochloric acid	Muriatic acid	HCl
Hydrogen sulfide		$H2_S$
Hypochlorous acid		HOCL
Magnesium hydroxide		$Mg(OH)_2$
Magnesium dioxide		MgO_2
Manganous bicarbonate		$Mn(HCO_3)2$
Sodium hydroxide	Lye	NaOH
Sodium hypochlorite		NaOCl
Sodium sulfate		Na_2SO_4
Sulfuric acid		H_2SO_4

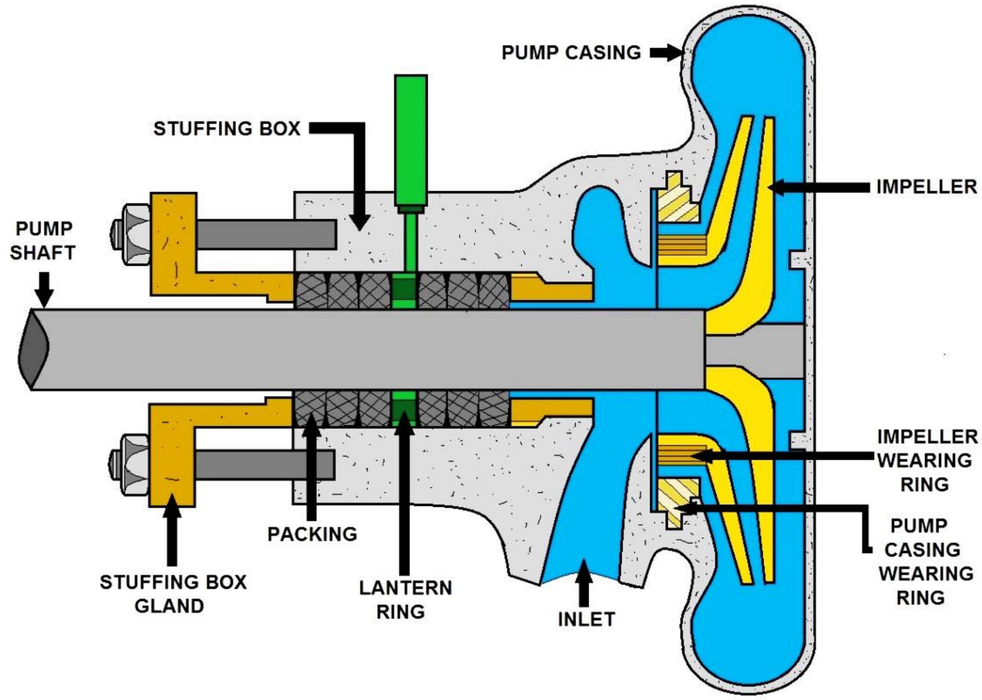
Practice Quiz, identify the following…
Cl
Cl_2

Atomic number of Cl

H_2SO_4
H_2S
Cu
S
Two compounds that contain Sulfur. Mercaptans and Phenols

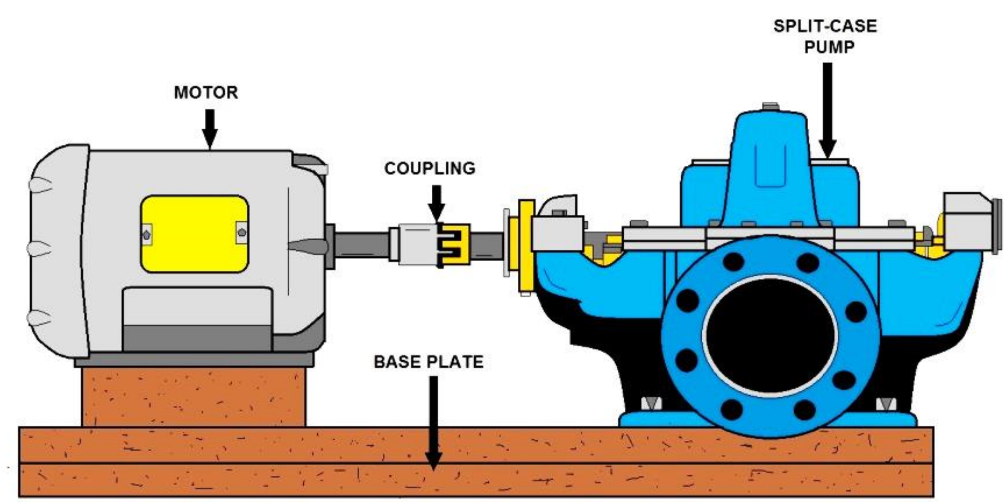
What does Cl_2 and H_2S have in common?

Pump and Motor Section Chapter 6



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.



CLOSED COUPLED PUMP

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.

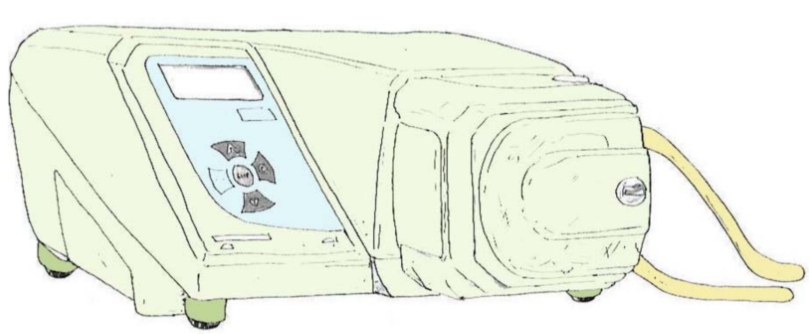
Pressure
The application of continuous force by one body upon another that it is touching; compression. Force per unit area, usually expressed in pounds per square inch (Pascal or bar).

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.

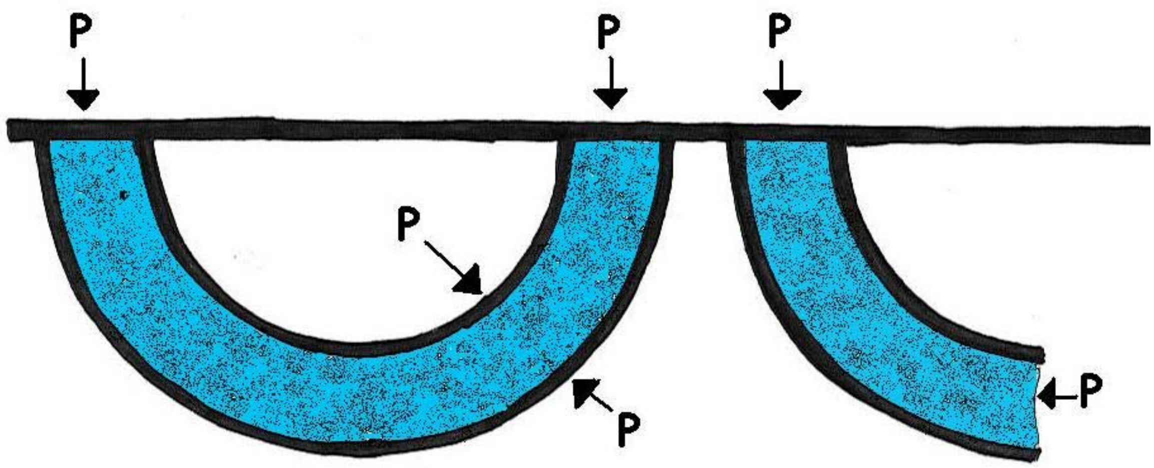
Pressure, Static
The pressure in a fluid at rest.



PERISTALTIC PUMP

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.



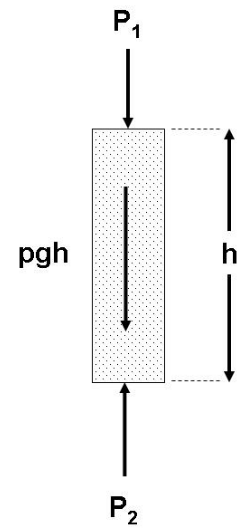
EQUALITY OF PRESSURE

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



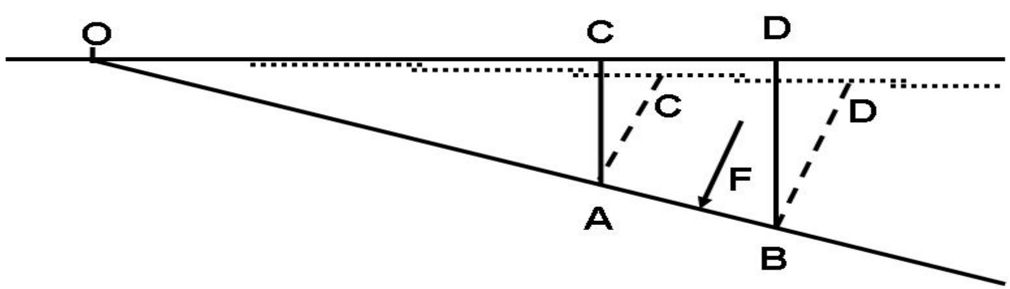
Increase of Pressure with Depth

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.

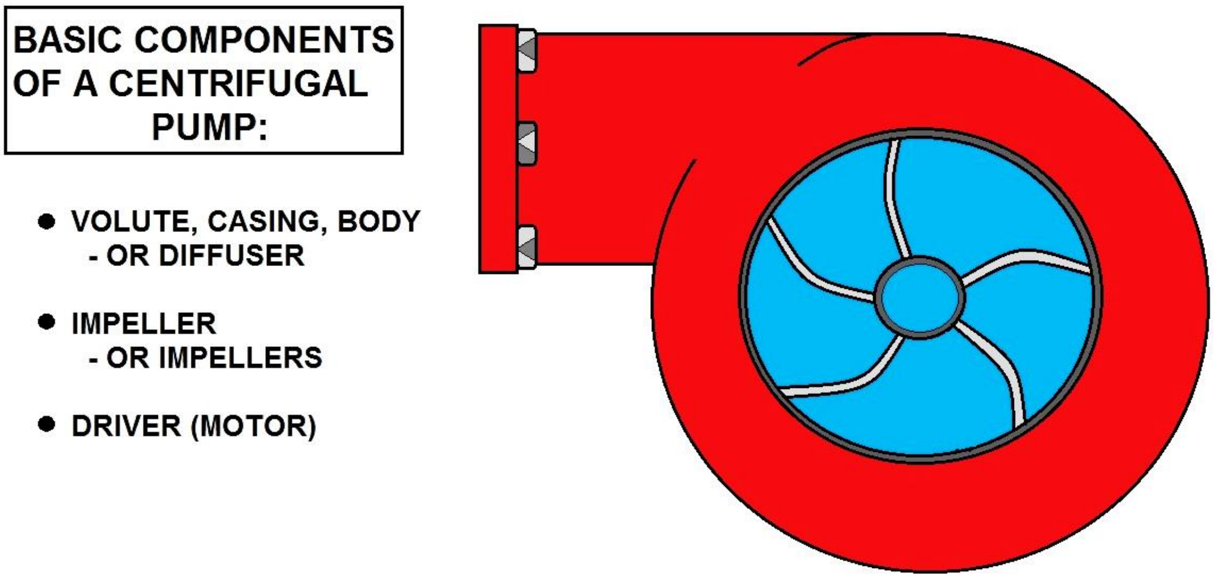
Vertical pumps: Pumps in which the center line of the shaft runs vertically.

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.

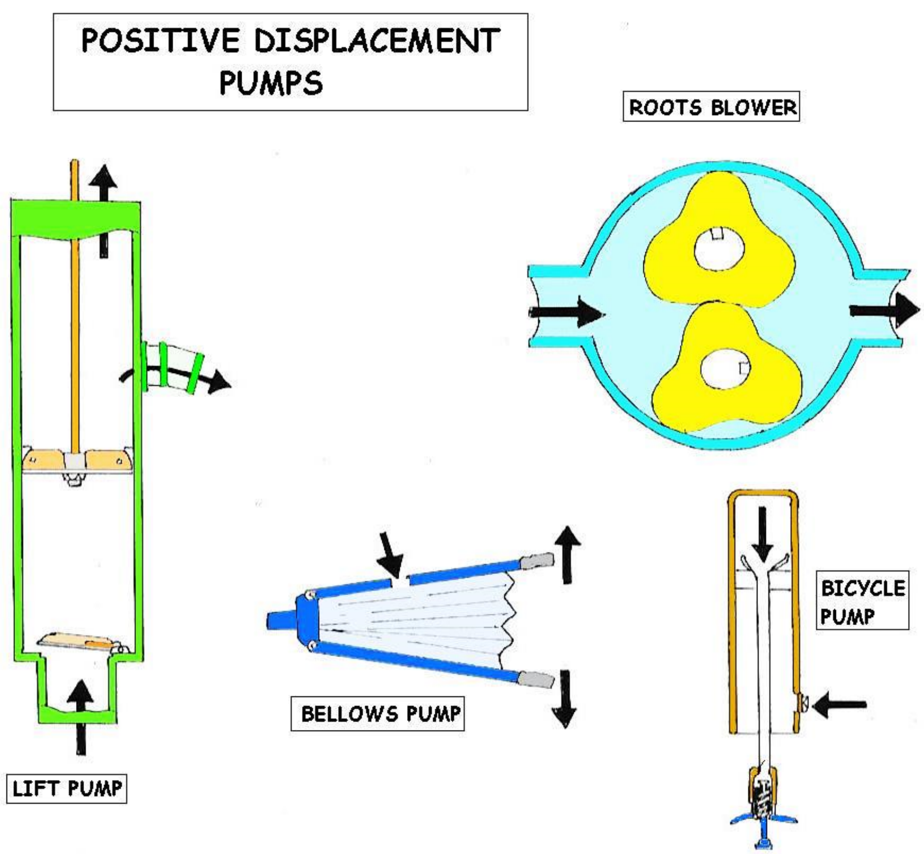
Diaphragm pumps are force pumps in which the oscillating diaphragm takes the place of the piston. The diaphragm may be moved mechanically, or by the pressure of the fluid on one side of the diaphragm.

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.



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.

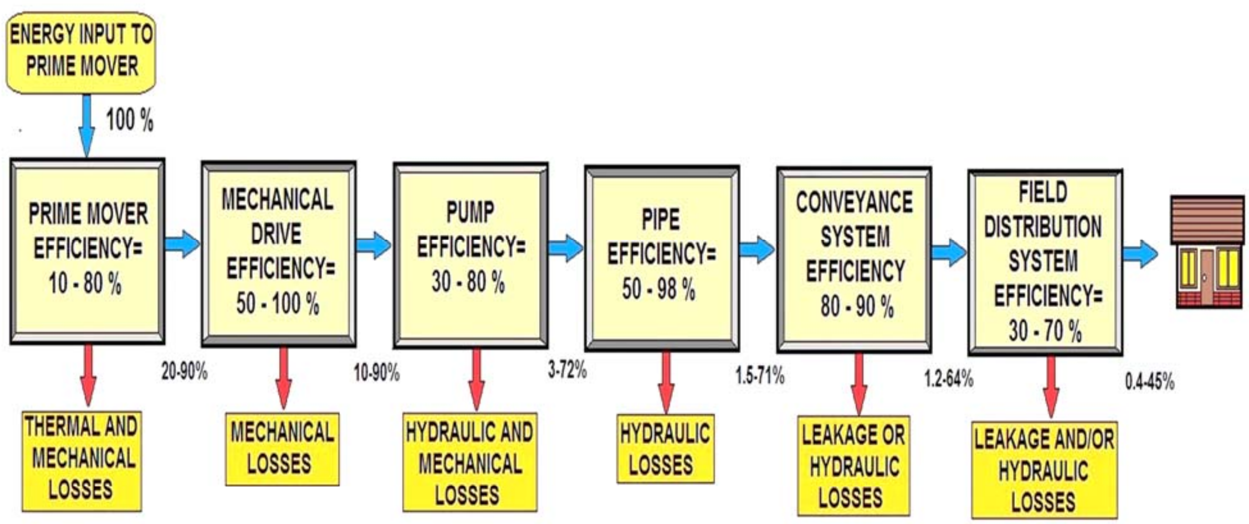
S.G.: Specific gravity. The weight of liquid in comparison to water at approx. 20 deg c (SG = 1).

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.

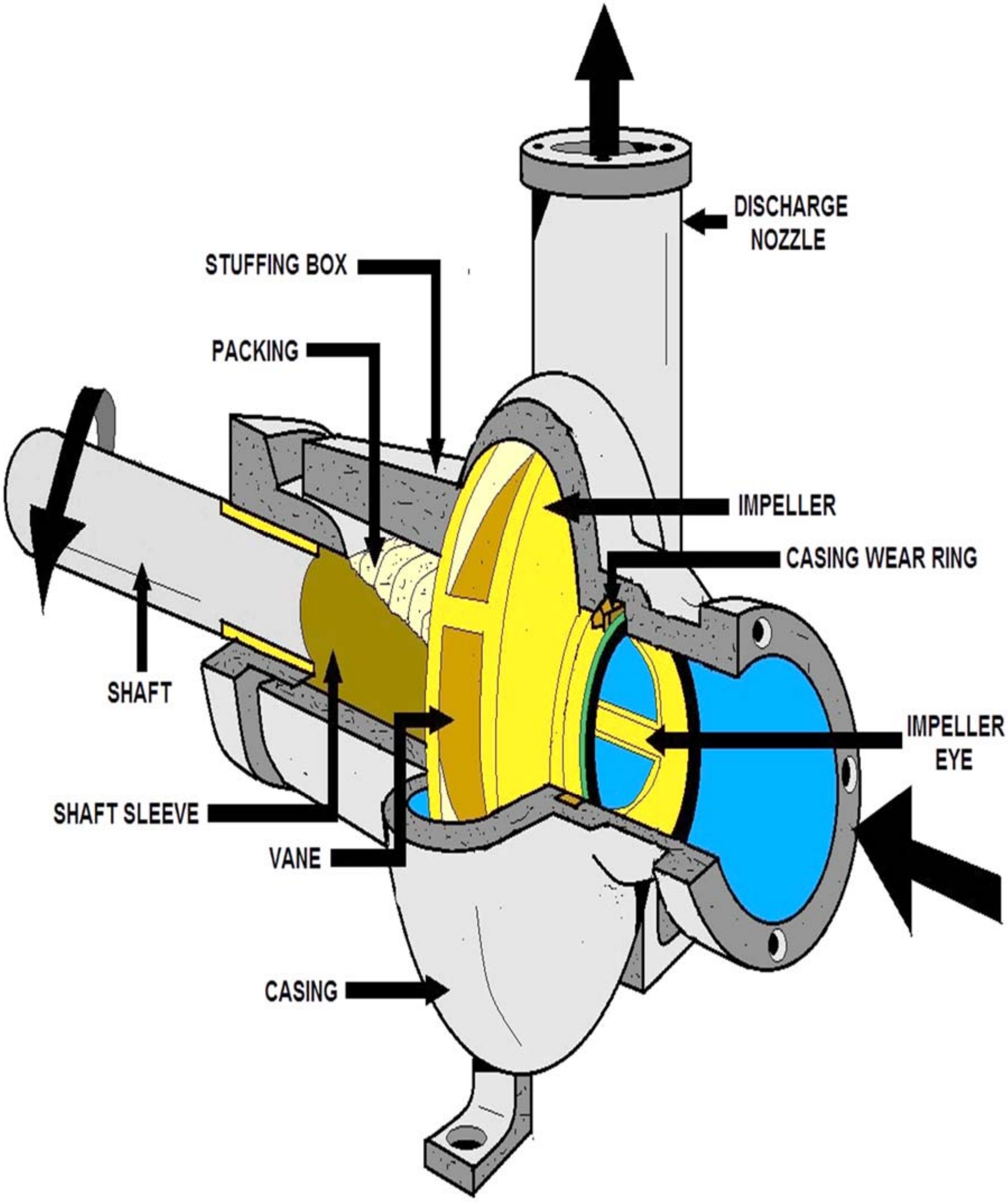
Vapor Pressure: If the vapor pressure of a liquid is greater than the surrounding air pressure, the liquid will boil.

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.

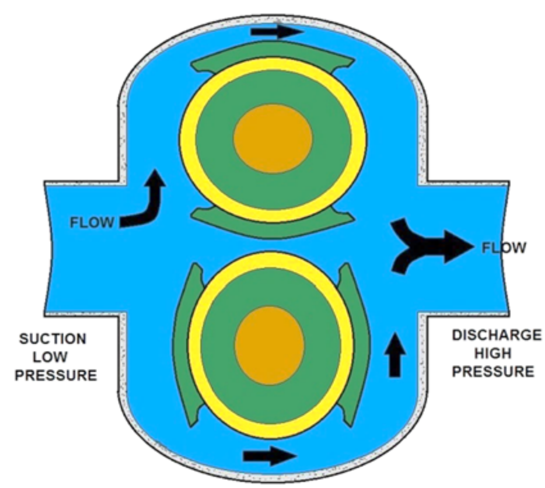
Positive Displacement Pumps

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.

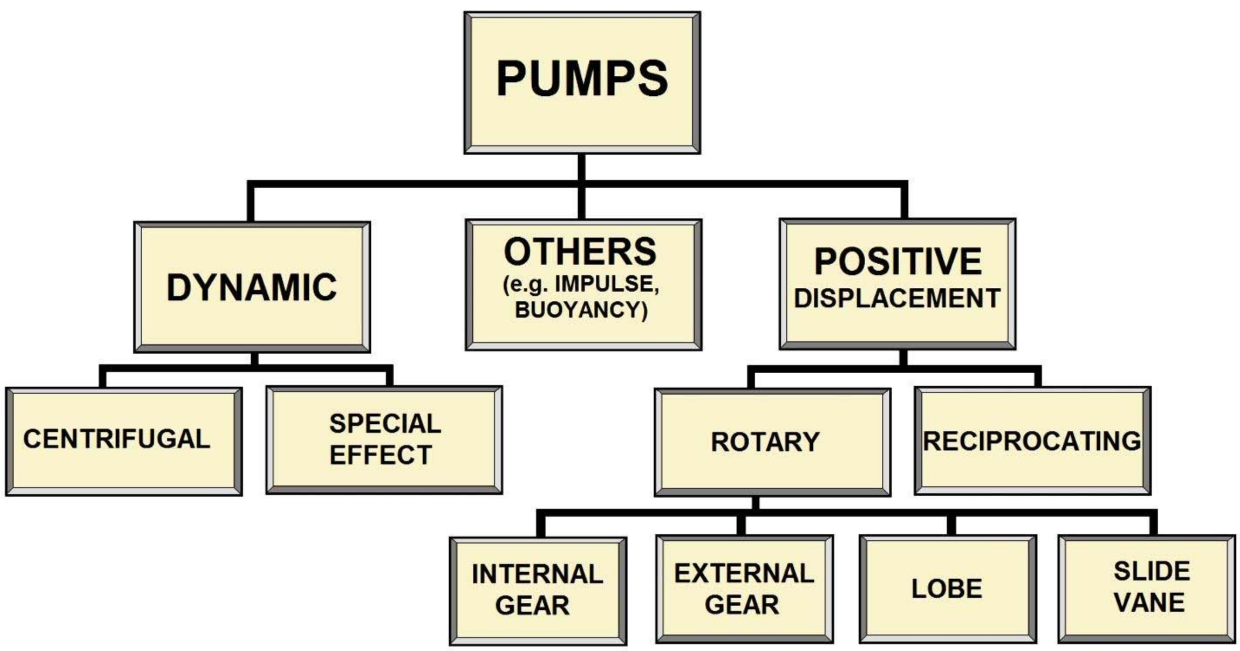
Diaphragm Pumps
In this type of pump, a diaphragm provides the mechanical action used to force liquid from the suction to the discharge side of the pump. The advantage the diaphragm has over the plunger is that the diaphragm pump does not come in contact with moving metal. This can be important when 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.

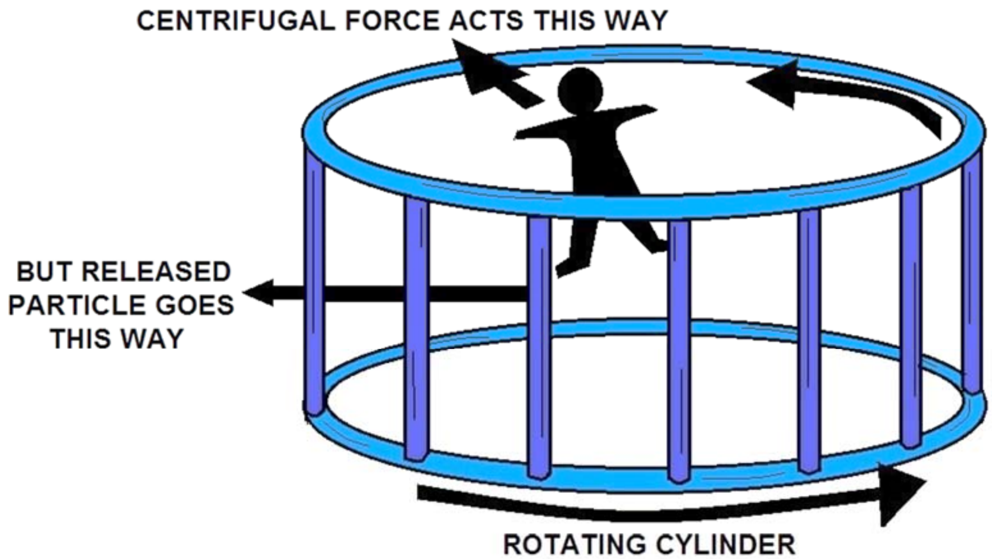
Pumps may be classified on the basis of the application they serve. All pumps may be divided into two major categories: (1) dynamic, in which energy is continuously added to increase the fluid velocities within the machine, and (2) displacement, in which the energy is periodically added by application of force.



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:

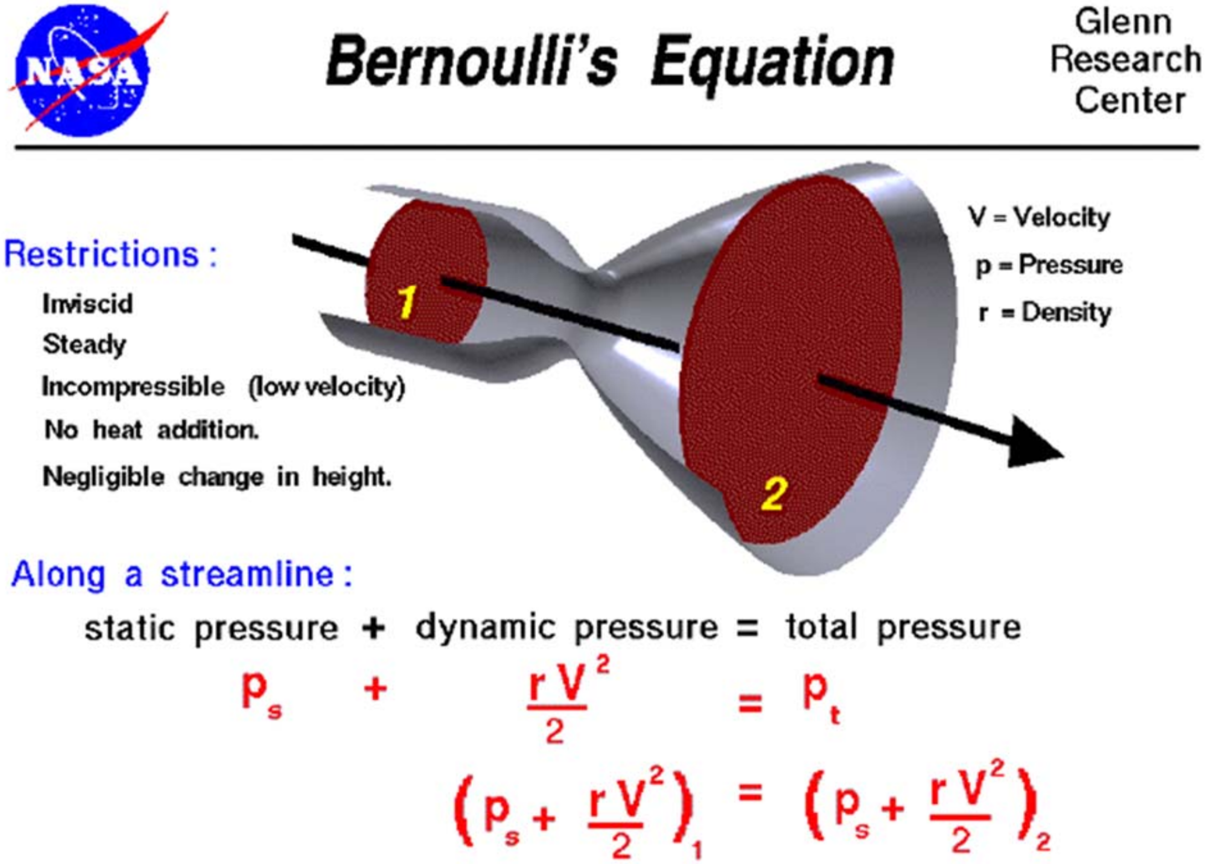


CENTRIFUGAL WATER EFFECTS

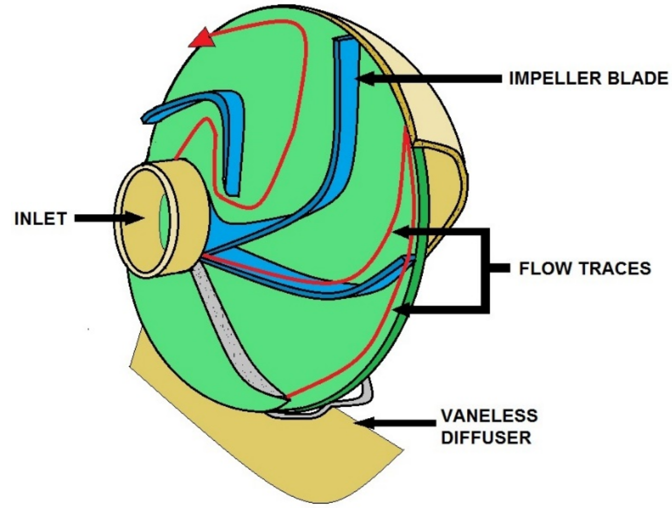
First, you can view the water between the impeller blades as an object traveling in a circle. Objects do not naturally travel in a circle--they need an inward force to cause them to accelerate inward as they spin. Without such an inward force, an object will travel in a straight line and will not complete 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.

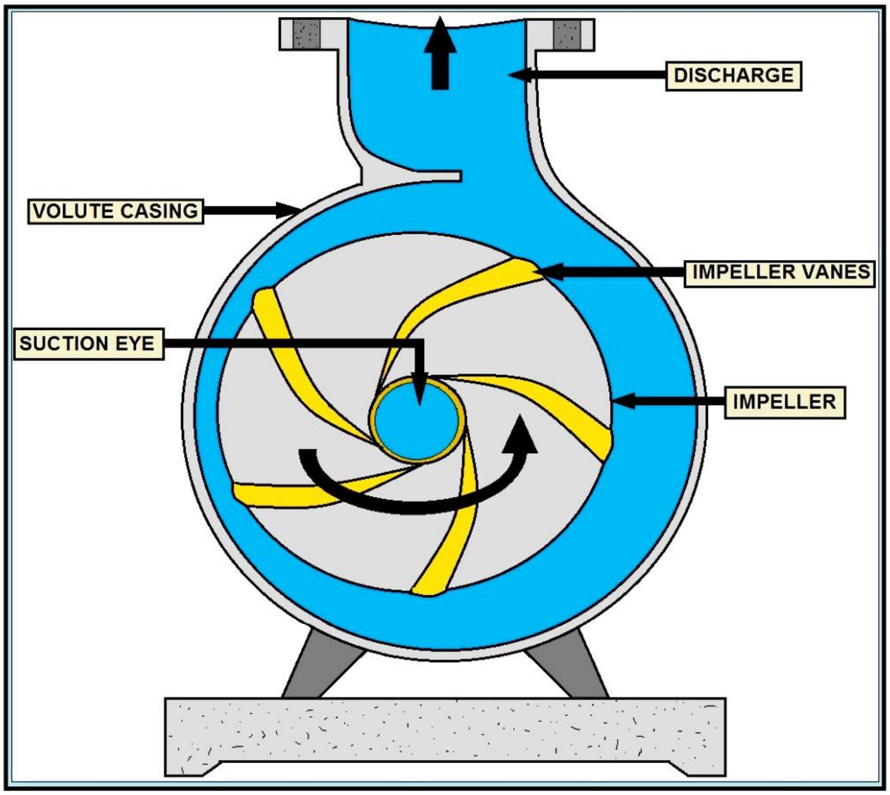
You can also view the water as an incompressible fluid, one that obeys Bernoulli's equation in the appropriate contexts. As water drifts outward between the impeller blades of the pump, it must move faster and faster because its circular path is getting larger and larger. The impeller blades cause the 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



- LIQUID FORCED INTO IMPELLER
- VANES PASS KINETIC ENERGY TO LIQUID BEING PUMPED: LIQUID IS ROTATED AND LEAVES THE IMPELLER
- VOLUTE CASING CONVERTS THE KINETIC ENERGY INTO PRESSURE ENERGY

HOW A CENTRIFUGAL PUMP WORKS

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.

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

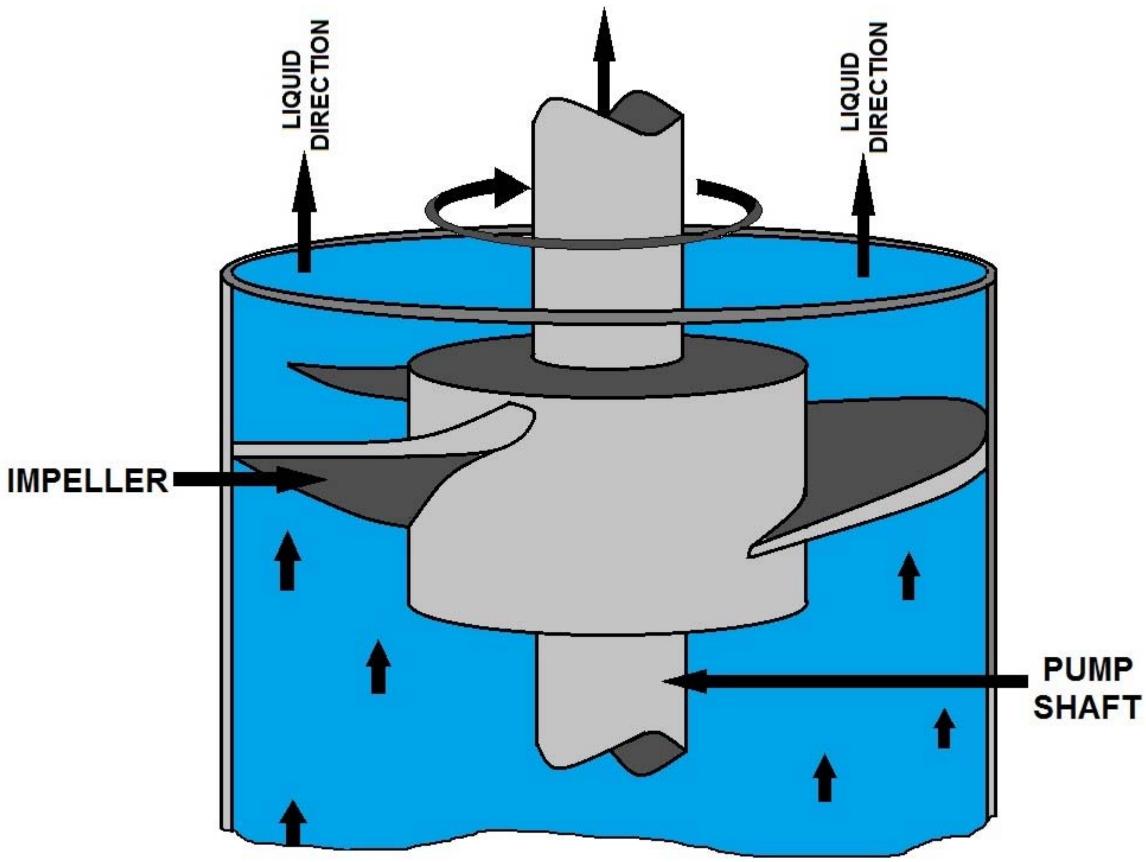
Open lineshaft bearings are lubricated by the pumped fluid and on close coupled units (less than 30' long), will usually not require pre or post lubrication. Enclosed lineshaft bearings are lubricated by extraneous liquid (usually oil or clean water), which is fed to the tension nut by either a gravity 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.



AXIAL FLOW PUMP PRINCIPAL
(IMPELLER FORCES LIQUID IN DIRECTION PARALLEL TO SHAFT)

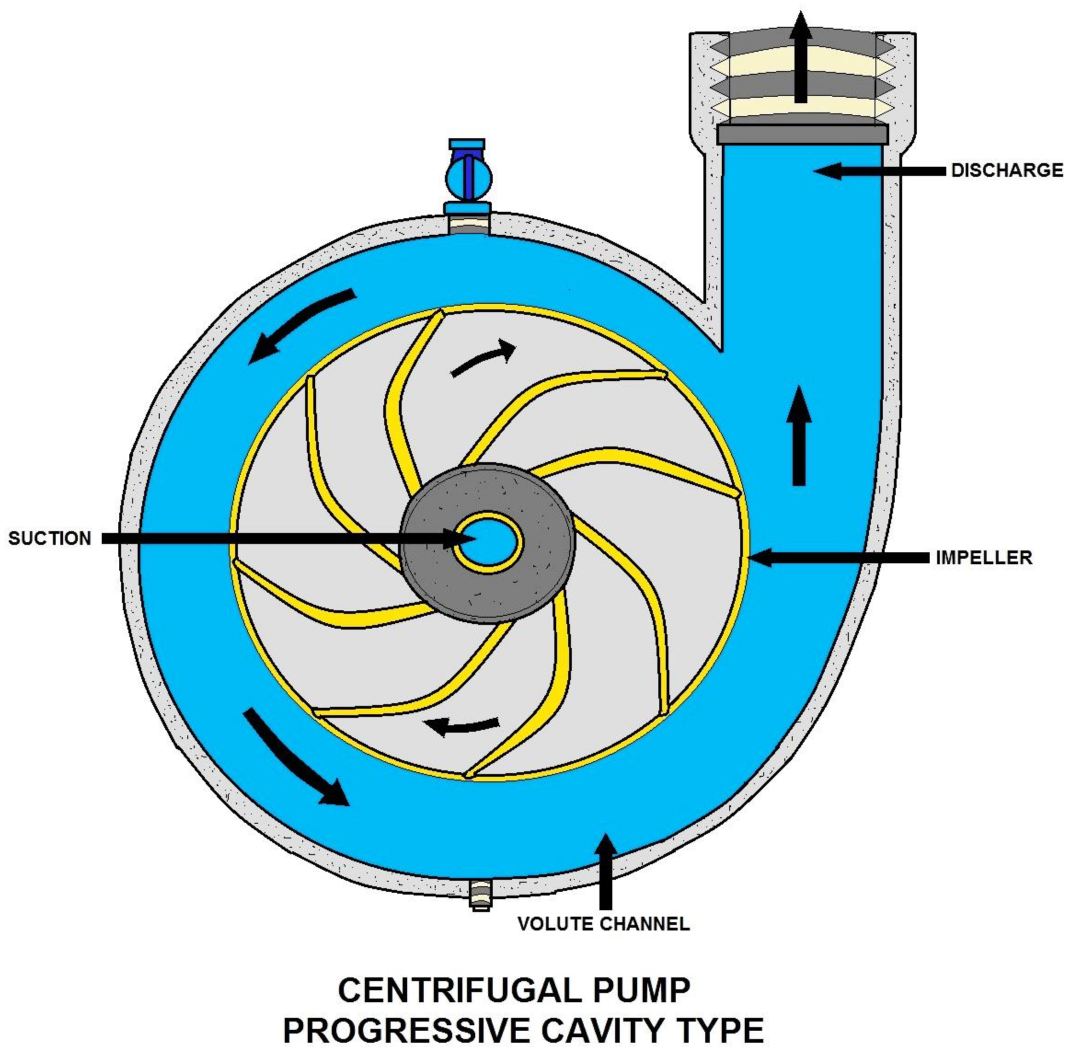
Centrifugal Pump

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.



CENTRIFUGAL PUMP
PROGRESSIVE CAVITY TYPE

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.

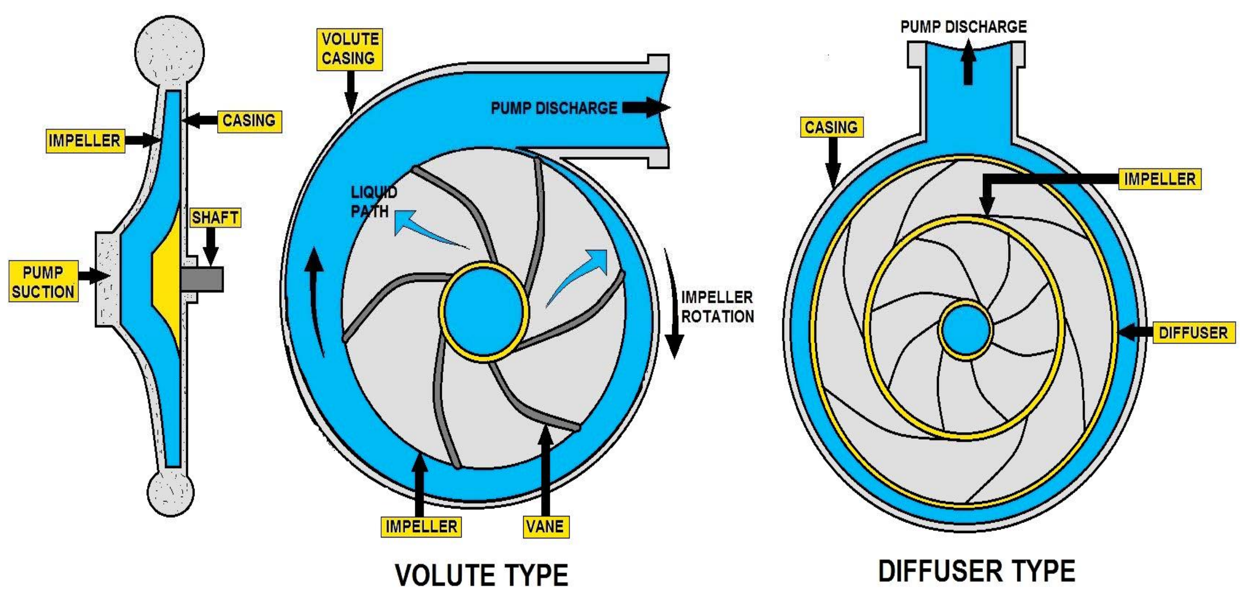
Impellers are also classified as CLOSED or OPEN. Closed impellers have side walls that extend from the eye to the outer edge of the vane tips. Open impellers do not have these side walls. Some small pumps with single-suction impellers have only a casing wearing ring and no impeller ring. In this type 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.

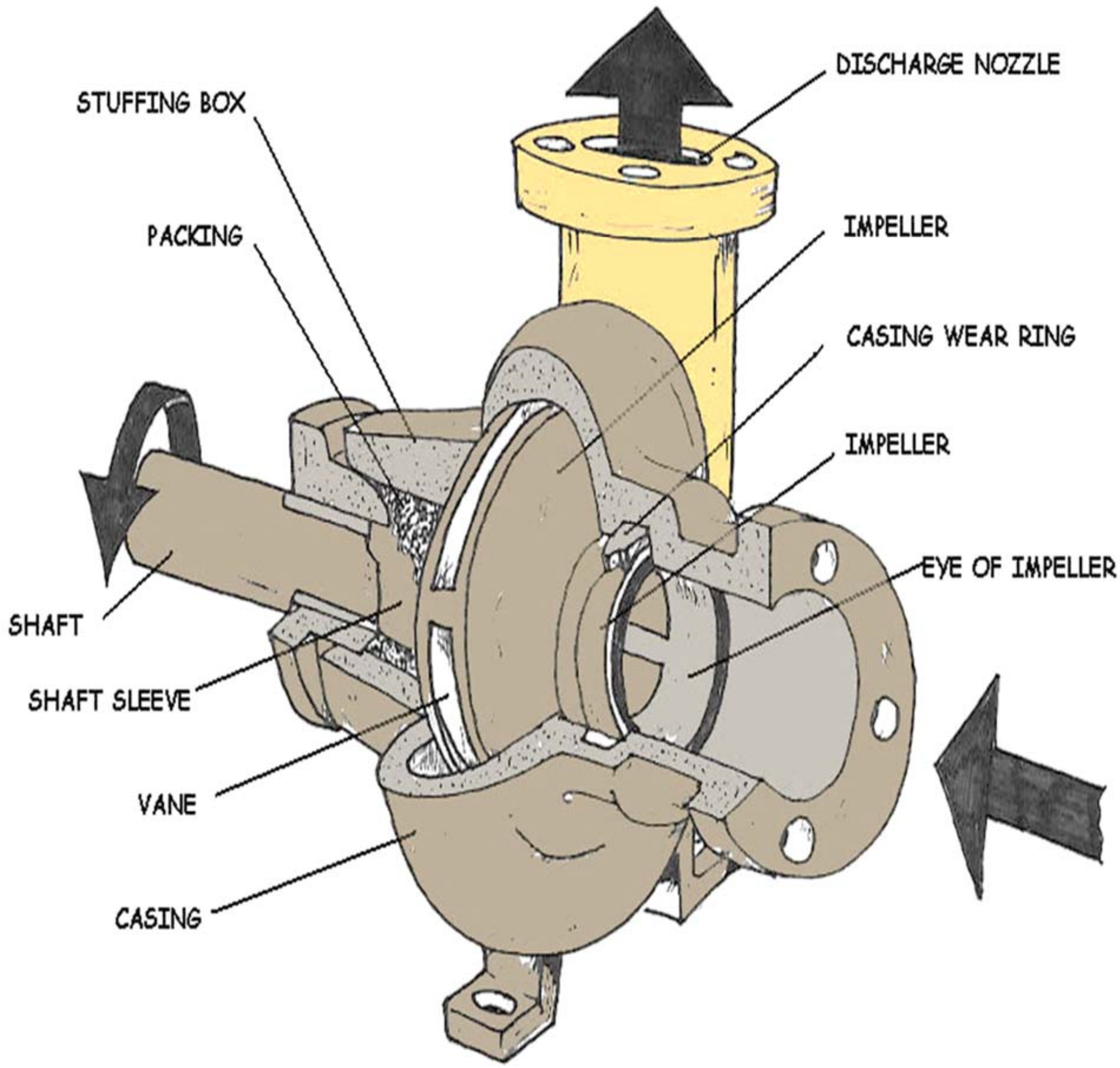
Seal piping leads the liquid from the discharge side of the pump to the annular space formed by the lantern ring. The web of the ring is perforated so that the water can flow in either direction along the shaft (between the shaft and the packing).

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.



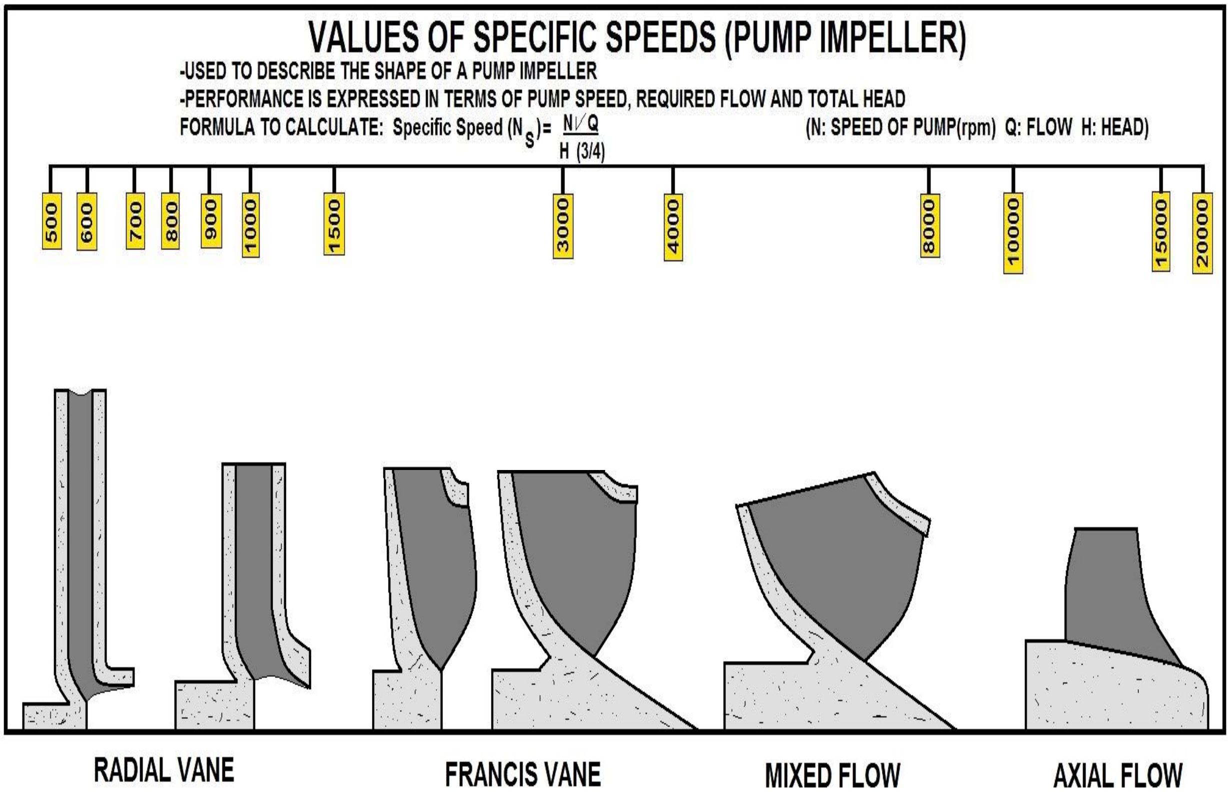
TYPES OF CENTRIFUGAL PUMPS

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.



SPECIFIC SPEED

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

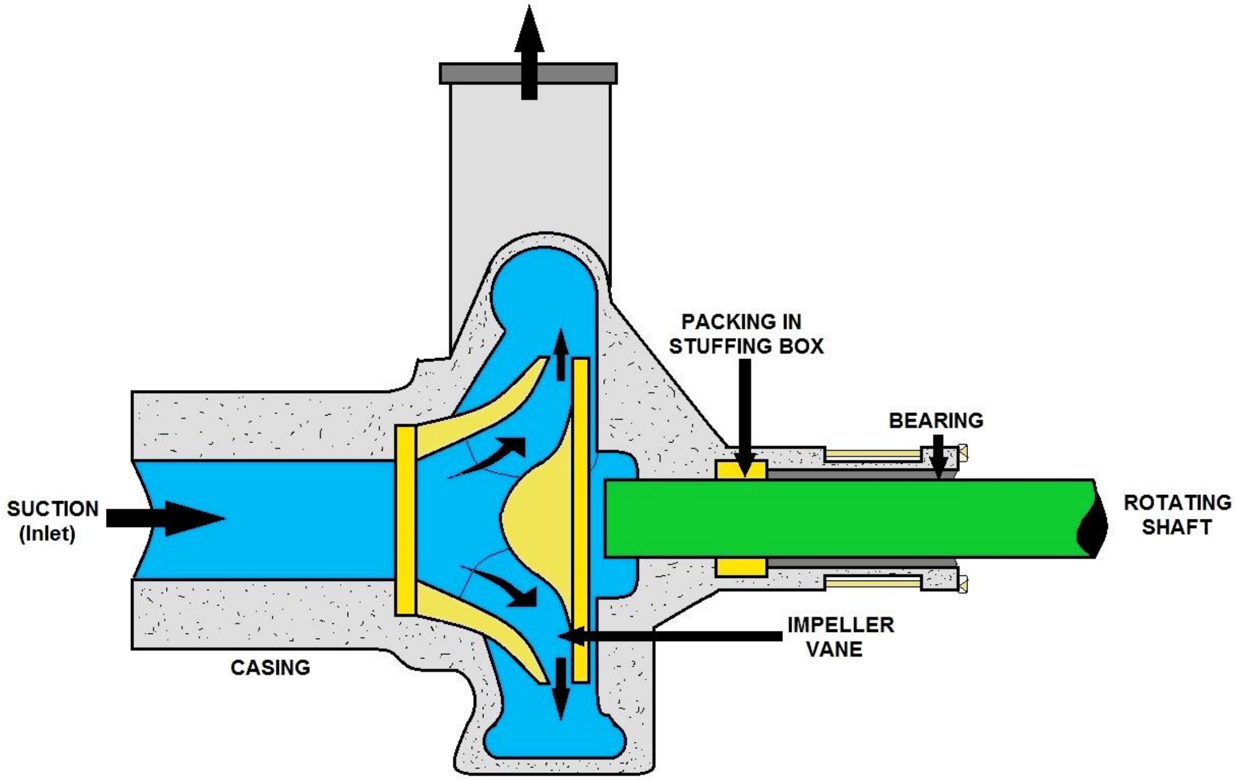
If the speed or impeller diameter of a pump changes, we can calculate the resulting performance change using:

Affinity laws

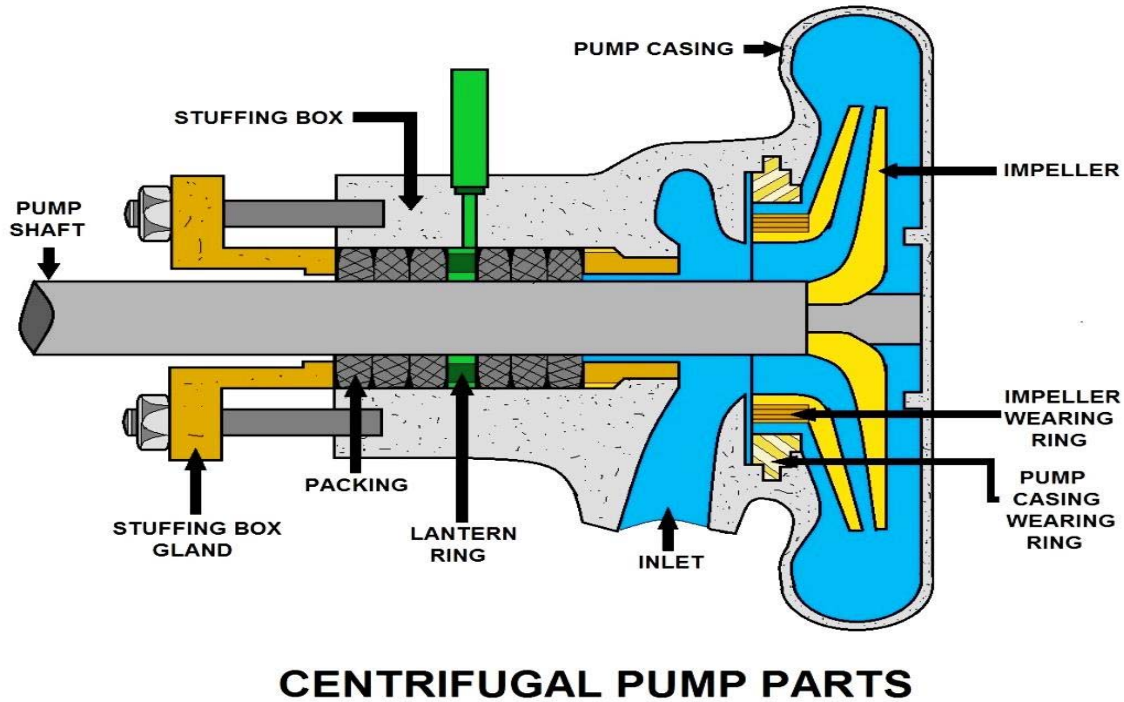
a. The flow changes proportionally to speed
i.e.: double the speed / double the flow
b. The pressure changes by the square of the difference
i.e.: double the speed / multiply the pressure by 4
c. The power changes by the cube of the difference
i.e.: double the speed / multiply the power by 8

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



CENTRIFUGAL PUMP PARTS

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.

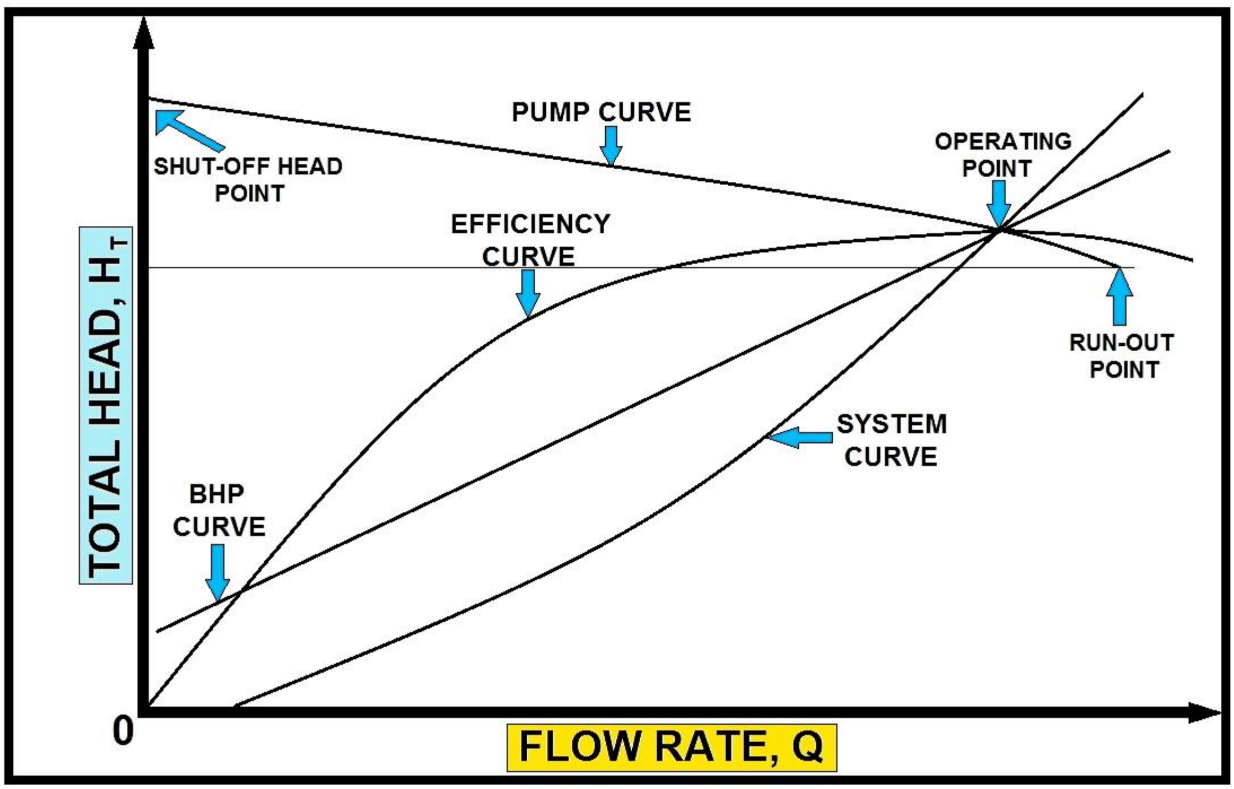
The **critical distance** of the impeller and how it is installed in the casing will determine if it is high volume / low pressure or the type of liquid that could be pumped.

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.

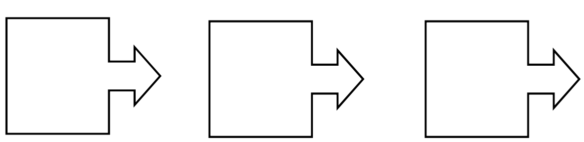
TDH = Static Lift + Static Height + Friction Loss

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 hp = 0.746 kW or $\dfrac{(\text{hp})\ (746\ \text{watts/hp})}{1000\ \text{watts/kW}}$

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.

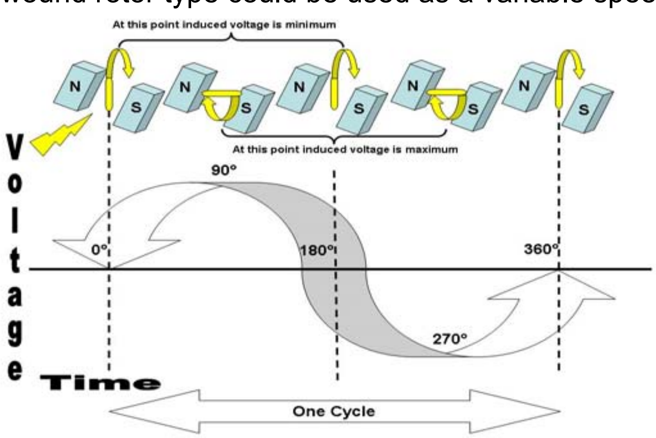
Motors
The purpose of this discussion on pump motors is to identify and describe the main types of motors, starters, enclosures, and motor controls, as well as to provide you with some basic maintenance and troubleshooting information. Although pumps could be driven by diesel or gasoline engines, pumps 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.

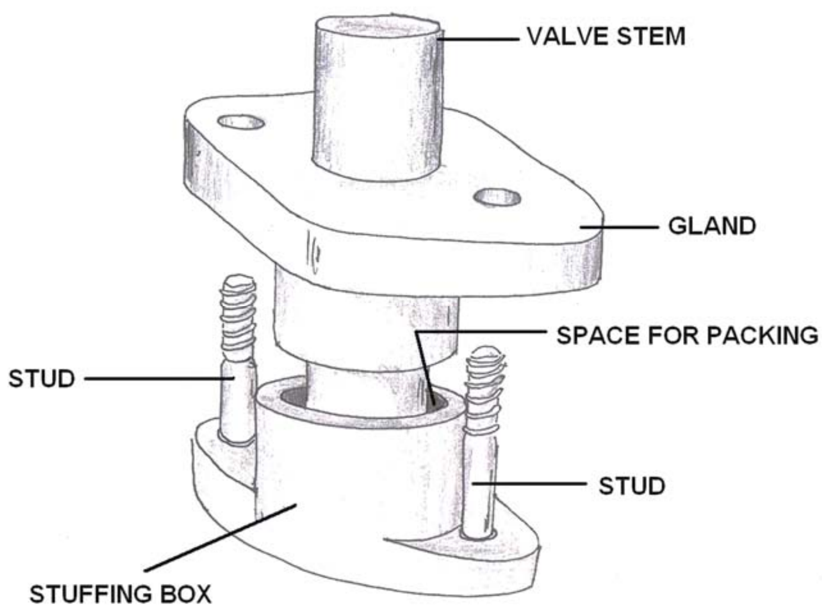
It compensates for small amounts of misalignment between the pump and the motor.

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.

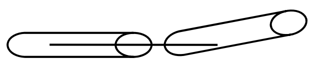


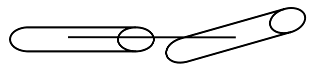
Alignment of Flexible and Rigid Couplings

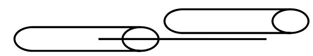
Both flexible and rigid couplings must be carefully aligned before they are connected.

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

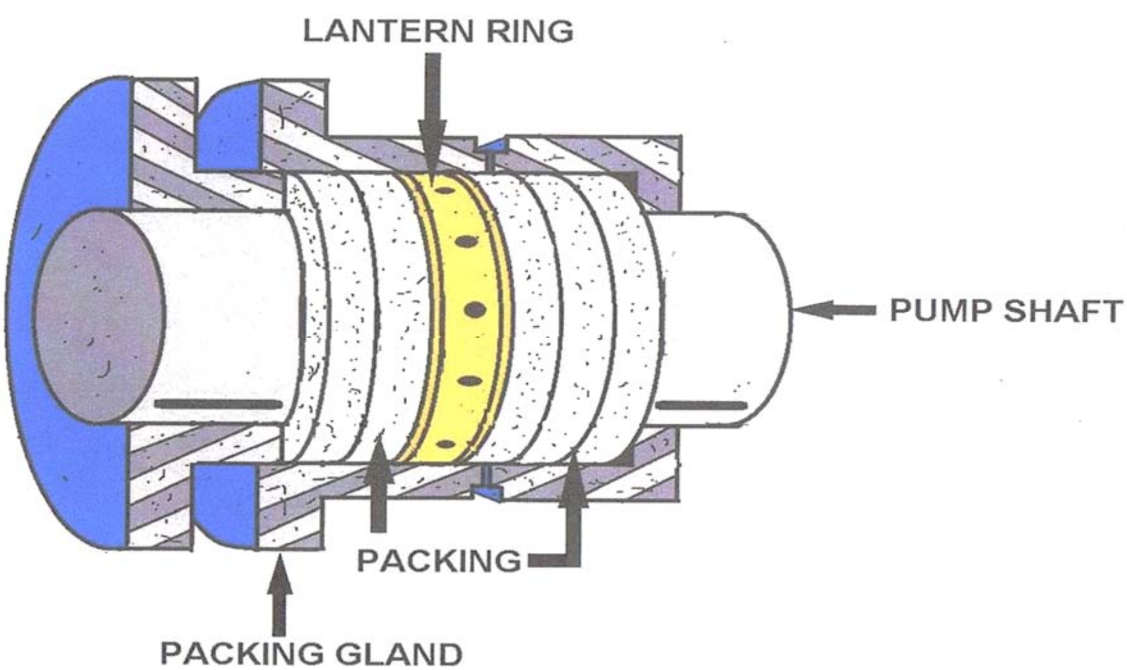
Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on rotary and positive-displacement pumps. Mechanical seals eliminate the problem of excessive stuffing box leakage, which causes failure of pump and motor bearings and motor windings.

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.

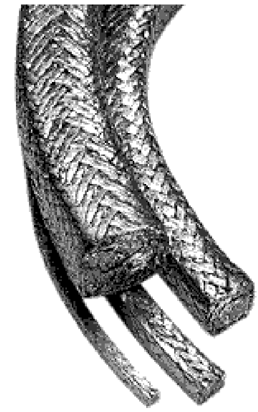
VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure may also cause vibration, as well as noisy operation and fluctuating discharge pressure, 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 broken.

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.

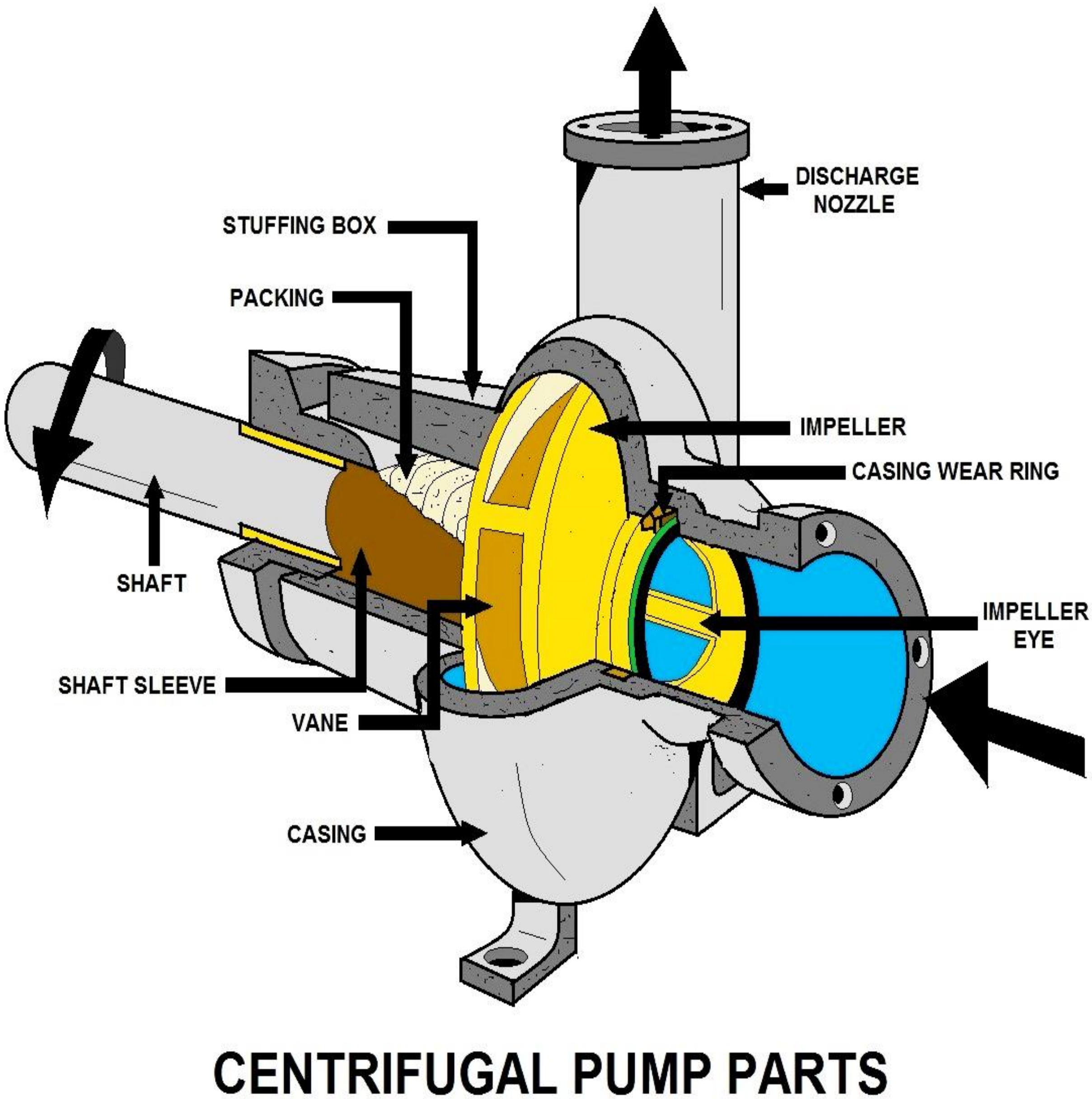
Mechanical Seals

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.

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 outboard ends for easy mechanical seal mounting.

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.



CENTRIFUGAL PUMP PARTS

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

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. $\frac{600\ \cancel{L}}{1} \quad \frac{1\ GAL}{3.785\ \cancel{L}} = 158.5\ GAL / 45.8\ SEC.$

2. $\frac{158.5\ \cancel{GAL}}{45.8\ SEC} \quad \frac{1\ CU\ FT}{7.48\ \cancel{GAL}} = .463\ CFS$

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. $\frac{199\ GAL}{1\ \cancel{MIN}} \quad \frac{1440\ \cancel{MIN}}{1\ DAY} = \frac{286560}{1,000,000} = .28656\ MGD$

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. $\frac{25\ GAL}{MIN} \quad \frac{1\ CU\ FT}{7.48\ GAL} \quad \frac{74.9\ LBS}{1\ CU\ FT} \quad \frac{1440\ MIN}{1\ DAY} = 360481.28\ LBS/DAY$

$\frac{25\ GAL}{MIN} \quad \frac{1440\ MIN}{1\ DAY} =$ 2. $\frac{GAL}{DAY} \quad \frac{1\ CU\ FT}{7.48\ GAL} =$ 3. $\frac{CU\ FT}{DAY} \quad \frac{74.9\ LBS}{1\ CU\ FT} = \frac{LBS}{DAY}$

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. $240\ CU\ FT. \times \frac{7.48\ GAL}{1\ CU\ FT.} = 1795.2\ GAL$

4. $1795.2\ GAL \times \frac{9\ TIMES}{1\ HOUR} \times \frac{24\ HOURS}{1\ DAY} = \frac{387763.2\ GAL}{1,000,000\ DAY} = .388\ MGD$

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. $.785 \times DIAMETER^2 \times DEPTH = V\ CU\ FT.$

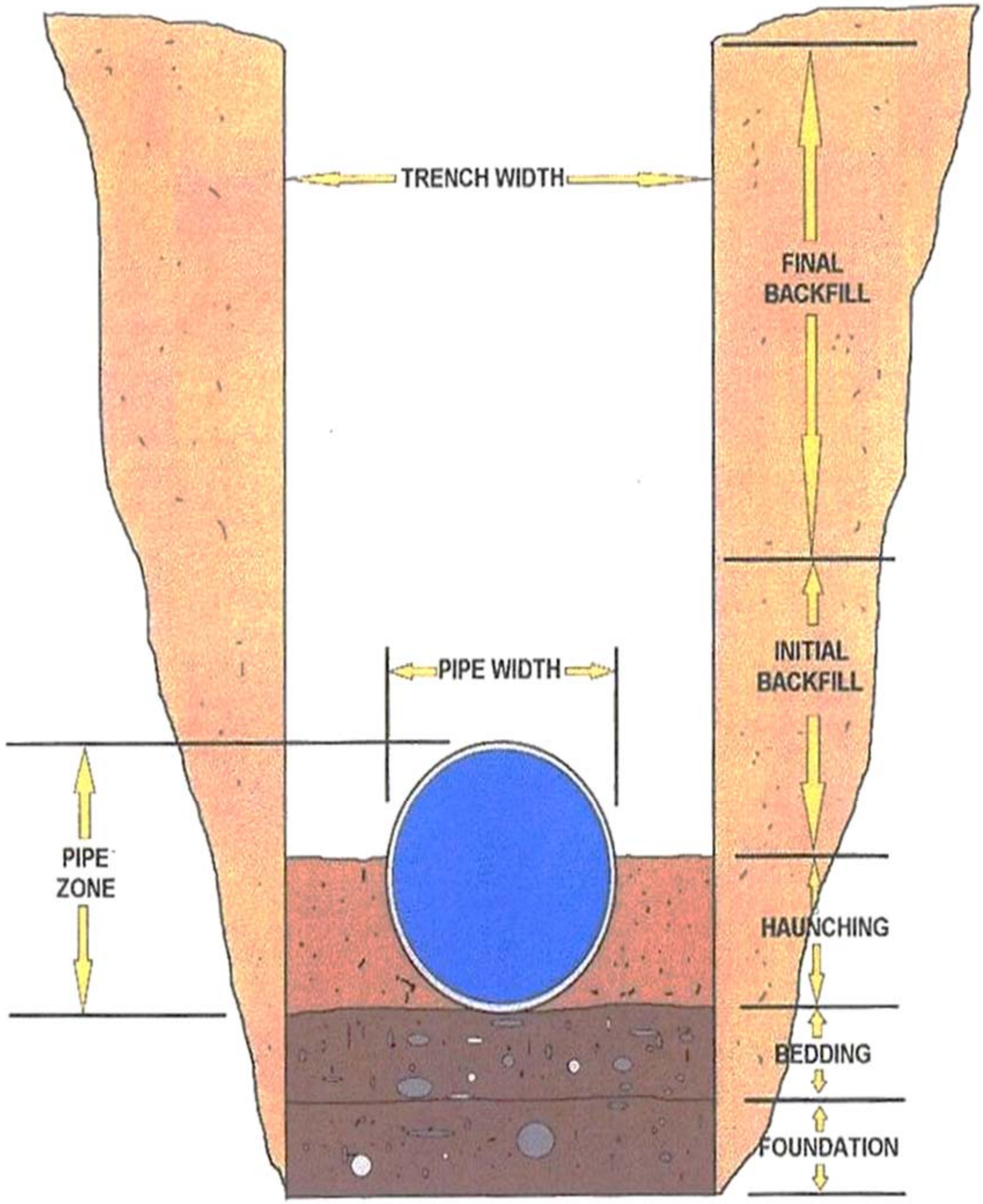
2. $.785 \times 10' \times 10' \times 6' = \underline{471}\ CU\ FT. \times \frac{7.48\ GAL}{CU\ FT.} = \underline{3523.08}\ GAL$

3. $\frac{3523.08\ GAL}{17.75\ MIN} = \underline{198.483}\ GPM$

Safety Chapter 5

Melissa shown here; allow TLC to teach you the Trenching and Shoring or Competent Person class, I guarantee that you will enjoy the class.

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. They have authorization to take prompt corrective measures to eliminate hazards. The Competent Person also is trained and knowledgeable about soil analysis and the use of protective systems.



CROSS-SECTION OF A TRENCH

Lockout - Tagout
(LOTO)

Purpose
Control of Hazardous energy is the purpose of the Lockout-Tagout Policy. This policy establishes the requirements for isolation of both kinetic and potential electrical, chemical, thermal, hydraulic, pneumatic and gravitational energy prior to equipment repair, adjustment or removal. The Lockout-Tagout electrical safety policy is part of your overall Safety Program. If you do not understand this policy, it is your responsibly to ask your supervisor to have this policy explained to you. (Reference: OSHA Standard 29 CFR 1910. 147, the control of hazardous energy).

Definitions
Authorized (Qualified) Employees are the only ones certified to lock and tagout equipment or machinery. Whether an employee is considered to be qualified will depend upon various circumstances in the workplace. It is likely for an individual to be considered "**qualified**" with regard to certain equipment in the workplace, but "unqualified" as to other equipment. An employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person, is considered to be "**qualified**" for the performance of those duties.

Affected Employees are those employees who operate machinery or equipment upon which lockout or tagging out is required under this program. Training of these individuals will be less stringent in that it will include the purpose and use of the lockout procedures.

Other Employees are identified as those that do not fall into the authorized, affected or qualified employee category. Essentially, it will include all other employees. These employees will be provided instruction in what the program is and not to touch any machine or equipment when they see that it has been locked or tagged out.

Training
Authorized Employees Training
All maintenance employees and Department Supervisors will be trained to use the Lock and Tagout Procedures. The training will be conducted by the Supervisor or Safety Coordinator at time of initial hire. Retraining shall be held at least annually.

The training will consist of the following:
- Review of General Procedures
- Review of Specific Procedures for machinery, equipment and processes
- Location and use of Specific Procedures
- Procedures when questions arise

Affected Employee Training

- ✓ Only trained and authorized employees will repair, replace or adjust machinery, equipment or processes.
- ✓ Affected employees may not remove locks, locking devices or tags from machinery, equipment or circuits.
- ✓ Purpose and use of the lockout procedures.

Other Employee Training

- ✓ Only trained and authorized employees will repair, replace or adjust machinery or Equipment.
- ✓ Other employees may not remove locks, locking devices or tags from machinery, equipment or circuits.

Preparation for Lock and Tagout Procedures

A Lockout - Tagout survey will be conducted to locate and identify all energy sources to verify which switches or valves supply energy to machinery and equipment. Dual or redundant controls will need to be removed.

A Tagout Schedule will be developed for each piece of equipment and machinery. This schedule describes the energy sources, location of disconnects, type of disconnect, special hazards and special safety procedures. The schedule will be reviewed each time to ensure employees properly lock and tag out equipment and machinery.

If a Tagout Schedule does not exist for a particular piece of equipment, machinery and process, one must be developed prior to conducting a Lockout - Tagout. As repairs and/or renovations of existing electrical systems are made, standardized controls will be used. It is your departmental supervisor's responsibility to ensure that a schedule is made.

Routine Maintenance & Machine Adjustments

Lock and Tag out procedures are not required if equipment must be operating for proper adjustment. This rare exception may be used only by trained and authorized employees when specific procedures have been developed to safely avoid hazards with proper training. All consideration shall be made to prevent the need for an employee to break the plane of a normally guarded area of the equipment by use of tools and other devices.

SOP: General Lock and Tag out Procedures

Before working on, repairing, adjusting or replacing machinery and equipment, the following procedures will be utilized to place the machinery and equipment in a neutral or zero mechanical state.

Preparation for Shutdown

Before authorized or affected employees turn off a machine or piece of equipment, the authorized employee will have knowledge of the type and magnitude of the energy, the hazards of the energy to be controlled, and the means to control the energy.

Notify all affected employees that the machinery, equipment or process will be out of service.

Machine or Equipment Shutdown

The machine or equipment will be turned off or shut down using the specific procedures for that specific machine.

An orderly shutdown will be utilized to avoid any additional or increased hazards to employees as a result of equipment de-energization. If the machinery, equipment, or process is in operation, follow normal stopping procedures (depress stop button, open toggle switch, etc.).

Move switch or panel arms to "**Off**" or "**Open**" positions and close all valves or other energy isolating devices so that the energy source(s) is disconnected or isolated from the machinery or equipment.

Machine or Equipment Isolation
All energy control devices that are needed to control the energy to the machine or equipment will be physically located and operated in such a manner as to isolate the machine or equipment from the energy source.

Lockout or Tagout Device Application
Lockout or tagout devices will be affixed to energy isolating devices by authorized employees. Lockout devices will be affixed in a manner that will hold the energy isolating devices from the "**safe**" or "**off**" position.

Where tagout devices are used they will be affixed in such a manner that will clearly state that the operation or the movement of energy isolating devices from the "**safe**" or "**off**" positions is prohibited. The tagout devices will be attached to the same point a lock would be attached. If the tag cannot be affixed at that point, the tag will be located as close as possible to the device in a position that will be immediately obvious to anyone attempting to operate the device. Lock and tag out all energy devices by the use of hasps, chains and valve covers with assigned individual lock(s).

Stored Energy
Following the application of the lockout or tagout devices to the energy isolating devices, all potential or residual energy will be relieved, disconnected, restrained, and otherwise rendered safe.

Where the re-accumulation of stored energy to a hazardous energy level is possible, verification of isolation will be continued until the maintenance or servicing is complete. Stored energy (capacitors, springs, elevated members, rotating fly wheels, and hydraulic/air/gas/steam systems) must be relieved or restrained by grounding, repositioning, blocking and/or bleeding the system.

Verification of Isolation
Prior to starting work on machines or equipment that have been locked or tagged out, the authorized employees will verify that isolation or de-energization of the machine or equipment has been accomplished. After assuring that no Employee will be placed in danger, test all lock and tag outs by following the normal start up procedures (depress start button, etc.). ***Caution:*** After Test, place controls in neutral position.
Extended Lockout - Tagout

Should the shift change before the machinery or equipment can be restored to service, the lock and tag out must remain. If the task is reassigned to the next shift, those Employees must lock and tag out before the previous shift may remove their lock and tag.

SOP Example: Release from LOCKOUT/TAGOUT
Before lockout or tagout devices are removed and the energy restored to the machine or equipment, the following actions will be taken:
1. The work area will be thoroughly inspected to ensure that nonessential items have been removed and that machine or equipment components are operational.
2. The work area will be checked to ensure that all employees have been safely positioned or removed. Before the lockout or tagout devices are removed, the affected employees will be notified that the lockout or tagout devices are being removed.
3. Each lockout or tagout device will be removed from each energy-isolating device by the employee who applied the device.

SOP: LOTO Procedure for Electrical Plug-Type Equipment
This procedure covers all Electrical Plug-Type Equipment such as Battery Chargers, some Product Pumps, Office Equipment, Powered Hand Tools, Powered Bench Tools, Lathes, Fans, etc. When working on, repairing, or adjusting the above equipment, the following procedures must be utilized to prevent accidental or sudden startup:
1. Unplug Electrical Equipment from wall socket or in-line socket.
2. Attach "**Do Not Operate**" Tag and Plug Box & Lock on end of power cord.
An exception is granted to not lock & tag the plug if the cord & plug remain in the exclusive control of the employee working on, adjusting, or inspecting the equipment.
3. Test Equipment to assure power source has been removed by depressing the "**Start**" or "**On**" Switch.
4. Perform required operations.
5. Replace all guards removed.
6. Remove Lock & Plug Box and Tag.

7. Inspect power cord and socket before plugging equipment into power source. Any defects must be repaired before placing the equipment back in service.
NOTE: Occasionally used equipment may be unplugged from power source when not in use.

SOP: LOTO Procedures Involving More Than One Employee
In the preceding SOPs, if more than one employee is assigned to a task requiring a lock and tag out, each must also place his or her own lock and tag on the energy isolating device(s).

SOP: Management's Removal of Lock and Tag Out
*Only the employee that locks and tags out machinery, equipment or processes may remove his/her lock and tag.

Excavation & Trenching Section

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.

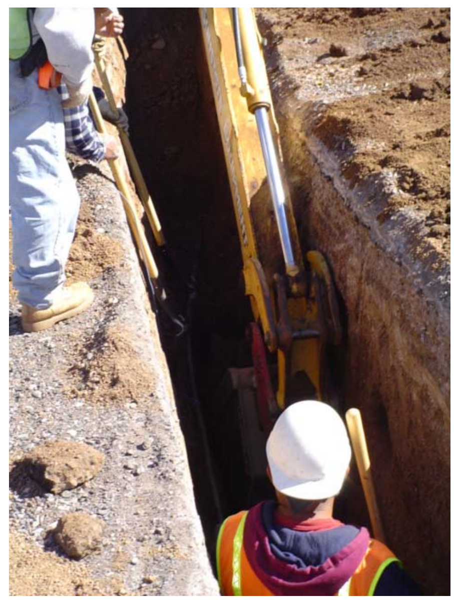
REFERENCES

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.

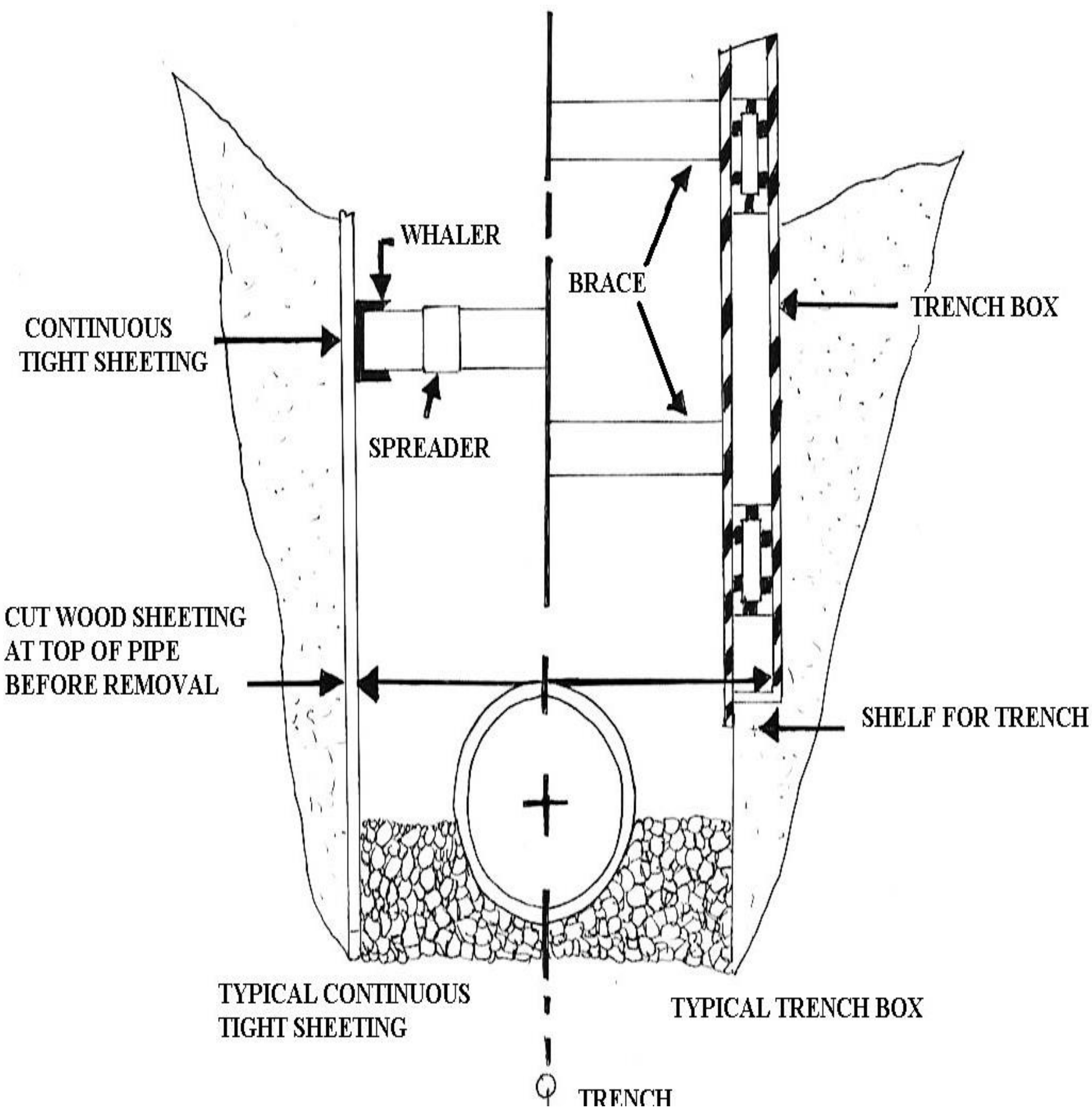
A competent person is required to:

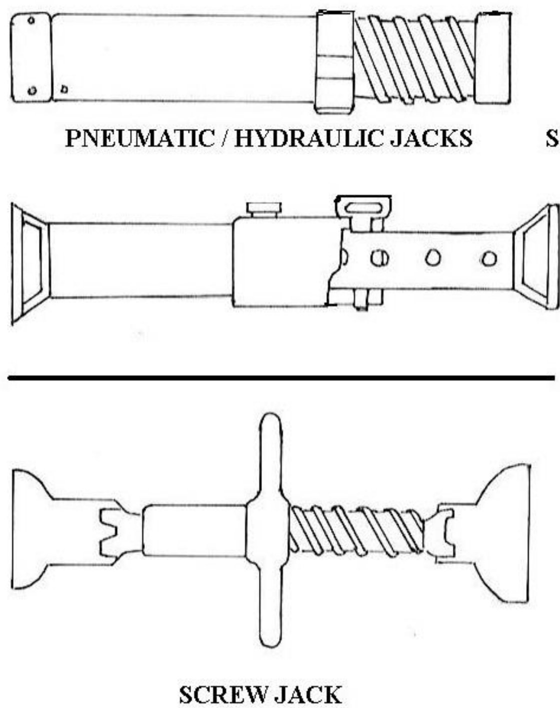
- ✓ Have a complete understanding of the applicable safety standards and any other data provided.
- ✓ Assure the proper locations of underground installations or utilities, and that the proper utility companies have been contacted.
- ✓ Conduct soil classification tests and reclassify soil after any condition 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.

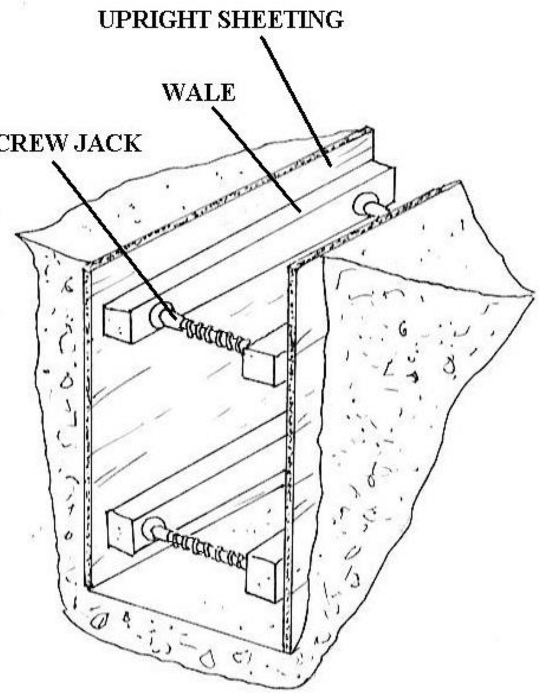
Excavation Safety Plan

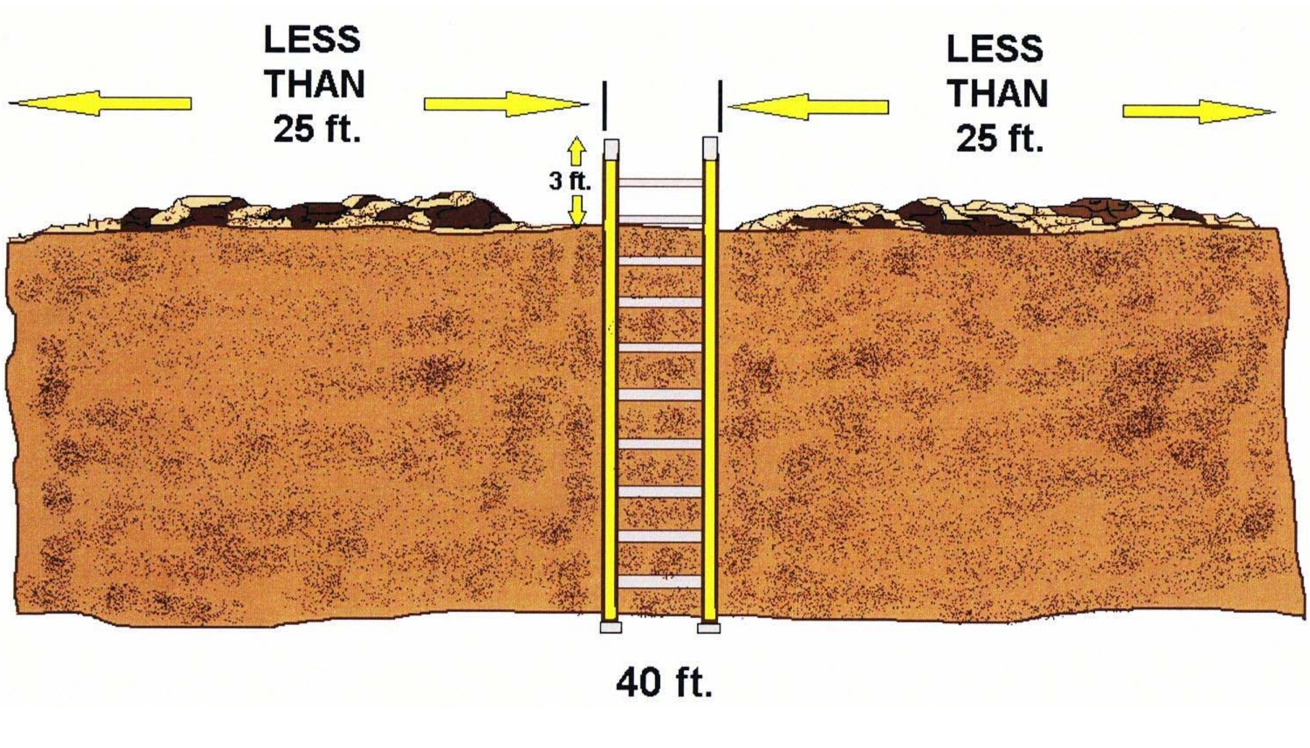
An excavation safety plan is required in written form. This plan is to be developed to the level necessary to ensure complete compliance with the OSHA Excavation Safety Standard and state and local safety standards.

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.




PNEUMATIC / HYDRAULIC JACKS
SCREW JACK


UPRIGHT SHEETING
WALE
SCREW JACK


LESS THAN 25 ft.
LESS THAN 25 ft.
3 ft.
40 ft.

Confined Space Entry Program

Purpose

The Confined Space Entry Program is provided to protect authorized employees that will enter confined spaces and may be exposed to hazardous atmospheres, engulfment in materials, conditions which may trap or asphyxiate due to converging or sloping walls, or contains any other safety or health hazards.

Reference: OSHA-Permit-Required Confined Spaces (**29 CFR 1910.146**).

Scope

You are required to recognize the dangers and hazards associated with confined spaces, and this program is designed to assist you in the safety of and compliance with the OSHA standards associated with such.

Most communities will utilize the Fire Department for all rescues and additional assistance dealing with confined spaces, understanding that most Fire Department operations utilize additional in house SOG's/SOP's pertaining to such operations.

Definitions

Confined space:

Is large enough or so configured that an employee can bodily enter and perform work.

Has limited or restricted means for entry or exit (i.e. tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).

Is not designed for continuous employee occupancy.

Permit required confined space (permit space), is a confined space that has one or more of the following characteristics:

1. Contains or has a potential to contain a hazardous atmosphere.

2. Contains a material that has the potential for engulfing an entrant.

3. Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly covering walls or by a floor which slopes downward and tapers to a smaller cross-section.

4. Contains any other recognized serious safety or health hazard.

Each Permit-Required Confined Space will be marked

"***Confined Space - Entry Permit Required***".

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.

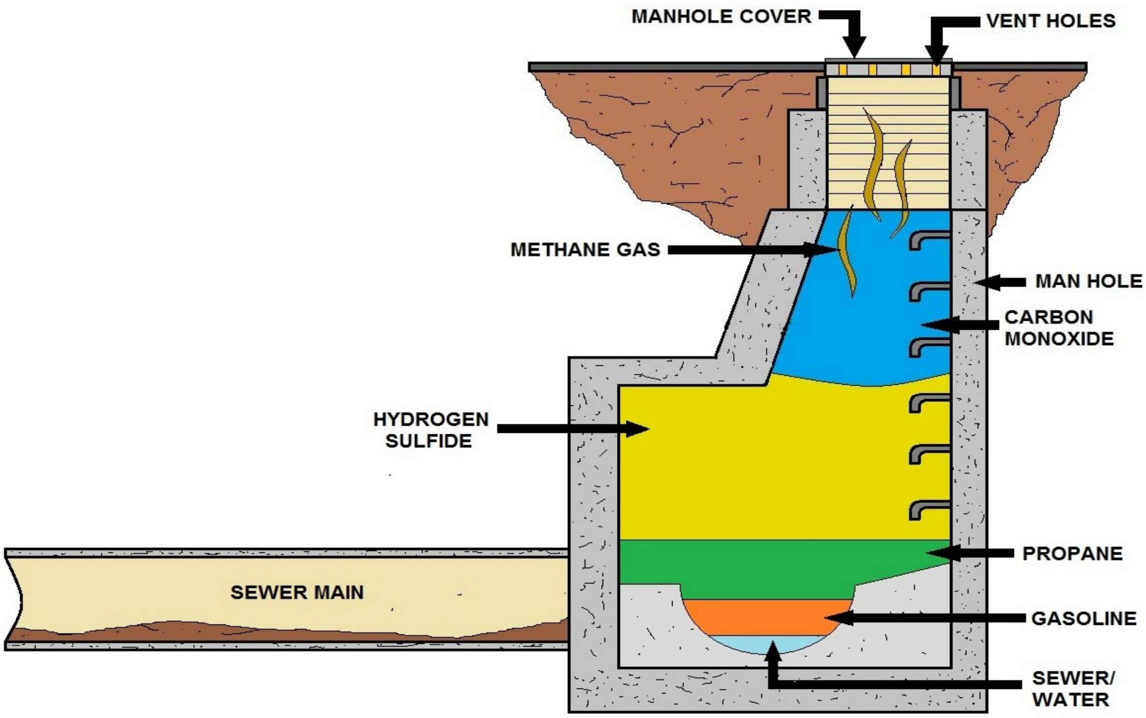
Attendant must be present at all times.

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.

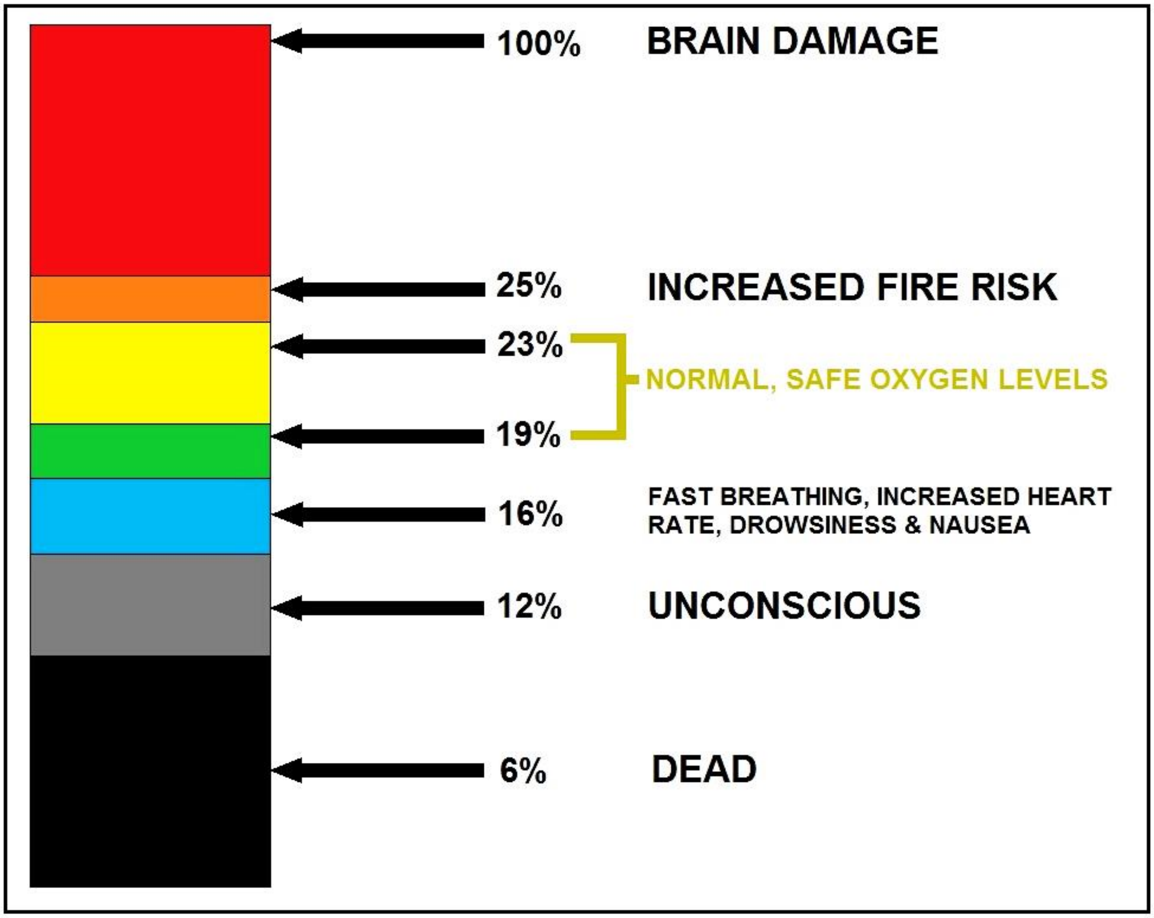
Ventilation & oxygen monitoring is required when welding is performed.



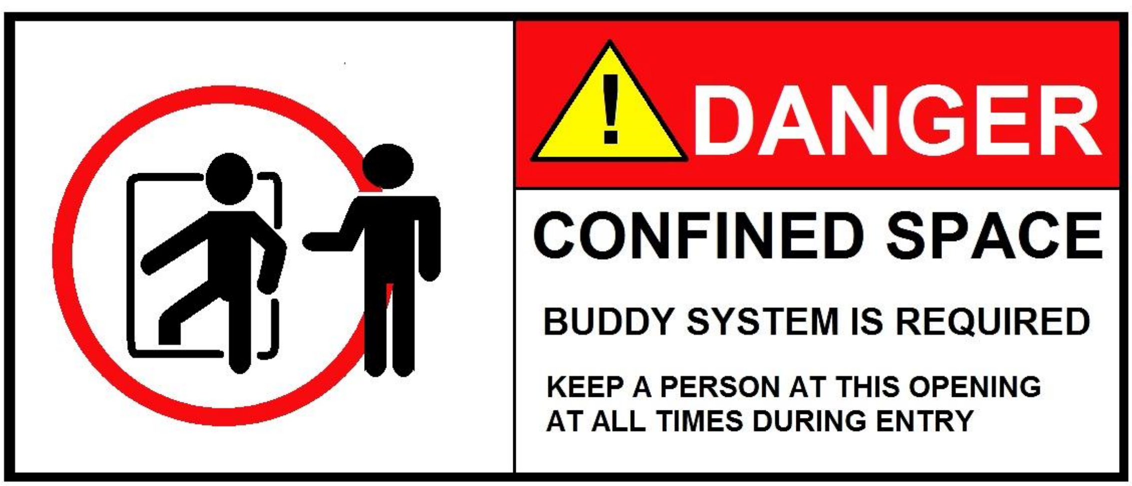
POSSIBLE HAZARDOUS ATMOSPHERES PRESENT IN A CONFINED SPACE (EXAMPLE IS OF A SEWER MAIN)

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



RESULTS OF OXYGEN LEVELS IN CONFINED SPACES



EXAMPLE OF A CONFINED SPACE ENTRY DANGER SIGN

Confined Space Hazards

Fatalities and injuries constantly occur among construction workers who, during the course of their jobs, are required to enter confined spaces. In some circumstances, these workers are exposed to multiple hazards, any of which may cause bodily injury, illness, or death.

Newspaper and magazine articles abound with stories of workers injured and killed from a variety of atmospheric factors and physical agents. Throughout the construction jobsite, contractors and workers encounter both inherent and induced hazards within confined workspaces.

Inherent Hazards
Inherent hazards, such as electrical, thermal, chemical, mechanical, etc., are associated with specific types of equipment and the interactions among them.

Examples include high voltage (shock or corona discharge and the resulting burns), radiation generated by equipment, defective design, omission of protective features (no provision for grounding non-current-carrying conductive parts), high or low temperatures, high noise levels, and high-pressure vessels and lines (rupturing with resultant release of fragments, fluids, gases, etc.).

Inherent hazards usually cannot be eliminated without degrading the system or equipment, or without making them inoperative. Therefore, emphasis must be placed on hazard control methods.

Induced Hazards
Induced hazards arise, and are induced from, a multitude of incorrect decisions and actions that occur during the actual construction process. Some examples are: omission of protective features, physical arrangements that may cause unintentional worker contact with electrical energy sources, oxygen-deficient atmospheres created at the bottom of pits or shafts, lack of safety factors in structural strength, and flammable atmospheres.

Typical Examples of Confined Workspaces
Following are typical examples of confined workspaces in construction which contain both inherent and induced hazards.

Vaults
A variety of vaults are found on the construction jobsite. On various occasions, workers must enter these vaults to perform a number of functions.

The restricted nature of vaults and their frequently below-grade location can create an assortment of safety and health problems.

Oxygen-Deficient Atmosphere
One of the major problems confronting construction workers while working in vaults is the ever-present possibility of an oxygen-deficient atmosphere.

Explosive or Toxic Gases, Vapors, or Fumes
While working in an electrical vault, workers may be exposed to the build-up of explosive gases such as those used for heating (propane). Welding and soldering produce toxic fumes which are confined in the limited atmosphere.

Electrical Shock
Electrical shock is often encountered from power tools, line cords, etc. In many instances, such electrical shock results from the fact that the contractor has not provided an approved grounding system or the protection afforded by ground-fault circuit interrupters or low-voltage systems.

Purging
In some instances, purging agents such as nitrogen and argon may enter the vault from areas adjacent to it. These agents may displace the oxygen in the vault to the extent that it will asphyxiate workers almost immediately.

Materials Falling In and On
A hazard normally considered a problem associated with confined spaces is material or equipment which may fall into the vault or onto workers as they enter and leave the vault.

Vibration could cause the materials on top of the vault to roll off and strike workers. If the manhole covers were removed, or if they were not installed in the first place, materials could fall into the vault, causing injury to the workers inside.

Condenser Pits
A common confined space found in the construction of nuclear power plants is the condenser pit. Because of their large size, they are often overlooked as potentially hazardous confined spaces.

These below-grade areas create large containment areas for the accumulation of toxic fumes, gases, and so forth, or for the creation of oxygen-deficient atmospheres when purging with argon, Freon, and other inert gases.

Other hazards will be created by workers above dropping equipment, tools, and materials into the pit.

Manholes
Throughout the construction site, manholes are commonplace. As means of entry into and exit from vaults, tanks, pits, and so forth, manholes perform a necessary function. However, these confined spaces may present serious hazards which could cause injuries and fatalities. A variety of hazards are associated with manholes. To begin with, the manhole could be a dangerous trap into which the worker could fall. Often covers are removed and not replaced, or else they are not provided in the first place.

Pipe Assemblies

One of the most frequently unrecognized types of confined spaces encountered throughout the construction site is the pipe assembly. Piping of sixteen to thirty-six inches in diameter is commonly used for a variety of purposes.

For any number of reasons, workers will enter the pipe. Once inside, they are faced with potential oxygen-deficient atmospheres, often caused by purging with argon or another inert gas. Welding fumes generated by the worker in the pipe, or by other workers operating outside the pipe at either end, subject the worker to toxic atmospheres.

The generally restricted dimensions of the pipe provide little room for the workers to move about and gain any degree of comfort while performing their tasks. Once inside the pipe, communication is extremely difficult. In situations where the pipe bends, communication and extrication become even more difficult. Electrical shock is another problem to which the worker is exposed.

Ungrounded tools and equipment or inadequate line cords are some of the causes. As well, heat within the pipe run may cause the worker to suffer heat prostration.

Ventilation Ducts
Ventilation ducts, like pipe runs, are very common at the construction site. These sheet metal enclosures create a complex network which moves heated and cooled air and exhaust fumes to desired locations in the plant.

Ventilation ducts may require that workers enter them to cut out access holes, install essential parts of the duct, etc. Depending on where these ducts are located, oxygen deficiency could exist. They usually possess many bends, which create difficult entry and exit and which also make it difficult for workers inside the duct to communicate with those outside it. Electrical shock hazards and heat stress are other problems associated with work inside ventilation ducts.

Tanks
Tanks are another type of confined workspace commonly found in construction. They are used for a variety of purposes, including the storage of water, chemicals, etc.

Tanks require entry for cleaning and repairs. Ventilation is always a problem. Oxygen-deficient atmospheres, along with toxic and explosive atmospheres created by the substances stored in the tanks, present hazards to workers. Heat, another problem in tanks, may cause heat prostration, particularly on a hot day.

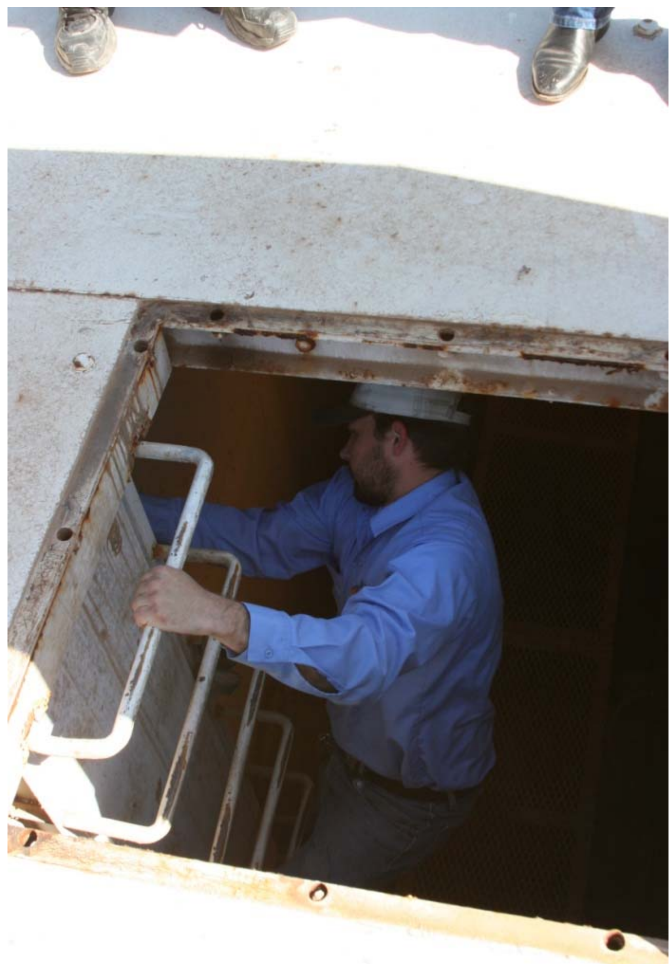
Since electrical line cords are often taken into the tank, the hazard of electrical shock is always present. The nature of the tank's structure often dictates that workers must climb ladders to reach high places on the walls of the tank.

Sumps
Sumps are commonplace. They are used as collection places for water and other liquids. Workers entering sumps may encounter an oxygen-deficient atmosphere.
Also, because of the wet nature of the sump, electrical shock hazards are present when power tools are used inside. Sumps are often poorly illuminated. Inadequate lighting may create an accident situation.

Containment Cavities
These large below-grade areas are characterized by little or no air movement. Ventilation is always a problem. In addition, the possibility of oxygen deficiency exists. As well, welding and other gases may easily collect in these areas, creating toxic atmospheres. As these structures near completion, more confined spaces will exist as rooms are built off the existing structure.

Electrical Transformers
Electrical transformers are located on the jobsite. They often contain a nitrogen purge or dry air. Before they are opened, they must be well vented by having air pumped in. Workers, particularly electricians and power plant operators, will enter these transformers through hatches on top for various work-related reasons. Testing for oxygen deficiency and for toxic atmospheres is mandatory.

Heat Sinks
These larger pit areas hold cooling water in the event that there is a problem with the pumps located at the water supply to the plant--normally a river or lake--which would prevent cooling water from reaching the reactor core.



When in the pits, workers are exposed to welding fumes and electrical hazards, particularly because water accumulates in the bottom of the sink.

Generally, it is difficult to communicate with workers in the heat sink, because the rebar in the walls of the structure deaden radio signals.

Unusual Conditions

Confined Space within a Confined Space
By the very nature of construction, situations are created which illustrate one of the most hazardous confined spaces of all--a confined space within a confined space.

This situation appears as tanks within pits, pipe assemblies or vessels within pits, etc. In this situation, not only do the potential hazards associated with the outer confined space require testing, monitoring, and control, but those of the inner space also require similar procedures.

Often, only the outer space is evaluated. When workers enter the inner space, they are faced with potentially hazardous conditions. A good example of a confined space within a confined space is a vessel with a nitrogen purge inside a filtering water access pit. Workers entering the pit and/or the vessel should do so only after both spaces have been evaluated and proper control measures established.

Hazards in One Space Entering another Space
During an examination of confined spaces in construction, one often encounters situations which are not always easy to evaluate or control. For instance, a room or area which classifies as a confined space may be relatively safe for work.

However, access passages from other areas outside or adjacent to the room could, at some point, allow the transfer of hazardous agents into the "***safe***" one. One such instance would be a pipe coming through a wall into a containment room.

Welding fumes and other toxic materials generated in one room may easily travel through the pipe into another area, causing it to change from a safe to an unsafe workplace.

A serious problem with a situation such as this is that workers working in the "**safe**" area are not aware of the hazards leaking into their area. Thus, they are not prepared to take action to avoid or control it.

Session Conclusion
In this discussion, we have defined inherent and induced hazards in confined spaces. We have examined typical confined spaces on construction sites and we have described representative hazards within these confined spaces.

Here is a small clip-on style multi-purpose gas meter. We tied a string to lower the meter in the confined space to get a gas reading before entering.

Permitted Confined Space Entry Program

Definition of Confined Spaces Requiring an Entry Permit

Confined space:

1. Is large enough or so configured that an employee can bodily enter and perform work.
2. Has limited or restricted means for entry or exit (i.e. tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
3. Is not designed for continuous employee occupancy.

Purpose

The Permit Required Space (**PRCS**) Program is provided to protect authorized employees that will enter confined spaces and may be exposed to hazardous atmospheres, engulfment in materials, conditions which may trap or asphyxiate due to converging or sloping walls, or contains any other safety or health hazards.

Many workplaces contain confined spaces not designed for human occupancy which due to their configuration hinder employee activities including entry, work and exit. Asphyxiation is the leading cause of death in confined spaces.

Subpart P applies to all open excavations in the earth's surface.

All trenches are excavations.

All excavations are not trenches.

Permit Required Confined Space Entry General Rules

During all confined space entries, the following safety rules must be strictly enforced:

1. Only authorized and trained employees may enter a confined space or act as safety watchmen/attendants.

2. No smoking is permitted in a confined space or near entrance/exit area.

3. During confined space entries, a watchmen or attendant must be present at all times.

4. Constant visual or voice communication will be maintained between the safety watchmen and employees entering a confined space.

5. No bottom or side entry will be made or work conducted below the level any hanging material or material which could cause engulfment.

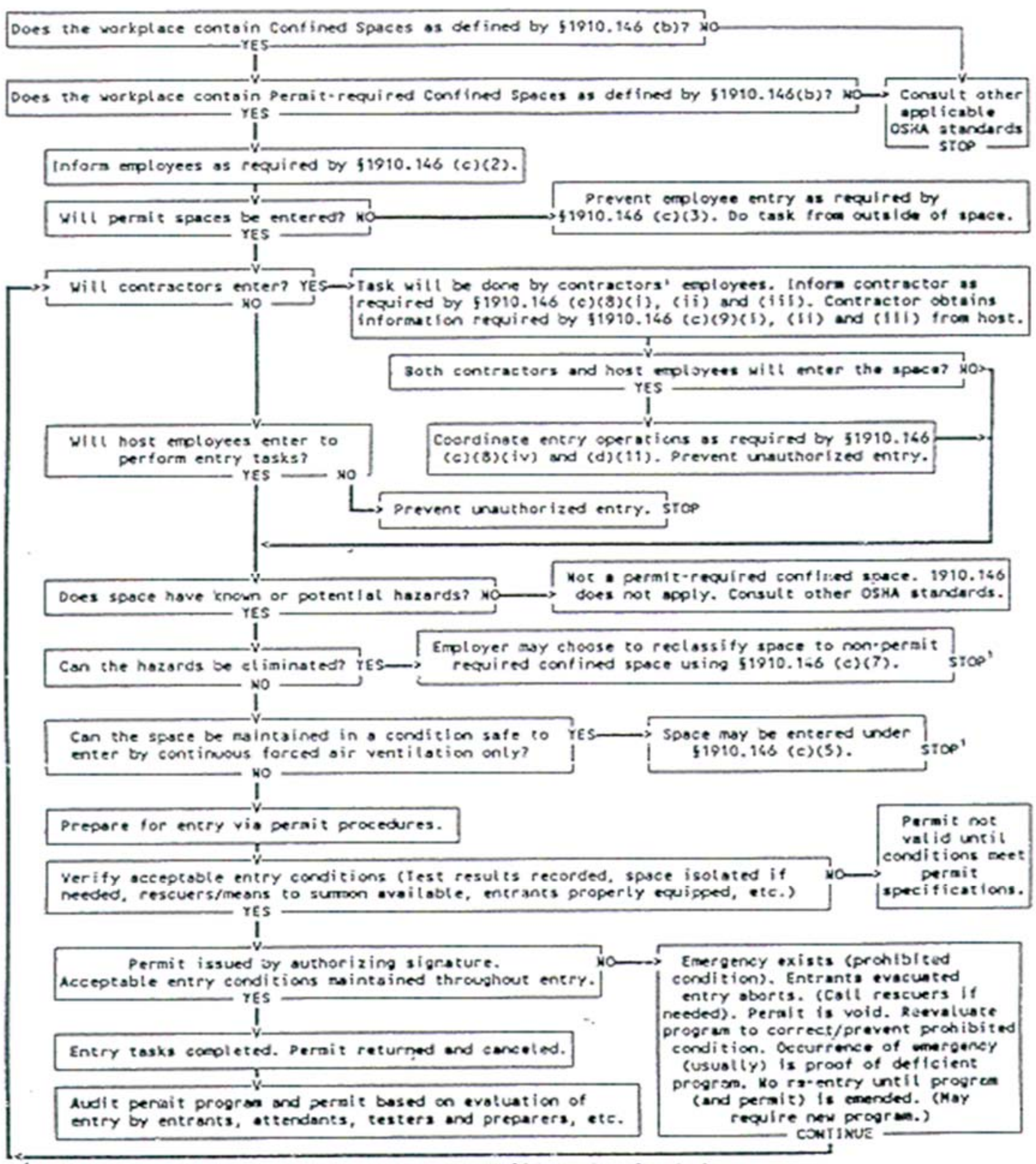
6. Air and oxygen monitoring is required before entering any permit-required confined space. Oxygen levels in a confined space must be between 19.5 and 23.5 percent. Levels above or below will require the use of an SCBA or other approved air supplied respirator. Additional ventilation and oxygen level monitoring is required when welding is performed. The monitoring will check oxygen levels, explosive gas levels and carbon monoxide levels. Entry will not be permitted if explosive gas is detected above one-half the Lower Explosive Limit (**LEL**).

7. To prevent injuries to others, all openings to confined spaces will be protected by a barricade when covers are removed.

Appendix A to §1910.146
Permit-Required Confined Space Decision Flow Chart

Note: Appendices A through F serve to provide information and non-mandatory guidelines to assist employers and employees in complying with the appropriate requirements of this section.

APPENDIX A TO §1910.146—PERMIT-REQUIRED CONFINED SPACE DECISION FLOW CHART



[1] Spaces may have to be evacuated and re-evaluated if hazards arise during entry

Confined Space Entry Permit *Example*

Date & Time Issued		Date & time Expires	
Space I.D.		Supervisor	
Equipment Affected		Task	
Standby Team			
Pre-Entry Atmospheric Checks	Time (am - pm)		
	Oxygen		
	Explosive (% LEL)		
	Toxic (PPM)		
	Testers Signature		

Pre-entry Fluid System Isolation	Yes	No
Pumps /lines blinded, blocked, disconnected		
Ventilation Source Established		
Mechanical Forced Air		
Natural Ventilation		
Post Ventilation Pre-Entry Atmospheric Checks		
Time		
Oxygen (%)		
Explosive (% LEL		
Toxic (PPM)		
Tester Signature		
Communication Procedures Established per specific Confined Space SOP		
Rescue Procedures established per specific Confined Space SOP		

Training Verification - for the following persons & space to be entered	YES	NO
All persons entering Confined Space		
All persons acting as Supervisor for the Entry		
All persons assigned backup positions		
All persons assigned to monitor access and interior activities		
All persons assigned to emergency rescue team		

Equipment on Scene	YES	NO	NA		YES	NO	NA
Gas Monitor				Life Line			
Safety Harness				Hoisting Equipment			
Fall Arrest Gear				Powered Comm Eq.			
SCBAs				Air Line Respirators			
Protective Clothing				Elect Gear Properly Rated			

Periodic Atmospheric Checks				
Time (am - pm)				
Oxygen				
Explosive (% LEL)				
Toxic (PPM)				
Testers Signature				

A review of the work authorized by this permit and the information contained on this Entry Permit. Written instructions and safety procedures have been received and are understood. Entry cannot be approved if any squares are marked in the "**No**" column. This permit is not valid unless all appropriate items are completed.

Permit Prepared By: (Supervisor) ________________________________

Approved By: (Unit Supervisor) __________________________________

This permit to be kept at job site.

Return job site copy to Safety Office following job completion.

Confined Space Duties & Responsibilities

Examples of assignments
Employees

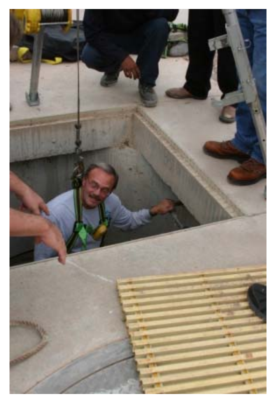
1. Follow program requirements.
2. Report any previously un-identified hazards associated with confined spaces.
3. Do not enter any confined spaces that have not been evaluated for safety concerns.

Management
Provide annual Confined Space training to all employees that may need confined space training.

- ✓ Ensure confined space assessments have been conducted.
- ✓ Annually review this program and all Entry Permits.

Rescue or Training Department
Ensure proper training for entry & rescue teams.
Provide proper equipment for entry & rescue teams.

- ✓ Ensure all permit required confined spaces are posted.
- ✓ Evaluate rescue teams and service to ensure they are adequately trained and prepared.
- ✓ Ensure rescue team at access during entry into spaces with Immediately Dangerous to Life or Health (IDLH) atmospheres.
- ✓ Provide annual confined space awareness training to all employees that may need confined space awareness training.



Entry Supervisor
Entry supervisors are responsible for the overall permit space entry and must coordinate all entry procedures, tests, permits, equipment and other relevant activities.

The following entry supervisor duties are required:
Know the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure.

Verify by checking that the appropriate entries have been made on the permit, all tests specified by the permit have been conducted, and that all procedures and equipment specified by the permit are in place before endorsing the permit and allowing entry to begin.

Terminate the entry and cancel the permit when the entry is complete or there is a need for terminating the permit.

Verify that rescue services are available and that the means for summoning them are operable.

Remove unauthorized persons who enter or attempt to enter the space during entry operations.

Determine whenever responsibility for a permit space entry operation is transferred and at intervals dictated by the hazards and operations performed within the space that entry operations remain consistent with the permit terms and that acceptable entry conditions are maintained.

Entry Attendants
At least one attendant is required outside the permit space into which entry is authorized for the duration of the entry operation.

Responsibilities include:

- ✓ To know the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure.
- ✓ To be aware of possible behavioral effects of hazard exposure on entrants.
- ✓ To continuously maintain an accurate count of entrants in the permit space and ensures a means to accurately identify authorized entrants.
- ✓ To remain outside the permit space during entry operations until relieved by another attendant (once properly relieved, they may participate in other permit space activities, including rescue if they are properly trained and equipped).
- ✓ To communicate with entrants as necessary to monitor entrant status and alert entrants of the need to evacuate.
- ✓ To monitor activities inside and outside the space to determine if it is safe for entrants to remain in the space; orders the entrants to immediately evacuate if: the attendant detects a prohibited condition, detects entrant behavioral effects of hazard exposure, detects a situation outside the space that could endanger the entrants; or if the attendant cannot effectively and safely perform all the attendant duties.
- ✓ To summon rescue and other emergency services as soon as the attendant determines the entrants need assistance to escape the permit space hazards.
- ✓ To perform non-entry rescues as specified by that rescue procedure and entry supervisor and not to perform duties that might interfere with the attendants' primary duty to monitor and protect the entrants.

Entering a Confined Space

This space requires an emergency retrieval system, continuous air monitoring, and safety watch or two-way communication for safe entry.

Donning the personal protective equipment (**PPE**) necessary for confined space entry.

The full-body harness provides fully adjustable leg and shoulder straps for worker comfort and proper fit.

Stamped steel sliding back D-ring and sub-pelvic strap provide optimum force distribution.

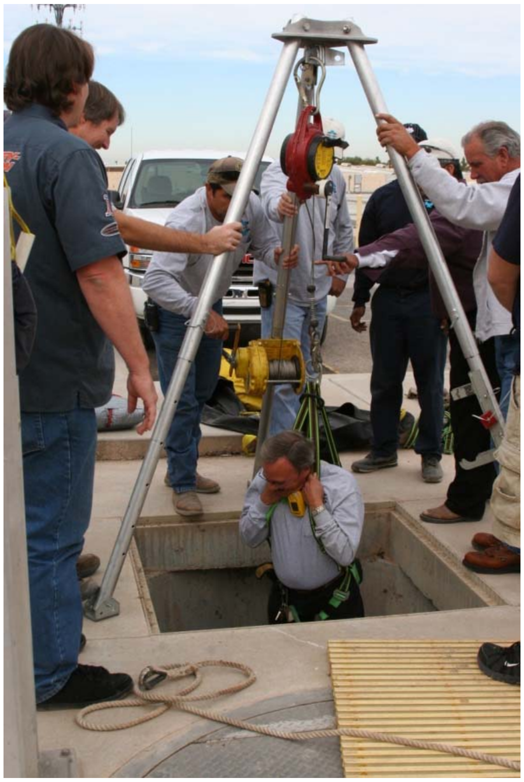
Example of a "***D-Ring***" and fall protection harness used when entering a confined space. The D-Ring provides a compatible anchor point for connecting devices such as lanyards or retractable lifelines. The shock absorbing lanyard provides a deceleration distance during a fall to reduce fall arrest forces for extra protection against injury.

Tripod-retrieval assembly in use for an entry into one of the many confined spaces.

Checking the cable tension and inertial locking mechanism of the retrieval assembly.

Correct use of this device prevents free-falls greater than 2 feet.

The entrant descends into the space as the attendant critiques the operation.



Dramatic rescue simulation using the tripod-retrieval system.

The entrant is now safely out of the space and is ready to return to his many other projects after this simulated exercise.

Duties of the Person Authorizing or in Charge of the Entry

The person who authorizes or is in charge of the permit entry confined space must comply with the following:

1. Make certain that all pre-entry requirements as outlined on the permit have been completed before any worker is allowed to enter the confined space.

2. Make certain that any required pre-entry conditions are present.

3. If an in-plant/facility rescue team is to be used in the event of an emergency, make sure they would be available. If your Employer does not maintain an in-plant rescue team, dial 911 on any telephone for the Rescue Squad.

4. Make sure that any communication equipment which would be used to summon either the in-plant rescue team or other emergency assistance is operating correctly.

5. Terminate the entry upon becoming aware of a condition or set of conditions whose hazard potential exceeds the limits authorized by the entry permit.

If the person who would otherwise issue an entry permit is in charge of the entry and present during the entire entry, then a written permit is not required if that person uses a checklist as provided in the section on "***Permits***".

This person may also serve as the attendant at the site.

Special Considerations During A Permit Required Entry
Certain work being performed in a permit entry confined space could cause the atmosphere in the space to change. Examples of this are welding, drilling, or sludge removal. In these situations, air monitoring of the confined space should be conducted on a continuous basis throughout the time of the entry.

If the workers leave the confined space for any significant period of time, such as for a lunch or other break, the atmosphere of the confined space must be retested before the workers reenter the confined space.

Unauthorized Persons

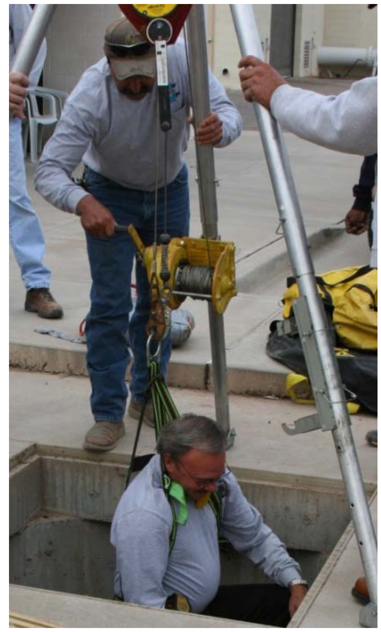
Take the following actions when unauthorized persons approach or enter a permit space while entry is under way:

1. Warn the unauthorized persons that they must stay away from the permit space,

2. Advise unauthorized persons that they must exit immediately if they have entered the space, and

3. Inform the authorized entrants and the entry supervisor if unauthorized persons have entered the permit space.

Entrants



All entrants must be authorized by the entry supervisor to enter permit spaces, have received the required training, have used the proper equipment, and observed the entry procedures and permit requirements.

The following entrant duties are required:
Know the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure;

Properly use the equipment required for safe entry;
Communicate with the attendant as necessary to enable the attendant to monitor the status of the entrants and to enable the attendant to alert the entrants of the need to evacuate the space if necessary;

Alert the attendant whenever; the entrant recognizes any warning signs or symptoms of exposure to a dangerous situation, or any prohibited condition is detected; and Exit the permit space as quickly as possible whenever the attendant or entry supervisor gives an order to evacuate the permit space, the entrant recognizes any warning signs or symptoms of exposure to a dangerous situation, the entrant detects a prohibited condition, or an evacuation alarm is activated.

Collection Hazards

Explosive / Flammable Atmospheres

Toxic Atmospheres

Engulfment

Asphyxiation

Entrapment

Slips & falls

Chemical Exposure

Electric Shock

Thermal / Chemical Burns

Noise & Vibration

Hazard Control

Engineering Controls
Locked entry points
Temporary ventilation
Temporary Lighting

Administrative Controls
Signs
Employee training
Entry procedures
Atmospheric Monitoring
Rescue procedures
Use of prescribed Personal Protective Equipment

Entry Standard Operating Procedures
This program outlines:
Hazards
Hazard Control & Abatement
Acceptable Entry Conditions
Means of Entry
Entry Equipment Required
Emergency Procedures

Permit Required Confined Space Entry General Rules

During all confined space entries, the following safety rules must be strictly enforced:

1. Only authorized and trained employees may enter a confined space or act as safety watchman/attendant.

2. No smoking is permitted in a confined space or near entrance/exit area.

3. During confined space entries, a watchman must be present at all times.

4. Constant visual or voice communication will be maintained between the safety watchman/attendant and employees entering a confined space.

5. No bottom or side entry will be made or work conducted below the level of any hanging material or material which could cause engulfment.

6. Air and oxygen monitoring is required before entering any permit-required confined space. Oxygen levels in a confined space must be between 19.5 and 23.5 percent. Levels above or below will require the use of an SCBA or other approved air supplied respirator. Additional ventilation and oxygen level monitoring is required when welding is performed.

The monitoring will check oxygen levels, explosive gas levels and carbon monoxide levels. Entry will not be permitted if explosive gas is detected above one-half the Lower Explosive Limit (**LEL**), or 10% of a specific gas explosive limit.

7. To prevent injuries to others, all openings to confined spaces will be protected by a barricade when covers are removed.

Confined Space Entry Procedures
Each employee who enters or is involved in the entry must:

1. Understand the procedures for confined space entry

2. Know the Hazards of the specific space

3. Review the specific procedures for each entry

4. Understand how to use entry and rescue equipment

Confined Space Entry Permits

- ✓Confined Space Entry Permits must be completed before any employee enters a permit-required confined space. The permit must be completed and signed by an authorized member of management before entry.
- ✓Permits will expire before the completion of the shift or if any pre-entry conditions change.
- ✓Permits will be maintained on file for 12 months.

Contractor Entry

All work by non-company employees that involves the entry into confined spaces will follow the procedures of this program. The information of this program and specific hazards of the confined spaces to be entered will be provided to contractor management prior to commencing entry or work.

Important Rescue Service Questions

What is the availability of the rescue service?

Is it unavailable at certain times of the day or in certain situations?

What is the likelihood that key personnel of the rescue service might be unavailable at times?

If the rescue service becomes unavailable while an entry is underway, does it have the capability of notifying the employer so that the employer can instruct the attendant to abort the entry immediately?

Confined Space Training

Training for Confined Space Entry includes:

1. Duties of entry supervisor, entrant and attendants
2. Confined space entry permits
3. Hazards of confined spaces
4. Use of air monitoring equipment
5. First aid and CPR training
6. Emergency action & rescue procedures
7. Confined space entry & rescue equipment
8. Rescue training, including entry and removal from representative spaces

Confined Space Training and Education
OSHA's General Industry Regulation, §1910.146 Permit-required confined spaces, contains requirements for practices and procedures to protect employees in general industry from the hazards of entry into permit-required confined spaces. This regulation does not apply to construction.

OSHA's Construction Safety and Health Regulations Part 1926 do not contain a permit-required confined space regulation. Subpart C, §1926.21 Safety training and education specifies training for personnel who are required to enter confined spaces and defines a "***confined or enclosed space***." These requirements are shown below.

§1926.21 Safety training and education. (Partial)
(b)(6)(i) All employees required to enter into confined or enclosed spaces shall be instructed as to the nature of the hazards involved, the necessary precautions to be taken, and in the use of protective and emergency equipment required. The employer shall comply with any specific regulations that apply to work in dangerous or potentially dangerous areas.

(ii) For purposes of paragraph (b)(6)(i) of this section, "***confined or enclosed space***" means any space having a limited means of egress, which is subject to the accumulation of toxic or flammable contaminants or has an oxygen deficient atmosphere. Confined or enclosed spaces include, but are not limited to, storage tanks, process vessels, bins, boilers, ventilation or exhaust ducts, sewers, underground utility vaults, tunnels pipelines, and open top spaces more than 4 feet in depth such as pits, tubs, vaults, and vessels.

OSHA's Construction Regulations also contain requirements dealing with confined space hazards in underground construction (Subpart S), underground electric transmission and distribution work (§1926.956), excavations (Subpart P), and welding and cutting (Subpart J). Further guidance may be obtained from American National Standard ANSI Z117.1-1989, Safety Requirements for Confined Spaces.

This standard provides minimum safety requirements to be followed while entering, exiting and working in confined spaces at normal atmospheric pressure. This standard does not pertain to underground mining, tunneling, caisson work or other similar tasks that have established national consensus standards.

Your Employer is Responsible for Certain Training Requirements

These are as follows:

1. **GENERAL** As an employer, your employer must ensure that all workers who must enter a permit entry confined space in the course of their work are informed of appropriate procedures and controls for entry into such spaces. These workers must be made aware of the fact that an unauthorized entry could be fatal, and that their senses are unable to detect and evaluate the severity of atmospheric hazards.

2. **TRAINING FOR AUTHORIZED ENTRANTS** Your employer must ensure that all authorized entrants know the emergency action plan and have received training covering the following subjects prior to entering any permit entry confined space:

a**. Hazard Recognition**: Each worker must understand the nature of the hazard before entering and the need to perform appropriate testing to determine if it is safe to enter.

b. **Use of Personal Protective Equipment**: Each employee must be taught the proper use of all personal protective equipment required for entry or rescue, and the proper use of protective barriers and shields.

c. **Self-Rescue**: Each worker must be trained to get out of the confined space as rapidly as possible without help whenever an order to evacuate is given by the attendant, whenever an automatic evacuation alarm is activated, or whenever workers recognize the warning signs of exposure to substances that could be found in the confined space. They must also be made aware of the toxic effects or symptoms of exposure to hazardous materials he could encounter in the confined space. This includes anything that could be absorbed through the skin or which could be carried through the skin by any solvents that are used. They must be trained to relay an alarm to the attendant and to attempt self- rescue immediately upon becoming aware of these effects.

d. **Special Work Practices or Procedures**: Each worker must be trained in any modifications of normal work practices that are necessary for permit entry confined space work.

3. **TRAINING FOR PERSONS AUTHORIZING OR IN CHARGE OF ENTRY** In addition to other requirements already covered, the person authorizing or in charge of entry shall be trained to recognize the effects of exposure to hazards that could be in the confined space. They must also carry out all duties that the permit assigns to them.

Rescue practice training. This photo is showing a sand bag being utilized as a dummy.

4. **TRAINING FOR ATTENDANT** Any worker functioning as an attendant at a permit entry confined space must be trained in the company's emergency action plan, the duties of the attendant, and in;

a. Proper use of the communications equipment furnished for communicating with authorized workers entering the confined space or for summoning emergency or rescue services.

b. Authorized procedures for summoning rescue or other emergency services.

c. Recognition of the unusual actions of a worker which could indicate that they could be experiencing a toxic reaction to contaminants that could be present in the space.

d. Any training for rescuers, if the attendant will function as a rescuer also.

e. Any training for workers who enter the confined space, if the permit specifies that the duty of the attendant will rotate among the workers authorized to enter the confined space.

Confined Space Entry Procedure

Space ________________ Date Last Modified ____________

Place check mark in all applicable areas

	Hazards		**Personal Protective Equipment**
	Explosive / Combustion Hazard		Air supplied Respirator
	Exposed Electrical Circuits		Air Purifying Respirator
	Unguarded Machine Parts		Welding Protection
	Atmospheric Hazard		Gloves
	Potential Atmospheric Hazard		Hard Hat
	Thermal Hazard		**Ventilation Requirements**
	Chemical Hazard		Continuous ___cuft/min Note*: See Ventilation Guidelines for Confined Spaces for typical ventilation configurations and formulas.*
	Fall Hazard		
	Engulfment hazard	Note: *Additional ventilation may be required for hot work, grinding or other operations that would produce airborne fumes, mist or dust. Entry Supervisor must assess additional ventilation requirements base on tasks to be performed in the space*	
	Converging Walls		
	Floors slope-small cross-section		
	Slip Hazard		
	Entry Path		Vent Exhaust Point:
	Side entry		Vent Supply Point:
	Bottom entry		Space Volume
	Door		**Initial Purge Time=** 7.5 X _____ (space volume) Effective Blower Capacity
	Top open entry		
	Top manhole entry		**20 Air Changes per Hour (ACH) for duration of entry**
	Hinged hatch		**Minimum initial Purge Time= 20 Minutes**

	Entry & Rescue Equipment			Adequate Blower Capacity (ABC) = ________ ABC = Space Volume x 20 ACH 60 minutes
	Life Line			
	Floor level opening barrier			**Acceptable Entry Conditions**
	Body Harness			Confined Space Entry permit posted
	Tripod			Oxygen 19.5 23.5%
	Man Winch			Lower Explosive Level %
	Fall Arrest Unit			Toxic fumes/vapors Less than PEL
	Emerg Retrieval Line			No engulfing material in space
	Atmospheric Monitor			No hazardous chemicals or material
	Blower /Saddle / Trunks			Drained - Flushed
	Drop Light			Rescue Team Available on Site
	Communication Gear			Ventilation Established & Maintained
	Ladder			LOTO Electrical components in space
	Hand held radios			LOTO Mechanical Components in space
	Portable Lighting			LOTO All pipes to and from space

Other Collections Hazards

Flammable Atmospheres
A flammable atmosphere generally arises from enriched oxygen atmospheres, vaporization of flammable liquids, byproducts of work, chemical reactions, concentrations of combustible dusts, and desorption of chemical from inner surfaces of the confined space.

An atmosphere becomes flammable when the ratio of oxygen to combustible material in the air is neither too rich nor too lean for combustion to occur. Combustible gases or vapors will accumulate when there is inadequate ventilation in areas such as a confined space.

Flammable gases such as acetylene, butane, propane, hydrogen, methane, natural or manufactured gases or vapors from liquid hydrocarbons can be trapped in confined spaces, and since many gases are heavier than air, they will seek lower levels as in pits, sewers, and various types of storage tanks and vessels. In a closed top tank, it should also be noted that lighter than air gases may rise and develop a flammable concentration if trapped above the opening.

The byproducts of work procedures can generate flammable or explosive conditions within a confined space. Specific kinds of work such as spray painting can result in the release of explosive gases or vapors. Welding in a confined space is a major cause of explosions in areas that contain combustible gas.

Chemical reactions forming flammable atmospheres occur when surfaces are initially exposed to the atmosphere, or when chemicals combine to form flammable gases. This condition arises when dilute sulfuric acid reacts with iron to form hydrogen or when calcium carbide makes contact with water to form acetylene.

Other examples of spontaneous chemical reactions that may produce explosions from small amounts of unstable compounds are acetylene-metal compounds, peroxides, and nitrates. In a dry state, these compounds have the potential to explode upon percussion or exposure to increased temperature.

Another class of chemical reactions that form flammable atmospheres arise from deposits of pyrophoric substances (carbon, ferrous oxide, ferrous sulfate, iron, etc.) that can be found in tanks used by the chemical and petroleum industry. These tanks containing flammable deposits will spontaneously ignite upon exposure to air.
Combustible dust concentrations are usually found during the process of loading, unloading, and conveying grain products, nitrated fertilizers, finely ground chemical products, and any other combustible material.

High charges of static electricity, which rapidly accumulate during periods of relatively low humidity (below 50%) can cause certain substances to accumulate electrostatic charges of sufficient energy to produce sparks and ignite a flammable atmosphere.

These sparks may also cause explosions when the right air or oxygen to dust or gas mixture is present.

Toxic Atmospheres
The substances to be regarded as toxic in a confined space can cover the entire spectrum of gases, vapors, and finely-divided airborne dust in industry. The sources of toxic atmospheres encountered may arise from the following:

1. The manufacturing process (for example, in producing polyvinyl chloride, hydrogen chloride is used as well as vinyl chloride monomer, which is carcinogenic).
2. The product stored [removing decomposed organic material from a tank can liberate toxic substances, such as hydrogen sulfide ($\mathbf{H_2S}$)].
3. The operation performed in the confined space (for example, welding or brazing with metals capable of producing toxic fumes).

During loading, unloading, formulation, and production, mechanical and/or human error may also produce toxic gases which are not part of the planned operation.
Carbon monoxide (**CO**) is a hazardous gas that may build up in a confined space. This odorless, colorless gas that has approximately the same density as air is formed from incomplete combustion of organic materials such as wood, coal, gas, oil, and gasoline; it can be formed from microbial decomposition of organic matter in sewers, silos, and fermentation tanks.

CO is an insidious toxic gas because of its poor warning properties. Early stages of CO intoxication are nausea and headache. CO may be fatal at as little as 1000 ppm or 10% in air, and is considered dangerous at 200 ppm or 2%, because it forms Carboxyhemoglobin in the blood which prevents the distribution of oxygen in the body.

CO is a relatively abundant colorless, odorless gas. Therefore, any untested atmosphere must be suspect. It must also be noted that a safe reading on a combustible gas indicator does not ensure that CO is not present. CO must be tested for specifically.

The formation of CO may result from chemical reactions or work activities, therefore fatalities due to CO poisoning are not confined to any particular industry. There have been fatal accidents in sewage treatment plants due to decomposition products and lack of ventilation in confined spaces.

Another area where CO results as a product of decomposition is in the formation of silo gas in grain storage elevators. In another area, the paint industry, varnish is manufactured by introducing the various ingredients into a kettle, and heating them in an inert atmosphere, usually town gas, which is a mixture of carbon dioxide and nitrogen.

In welding operations, oxides of nitrogen and ozone are gases of major toxicologic importance, and incomplete oxidation may occur and carbon monoxide can form as a byproduct. Another poor work practice, which has led to fatalities, is the recirculation of diesel exhaust emissions. Increased CO levels can be prevented by strict control of the ventilation and the use of catalytic converters.

Atmospheric Testing Policy *Example*

Before entry, it is necessary to test the atmosphere in the confined space for oxygen levels, flammability, and/or any contaminants that have a potential to be present in that confined space. This testing must be done by a qualified person using equipment which has been approved for use in such areas.

The testing equipment itself should be checked to make sure it is working properly before using it. Follow the manufacturer's recommended procedures.

Testing of the confined spaces should be conducted throughout the entire portion of the space that workers will occupy during the entry. This testing shall be done without the use of ventilation systems.

Where the entry is vertical into the confined space, it is recommended that remote probes be used to measure the atmosphere at various levels. This is necessary because some gases and vapors are lighter or heavier than air and can accumulate at different levels in the confined space. Test outside the confined space to make sure the surrounding air is not contaminated.

Atmospheric conditions are considered unacceptable if oxygen levels are less than 19.5% or greater than 23.5%. Regulations define the following unacceptable levels of other hazards monitored:

1. A flammable gas, vapor or mist greater than 10% of its lower flammable limit (**LFL**). LFL means the minimum concentration of the flammable material which will ignite if an ignition source is present.

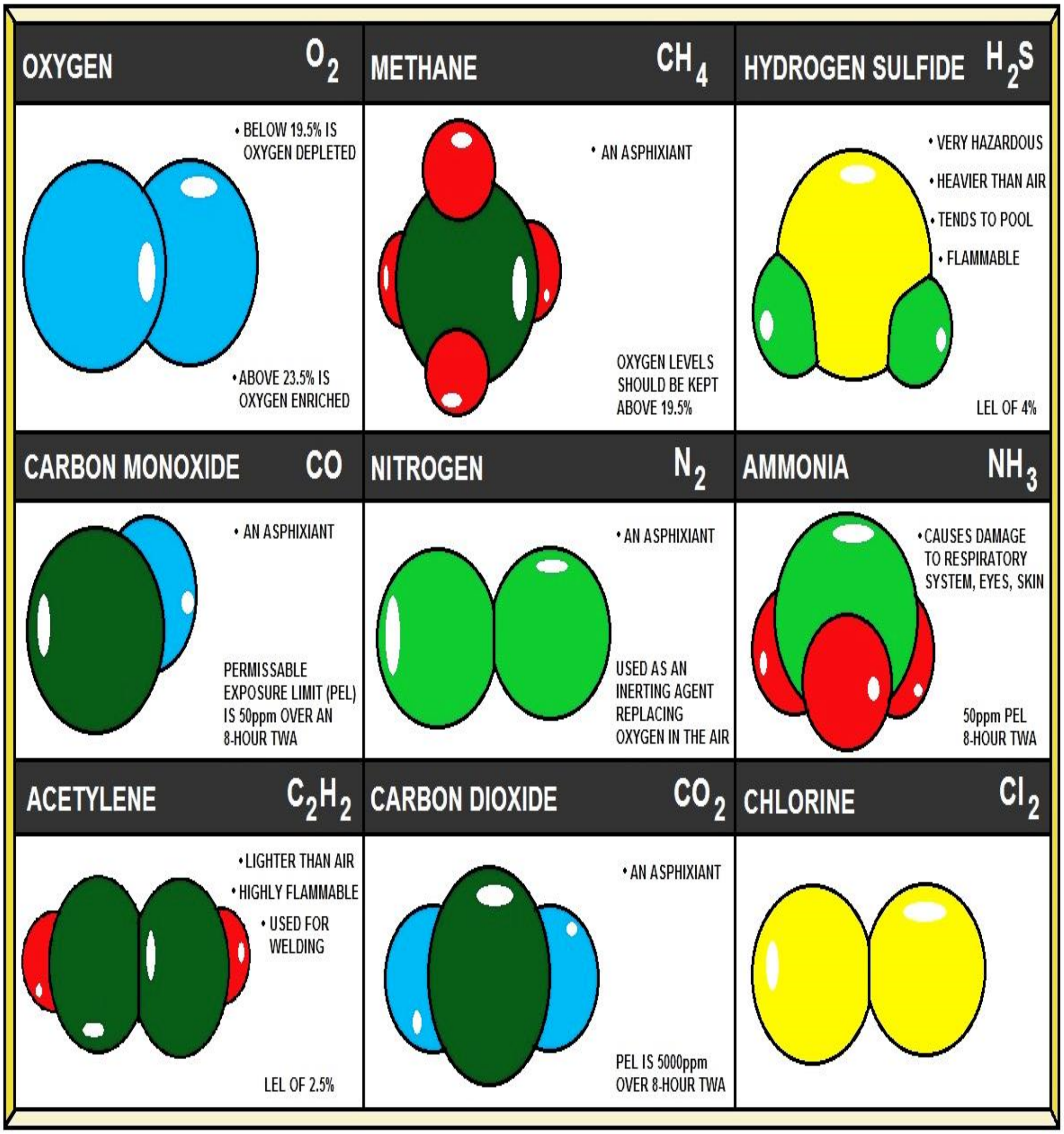
2. An airborne combustible dust at a concentration that obscures vision at a distance of five feet or less.

3. An atmospheric concentration of a substance greater than the allowed limit in the Material Safety Data Sheet for that substance.

If test results conclude that the atmospheric condition of the confined space is unacceptable, entry is prohibited until such conditions are brought into acceptable limits. This may be done by purging, cleaning and/or ventilating the space.

Purging refers to the method by which gases, vapors, or other airborne impurities are displaced from a confined space.

The confined space may also be made non-flammable, non-explosive or otherwise chemically non-reactive by displacing or diluting the original atmosphere with steam or gas that is non-reactive with respect to that space, a process referred to as "***inerting***".



COMMON GASES THAT CAN BE FOUND IN CONFINED SPACE

Irritant (Corrosive) Atmospheres

Irritant or corrosive atmospheres can be divided into primary and secondary groups. The primary irritants exert no systemic toxic effects (effects on the entire body). Examples of primary irritants are chlorine, ozone, hydrochloric acid, hydrofluoric acid, sulfuric acid, nitrogen dioxide, ammonia, and sulfur dioxide. A secondary irritant is one that may produce systemic toxic effects in addition to surface irritation. Examples of secondary irritants include benzene, carbon tetrachloride, ethyl chloride, trichloroethane, trichloroethylene, and chloropropene.

Irritant gases vary widely among all areas of industrial activity. They can be found in plastics plants, chemical plants, the petroleum industry, tanneries, refrigeration industries, paint manufacturing, and mining operations.

Prolonged exposure at irritant or corrosive concentrations in a confined space may produce little or no evidence of irritation. This may result in a general weakening of the defense reflexes from changes in sensitivity. The danger in this situation is that the worker is usually not aware of any increase in his/her exposure to toxic substances.

Asphyxiating Atmospheres
The normal atmosphere is composed approximately of 20.9% oxygen and 78.1% nitrogen, and 1% argon with small amounts of various other gases. Reduction of oxygen in a confined space may be the result of either consumption or displacement.

The consumption of oxygen takes place during combustion of flammable substances, as in welding, heating, cutting, and brazing. A more subtle consumption of oxygen occurs during bacterial action, as in the fermentation process.

Oxygen may also be consumed during chemical reactions as in the formation of rust on the exposed surface of the confined space (iron oxide). The number of people working in a confined space and the amount of their physical activity will also influence the oxygen consumption rate.

A second factor in oxygen deficiency is displacement by another gas. Examples of gases that are used to displace air, and therefore reduce the oxygen level are helium, argon, and nitrogen.

Carbon dioxide may also be used to displace air and can occur naturally in sewers, storage bins, wells, tunnels, wine vats, and grain elevators.
Aside from the natural development of these gases, or their use in the chemical process, certain gases are also used as inerting agents to displace flammable substances and retard pyrophoric reactions.

Gases such as nitrogen, argon, helium, and carbon dioxide, are frequently referred to as non-toxic inert gases but have claimed many lives. The use of nitrogen to inert a confined space has claimed more lives than carbon dioxide.

The total displacement of oxygen by nitrogen will cause immediate collapse and death.

Carbon Dioxide
Carbon dioxide and argon, with specific gravities greater than air, may lie in a tank or manhole for hours or days after opening. Since these gases are colorless and odorless, they pose an immediate hazard to health unless appropriate oxygen measurements and ventilation are adequately carried out.

Oxygen Deprivation
Oxygen deprivation is one form of asphyxiation. While it is desirable to maintain the atmospheric oxygen level at 21% by volume, the body can tolerate deviation from this ideal. When the oxygen level falls to 17%, the first sign of hypoxia is deterioration to night vision, which is not noticeable until a normal oxygen concentration is restored. Physiologic effects are increased breathing volume and accelerated heartbeat.

Between 14-16% physiologic effects are increased breathing volume, accelerated heartbeat, very poor muscular coordination, rapid fatigue, and intermittent respiration.

Between 6-10% the effects are nausea, vomiting, inability to perform, and unconsciousness. Less than 6%, the effects are spasmodic breathing, convulsive movements, and death in minutes.

Mechanical Hazards
If activation of electrical or mechanical equipment would cause injury, each piece of equipment should be manually isolated to prevent inadvertent activation before workers enter or while they work in a confined space. The interplay of hazards associated with a confined space, such as the potential of flammable vapors or gases being present, and the build-up of static charge due to mechanical cleaning, such as abrasive blasting, all influence the precautions which must be taken.

To prevent vapor leaks, flashbacks, and other hazards, workers should completely isolate the space. To completely isolate a confined space, the closing of valves is not sufficient.

All pipes must be physically disconnected or isolation blanks bolted in place. Other special precautions must be taken in cases where flammable liquids or vapors may re-contaminate the confined space.

The pipes blanked or disconnected should be inspected and tested for leakage to check the effectiveness of the procedure. Other areas of concern are steam valves, pressure lines, and chemical transfer pipes. A less apparent hazard is the space referred to as a void, such as double walled vessels, which must be given special consideration in blanking off and inerting.

Thermal Effects
Four factors influence the interchange of heat between people and their environment. They are: (1) air temperature, (2) air velocity, (3) moisture contained in the air, and (4) radiant heat. Because of the nature and design of most confined spaces, moisture content and radiant heat are difficult to control.

As the body temperature rises progressively, workers will continue to function until the body temperature reaches approximately 102°F.

When this body temperature is exceeded, the workers are less efficient, and are prone to heat exhaustion, heat cramps, or heat stroke. In a cold environment, certain physiologic mechanisms come into play, which tend to limit heat loss and increase heat production.

The most severe strain in cold conditions is chilling of the extremities so that activity is restricted. Special precautions must be taken in cold environments to prevent frostbite, trench foot, and general hypothermia.

Proper signage is essential.

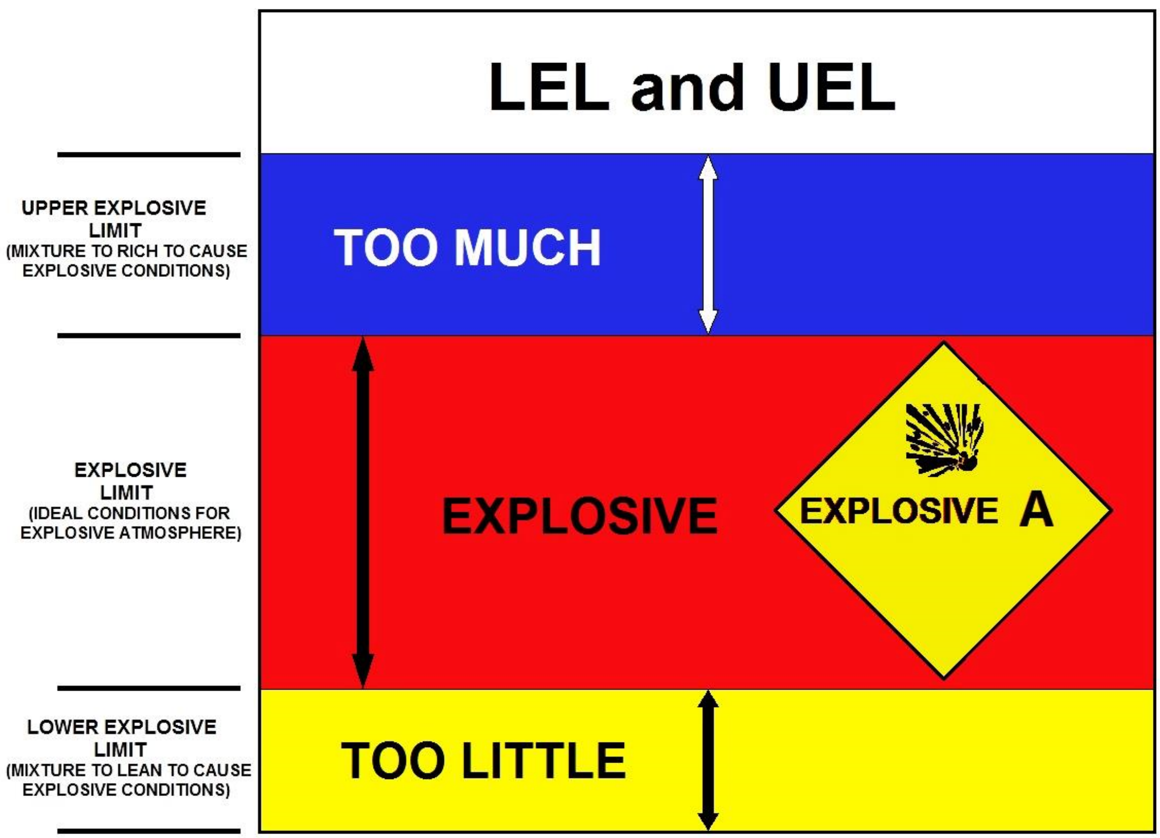
Abbreviations:

PEL - permissible exposure limit: Average concentration that must not be exceeded during 8-hour work shift of a 40-hour workweek.

STEL - Short-term exposure limit: 15-minute exposure limit that must not be exceeded during the workday.

REL - Recommended exposure limit: Average concentration limit recommended for up to a 10-hour workday during a 40-hour workweek.

IDLH - Immediately dangerous to life or health: Maximum concentration from which person could escape (in event of respirator failure) without permanent or escape-impairing effects within 30 minutes.



UNDERSTANDING UPPER (UEL) & LOWER (LEL) EXPLOSIVE LIMITS

Safety Chapter Glossary

Barricades Visible warning barriers that keep vehicles and pedestrians from entering a construction site.

Braces Devices that hold or fasten two or more parts together or in place. Braces are diagonal or horizontal. They may be made of wood or metal.

Bracing System A system of braces which applies pressure against trench walls to stabilize them. A bracing system is part of a trench shoring system used to prevent trench walls from collapsing.

Benching A method of cutting back the sides of a trench into horizontal steps to prevent cave-ins.

Bulge An outward swelling in the soil of a trench; may be a warning sign of trench failure.

Buried Structures Manholes, junction boxes or catch basins beneath the ground, or any other installations that may be encountered during trenching.

Clay Fine-grained natural soil that is plastic when moist and hard and brittle when dry. Clay is made up of particles smaller than .0002 millimeters.

Clumps Heavy lumps or thick groupings of soil.

Cohesion The relative ability to clump together; the force holding two like substances together.

Cohesive When a soil has grains that hold together and clump well.

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. They also have the authorization to take prompt corrective measures to eliminate hazards. The Competent Person is trained and knowledgeable about soil analysis and the use of protective systems.

Confined Space Has limited or restricted means of entry or exit, is large enough for an employee to enter and perform assigned work, and is not designed for continuous occupancy by the employee. These spaces may include, but are not limited to, underground vaults, tanks, storage bins, pits, diked areas, vessels, and silos.

Diversion Ditches A ditch cut around the work site to keep water from entering the trench.

Drainage System Pumps, pipe or channel used to drain off rain or groundwater from inside the trench.

Excavation Any man-made cut, cavity trench or depression in an earth surface, formed by earth removal.

Fissure A long narrow opening or crack in the rock or soil. Fissures are often a sign of trench wall failure.

Grain Particles that once were large rocks, but have been broken down through time and the effects of weathering. The size of the grain of a soil determines the stability and cohesiveness of a soil. The larger the grain, the more unstable the soil.

Gravel A loose mixture of pebbles and rock fragments, which is coarser than sand.

Hardpan A layer of hard subsoil or clay that does not allow water in. Hardpan is classified as a Type A soil.

Heaving The swelling of a soil.

Jacks Jacks are braces or supports within a shoring system. They are placed against beams to resist the pressure of the earth.

Loamy Sand Soil composed of a mixture of sand, clay, and silt, with more sand grains than clay or silt. It is classified as a Type C soil.

Manufacturer's Tabulated Data Tables and charts approved by a registered professional engineer and used to design and construct a protective system.

Permit Required Confined Space Is one that meets the definition of a confined space and has one or more of these characteristics: (1) contains or has potential to contain a hazardous atmosphere, (2) contains a material that has the potential for engulfing an entrant, (3) has an internal configuration that might cause an entrant to be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross section, and/or (4) contains any other recognized serious safety or health hazards.

Personal Protective Equipment Includes: safety goggles and glasses, reflective clothing, work gloves, hard hat, safety shoes, rubber boots, earplugs or protectors, face shield and face mask or respirator.

Registered Professional Engineer A person who is registered as a professional engineer in the state where the work is to be performed.

Sand A type C soil with small, loose grains of disintegrated rock.

Sandy Loam Granular soil with enough silt and clay to make it slightly cohesive

Saturation The process of a soil being filled to capacity with moisture.

Shear A phenomenon which happens when a trench wall is subjected to stress. Fissured cracks widen until a portion of the trench wall breaks off and slides into the trench.

Sheeting Durable sheets of metal or wood, which are held firmly against a trench wall to prevent it from caving-in. Sheeting is a component of a trench shoring system.

Shielding A device which provides adequate protection from falling or collapsing earth loads. The trench box is a common form of shielding. Shoring is the main method of stabilizing and supporting a trench wall to prevent cave-ins. It consists of uprights, stingers, and braces.

Silt A soil which contains fine particles and is very smooth.

Silty Clay A plastic soil that will appear rough or broken when rubbed over the thumb and finger.

Sloping The process of cutting back the sides of a trench to avoid a cave-in.

Sloughing When loose soil begins to run in from the lower part of the wall into the excavation. It is the first step to a wall collapse.

Soil Type A system of classifying soils and rock deposits. Soil must be classified by a qualified person as: Stable rock, Type-A, Type-B, Type-C.

Spall When a soil begins to crack or flake due to pressure, or from moisture from within the trench.

Spoil Pile/Spoilage Rock waste, banks, and dumps from the excavation.

Supports Part of a shoring system which helps to bear the weight of braces and other parts of the shoring system.

Trench Box A prefabricated moveable box usually constructed of metal plates welded to a heavy steel frame. The box is moved along as work progresses. It is able to withstand the forces imposed on it by a cave-in, and thereby protects trench workers.

Type-A Soil The most stable and cohesive type of soil while working at a trench site. Examples are clay, silty clay, and hardpan.

Type-B Soil Type-B soil is next to the most stable soil. Silt, silt loam, sandy loam, medium clay, and unstable rock would be good examples of Type-B soils.

Type-C Soil The least stable type of soil. Examples of Type-C soils are gravel, loamy sand, soft clay, submerged silt, and heavy unstable rock.

Unconfined Compressive Strength Through a variety of tests, a soil's strength is found. The unconfined compressive strength is the soil's measure of bearing capacity and shearing resistance. Measured as the amount of weight per square foot needed to collapse a soil sample.

Uprights Vertical members of a trench shoring system placed in context with the earth. These members usually are not placed in direct contact with one another.

Vibration When a soil or excavation site trembles and shakes rapidly due to forces such as loud noises or heavy equipment or traffic.

Voids Voids are empty spaces between particles of rocks.

Wales Wales are parts of a shoring system. They are positioned horizontally and help to brace vertical beams and supports. Wales can be fastened to studs with nails, clips, or brackets.

Wall Stability The relative strength and capacity of walls of a trench.

Does this scenario need shoring?

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 Chapter Highlights *Memorize these statements for your exam.*

A confined space is defined as an area where existing ventilation is inadequate to remove contaminants or provide a sufficient air supply. Other criterion that defines confined space are areas that are difficult to enter or evacuate.

An atmospheric analyzer will have an audible and visible alarm that will warn when the flammable gases exceed 10%, sometimes expressed as 0.1. Atmospheric monitors continuously sample the atmosphere for the following levels: Toxicity, Oxygen, and Flammability.

Upon entering a confined space, your oxygen meter indicates an oxygen concentration of 23.9%. The appropriate course of action is to evacuate the area immediately. Keep the O_2 in the range of 19.5 to 23.5.

When a trench is dug for a new line or replacement of an old line, the trench should be dug and backfilled in such a manner to support the pipe. A rule of thumb as to the width of the trench is that the trench should be narrow as possible for safety and to increase pipe sidewall support.

When purchasing a specific type of shoring for the collection system, the operator should consider price and quality of the material. The type of shoring purchased for an agency is governed by soil conditions in the area.

The operator has installed a screw jack between the solid sheeting material for shoring a trench. To ensure safe conditions in the trench the operator needs to perform the following additional task on the screw jacks; driving nails into the base of the jack and timbers. An alternative to screw jacks as a shoring brace is to use air shores.

The operator is installing air shores. The tank is used to fill the cylinders which reinforce the trench walls. The cylinders are pressurized to 300 PSI. The next step in using this type of shoring equipment as well as related shoring equipment is to insert a metal pin behind the collar to form a mechanical lock.

Hydraulic shores are used due to their ease of installation and removal. However, they are usually not used on jobs for a time period greater than five (5) days, because there is a possibility of the hydraulic pressure bleeding off during a time period longer than five (5) days.

Hydraulic shoring fluid is the only fluid recommended for use in hydraulic shoring equipment.

Driving: If the operator is confronted by an unsafe or discourteous driver while driving a treatment plant vehicle, he should swallow his pride and handle the situation with manners.

The advance traffic warning area is located from the first sign to the start of the next sign and should be at least one block for urban streets. The transition area is the area that barricades are utilized to push the traffic over. The safety buffer zone is the area that employees can work safely away from traffic.

LOTO, the lock is a physical restraint and only the person that locked the lock should have the key to open it. The tag is an identification device to identify the person and reason for the lock.

Two unsafe excavation examples; Top--notice the man in a 6 foot deep trench with no ladder or shoring and the placement of spoil. Bottom picture--utilities are marked after the excavation has begun; no hard hats, no ladders, no protective system, incorrect spoil placement.

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"?

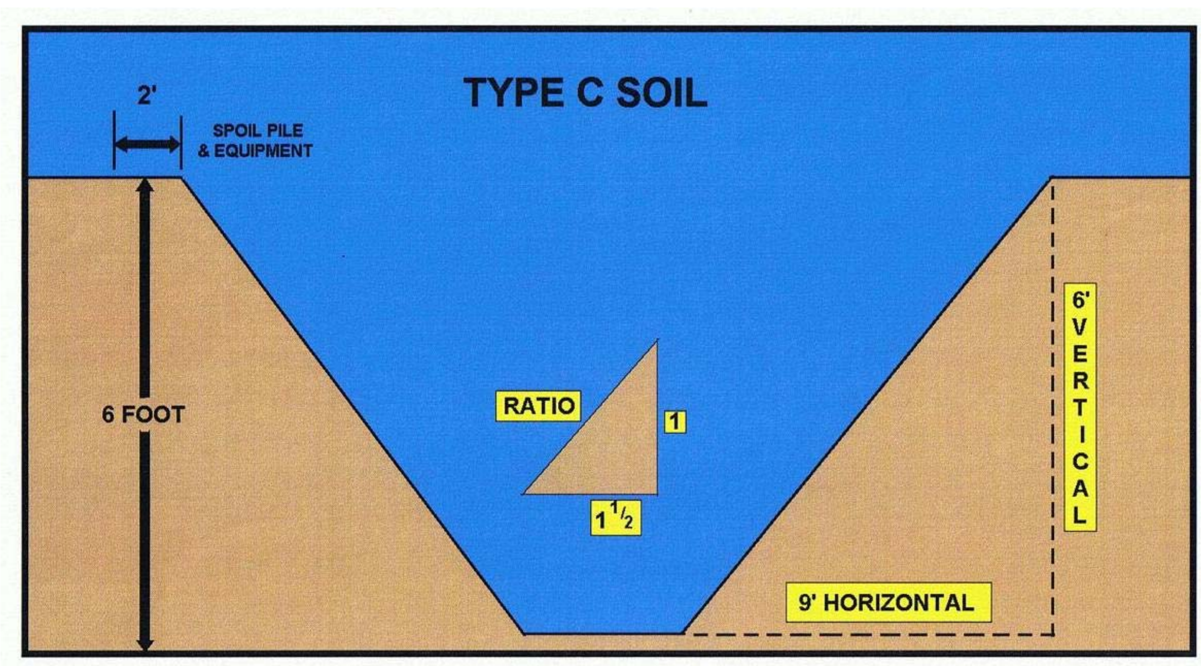
10. What is the classification of material that includes granular soils such as gravel, sand and loamy sand, submerged soil, soil from which water is freely seeping?

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



Wastewater Collections Glossary

Aeration: A method of controlling hydrogen sulfide by chemical treatment which is considered the least expensive.

Air Gap Installation: The only acceptable method to prevent a cross-connection when filling a tank truck from a fire hydrant.

Air Gap: This device should be observed when filling a water truck to clean sewers. There should be an air gap between the discharge line and the top of the water level to prevent a cross connection.

Ambient Temperature: The surrounding temperature.

Anaerobic: The absence of dissolved molecular oxygen.

CCTV: The main purpose for using a video camera while inspecting a sewer line is that it provides operators with a picture record, for log entries and of conditions of trouble spots in the lines. During a CCTV inspection of a sewer line, roots intruding a joint, illegal taps or cracks may be observed.

Centrifugal Pump: Centrifugal pumps are a sub-class of dynamic axisymmetric work-absorbing turbomachinery. Centrifugal pumps are used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow. The rotational energy typically comes from an engine or electric motor.

Confined Space: The definition of a hazardous atmosphere is an atmosphere that is explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful that may cause death, illness, or injury. Below 19.5%O_2 percentage an atmosphere is considered oxygen deficient. The detailed plan for emergency response to an injury or other emergency within the confined space should be described in detail in the water system's Confined Space Entry Program. Entry into a confined space requires a confined space entry permit. Atmospheric monitoring in a confined space should be performed continuously from pre-entry to exit. Hot Work permit type 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. A Type 2 confined space or permit required confined space has the characteristic of containing or has the potential to contain a hazardous atmosphere.

Ductile iron pipe (DIP): A type of pipe that is recommended when crossing another underground utility.

Ferric Chloride: ($FeCl_3$) This chemical can be used to remove sulfides by precipitation.

Fire Point: The temperature at which oil vaporizes enough to keep burning.

Gas Chlorine: Discharged when opening the top valve on a one-ton chlorine cylinder.

Gravity Sewer: A sewer systems that conveys sewage via gravity. Components of a gravity collection system: Main sewers, Manholes, Lateral sewers and Lift stations, but does not contain not Vacuum interface pumps or Grinder Pumps.

Grease Removal: Various methods are often implemented to control grease, including Ordinances, Violations of codes, Inspections and complaints. Some chemicals will remove grease, but chemicals may be very effective under specific conditions, but may not work in all conditions. The best method is for the customer to maintain the grease device and for regular cleaning.

Hazardous Energy: Hazardous energy comes in different forms. Understanding these sources of hazardous energy is very important in the overall process of controlling it. First is kinetic or mechanical energy, which comes from moving parts of machines like propellers, blades, moving chains, and conveyor belts. When not properly controlled, these can lacerate, cut, crush, amputate, and fracture body parts. Another form of hazardous energy is electrical energy, which generates electricity and can be stored in batteries and capacitors. Pneumatic and hydraulic system, springs, gas tanks, and pressure vessels uses potential energy. On the other hand, some hazards can come from thermal energy. But whatever the source of energy, it all boils down to one point: it can bring danger and therefore, must be controlled.

Hearing Protection: It is the employer's responsibility to ensure that you are provided proper hearing protection. The first step to ensure adequate protection for employees is to ensure that engineered controls are used on equipment whenever possible and provide hearing protection.

Hydro-brake: A vortex flow regulator.

Hydrogen Sulfide: Hydrogen sulfide is the chemical compound with the formula H 2S. It is a colorless chalcogen hydride gas with the characteristic foul odor of rotten eggs. It is very poisonous, corrosive, and flammable. Hydrogen sulfide often produced from the microbial breakdown of organic matter in the absence of oxygen gas, such as in swamps and sewers; this process is commonly known as anaerobic digestion which is done by sulfate-reducing microorganisms.

Hydrogen Sulfide Reduction: Salts of zinc and iron may precipitate sulfides. Lime treatments can kill bacteria which produce hydrogen sulfide, but create a sludge disposal problem. Chlorination is effective at reducing the bacteria which produce hydrogen sulfide. Chemical treatment is not the preferred treatment method for reducing hydrogen sulfide, but regular cleaning is. A concentration of 0.4 or 40% hydrogen peroxide should be used to control hydrogen sulfide.

Hypochlorous acid: This species of chlorine is the most germicidal of all chlorine compounds with the possible exception of chlorine dioxide.

Invert: The invert of a pipe is the inner bottom of the pipe.

Lamping: Using reflected sunlight or artificial light to inspect a sewer between two adjacent manholes. The light is directed down the pipe from one manhole. If it can be seen from the next manhole, it indicates that the line is open and straight. The purpose of lamping a new collection system is to test for obstructions and straightness.

Lift Station: A **lift station** is a type of pumping **station** used to move wastewater from a lower elevation to a higher one. It is typically used to move raw sewage to a treatment facility for processing. Most failures of a lift station can be avoided by proper preventive maintenance. The following pieces of equipment would be expected in a dry well: Electric controls, Motors, Pumps but not float switches

Lift Station Book: A book or log inside the lift stationcontains all the ID numbers and maps of the station.

Lift Station Pump: A positive pressure develops when a lift station pump discharges into the force main. A Swing check valve is used to prevent the discharged wastewater from flowing back into the wet well when the pump shuts off.

LOTO Lock: See hazardous energy: The definition of an "Energy Isolating Device" is a mechanical device that physically prevents the transmission or release of energy. Pneumatic, Chemical, Hydraulic, Kinetic, Electrical, Thermal and Mechanical are all forms of hazardous energy. The following are listed as a form 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.

Magnetic Starters: A magnetic starter is an electromagnetically operated switch which provides a safe method for starting an electric motor with a large load. Magnetic starters also provide under-voltage and overload protection and an automatic cutoff in the event of a power failure.

Manhole: A manhole is the top opening to an underground utility vault used to house an access point for making connections, inspection, valve adjustments or performing maintenance on underground and buried public utility and other services including water, sewers, telephone, electricity, storm drains, district heating and gas. The following items are to be examined when inspecting a manhole: Inside surfaces and joints for cracks or breaks, Elevation of the lid and noises that indicate infiltration from cracked or broken pipes, not inadequate sewer use ordinances. If a manhole has been covered due to construction, landscaping, or other activities, bring the entry up to grade. Upstream and downstream manholes should be inspected prior to excavating a section of sewer for replacement to determine the volume of flow.

Mechanical seals: A **mechanical seal** is a device that helps join systems or mechanisms together by preventing leakage (e.g. in a plumbing system), containing pressure, or excluding contamination. Most mechanical seals require tap water lubrication.

Megger: A piece of equipment used to aid in testing for insulation resistance in a submersible pump motor. **Megohmmeter** is a special type of ohmmeter used to measure the electrical resistance of insulators. Insulating components, for example cable jackets, must be tested for their insulation strength at the time of commissioning and as part of maintenance of high voltage electrical equipment and installations. For this purpose megohmmeters, which can provide high DC voltages (typically, in ranges from 500 V to 5 kV, some are up to 15 kV) at specified current capacity, are used. Acceptable insulator resistance values are typically 1 to 10 megohms, depending on the standards referenced.

Offset Stakes: Are control points and are set from the actual sewer line at 5 ft. - 10 ft.

Ohmmeter: See Megger. A Coil or relay might be tested using an Ohmmeter. Infinity is the most likely Ohmmeter reading of a circuit or relay that is found to be defective.

Olfactory Fatigue: Olfactory fatigue is the loss of smell. Common with Cl_2 and H_2S.

Oxygen Deficient: The condition of deficient oxygen is **hypoxia**, and the condition of no oxygen is anoxia. Blood cells are aerobic so they need oxygen to survive. If you have below normal oxygen levels, you're not providing your blood with its fuel; you're basically starving your blood cells. Typically, any time your gas meter reads less than 19.5 percent oxygen.

Piezometer: An instrument used to measure the pressure head in a pipe, tank, or soil.

Piston Pump: Concerning the discharge of water from a piston pump, the discharge valve should always remain open. Relief valve on discharge side of pump is used in order to prevent injuries or severe damage to piston pumps.

Plug Valve: Can be used to replace a suction side pump valve that is continually clogging.

Pump Closed-Coupled: A close-coupled pump means that there is no coupling between the motor and pump.

Pump Curve: Used to compare the actual pump efficiency to its expected efficiency.

Pump Problems: A Plugged exhaust port might cause a positive displacement diaphragm pump to cycle improperly.

Relative Compaction: Refers to the level of compaction obtained compared to the level possible under ideal conditions.

Rodding: A stick, wand, staff, or the like, of wood, metal, or other material used to clean a sewer line. It may be advantageous to rod a sewer line from an upstream position if a high head of water developed at the stoppage. Rodding the line would be the best suited for cutting roots, removing hardened grease, and for scraping and dislodging certain types of materials found in sewers.

Scouring Velocity: Refers to the flow required to prevent the deposition and buildup of solids.

Sewer Bedding: The proper method for bedding a sewer line is to bed the new section 6 to 12 inches above the top of the pipe.

Sewer Cleaning: Sewer cleaning should be scheduled on a regular cycle: for example, 100 percent of the pipes are cleaned every 1, 3, or 5 years. However, unless the cleaning schedule is adjusted to take into account the actual conditions in various parts of the collection system pipelines, routine cleaning can result in over-maintenance of the system. In most collection systems, some sections do not require frequent cleaning while other sections may require cleaning on a more frequent basis, such as monthly, if they are susceptible to blockages. Information from the inspection program should be used to help identify chronic problem areas in the gravity sewer system and related structures in the wastewater collection system, quantify defects and problem areas, and develop a preventive maintenance sewer cleaning program based on actual conditions in a particular wastewater collection system.

Cleaning is either scheduled or unscheduled. Scheduled cleaning is proactive in that cleaning is done on a preventive basis to remove material prior to a stoppage occurring. Preventive cleaning activities can be supplemented by additional cleaning on an as-needed basis in cases where predictive information such as previous history, inspection data, pipe age and material, slope, or other information indicates a need for more frequent cleaning.

Scheduled cleaning is usually coordinated with planned CCTV since televising requires a clean pipe for access and visually provides a much better picture of conditions.

Unscheduled cleaning is usually the result of a reported stoppage and is therefore reactive. When reactive maintenance is the primary form of maintenance (that is, waiting until a failure occurs before performing maintenance), it will always result in poor system performance, especially as the system ages. Normally, this type of cleaning is done on an emergency basis to clear a stoppage, restore pipe capacity to full flow, and relieve a surcharging situation in the sewer that has caused a backup into homes and/or an overflow..

Sewer Map: Elevations typically represented on a collection system map by the elevation of the invert.

Sewer Odor: Primarily is H_2S. A major problem with using an odor-masking agent is that they do not eliminate the source of the odor problem.

Sewer Problem: A few problems that result from the blockage of a sewer system: Overflowing manholes, septic wastewater, flooded basements and buildings but not increased annual flows. An air seal will form; causing odor problems that could be expected in a sewer line that enters a larger sewer line below the water level.

Smoke Testing: A method used to detect any water other than wastewater entering the **sewer** system. This water could be coming from roof leaders, cross connections between the wastewater and stormwater systems, cleanouts, driveway and yard drains, damage to the wastewater system, loose joints in the wastewater pipes, etc. When smoke testing a line, a non-toxic smoke bombs should be used.

Thermal overload: The greatest cause of failure in an electric motor. A **thermal overload** relay is a small electromechanical device that protects motors from overheating. These relays help to control the electrical current that goes to the motor to prevent it from overheating.

Time-delay fuse: The recommended type of fuse to use in the circuit leading to the electric motor.

Trench: **I**s a type of excavation or depression in the ground that is generally deeper than it is wide (as opposed to a wider gully, or ditch), and narrow compared with its length (as opposed to a simple hole).

Trench Safety: If a trench is more than five feet deep the spoil must be placed at least 2 feet from the trench and only on one side of the trench.12 inches is the minimum compaction height of backfill when laying piping in Class A or Class B bedding. Subsidence of ground and/or adjacent structures could possibly happen when groundwater is removed from a construction site or trench. 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.

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 = Flow (gpm) X Head (ft)
X Pump Efficiency

MOTOR HORSEPOWER = Flow (gpm) X Head (ft)
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 (%)** = $\frac{\text{Rise (ft)}}{\text{Run (ft)}} \times 100$

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 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, % = $\frac{\text{(In – Out) (100\%)}}{\text{In}}$

Feed rate, lbs/day = $\frac{\text{(Dosage, mg/L) (Capacity, MGD) (8.34 lbs/gals)}}{\text{(Available fluoride ion) (Purity)}}$

Feed rate, gal/min (Saturator) = $\frac{\text{(Plant capacity, gal/min.) (Dosage, mg /L)}}{\text{18,000 mg/L}}$

Filter Backwash Rate = $\frac{\text{Flow}}{\text{Filter Area}}$

Filter Yield, lbs/hr/sq ft = $\frac{\text{(Solids Loading, lbs/day) (Recovery, \% / 100\%)}}{\text{(Filter operation, hr/day) (Area, ft}^2\text{)}}$

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

Horsepower (motor) = $\frac{\text{(Flow, gpm) (Head, ft)}}{\text{(3960) (Pump, Eff) (Motor, Eff)}}$

Horsepower (water) = $\frac{\text{(Flow, gpm) (Head, ft)}}{\text{(3960)}}$

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, % = $\frac{\text{(Dry Solids - Ash Solids) (100\%)}}{\text{Dry Solids}}$

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)

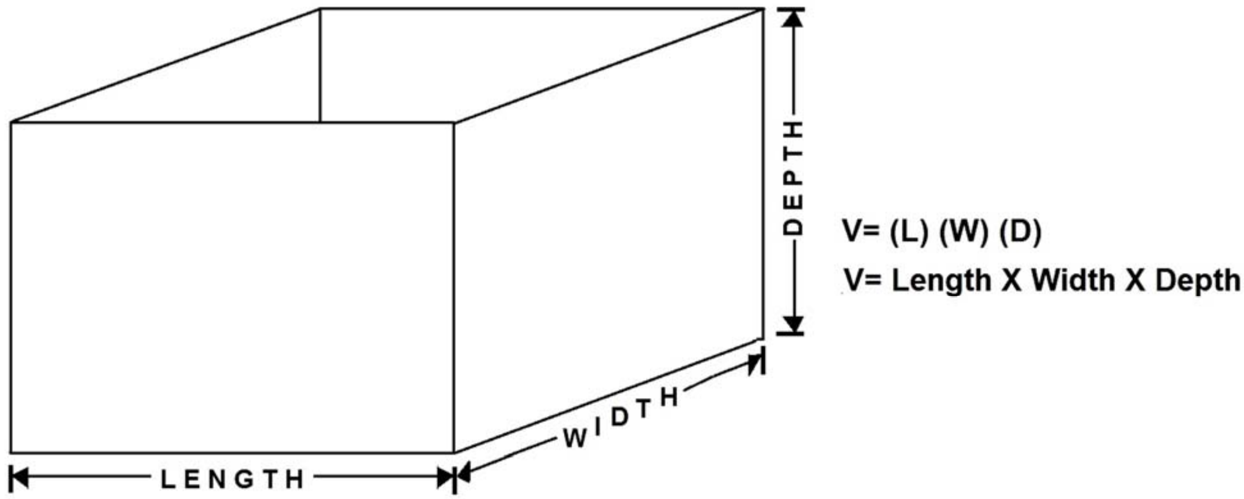
Waste Normality = $\frac{\text{(Titrant Volume) (Titrant Normality)}}{\text{Sample Volume}}$

Weir Overflow Rate = $\frac{\text{Flow}}{\text{Weir Length}}$

Conversion Factors

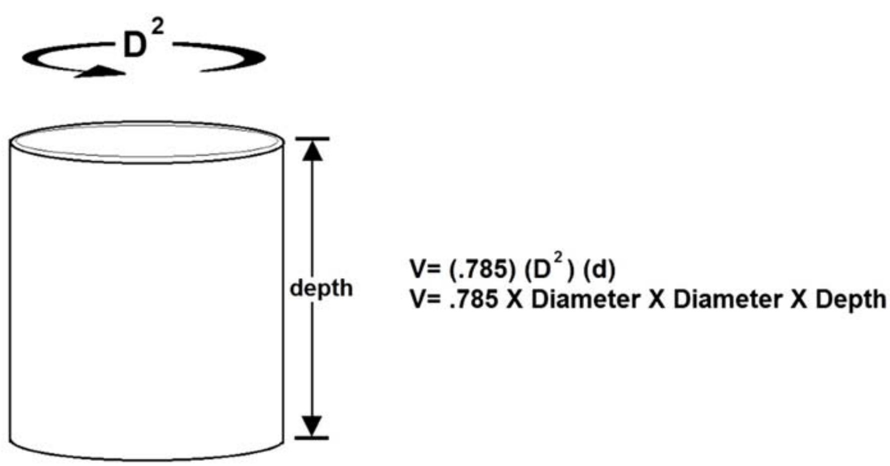
1 acre = 43,560 square feet
1 cubic foot = 7.48 gallons
1 foot = 0.305 meters
1 gallon = 3.785 liters
1 gallon = 8.34 pounds
1 grain per gallon = 17.1 mg/L
1 horsepower = 0.746 kilowatts
1 million gallons per day = 694.45 gallons per minute
1 pound = 0.454 kilograms
1 pound per square inch = 2.31 feet 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



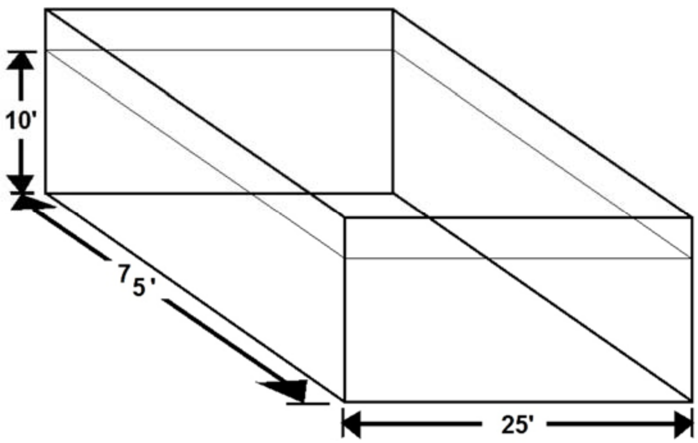
CALCULATING THE VOLUME OF A CUBE

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

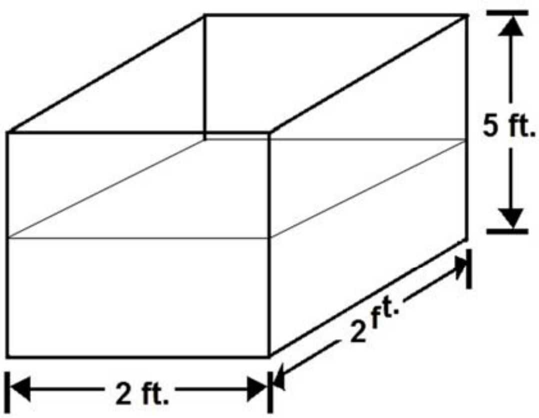
V= (L) (W) (D)

(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.



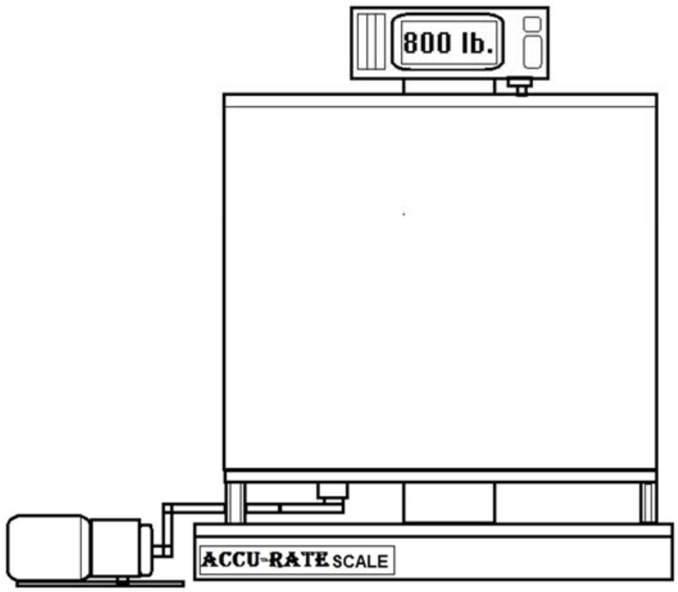
Convert 10 cu.ft. to gallons of water:

$(10\ ft.^3)(7.48)$

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?



LIQUID IN A TANK WEIGHS 800 lbs. / HOW MANY GALLONS ARE IN THE TANK:

800 lbs. DIVIDED BY 8.34 lbs./gal.

$$\frac{800\text{lbs.}}{8.34\text{ lbs./gal.}} =$$

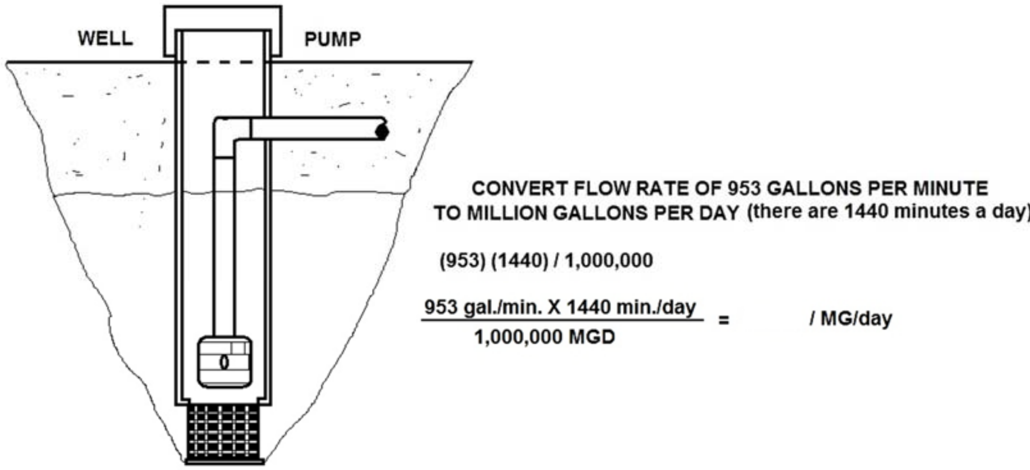
CONVERTING POUNDS TO GALLONS

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?

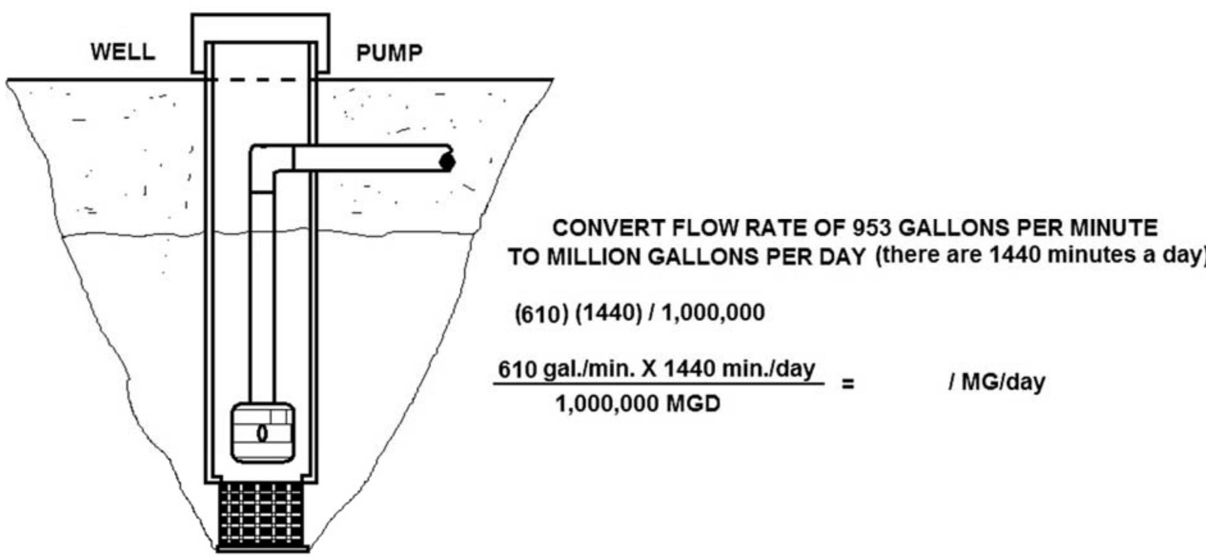
3. Convert a flow rate of 953 gallons per minute to million gallons per day.
There is 1440 minutes in a day.



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.

$$\mathbf{1\ MG} = \frac{\mathbf{100{,}000\ Gallons}}{\mathbf{24\ Hours\ (fill\ time)}}$$



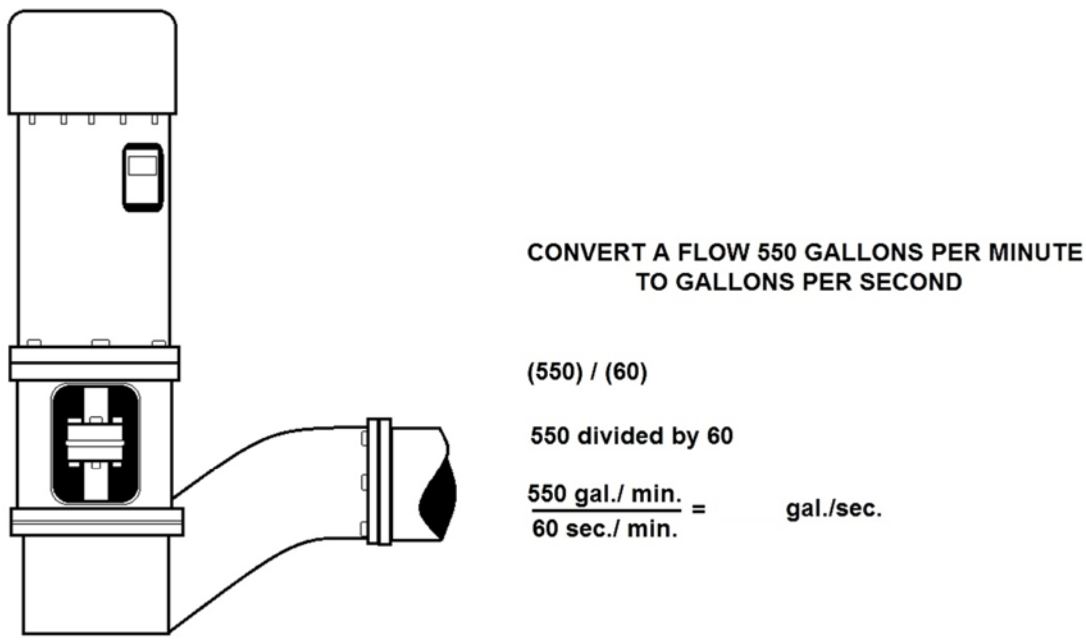
CONVERTING GALLONS PER MINUTE TO MILLION GALLONS PER DAY

Practice Questions, no answers provided

A2. Convert a flow rate of 14,750 gallons per minute to million gallons per day.

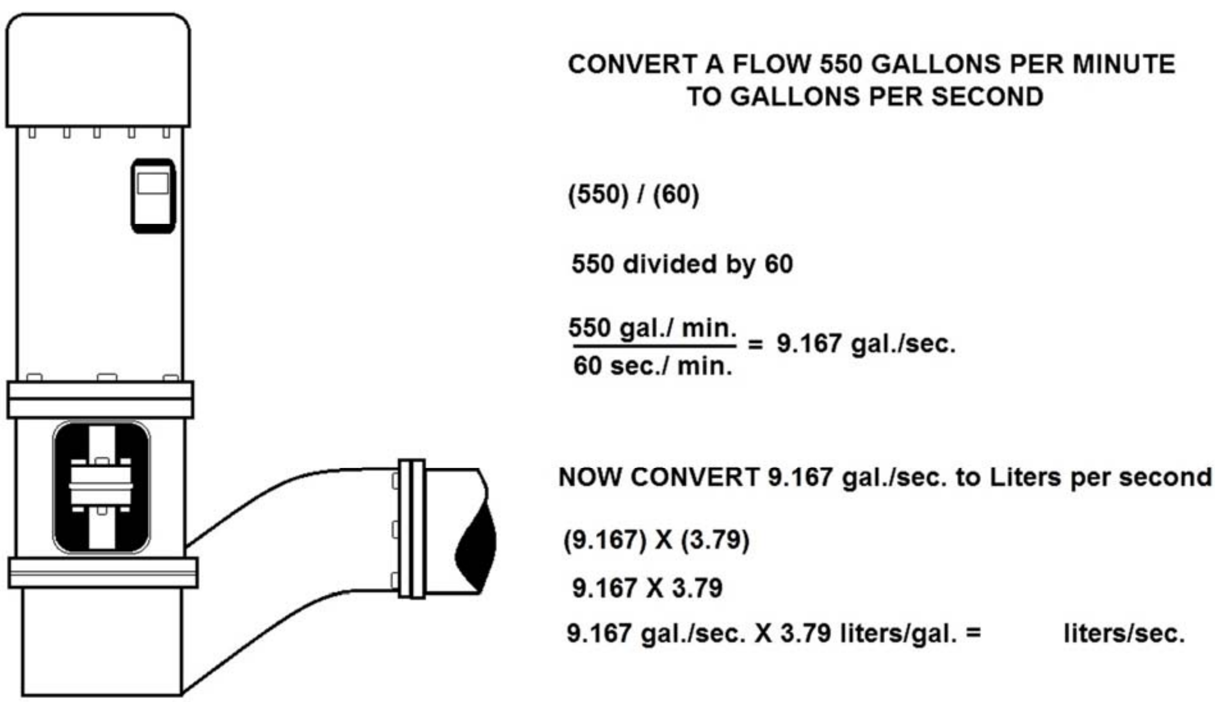
B2. Convert a flow rate of 5880 gallons per minute to millions of gallons per day.

5. Convert a flow of 550 gallons per minute to gallons per second.



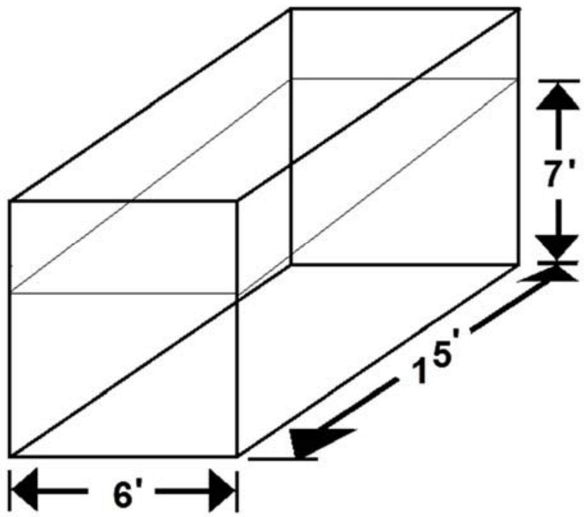
CONVERTING GALLONS PER MINUTE TO GALLONS PER SECOND

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 =



A TANK 6' x 15' x 7' HOLDS A MAXIMUM OF ____________ GALLONS OF WATER

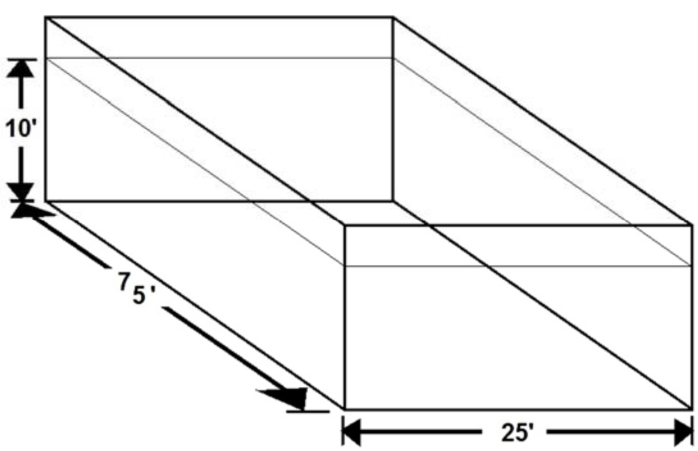
V= (L) (W) (D) x 7.48

V= (6') (15') (7') (7.48)

6' x 15' x 7' x 7.48 =   gallons

8. A tank is 25’ X 75’ X 10’ what is the volume of water in gallons?

V= (L) (W) (D) X 7.48 =



A TANK IS 25' x 75' x 10', WHAT IS THE VOLUME OF WATER IN GALLONS

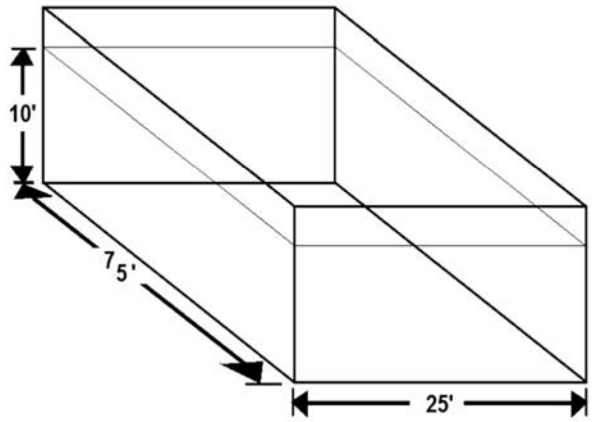
V= (L) (W) (D)

(25) (75) (10) (7.48)

25' x 75' x 10' x 7.48 =   gallons

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

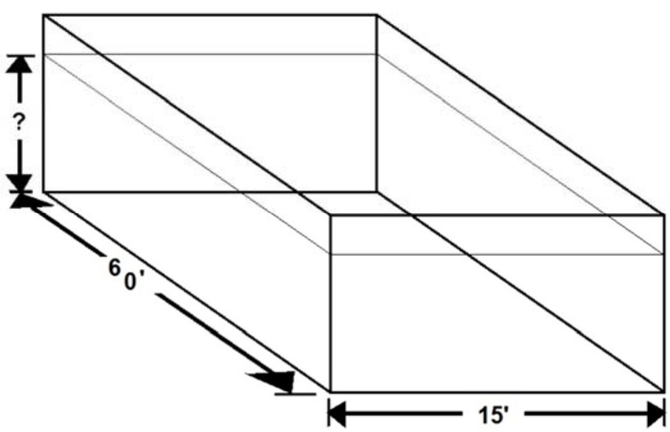
1 GALLON = 3.79 LITERS

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 <u>67,320</u> / 7.48 = <u>9000 gal.</u>

60' X 15' = 900 ft.

$$\frac{\text{9000 gal.}}{\text{900 ft.}} = \quad \text{ft.}$$

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

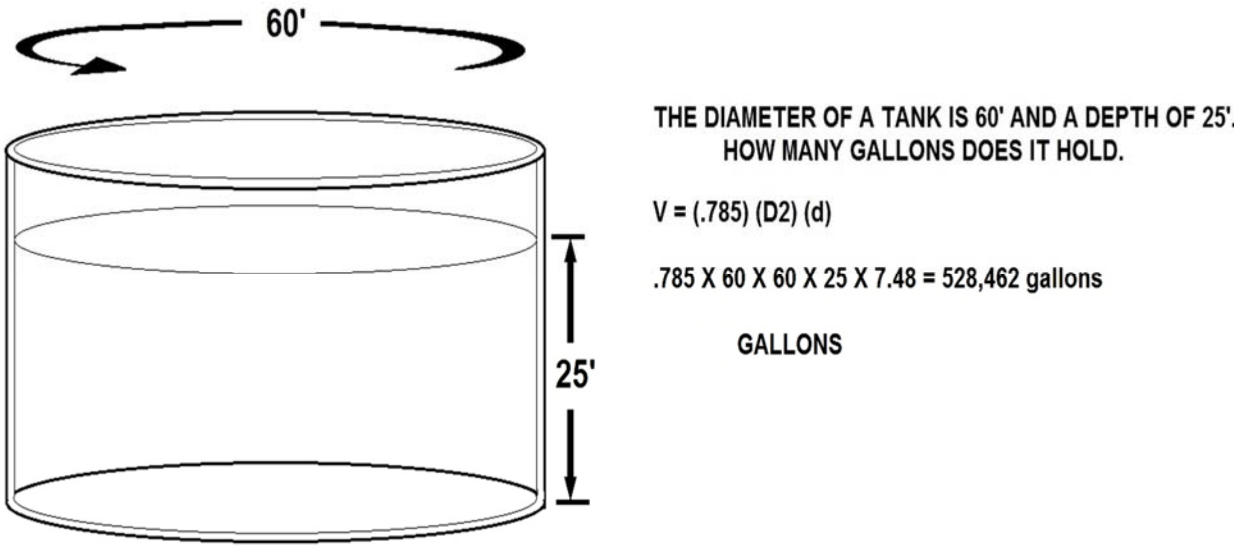
E3. A tank holds 85,000 gallons of water. The length is 75' and the width is 14'. How deep is the tank?

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.

$$\textbf{1 MG} = \frac{\textbf{100,000 Gallons}}{\textbf{24 Hours (fill time)}}$$

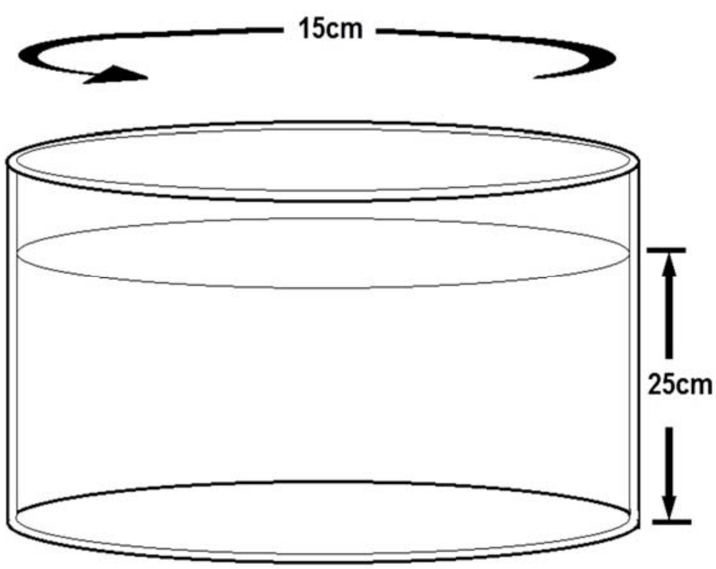
FILL TIME= 2.4 Hours

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

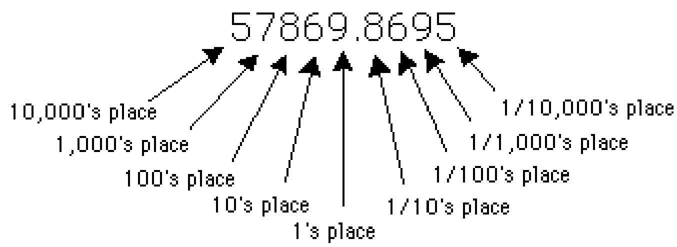
.785 X .492' X .492' X .82 X 7.48 = 1.17

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

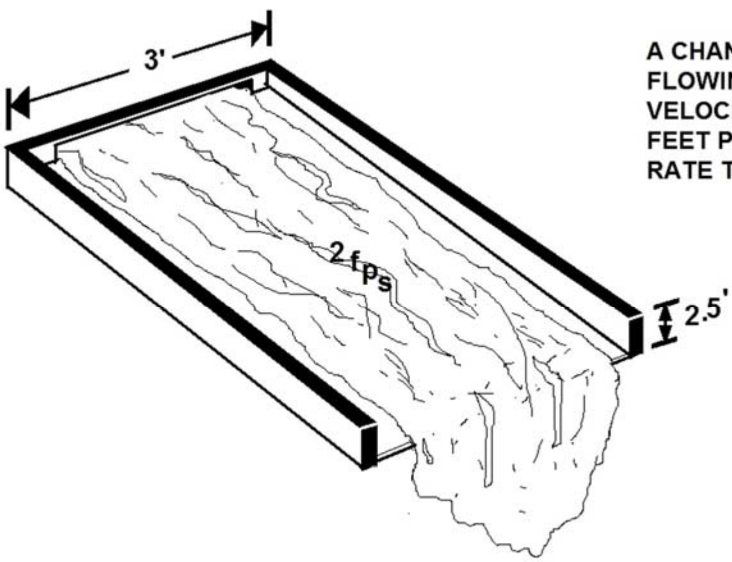
$$Q = A \times V$$

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.

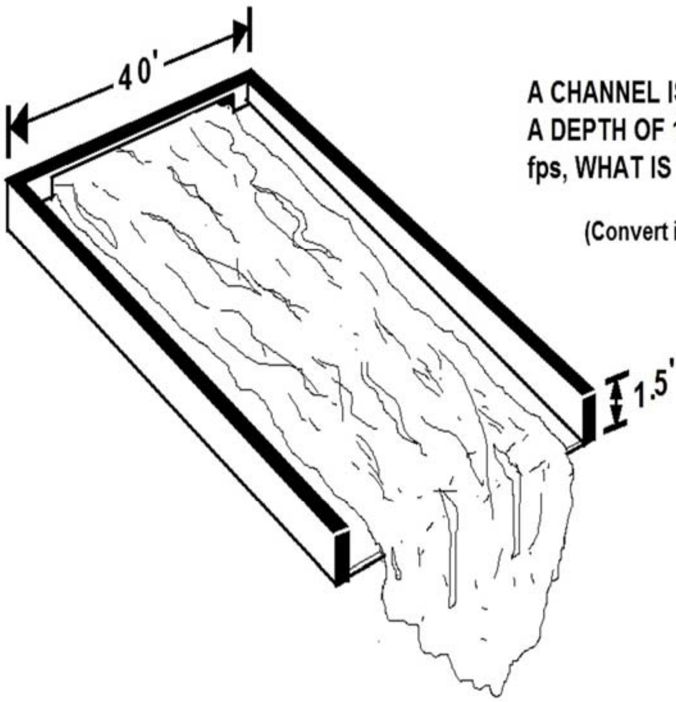
Q = /sec.

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 = 2.3ft/sec.

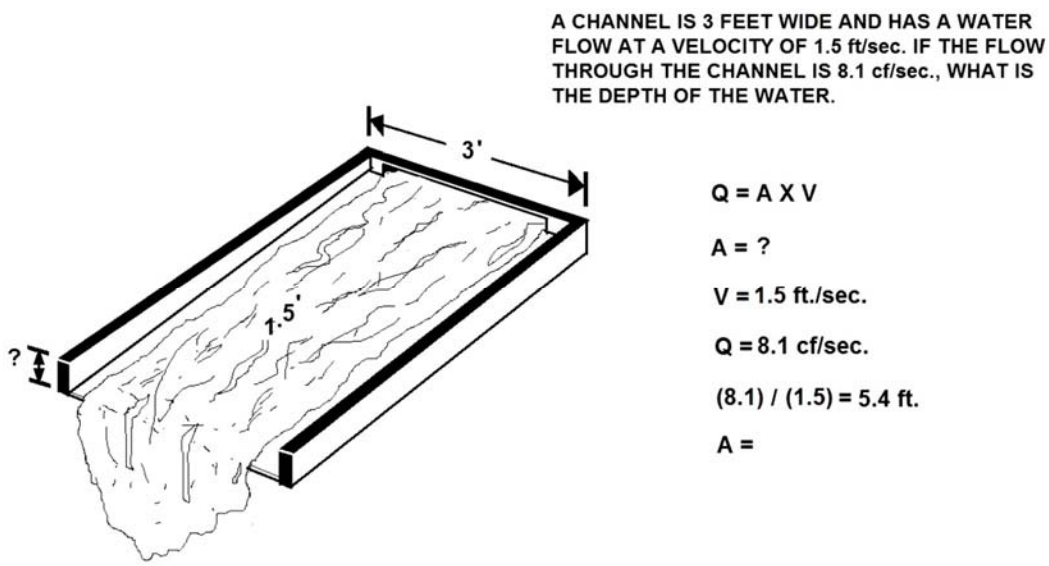
Q = 2.3ft/sec. X 5ft

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?

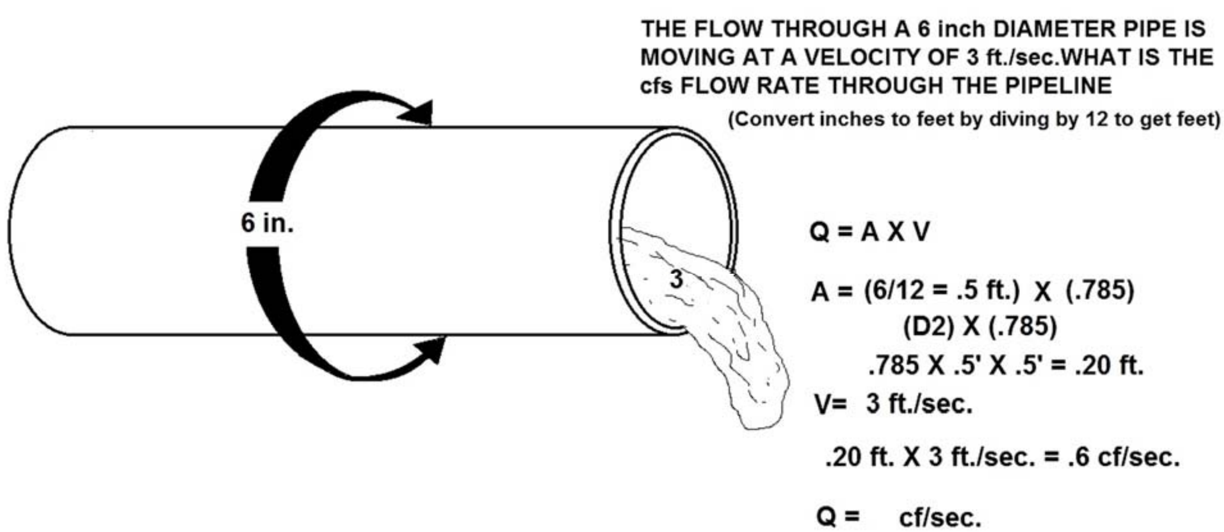
Q = 8.1 cfs
V = 1.5 fps
A = ?

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?

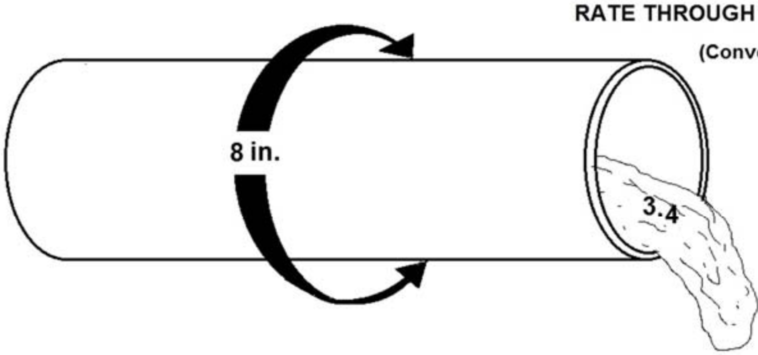
Q =
A = .785 X .5' X .5' =
V = 3 fps



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

AN 8 inch DIAMETER PIPE HAS WATER FLOWING AT A VELOCITY OF 3.4 ft./sec. WHAT IS THE gpm (gal./min.) FLOW RATE THROUGH THE PIPE.

(Convert inches to feet by diving by 12 to get feet)



Q = A X V

A = (8/12 = .667 ft.) (.785)
(D2) X (.785)
.785 X .667' X .667' = .35 ft.

V= 3.4 ft/sec.

.35 ft. X 3.4 ft./sec. = 1.19 cf/sec.

Q = 1.19 cf/sec. X 60 sec./min. X 7.48 =

Q = gal./min.

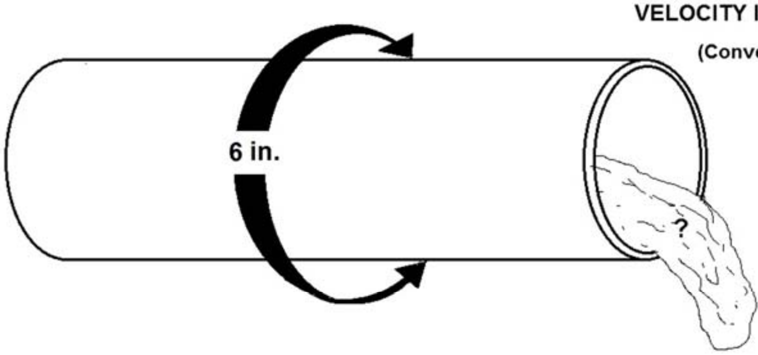
18. A 6 inch diameter pipe delivers 280 gpm. What is the velocity of flow in the pipe in ft/sec?

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.

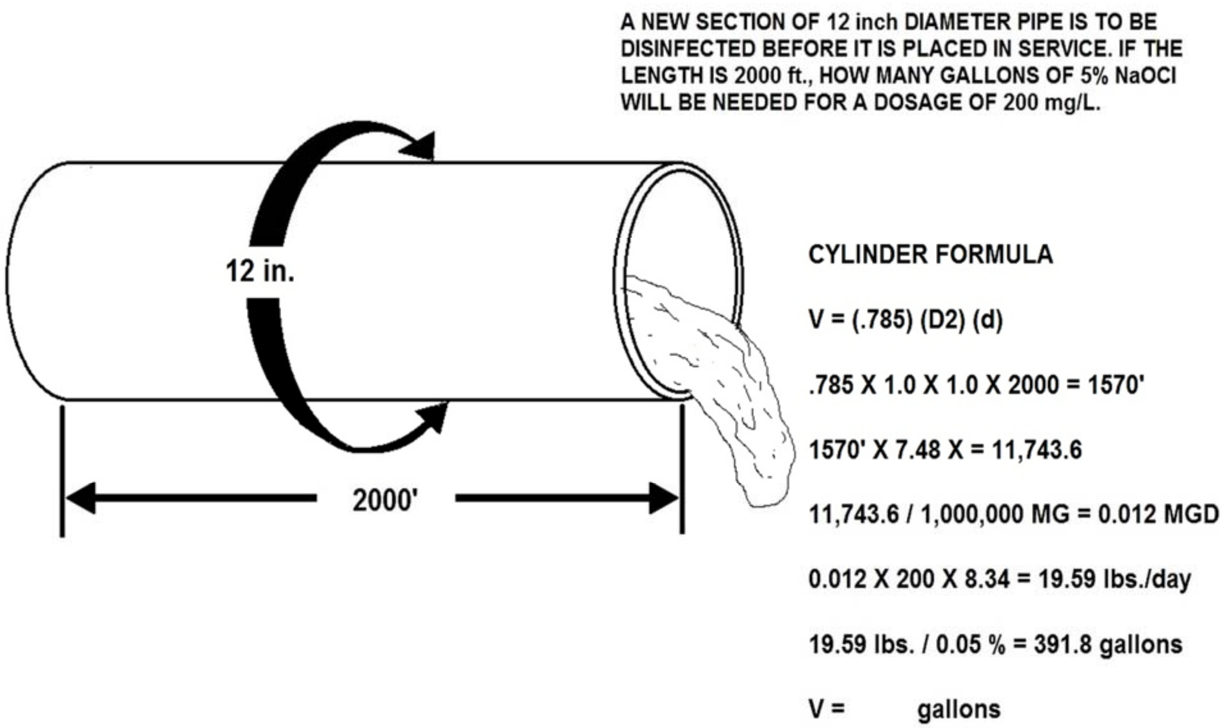
19. A new section of 12 inch diameter pipe is to be disinfected before it is placed in service. If the length is 2000 feet, how many gallons of 5% NaOCl will be needed for a dosage of 200 mg/L?

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 %

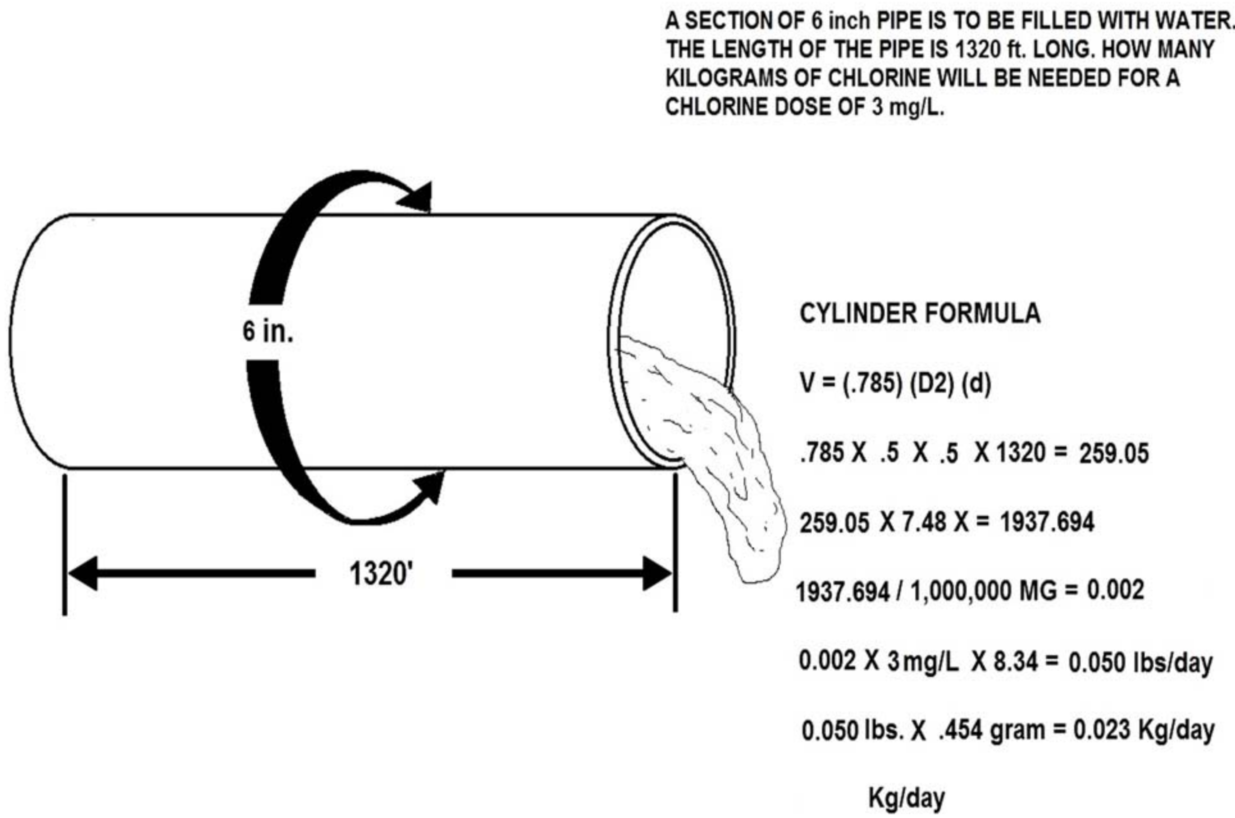
0.0117436 MG X 200 mg/L X 8.34 =_________ lbs/day ÷ .05 =



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



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

$$\text{DOSE , mg/L} = \frac{(332)\quad \text{lbs. / day}}{(5.27)\quad \text{MGD x 8.34 lbs./mg/L/MG}}$$

$$\text{DOSE , mg/L} = (7.6)\ \text{mg/L}$$

DOSE CALCULATION EXAMPLE

Chlorine Residual Formula

$$\text{Dose, mg / L} = \text{Demand, mg / L} + \text{Residual, mg / L}$$

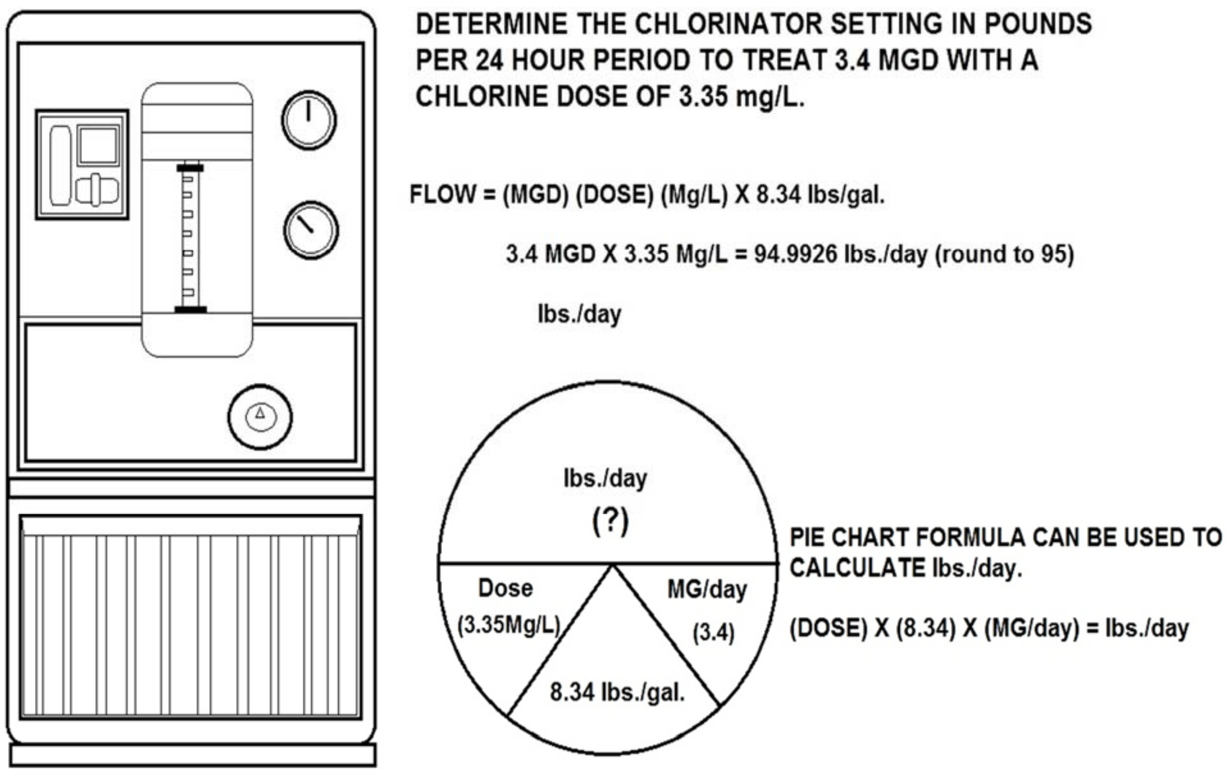
How To Calculate Chlorine Dose

$$(\text{mg / L } Cl_2)\ (\text{MGD flow})\ (8.34 \text{ lbs. / gal.}) = \text{lbs. / day } Cl_2$$

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.

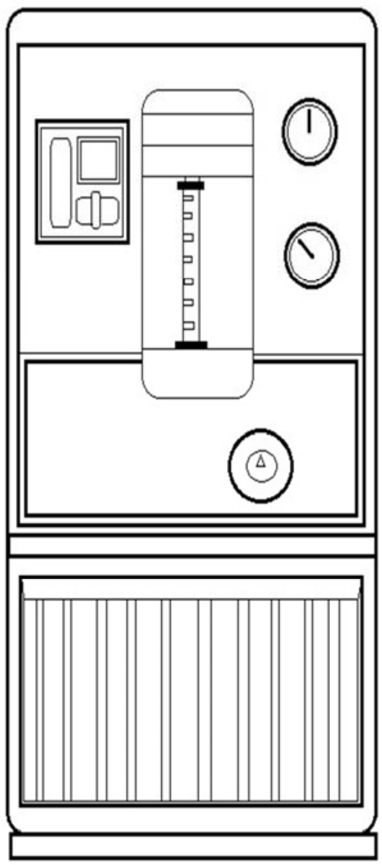
Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal



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.

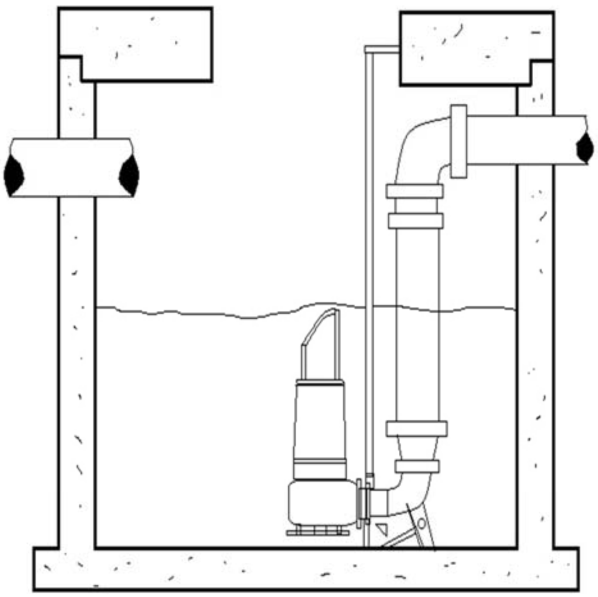
NOW CONVERT TO MGD: 122,400 divided by 1,000,000 = .1224 MGD.

.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.

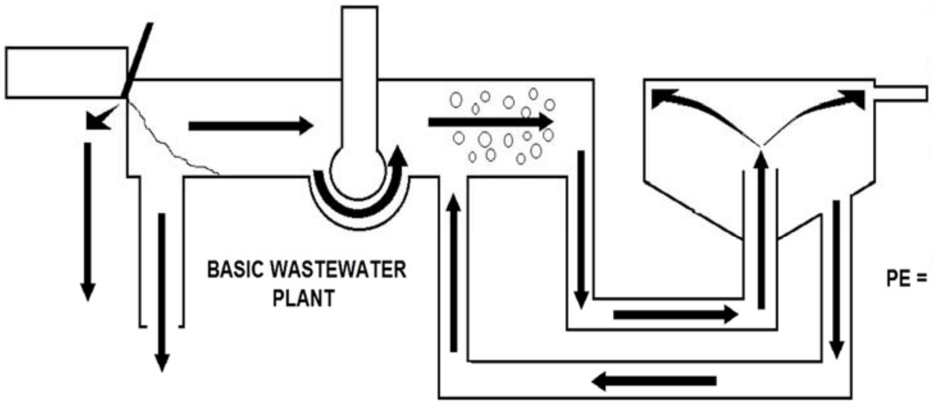
1795.2 gals. X 216 times/day = 387763.2 gals./day

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?

$$PE = \frac{\text{(FLOW/MGD) (BOD mg/L) (8.34)}}{\text{lbs. day/per person}}$$

$$\frac{\text{(0.7 /MGD) (225 mg/L) (8.34)}}{\text{0.2 lbs. day/per person}}$$

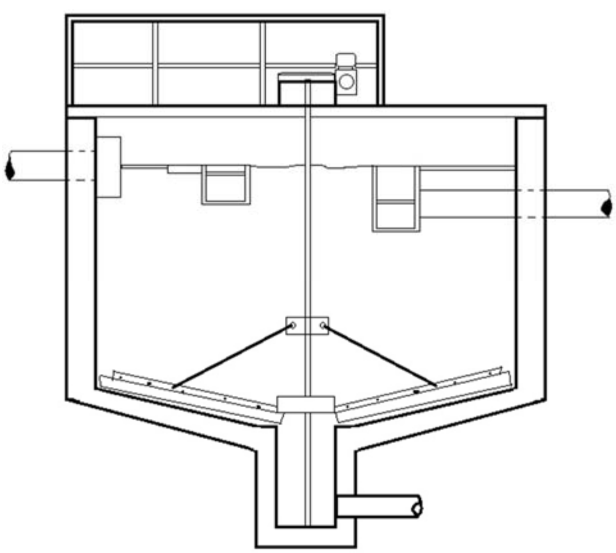
$$\frac{1313.55}{0.2} =$$

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.

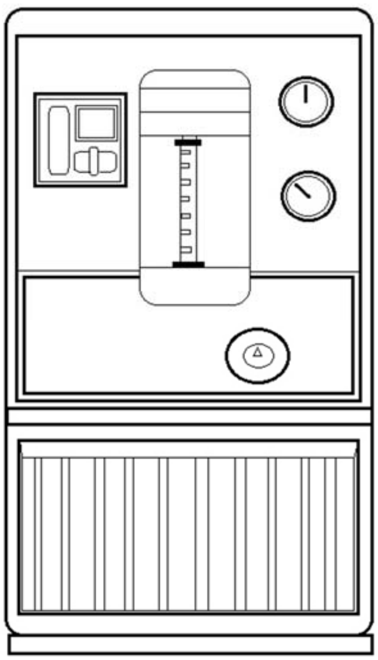
Answers

21. 94.9 lbs/day
22. $950.12
23. .388 or .39 MGD
24. 6567.75
25. 2 hrs

Practice Math 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

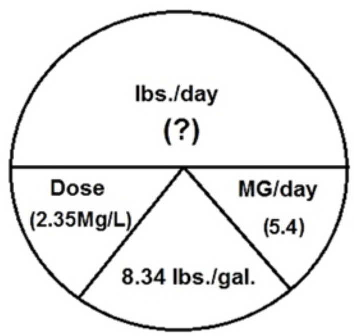


DETERMINE THE CHLORINATOR SETTING IN POUNDS PER 24 HOUR PERIOD TO TREAT 5.4 MGD WITH A CHLORINE DOSE OF 2.35 mg/L.

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

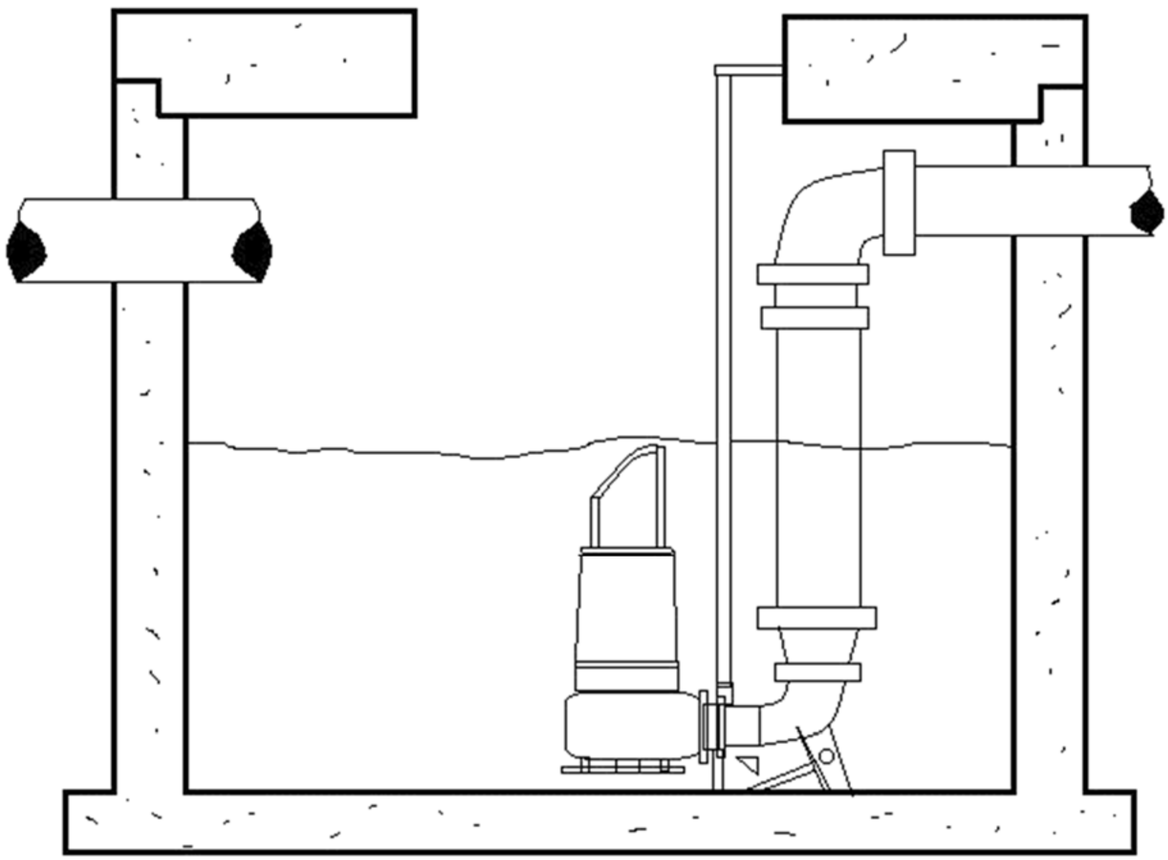
DIVIDE gal./day BY 1,000,000 TO GET MGD

10,080 / 1,000,000 = 0.010 MGD

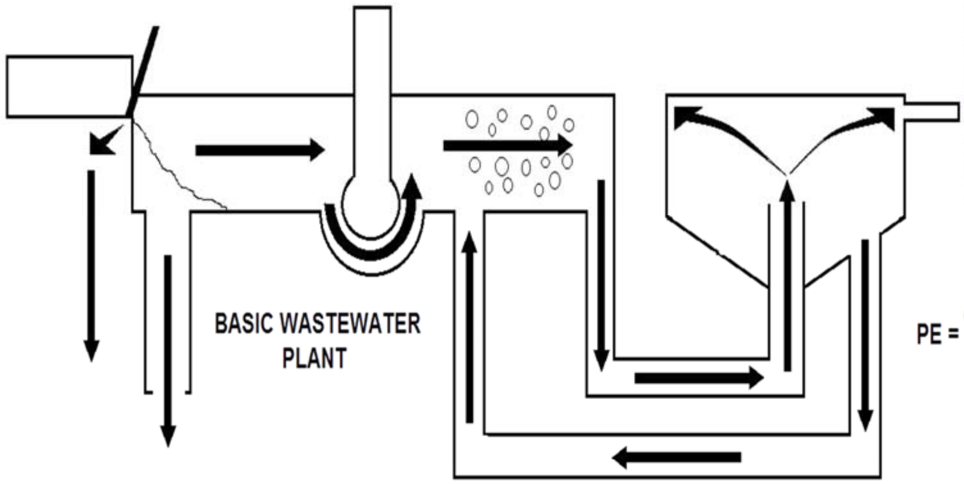
(0.010 MGD) (15 mg/L) (8.34 lbs./gal.) ($0.15/lb.) (365 days/year)= $68.49

$ 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?



A SEWAGE TREATMENT PLANT HAS A FLOW OF 1.3 MGD AND A BOD OF 25 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?

$$PE = \frac{\text{(FLOW/MGD) (BOD mg/L) (8.34)}}{\text{lbs. day/per person}}$$

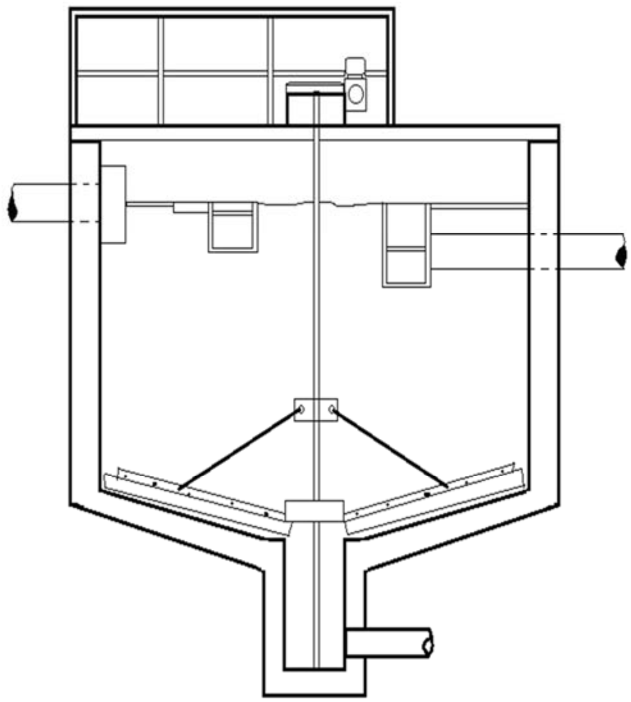
$$\frac{\text{(1.3 /MGD) (25 mg/L) (8.34)}}{\text{0.2 lbs. day/per person}}$$

$$\frac{271.5}{0.2} = 1355.25$$

1355.25 Population Equivalent

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)

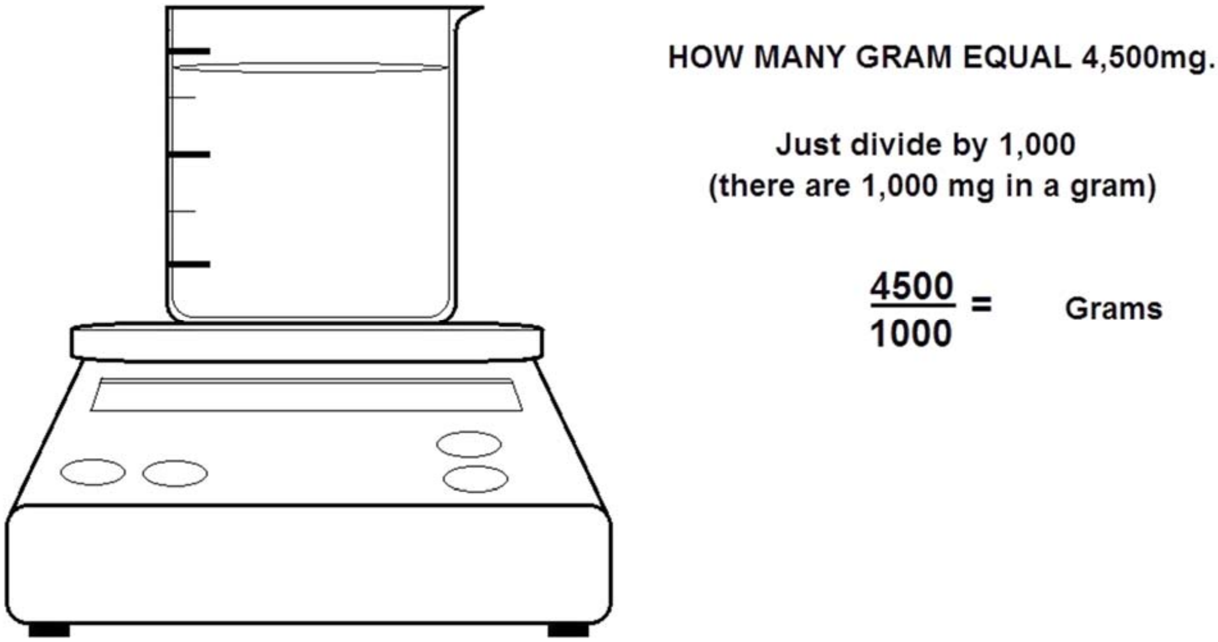
One Part in a Million Parts

Milligrams Per Liter

(Refers to a Weight Ratio)

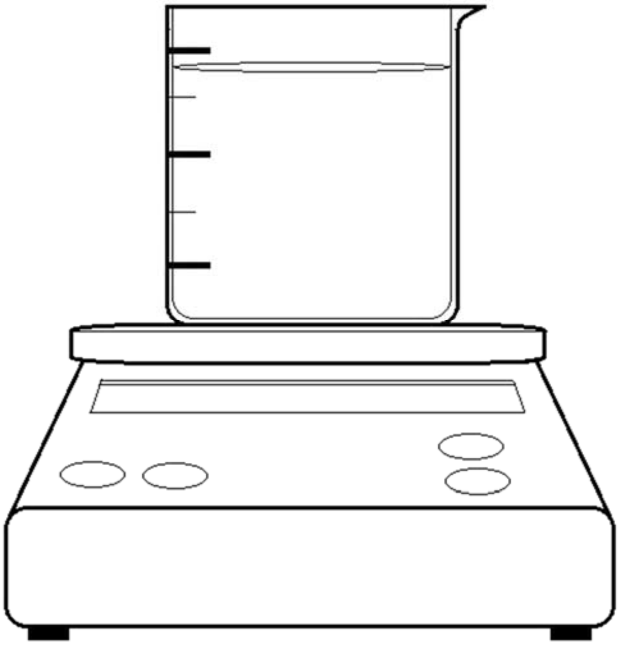
26. How many grams equal 4,500 mg?

Just simply divide by 1,000.



Practice Questions

A7. How many grams equal 7,500 mg?

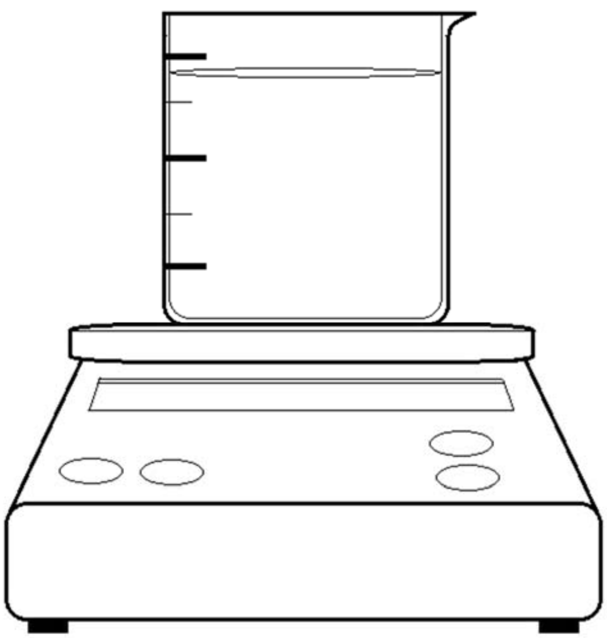


HOW MANY GRAM EQUAL 7,500mg.

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)

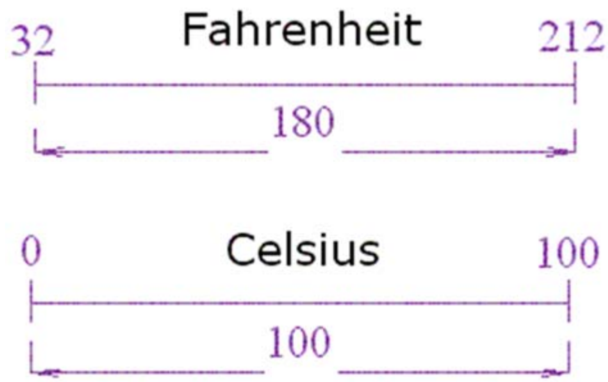
$$\frac{12500}{1000} = 12.5 \text{ Grams}$$

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

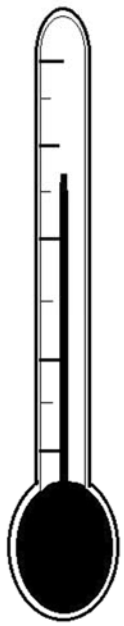
Note: 180/100 can be simplified to 9/5, and likewise 100/180=5/9.

^{0}F = (0C X 9/5) + 32 9/5 =1.8

^{0}C = (0F - 32) X 5/9 5/9 = .555

27. Convert 20 degrees Celsius to degrees Fahrenheit.

20 ° X 1.8 + 32 = F



CONVERT 20 degrees CELSIUS TO degrees FAHRENHEIT

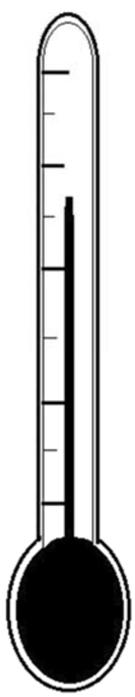
To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

(20) (1.8) + 32 = 68

20°C =

28. Convert 4 degrees Celsius to degrees Fahrenheit.

4° X 1.8 + 32 = F



CONVERT 4 degrees CELSIUS TO degrees FAHRENHEIT

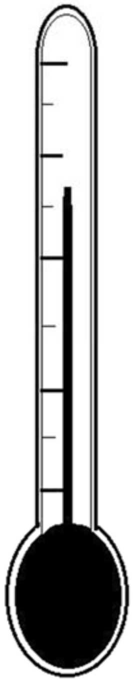
To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

(4) (1.8) + 32 = 39.2

4°C =

Practice Questions

A8. Convert 22 degrees Celsius to degrees Fahrenheit.



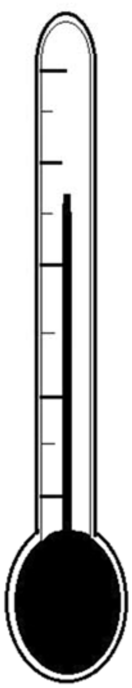
CONVERT 22 degrees CELSIUS TO degrees FAHRENHEIT

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.



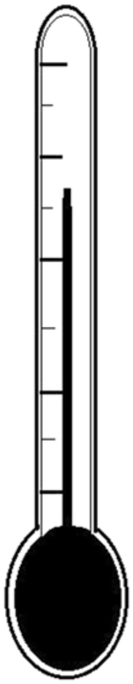
CONVERT 2 degrees CELSIUS TO degrees FAHRENHEIT

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

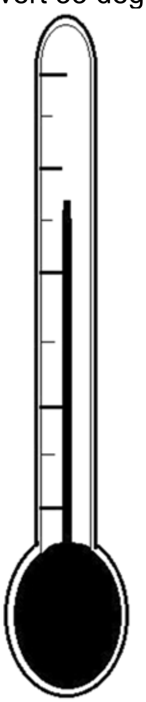
To convert Fahrenheit to Celsius :

First subtract by 32 then multiply by .555

$$82 - 32\ (.555) = 27.75$$

$$82^{\circ}F = 27.75^{\circ}C$$

D8. Convert 33 degrees Fahrenheit to degrees Celsius.



CONVERT 33 degrees FAHRENHEIT TO degrees CELSIUS

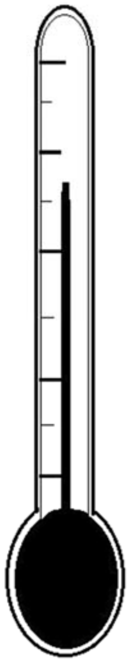
To convert Fahrenheit to Calsius :

First subtract by 32 then multiply by .555

$$33 - 32\ (.555) = .555$$

$$33^{\circ}F = .555^{\circ}C$$

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

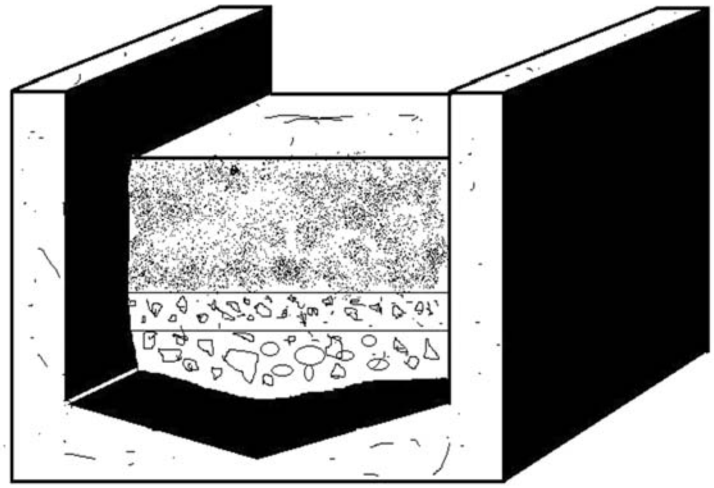
$$72 - 32\ (.555) = 22.2$$

$$72^{\circ}F = 22.2^{\circ}C$$

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



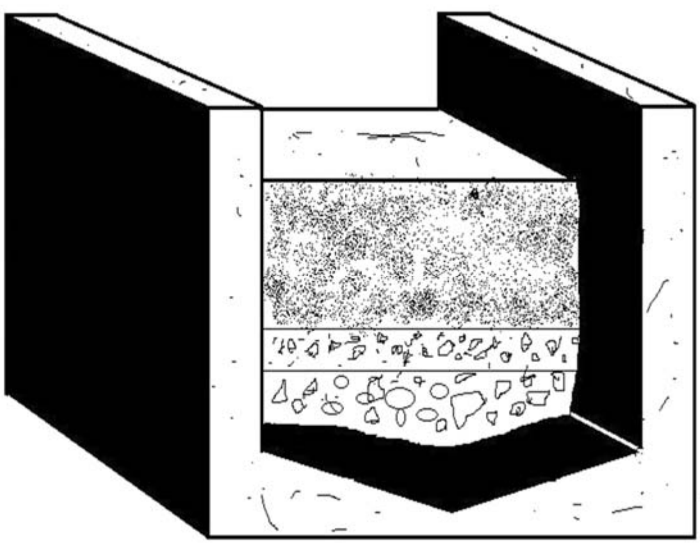
A 19 FOOT WIDE BY 31 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 2,050 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

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.

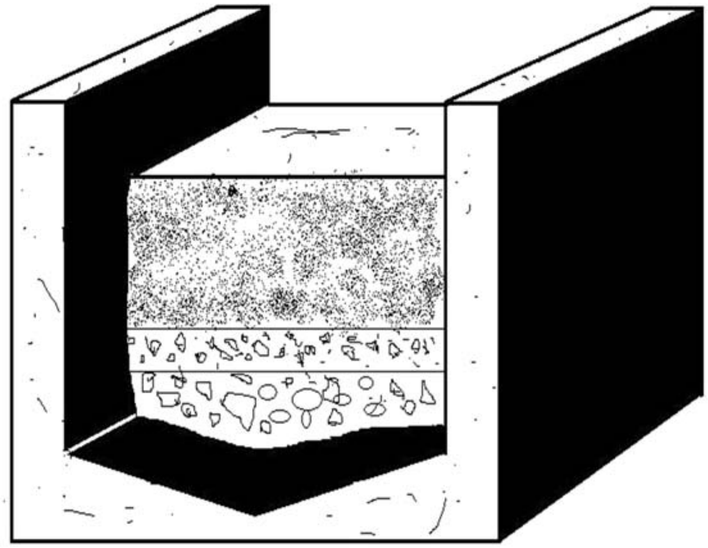
GPM divided by Square Feet

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.



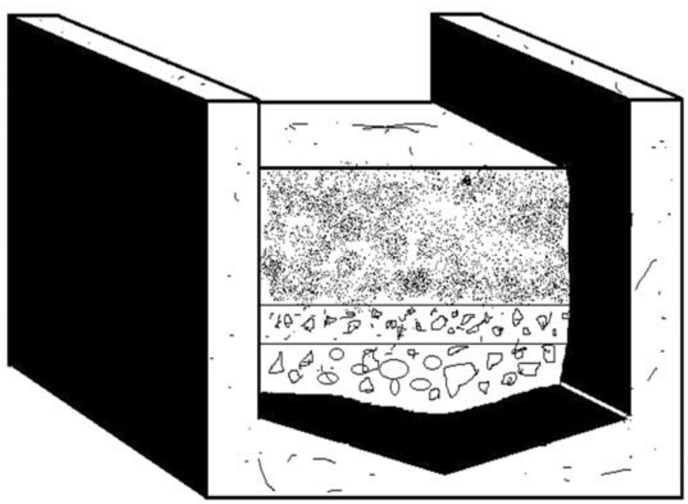
A 25 FOOT WIDE BY 25 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 300 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

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

$$\text{GPD} = \frac{\text{GALLONS}}{\text{MINUTE}} \times \frac{\text{60 MINUTES}}{\text{HOUR}} \times \frac{\text{24 HOURS}}{\text{DAY}}$$

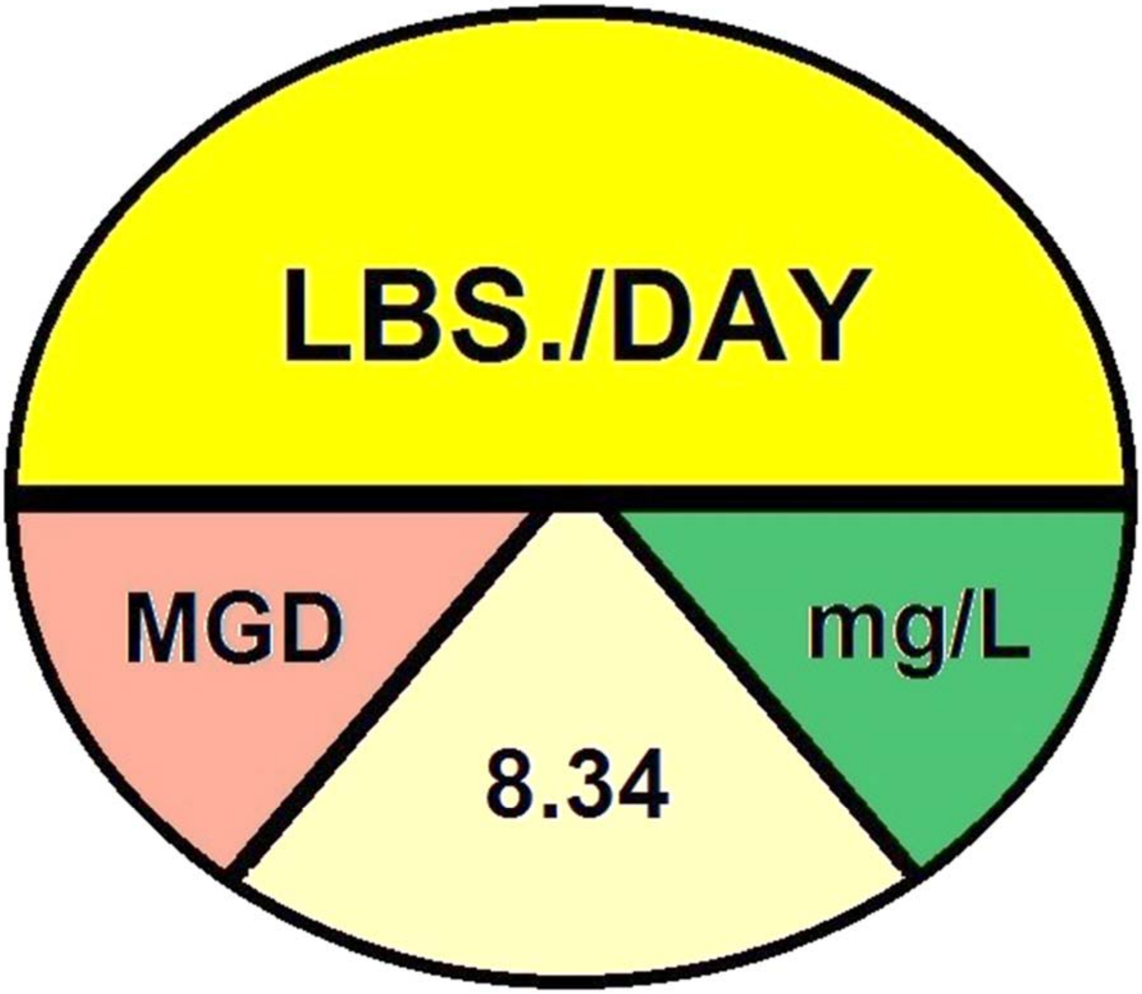
$$\text{GT} = \frac{\text{CHLORINE \% X 10,000}}{\text{1 PPM}}$$

$$\frac{\text{GPD}}{\text{GT}} = \text{GALLONS OF CHLORINE PER 24 HOURS}$$

GPD= Gallon Per Day
GT= Gallons Treated

$$(\text{mg / L } Cl_2)\ (\text{MGD flow})\ (\text{8.34 lbs. / gal.}) = \text{lbs. / day } Cl_2$$

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?

$$\text{SLOPE} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \qquad \text{SLOPE (\%)} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \text{ X } 100$$

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

Practice Questions, no answers provided

A13. A 24-inch sewer carries an average daily flow of 3 MGD. If the average daily flow per person from the area served is 125 GPCD (gallons per capita per day), approximately how many people discharge into the wastewater collection system?

B13. Using a dose rate of 4 mg/L, how many pounds of chlorine per day should be used if the flow rate is 3.2 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

C13. What capacity blower will be required to ventilate a manhole which is 3.0 feet in diameter and 18 feet deep? The air exchange rate is 16 air changes per hour.

D13. Approximately how many feet of drop are in 575 feet of 8-inch sewer with a 0.0375 ft/ft. slope?

E13. How much brake horsepower is required to meet the following conditions: 50 gpm, total head = 110 feet? The submersible pump that is being specified is a combined 58% efficient?

F13. How wide is a trench at ground surface if a sewer trench is 2 feet wide at the bottom, 12 feet deep, and the sides have been sloped at a 4/5 horizontal to 1 vertical (3/4:1) ratio?

42. A float arrives in a manhole 550 feet down stream three minutes and thirty seconds from its release point. What is the velocity in ft/sec.?
Velocity ft/sec = distance ÷ time
550’ ÷ 3 min stop convert min to sec. 3 X 60 = 180 + 30 = 210 sec
550’ ÷ 210 sec = ______ fps

43. A new sewer line plan calls out a 0.6% slope of the line. An elevation reading of 108.8 feet at the manhole discharge and an elevation of 106.2 feet at a distance of 200 feet from the manhole are recorded. What is the existing slope of the line that has been installed?

$$\text{SLOPE} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \qquad \text{SLOPE (\%)} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \times 100$$

44. A triangular pile of spoil is 12 feet high and 12 feet wide at the base. The pile is 60' long. If the dump truck hauls 9 cubic yards of dirt, how many truck loads will it take to remove all of the spoil?

Given the base and the height of a triangle, we can find the area. Given the area and either the base or the height of a triangle, we can find the other dimension. The formula for area of a triangle is:

$A = \frac{1}{2} \cdot b \cdot h$ Or $A = \frac{b \cdot h}{2}$ where b is the base, h is the height.

12’ X 12’ ÷ 2 X 60’ = _________ cu.ft (27cuft/cuyrd)

45. A red dye is poured into an upstream manhole connected to a 12 inch sewer. The dye first appears in a manhole 400 feet downstream 3 minutes later. After 3 minutes and 40 seconds the dye disappears. Estimate the flow velocity in feet per second.

Velocity ft/sec = distance ÷ time

Make sure and convert time and average it.

46. 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

Practice Questions, no answers provided

A14. A float arrives in a manhole 850 feet down stream four minutes and thirty seconds from its release point. What is the velocity in ft/sec.?
Velocity ft/sec = distance ÷ time

B15. A new sewer line plan calls out a 0.6% slope of the line. An elevation reading of 210.3 feet at the manhole discharge and an elevation of 106.2 feet at a distance of 100 feet from the manhole are recorded. What is the existing slope of the line that has been installed?

$$\text{SLOPE} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \qquad \text{SLOPE (\%)} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \times 100$$

C15. A triangular pile of spoil is 15 feet high and 25 feet wide at the base. The pile is 40' long. If the dump truck hauls 9 cubic yards of dirt, how many truck loads will it take to remove all of the spoil?

Given the base and the height of a triangle, we can find the area. Given the area and either the base or the height of a triangle, we can find the other dimension. The formula for area of a triangle is:

$A = \frac{1}{2} \cdot b \cdot h$ Or $A = \frac{b \cdot h}{2}$ where b is the base, h is the height.

D15. A red dye is poured into an upstream manhole connected to a 12 inch sewer. The dye first appears in a manhole 300 feet downstream 3 minutes later. After 3 minutes and 20 seconds the dye disappears. Estimate the flow velocity in feet per second.

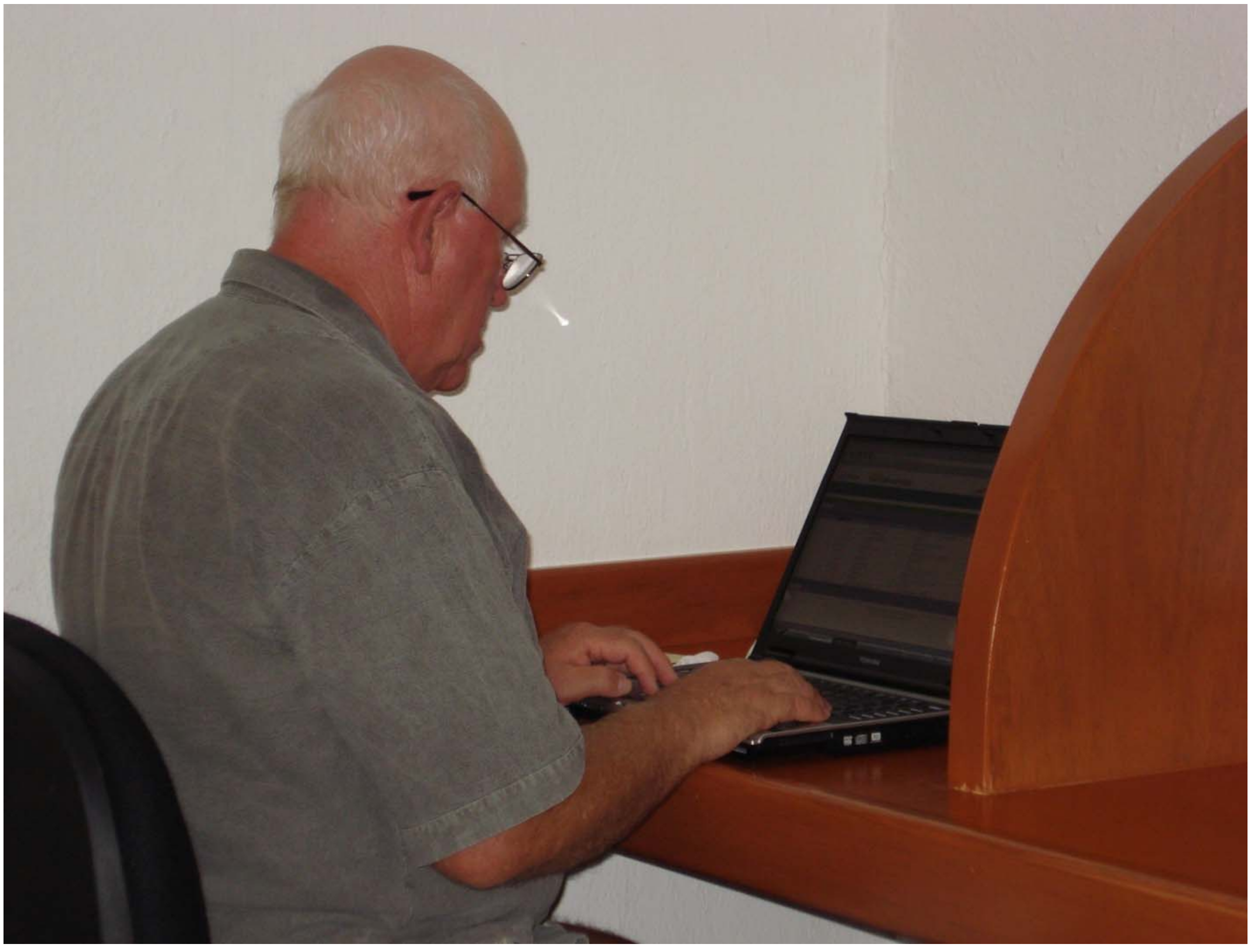
Velocity ft/sec = distance ÷ time

Make sure and convert time and average it.

E15. Calculate the total dosage in pounds of a chemical. Assume the sewer is completely filled with the concentration. Pipe diameter: 24 inches, Pipe length: 500 feet, Dose: 20 mg/L.

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
42. 2.62 fps
43. .013 or 1.3%
44. 17.7 or 18 trucks
45. 2 fps
46. 5.55 lbs



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