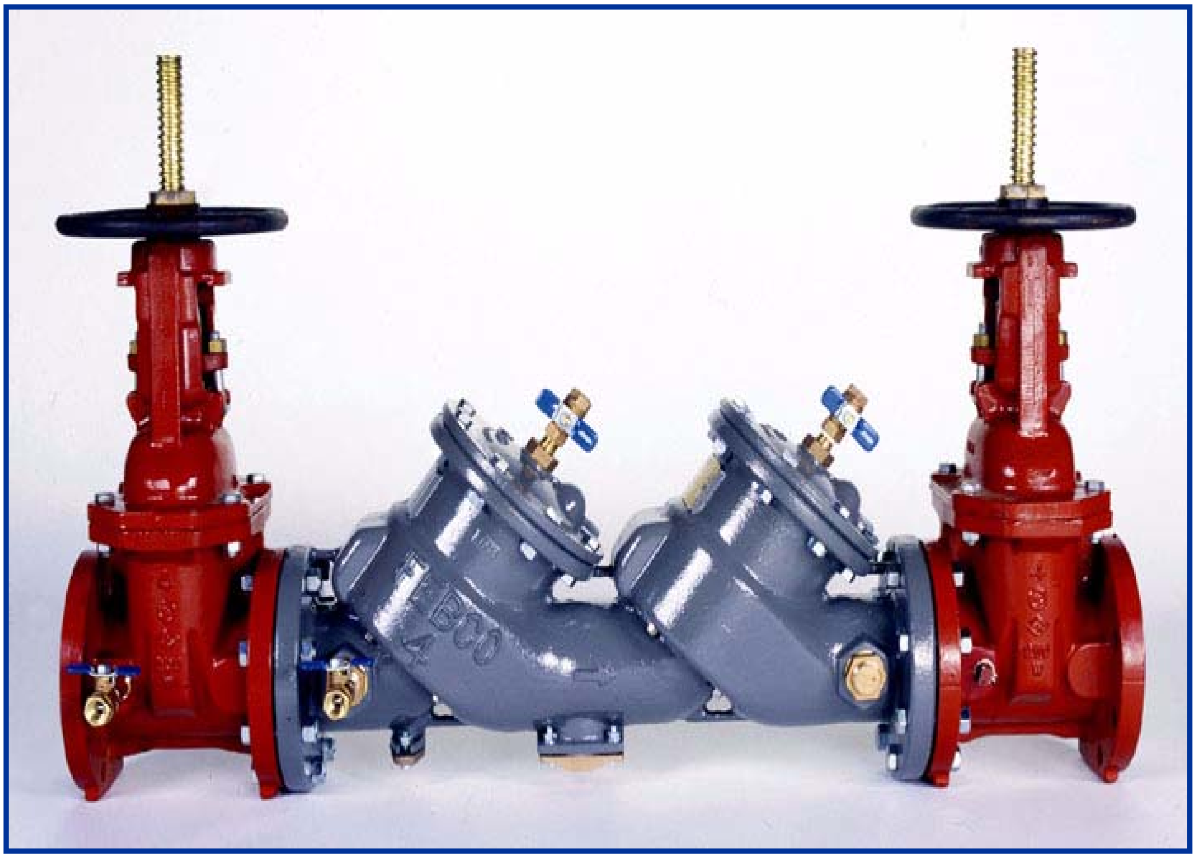
BACKFLOW AWARENESS

CONTINUING EDUCATION
PROFESSIONAL DEVELOPMENT COURSE



Technical Learning College

Printing and Saving Instructions

The best thing to do is to download this pdf document to your computer desktop and open it with Adobe Acrobat reader.

Abode Acrobat reader is a free computer software program and you can find it at Abode Acrobat's website.

You can complete the course by viewing the course materials on your computer or you can print it out. We give you permission to print this document.

Printing Instructions: If you are going to print this document, this document is designed to be printed double-sided or duplexed but can be single-sided.

This course booklet does not have the assignment. Please visit our website and download the assignment also.

Link to Assignment…
http://www.abctlc.com/PDF/BACKFLOW%20Assignment.pdf

State Approval Listing Link, check to see if your State accepts or has pre-approved this course. Not all States are listed. Not all courses are listed. If the course is not accepted for CEU credit, we will give you the course free if you ask your State to accept it for credit.

Professional Engineers; Most states will accept our courses for credit but we do not officially list the States or Agencies.

State Approval Listing URL…
http://www.tlch2o.com/PDF/CEU%20State%20Approvals.pdf

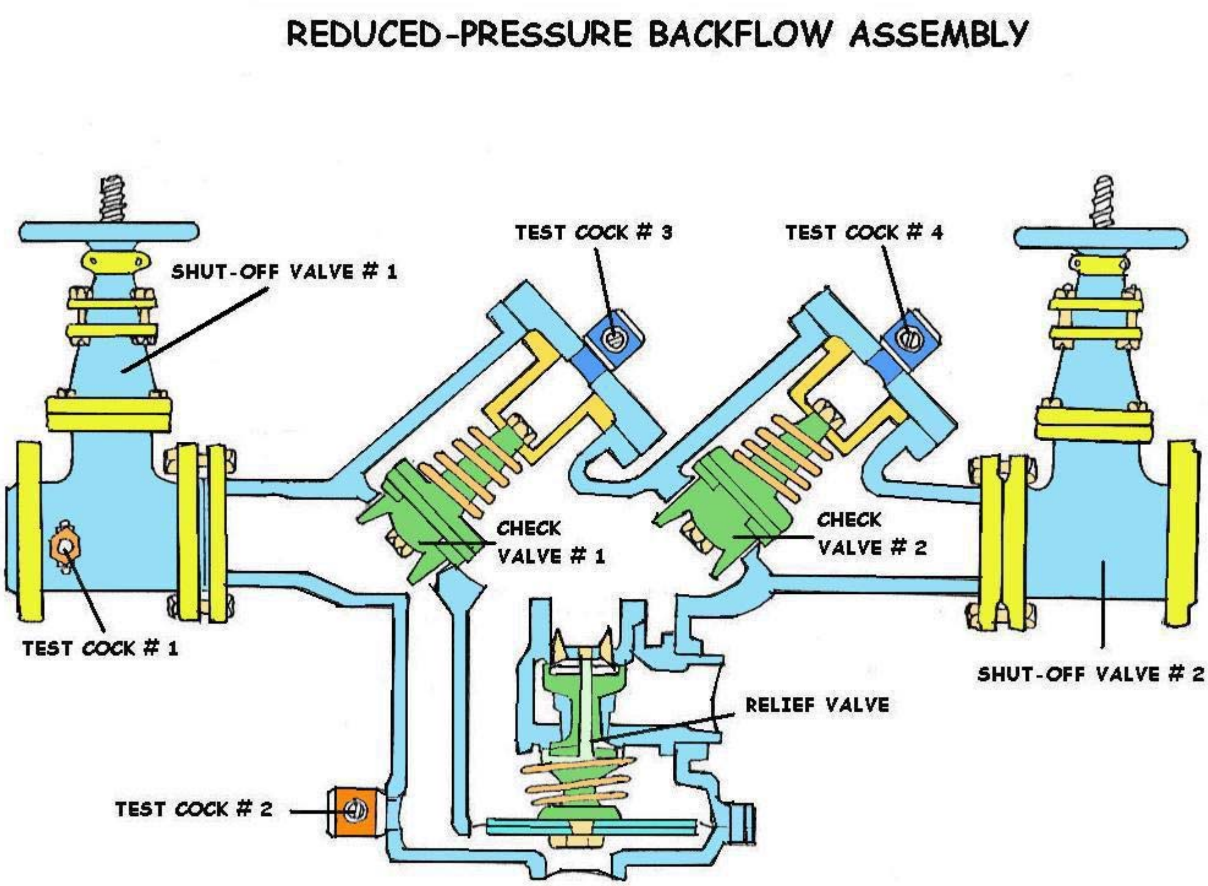
You can obtain a printed version from TLC for an additional $49.95 plus shipping charges.

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

Dr. Eric Pearce S.M.E., chemistry and biological review.

Dr. Pete Greer S.M.E., retired biology instructor.

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



Top, a highly trained General Backflow Assembly Tester is working on a fireline assembly. Bottom, a double check backflow preventor with OS& Y valves.

Important Information about this Manual

This manual has been prepared to educate operators in the general awareness of cross-connections and backflow prevention. The scope of cross-connection control and backflow prevention is quite large, requiring a major effort to bring it under control.

Water customers health and safety, as well as that of the operators, depend upon careful application of backflow prevention methods and effective cross-connection control procedures/programs. The manner in which we deal with such hazards will affect the earth and its inhabitants for many generations to come.

This manual covers general laws, regulations, required procedures and work rules relating to cross-connection control. It should be noted, however, that the regulation of backflow prevention and plumbing codes is an on going 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 should not be used as a guidance document for employees who are involved with cross-connection control. It is not designed to meet the requirements of the United States Environmental Protection Agency (EPA) or the Department of Labor-Occupational Safety and Health Administration (OSHA) or your state environmental or health agency. Technical Learning College or Technical Learning Consultants, Inc. make 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 purposes and is not considered a legal document. Individuals who are responsible for cross-connection control, backflow prevention or water distribution should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with OSHA, the EPA and other appropriate federal, state and local agencies.

Copyright Notice

Technical Learning College's Scope and Function

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

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. Most of TLC's distance based or independent study courses are offered in a print based format and you are welcome to examine this material on your computer with no obligation. Our courses are designed to be flexible and for you to finish the material at your leisure. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and assignments. Most CEU courses allow students to submit lessons using e-mail or fax, however some courses require students to submit lessons by postal mail. (See the course description for more information.) Students have direct contact with their instructor—primarily by e-mail. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling, i.e., printer, Microsoft Word and/or Adobe Acrobat Reader. Some courses may require proctored exams depending upon your state requirements.

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

We will beat any other training competitor's price for the same CEU material or classroom training. Student satisfaction is guaranteed.

Course Structure
TLC's online courses combine the best of online delivery and traditional university textbooks. Online you will find the course syllabus, course content, assignments, and online open book exams. This student-friendly course design allows you the most flexibility in choosing when and where you will study.

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

Satisfaction Guaranteed
Our Iron-Clad, Risk-Free Guarantee ensures you will be another satisfied TLC student. We have many years of experience, dealing with thousands of students. We assure you, our customer satisfaction is second to none. This is one reason we have taught more than 10,000 students.

Our administrative staff is trained to provide the best customer service in town. Part of that training is knowing how to solve most problems on the spot with an exchange or refund.

TLC Continuing Education Course Material Development
Technical Learning College's (TLC's) continuing education course material development was based upon several factors; extensive academic research, advice from subject matter experts, data analysis, task analysis and training needs assessment process information gathered from other states.

Please fax or e-mail the answer key to TLC
Western Campus Fax (928) 272-0747.

Rush Grading Service

If you need this assignment graded and the results mailed to you within a 48-hour period, prepare to pay an additional rush service handling fee of $50.00. This fee may not cover postage costs. If you need this service, simply write RUSH on the top of your Registration Form. We will place you in the front of the grading and processing line.

For security purposes, please fax or e-mail a copy of your driver's license and always call us to confirm we've received your assignment and to confirm your identity.

Thank you…

CEU Course Description

Backflow Awareness CEU Training Course

Review of backflow and plumbing related fundamentals and principles. This course will cover the basics of backflow prevention, cross-connection control, water quality issues and hydraulic fundamentals. 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). ***You will not need any other materials for this course.***

Water Distribution, Well Drillers, Pump Installers, Water Treatment Operators, Wastewater Treatment Operators, Wastewater Collection Operators, Industrial Wastewater Operators and General Backflow Assembly Testers. The target audience for this course is the person interested in working in a water or wastewater treatment or distribution/collection 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.

Prerequisites: None

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 their social security number or a unique number will be assigned to the student.

Instructions for Written Assignments

The Backflow Awareness CEU training course uses a multiple choice answer key. You can find a copy of the exam in a Word format on TLC’s website under the Assignment Page. You can also find complete course support under the Assignment Page.

You can write your answers in this manual or type out your own answer key. TLC would prefer that you type out and e-mail the final exam to TLC, but it is not required.

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 rear of the course or lesson.

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 ***Backflow Awareness*** 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.

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. This course is also available in Spanish. Please check with your State for special instructions.

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.

If you should need any assistance, please email all concerns and the final test to: info@tlch2o.com.

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,

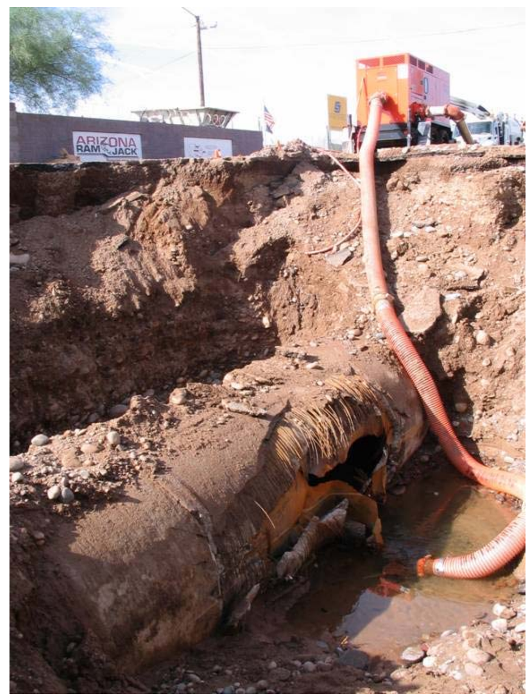
To provide TLC students with opportunities to apply and understand the theory and skills needed for operator certification and environmental education,

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.

TABLE OF CONTENTS



Water main break, prefect time to create a cross-connection. Waterborne

Pathogens and Disease Introduction

Bacteria, viruses, and protozoan that cause disease are known as pathogens. Most pathogens are generally associated with diseases that cause intestinal illness and affect people in a relatively short amount of time, generally a few days to two weeks. They can cause illness through exposure to small quantities of contaminated water or food, or from direct contact with infected people or animals.

How Diseases are Transmitted

Pathogens that may cause waterborne outbreaks through drinking water have one thing in common: they are spread by the fecal-oral or feces-to-mouth route. Pathogens may get into water and spread when infected humans or animals pass the bacteria, viruses, and protozoa in their stool. For another person to become infected, he or she must take that pathogen in through the mouth. Waterborne pathogens are different from other types of pathogens such as the viruses that cause influenza (the flu) or the bacteria that cause tuberculosis. Influenza virus and tuberculosis bacteria are spread by secretions that are coughed or sneezed into the air by an infected person.

Cryptosporidium→

Human or animal wastes in watersheds, failing septic systems, failing sewage treatment plants or cross-connections of water lines with sewage lines provide the potential for contaminating water with pathogens. The water may not appear to be contaminated because the feces has been broken up, dispersed, and diluted into microscopic particles. These particles, containing pathogens, may remain in the water and be passed to humans or animals unless adequately treated.

Only proper treatment will ensure eliminating the spread of disease. In addition to water, other methods exist for spreading pathogens by the fecal-oral route. The foodborne route is one of the more common methods. A frequent source is a food handler who does not wash his hands after a bowel movement and then handles food with *unclean* hands. The individual who eats feces-contaminated food may become infected and ill. It is interesting to note the majority of foodborne diseases occur in the home, not restaurants.

Day care centers are another common source for spreading pathogens by the fecal-oral route. Here, infected children in diapers may get feces on their fingers, then put their fingers in a friend's mouth or handle toys that other children put into their mouths. The general public and some of the medical community usually refer to diarrhea symptoms as stomach flu.

Technically, influenza is an upper respiratory illness and rarely has diarrhea associated with it; therefore, stomach flu is a misleading description for foodborne or waterborne illnesses, yet is accepted by the general public. So the next time you get the stomach flu, you may want to think twice about what you've digested within the past few days.

Chain of Transmission

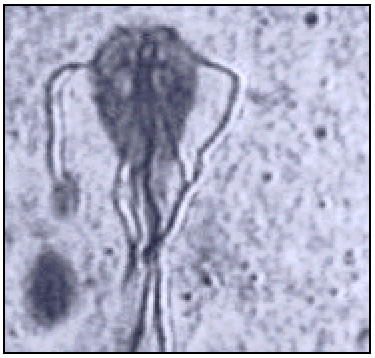
Water is contaminated with feces. This contamination may be of human or animal origin. The feces must contain pathogens (disease-causing bacteria, viruses or protozoa). If the human or animal source is not infected with a pathogen, no disease will result. The pathogens must survive in the water. This depends on the temperature of the water and the length of time the pathogens are in the water. Some pathogens will survive for only a short time in water, others, such as Giardia or Cryptosporidium, may survive for months.

The pathogens in the water must enter the water system's intake and in numbers sufficient to infect people. The water is either not treated or inadequately treated for the pathogens present. A susceptible person must drink the water that contains the pathogen. Illness (disease) will occur.

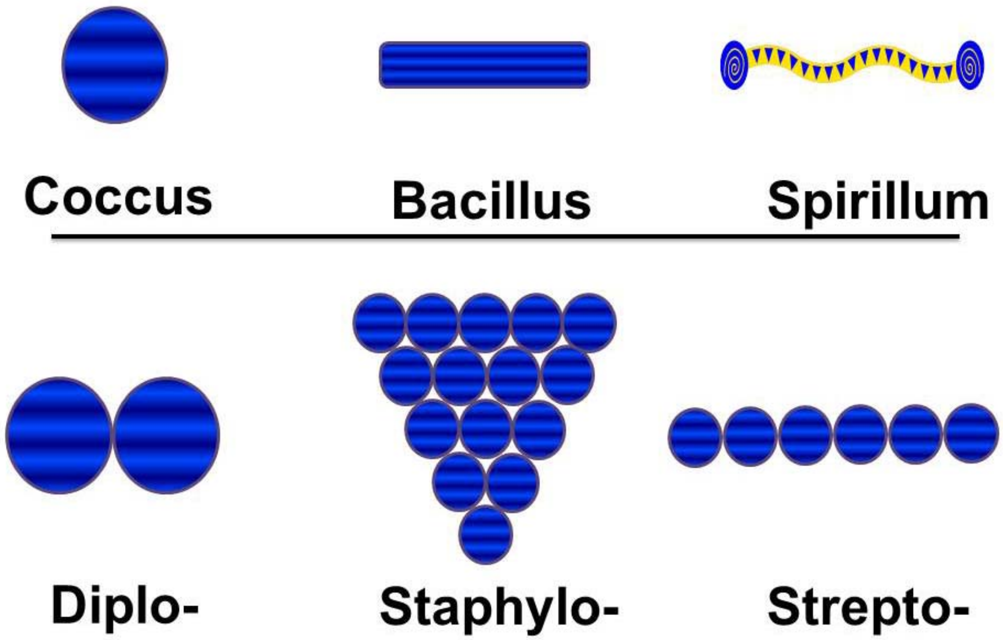
This chain lists the events that must occur for the transmission of disease via drinking water. By breaking the chain at any point, the transmission of disease will be prevented.

Bacterial Diseases

Giardia→



Campylobacteriosis is the most common diarrhea illness caused by bacteria. Symptoms include abdominal pain, malaise, fever, nausea and vomiting, and they usually begin three to five days after exposure. The illness is frequently over within two to five days and usually lasts no more than 10 days. Campylobacteriosis outbreaks have most often been associated with food, especially chicken and unpasteurized milk, as well as un-chlorinated water.



Types of Bacteria

These organisms are also an important cause of travelers' diarrhea. Medical treatment generally is not prescribed for campylobacteriosis because recovery is usually rapid. Cholera, Legionellosis, salmonellosis, shigellosis, and yersiniosis are other bacterial diseases that can be transmitted through water. All bacteria in water are readily killed or inactivated with chlorine or other disinfectants.

Viral-Caused Diseases

Hepatitis A is an example of a common viral disease that may be transmitted through water. The onset is usually abrupt with fever, malaise, loss of appetite, nausea and abdominal discomfort, followed within a few days by jaundice. The disease varies in severity from a mild illness lasting one to two weeks, to a severely disabling disease lasting several months (rare).

The incubation period is 15-50 days and averages 28-30 days. Hepatitis A outbreaks have been related to fecally contaminated water; food contaminated by infected food handlers, including sandwiches and salads that are not cooked or are handled after cooking and raw or undercooked mollusks harvested from contaminated waters. Aseptic meningitis, polio and viral gastroenteritis (Norwalk agent) are other viral diseases that can be transmitted through water. Most viruses in drinking water can be inactivated by chlorine or other disinfectants.

Protozoan Caused Diseases

Protozoan pathogens are larger than bacteria and viruses but still microscopic. They invade and inhabit the gastrointestinal tract. Some parasites enter the environment in a dormant form, with a protective cell wall, called a *cyst*. The cyst can survive in the environment for long periods of time and is extremely resistant to conventional disinfectants such as chlorine. Effective filtration treatment is therefore critical to removing these organisms from water sources.

Giardiasis is a commonly reported protozoan-caused disease. It has also been referred to as *backpacker's disease* and *beaver fever* because of the many cases reported among hikers and others who consume untreated surface water. Symptoms include chronic diarrhea, abdominal cramps, bloating, frequent loose and pale greasy stools, fatigue and weight loss. The incubation period is 5-25 days or longer, with an average of 7-10 days. Many infections are asymptomatic (no symptoms). Giardiasis occurs worldwide. Waterborne outbreaks in the United States occur most often in communities receiving their drinking water from streams or rivers without adequate disinfection or a filtration system.

Giardia lamblia
Giardia lamblia has been responsible for more community-wide outbreaks of disease in the U.S. than any other pathogen. Drugs are available for treatment, but these are not 100% effective.

Cryptosporidiosis
Cryptosporidiosis is an example of a protozoan disease that is common worldwide, but was only recently recognized as causing human disease. The major symptom in humans is diarrhea, which may be profuse and watery. The diarrhea is associated with cramping abdominal pain. General malaise, fever, anorexia, nausea and vomiting occur less often.

Symptoms usually come and go, and end in fewer than 30 days in most cases. The incubation period is 1-12 days, with an average of about seven days. *Cryptosporidium* organisms have been identified in human fecal specimens from more than 50 countries on six continents. The mode of transmission is fecal-oral, either by person-to-person or animal-to-person. There is no specific treatment for *Cryptosporidium* infections.

All of these diseases, with the exception of hepatitis A, have one symptom in common: diarrhea. They also have the same mode of transmission, fecal-oral, whether through person-to-person or animal-to-person contact, and the same routes of transmission, being either foodborne or waterborne. Although most pathogens cause mild, self-limiting disease, on occasion, they can cause serious, even life threatening illness. Particularly vulnerable are persons with weak immune systems such as those with HIV infections or cancer.

By understanding the nature of waterborne diseases, the importance of properly constructed, operated and maintained public water systems becomes obvious. While water treatment cannot achieve sterile water (no microorganisms), the goal of treatment must clearly be to produce drinking water that is as pathogen-free as possible at all times. For those who operate water systems with inadequate source protection or treatment facilities, the potential risk of a waterborne disease outbreak is real. For those operating systems that currently provide adequate source protection and treatment, operating, and maintaining the system at a high level on a continuing basis is critical to prevent disease.

Waterborne Diseases

Name	Causative organism	Source of organism	Disease
Viral gastroenteritis	**Rotavirus** (mostly in young children)	Human feces	Diarrhea or vomiting
Norwalk Agent	**Noroviruses** (genus *Norovirus*, family *Caliciviridae*) [*1]	Human feces; also, shellfish; lives in polluted waters	Diarrhea and vomiting
Salmonellosis	***Salmonella*** (bacterium)	Animal or human feces	Diarrhea or vomiting
Gastroenteritis Escherichia *coli*	-- ***E. coli O1*** **57:H7** (bacterium): Other *E. coli* organisms:	Human feces	Symptoms vary with type caused
Typhoid	***Salmonella typhi*** (bacterium)	Human feces, urine	Inflamed intestine, enlarged spleen, high temperature-sometimes fatal
Shigellosis	***Shigella*** (bacterium)	Human feces	Diarrhea
Cholera	***Vibrio choleras*** (bacterium)	Human feces; also, shellfish; lives in many coastal waters	Vomiting, severe diarrhea, rapid dehydration, mineral loss-high mortality
Hepatitis A	**Hepatitis A** virus	Human feces; shellfish grown in polluted waters	Yellowed skin, enlarged liver, fever, vomiting, weight loss, abdominal pain-low mortality, lasts up to four months
Amebiasis	***Entamoeba histolytica*** (protozoan)	Human feces	Mild diarrhea, dysentery, extra intestinal infection
Giardiasis	***Giardia lamblia*** (protozoan)	Animal or human feces	Diarrhea, cramps, nausea, and general weakness — lasts one week to months
Cryptosporidiosis	***Cryptosporidium parvum***	Animal or human feces	Diarrhea, stomach pain — lasts (protozoan) days to weeks

Notes:
*1 **http://www.cdc.gov/**

Backflow Introduction

Backflow Prevention, also referred to as Cross-Connection Control, addresses a serious health issue. This issue was addressed on the federal level by passage of the "*Federal Safe Drinking Water Act*" as developed by the Environmental Protection Agency (E.P.A.) and passed into law on December 16, 1974. This Act tasked each state with primary enforcement responsibility for a program to assure access to safe drinking water by all citizens. Such state program regulations as adopted are required to be at least as stringent as the federal regulations as developed and enforced by the E.P.A.

The official definition of a cross-connection is *"the link or channel connecting a source of pollution with a potable water supply*." There are two distinct levels of concern with this issue. The first is protection of the general public and the second is protection of persons subject to such risks involving service to a single customer, be that customer an individual residence or business.

Sources of pollution which may result in a danger to health are not always obvious and such cross-connections are certainly not usually intentional. They are usually the result of oversight or a non-professional installation. As source examples, within a business environment the pollutant source may involve the unintentional cross-connection of internal or external piping with chemical processes or a heating boiler. In a residential environment the pollutant source may be an improper cross-connection with a landscape sprinkler system or reserve tank fire protection system. Or, a situation as simple as leaving a garden hose nozzle submerged in a bucket of liquid or attached to a chemical sprayer.

Another potential hazard source within any environment may be a cross-connection of piping involving a water well located on the property. This is a special concern with older residences or businesses, which may have been served by well water prior to connection to the developed water system. There are many other potential sources of pollutant hazards. Control of cross-connections is possible but only through knowledge and vigilance. Public education is essential, for many that are educated in piping and plumbing installations fail to recognize cross-connection dangers.

Another buried RP assembly deep inside a vault, all we can see is a test cock. All RPs need to be installed 12 inched above the ground. This device was buried in ground and not tested for over 25 years. Owners are required to test their devices once a year at a minimum.

Top photo, a Hot Box, a good method of keeping the assembly from freezing during the winter. Bottom, electrical heat tape method for freeze protection**.**

Key Words

ABSOLUTE PRESSURE: 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).

AIR BREAK: A physical separation which may be a low inlet into the indirect waste receptor from the fixture, or device that is indirectly connected. You will most likely find an air break on waste fixtures or on non-potable lines. You should never allow an air break on an ice machine.

AIR GAP SEPARATION: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet.

ATMOSPHERIC PRESSURE: 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.)

BACKFLOW PREVENTION: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquid, gases, or solid substances back in to the public potable (drinking) water supply. See Cross-connection control.

BACKFLOW: To reverse the natural and normal directional flow of a liquid, gases, or solid substances back in to the public potable (drinking) water supply. This is normally an undesirable effect.

BACKSIPHONAGE: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point.

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

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

CORROSION: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

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

DISINFECT: To kill and inhibit growth of harmful bacterial and viruses in drinking water.

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

ELEVATION HEAD: The energy possessed per unit weight of a fluid because of its elevation. 1 foot of water will produce .433 pounds of pressure head.

ENERGY: The ability to do work. Energy can exist in one of several forms, such as heat, light, mechanical, electrical, or chemical. Energy can be transferred to different forms. It also can exist in one of two states, either potential or kinetic.

FLOOD RIM: The point of an object where the water would run over the edge of something and begin to cause a flood. See Air Break.

FRICTION HEAD: 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.

GAUGE PRESSURE: Pressure differential above or below ambient atmospheric pressure.

HAZARDOUS ATMOSPHERE : An atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

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

HYDRAULICS: Engineering science pertaining to liquid pressure and flow.

HYDROKINETICS: Engineering science pertaining to the energy of liquid flow and pressure.

IRRIGATION: Water that is especially furnished to help provide and sustain the life of growing plants. It comes from ditches; it is sometimes treated with herbicides and pesticides to prevent the growth of weeds and the development of bugs in a lawn and a garden.

KINETIC ENERGY: The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head.

MECHANICAL SEAL: A mechanical device used to control leakage from the stuffing box of a pump. Usually made of two flat surfaces, one of which rotates on the shaft. The two flat surfaces are of such tolerances as to prevent the passage of water between them.

Mg/L: milligrams per liter

MICROBE, MICROBIAL: Any minute, simple, single-celled form of life, especially one that causes disease.

MICROBIAL CONTAMINANTS: Microscopic organisms present in untreated water that can cause waterborne diseases.

ML: milliliter

PASCAL'S LAW: A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

PATHOGENS: Disease-causing pathogens; waterborne pathogens A pathogen is a bacterium, virus or parasite that causes or is capable of causing disease. Pathogens may contaminate water and cause waterborne disease.

PIPELINE APPURTENANCE: Pressure reducers, bends, valves, regulators (which are a type of valve), etc.

POTABLE: Good water which is safe for drinking or cooking purposes. Non-Potable: A liquid or water that is not approved for drinking.

POLLUTION: To make something unclean or impure. Some states will have a definition of pollution that relates to non-health related water problems, like taste and odors. See Contaminated.

POTENTIAL ENERGY: The energy that a body has by virtue of its position or state enabling it to do work.

PPM: Abbreviation for parts per million.

PRESSURE HEAD: The height to which liquid can be raised by a given pressure.

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).

RESIDUAL DISINFECTION/ PROTECTION: A required level of disinfectant that remains in treated water to ensure disinfection protection and prevent recontamination throughout the distribution system (i.e., pipes).

SOLDER: A fusible alloy used to join metallic parts. Solder for potable water pipes shall be lead-free.

SHOCK: Also known as superchlorination or break point chlorination. Ridding a pool of organic waste through oxidization by the addition of significant quantities of a halogen.

STATIC HEAD: The height of a column or body of fluid above a given point

STATIC PRESSURE: The pressure in a fluid at rest.

STUFFING BOX: That portion of the pump which houses the packing or mechanical seal.

SUMMERGED: To cover with water or liquid substance.

TURBIDITY: A measure of the cloudiness of water caused by suspended particles.

VALVE: A device that opens and closes to regulate the flow of liquids. Faucets, hose bibs, and Ball are examples of valves.

VELOCITY HEAD: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.

VENTURI: If water flows through a pipeline at a high velocity, the pressure in the pipeline is reduced. Velocities can be increased to a point that a partial vacuum is created.

VIBRATION: A force that is present on construction sites and must be considered. The vibrations caused by backhoes, dump trucks, compactors and traffic on job sites can be substantial.

VOLUTE: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharge by the impeller.

WATER PURVEYOR: The individuals or organization responsible to help provide, supply, and furnish quality water to a community.

WATER WORKS: All of the pipes, pumps, reservoirs, dams and buildings that make up a water system.

WATERBORNE DISEASES: A disease, caused by a virus, bacterium, protozoan, or other microorganism, capable of being transmitted by water (e.g., typhoid fever, cholera, amoebic dysentery, gastroenteritis).

Several AVBS that fed irrigation on a hill. Very rare to see any longer and totally wrong.

Actual Backflow Events

Paraquat
In June 1983, "*yellow gushy stuff*" poured from some faucets in the Town of Woodsboro, Maryland. Town personnel notified the County Health Department and the State Water Supply Division. The State dispatched personnel to take water samples for analysis and placed a ban on drinking the Town's water.

Firefighters warned residents not to use the water for drinking, cooking, bathing, or any other purpose except flushing toilets. The Town began flushing its water system. An investigation revealed that the powerful agricultural herbicide Paraquat had backflowed into the Town's water system.

Someone left open a gate valve between an agricultural herbicide holding tank and the Town's water system and, thus, created a cross-connection. Coincidentally, water pressure in the Town temporarily decreased due to failure of a pump in the Town's water system. The herbicide Paraquat was backsiphoned into the Town's water system. Upon restoration of pressure in the Town's water system, Paraquat flowed throughout much of the Town's water system.

Fortunately, this incident did not cause any serious illness or death. The incident did, however, create an expensive burden on the Town. Tanker trucks were used temporarily to provide potable water, and the Town flushed and sampled its water system extensively.

Mortuary
The chief plumbing inspector in a large southern city received a telephone call advising that blood was coming from drinking fountains at a mortuary (i.e., a funeral home). Plumbing and health inspectors went to the scene and found evidence that blood had been circulating in the potable water system within the funeral home. They immediately ordered the funeral home cut off from the public water system at the meter.

City water and plumbing officials did not think that the water contamination problem had spread beyond the funeral home, but they sent inspectors into the neighborhood to check for possible contamination. Investigation revealed that blood had backflowed through a hydraulic aspirator into the potable water system at the funeral home.

The funeral home had been using a hydraulic aspirator to drain fluids from bodies as part of the embalming process. The aspirator was directly connected to a faucet at a sink in the embalming room. Water flow through the aspirator created suction used to draw body fluids through a needle and hose attached to the aspirator. When funeral home personnel used the aspirator during a period of low water pressure, the potable water system at the funeral home became contaminated. Instead of body fluids flowing into the wastewater system, they were drawn in the opposite direction--into the potable water system.

U.S. Environmental Protection Agency, Cross-Connection Control Manual, 1989

Recent Backflow Situations

Oregon 1993
Water from a drainage pond, used for lawn irrigation, is pumped into the potable water supply of a housing development.

California 1994
A defective backflow device in the water system of the County Courthouse apparently caused sodium nitrate contamination that sent 19 people to the hospital.

New York 1994
An 8-inch reduced pressure principle backflow assembly in the basement of a hospital discharged under backpressure conditions, dumping 100,000 gallons of water into the basement.

Nebraska 1994
While working on a chiller unit of an air conditioning system at a nursing home, a hole in the coil apparently allowed Freon to enter the circulating water and from there into the city water system.

California 1994
The blue tinted water in a pond at an amusement park backflowed into the city water system and caused colored water to flow from homeowner's faucets.

California 1994
A film company shooting a commercial for television accidentally introduced a chemical into the potable water system.

Iowa 1994
A backflow of water from the Capitol Building chilled water system contaminates potable water with Freon.

Indiana 1994
A water main break caused a drop in water pressure allowing anti-freeze from an air conditioning unit to backsiphon into the potable water supply.

Washington 1994
An Ethylene Glycol cooling system was illegally connected to the domestic water supply at a veterinarian hospital.

Ohio 1994
An ice machine connected to a sewer sickened dozens of people attending a convention.

Hydraulics

Definition: Hydraulics is a branch of engineering concerned mainly with moving liquids. The term is applied commonly to the study of the mechanical properties of water, other liquids, and even gases when the effects of compressibility are small. Hydraulics can be divided into two areas, hydrostatics and hydrokinetics.

Hydraulics: *The Engineering science pertaining to liquid pressure and flow.*
The word ***hydraulics*** is based on the Greek word for water, and originally covered the study of the physical behavior of water at rest and in motion. Use has broadened its meaning to include the behavior of all liquids, although it is primarily concerned with the motion of liquids. Hydraulics includes the manner in which liquids act in tanks and pipes, deals with their properties, and explores ways to take advantage of these properties.

Hydrostatics, the consideration of liquids at rest, involves problems of buoyancy and flotation, pressure on dams and submerged devices, and hydraulic presses. The relative incompressibility of liquids is one of its basic principles. Hydrodynamics, the study of liquids in motion, is concerned with such matters as friction and turbulence generated in pipes by flowing liquids, the flow of water over weirs and through nozzles, and the use of hydraulic pressure in machinery.

Hydrostatics
Hydrostatics is about the pressures exerted by a fluid at rest. Any fluid is meant, not just water. Research and careful study on water yields many useful results of its own, however, such as forces on dams, buoyancy and hydraulic actuation, and is well worth studying for such practical reasons. Hydrostatics is an excellent example of deductive mathematical physics, one that can be understood easily and completely from a very few fundamentals, and in which the predictions agree closely with experiment.

There are few better illustrations of the use of the integral calculus, as well as the principles of ordinary statics, available to the student. A great deal can be done with only elementary mathematics. Properly adapted, the material can be used from the earliest introduction of school science, giving an excellent example of a quantitative science with many possibilities for hands-on experiences.

The definition of a fluid deserves careful consideration. Although time is not a factor in hydrostatics, it enters in the approach to hydrostatic equilibrium. It is usually stated that a fluid is a substance that cannot resist a shearing stress, so that pressures are normal to confining surfaces. Geology has now shown us clearly that there are substances which can resist shearing forces over short time intervals, and appear to be typical solids, but which flow like liquids over long time intervals. Such materials include wax and pitch, ice, and even rock.

A ball of pitch, which can be shattered by a hammer, will spread out and flow in months. Ice, a typical solid, will flow in a period of years, as shown in glaciers, and rock will flow over hundreds of years, as in convection in the mantle of the earth.

Shear earthquake waves, with periods of seconds, propagate deep in the earth, though the rock there can flow like a liquid when considered over centuries. The rate of shearing may not be strictly proportional to the stress, but exists even with low stress.

Viscosity may be the physical property that varies over the largest numerical range, competing with electrical resistivity. There are several familiar topics in hydrostatics which often appears in expositions of introductory science, and which are also of historical interest and can enliven their presentation. Let's start our study with the principles of our atmosphere.

Atmospheric Pressure

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

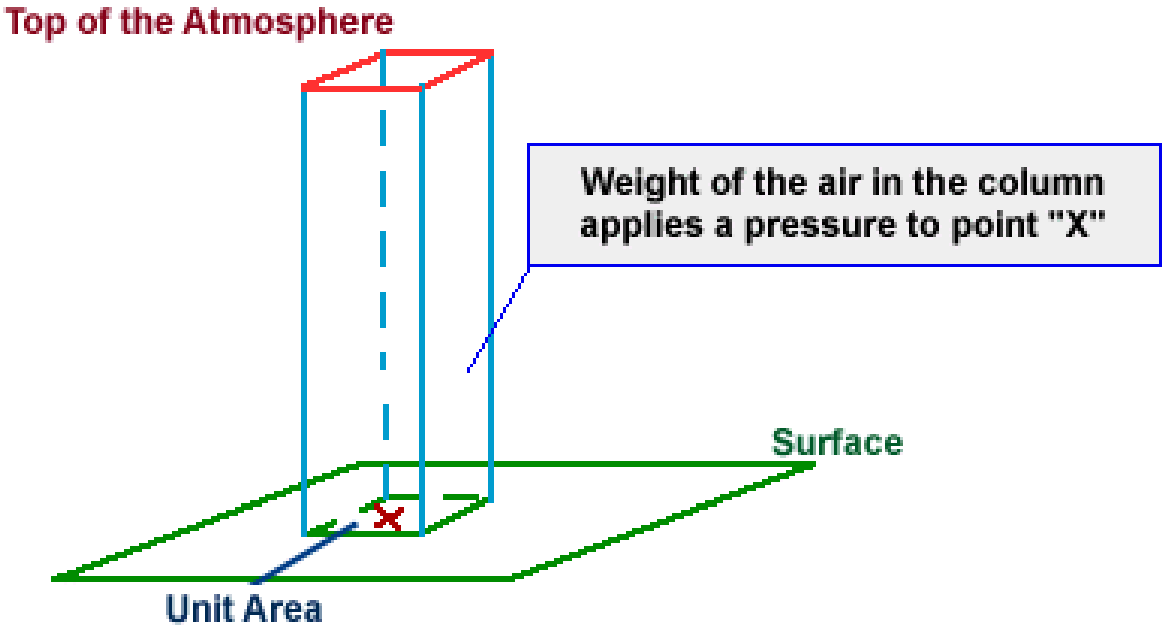
If a column of air 1-inch square extending all the way to the "*top*" of the atmosphere could be weighed, this column of air would weigh approximately 14.7 pounds at sea level. Thus, atmospheric pressure at sea level is approximately 14.7 psi.

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

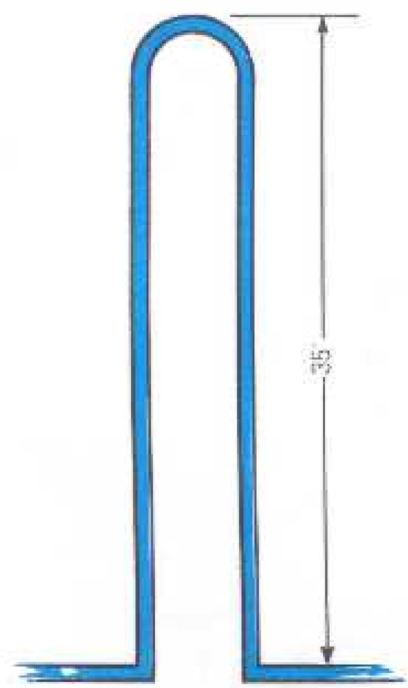
Atmospheric pressure can be measured by any of several methods. The common laboratory method uses the mercury column barometer. The height of the mercury column serves as an indicator of atmospheric pressure. At sea level and at a temperature of 0° Celsius (**C**), the height of the mercury column is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

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

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



Barometric Loop



The barometric loop consists of a continuous section of supply piping that abruptly rises to a height of approximately 35 feet and then returns back down to the originating level. It is a loop in the piping system that effectively protects against backsiphonage. It may not be used to protect against back-pressure.

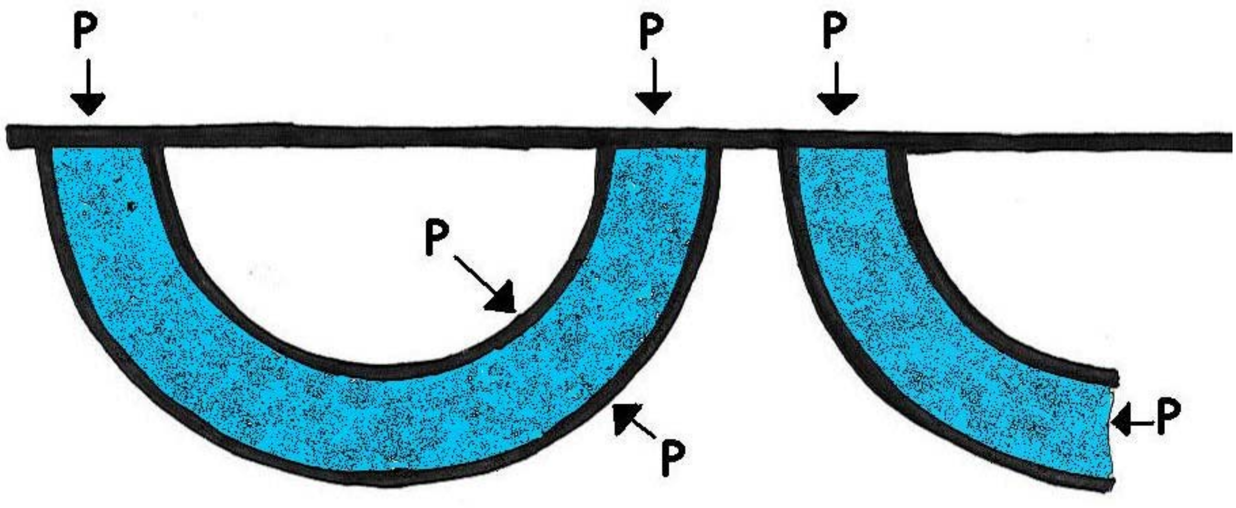
Its operation, in the protection against backsiphonage, is based upon the principle that a water column, at sea level pressure, will not rise above 33.9 feet. In general, barometric loops are locally fabricated, and are 35 feet high.

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

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

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

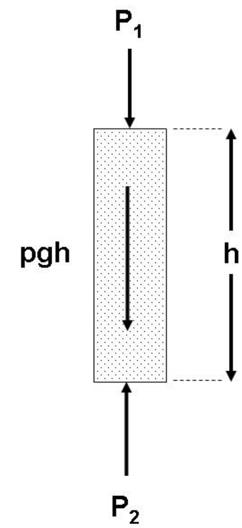
A fluid, therefore, is a substance that cannot exert any permanent forces tangential to a boundary. Any force that it exerts on a boundary must be normal to the boundary. Such a force is proportional to the area on which it is exerted, and is called a pressure. We can imagine any surface in a fluid as 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 $\gamma = \rho g$ 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 $dp = \rho g\, dh$, 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 $p = \rho g h + p0$.

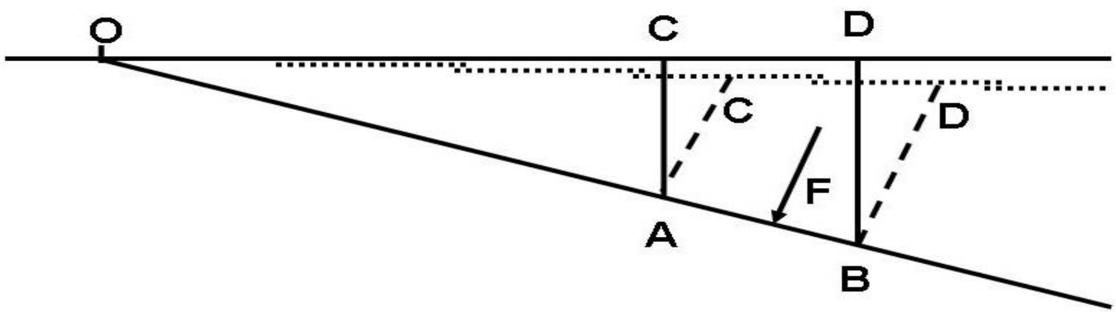
The density of water is about 1 g/cm^3, or its specific weight is 62.4 pcf. We may ask what depth of water gives the normal sea-level atmospheric pressure of 14.7 psi, or 2117 psf.

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.



Increase of Pressure with Depth

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 right-hand part of 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.



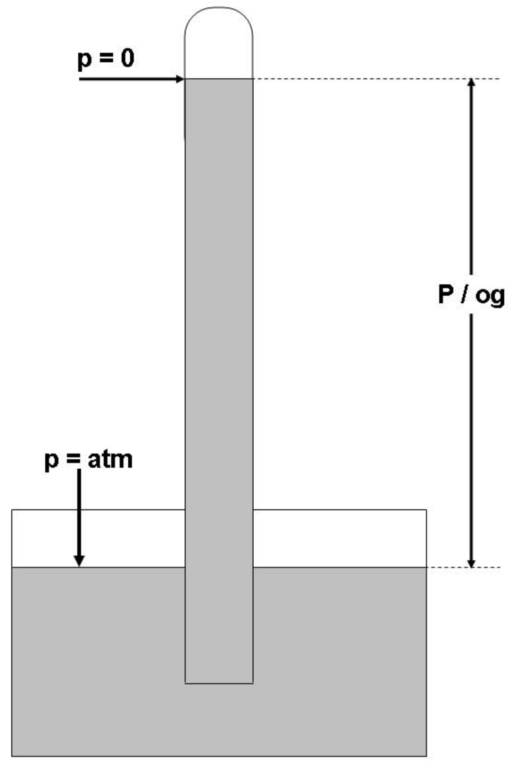
Thrust on a Plane

Free Surface Perpendicular to Gravity

When gravity acts, the liquid assumes a free surface perpendicular to gravity, which can be proved by Thomson's method. A straight cylinder of unit cross-sectional area (assumed only for ease in the arithmetic) can be used to find the increase of pressure with depth. Indeed, we see that p2 = p1 + ρgh. The upper surface of the cylinder can be placed at the free surface if desired. The pressure is now the same in any direction at a point, but is greater at points that lie deeper. From this same figure, it is easy to prove Archimedes's Principle that the buoyant force is equal to the weight of the displaced fluid, and passes through the center of mass of this displaced fluid.

Geometric Arguments

Ingenious geometric arguments can be used to substitute for easier, but less transparent arguments using calculus. For example, the force acting on one side of an inclined plane surface whose projection is AB can be found as in the diagram on the previous page. O is the point at which the prolonged projection intersects the free surface. The line AC' perpendicular to the plane is made equal to the depth AC of point A, and line BD' is similarly drawn equal to BD. The line OD' also passes through C', by proportionality of triangles OAC' and OAD'. Therefore, the thrust F on the plane is the weight of a prism of fluid of cross-section AC'D'B, passing through its centroid normal to plane AB. Note that the thrust is equal to the density times the area times the depth of the center of the area; its line of action does not pass through the center, but below it, at the center of thrust. The same result can be obtained with calculus by summing the pressures and the moments, of course.



Barometer

Atmospheric Pressure and its Effects

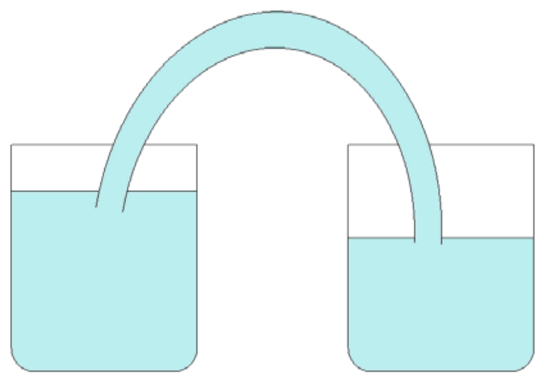
Suppose a vertical pipe is stood in a pool of water, and a vacuum pump applied to the upper end. Before we start the pump, the water levels outside and inside the pipe are equal, and the pressures on the surfaces are also equal and are equal to the atmospheric pressure.

Now start the pump. When it has sucked all the air out above the water, the pressure on the surface of the water inside the pipe is zero, and the pressure at the level of the water on the outside of the pipe is still the atmospheric pressure. Of course, there is the vapor pressure of the water to worry about if you want to be precise, but we neglect this complication in making our point. We require a column of water 33.9 ft high inside the pipe, with a vacuum above it, to balance the atmospheric pressure. Now do the same thing with liquid mercury, whose density at 0 °C is 13.5951 times that of water. The height of the column is 2.494 ft, 29.92 in, or 760.0 mm.

Standard Atmospheric Pressure

This definition of the standard atmospheric pressure was established by Regnault in the mid-19th century. In Britain, 30 in. Hg (inches of mercury) had been used previously. As a practical matter, it is convenient to measure pressure differences by measuring the height of liquid columns, a practice known as manometry. The barometer is a familiar example of this, and atmospheric pressures are traditionally given in terms of the length of a mercury column. To make a barometer, the barometric tube, closed at one end, is filled with mercury and then inverted and placed in a mercury reservoir. Corrections must be made for temperature, because the density of mercury depends on the temperature, and the brass scale expands for capillarity if the tube is less than about 1 cm in diameter, and even slightly for altitude, since the value of g changes with altitude.

The vapor pressure of mercury is only 0.001201 mmHg at 20°C, so a correction from this source is negligible. For the usual case of a mercury column (α = 0.000181792 per °C) and a brass scale (& alpha = 0.0000184 per °C) the temperature correction is -2.74 mm at 760 mm and 20°C. Before reading the barometer scale, the mercury reservoir is raised or lowered until the surface of the mercury just touches a reference point, which is mirrored in the surface so it is easy to determine the proper position.


Siphon

An aneroid barometer uses a partially evacuated chamber of thin metal that expands and contracts according to the external pressure. This movement is communicated to a needle that revolves in a dial. The materials and construction are arranged to give a low temperature coefficient. The instrument must be calibrated before use, and is usually arranged to read directly in elevations. An aneroid barometer is much easier to use in field observations, such as in reconnaissance surveys. In a particular case, it would be read at the start of the day at the base camp, at various points in the vicinity, and then finally at the starting point, to determine the change in pressure with time. The height differences can be calculated from h = 60,360 log (P/p) [1 + (T + t - 64)/986) feet, where P and p are in the same units, and T, t are in °F. An absolute pressure is referring to a vacuum, while a gauge pressure is referring to the atmospheric pressure at the moment. A negative gauge pressure is a (partial) vacuum. When a vacuum is stated to be so many inches, this means the pressure below the atmospheric pressure of about 30 in. A vacuum of 25 inches is the same thing as an absolute pressure of 5 inches (of mercury).

Vacuum

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

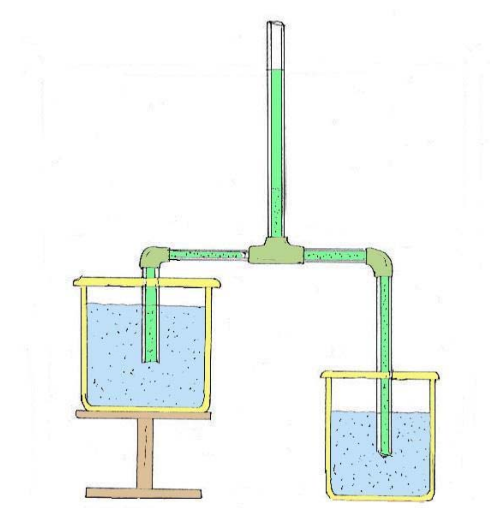
Water Pressure

The weight of a cubic foot of water is 62.4 pounds per square foot. The base can be subdivided into 144-square inches with each subdivision being subjected to a pressure of 0.433 psig. Suppose you placed another cubic foot of water on top of the first cubic foot. The pressure on the top surface of the first cube which was originally atmospheric, or 0 psig, would now be 0.4333 psig as a result of the additional cubic foot of water. The pressure of the base of the first cubic foot would be increased by the same amount of 0.866 psig or two times the original pressure.

Pressures are very frequently stated in terms of the height of a fluid. If it is the same fluid whose pressure is being given, it is usually called "head," and the factor connecting the head and the pressure is the weight density ρg. In the English engineer's system, weight density is in pounds per cubic inch or cubic foot. A head of 10 ft is equivalent to a pressure of 624 psf, or 4.33 psi. It can also be considered an energy availability of ft-lb per lb. Water with a pressure head of 10 ft can furnish the same energy as an equal amount of water raised by 10 ft. Water flowing in a pipe is subject to head loss because of friction.

Take a jar and a basin of water. Fill the jar with water and invert it under the water in the basin. Now raise the jar as far as you can without allowing its mouth to come above the water surface. It is always a little surprising to see that the jar does not empty itself, but the water remains with no visible means of support. By blowing through a straw, one can put air into the jar, and as much water leaves as air enters. In fact, this is a famous method of collecting insoluble gases in the chemical laboratory, or for supplying hummingbird feeders. It is good to remind oneself of exactly the balance of forces involved.

Another application of pressure is the siphon. The name is Greek for the tube that was used for drawing wine from a cask. This is a tube filled with fluid connecting two containers of fluid, normally rising higher than the water levels in the two containers, at least to pass over their rims. In the diagram, the two water levels are the same, so there will be no flow. When a siphon goes below the free water levels, it is called an inverted siphon. If the levels in the two basins are not equal, fluid flows from the basin with the higher level into the one with the lower level, until the levels are equal.



PASCAL'S SIPHON

A siphon can be made by filling the tube, closing the ends, and then putting the ends under the surface on both sides. Alternatively, the tube can be placed in one fluid and filled by sucking on it. When it is full, the other end is put in place. The analysis of the siphon is easy, and should be obvious. The pressure rises or falls as described by the barometric equation through the siphon tube. There is obviously a maximum height for the siphon which is the same as the limit of the suction pump, about 34 feet. Inverted siphons are sometimes used in pipelines to cross valleys. Differences in elevation are usually too great to use regular siphons to cross hills, so the fluids must be pressurized by pumps so the pressure does not fall to zero at the crests.

Liquids at Rest

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

Pressure and Force

Pressure is the force that pushes water through pipes. Water pressure determines the flow of water from the tap. If pressure is not sufficient then the flow can reduce to a trickle and it will take a long time to fill a kettle or a cistern.

The terms **force** and **pressure** are used extensively in the study of fluid power. It is essential that we distinguish between the terms.

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

Computing Force, Pressure, and Area

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

Development of Hydraulics

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

After the breakup of the ancient world, there were few new developments for many centuries. Then, over a comparatively short period, beginning near the end of the seventeenth century, Italian physicist, Evangelista Torricelle, French physicist, Edme Mariotte, and later, Daniel Bernoulli conducted experiments to study the elements of force in the discharge of water through small openings in the sides of tanks and through short pipes. During the same period, Blaise Pascal, a French scientist, discovered the fundamental law for the science of hydraulics. Pascal's law states that increase in pressure on the surface of a confined fluid is transmitted undiminished throughout the confining vessel or system.

For Pascal's law to be made effective for practical applications, it was necessary to have a piston that "fit exactly." It was not until the latter part of the eighteenth century that methods were found to make these snugly fitted parts required in hydraulic systems.

This was accomplished by the invention of machines that were used to cut and shape the necessary closely fitted parts and, particularly, by the development of gaskets and packings. Since that time, components such as valves, pumps, actuating cylinders, and motors have been developed and refined to make hydraulics one of the leading methods of transmitting power.

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

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

Evangelista Torricelli

Evangelista Torricelli (1608-1647), Galileo's student and secretary, and a member of the Florentine Academy of Experiments, invented the mercury barometer in 1643, and brought the weight of the atmosphere to light. The mercury column was held up by the pressure of the atmosphere, not by horror vacui as Aristotle had supposed. Torricelli's early death was a blow to science, but his ideas were furthered by Blaise Pascal (1623-1662).

Pascal had a barometer carried up the 1465 m high Puy de Dôme, an extinct volcano in the Auvergne just west of his home of Clermont-Ferrand in 1648 by Périer, his brother-in-law. Pascal's experimentum crucis is one of the triumphs of early modern science. The Puy de Dôme is not the highest peak in the Massif Central--the Puy de Sancy, at 1866 m is, but it was the closest. Clermont is now the centre of the French pneumatics industry.

Burgomeister of Magdeburg

The remarkable Otto von Guericke (1602-1686), Burgomeister of Magdeburg, Saxony, took up the cause, making the first vacuum pump, which he used in vivid demonstrations of the pressure of the atmosphere to the Imperial Diet at Regensburg in 1654. Famously, he evacuated a sphere consisting of two well-fitting hemispheres about a foot in diameter, and showed that 16 horses, 8 on each side, could not pull them apart. An original vacuum pump and hemispheres from 1663 are shown at the right (photo edited from the Deutsches Museum). He also showed that air had weight, and how much force it did require to separate the evacuated hemispheres. Then, in England, Robert Hooke (1635-1703) made a vacuum pump for Robert Boyle (1627-1691). Christian Huygens (1629-1695) became interested in a visit to London in 1661 and had a vacuum pump built for him. By this time, Torricelli's doctrine had triumphed over the Church's support for horror vacui. This was one of the first victories for rational physics over the illusions of experience, and is well worth consideration.

Pascal demonstrated that the siphon worked by atmospheric pressure, not by horror vacui. The two beakers of mercury are connected by a three-way tube, with the upper branch open to the atmosphere. As the large container is filled with water, pressure on the free surfaces of the mercury in the beakers pushes mercury into the tubes. When the state shown is reached, the beakers are connected by a mercury column, and the siphon starts, emptying the upper beaker and filling the lower. The mercury has been open to the atmosphere all this time, so if there were any horror vacui, it could have flowed in at will to soothe itself.

Torr

The mm of mercury is sometimes called a torr after Torricelli, and Pascal also has been honored by a unit of pressure, a newton per square meter or 10 dyne/cm^2. A cubic centimeter of air weighs 1.293 mg under standard conditions, and a cubic meter 1.293 kg, so air is by no means even approximately weightless, though it seems so.

The weight of a sphere of air as small as 10 cm in diameter is 0.68 g, easily measurable with a chemical balance. The pressure of the atmosphere is also considerable, like being 34 ft under water, but we do not notice it. A bar is 106 dyne/cm^2, very close to a standard atmosphere, which is 1.01325 bar. In meteorology, the millibar, mb, is used. 1 mb = 1.333 mmHg = 100 Pa = 1000 dyne/cm^2.

A kilogram-force per square centimeter is 981,000 dyne/cm^2, also close to one atmosphere. In Europe, it has been considered approximately 1 atm, as in tire pressures and other engineering applications. As we have seen, in English units the atmosphere is about 14.7 psi, and this figure can be used to find other approximate equivalents.

For example, 1 psi = 51.7 mmHg. In Britain, tons per square inch has been used for large pressures. The ton in this case is 2240 lb, not the American short ton. 1 tsi = 2240 psi, 1 tsf = 15.5 psi (about an atmosphere!).

The fluid in question here is air, which is by no means incompressible. As we rise in the atmosphere and the pressure decreases, the air also expands.

To see what happens in this case, we can make use of the ideal gas equation of state, $p = \rho RT/M$, and assume that the temperature T is constant. Then the change of pressure in a change of altitude dh is $dp = -\rho g\ dh = -(pM/RT)gdh$, or $dp/p = -(Mg/RT)dh$.

This is a little harder to integrate than before, but the result is $\ln p = -Mgh/RT + C$, or $\ln(p/p0) = -Mgh/RT$, or finally $p = p0\exp(-Mgh/RT)$.

In an isothermal atmosphere, the pressure decreases exponentially. The quantity $H = RT/Mg$ is called the "height of the homogeneous atmosphere" or the scale height, and is about 8 km at T = 273K.

This quantity gives the rough scale of the decrease of pressure with height. Of course, the real atmosphere is by no means isothermal close to the ground, but cools with height nearly linearly at about 6.5°C/km up to an altitude of about 11 km at middle latitudes, called the tropopause.

Above this is a region of nearly constant temperature, the stratosphere, and then at some higher level the atmosphere warms again to near its value at the surface. Of course, there are variations from the average values. When the temperature profile with height is known, we can find the pressure by numerical integration quite easily.

Meteorology

The atmospheric pressure is of great importance in meteorology, since it determines the winds, which generally move at right angles to the direction of most rapid change of pressure, that is, along the isobars, which are contours of constant pressure. Certain typical weather patterns are associated with relatively high and relatively low pressures, and how they vary with time. The barometric pressure may be given in popular weather forecasts, though few people know what to do with it. If you live at a high altitude, your local weather reporter may report the pressure to be, say, 29.2 inches, but if you have a real barometer, you may well find that it is closer to 25 inches. At an elevation of 1500 m (near Denver, or the top of the Puy de Dôme), the atmospheric pressure is about 635 mm, and water boils at 95 °C.

In fact, altitude is quite a problem in meteorology, since pressures must be measured at a common level to be meaningful. The barometric pressures quoted in the news are reduced to sea level by standard formulas that amount to assuming that there is a column of air from your feet to sea level with a certain temperature distribution, and adding the weight of this column to the actual barometric pressure. This is only an arbitrary 'fix' and leads to some strange conclusions, such as the permanent winter highs above high plateaus that are really imaginary.

Pascal's Law

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

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

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

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

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

Gravity

Gravity is one of the four forces of nature. The strength of the gravitational force between two objects depends on their masses. The more massive the objects are, the stronger the gravitational attraction.

When you pour water out of a container, the earth's gravity pulls the water towards the ground. The same thing happens when you put two buckets of water, with a tube between them, at two different heights. You must work to start the flow of water from one bucket to the other, but then gravity takes over and the process will continue on its own.

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

Static Pressure

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

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

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

Volume and Velocity of Flow

The volume of a liquid passing a point in a given time is known as its *volume of flow* or flow rate. The volume of flow is usually expressed in gallons per minute (gpm) and is associated with relative pressures of the liquid, such as 5 gpm at 40 psi.

The *velocity of flow* or velocity of the fluid is defined as the average speed at which the fluid moves past a given point. It is usually expressed in feet per second (fps) or feet per minute (fpm). Velocity of flow is an important consideration in sizing the hydraulic lines.

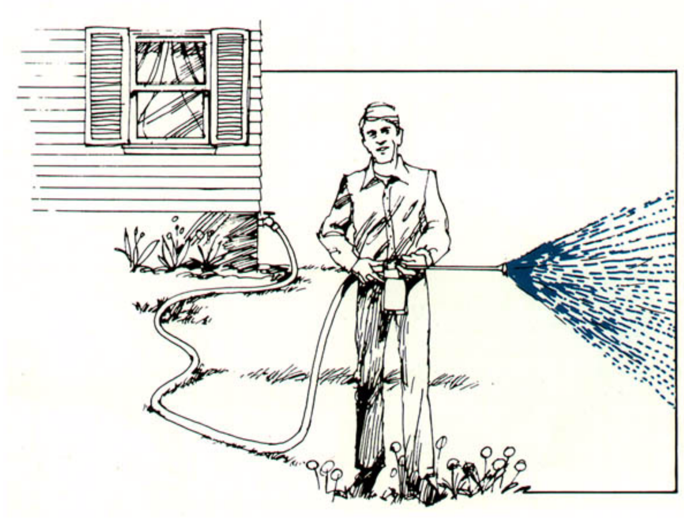
Volume and velocity of flow are often considered together. With other conditions unaltered—that is, with volume of input unchanged—the velocity of flow increases as the cross section or size of the pipe decreases, and the velocity of flow decreases as the cross section increases. For example, the velocity of flow is slow at wide parts of a stream and rapid at narrow parts, yet the volume of water passing each part of the stream is the same.

Bernoulli's Principle

Bernoulli's principle thus says that a rise (or fall) in pressure in a flowing fluid must always be accompanied by a decrease (or increase) in the speed, and conversely, if an increase (decrease) in, the speed of the fluid results in a decrease (or increase) in the pressure.

This is at the heart of a number of everyday phenomena. As a very trivial example, Bernoulli's principle is responsible for the fact that a shower curtain gets "***sucked inwards***" when the water is first turned on. What happens is that the increased water/air velocity inside the curtain (relative to the still air on the other side) causes a pressure drop.

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

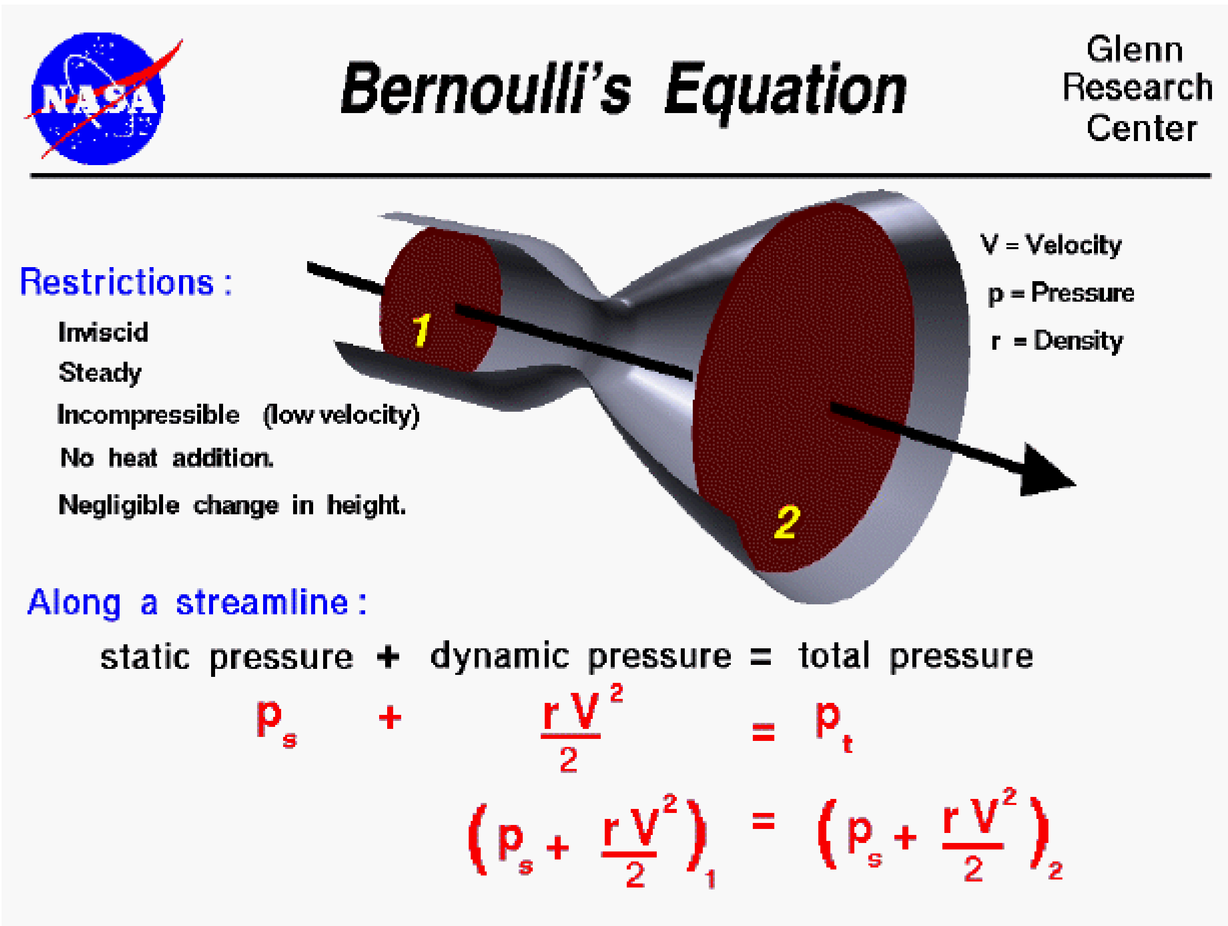


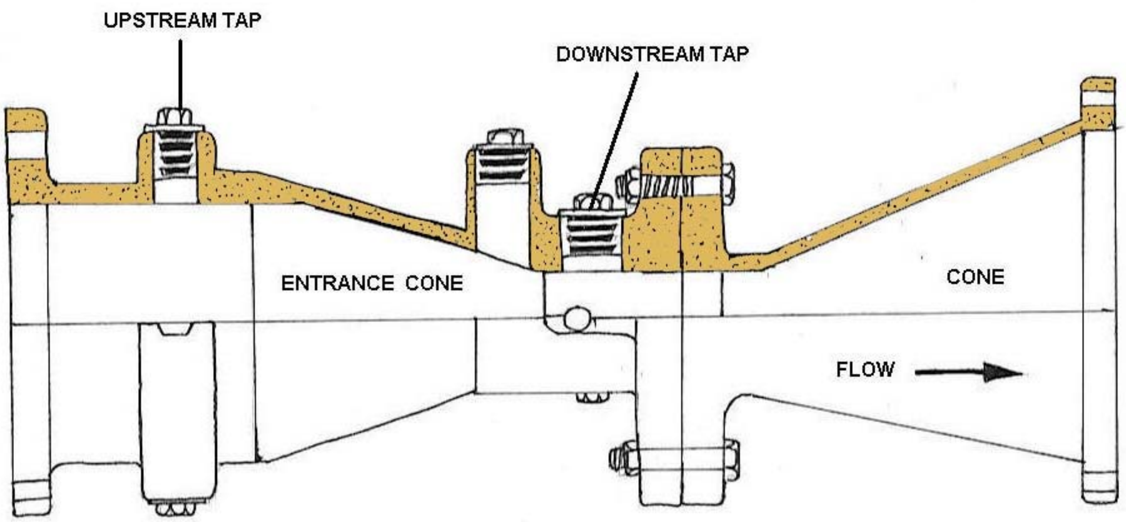
Action of a spray atomizer.

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

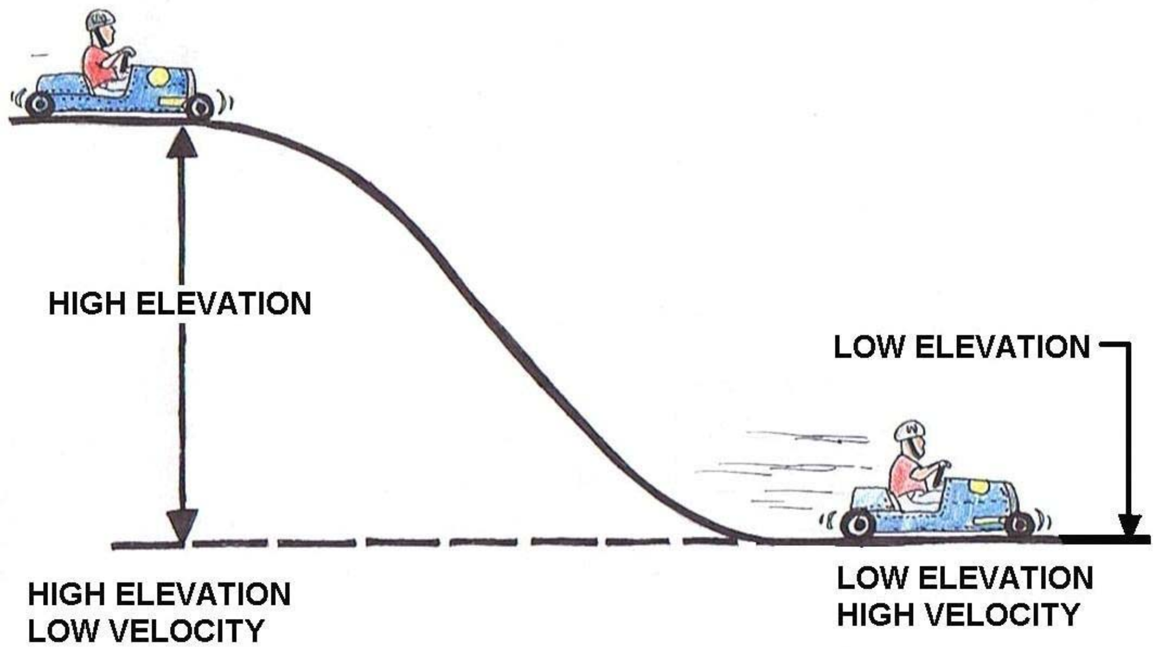
The difference in force pushes the windows outward, and hence they explode. If you know that a hurricane is coming it is therefore better to open as many windows as possible, to equalize the pressure inside and out.

Another example of Bernoulli's principle at work is in the lift of aircraft wings and the motion of "*curve balls"* in baseball. In both cases the design is such as to create a speed differential of the flowing air past the object on the top and the bottom - for aircraft wings this comes from the movement of the flaps, and for the baseball it is the presence of ridges. Such a speed differential leads to a pressure difference between the top and bottom of the object, resulting in a net force being exerted, either upwards or downwards.





VENTURI TUBE



Understanding the Venturi

It is not easy to understand the reason low pressure occurs in the small diameter area of the venturi. This explanation may seem to help the principle.

It is clear that all the flow must pass from the larger section to the smaller section. Or in other words, the flow rate will remain the same in the large and small portions of the tube. The flow rate is the same rate, but the velocity changes. The velocity is greater in the small portion of the tube. There is a relationship between the pressure energy and the velocity energy; if velocity increases the pressure energy must decrease.

This is known as the principle of conservation of energy at work which is also Bernoulli's law. This is similar to the soapbox derby car in the illustration at the top of a hill. At the top or point, the elevation of the soapbox derby car is high and the velocity low. At the bottom the elevation is low and the velocity is high, elevation (potential) energy has been converted to velocity (kinetic) energy. Pressure and velocity energies behave in the same way. In the large part of the pipe the pressure is high and velocity is low, in the small part, pressure is low and velocity high.

If you ever need to prove for a need for backflow protection, visit your local fair grounds or trailer park. I guarantee that you'll find all you need at the concession stand and most health departments and plumbing officials either do not know or could care less. Here is a photograph of a drinking water and sewer connection in the same meter box with the sewer backing up. The white hose is for drinking water and it is back siphoning the sewage water, the sheen is a reflection of the water pulsating in and out of the meter box.

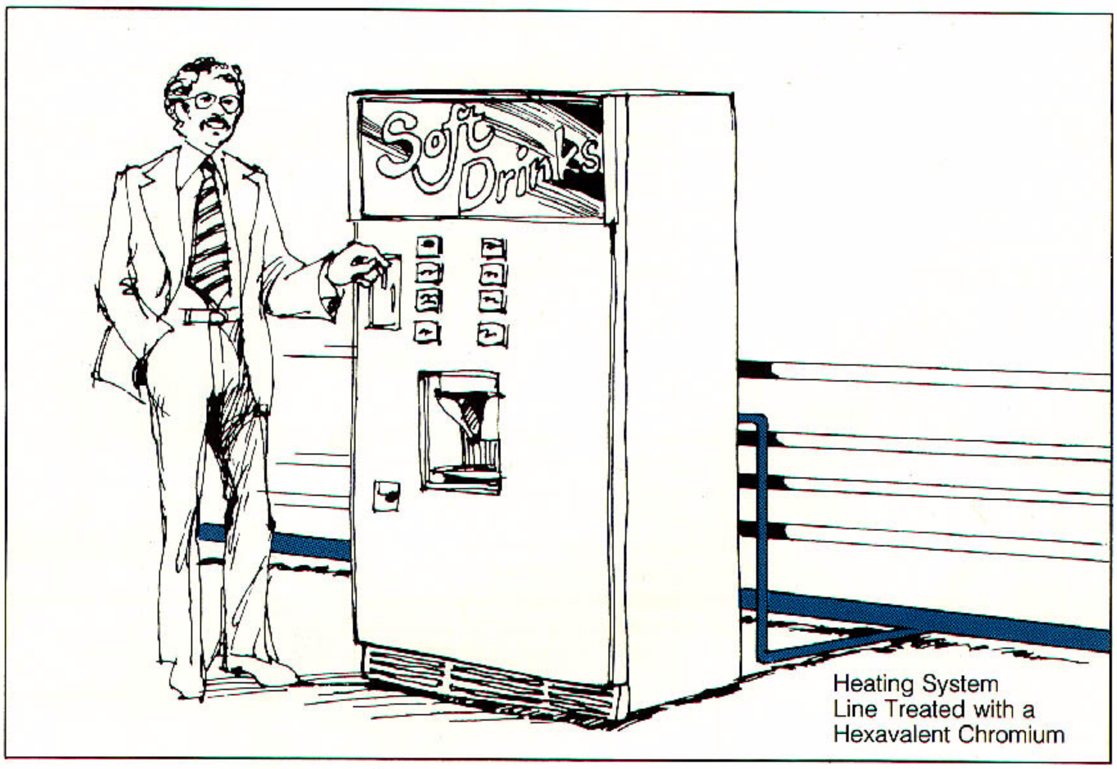
What is backflow? *Reverse flow condition.*

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

Common Cross-Connection Terms

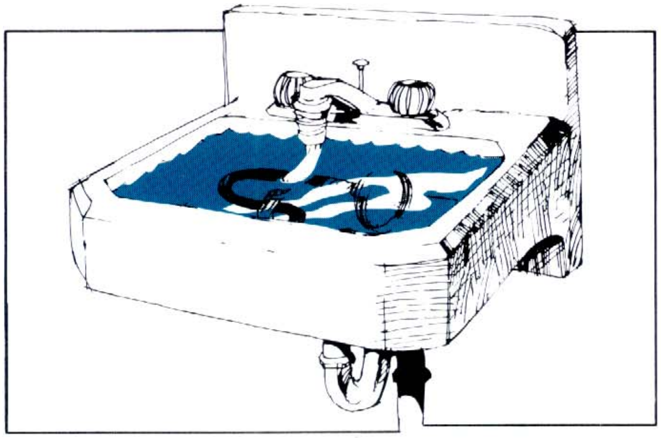
Cross-Connection

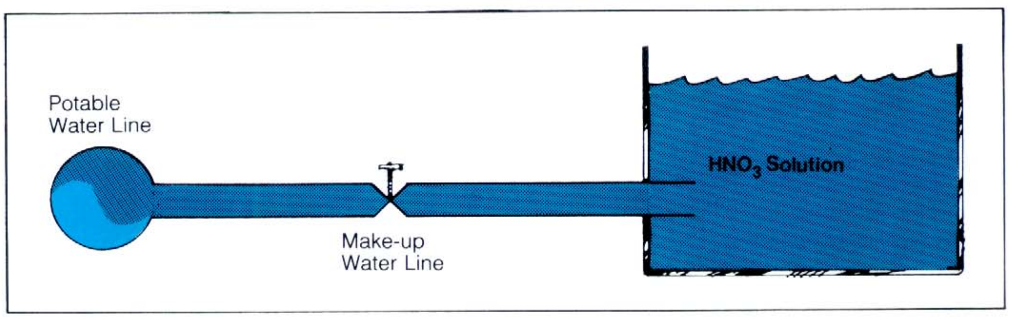
A cross-connection is any temporary or permanent connection between a public water system or consumer's potable (i.e., drinking) water system and any source or system containing nonpotable water or other substances. An example is the piping between a public water system or consumer's potable water system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

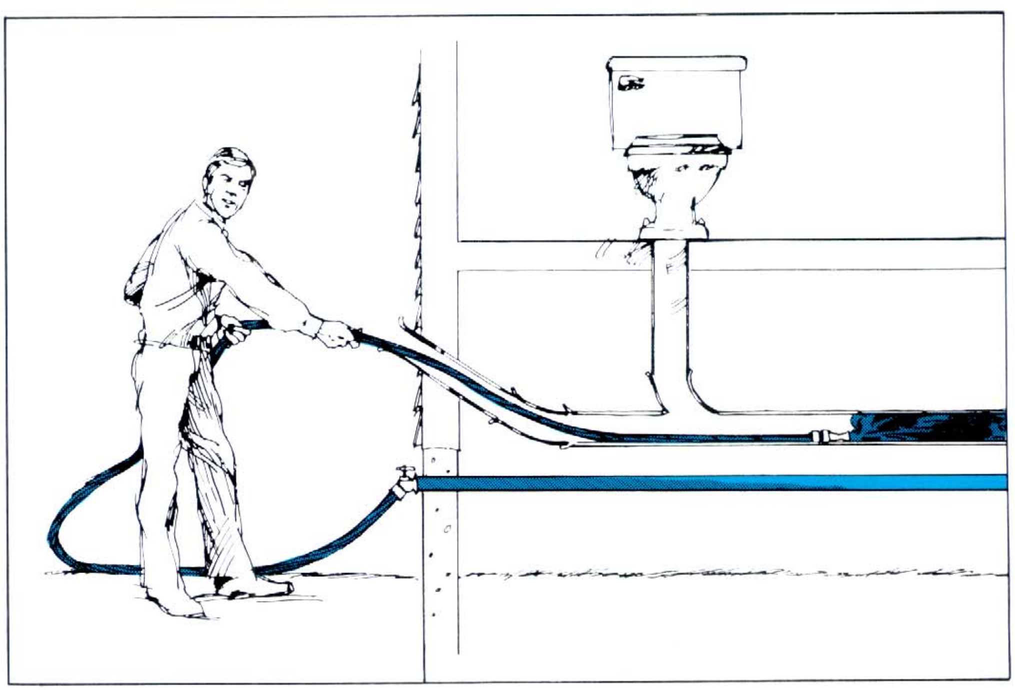


Several cross-connection have been made to soda machines, the one to worry about is when you have a copper water line hooked to CO_2 without a backflow preventer. The reason is that the CO_2 will mix in the water and create copper carbonic acid which can be deadly. This is one reason that you will see clear plastic lines at most soda machines and no copper lines. Most codes require a stainless steel RP backflow assembly at soda machines.

Common Cross-Connections





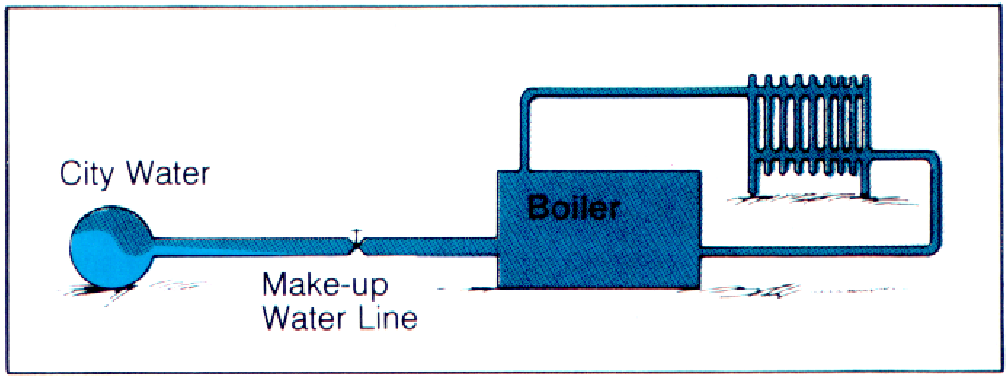


Bottom, a direct connection between water and sewage. ***A perfect cross-connection and it happens all day long.***

Backflow

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

Backsiphonage

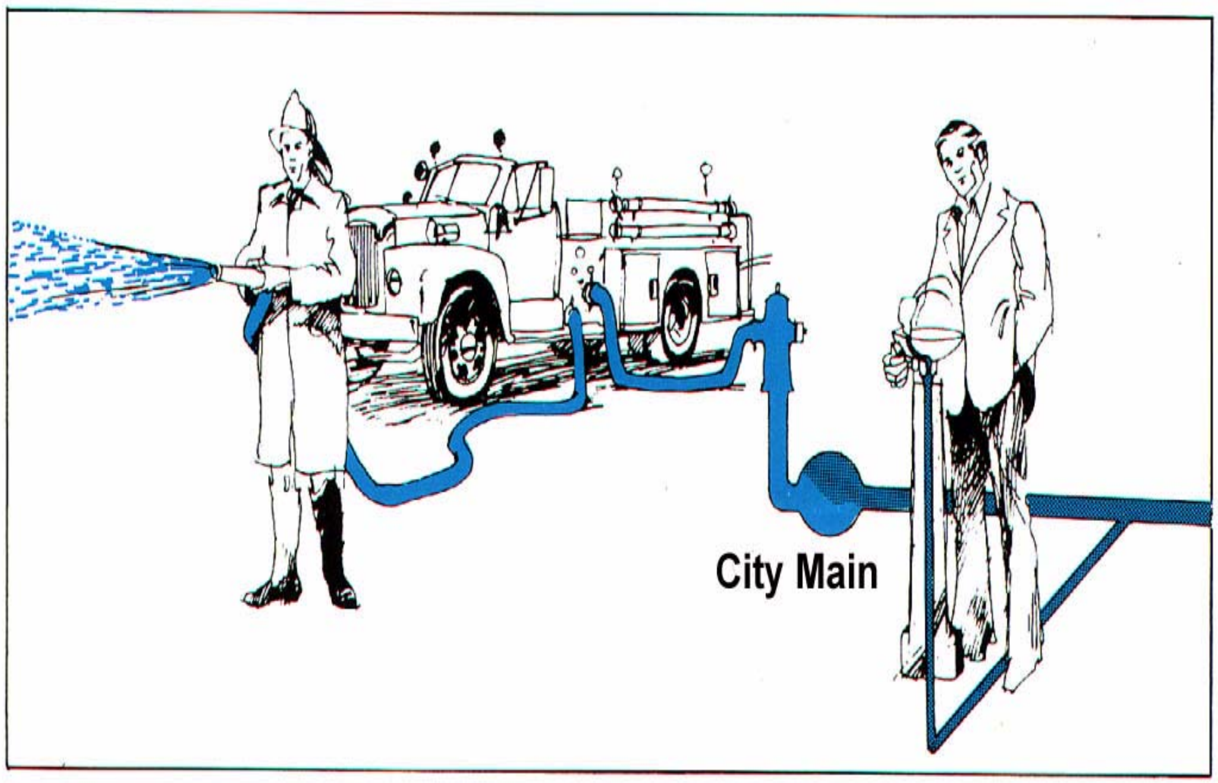


Backpressure caused by heat.

Backsiphonage

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

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



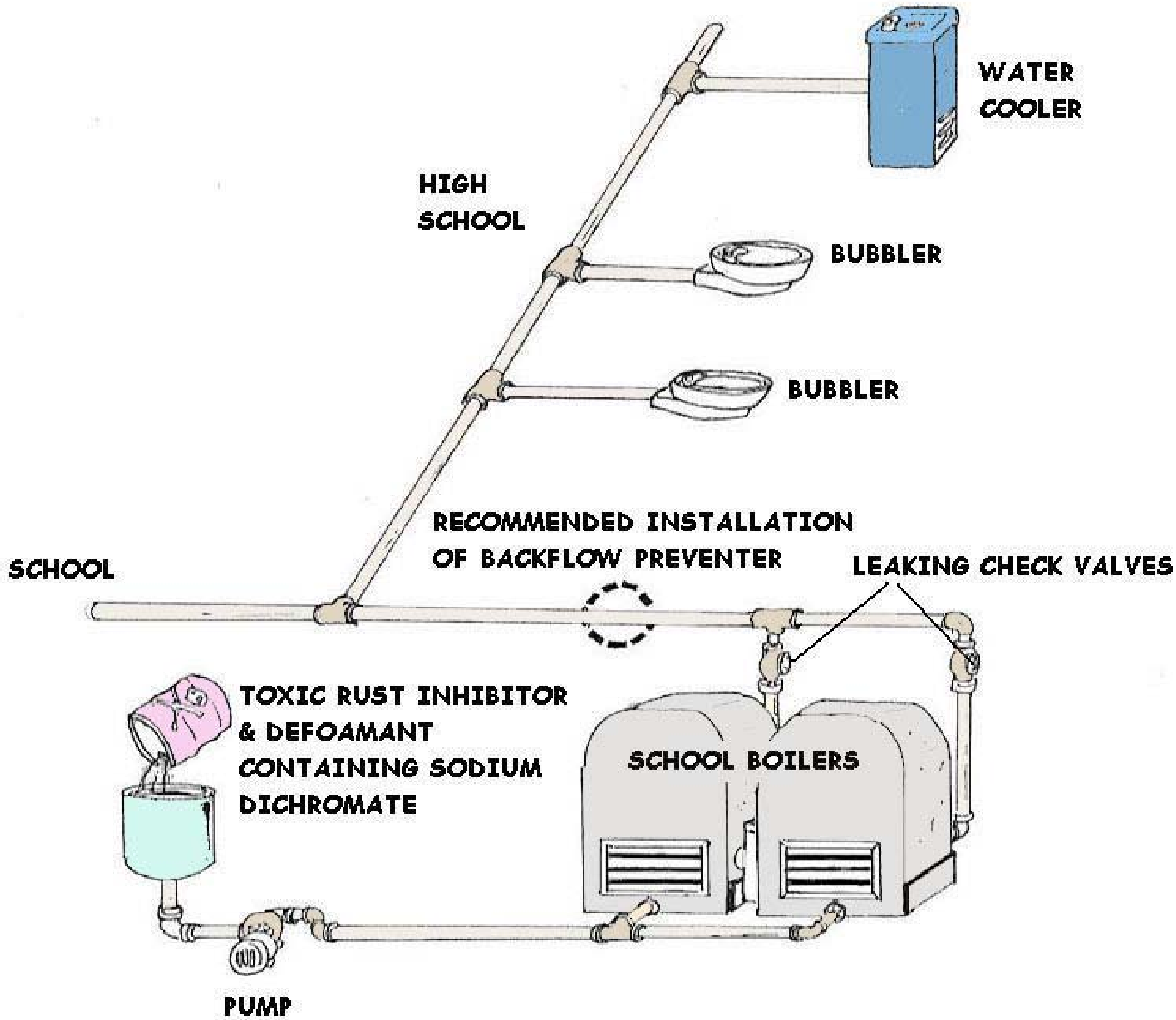
Every day, our public water system has several backsiphonage occurrences, Think of people that use water driven equipment, from a device that drains water-beds to pesticide applicators.

Backpressure is rarer, but does happen in areas of high elevation, like tall buildings or buildings with pumps. A good example is the pressure exerted by a building that is 100 feet tall is about 43 PSI, the water main feeding the building is at 35 PSI. The water will flow back to the water main. Never drink water or coffee inside a funeral home, vet clinic or hospital.

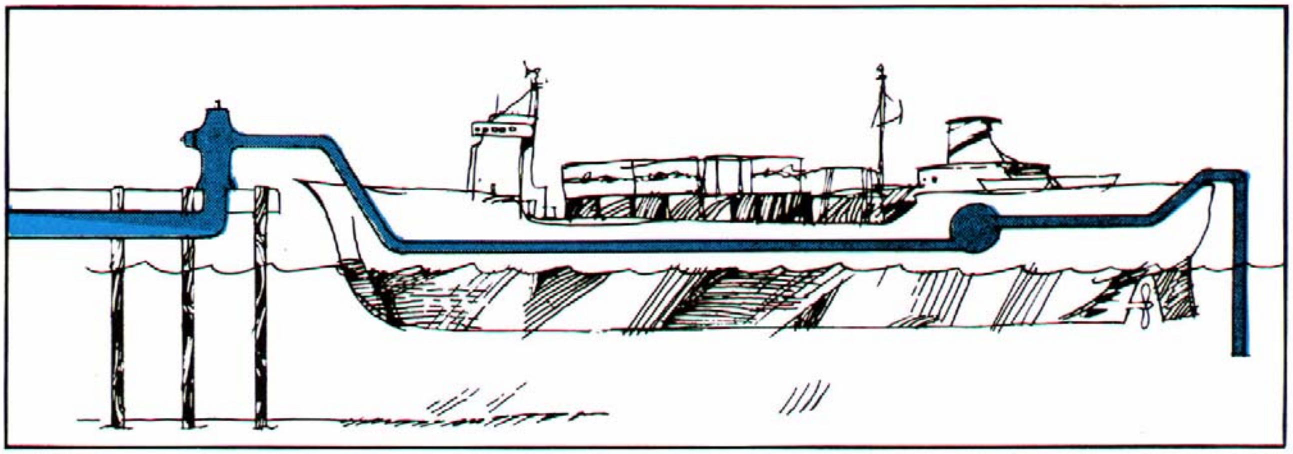
Backpressure

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

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



Backpressure Examples
Booster pumps, pressure vessels, elevation, heat



Here we see the backpressure of salt water back into the public water system from a ship's pressure pump. Most water providers are now requiring a RP assembly at the hydrant.

What is a backflow preventer?
A backflow preventer is a means or mechanism to prevent backflow. The basic means of preventing backflow is an air gap, which either eliminates a cross-connection or provides a barrier to backflow. The basic mechanism for preventing backflow is a mechanical backflow preventer, which provides a physical barrier to backflow. The principal types of mechanical backflow preventer are the reduced-pressure principle assembly, the pressure vacuum breaker assembly, and the double check valve assembly.

Residential Dual Check Valve
A secondary type of mechanical backflow preventer is the residential dual check valve. We do not recommend the installation of dual checks because there is no testing method or schedule for these devices. Once these devices are in place, they, like all mechanical devices, are subject to failure and will probably be stuck open.

Some type of debris will keep the device from working properly.

Types of Backflow Prevention Methods and Assemblies

Backflow Devices

Cross connections must either be physically disconnected or have an approved backflow prevention device installed to protect the public water system. There are five types of approved devices/methods:

1. **Air gap-** ***Is not really a device but is a method.***
2. **Atmospheric vacuum breaker**
3. **Pressure vacuum breaker**
4. **Double check valve**
5. **Reduced pressure principle backflow preventer (RP device)**

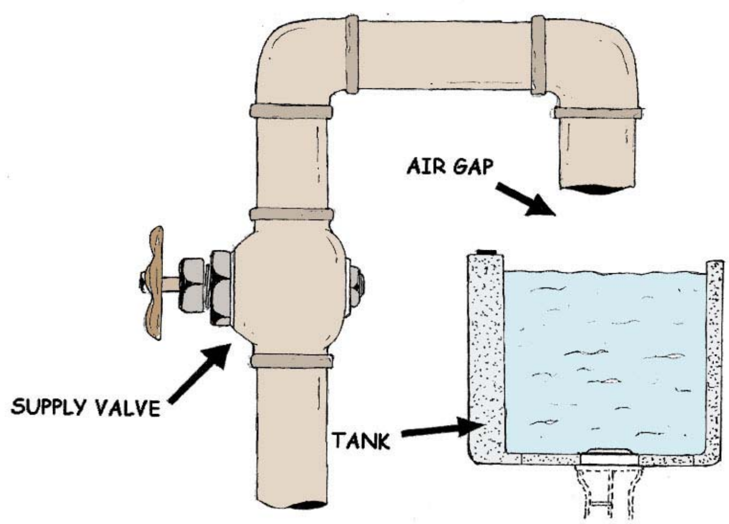
The type of device selected for a particular installation depends on several factors. First, the degree of hazard must be assessed. A high hazard facility is one in which a cross connection could be hazardous to health, such as a chrome plating shop or a sewage treatment plant. A low hazard situation is one in which a cross connection would cause only an aesthetic problem such as a foul taste or odor.

Second, the plumbing arrangement must be considered.

Third, it must be determined whether protection is needed at the water meter or at a location within the facility. A summary of these factors and the recommended device selection is given in Table 7-1.

Approved Air Gap Separation (AG)

An approved air gap is a physical separation between the free flowing discharge end of a potable water supply pipeline, and the overflow rim of an open or non pressure receiving vessel. These separations must be vertically orientated a distance of at least twice the inside diameter of the inlet pipe, but never less than one inch.



An obstruction around or near an air gap may restrict the flow of air into the outlet pipe and nullify the effectiveness of the air gap to prevent backsiphonage. When the air flow is restricted, such as the case of an air gap located near a wall, the air gap separation must be increased. Also, within a building where the air pressure is artificially increased above atmospheric, such as a sports stadium with a flexible roof kept in place by air blowers, the air gap separation must be increased.

Which of these ice machine drains has an approved air gap? Here is a better question; would you use the ice from this ice machine? Here is where all those stories about cockroaches and stomach flu originate. The stories are true.

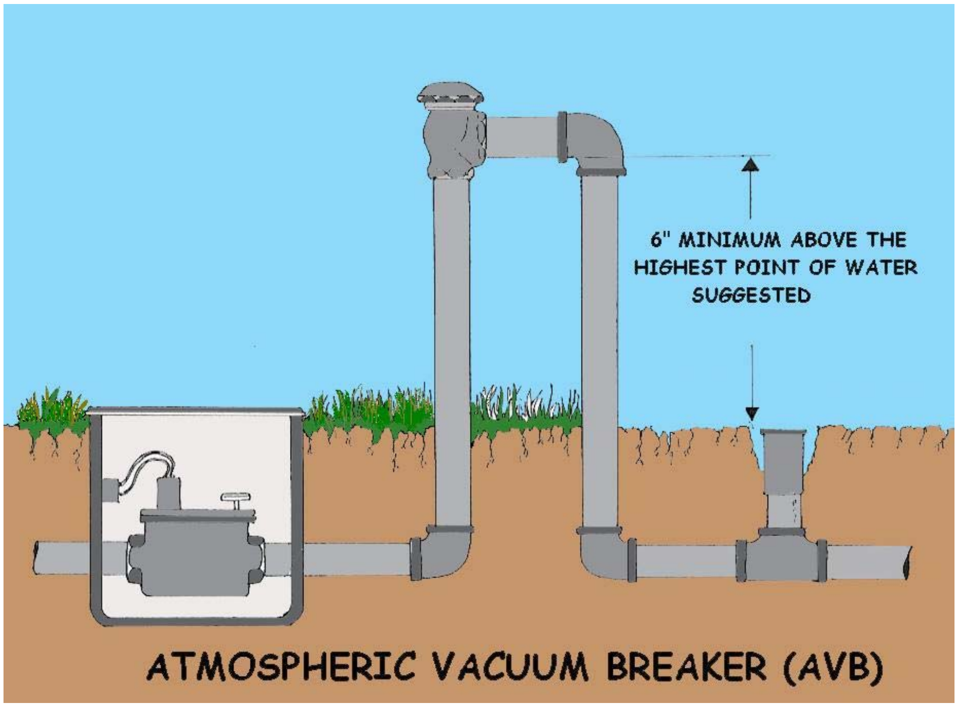
Air Gap

An air gap is a physical disconnection between the free flowing discharge end of a potable water pipeline and the top of an open receiving vessel. The air gap must be at least two times the diameter of the supply pipe and not less than one inch. This type of protection is acceptable for high hazard installations and is theoretically the most effective protection.

However, this method of prevention can be circumvented if the supply pipe is extended.

Vacuum Breakers

There are two types of vacuum breakers, atmospheric and pressure. The difference between them is that the pressure vacuum breaker is spring loaded to assist the device's opening. Both devices open the pipeline to atmosphere in the event of backsiphonage only. Neither device is approved for backpressure conditions. Both devices are only suitable for low hazard applications. Their primary purpose is to protect the water system from cross connections due to submerged inlets, such as irrigation systems and tank applications. Shutoff valves may not be installed downstream of atmospheric vacuum breakers but are allowed on pressure vacuum breakers. The devices must be installed above the highest downstream piping.

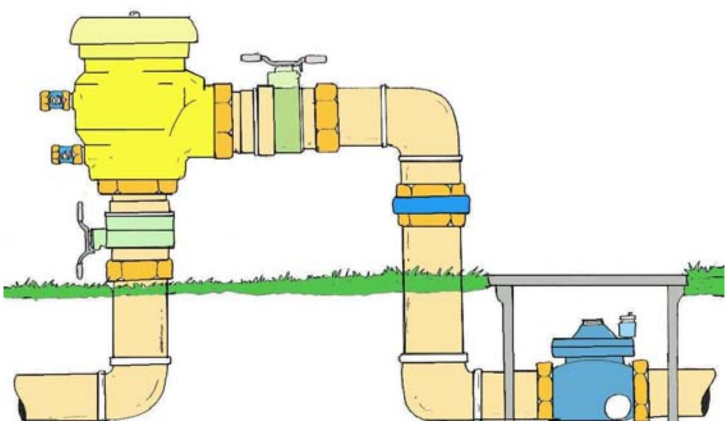


Atmospheric Vacuum Breaker (AVB) The Atmospheric Vacuum Breaker contains a float check (poppet), a check seat, and an air inlet port. The device allows air to enter the water line when the line pressure is reduced to a gauge pressure of zero or below. The air inlet valve is not internally loaded. To prevent the air inlet from sticking closed, the device must not be installed on the pressure side of a shutoff valve, or wherever it may be under constant pressure more than 12 hours during a 24 hour period.

Atmospheric vacuum breakers are designed to prevent backflow caused by backsiphonage only from low health hazards. Atmospheric Vacuum Breaker Uses: Irrigation systems, commercial dishwasher and laundry equipment, chemical tanks and laboratory sinks (backsiphonage only, nonpressurized connections.) (Note: hazard relates to the water purveyor's risk assessment; plumbing codes may allow AVB for high hazard fixture isolation).

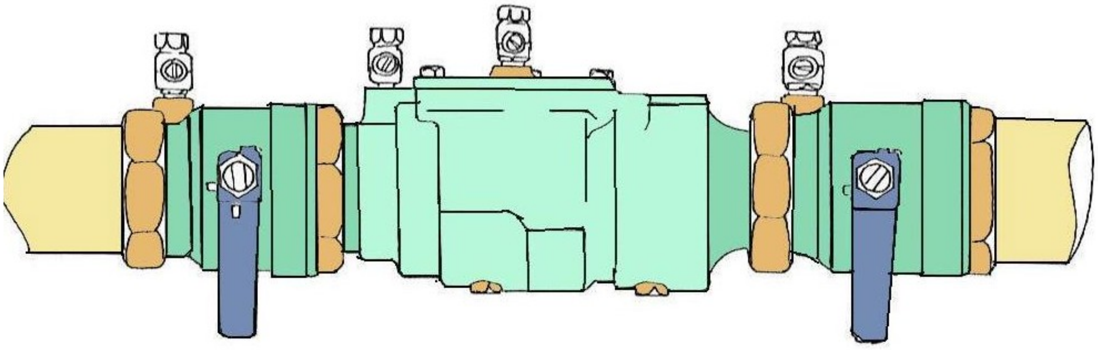
Pressure Vacuum Breaker Assembly (PVB) The Pressure Vacuum Breaker Assembly consists of a spring loaded check valve, an independently operating air inlet valve, two resilient seated shutoff valves, and two properly located resilient seated test cocks. It shall be installed as a unit as shipped by the manufacturer. The air inlet valve is internally loaded to the open position, normally by means of a spring, allowing installation of the assembly on the pressure side of a shutoff valve. The PVB needs to be installed 12 inches above the highest downstream outlet to work correctly.

PRESSSURE VACUUM BREAKER ASSEMBLY



Double Check Valve Assembly (DC)

The Double Check Valve Assembly consists of two internally loaded check valves, either spring loaded or internally weighted, two resilient seated full ported shutoff valves, and four properly located resilient seated test cocks. This assembly shall be installed as a unit as shipped by the manufacturer. The double check valve assembly is designed to prevent backflow caused by backpressure and backsiphonage from low health hazards or pollutional concerns only. The double check valve should be installed in an accessible location and protected from freezing. The DC needs to be installed 12 inches above the ground for testing purposes only.



DOUBLE CHECK VALVE ASSEMBLY

Reduced Pressure Backflow Assembly (RP)

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

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

The reduced pressure backflow assembly is designed to prevent backflow caused by backpressure and backsiphonage from low to high health hazards. The RP needs to installed 12 inches above the ground for testing purposes only.

Two brand new RPs.

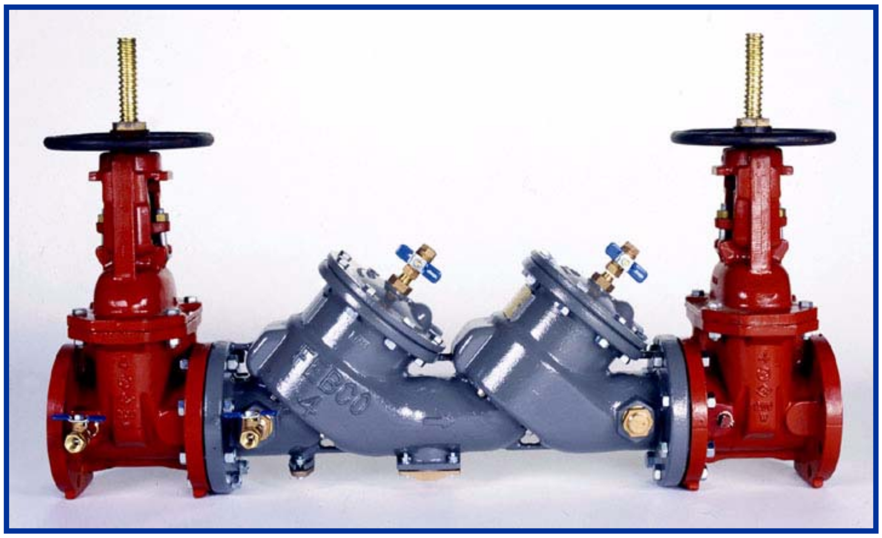
Different Types of RPs

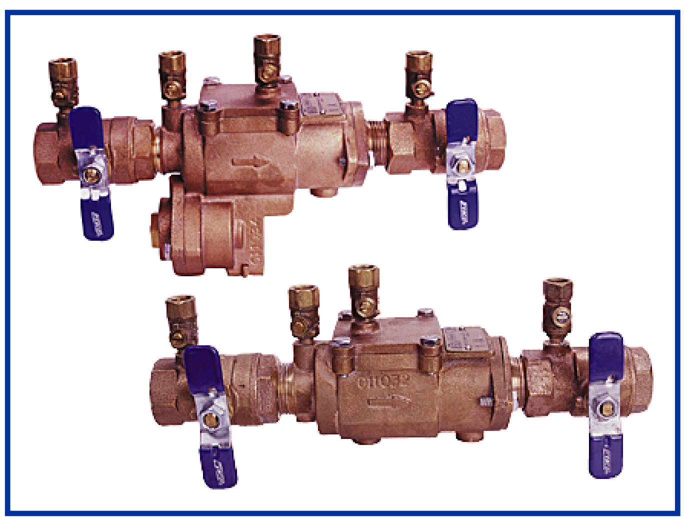
The RP consists of two internally loaded (weighted or spring loaded) check valves separated by a reduced pressure zone with a relief port to vent water to the atmosphere.

The reduced pressure device can be used for high hazard situations under both backpressure and backsiphonage conditions. Under normal conditions, the second check valve should prevent backflow.

However, if the second check valve fails or becomes fouled and backflow into the reduced pressure zone occurs, the relief port vents the backflow to atmosphere.

The reduced pressure zone port opens anytime pressure in the zone comes within 2 psi of the supply pressure.





Why do Backflow Preventors have to be Tested Periodically?

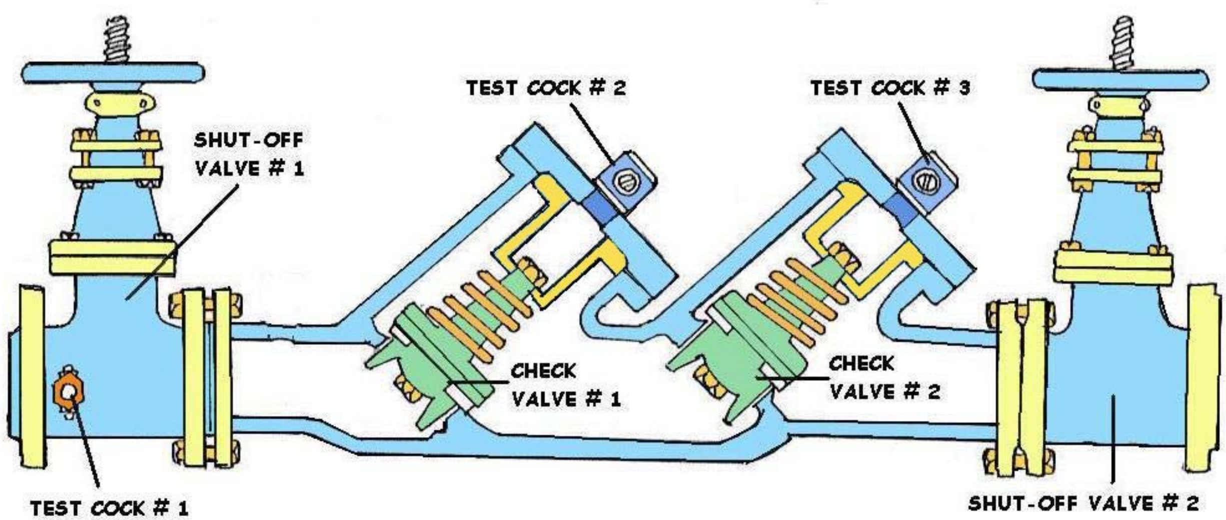
Mechanical backflow preventors have internal seals, springs, and moving parts that are subject to fouling, wear, or fatigue. Also, mechanical backflow preventors and air gaps can be bypassed. Therefore, all backflow preventors have to be tested periodically to ensure that they are functioning properly.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

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

If a device is not tested annually, Public Works or the Water Purveyor will notify the property owner, asking them to comply. If the property owner does not voluntarily test their device, the City may be forced to turn off water service to that property. State law requires the City to discontinue water service until testing is complete.

Leaky RP--have your assemblies tested annually or more often. Re-test after repairs and problems. A RP should not leak more than 1 or 2 minute—any more than that, there is a problem; a piece of debris or stuck check is causing the RP's hydraulic relief port to dump.

Here is an RP that had never been tested and leaked every day until the grass was 3 feet high and the owner notified the Water Department of a water leak. The water meter reader should have caught this problem in the first couple months.



DOUBLE-CHECK BACKFLOW ASSEMBLY

Fireline Backflow Assemblies

Example of an inline and vertical Reduced Pressure Backflow Assembly.

Fire Suppression Systems

- ✓ Properly designed and installed fixed fire suppression systems enhance fire safety in the workplace. Automatic sprinkler systems throughout the workplace are among the most reliable fire fighting means. The fire sprinkler system detects the fire, sounds an alarm and puts the water where the fire and heat are located.

- ✓ Automatic fire suppression systems require proper maintenance to keep them in serviceable condition. When it is necessary to take a fire suppression system out of service while business continues, the employer must temporarily substitute a fire watch of trained employees standing by to respond quickly to any fire emergency in the normally protected area. The fire watch must interface with the employers' fire prevention plan and emergency action plan.

- ✓ Signs must be posted about areas protected by total flooding fire suppression systems which use agents that are a serious health hazard such as carbon dioxide, Halon 1211, etc. Such automatic systems must be equipped with area pre-discharge alarm systems to warn employees of the impending discharge of the system and allow time to evacuate the area. There must be an emergency action plan to provide for the safe evacuation of employees from within the protected area. Such plans are to be part of the overall evacuation plan for the workplace facility.

Halon Systems

Fire System Classifications

Industrial fire protection systems will usually consist of sprinklers, hose connections, and hydrants. Sprinkler system may be dry or wet, open or closed. Systems of fixed-spray nozzles may be used indoors or outdoors for protection of flammable-liquid and other hazardous processes. It is standard practice, especially in cities, to equip automatic sprinkler systems with fire department pumper connections.

For cross-connection control, fire protection systems may be classified on the basis of water source and arrangement of supplies as follows:

1. **Class 1**--direct connections from public water mains only; no pumps, tanks, or reservoirs; no physical connection from other water supplies; no antifreeze or other additives of any kind; all sprinkler drains discharging to atmosphere, dry wells, or other safe outlets.

2. **Class 2**--same as class 1, except that booster pumps may be installed in the connections from the street mains (Booster pumps do not affect the potability of the system; it is necessary, however, to avoid drafting so much water that pressure in the water main is reduced below 10 psi.)

3. **Class 3**--direct connection from public water supply main plus one or more of the following: elevated storage tanks; fire pumps taking suction from above-ground covered reservoirs or tanks; and pressure tanks (All storage facilities are filled or connected to public water only, the water in the tanks to be maintained in potable conditions. Otherwise, Class 3 systems are the same as Class 1.)

4. **Class 4**--directly supplied from public mains similar to Classes 1 and 2, and with an auxiliary water supply on or available to the premises; or an auxiliary water supply may be located within l,700 ft. of the pumper connection.

5. **Class 5**--directly supplied from public mains, and interconnected with auxiliary supplies, such as: pumps taking suction from reservoirs exposed to contamination, or rivers and ponds; driven wells; mills or other industrial water systems; or where antifreeze or other additives are used.

6. **Class 6**--combined industrial and fire protection systems supplied from the public water mains only, with or without gravity storage or pump suction tanks.

Industrial Fluids - shall mean any fluid or solution which may chemically, biologically or otherwise contaminated or polluted in a form or concentration such as would constitute a health, system, pollutional or plumbing hazard if introduced into an approved water supply.

This may include, but not be limited to: polluted or contaminated used water; all types of process waters and "*used waters*" originating from the public water system which may deteriorate in sanitary quality; chemicals in fluids from: plating acids and alkalies; circulated cooling waters connected to an open cooling tower and/or cooling waters that are chemically or biologically treated or stabilized with toxic substances; contaminated natural waters such as from wells, springs, streams, rivers, bays, harbors, seas, irrigation canals or systems, etc.; oils, gases, glycerin, paraffins, caustic and acid solutions and other liquid and gaseous fluids used in industrial or other processes or for fire fighting purposes.

In some states, Fire lines need backflow prevention assemblies for certain criteria: a. Class 1 and 2 fire systems are not currently required to have any backflow prevention equipment at the service connection other than the equipment that is required for those systems under the state fire code standards. b. Class 3 fire systems may be converted to Class 1 or 2 systems by removing the tank. However, you must have the approval of the fire authority. c. Class 4 and 5 must comply with backflow requirements. Class 5 includes those fire systems that use antifreeze or other additives (RPDA required). This may apply to residential homes over 3,000 sq. ft. d. Class 6 fire systems require an on-site review to determine backflow requirements.

Double Check Backflow Assembly (Notice chain common on OS&Y).

Types of Pipes

Several types of pipe are used in water distribution systems, but only the most common types used by operators will be discussed. These piping materials include copper, plastic, galvanized steel, and cast iron. Some of the main characteristics of pipes made from these materials are presented below.

Plastic pipe has been used extensively in current construction. Available in different lengths and sizes, it is lighter than steel or copper and requires no special tools to install. Plastic pipe has several advantages over metal pipe: it is flexible; it has superior resistance to rupture from freezing; it has complete resistance to corrosion; and, in addition, it can be installed aboveground or below ground.

One of the most versatile plastic and polyvinyl resin pipes is the polyvinyl chloride (PVC). PVC pipes are made of tough, strong thermoplastic material that has an excellent combination of physical and chemical properties. Its chemical resistance and design strength make it an excellent material for application in various mechanical systems.

Sometimes polyvinyl chloride is further chlorinated to obtain a stiffer design, a higher level of impact resistance, and a greater resistance to extremes of temperature. A CPVC pipe (a chlorinated blend of PVC) can be used not only in cold-water systems, but also in hot-water systems with temperatures up to 210°F. Economy and ease of installation make plastic pipe popular for use in either water distribution and supply systems or sewer drainage systems.

Galvanized pipe is commonly used for the water distributing pipes inside a building to supply hot and cold water to the fixtures. This type of pipe is manufactured in 21-ft lengths. It is GALVANIZED (coated with zinc) both inside and outside at the factory to resist corrosion. Pipe sizes are based on nominal INSIDE diameters. Inside diameters vary with the thickness of the pipe. Outside diameters remain constant so that pipe can be threaded for standard fittings.

Ductile/Cast-iron pipe, sometimes called cast-iron pressure pipe, is used for water mains and frequently for service pipe up to a building. Unlike cast-iron soil pipe, cast-iron water pipe is manufactured in 20-ft lengths rather than 5-ft lengths.

Besides bell-and-spigot joints, cast-iron water pipes and fittings are made with flanged, mechanical, or screwed joints. The screwed joints are used only on small-diameter pipe.

Copper is one of the most widely used materials for tubing. This is because it does not rust and is highly resistant to any accumulation of scale particles in the pipe. This tubing is available in three different types: **K, L, and M.**

K has the thickest walls, and M, the thinnest walls, with L's thickness in between the other two. The thin walls of copper tubing are soldered to copper fittings.

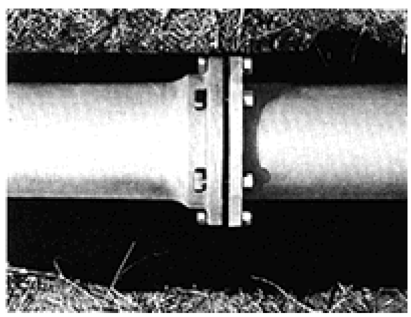
Soldering allows all the tubing and fittings to be set in place before the joints are finished. Generally, faster installation will be the result.

Type K copper tubing is available in either rigid (hard temper) or flexible (soft temper) and is primarily used for underground service in the water distribution systems. Soft temper tubing is available in 40- or 60-ft coils, while hard temper tubing comes in 12- and 20-ft straight lengths. Type L copper tubing is also available in either hard or soft temper and either in coils or in straight lengths. The soft temper tubing is often used as replacement plumbing because of the tube's flexibility, which allows easier installation.

Type L copper tubing is widely used in water distribution systems.

Type M copper tubing is made in hard temper only and is available in straight lengths of 12 and 20 ft. It has a thin wall and is used for branch supplies where water pressure is low, but it is NOT used for mains and risers. It is also used for chilled water systems, for exposed lines in hot-water heating systems, and for drainage piping.

Fittings
Fittings vary according to the type of piping material used. The major types commonly used in water service include elbows, tees, unions, couplings, caps, plugs, nipples, reducers, and adapters.



Caps— A pipe cap is a fitting with a female (inside) thread. It is used like a plug, except that the pipe cap screws on the male thread of a pipe or nipple.

Couplings— The three common types of couplings are straight coupling, reducer, and eccentric reducer. The STRAIGHT COUPLING is for joining two lengths of pipe in a straight run that does not require additional fittings. A run is that portion of a pipe or fitting continuing in a straight line in the direction of flow. A REDUCER is used to join two pipes of different sizes. The ECCENTRIC REDUCER (also called a BELL REDUCER) has two female (inside) threads of different sizes with centers so designed that when they are joined, the two pieces of pipe will not be in line with each other, but they can be installed so as to provide optimum drainage of the line.

Elbows (Ells) 90° and 45°.— These fittings (fig. 8-5, close to middle of figure) are used to change the direction of the pipe either 90 or 45 degrees. REGULAR elbows have female threads at both outlets.

Street elbows change the direction of a pipe in a close space where it would be impossible or impractical to use an elbow and nipple. Both 45- and 90-degree street elbows are available with one female and one male threaded end. The REDUCING elbow is similar to the 90-degree elbow except that one opening is smaller than the other.

A nipple is a short length of pipe (12 in. or less) with a male thread on each end. It is used for extension from a fitting.

At times, you may use the **DIELECTRIC** or **INSULATING TYPE** of fittings. These fittings connect underground tanks or hot-water tanks. They are also used when pipes of dissimilar metals are connected.

Tees — A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs. A common type of pipe tee is the STRAIGHT tee, which has a straight-through portion and a 90-degree takeoff on one side. All three openings of the straight tee are of the same size. Another common type is the REDUCING tee, similar to the straight tee just described, except that one of the threaded openings is of a different size than the other.

Unions— There are two types of pipe unions. The GROUND JOINT UNION consists of three pieces, and the FLANGE UNION is made in two parts. Both types are used for joining two pipes together and are designed so that they can be disconnected easily. When joined, the two pieces of pipe will not be in line with each other, but they can be installed so as to provide optimum drainage of the line.

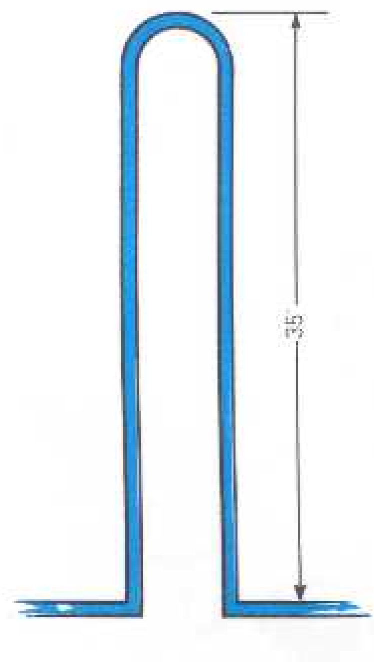
Thermal Expansion Tank *(Closed Loop System*)

However, the installation of backflow preventors may require some modification to your home plumbing. Prior to the installation of the backflow device, the volume of water in your home's pipes, which can expand when heated, could easily flow back into the public water system. With the installation of the backflow preventer, the water pressure in your home may build up, particularly when the hot water system is activated. To prevent thermal expansion, the Administrative Authority or Water Provider will suggest having a thermal expansion tank installed.

If after the backflow prevention device is installed you notice your faucets leak or the emergency relief valve on the hot water tank is continuously activated, you should call a plumbing professional, as damage to your system may occur. For many homeowners, merely lowering the temperature on the hot water tank will eliminate the need for plumbing work. A setting between 115-125 degrees is considered appropriate for most household users.

A thermal expansion tank is a small tank with an air/ water bladder. The air in the bladder can be compressed, enabling the water to expand into this tank, relieving pressure on other fixtures. This tank is to be located on the cold water side of the hot water tank.

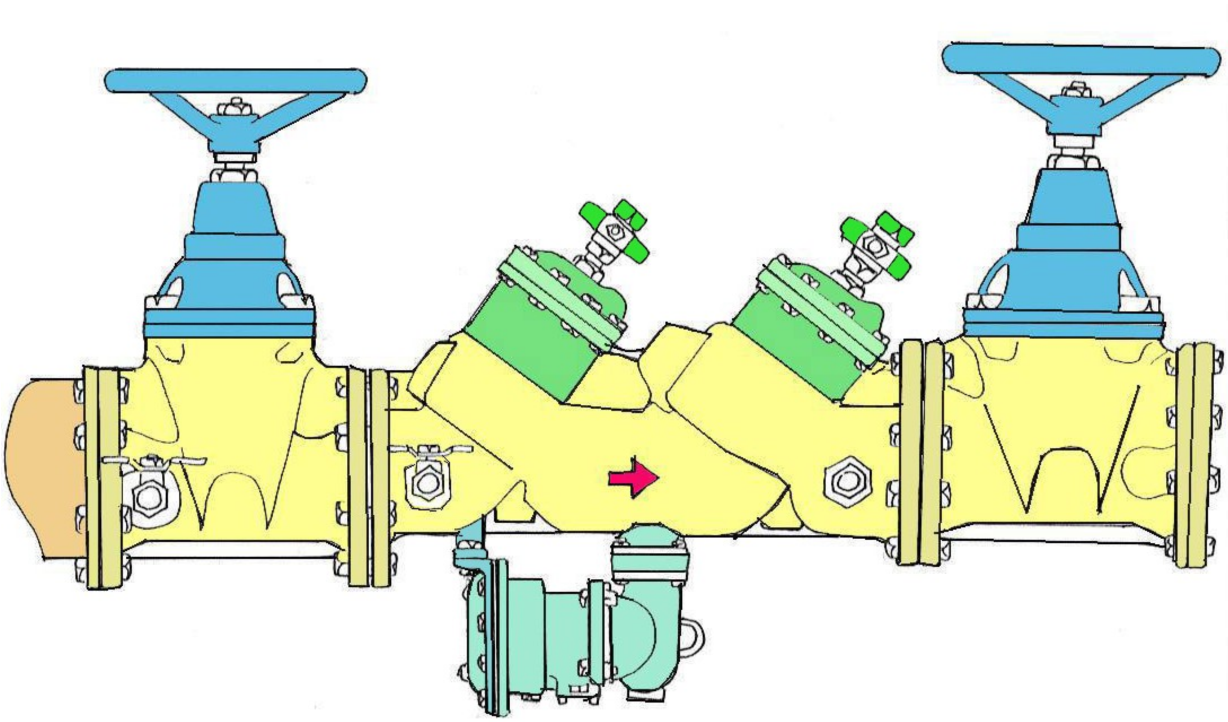
Barometric Loop



The barometric loop consists of a continuous section of supply piping that abruptly rises to a height of approximately 35 feet and then returns back down to the originating level. It is a loop in the piping system that effectively protects against backsiphonage. It may not be used to protect against back-pressure.

Its operation, in the protection against backsiphonage, is based upon the principle that a water column, at sea level pressure, will not rise above 33.9 feet.

In general, barometric loops are locally fabricated, and are 35 feet high.



REDUCED PRESSURE BACKFLOW ASSEMBLY

Cross-Connection Control Responsibility

The Public Water Purveyor
The primary responsibility of the water purveyor is to develop and maintain a program to prevent or control contamination from water sources of lesser quality or other contamination sources from entering into the public water system.

Under the provisions of the Safe Drinking Water Act of 1974 (SDWA) and current Groundwater Protection rules, the Federal Government through the EPA, (Environmental Protection Agency), set national standards of safe drinking water. The separate states are responsible for the enforcement of these standards as well as the supervision of public water systems and the sources of drinking water.

The water purveyor or supplier is held responsible for compliance to the provisions of the Safe Drinking Water Act, to provide a warranty that water quality by their operation is in conformance with EPA standards at the source, and is delivered to the customer without the quality being the compromised as its delivery through the distribution system.

This is specified in the Code of Federal Regulations (Volume 40, Paragraph141.2 Section c):
Maximum contaminant level means the permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry (POE) to the distribution system.

Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

The Water Consumer
Has the responsibility to prevent contaminants from entering into the public water system by way of their individual plumbing system, and retain the expenses of installation, maintenance, and testing of the approved backflow prevention assemblies installed on their individual water service line.

The Certified General Backflow Tester
Has the responsibility to test, maintain, inspect, repair, and report/notify on approved backflow prevention assemblies as authorized by the persons that have jurisdiction over those assemblies.

Why do water suppliers need to control cross-connections and protect their public water systems against backflow?

Backflow into a public water system can pollute or contaminate the water in that system (i.e., backflow into a public water system can make the water in that system unusable or unsafe to drink), and each water supplier has a responsibility to provide water that is usable and safe to drink under all foreseeable circumstances.

Furthermore, consumers generally have absolute faith that water delivered to them through a public water system is always safe to drink. For these reasons, each water supplier must take reasonable precautions to protect its public water system against backflow.

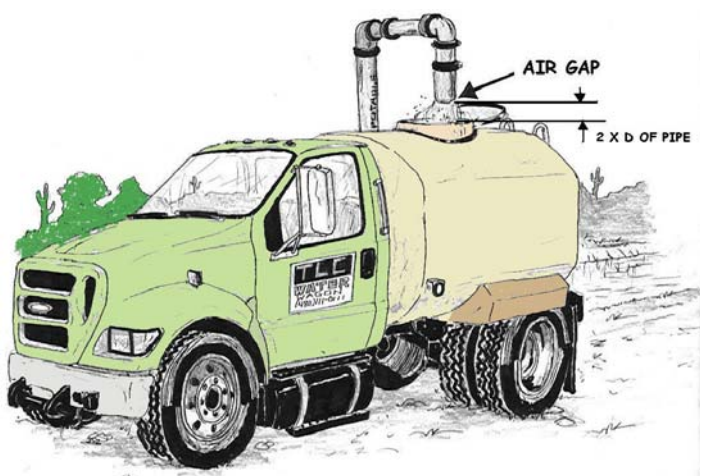
What should water suppliers do to control cross-connections and protect their public water systems against backflow?

Water suppliers usually do not have the authority or capability to repeatedly inspect every consumer's premises for cross-connections and backflow protection.

Alternatively, each water supplier should ensure that a proper backflow preventer is installed and maintained at the water service connection to each system or premises that poses a significant hazard to the public water system.

Generally, this would include the water service connection to each dedicated fire protection system or irrigation piping system and the water service connection to each of the following types of premises:
(1) premises with an auxiliary or reclaimed water system;
(2) industrial, medical, laboratory, marine or other facilities where objectionable substances are handled in a way that could cause pollution or contamination of the public water system;
(3) premises exempt from the State Plumbing Code and premises where an internal backflow preventer required under the State Plumbing Code is not properly installed or maintained;
(4) classified or restricted facilities; and
(5) tall buildings.

Each water supplier should also ensure that a proper backflow preventer is installed and maintained at each water loading station owned or operated by the water supplier.



EXAMPLE OF AN AIR GAP

Common Backflow Questions and Answers

1. What is a cross connection, what two types of backflow can cause one, and what methods of protection can be used to prevent them?

Backflow: Water that flows back to the distribution system. It is sometimes caused by a loss of pressure in the water system. A reverse flow condition.

Cross-Connection: A physical connection between potable water and any other source or non-potable water.

Backpressure: Backpressure backflow is backflow caused by a downstream pressure that is greater than the upstream or supply pressure in a public water system or consumer's potable water system. Backpressure (i.e., downstream pressure that is greater than the potable water supply pressure) can result from an increase in downstream pressure, a reduction in the potable water supply pressure, or a combination of both. Increases in downstream pressure can be created by pumps, temperature increases in boilers, etc. Reductions in potable water supply pressure occur whenever the amount of water being used exceeds the amount of water being supplied, such as during water line flushing, fire fighting, or breaks in water mains.

Backsiphonage: Backsiphonage is backflow caused by a negative pressure (i.e., a vacuum ~ or partial vacuum) in a Public water system or consumer's potable water system. The effect is similar to drinking water through a straw. Backsiphonage can occur when there is a stoppage of water supply due to nearby fire fighting, a break in a water main, etc.

2. Why do water suppliers need to control cross-connections and protect their public water systems against backflow?

Backflow: Backflow into a public water system can pollute or contaminate the water in that system (i.e., backflow into a public water system can make the water in that system unusable or unsafe to drink), and each water supplier has a responsibility to provide water that is usable and safe to drink under all foreseeable circumstances. Furthermore, consumers generally have absolute faith that water delivered to them through a public water system is always safe to drink. For these reasons, each water supplier must take reasonable precautions to protect its public water system against backflow.

3. What should water suppliers do to control cross-connections and protect their public water systems against backflow?

Water suppliers usually do not have the authority or capability to repeatedly inspect every consumer's premises for cross-connections and backflow protection. Alternatively, each water supplier should ensure that a proper backflow preventer is installed and maintained at the water service connection to each system or premises that poses a significant hazard to the public water system.

Generally, this would include the water service connection to each dedicated fire protection system or irrigation piping system and the water service connection to each of the following types of premises: (I) premises with an auxiliary or reclaimed water system: (2) industrial, medical, laboratory, marine or other facilities where objectionable substances are handled in a way that could cause pollution or contamination of the public water system; (3) premises exempt from the State Plumbing Code and premises where an internal backflow preventer required under the State Plumbing Code is not properly installed or maintained; (4) classified or restricted facilities; and (S) tall buildings. Each water supplier should also ensure that a proper backflow preventer is installed and maintained at each water loading station owned or operated by the water supplier.

4. Air gap: An air gap is a vertical, physical separation between the end of a water supply outlet and the flood-level rim of a receiving vessel. This separation must be at least twice the diameter of the water supply outlet and never less than one inch. An air gap is considered the maximum protection available against backpressure backflow or backsiphonage but is not always practical and can easily be bypassed.

5. RP: An RP or reduced pressure principle backflow prevention assembly is a mechanical backflow preventer that consists of two independently acting, spring-loaded check valves with a hydraulically operating, mechanically independent, spring-loaded pressure differential relief valve between the check valves and below the first check valve. It includes shutoff valves at each end of the assembly and is equipped with test cocks. An RP is effective against backpressure backflow and backsiphonage and may be used to isolate health or nonhealth hazards.

6. DC: A DC or double check is a mechanical backflow preventer that consists of two independently acting, spring-loaded check valves. It includes shutoff valves at each end of the assembly and is equipped with test cocks. A DC is effective against backpressure backflow and backsiphonage but should be used to isolate only nonhealth hazards.

7. Vacuum breaker: A PVB is a mechanical backflow preventer that consists of an independently acting, spring-loaded check valve and an independently acting, spring-loaded, air inlet valve on the discharge side of the check valve. It includes shutoff valves at each end of the assembly and is equipped with test cocks. A PVB may be used to isolate health or nonhealth hazards but is effective against backsiphonage only.

8. What is thermal expansion and what are the considerations with regards to backflow assemblies and devices?

A backflow assembly will create a closed system. A closed system will not allow built up pressure to be released. You need to release excessive pressure in a closed system. One method is by installing expansion tanks or blow-offs.

Cross-Connection Control Program Section

All public water system operators are required to maintain an active cross connection control program to identify and eliminate or isolate all cross connections within their systems. This program should provide for inspections of premises which may contain cross connections, installation of approved backflow prevention devices and annual testing of installed devices.

A cross connection ordinance (or other enabling authority) that prohibits water service to any premise on which a cross connection exists without proper protection is required. The ordinance can also specify who will do the inspections and can specify testing of devices. Only backflow prevention devices that are approved by the State Environ-mental Quality or Health Division may be installed. Backflow prevention devices must be tested annually by certified testers to be sure the devices are functioning properly.

Responsibility Administration of a Cross-Connection Program

Under the provisions of the Safe Drinking Water Act of 1974, the Federal Government has established, through the EPA (Environmental Protection Agency), national standards of safe drinking water. The states are responsible for the enforcement of these standards as well as the supervision of public water supply systems and the sources of drinking water.

The water purveyor (supplier) is held responsible for compliance to the provisions of the Safe Drinking Water Act, to include a warranty that water quality provided by his operation is in conformance with the EPA standards at the source, and is delivered to the customer without the quality being compromised es a result of its delivery through the distribution system. As specified in the Code of Federal Regulations

(Volume 40, Paragraph 141.2, Section (c)) "*Maximum contaminant level, means the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system.*

Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition."

Containment

There are several options that are open to a water purveyor when considering cross-connection protection to commercial, industrial, and residential customers. He may elect to work initially on the "*containment*" theory. This approach utilizes a minimum of backflow devices and isolates the customer from the water main. It virtually insulates the customer from potentially contaminating or polluting the public water supply system.

While it is recognized that "*containment"* does not protect the customer within his building, it does effectively remove him from possible contamination to the public water supply system.

If the water purveyor elects to protect his customers on a domestic internal protective basis and/or *"fixture outlet protective basis*," then cross-connection control protective devices are placed at internal high hazard locations as well as at all locations where cross-connections exist at the "*last free-flowing outlet*."

This approach entails extensive cross-connective survey work on behalf of the water superintendent as well as constant policing of the plumbing within each commercial, industrial and residential account.

In large water supply systems, fixture outlet protection cross-connection control philosophy, in itself, is a virtual impossibility to achieve and police due to the quantity of systems involved, the complexity of the plumbing systems inherent in many industrial sites, and the fact that many plumbing changes are made within industrial and commercial establishments that do not require the water department to license or otherwise endorse or ratify when contemplated or completed.

Containment Protection *Secondary protection*
This approach utilizes a minimum of backflow devices and isolates the customer from the water main. It virtually insulates the customer from potentially contaminating or polluting the public water supply system.

Containment protection does not protect the customer within his own building, it does effectively remove him from the possibility public water supply contamination.

Containment protection is usually a backflow prevention device as close as possible to the customer's water meter and is often referred to as "Secondary Protection".

This type of backflow protection is excellent for water purveyors and is the least expense to the water customer but does not protect the occupants of the building.

Internal Protection, ***Primary protection***

The water purveyor may elect to protect his customers on a domestic internal protective basis and/or "*fixture outlet protective basis*," in this case cross-connection-control devices (backflow preventors) are placed at internal hazard locations and at all locations where cross-connections may exist including the "*last free flowing outlet*."

This type of protection entails extensive cross-connection survey work usually preformed by a plumbing inspector or a Cross-Connection Specialist.

In a large water supply system, internal protection in itself is virtually impossible to achieve and police due to the quantity of systems involved, the complexity of the plumbing systems inherent in many industrial sites, and the fact that many plumbing changes are made within commercial establishments that do not get the plumbing department's approval or require that the water department inspects when the work is completed.

Internal protection is the most expensive and best type of backflow protection for both the water purveyor and the customer alike, but is very difficult to maintain.

In order for the purveyor to provide maximum protection of the water distribution system, consideration should be given to requiring the owner of the premises to provide at his own expense, adequate proof that his internal water supply system complies with the local or state plumbing code(s). In addition, he may be required to install, test, maintain all backflow protection assemblies.

Method of Action

In addition, internal plumbing cross-connection control survey work is generally foreign to the average water purveyor and is not normally a portion of his job description or duties. While it is admirable for the water purveyor to accept and perform survey work, he should be aware that he runs the risk of additional liability in an area that may be in conflict with plumbing inspectors, maintenance personnel and other public health officials.

Even where extensive "*fixture outlet protection*," cross-connection control programs are in effect through the efforts of an aggressive and thorough water supply cross-connection control program, the water authorities should also have an active "*containment*" program in order to address the many plumbing changes that are made and that are inherent within commercial and industrial establishments.

In essence, fixture outlet protection becomes an extension beyond the "*containment*" program.

Also, in order for the supplier of water to provide maximum protection of the water distribution system, consideration should be given to requiring the owner of a premise (commercial, industrial, or residential) to provide at his own expense, adequate proof that his internal water system complies with the local or state plumbing code(s).

In addition, he may be required to install, have tested, and maintain, all backflow protection devices that would be required - at his own expense!

The supplier of water should have the right of entry to determine degree of hazard and the existence of cross-connections in order to protect the potable water system. By so doing he can assess the overall nature of the facility and its potential impact on the water system (determine degree of hazard), personally see actual cross-connections that could contaminate the water system, and take appropriate action to insure the elimination of the cross-connection or the installation of required backflow devices.

To assist the water purveyor in the total administration of a cross-connection control program requires that all public health officials, plumbing inspectors, building managers, plumbing installers, and maintenance men participate and share in the responsibility to protect the public health and safety of individuals from cross-connections and contamination or pollution of the public water supply system.

A complete cross-connection control program requires a carefully planned and executed initial action plan followed by aggressive implementation and constant follow-up. Proper staffing and education of personnel is a requirement to insure that an effective program is achieved.

A recommended plan of action for a cross-connection control program should include the following characteristics:
(1) Establish a cross-connection control ordinance at the local level and have it approved by the water commissioners, town manager, etc., and ensure that it is adopted by the town or private water authority as a legally enforceable document.
(2) Conduct public informative meetings that define the proposed cross-connection control program, review the local cross-connection control ordinance, and answer all questions that may arise concerning the reason for the program, why and how the survey will be conducted, and the potential impact upon the industrial, commercial and residential water customers. Have state authorities and the local press and radio attend the meeting.
(3) Place written notices of the pending cross-connection control program in the local newspaper, and have the local radio station make announcements about the program as a public service notice.
(4) Send employees who will administer the program, to a course, or courses, on backflow tester certification, backflow survey courses, backflow device repair courses, etc.
(5) Equip the water authority with backflow device test kits.
(6) Conduct meeting(s) with the local plumbing inspection people, building inspectors, and licensed plumbers in the area who will be active in the inspection, installations and repair of backflow devices. Inform them of the intent of the program and the part that they can play in the successful implementation of the program.
(7) Prior to initiating a survey of the established commercial and industrial installations, prepare a list of these establishments from existing records, then prioritize the degree of hazard that they present to the water system, i.e., plating plants, hospitals, car wash facilities, industrial metal finishing and fabrication, mortuaries, etc.

These will be the initial facilities inspected for cross-connections and will be followed by less hazardous installations.
(8) Ensure that any new construction plans are reviewed by the water authority to assess the degree of hazard and ensure that the proper backflow preventer is installed concurrent with the potential degree of hazard that the facility presents.
(9) Establish a residential backflow protection program that will automatically ensure that a residential backflow device is installed automatically at every new residence.
(10) As water meters are repaired or replaced at residences, ensure that a residential backflow preventer is set with the new or reworked water meter. Be sure to have the owner address thermal expansion provisions.

Cross-connection Control Survey Work

(1) Prepare a listing of all testable backflow devices in the community and ensure that they are tested by certified test personnel at the time intervals consistent with the local cross-connection control ordinance.
(2) Prepare and submit testing documentation of backflow devices to the State authority responsible for monitoring this data.
(3) Survey all commercial and industrial facilities and require appropriate backflow protection based upon the containment philosophy and/or internal protection and fixture outlet protection.

Follow up to ensure that the recommended devices are installed and tested on both an initial basis and a periodic basis consistent with the cross-connection control ordinance.

The surveys should be conducted by personnel experienced in commercial and industrial processes. The owners or owner's representatives should be questioned as to what the water is being used for in the facility and what hazards the operations may present to the water system (both within the facility and to the water distribution system) in the event that a back-siphonage or backpressure condition were to exist concurrent with a non-protected cross-connection.

In the event that experienced survey personnel are not available within the water authority to conduct the survey, consideration should be given to having a consulting firm perform the survey on behalf of the water department.

Cross-connection control survey work should only be performed by personnel knowledgeable about commercial and industrial potential cross-connections as well as general industrial uses for both potable and process water.

If "*containment*" is the prime objective of the survey, then only sufficient time need be spent in the facility to determine the degree of hazard inherent within the facility or operation. Once this is determined, a judgment can be made by the cross-connection control inspector as to what type of backflow protective device will be needed at the potable supply entrance, or immediately downstream of the water meter.
In the event that the cross-connection control program requires "*total*" protection to the last

free flowing outlet, then the survey must be conducted in depth to visually inspect for all cross-connections within the facility and make recommendations and requirements for fixture outlet protective devices, internal protective devices, and containment devices.

It is recommended that consideration be given to the following objectives when performing a cross-connection control survey:

(1) Determine if the survey will be conducted with a pre-arranged appointment or unannounced.

(2) Upon entry, identify yourself and the purpose of the visitation and request to see the plant manager, owner, or maintenance supervisor in order to explain the purpose of the visit and why the cross-connection survey will be of benefit to him.

(3) Ask what processes are involved within the facility and for what purpose potable water is used, i.e., do the boilers have chemical additives? Are air conditioning cooling towers in use with chemical additives? Do they use water savers with chemical additives? Do they have a second source of water (raw water from wells, etc.) in addition to the potable water supply? Does the process water cross-connect with potentially hazardous chemical etching tanks, etc.?

(4) Request "*as-built*" engineering drawings of the potable water supply in order to trace out internal potable lines and potential areas of cross-connections.

(5) Initiate the survey by starting at the potable entrance supply (the water meter in most cases) and then proceed with the internal survey in the event that total internal protective devices and fixture outlet protective devices are desired.

(6) Survey the plant facilities with the objective of looking for cross-connections at all potable water outlets such as:

- **Hose bibbs**
- **Slop sinks**
- **Wash room facilities**
- **Cafeteria and kitchens**
- **Fire protection and Siamese**
- **outlets**
- **Irrigation outlets**
- **Boiler rooms**
- **Mechanical rooms**
- **Laundry facilities (hospitals)**
- **Production floor**

(7) Make a sketch of all areas requiring backflow protection devices.

(8) Review with the host what you have found and explain the findings to him.

Inform him that he will receive a written report documenting the findings together with a written recommendation for corrective action. Attempt to answer all questions at this time. Review the findings with the owner or manager if time and circumstances permit.

(9) Document all findings and recommendations prior to preparing the written report. Include as many sketches with the final report as possible and specifically state the size and generic type of backflow preventer required at each cross-connection found.

Developing a Cross-Connection Control Program

Introduction
Establishing a cross connection control program for a small water utility can be a daunting task. The responsibility of creating and implementing the program will often fall on the operator, who will most likely be responsible for water, sewer, roads, parks and other public work projects as well.

This can seem overwhelming, but with an organized approach an effective program can be established.

What is a Cross-Connection?
Before anyone can start a cross connection program, he or she must understand what cross connections are, why they are dangerous, and how they can be corrected. Therefore, the first step must be education. The approach to learning about cross connection control will vary depending on time and funding constraints.

The best approach will be to attend a training course that is specifically designed to teach cross connection control practices for public water systems. If this is not possible, then the operator will have to pursue other avenues. Some agencies and organizations offer training courses that include sessions on cross connection control for little or no cost. Some areas have committees, associations or other groups dedicated to cross connection control.

These groups can be a great source of information and networking. Many cross connection control publications and videos are available. It is also advisable for the operator to contact neighboring water utilities for information on their cross connection control programs.

Legal Authority
Once the operator has a good understanding of cross connection control, the next task will be to prepare a written document that will establish legal authority for the program. This may be in the form of an ordinance, resolution, by-law, etc., depending on the organization of the water system.

This document will define the utility's cross connection control requirements, such as what circumstances will require the installation of a backflow preventer; who will be responsible for the installation, testing and maintenance costs; program enforcement; approval of backflow preventors and installation requirements.

This document must avoid conflicts with other agencies. It is important to consider the requirements of local building, plumbing and fire codes in addition to Health Services requirements. It is useful to obtain copies of ordinances from nearby utilities and consider their requirements. It is preferable for utilities to have similar requirements when possible. This will minimize confusion for those who work in several districts and are expected to be familiar with local requirements, such as backflow assembly testers, plumbers and vendors. It will also help avoid critical comparisons between utilities.

"The Board"
A cross connection ordinance will be useless without the approval of the board of directors or city council.

This fact can present problems of its own. As is often the case, the operator will be given the responsibility of running a cross connection control program but will not have the authority to create and enforce the ordinance. For this reason, it is extremely important to have the support of the board.

Board members must be educated about cross connection control. They need to understand the hazards cross connections present to the safety of the water supply, and the liability they are vulnerable to in the event of a backflow incident. Once they understand the importance of a cross connection control program, they can be strong allies in adopting an effective ordinance and implementing the program.

Organize the Program
Once an ordinance has been adopted, it must be implemented. This requires an organized approach. The responsibilities of each person involved in the program must be clearly defined; a system for coordinating with other agencies must be developed; a plan to educate the public must be in place; an efficient system for keeping records is critical; and various form letters and notices will need to be developed.

Work Responsibilities
It is important to identify who is responsible for each element in the cross connection control program. Who will determine when a backflow preventer is required? Who will prioritize installations? Who will verify the correct installation of the backflow preventer? Who will test backflow preventors?

Who will send out letters and notices? Who will track the testing and maintenance of the backflow preventors in the system? Who will respond to customer inquiries and complaints? These are all questions that need to be answered before the program is presented to the customers.

Agency Coordination
Working with other agencies can be a great benefit to the cross connection control program. The local building department plan review process can be a useful tool. If an agreement can be made to include the water utility in the plan review process, any needed backflow preventors can be included in the planning stage. A good relationship with local plumbing inspectors can be a great benefit to the program. They can serve as extra eyes to spot any variations from building plans that might create a need for backflow prevention. Working with fire officials is extremely important. The installation of backflow preventors on fire lines will increase the pressure loss, and this needs to be considered in the system design. Good working relationships with these officials will eliminate the headache of retrofitting a new building, and the bad publicity that follows a lack of coordination between agencies.

Public Education

Public education is an important aspect of cross connection control that is too often overlooked or minimized. This can have disastrous consequences. If a customer receives a notice to install a backflow preventer with no explanation, they will often have a negative response. It is important to educate the customers to the dangers of cross connections and the importance of installing backflow preventors when needed.

It is also very important to explain the program priorities so the customers don't feel singled out. If one customer is notified to install a backflow preventer and their neighbor isn't, they will want to know why. It is better for the utility to answer these questions with public education, rather than leave the customers wondering, or worse yet, doubting the sensibility of the cross connection control program. Most customers will be willing to support the cross connection control program when they understand that the safety of their drinking water is at stake.

Record-keeping, Forms and Notices

An active cross connection control program will generate information that must be organized and tracked. It is important to give careful consideration to record keeping methods before information begins to accumulate.

Once information is stored, changing the format becomes quite difficult. A system needs to be in place for notifying customers when backflow preventors must be installed, tested or repaired, and for tracking the responses. Backflow preventors must be tested regularly, so a system of tracking due dates is needed in order to send notices on time.

Certain letters will be sent out frequently, so it is helpful to have a standard form prepared for these occasions. Cross connection software is available to assist with this aspect of the program. The software is available in a wide range of prices and capabilities.

Cross-Connection Program Implementation

Once these preparations have been completed, the cross connection control program is ready for implementation. Public education can be initiated to gain customer support for the program.

The operator will be ready to identify cross connection hazards in the system and begin the process of eliminating or isolating them. As the program begins to function, the utility will be prepared to handle the paper flow and phone calls that are generated.

Summary

Creating an effective cross connection control program is an important and challenging responsibility. An organized approach in the beginning will help avoid many problems and conflicts once the program begins to function. Once the program is established, the utility can take pride in the knowledge that they are taking an active role in protecting the public water supply from potentially life-threatening contamination.

What is Backsiphonage?

Backsiphonage is backflow caused by a negative pressure (i.e., a vacuum or partial vacuum) in a public water system or consumer's potable water system. The effect is similar to drinking water through a straw. Backsiphonage can occur when there is a stoppage of water supply due to nearby fire fighting, a break in a water main, etc.

Water Quality Inspector-Backflow Unit Program Duty *Example*

The technical and administrative demands for a Backflow Prevention Program are extensive for a water system the size of the City of Sunflower. These responsibilities cannot be met merely by delegating additional duties among existing staff and field personnel. Personnel possessing the appropriate administrative, technical and clerical skills need to be organized as a "*Backflow Prevention Unit*" to form the nucleus for such a program.

General Duties - Responsible for the enforcement of the City's Backflow Prevention Program and policy that include: system review, determining new service and retrofit replacements; field investigation and correction of backflow occurrences; and the review of testing and repair reports to ensure compliance.

Specific Duties:

(1) Conduct surveys of commercial and industrial water users to determine backflow prevention compliance.

(2) Meet with affected business groups to explain and promote the City's backflow prevention objectives.

(3) Act as Department representatives involving various requests regarding backflow prevention requirements.

(4) Review test report forms of backflow prevention devices.

(5) Investigate reported incidents of cross-connections or backflow problems.

(6) Perform quality assurance tests on backflow prevention assemblies repaired by certified general testers.

(7) Establish and update maintenance history files of backflow prevention assemblies.

(8) Monitor and track progress of retrofit requirements placed on individual commercial and industrial users.

(9) Remain current with backflow technology in order to answer general and technical inquiries about backflow prevention requirements.

(10) Maintain General Tester certification.

Evaluation of Hazard Policy *Example*

The Department shall evaluate potential hazard to the public water supply which may be created as a result of a condition on a user's premises. However, the Department shall not be responsible for abatement of cross-connection that may exist within the user's premises.

This evaluation shall give particular consideration to the premises that involve the following type of situations of water uses:

(1) Premises where substances harmful to health are handled under pressure.
(2) Premises that boost the pressure of water delivered by the public water system.
(3) Premises which could expose the public water system to backflow.
(4) Premises having an auxiliary water supply.
(5) Premises where water from the public water system, under normal circumstances, could develop a polluted water source.
(6) Premises where entry for investigation or information regarding water use is restricted.
(7) Premises that contain a degree of piping system complexity and the potential for routine system modification.

1. Hazard Types
The type and degree of hazard potential to the public potable water supply and system from a customer's water supply system shall be determined using the following hazard factors:

a. **Plumbing Hazard** - an actual or potential plumbing type cross-connection that is not properly protected by an approved backflow prevention method.

b. **System Hazard** - an actual or potential threat that may cause severe damage to the physical facilities of the public water supply system or that may have a protracted effect on the quality of the water in the system.

2. Degree of Hazard

a. **Pollution** - (non-health) an actual or potential threat to the physical facilities of the public water supply system or to the public water supply that, although not dangerous to health, would constitute a nuisance or be aesthetically objectionable, or could cause damage to the system or its appurtenances.

b. **Contamination** - (health) any condition, device or practice that, in the judgment of the Department, may create a danger to the health and well-being of the public water users.

Backflow Requirements *Example*
TABLE 7.1

Facilities or Activities Requiring Backflow Assembly

The following criteria will be used to determine the backflow prevention requirements for all service connections:

1. Specified Facilities or Activities

When any of the following activities are conducted on premises served by the public potable water system, a potential hazard to the public potable water supply shall be presumed and a backflow prevention method, of the type specified for that activity herein, must be utilized or installed at the service connection for that premise.

(1) Aircraft and missile plants: RP
(2) Animal clinics and animal grooming shops: RP
(3) Any premises where a cross-connection is maintained: RP
(4) Automotive repair with steam cleaner, acid cleaning equipment, or solvent facilities: RP
(5) Auxiliary water system: RP
(6) Bottling plants, beverage or chemical: RP
(7) Breweries: RP
(8) Buildings with house pumps and/or potable water storage tank: RP
(9) Buildings with landscape fountains, ponds, or baptismal tanks: Air Gap or RP
(10) Building with sewage ejector: Air Gap or RP
(11) Canneries, packing houses, and reduction plants: RP
(12) Car wash facilities: RP
(13) Centralized heating and air conditioning plants: RP
(14) Chemical plants: RP
(15) Chemically treated potable or nonpotable water system: RP
(16) Civil works (government owned or operated facilities not open for inspection by the Department): RP
(17) Commercial laundries: RP
(18) Dairies and cold storage plants: RP
(19) Dye works: RP
(20) Film processing laboratories: RP
(21) Fire system-American Water Works Association Classes 1, 2. Any system constructed of a piping material not approved as a potable water system material per the Uniform Plumbing Code as adopted by the City: DC
(22) Fire system-American Water Work Association Classes 3, 4, 5, 6: RP
(23) Food processing plants: RP
(24) High schools, trade schools and colleges: RP
(25) Holding tank disposal stations: RP
(26) Hospitals and mortuaries: RP

(27) Irrigation systems (not to include single family detached residences):
   a. Premises having separate systems used in elevated areas: RP
   b. Premises having nonpotable water piping (lawn sprinklers) two (2) inches and smaller: PVB
(28) Laboratories using toxic materials: RP
(29) Manufacturing, processing, and fabricating plants: RP
(30) Medical and dental buildings, sanitariums, rest and convalescent homes engaged in diagnosis, care or treatment of human illness: RP
(31) Motion picture studios: RP
(32) Multiple Services Interconnected: RP or DC
(33) Multiple Use Facilities/activities - When two or more of the activities listed above are conducted on the same premises and served by the same service connection, the most restrictive backflow prevention method required for any of the activities conducted on the premises shall be required at the service connection. The order of the most restrictive to least restrictive backflow prevention method shall be as follows:
   (A) Air Gap (most restrictive)
   (B) Reduced Pressure Principle Assembly (RP)
   (C) Pressure vacuum Breaker Assembly (PVB)
   (D) Double Check Valve Assembly (DC) (least restrictive)
(34) Oil and gas production plants: RP
(35) Paper and paper production plants: RP
(36) Plating plants: RP
(37) Portable insecticide and herbicide spray tanks: Air Gap or RP
(38) Power plants: RP
(39) Radioactive materials processing facilities: RP
(40) Recreational vehicle parks, trailer parks (seasonal): RP (41) Restricted, classified, or other closed facilities: RP
(42) Rubber plants: RP
(43) Sand and gravel plants: RP
(44) Sewage and storm drainage facilities: Air Gap or RP
(45) Street sweepers, steel wheeled rollers: Air Gap or RP
(46) Temporary Services-Construction water: Air Gap or RP
(47) Water trucks, water tanks or hydraulic sewer cleaning equipment: Air Gap or RP

2. Non-Specified Facilities or Activities

The Department shall determine backflow prevention requirements for all other facilities or activities not specified herein. This determination will be on a case by case basis and shall require the consumer to comply with all other provisions within the policy.

3. Private Fire Hydrants

When a single fire service connection provides service solely to privately owned fire hydrants upon a premise no protection is required provided: 1) The fire system is designed, furnished, installed and tested in conformance with current department specifications. 2) The entire route of the service pipe shall constantly remain visible from the point of connection.

Installation Requirements *Example*

1. **General Requirements:**

(a) Backflow prevention assemblies shall be installed by the user, at the user's expense, in compliance with the standards and specifications adopted by the City, at the service connection. The assembly or assemblies shall be sized equivalent to the diameter of the service connection.

(b) All assemblies shall be installed in a manner as to be readily accessible for testing and maintenance. It will be located as close as practicable to the point of service delivery. A reduced pressure principle assembly, a double check valve assembly and a pressure vacuum breaker assembly shall be installed above ground. With the Department's approval, a double check valve assembly may be installed in below ground vault.

(c) An air-gap separation shall be located as close as practicable to the user's point of service delivery. All piping between the user's connection and receiving tank shall be entirely visible unless otherwise approved by the City.

(d) It shall be unlawful, and punishable as a misdemeanor, for any person to bypass or remove a backflow prevention method without the approval of the City.

(e) **Fire Protection Systems -** the user shall make proper application to the Fire Department for a permit prior to installation of an assembly on an existing fire system.

2. **Continuous Water Supply**

(a) **Domestic or Building Supply Systems** - when a customer desires a continuous water supply during testing and repairs, two or more backflow prevention assemblies shall be installed parallel to one another at the service connection to allow a continuous water supply during testing of the backflow prevention assemblies.

(b) **Fire Protection Systems -** where it is determined by the Sunflower Fire Department that a fire sprinkler system shall have a continuous water supply that may not be interrupted during testing and maintenance of the backflow prevention assembly, the user shall install two backflow prevention assemblies parallel to one another at the service connection.

The diameter of each assembly shall be as approved by the Fire Department.

Testing Frequency

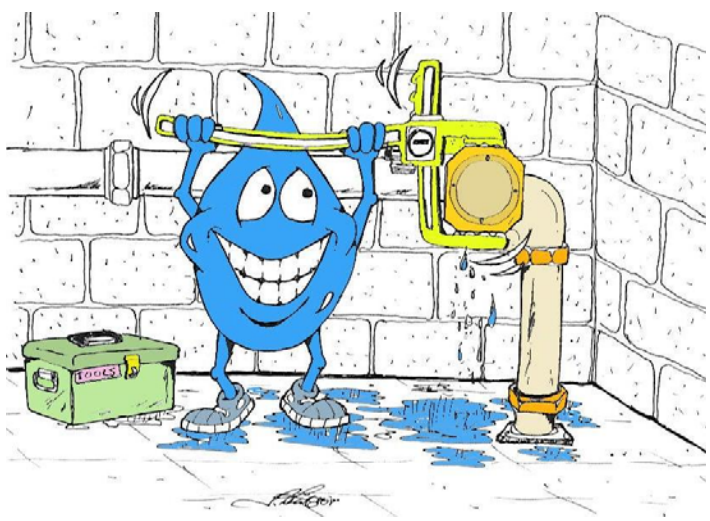
1. **General Requirements:**

(a) The user shall test backflow prevention assemblies at least once a year. Affected user will be notified of the testing due date. If the test reveals the assembly to be defective or in unsatisfactory operating condition, the user shall perform any necessary repairs, including replacement of the assembly if necessary, which will return the assembly to satisfactory operating condition.
(b) As a condition of water service, the user is responsible for the effective operating condition of the backflow prevention assembly at all times.
(c) All expenses associated with the annual testing and maintenance of backflow prevention assemblies shall be the responsibility of the user.
(d) The Department reserves the right to require more testing.

Qualified Certified General Testers List *Policy Example*

The purpose of this list is to identify qualified general testers for user/customer to contact and hire for backflow assembly testing.

(a) The Department may recognize other agencies or organizations involved with the training and certification of testers.
(b) It is the responsibility of the certified general tester to submit accurate and current certification to the Backflow Unit of the Water Quality Division. A list of certified general testers will be maintained by the Department and made available upon request to all users required to install or maintain a backflow prevention assembly.
(c) The Department may disqualify a tester, at any time, without warning, for any malfeasance or misrepresentation.



Compliance Program *Example*

1. New Service Connections

(a) An approved backflow prevention assembly shall be installed and maintained at every service connection to a user's water system when the Department determines that the water supplied by the public water system may be subject to contamination, pollution or other deterioration in sanitary quality by conditions within the user's water system.

(b) The backflow prevention method to be utilized shall be determined by the Department. The method shall be sufficient to protect against the potential hazard, as determined by the Department, to the public water supply.

2. Existing Service Connections

(a) The provision herein shall apply to all new water customers and all water customers existing prior to enactment date of this policy.

(b) Backflow prevention assemblies installed prior to enactment of this policy that do not comply with these requirements shall be replaced at the user's expense with assemblies that comply with the standards set forth herein.

(c) All existing water service connections will be subject to a survey by the Water and Wastewater Department to identify water user premises where service protection is required. The selection of service connections to be surveyed will be determined by the Department and based on suspected hazards. A letter of notification will be sent to all users identified to install, upgrade, or utilize a backflow prevention assembly. The user shall have no more than twelve (12) months from the date of notification to comply with requirements set forth in this policy.

(d) A water user survey will automatically be initiated should a user apply for a building permit to install or modify existing plumbing. This investigation may be performed by the Development Services Department in conjunction with the plan review or the permit application process. The issuance of a building permit requiring that a backflow prevention assembly be installed, upgraded, or utilized shall constitute written notice and shall hold the user responsible to the provisions set forth in this policy.

(e) A permit from the Fire Department, Division of Fire Prevention, shall be secured prior to issuance of a Building Permit for any retrofit application.

Failure to Comply

1. **Notice of Violation**

(a) Prior to disconnecting any water service, the Department shall make written notification to the user describing the violation and give notice that the condition must be remedied within forty-five (45) days. If such condition is not remedied within (45) days, the Department shall send a second notice, by certified mail, notifying the user that water service will be discontinued in fifteen (15) days if the condition is not remedied within such time period.

2. **Discontinuance of Water Service *Example***

(a) If the customer within the time specified in this section:

- fails to install a required backflow prevention assembly; or
- fails to properly test; or
- fails to properly maintain a backflow device; or
- bypasses or removes a backflow device; or
- fails to submit records of tests and repair of a backflow device; or
- has an identified unprotected cross-connection existing in the user's water system; then water service to that service connection shall be discontinued. Their service shall not be restored until the condition is remedied. See Appendix I - Section IV.

(b) Water services to a fire protection system shall not be subject to disconnection under this section. If the situation is not remedied within the time specified to the user, the user may be issued a citation for a misdemeanor offense. Each day the situation is allowed to continue thereafter shall constitute a separate violation of this section.
(c) The Department shall disconnect, without notice, water service to any customer when the Department discovers or determines that the customer's water system is contaminating the public water supply.

3. **Citations *Example***

(a) If a situation, which would otherwise result in discontinuance of water service in section (2), subsection (b) above, is not remedied within the time provided in the notice sent to the customer, the customer may be issued a citation for a misdemeanor offense. Each day the situation is allowed to continue, thereafter, shall constitute a separate violation of this section.
(b) If a customer commits a deliberate act to fraud, misrepresent, falsify or act in an unauthorized capacity in violation of this policy relating to falsification of records, the deliberate bypass of a backflow prevention device, the illegal restoration of a service or the willful withholding or concealing of information or activity for the purpose of avoiding service protection requirements, a citation for a misdemeanor offense may be issued for each separate violation of this policy. See Appendix I - Section V.

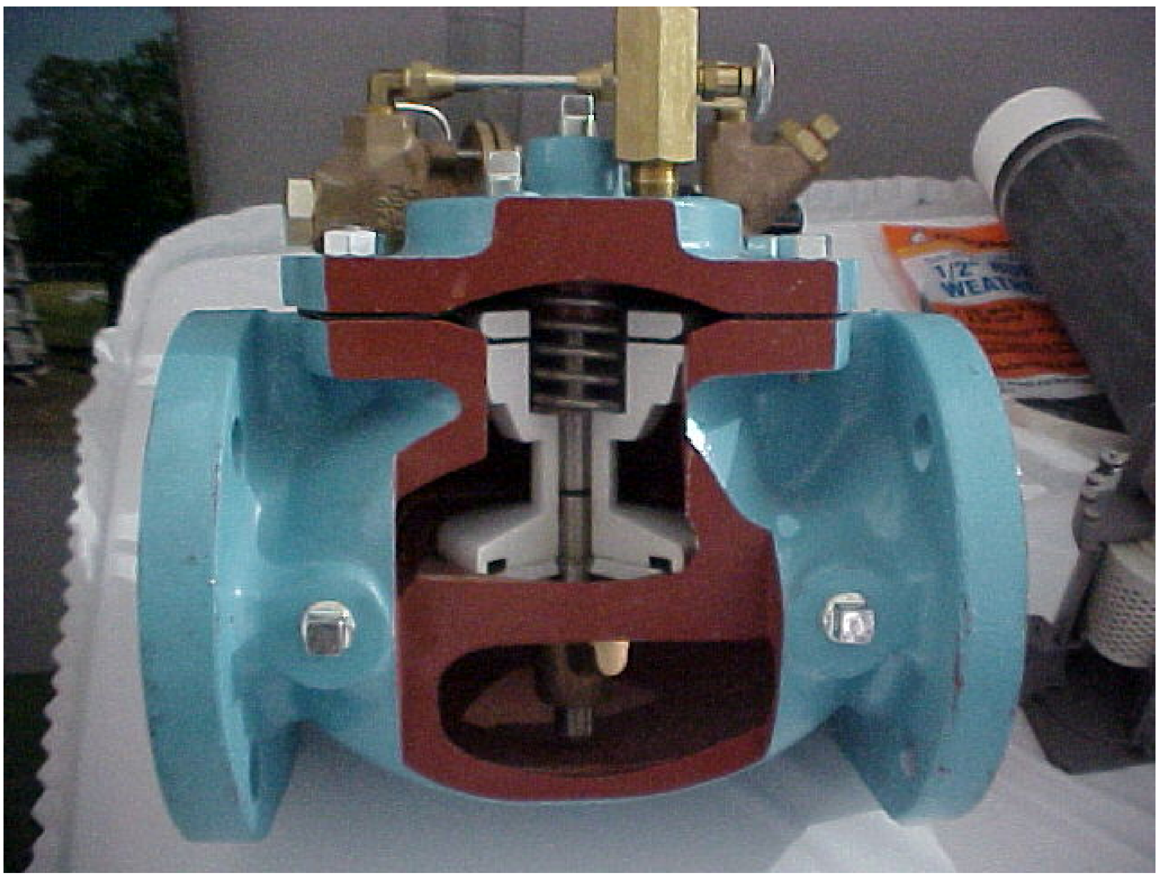
Records Requirements *Policy Example*

(a) The user/customer shall submit on forms approved by the Department, results of all tests, repairs to, or replacement of backflow prevention assemblies.

(b) Submitted records shall be completed and signed by a certified general tester.

(c) The user/customer shall be responsible for prompt submission of records to the Department after completion of the activity for which the record is made. Failure to submit records within the time frames established by the Department shall constitute a violation of this policy. Refer to Section VI.E., Failure to Comply, for more details.

(d) It is recommended records be kept by the user and tester for at least three (3) years.



Here is an example of a PRV Valve, which is not a backflow preventer, but a Pressure Regulation Valve, common in the water distribution system.

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

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

Incident Response Plan *Example*

1. **Introduction**

This is a reference document to be used in incident and emergency incident response situations affecting public drinking water supplies. Although every effort has been made to make this document as complete as possible, the user must recognize that not every situation can be anticipated. The responder may be called upon to use their best judgment in a given situation.

(a) **Incident Response *Example***

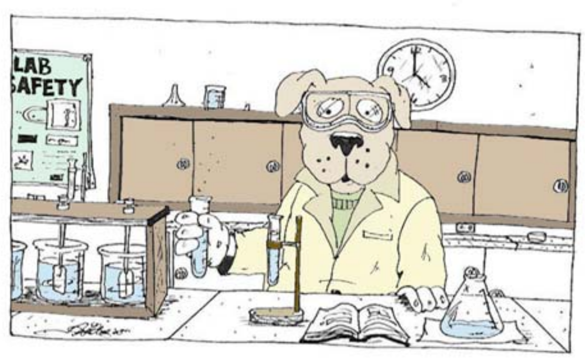
A customer complaint is usually handled by contacting Customer Services, 262-6215 between 8:00 a.m. and 5:30 p.m. on weekdays and Water Distribution, 261-8000 after 5:30 p.m. and on weekends. If the complaint concerns system problems (pressure, leaks) the complaint is referred to the Water Distribution Division.

If the complaint is in reference to the quality of the water (taste, odor, color), the complaint is referred to the Water Quality Division, Water Monitoring Unit.

The Water Monitoring Unit will perform a phone interview to determine the seriousness and magnitude of the water quality problem. If it is felt that the situation warrants, a member of the Water Monitoring Unit will visit the site to perform an inspection and sample the water at the site.

The samples will be delivered to the Water Quality Laboratory for analysis. If the inspector suspects the water has been contaminated by an outside source through a possible cross-connection, the Backflow Prevention Unit will be notified.

Upon notification of a possible backflow incident, the Backflow Prevention Unit will visit the site, perform an inspection of the premise for possible cross-connections, and evaluate the water use within the premises. A determination of the proper backflow protection will be made and notification to install the assembly may be issued.



The water may be turned off at the service connection if it is determined that the user's water system is contaminating the public water system.

The appropriate Customer Services Area Field Supervisor will be notified of the water being turned off. Also notify Customer Services that the water was turned off.

Emergency Incident Response *Example*

An emergency incident response to a possible backflow situation would be triggered if it involved a health hazard concerning the potable water system. Notification of such an incident could come from the Health Department directly to the Water Quality Division or from 911. The 911 dispatcher then notifies the City Operator that there is an incident involving the water distribution system, who in turn notifies the Water Distribution 24 hour Emergency Dispatcher.

This dispatcher then notifies the Water Distribution Superintendent, the Water Quality Superintendent and the Water and Wastewater Information Officer. The Water Distribution Superintendent notifies and dispatches the appropriate crews to isolate, flush, or neutralize the contamination. The Water Quality Superintendent will notify the Chief Water Quality Inspector who will then dispatch the Water Monitoring Unit and/or the Backflow Prevention Unit to perform their duties as described in the incident response section. The Water Quality Lab would submit a written report to the Water and Wastewater Information Officer who would handle all media contact. See Appendix I - Section VI.

2. **Reports and Records *Example***

(a) Customer

In the event the customer's water system or the public water system is contaminated or polluted due to a cross-connection or other cause, and the customer has knowledge of such an event, the Department shall be promptly notified by the customer so that the appropriate measures may be taken to overcome the contamination. The customer shall submit a written incident report within 72 hours of first knowledge of the event. ***The report shall address all of the following:***

1. Date and time of discovery;
2. Nature of the problem;
3. Affected area;
4. Cause of the problem;
5. Public health impact;
6. Corrective action taken;
7. Date of completion of corrective actions.

(b) Water Purveyor

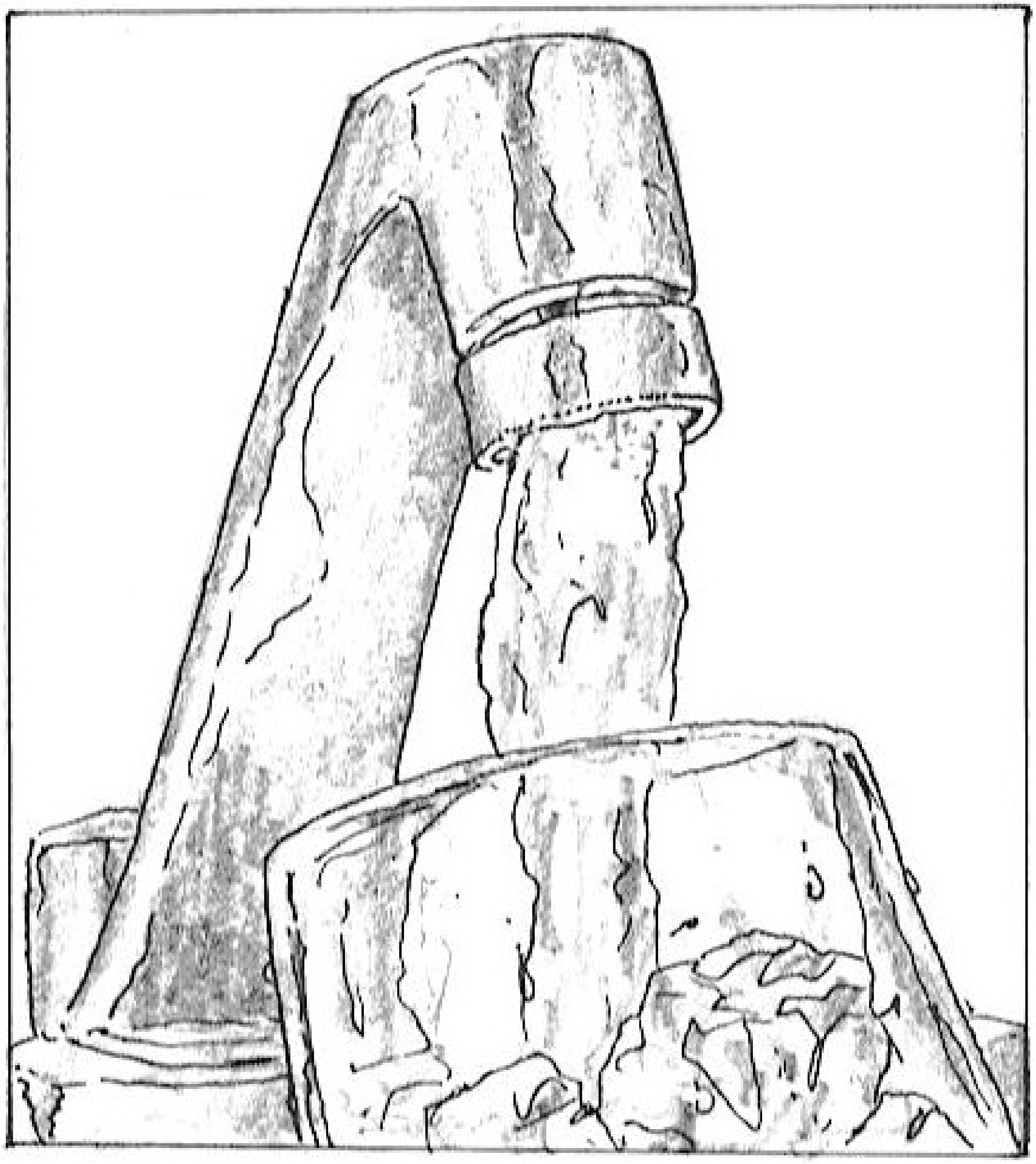
The water purveyor shall submit a written cross-connection incident report within five business days to the Department of Environmental Quality or equivalent agency and the local health authority whenever a cross-connection problem has occurred which resulted in contamination of the public water system.

The report shall address all of the following:

1. Date and time of discovery of the unprotected cross-connection;
2. Nature of the cross-connection problem;
3. Affected area;
4. Cause of the cross-connection problem;
5. Public health impacts;
6. Dates and text of any public health advisories issued;
7. Corrective actions taken; and
8. Date of completion of corrective actions.

Accurate records and reports must be written and maintained because unfortunately the end result of a backflow incident will probably be a court case, and the damages ensuing may be partly the water purveyor's responsibility.

Looking inside a Check Valve.
This is not a backflow prevention assembly! I've hurt a lot of salesmen's feelings on this issue. A check valve is a device not an assembly.



Sources of Pollution

Sources of pollution which may result in a danger to health are not always obvious and such cross-connections are certainly not usually intentional. They are usually the result of oversight or a non-professional installation. As source examples, within a business environment the pollutant source may involve the unintentional cross-connection of internal or external piping with chemical processes or a heating boiler. In a residential environment the pollutant source may be an improper cross-connection with a landscape sprinkler system or reserve tank fire protection system. Or, a situation as simple as leaving a garden hose nozzle submerged in a bucket of liquid or attached to a chemical sprayer.

HOMELAND SECURITY INFORMATION UPDATE

Suggested Guidance on Protective Measures

Information Bulletin 03-002
February 7, 2003

National Threat Warning System–Homeland Security Information Update–HSAS Threat Level Orange (**High**); joint guidance from the Department of Homeland Security and the FBI.

As recipients were advised, the Homeland Security Advisory System (**HSAS**) was raised to High (**Orange**) from Elevated (**Yellow**) on 2/7/03. This communication provides critical infrastructure owners/operators suggested guidance for developing protective measures based on this heightened threat condition. This communication also provides potential indicators of threats involving weapons of mass destruction.

PART I: GENERAL PROTECTIVE MEASURES

In addition to continuing all precautions from the lower threat condition (**Yellow**), the following general protective measures may be utilized. Recipients are advised to take other appropriate steps, in conjunction with local conditions, policies, and procedures. The list that follows is not intended to be exhaustive, but merely illustrative:

-- coordinate necessary security efforts with Armed Forces or law enforcement agencies.

-- take additional precautions at public events.

-- review contingency plans to work at an alternate site or with a dispersed work force.

-- review plans to restrict access to facilities.

PART II: SPECIFIC PROTECTIVE MEASURES FOR INFRASTRUCTURE OWNERS/OPERATORS AT HIGH CONDITION (ORANGE)

-- announce threat condition high (orange) to all employees.

-- consider full or partial activation of emergency operations center.

-- review policy and plans relating to restricting access to critical facilities and infrastructure.

-- conduct periodic inspections of building facilities and HVAC systems for potential indicators/irregularities.

-- direct people to the Red Cross website for further review of protective measures for families and businesses.

-- enhance security at critical facilities.

-- institute/increase vehicle, foot and roving security patrols.

-- implement random security guard shift changes.

-- increase visibility in and around perimeters by increasing lighting and removing or trimming vegetation.

-- implement stringent identification procedures to include conducting “hands on” checks of security badges for all personnel, if badges are required.

-- remind personnel to properly display badges, if applicable, and enforce visibility.

-- rearrange exterior vehicle barriers to alter traffic patterns near facilities.

-- arrange for law enforcement vehicles to be parked randomly near entrances and exits.

-- approach all illegally parked vehicles in and around facilities, question drivers and direct them to move immediately. If the owner can not be identified, have vehicle towed by law enforcement.

-- if possible, institute a vehicle inspection program to include checking under the undercarriage of vehicles, under the hood, and in the trunk. Provide vehicle inspection training to security personnel.

-- instruct citizens to report suspicious activities, packages and people, and report all suspicious activity immediately to local law enforcement.

-- x-ray packages, if possible, prior to entry, and inspect handbags, and briefcases, if possible.

-- encourage personnel to avoid routines, vary times and routes, and pre-plan with family members and supervisors.

-- validate vendor lists for all routine deliveries and repair services.

-- restrict vehicle parking close to buildings.

-- inspect all deliveries and consider accepting shipments only at offsite locations.

-- require identification, sign-in, and escorts for visitors.

-- instruct people to be especially watchful for suspicious or unattended packages and articles either delivered or received through the mail.

-- send a public information officer to the state joint information center.

-- install special locking devices on manhole covers in and around critical infrastructure facilities.

-- initiate a system to enhance mail and package screening procedures (both announced and unannounced).

-- review current contingency plans and if not already in place, develop and implement procedures for receiving and acting on: threat information, alert notification procedures, terrorist incident response procedures, evacuation procedures, shelter in place procedures, bomb threat procedures, hostage and barricade procedures, chemical, biological, radiological and nuclear (**CBRN**) procedures, consequence and crisis management procedures, accountability procedures and media procedures.

PART III: POTENTIAL INDICATORS OF THREATS INVOLVING WEAPONS OF MASS DESTRUCTION (WMD)

POTENTIAL INDICATORS OF WMD THREATS OR INCIDENTS:

-- unusual/suspicious packages or containers, especially those found in unlikely or sensitive locations, such as those found near air intake/HVAC systems or enclosed spaces.

-- unusual powders or liquids/droplets/mists/clouds, especially found near air intake/HVAC systems or enclosed spaces.

-- signs of tampering or break-in to a facility or maintenance/utility area

-- reports of suspicious person(s) or activities, especially those involving sensitive locations within or around a building

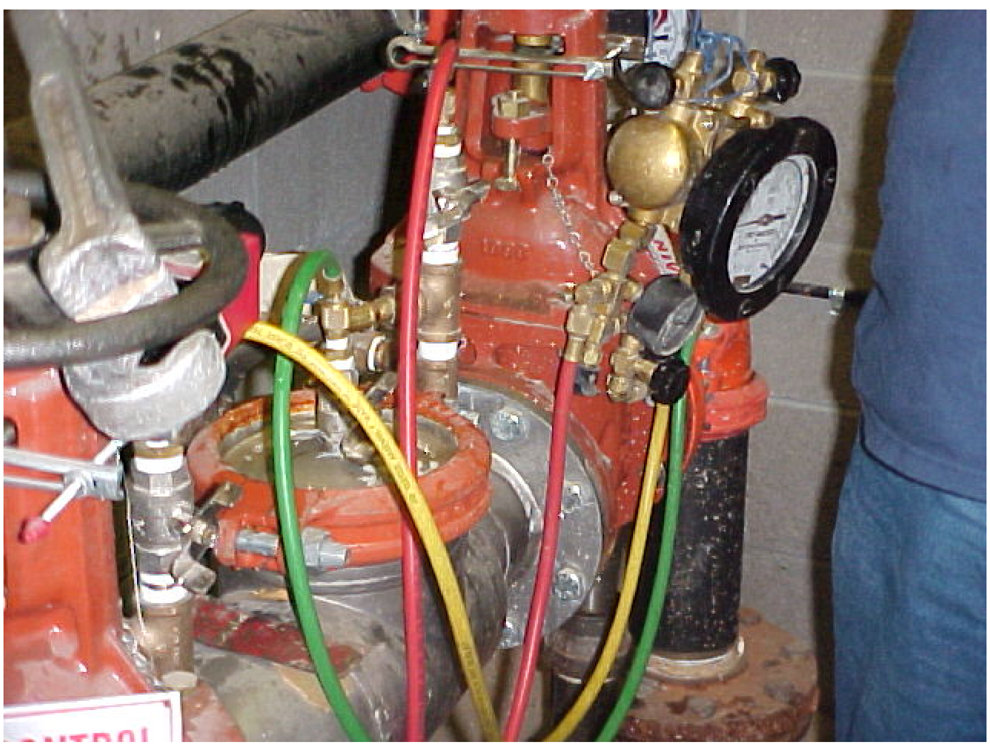
-- dead animals/birds, fish, or insects

-- unexplained/unusual odors. Smells may range from fruity/flowery to sharp/pungent, garlic/horseradish-like, bitter almonds, peach kernels, and new mown grass/hay.

-- unusual/unscheduled spraying or discovery of spray devices or bottles

The NIPC encourages individuals to report information concerning suspicious activity to their local FBI Joint Terrorism Task Force (**JTTF**) office, http://www.fbi.gov/contact/fo/fo.htm, the NIPC, or to other appropriate authorities. Individuals can reach the **NIPC WATCH AND WARNING UNIT** at (202) 323-3205, tol1 free at-1-888-585-9078 or by email to nipc.watch@fbi.gov.

A Certified Tester is testing the integrity of this RP. Notice OS &Y.

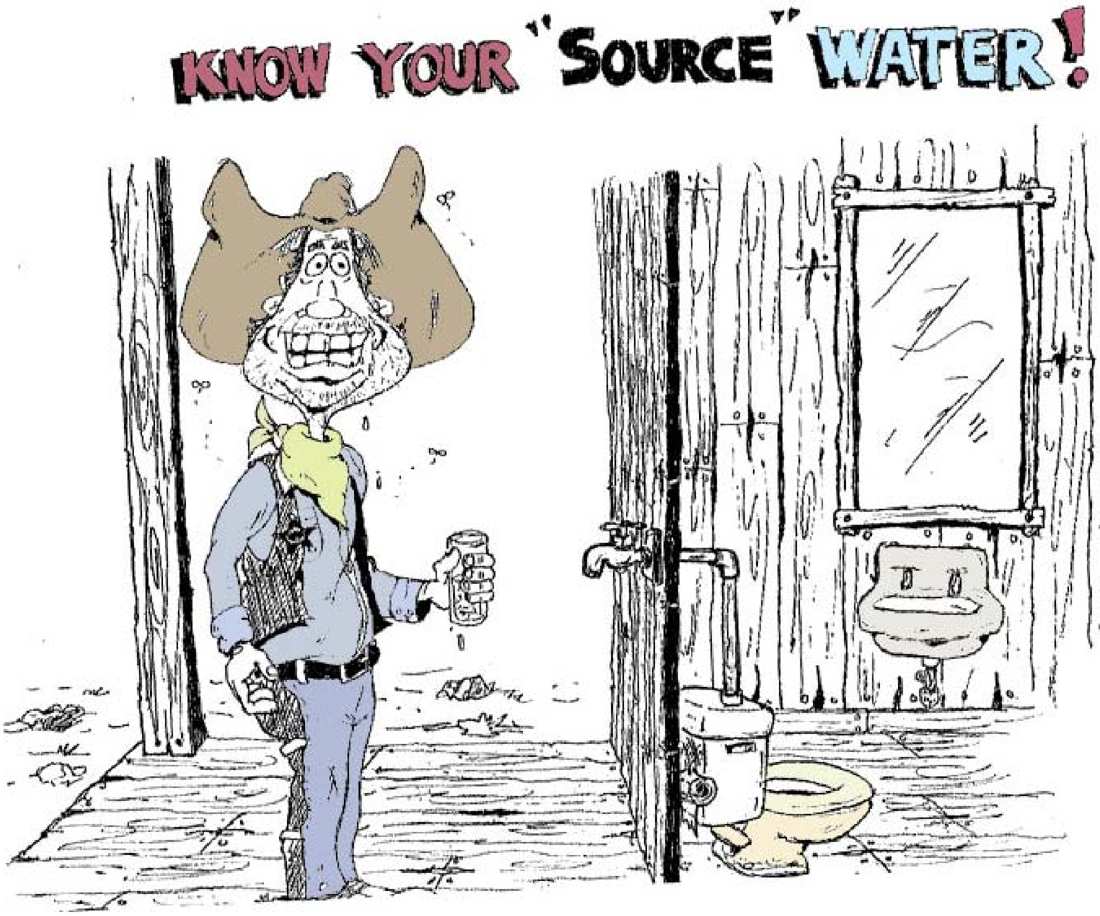


Above, this is an Ames Silver Bullet RP on a fireline.

Notification Letters/Forms Examples and Related Documents

Example of frost protection.
I've seen everything from a fake rock to a fake statue. This frost protection and assembly protection stuff has grown into a full blown industry. There are people that only install protective devices and don't even test the assembly because they have too much work.

The following are several examples of backflow related letters and notices.



April 30, 2015

ABC Company
12345 North Beeline Highway
Sunflower, Arizona 85547

Dear Wyatt Curtiss:

Example of a regulatory letter

In order to protect the public water supply from contamination, State and local regulations require approved backflow prevention assemblies for your water service lines. These assemblies, which should be located on your domestic, fire sprinkler and/or landscape water supply lines, are due for an annual operation test. This test must be performed by a backflow prevention assembly tester who possesses a valid certification. A list of certified testers recognized by the Sunflower Water Department has been enclosed to assist you in selecting a qualified contractor.

Prices charged for installation, testing and/or repair of assemblies can vary widely between contractors. So, for your own protection, carefully check service costs and qualifications before employing a contractor for your assemblies. Generally, testing costs range from approximately $35-50 per assembly. If needed, repairs are usually an additional expense.

You are responsible for submitting test results for your assemblies *on the proper form* to the Town of Sunflower Water Department no later than June 07, 2005. Test forms and information packages are available at no charge from the Town of Sunflower Water Department located at 303A North Beeline Highway.

If you have any questions about the testing requirements, or need additional information, please contact me at (520) 474-5242, Ext. 235 or Michael Ploughe at Ext. 284.

Sincerely,

Jim Bevan
Water Resources Specialist

< DATE > <CERTIFIED MAIL>

< CONTACT > OR
< TITLE >
< COMPANY NAME> <HAND DELIVERED TO:>
< STREET ADDRESS >
< CITY AND STATE AND ZIP >

REMINDER NOTICE

Annual Testing Requirement Example

Dear------------------------:

In reviewing our files, we have been unable to find this year's test results for your backflow device(s) (see attached).

City Ordinances G3672 / G3674 require yearly testing of all containment backflow devices. These Ordinances also require reporting the results to:

City of Sunflower
Pollution Control Division
Backflow Prevention Unit
2303 West Beeline Street
Sunflower, AZ 85009

We are notifying each customer at least 30 days in advance of their yearly test date. If we have missed notifying you previously, please accept this letter as that notification. If you have forgotten to test or mail the test results, please consider this letter a reminder. We appreciate your continued co-operation.

Should you have any questions please contact me at (602) 534-2140. Our office hours are 8:00 a.m. to 5:00 p.m., Monday through Friday.

Sincerely,

Scott Stratton
Senior Water Quality Inspector
Backflow Prevention Unit

Enclosure

< DATE > <CERTIFIED MAIL>

< CONTACT > OR
< TITLE >
< COMPANY NAME> <HAND DELIVERED TO:>
< STREET ADDRESS >
< CITY AND STATE AND ZIP >

NOTICE OF FAILURE TO COMPLY

Annual Testing Requirement *EXAMPLE*

Two notices have been sent to you requesting the annual testing of the containment backflow prevention assembly(s) (see attached notices). We have not received the test report(s) as of the date of this letter.

This is the last notification. A passing test report for the containment device(s) must be received by <DATE>. The mailing address is:

City of Sunflower
Pollution Control Division
Backflow Prevention Unit
2303 West Beeline Street
Sunflower, AZ 85009

FAILURE TO COMPLY WITH THE REQUIREMENTS OF THIS LETTER MAY RESULT IN A REVIEW MEETING BEING SCHEDULED TO DISCUSS THE FOLLOWING APPLICABLE ENFORCEMENT ACTIONS OUTLINED IN CHAPTER 37 OF THE SUNFLOWERCITY CODE.

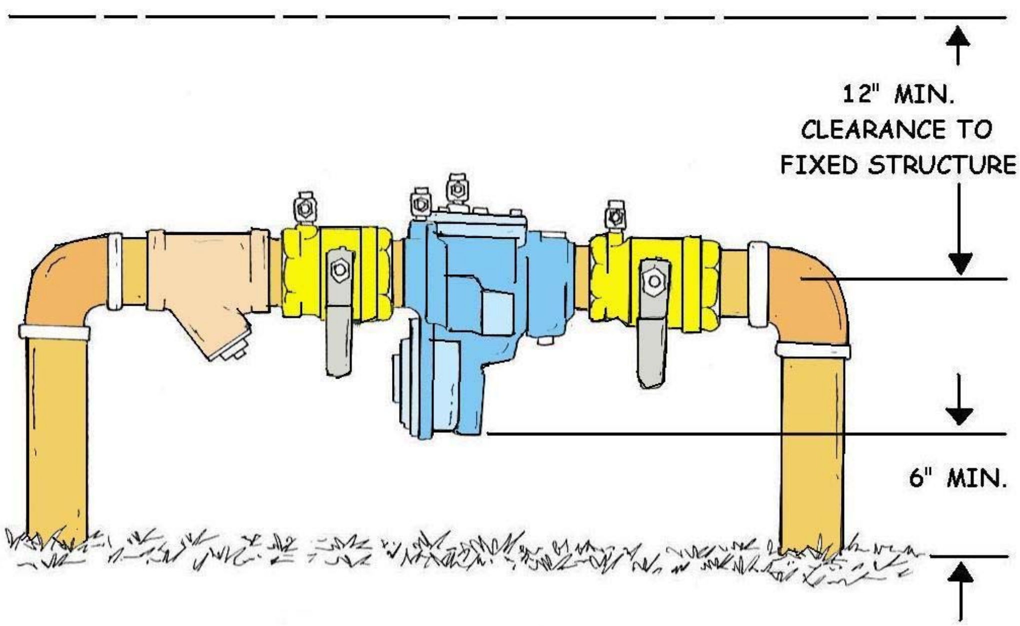
- A civil penalty not to exceed one thousand percent per billing period on the charges for all water used beginning from the date the corrective action was required and until the corrective action has been completed by the customer.
- Publication in the largest daily newspaper published in the City as a violator of the requirements of Chapter 37.
- TERMINATION OF WATER SERVICE.
- All costs, fees, expenses incurred, surcharges, and penalties relating to the termination and restoration of water service shall be paid by the customer prior to the water service being restored.

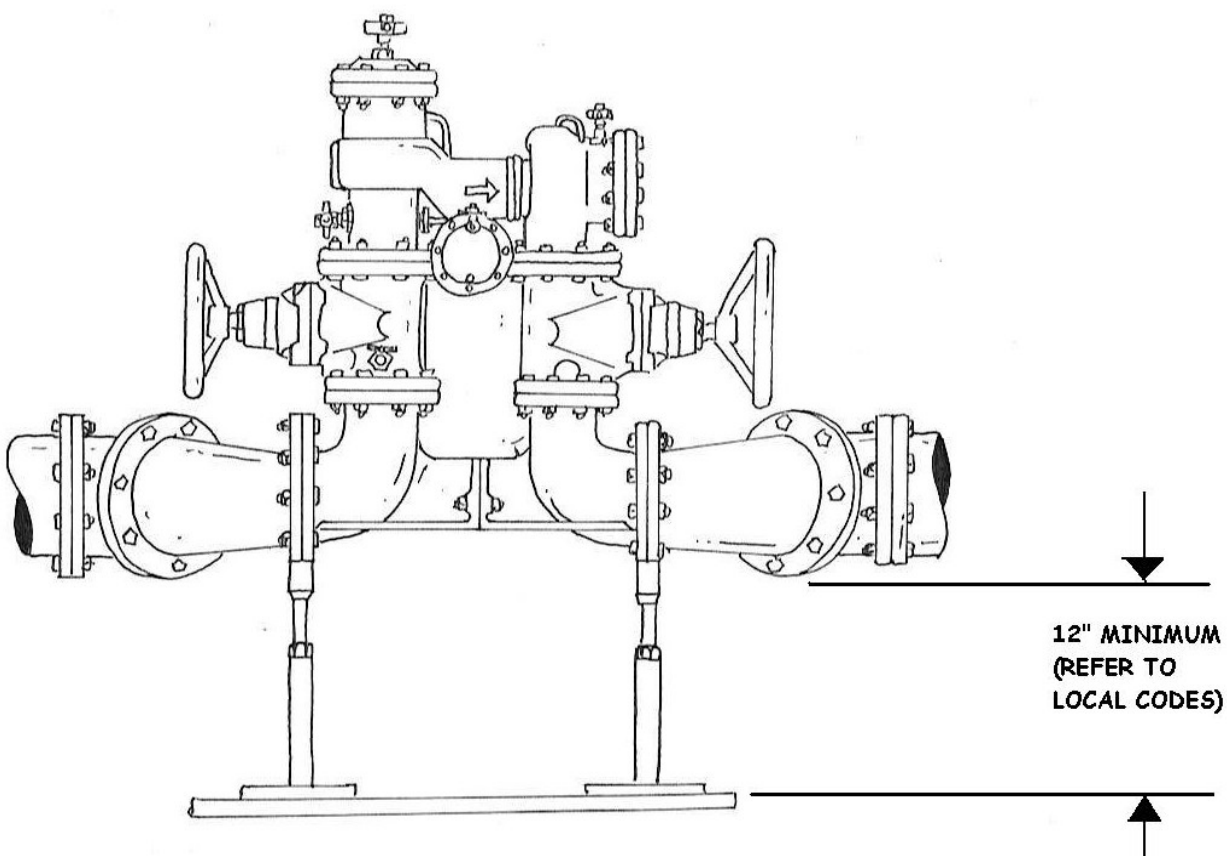
Should you have any questions regarding this Notice, please call me at 534-9506. Our office hours are 8:00 a.m. through 4:30 p.m., Monday through Friday.

Sincerely,

Bill Fields
Chief Water Quality Inspector
Backflow Prevention Unit

Enclosures


12" MIN.
CLEARANCE TO
FIXED STRUCTURE
6" MIN.


12" MINIMUM
(REFER TO
LOCAL CODES)

Date: December 11, 2016

To: Bill Fields, Public Works Director

From: Chris Mitchell, Water Resource Specialist

RE: Owner's refusal to install Required Backflow Prevention Assembly at Sunflower Car Wash - 114 W. Kiedel Street

Current State and Local Backflow Requirements

Current state drinking water regulations adopted by the Arizona Department of Environmental Quality require a water supplier to "protect its public water system from contamination caused by backflow through unprotected cross connections by requiring the installation and periodic testing of backflow prevention assemblies" (A.A.C., Title 18, Chapter 4, Article 1, Section R18-4-115). In addition, Sunflower Town Ordinance Number 422 adopts Resolution Number 1016 which establishes rules, regulations and penalties relative to cross connection control for users of the public water supply.

Section 13-4-3, Part I of Town of Sunflower Resolution Number 1016 [Discontinuance of Service] states the penalty for failure to comply with backflow prevention requirements as follows:

"Service of water to any premises may be discontinued by the Department if a backflow prevention assembly required by this ordinance is not installed, tested and maintained; if it has been found that a backflow prevention assembly has been removed or bypassed; or if a cross connection exists on the premises. Service will not be restored until such conditions or defects are corrected. Sunflower may also terminate a user's service upon twenty (20) days notice in writing in non-emergency."

Procedure Used to Notify Sunflower Water Customers of Backflow Prevention Requirements

Sunflower Water Department staff has designed a backflow prevention program that is designed to help customers achieve compliance with state regulations and local ordinance. Customers who are required to install a backflow prevention assembly at their water meter are notified of the requirement as follows:

Water Department staff mailed a "First Notice" letter to customers who are required to install a backflow assembly at their water meter. If the customer does not comply with the requirement after 30 days, a "***Second Notice***" letter is mailed. If the water customer does not install and test the required backflow assembly after 60 days, a "***Water Service Shutoff Notice"*** is mailed to the customer [Refer to copies of attached letters].

Water Department staff also telephone the water system customer to verify that they have received the backflow prevention letters, to answer their questions about the requirements and to advise them that their water service will be discontinued if the specified assemblies are not properly installed and tested.

Schedule of Notification for Sunflower Car Wash
On June 04, 2013, a first notice letter was mailed to the property owner of Sunflower Car Wash located at 114 West Kiedel Street. A second notice letter was mailed on July 29, 2013. The owner of the car wash, Mr. Duane Smith, did not respond to either letter. Finally, on November 07, 2013, Town staff mailed a letter to advise Mr. Jones that his water service would be discontinued if he did not comply with the backflow prevention requirements within thirty (30) days of the final notice.

Mike Ploughe, Hydrogeologist for the Sunflower Water Department, attempted to contact Mr. Jones several times after mailing the final notice. During the third week in November, 2013, Mr. Jones left a voice mail message at my extension, and said that he didn't think an assembly was needed at his car wash. I asked Mike Ploughe to contact him and schedule an on-site survey. Mike was unable to contact Mr. Jones until Tuesday, December 10, 2013.

On Wednesday morning, December 11, 2011, Mike surveyed the site, but was uncertain if the mixing basins for the car wash chemicals were properly air-gapped. As a result, I contacted Mr. Jones at the car wash in the afternoon and resurveyed the site. Several backflow hazards exist at the facility. First, the mixing basins for the car wash chemicals are not properly air-gapped. The water inlet for the basins is below the rim of the receiving vessel, which violates the air-gap requirements of the Uniform Plumbing Code. Furthermore, the car wash facility has two hose bibs with attached hoses that are not protected against backsiphonage.

Owner's Refusal To Comply With Backflow Prevention Requirements
When I showed Mr. Jones the backflow hazards and explained the requirements for installation and testing of a backflow prevention assembly, Mr. Jones told me that he would not comply with the requirements if it would cost him too much money.

He looked through a plumbing supply catalog for a few minutes and estimated that he would probably need to pay $400-600 for the installation and an additional $35 - 50 for the testing. Then he told me that he had already contacted his lawyer, and that we should shut off his water and he would see us in court.

Cross-Connection Specialist Job Description *Example*

JOB SUMMARY:
Performs specialized work analyzing industrial and commercial water systems and inspecting new installations to ensure compliance with permit requirements, ordinances and state and federal regulations regarding cross connection control.

ESSENTIAL FUNCTIONS:
1. Evaluates industrial and commercial on-site water systems for proper cross connection devices to protect the city water supply from contamination.
2. Inspects new plumbing installations for compliance with cross-connection ordinances and engineering standards and follows up on deficiencies.
3. Reviews civil and architectural drawings for compliance with backflow prevention ordinances, approved components and systems.
4. Explains to owners and managers approved methods for retrofit and negotiates compliance dates.
5. Develops and presents specialized training on cross connection control and back flow prevention.
6. Provides lead supervision to support staff and serves as a technical expert for General and Specialist Building Inspectors.
7. Conducts research on cross-connection issues, construction materials and potential hazards, and prepares reports.
8. Maintains files and prepares various activity reports; develops surveys, forms, schedules, graphics, permits and draft ordinances and special programs.
9. Reviews qualifications of independent testers and issues approvals to test in our jurisdiction.
10. Tests back flow prevention assemblies to ensure certified tester accuracy.
11. Explains, interprets and enforces the City Cross-Connection Code and other codes, ordinances and guidelines related to cross connection control; issues citations and prepares materials for court cases.
12. Investigates water quality complaints and takes appropriate action.
13. Provides quality customer service.

SECONDARY FUNCTIONS:
14. Performs other related duties as assigned.

KNOWLEDGE, SKILLS, ABILITIES:
Knowledge of:

Local ordinances, codes, state and federal regulations governing the causes and control of contamination of City potable water supply.

Complex piping systems and engineering principles applicable to commercial construction.

Techniques involved in testing, identifying and correcting problems with cross connection control devices.

Installations of the correct back flow prevention devices and the proper device application.
Legal requirements related to Building Code Enforcement.

Ability to:

Make decisions within area of specialization.
Use and maintain testing equipment.
Identify possible cross connections within user's system for conformance with specifications and ordinances.
Read and interpret plans for the proper cross connection control devices.
Conduct research.
Communicate effectively verbally and in writing.
Establish and maintain effective working relationships with business owners, managers, Engineers, State and City officials and testers.
Negotiate effectively and obtain regulatory compliance.

WORKING CONDITIONS:

Fieldwork, which requires some heavy lifting and climbing up and down, ladders with possible exposure to gases and chemicals and open trenches.

MINIMUM QUALIFICATIONS:

Two years of college coursework in Engineering, Building Construction or a related field, and four years technical experience in plumbing inspection, water or wastewater systems, or water distribution treatment experience in cross connection control preferred.
Any equivalent combination of training and experience, which provides the required knowledge, skills, and abilities, is qualifying.

SPECIAL REQUIREMENTS:

Back flow Prevention Assembly Tester Certification within six months of appointment.
Driver's license.
Cross Connection Control Specialist Certification within six months of appointment.
ICBO Certification as a Plumbing Inspector within one year of appointment.

TOWN OF SUNFLOWER
Backflow Prevention Program *(Checklist Example)*

Developers, Contractors and Sunflower Residents:

An approved backflow prevention assembly may be required on your water service line(s) to protect the public water system from the possibility of contamination. The assemblies, required by State and local regulations are not needed on most single family residential water services, but are required for most industrial, commercial, irrigation and fire sprinkler service connections.

This information package is designed to explain the Town of Sunflower's Backflow Prevention Program and provide you with information you will need to install and test your backflow prevention assemblies.

Inside you will find the following information:

X **Backflow: Protecting Our Water Quality**: General backflow prevention information.

X **Program:** Outlines customer and Sunflower Water Department's responsibilities for backflow prevention.

X **Customer Checklist:** Lists steps necessary for permitting, installation, testing and final approval.

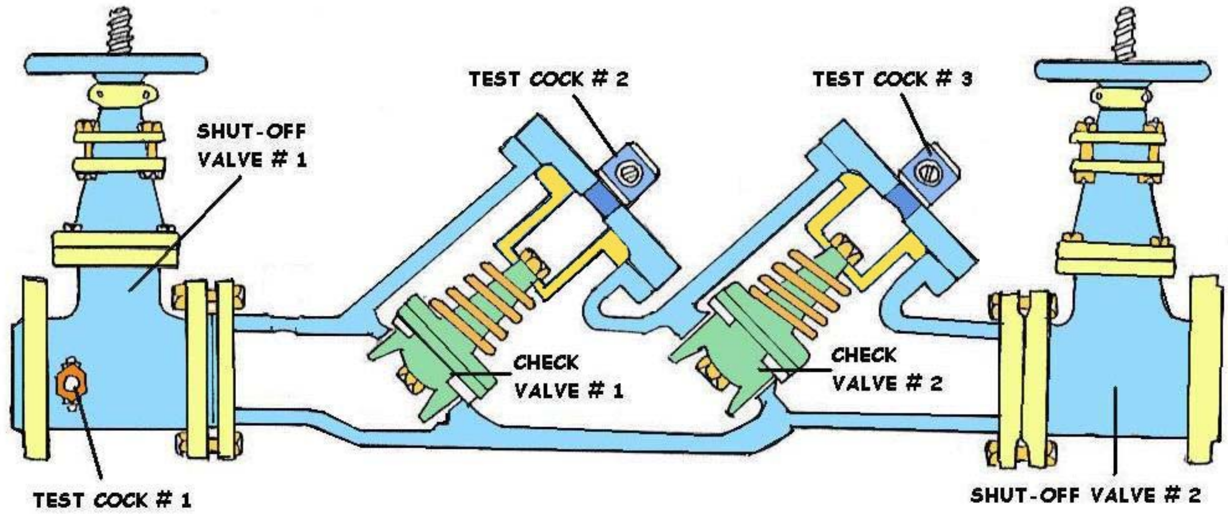
X **Permit Application:** Application and two signed forms needed to obtain an installation permit.

X **Freeze and Theft Protection:** A list of manufacturers who produce heating devices and locking enclosures to safeguard your assemblies.

X **Standard Details and Approved Assemblies:** Sunflower Water Department Standard Details for assembly installation and information on currently approved assemblies.

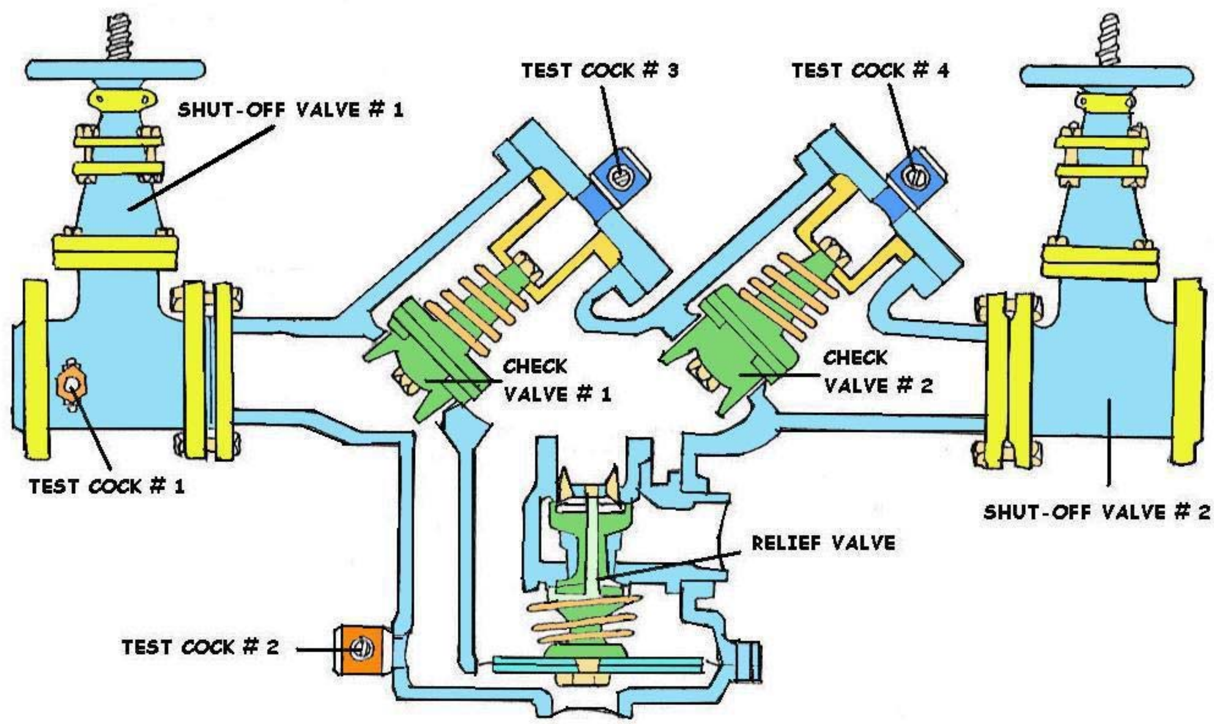
X **Testers:** A directory of Sunflower Water Department approved Certified Backflow Testers. This list is presented in random order and may not include recent changes. Ask the contractor about current registration with Sunflower Water and insurance coverage before work is performed.

X **Fire:** Special information relating to fire services and systems.



DOUBLE-CHECK BACKFLOW ASSEMBLY

REDUCED-PRESSURE BACKFLOW ASSEMBLY



CUSTOMER CHECKLIST FOR NEW AND RETROFIT INSTALLATIONS *(Example)*

INSTALLATION OF A BACKFLOW PREVENTION ASSEMBLY REQUIRES THE FOLLOWING ITEMS:

STEP 1) Inspections Required: Install required assemblies and call the Backflow Prevention Staff at 978-5242, Ext. 379 to schedule an inspection.

a) Inspection for Correct Installation (Use Attached Town of Sunflower Standard Details).
b) Inspection of Underground Piping- *DOES* ***NOT BACKFILL THE TRENCH UNTIL SUNFLOWER WATER DEPARTMENT STAFF HAVE APPROVED YOUR INSTALLATION.***
c) Inspection for Adequate Clearance from obstructions to permit proper testing.
d) Inspection for use of assemblies approved by the University of Southern California Foundation for Cross Connection Control and Hydraulic Research (USC FCCCHR) approved assemblies [Call the Sunflower Water Department to check on current approvals].

***** The Town of Sunflower will specify what types of assemblies are needed to protect each service connection during the plan review process. Specific locations of installed assemblies must be reported to the Water Department for testing and recordkeeping purposes. Assemblies must be installed as close to the service connection (downstream side of the water meter) as practical, unless an alternate installation location has been approved by the Sunflower Water Department. [Town Ordinance Article 13, Section 13-4-3, Number 422] [State of Arizona Administrative Code - Title 18, R18-4-115]

STEP 2) Testing Requirements:

a) After the installation inspection and approval, each backflow prevention assembly must be tested by a certified contractor prior to active use (refer to attached list of backflow prevention assembly general testers). Water service will be discontinued if backflow assemblies are not properly tested prior to occupancy!

b) Submit test reports to the Sunflower Water Department after completion of the tests (Use Attached Form) at the following address:

Attention: Backflow Prevention Program
Town of Sunflower Water Department
978A North Beeline Highway
Sunflower, Arizona 85547

c) Annual testing of each assembly is required. Reminder notices will be sent by the Water Department.

STEP 3) Requirements for Final Approval:
a) All Final Inspections and Testing Complete
b) Chains and locks on fire lines to keep them in the open position and prevent system shut off.

If you have any questions about this program, please contact the Backflow Prevention Department at (520) 978-5242, Ext. 379.

Possible Bad Connection

Direct connection from hyrant to pump.

Air Gap

Fitting at hydrant

Lines cut but it had been connected to a chemical barrel earlier.

Closed-Loop Water System Form *(Example)*

WARNING - HOT WATER HEATER LEAK, RUPTURE OR EXPLOSION HAZARD!

Normally, cold water flows in from your water service line and fills your hot water heater. Then, as the water is heated, it expands and flows back out through the pipe towards the water meter. As long as the flow of the expanded water is not blocked, the water pressure in the service line remains normal. However, when a backflow preventer is installed, the hot expanded water can no longer escape out through the water meter. In this case, the only way to prevent excessive heat and pressure from building up in the service line is to install a temperature and pressure (T&P) relief valve on the water heater and an expansion tank to the water system (1991 Uniform Plumbing Code- Section 1007). Other forms of added protection include toilet tank relief valves and in-line relief valves.

The T&P relief valve should be checked regularly to ensure that it is functioning properly. This test should be performed on an annual basis when the backflow prevention assembly is tested.

If you understand this information, please sign and return this form to obtain your assembly installation permit. If you do not understand this information, please contact the Backflow Prevention Office at (520) 978-5242, Ext. 379.

I, the undersigned, do hereby state that I fully understand the potential hazards of a closed water system and the consequences which may occur if the temperature and pressure relief valve on my hot water heater is not functioning as designed OR if expansion tanks and/or relief valves are not added to the water system when needed.

SIGNATURE: ____

NAME: (Please print) ________________________________ DATE: ___/___/

ADDRESS: ____

CITY: ____________________ STATE: ______________ ZIP CODE: ________

**A SIGNED COPY OF THIS FORM MUST BE SUBMITTED TO OBTAIN YOUR BACKFLOW ASSEMBLY INSTALLATION PERMIT

Fire Services and Systems Policy *(Example)*

- Class 1 and 2 fire systems are not currently required to have any backflow prevention equipment at the service connection other than the equipment that is required for those systems under the state fire code standards. However, backflow prevention assemblies may be required on all Class 1 and 2 fire systems after future legislative review. (Refer to the Suggested Removable Pipe Spool Installation for Class 1 and 2 Fire Sprinkler Systems@ - Standard Detail W1-07 in this information package).

- Class 3 fires systems may be converted to Class 1 or 2 systems by removing the tank. However, you must have the approval of the fire authority. Contact your fire authority prior to making any changes to your existing fire system. If the system cannot be modified, a backflow assembly will be required.

- Class 4 and 5 must comply with backflow requirements. Class 5 includes those fire systems that use antifreeze or other additives (RPDA required). This may apply to residential homes over 3000 sq. ft.

- Class 6 fire systems require an on-site review to determine backflow requirements.

- Customers who want to increase the size of an incoming service line must comply with backflow requirements prior to the completion of construction. Contact the Sunflower Water Department at 978-5242, Ext. 379 or e-mail for more information.

- Customers who will receive reclaimed water must comply with backflow prevention requirements prior to completion of construction and before receiving reclaimed water. Contact the Sunflower Water Department at 978-5242, Ext. 379 for more information.

I've seen this type of poor installation many times and is a common site because of un-educated Inspectors and/or backflow personnel. This line feeds an irrigation system, no protection at all and was in place for many years. I also hate to see an AVB or PVB installed and see the potential for back-pressure downstream.

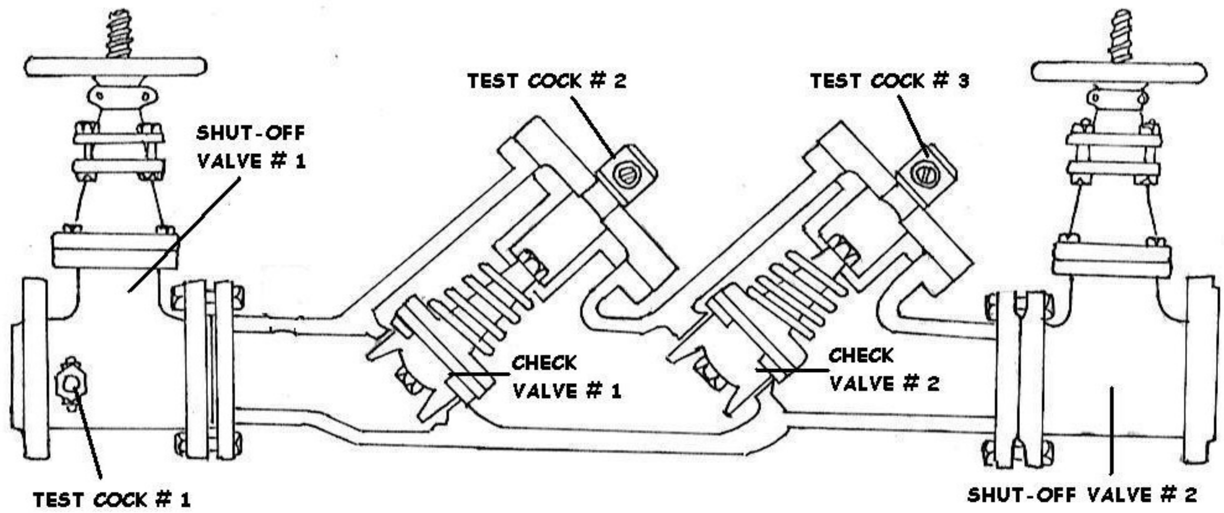
Customer Responsibilities

- Installation of Approved Backflow Assembly
- Maintenance, Repair and Annual Testing of Assembly
- Annual inspection of check valve assemblies for Class I and 2 fire sprinkler systems by an L-16 or C-16 contractor (Refer to Fire System Section in this information package)

Sunflower Water Department Responsibilities

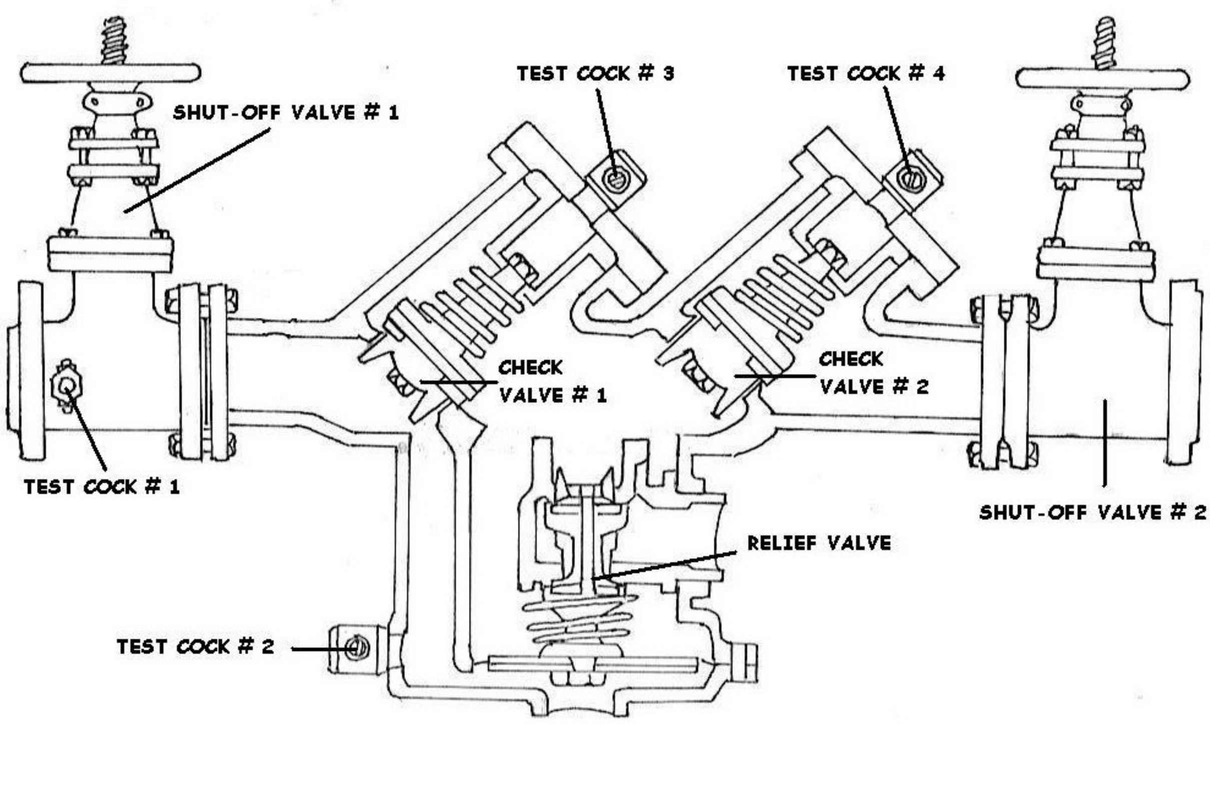
- Assurance of Water Quality
- Enforcement of Laws, Ordinances and Codes
- Implementation of Backflow Prevention Program
- Inspections, Surveys and Water Service Evaluations
- Retain Inventory and Service Records of All Backflow Prevention Assemblies
- Submit Reports to the State

Rust Particles



DOUBLE-CHECK BACKFLOW ASSEMBLY

REDUCED-PRESSURE BACKFLOW ASSEMBLY



Freeze and Theft Protection for Backflow Prevention Assemblies *Example*

If a backflow prevention assembly is installed outside in a location subject to freezing weather, it must be protected to prevent damage and to ensure proper operation. Several manufacturers of enclosures designed to protect assemblies from freeze and theft damage are listed below:

1) **Heat Hut from Northern Arizona Backflow, Inc**.
   Flagstaff, Arizona
   Contact: Rick Williams at (520) 527-8919

2) **HydroCowl, Inc.**
   Nashville, TN
   (615) 833-0233 Fax: (615) 831-0156
   1-800-245-6333

3) **FreezeGuard from Astra Industrial Services**
   1-800-776-1464 Fax: (805) 499-9084

4) **Hot Box from Hot Box-NFE, Inc.**
   250 N. Lane Avenue
   Jacksonville, Florida 32254

   (904) 786-0204 Fax: (904) 783-6965
   1-800-736-0238

5) **Just Set Thermo Shelters from Pennsylvania Insert Corporation**
   Bridge Street
   Spring City, Pennsylvania 19475
   (610) 948-9688 Fax: (610) 948-9750

Facility owners may install assemblies inside the building with approval from the Backflow Prevention Section of the Sunflower Water Department at (520) 978-5242, Ext. 379, or e-mail.

All customers whether installing an assembly outdoors or indoors must complete and submit a copy of the attached Freeze Protection Installation Approval Form when applying for a backflow assembly permit.

Freeze Protection Installation Approval Form *Example*

Please check the appropriate box.

☐ Outdoor Installation:

I, the undersigned, do hereby agree to install all required backflow prevention assemblies for my facility or residence in an *outdoor* location (as close to the meter as possible) with adequate freeze protection to prevent damage to the assembly and to ensure its proper operation. I understand that the Town of Sunflower Backflow Ordinance prohibits any taps between the water meter and backflow assembly or any bypass lines around the assembly and certify that no such taps or bypasses exist on my domestic, fire or irrigation water service lines.

☐ Indoor Installation with Water Department Approval:

I, the undersigned, have obtained approval from the Backflow Prevention Section of the Water Department to install all required backflow prevention assemblies for my facility or residence *inside the building* in a location (as close to the meter as practical) that will protect the assembly from freeze damage. I understand that the Town of Sunflower Backflow Ordinance prohibits any taps between the water meter and backflow assembly or any bypass lines around the assembly and certify that no such taps or bypasses exist on my domestic, fire or irrigation water service lines. I also understand the potential for flooding that may result within my facility if an installed reduced pressure principle assembly reaches a full port dump condition. I agree to accept all responsibility for damage if this situation occurs.

SIGNATURE:

NAME: (Please print) ___________________________________ DATE: ___/___/

ADDRESS: ____

CITY: ______________________ STATE: _____________ ZIP CODE: __________

TELEPHONE: (_____) _______________________________

**A SIGNED COPY OF THIS FORM MUST BE SUBMITTED TO OBTAIN YOUR BACKFLOW

Assembly Installation Permit *Example*

BACKFLOW ASSEMBLY PERMIT APPLICATION

WATER CUSTOMER MAILING ADDRESS **ASSEMBLY INFORMATION**

Name: ________________________________ Serial No.

Address: ________________________________ MFR: ________ Model _______ Size

City, State, Zip ___________________________ Water Meter No:

PROJECT NAME:
PROJECT CONTRACTOR:
SERVICE ADDRESS:
CITY, STATE, ZIP:
CONTACT PERSON: ____________________________ TELEPHONE:
PAGER: ___________ASSEMBLY LOCATION:

_______________________1) What type of assembly will be installed? ☐ Reduced Pressure Principle Assembly (RP)
(Please Check One) ☐ Double Check Valve Assembly (DC)
☐ Pressure Vacuum Breaker (PVB)
☐ Reduced Pressure Principle Detector Assembly (RPDA) - *Fire Systems Only*
☐ Double Check Detector Assembly (DCDA) - *Fire Systems Only*

2) What size is your service line? ☐ 3/4 inch ☐ 3 inch
☐ 1 inch ☐ 4 inch
☐ 1 1/2 inch ☐ Other, Please specify
☐ 2 inch

3) Which Town of Sunflower Standard Detail will you be using to install the backflow prevention assembly?

☐ Reduced Pressure Principle Assembly (RP) - 3" and larger Detail # W1-01
☐ Double Check Valve Assembly (DC) - 3" and larger Detail # W1-02
☐ Reduced Pressure Principle Assembly (RP) - INDOOR - 2 1/2 " and less Detail # W1-03
☐ Reduced Pressure Principle Assembly (RP) - OUTDOOR - 21/2 " and less Detail # W1-04
☐ Double Check Valve Assembly (DC) - 21/2 " and less Detail # W1-05
☐ Pressure Vacuum Breaker (PVB) Detail # W1-06
☐ Suggested Spool Installation for Class 1 and 2 Fire Sprinkler System Detail # W1-07
☐ Safety Post - MAG STANDARD DETAIL #140

TOWN OF SUNFLOWER - BACKFLOW PREVENTION CODE OF CONDUCT FOR CERTIFIED TESTERS *Example*

Backflow prevention general testers recognized by the Town of Sunflower must test, repair, and install assemblies under the direction of the Town of Sunflower Water Department and according to Town of Sunflower Ordinance # Article 13, Section 13-4-3, Number 422. The backflow prevention program for the Town has been established as follows:

- X Monthly test notices will be mailed on the first day of each month to customers whose backflow prevention assemblies are due for testing in that month. A copy of the approved list of testers will be sent with the notification letter. The customer will be responsible for contacting a certified tester.

- X The Town will recognize testers who have been certified by AWWA, USC FCCCHR, ASETT Center, and the Pipe Industry Progress and Education Fund (P.I.P.E.) . A copy of the tester's certification, the test gauge calibration certificate, insurance certificate and Plumber or Contractor's License must be on file with the Town of Sunflower Water Department. Testers must use recognized test equipment and provide proof of its accuracy annually.

- X All backflow assemblies must be tested in accordance with the procedures outlined in Section 9 of the *9th edition* of the USC FCCCHR Manual of Cross Connection Control. In addition, testers must perform a backpressure check on each pressure vacuum breaker. Testers who are unsure of the current procedure to check for backpressure may contact the Sunflower Water Department at (520) 978-5242, Ext. 379.

- X The Town will provide test forms to testers. **Forms other than that provided by the Town will not be accepted.** Each form must be filled out correctly and completely after each test or repair is performed on any assembly within the jurisdiction of the Town of Sunflower.

- X All tests must be performed during the month for which they are designated. Early tests will not be accepted.

- X Completed **original** test forms must be returned by the certified tester to the Town by the due date indicated on the monthly mailing record. Any test performed during the appropriate time interval, but received after the due date will be considered late, and handled as follows:

  1) A written warning will be issued to the tester whenever the form is received late.
  2) Testers receiving two warnings within a six month period will have their certification suspended for a period of three months.
  3) Testers receiving two warnings within any six-month interval, after having a three month suspension, will have their certification revoked permanently.
  4) Tests performed after the monthly deadline, because of a delay caused by the owner, will not result in a written warning, if the tester provides a written explanation for the delay. The explanation shall be attached to the test form.
  5) Incomplete test forms will not be accepted.

- X Testers who dismantle an assembly are responsible for having replacement parts readily available so that the assembly may be restored to proper working condition within the same working day. Under no circumstances should a customer's water be left shut off while a tester attempts to obtain repair parts.

- X A tester may be suspended or removed from the list of certified testers for improper testing, maintenance, reporting or any other practices determined to be improper by the Backflow Program Manager.

I, _________________________________ have received a copy of the Town of Sunflower Backflow Prevention Ordinance and read the above information. As a certified tester recognized by the Town of Sunflower, I will follow all established laws and accepted practices for installation, testing and repair of backflow prevention assemblies.

***Tester's Signature*______________________________________ *Date*______________**

Confined Space and Related Hazards Section

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.

Permitted Confined Space Entry Program

Definition of Confined Spaces Requiring an Entry Permit

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.

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

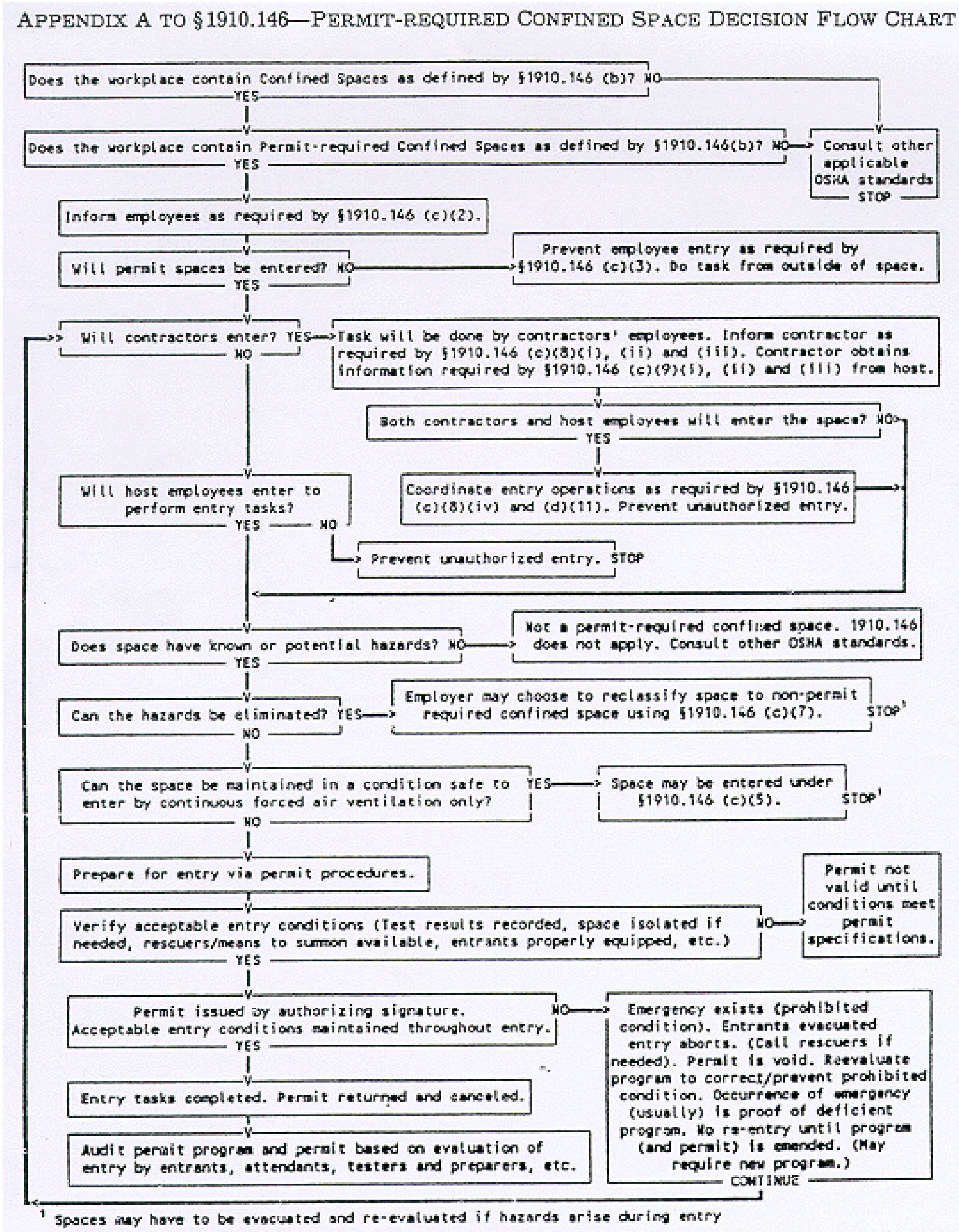
During all confined space entries, the following safety rules must be strictly enforced:

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

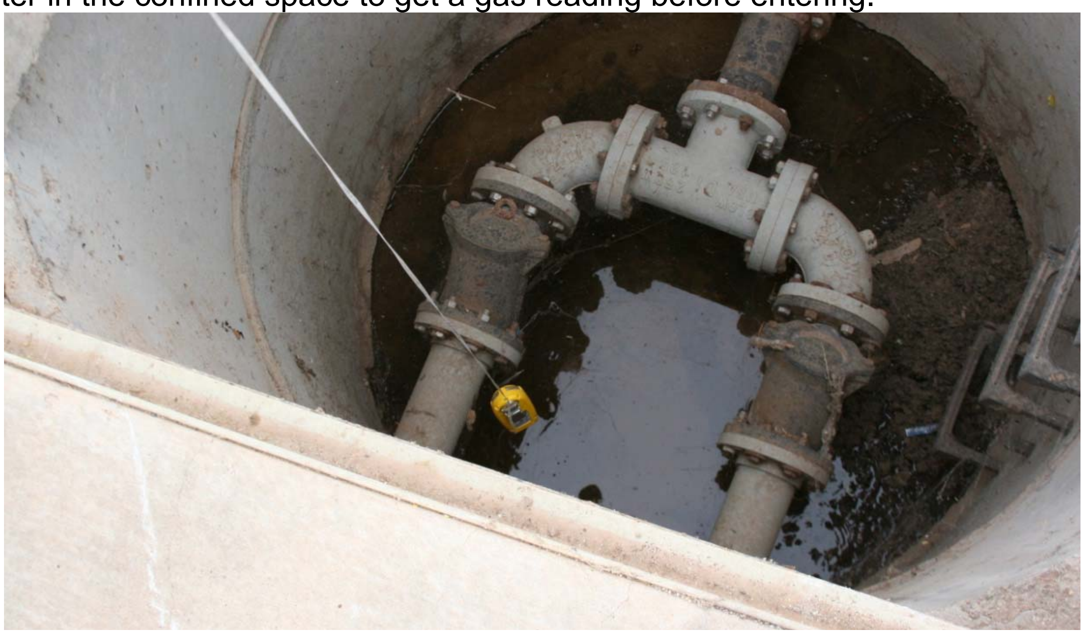
Permit-Required Confined Space Decision Flow Chart

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.



[58 FR 4549, Jan. 14, 1993; 58 FR 34846, June 29, 1993; 63 FR 66039, Dec. 1, 1998]

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.



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.

Copies: Safety Office, Unit Supervisor, Job site

Confined Space Duties & Responsibilities

Examples of assignments

Employees

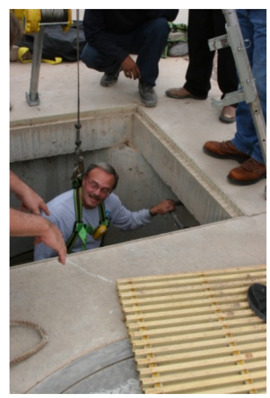
- ➢ Follow program requirements.
- ➢ Report any previously un-identified hazards associated with confined spaces.
- ➢ Do not enter any confined spaces that have not been evaluated for safety concerns.

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.

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.

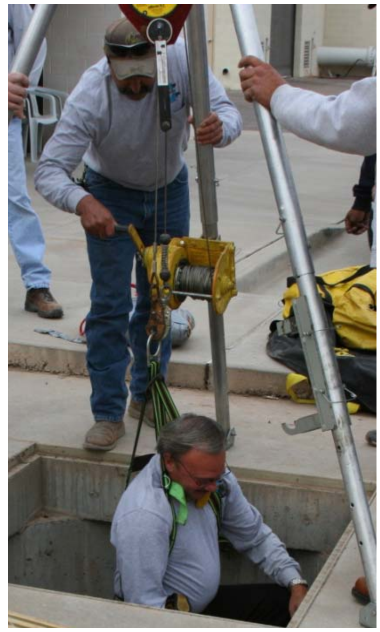
If the workers leave the confined space for any significant period of time, such as for a lunch or other break, the atmosphere of the confined space must be retested before the workers reenter the confined space.

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.

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.

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 picture 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.

Other 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.

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.

Protective Insulated Clothing

Protective insulated clothing for both hot and cold environments will add additional bulk to the worker and must be considered in allowing for movement in the confined space and exit time. Therefore, air temperature of the environment becomes an important consideration when evaluating working conditions in confined spaces.

Noise

Noise problems are usually intensified in confined spaces because the interior tends to cause sound to reverberate and thus expose the worker to higher sound levels than those found in an open environment.

This intensified noise increases the risk of hearing damage to workers, which could result in temporary or permanent loss of hearing. Noise in a confined space which may not be intense enough to cause hearing damage may still disrupt verbal communication with the emergency standby person on the exterior of the confined space. If the workers inside are not able to hear commands or danger signals due to excessive noise, the probability of severe accidents can increase.

Vibration

Whole body vibration may affect multiple body parts and organs, depending upon the vibration characteristics. Segmental vibration, unlike whole body vibration, appears to be more localized in creating injury to the fingers and hands of workers using tools, such as pneumatic hammers, rotary grinders or other hand tools which cause vibration.

Other Hazards

Some physical hazards cannot be eliminated because of the nature of the confined space or the work to be performed. These hazards include such items as scaffolding, surface residues, and structural hazards. The use of scaffolding in confined spaces has contributed too many accidents caused by workers or materials falling, improper use of guard rails, and lack of maintenance to insure worker safety.

The choice of material used for scaffolding depends upon the type of work to be performed, the calculated weight to be supported, and the surface on which the scaffolding is placed, as well as the substance previously stored in the confined space.

Surface residues in confined spaces can increase the already hazardous conditions of electrical shock, reaction of incompatible materials, liberation of toxic substances, and bodily injury due to slips and falls. Without protective clothing, additional hazards to health may arise due to surface residues.

Structural hazards within a confined space such as baffles in horizontal tanks, trays in vertical towers, bends in tunnels, overhead structural members, or scaffolding installed for maintenance constitute physical hazards, which are exacerbated by the physical surroundings. In dealing with structural hazards, workers must review and enforce safety precautions to assure safety.

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.

SCBA Storage Box

Required Confined Space Equipment Policy *Example*

Air Testing Equipment
All air-testing equipment should be calibrated in accordance with the manufacturer's instruction.

Oxygen Meters and Monitors
The oxygen content of the air in a confined space is the first and most important constituent to measure before entry is made. The acceptable range of oxygen is between 19.5 and 23.5 percent. This content is measured before flammability is tested because rich mixtures of flammable gases or vapors give erroneous measurement results.

For example, a mixture of 90 percent methane and 10 percent air will test nonflammable because there is not enough oxygen to support the combustion process in the flammability meters. This mixture will not support life and will soon become explosive if ventilation is provided to the space. Before entry, spaces must be ventilated until both oxygen content and flammability are acceptable.

Flammability Meters
Flammability meters are used to measure the amount of flammable vapors or gases in the atmosphere as a percent of the LEL/LFL. The oxygen content must be near 21 percent for results to be meaningful.

Toxic Air Contamination Testers
Tests for toxic contaminants must be specific for the target toxin. The instrument manufacturer should be consulted for interferences. Therefore, it is important to know the history of the confined space so proper tests can be performed. Part of hazard assessment is to identify all possible contaminants that could be in the confined space.

Protective Devices

Fall-Protection Equipment
Fall-protection equipment for confined spaces should be the chest-waist harness type to minimize injuries from uncontrolled movements when it arrests a worker's fall. This type of harness also permits easier retrieval from a confined space than a waist belt. Adjustable lanyards should be used to limit free fall to two feet before arrest.

Respirators
An industrial hygienist should select respirators on the basis of his or her evaluation of possible confined-space hazards. NIOSH-approved respirators should be identified in the approved procedure required by the confined-space entry permit. It is important to note that air-purifying respirators cannot be used in an oxygen deficient atmosphere.

Lockout/Tagout Devices
Lockout/tagout devices permit employees to work safely on de-energized equipment without fear that the devices will be accidentally removed. Lock and tag devices are required to withstand a 50-pound pull without failure.

Devices used to block or restrain stored mechanical energy devices must be engineered for safety.

Safety Barriers
Safety barriers separate workers from hazards that cannot reasonably be eliminated by other engineering controls.

Required barriers will be identified in the approved confined-space entry procedure.

Ground Fault Circuit Interrupters
Ground fault circuit interrupter must be used for all portable electrical tools and equipment in confined spaces because most workers will be in contact with grounded surroundings.

Emergency Response Equipment

Fire Extinguishers
"***Hot work***" inside a confined space requires that an approved fire extinguisher and a person trained in its use be stationed in the confined space or in a suitable vantage point where he or she could effectively suppress any fire that might result from the work.

First Aid Equipment
Blankets, first-aid kit, Stokes stretchers, and any other equipment that may be needed for first-response treatment must be available just outside the confined space. Medical and safety professionals should select equipment on the basis of their evaluations of the potential hazards in the confined space.

Retrieval Equipment
A tripod or another suitable anchorage, hoisting device, harnesses, wristlets, ropes, and any other equipment that may be needed to make a rescue must be identified in the confined-space safe-entry procedures.

It is important that this equipment be available for immediate use. Harnesses and retrieval ropes must be worn by entrants unless they would increase hazards to the entrants or impede their rescue.

Excavation and Trenching Chapter
OSHA SUBPART P - 29 CFR 1926.650-652
COMPETENT PERSON TRAINING

PREFACE

Anyone who has done excavation work will tell you that once the first bucket of dirt is out of the ground, you never know what surprises await. Tales of unmarked utilities, unexpected rock and other nightmares are common. The greatest variable, however, is the type of excavation or trenching will be done and how to protect yourself for a cave-in.

The OSHA excavation standard was revised because excavating is the most dangerous of all construction operations. More workers are killed or seriously injured in and around excavations than in any other construction work. The second reason that OSHA revised the existing standard was to clarify the requirements. The revised standard makes the standard easier to understand. The new standard uses performance criteria where ever possible. This added flexibly provides employers with options when classifying soil and when selecting methods to protect the employee from cave-ins.

Although the standard has been clarified and employers have options when meeting some of the requirements, employers must realize that the employee must be protected at all times. Some employers have a mindset of not needing this training until they are caught by OSHA, which is equivalent to buying car insurance only after a car collision.

Excavation decisions will have to be made right from the planning stages through completion of the work. Some sections of the standard require that documentation be kept. TLC will provide a sample of this type of documentation. In some situations professional engineers will be required to plan or design the excavation and/or method of protecting the worker (such as when an excavation exceeds 20 feet in depth).

The purpose of this session is to provide you with information about the OSHA excavation standard. This program is not designed or intended to provide participants with all the information, rules, regulations, and methods that they may need to know to perform all excavation work safety. Every plan involving excavation must be studied carefully to determine the specific hazards for each job.

Supporting Utilities is mandatory.

Major OSHA Violation. Do not operate equipment in unprotected trenches. This guy is trying hard to get to Heaven before his time is up.

Excavation Facts

Every year in the United States:

- ✓ **100 to 500 people are killed in an excavation cave-in.**
- ✓ **1000 to 5000 employees are seriously injured.**

The average worker that is killed by a cave-in is a 20 to 30 year old male who has had little or no training at all. Most deaths occur in trenches 5 feet to 15 feet in depth.

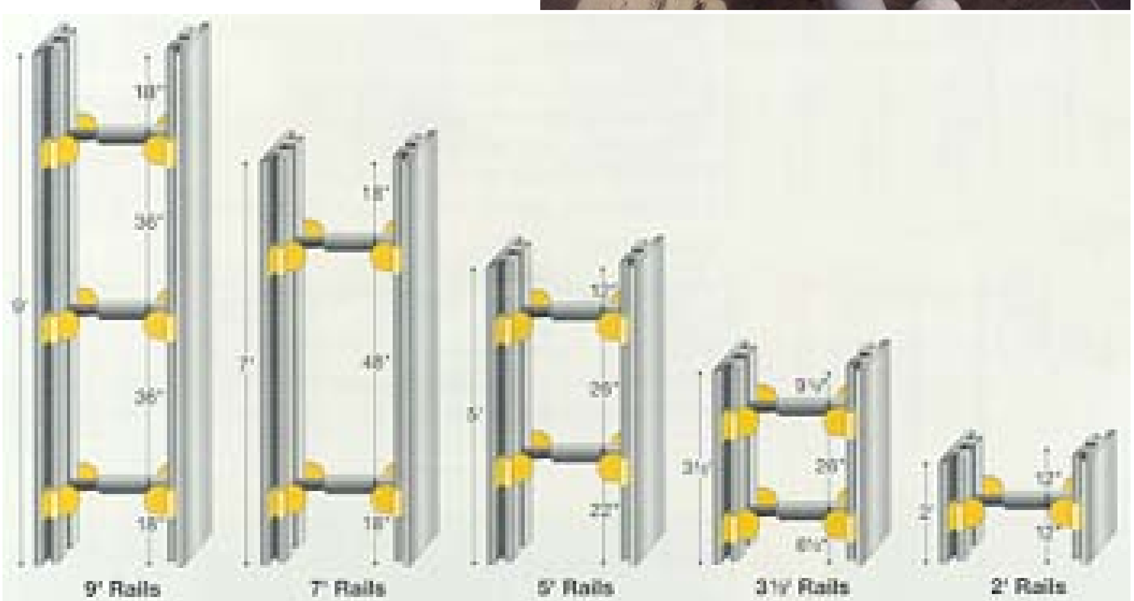
Cave-ins cause deaths and injuries by:

- ✓ **Suffocation**
- ✓ **Crushing**
- ✓ **Loss of circulation**
- ✓ **Falling objects**

One cubic foot (12" x 12" x 12") can weigh between 90 and 140 pounds. Therefore, one cubic yard (3' x 3' x 3') weights as much as a backhoe (approximately 3000 pounds).

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

- ✓ **All trenches are excavations.**
- ✓ **All excavations are not trenches.**



Notice that employees are wearing hard hats but no ladders are present. Spoil piles are too close to the hole. Almost looks like they over did the shores for the photograph but no ladder for miles.

Notice the ladder is partially properly tied down. Three rungs out and tied but not staked.

Competent Person

Competent person means one who is capable of identifying existing hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees and has authorization to take prompt corrective measures to eliminate them.

In order to be a "**Competent Person**" for the purpose of this standard, one must have specific training in and be knowledgeable about soils analysis, the use of protective systems and the requirements of 29 CFR Part 1926.650-652 Subpart P.

Rescue training exercises are essential. Everyone is required to practice once a year. Yes, once a year.

Competent Person Duties

- Performs daily inspections of the protective equipment, trench conditions, safety equipment and adjacent areas.
- Inspections shall be made prior to the start of work and as needed throughout the shift.
- Inspections shall be made after every rainstorm or other hazard occurrence.
- Knowledge of emergency contact methods, telephone or radio dispatch.
- Removes employees and all other personnel from hazardous conditions and makes all changes necessary to ensure their safety.
- Insures all employees have proper protective equipment, hard-hats, reflective vests, steel-toed boots, harnesses, eye protection, hearing protection and drinking water.
- Categorize soil conditions and conduct visual and manual tests.
- Determine the appropriate protection system to be used.
- Maintain on-site records of inspections and protective systems used.
- Maintain on-site Hazard Communication program, Material Safety Data Sheets and a Risk Management Plan, if necessary.
- Maintain current First Aid and CPR certifications. Maintain current Confined Space certification training.

Scope of Work

1. During excavation work a competent person shall be on the job site at all times when personnel are working within or around the excavation. This is necessary in order to monitor soil conditions, equipment and protection systems employed.
2. The estimated locations of utility installations, such as sewer, telephone, fuel, electric, water lines, or any other underground installation that reasonably may be expected to be encountered during excavation work, shall be determined prior to opening an excavation.
3. Adequate precautions shall be taken to protect employees working in excavations, against the hazards posed by water accumulation.
4. Employees shall be protected from excavated or other materials or equipment that could pose a hazard by falling or rolling into excavations. Protection shall be provided by placing and keeping such material or equipment at least two (2') feet from the edge of excavations.
5. A stairway, ladder, or ramp shall be used as a means of access or egress in trench excavations that are four (4') feet or more in depth. The ladder(s), stairway(s), or ramp shall be spaced so that no employee in the trench excavation is more than twenty five (25') feet from a means of egress. When ladder(s) are employed, the top of the ladder shall extend a minimum of three (3') feet above the ground and shall be properly secured.
6. When excavations are exposed to vehicular traffic, each employee shall wear a warning vest made with reflective material or highly visibility material. All personnel within the construction area shall wear a hard-hat at all times.
7. Employees shall not be permitted underneath loads handled by lifting or digging equipment. Employees shall be required to stand away from any vehicle being loaded or unloaded to avoid being struck by any spillage or falling materials.
8. In excavations where oxygen deficiency or gaseous conditions exist, or could be reasonably expected to exist, air in the excavation shall be tested.
9. Where oxygen deficiency (atmospheres containing less than 19.5 percent oxygen) exists, the area must be continuously ventilated until the oxygen levels are above 19.5 percent.

10. Where a gaseous condition exists, the area shall be ventilated until the flammable gas concentration is below 20 percent of the lower flammable limit.
11. Whenever oxygen deficiency or gaseous conditions exist or could reasonably exist, the area shall be monitored continuously to assure that employees are protected.
12. Where the stability of adjoining buildings, walls or other structures are endangered by excavation operations, support systems such as shoring, bracing, or underpinning shall be provided to ensure the stability of such structures for the protection of employees.
13. Sidewalks, pavement and appurtenant structures shall not be undermined unless a support system such as shoring is provided to protect employees from the possible collapse of such structures.

Always wait for the buried utilities to be marked before excavation begins. Believe it or not, this crew dug 9 feet deep before the Locator showed up and marked fiber optics in the same trench. Notice that the employees do not have hard hats, ladders, or any protective systems. Major OSHA violations.

Personnel Protective Systems

Employees in excavations shall be protected from cave-ins by an adequate protective system, which shall be inspected by a competent person.

The use of protective systems is required for all excavations, in excess of five (5') feet, except when excavation is within stable rock.

Trench excavation less than five (5') feet in depth may not require the use of protective systems, unless there is evidence of a potential cave-in. The competent person shall determine the need for the use of protective systems when such conditions exist.

When sloping, benching or protective systems are required, refer to requirements in CFR 1926.652 (**OSHA Construction Standards**).

Whenever support systems, shield systems, or other protective systems are being used, a copy of the manufacturer's specifications, recommendations, and limitations sheet shall be in written form and maintained at the job site.

This poor soul is probably going to be a short timer here on earth. He is sitting on the sewer main in a bell shaped hole under a steel plate which cars are driving over. No protection at all. There was a ladder in the trench was about 50 feet away. He wouldn't make it out of a cave-in unless he had wings.

Excavation Protection Systems

The three basic protective systems for excavations and trenches are sloping and benching systems, shoring, and shields. The protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied to or transmitted to the system. Every employee in an excavation shall be protected from cave-ins by an adequate protective system.

Exceptions to Using Protective System:
- Excavations are made entirely in stable rock.
- Excavations are less than 5 feet deep and declared safe by a competent person.

Sloping and Benching Systems
There are four options for sloping**:**
- Slope to the angle required by the standard for Type C, which is the most unstable soil type.
- The table provided in Appendix B of the standard may be used to determine the maximum allowable angle (after determining the soil type).
- Tabulated data prepared by a registered professional engineer can be utilized.
- A registered professional engineer can design a sloping plan for a specific job.

Sloping and benching systems for excavations five (5) to twenty (20) feet in depth must be constructed under the instruction of a designated competent person. Sloping and benching systems for excavations greater than twenty (20) feet must be designed and stamped by a registered professional engineer. Sloping and benching specifications can be found in Appendix B of the OSHA Standard (Subpart P).

Shoring Systems
Shoring is another protective system or support system. Shoring utilizes a framework of vertical members (uprights), horizontal members (whales), and cross braces to support the sides of the excavation to prevent a cave-in. Metal hydraulic, mechanical or timber shoring are common examples.

This is my favorite picture of all. Here are two men in a 30 foot deep trench without any protection or ladders. They are lucky to have a rope. Please do not work in this dangerous environment.

The different examples of shoring are found in the OSHA Standard under these appendices:
APPENDIX C - Timber Shoring for Trenches
APPENDIX D - Aluminum Hydraulic Shoring for Trenches
APPENDIX E - Alternatives to Timber Shoring

Shield Systems (Trench Boxes)

Shielding is the third method of providing a safe workplace. Unlike sloping and shoring, shielding does not prevent a cave-in. Shields are designed to withstand the soil forces caused by a cave-in and protect the employees inside the structure. Most shields consist of two flat, parallel metal walls that are held apart by metal cross braces.

Shielding design and construction is not covered in the OSHA Standards. Shields must be certified in design by a registered professional engineer and must have either a registration plate on the shield or registration papers from the manufacturer on file at the jobsite office. ***ANY REPAIRS OR MODIFICATIONS MUST BE APPROVED BY THE MANUFACTURER.***

Safety Precautions for Shield Systems

- Shields must not have any lateral movement when installed.
- Employees will be protected from cave-ins when entering and exiting the shield (examples - ladder within the shield or a properly sloped ramp at the end).
- Employees are not allowed in the shield during installation, removal, or during any vertical movement.
- Shields can be 2 ft. above the bottom of an excavation if they are designed to resist loads at the full depth and if there are no indications of caving under or behind the shield.
- The shield must extend at least 18 inches above the point where proper sloping begins (the height of the shield must be greater than the depth of the excavation).

- The open end of the shield must be protected from the exposed excavation wall. The wall must be sloped, shored, or shielded. Engineer designed end plates can be mounted on the ends of the shield to prevent cave-ins.

Personal Protective Equipment

It is **OSHA** policy for you to wear a hard hat, safety glasses, and work boots on the jobsite. Because of the hazards involved with excavations, other personal protective equipment may be necessary, depending on the potential hazards present (examples-goggles, gloves, and respiratory equipment).

Excavation & Trenching Guidelines

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.

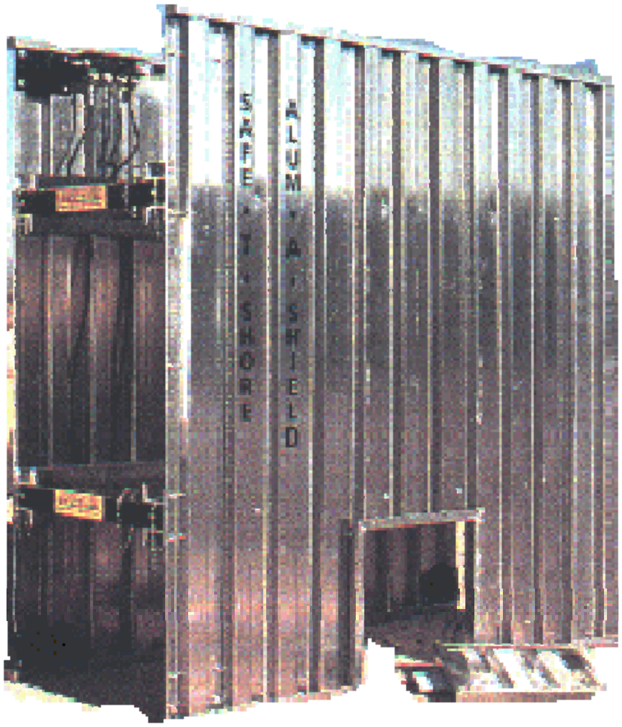
Safety compliance is mandatory to ensure employee protection when working in or around excavations.

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



Trench Shields and Boxes

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 insured:

- 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 underground 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 the 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.

Excavation Safety Plan

An excavation safety plan is required in written form. This plan is to be developed to the level necessary to insure 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.

1. Warning system for mobile equipment, methods to help prevent vehicles and equipment from falling in the trench can be accomplished by providing:

A. Barricades.

B. Hand or mechanical signals.

C. Stop logs.

D. Grade away from the excavation.

All equipment with an obstructed rear view is required to have a back-up alarm or an observer when backing {1926.601 (b) (4).}

2. Hazardous atmospheres, you must limit all exposures to hazardous atmospheres.

A. Oxygen deficient is anything less than 19.5% oxygen. Symptoms will include dizziness, increased heart rate or may experience a buzzing in the ears.

B. Normal is 21% oxygen.

C. Oxygen enriched atmospheres increase flammability of combustible materials.

D. Carbon monoxide causes oxygen starvation and can be fatal at a concentration of 1% for one minute. This is equal to 10,000 PPM. The Threshold Limit Value (**TLV**) is only 50 PPM.

E. If there is a possibility that a hazardous atmosphere exists or could be reasonably expected to exist, test the atmosphere before the employee enters an excavation. Some areas of concern include; digging near gas lines, sewers, landfills and near areas of high traffic.

F. Provide respirators or ventilation when needed. All personnel must be fit tested before wearing a respirator and all personnel must be training how to use ventilation.

The use of any respirator by employees will require a written respirator program form the employer {1926.103).

A. Ventilate trench if flammable gas exceeds 20% of the lower flammable limit.

B. Test the atmosphere often--this will ensure that the trench remains safe.

C. Perform regular maintenance on gas meters. Calibrate and change out filters regularly.

D. Never enter a hazardous atmosphere to rescue an employee unless you have been trained in rescue techniques and have proper rescue equipment. More than half the deaths occur while attempting a rescue.

3. **Emergency rescue equipment must be available when a hazardous atmosphere exists or could be reasonably expected to exist**.

A. Respirator must be suitable for the exposure. An air supplied or self-contained breathing apparatus is preferable

B. Harness and lifeline is required when an employee enters bellbottom piers and other deep confined spaces. The lifeline must be attended at all times.

Employees entering confined spaces must be trained. {1926.21 (b) (6) I}
Specific requirements for welding in confined spaces {1926.352 (g) and 1926.653 (b)}.

4. Protection from hazards associated with water accumulation is necessary to prevent cave-ins.

A. Methods for controlling accumulated water vary with each situation.

B. Employees are not permitted to work in trenches were water accumulation exists.

C. Special support system or shield systems may be used to protect employees from cave-ins.

D. Water removal equipment may be used and must be monitored by a competent person to prevent water accumulation.

E. Safety harness and lifeline may be used to protect employees.

F. Surface water must be diverted and controlled.

G. Trench must be inspected after rain.

5. Stability of adjacent structures to protect employees from cave-ins.

A. Support systems such as shoring, bracing, or underpinning must be used to support structures that may be unstable due to excavation operations.

B. Excavation below the base or footing of a foundation or wall is not permitted unless:

i. Support system is provided to ensure the stability of the structure.
ii. The excavation is in stable rock.
iii. A Registered Professional Engineer approves the operation.

C. Support systems must be provided for sidewalks, pavements and other structures that may be affected by the excavation operations.

6. Protection of employees from loose rock or soil.

A. Employees must be protected from being struck by materials falling or rolling from the edge and the face of the trench.

B. Spoils and equipment must be set back at least 2 feet from the edge of the trench and/or a retaining device must be installed.

7. Fall protection is required for walkways and bridges over trenches. Other fall protection may also be required.

8. Remotely located excavations shall be backfilled, covered, or barricaded (for example wells, pits, shafts, etc.)

Inspections must be made:

A. Daily prior to starting work

B. As needed throughout the shift by a competent person.

C. After every rainstorm.

D. After other hazard increasing occurrence (snowstorm, windstorm, thaw, earthquake, etc.).

E. Inspect the trench for indications of possible cave-ins (fissures, tension cracks, sloughing, undercutting, water seepage, bulging at the bottom).

F. Inspect adjacent areas (spoil piles, structures).

G. To protective systems and their components (uprights, wales sheeting, shields hydraulics) before and after use.

H. Check for indications of a hazardous or potentially hazardous atmosphere.

I. Test the atmosphere if a hazard could reasonably be expected to exist.

Remove employees from the trench when there are indications of possible cave-ins, protective system failures, or other potentially hazardous conditions. Never work in water without proper protection. You will have to wear a Lifeline with a rope to drag your dead body out of these hazardous conditions.

It is not a great place for ladder storage.

Soil Classification and Identification

The OSHA Standards define soil classifications within the Simplified Soil Classification Systems, which consist of four categories: Stable rock, Type A, Type B, and Type C. Stability is greatest in stable rock and decreases through Type A and B to Type C, which is the least stable. Appendix A of the standard provides soil mechanics terms and types of field tests used to determine soil classifications. Stable rock is defined as natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Type A soil is defined as:

- Cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (**TSF**) or greater.
- Cemented soils like caliche and hardpan are considered Type A.

Soil is NOT Type A if:

- It is fissured.
- The soil is subject to vibration from heavy traffic, pile driving or similar effects.
- The soil has been previously disturbed.
- The material is subject to other factors that would require it to be classified as a less stable material.
- The exclusions for Type A most generally eliminate it from most construction situations.

Type B soil is defined as:

- Cohesive soil with an unconfined compressive strength greater than .5 TSF, but less than 1.5 TSF.
- Granular cohesion-less soil including angular gravel, silt, silt loam, and sandy loam.
- The soil has been previously disturbed except that soil classified as Type C soil.
- Soil that meets the unconfined compressive strength requirements of Type A soil, but is fissured or subject to vibration.
- Dry rock that is unstable.

Type C soil is defined as:

- Cohesive soil with an unconfined compressive strength of .5 TSF or less.
- Granular soils including gravel, sand and loamy sand.
- Submerged soil or soil from which water is freely seeping.
- Submerged rock that is not stable.

Soil Test & Identification

The competent person will classify the soil type in accordance with the definitions in Appendix A based on at least one visual and one manual analysis. These tests should be run on freshly excavated samples from the excavation and are designed to determine stability based on a number of criteria: the cohesiveness, the presence of fissures, the presence and amount of water, the unconfined compressive strength, and the duration of exposure, undermining, and the presence of layering, prior excavation and vibration.

The cohesion tests are based on methods to determine the presence of clay. Clay, silt, and sand are size classifications, with clay being the smallest sized particles, silt intermediate and sand the largest.

Clay minerals exhibit good cohesion and plasticity (can be molded). Sand exhibits no elasticity and virtually no cohesion unless surface wetting is present. The degree of cohesiveness and plasticity depend on the amounts of all three types and water.
When examining the soil, three questions must be asked: Is the sample granular or cohesive? Is it fissured or non-fissured? What is the unconfined compressive strength measured in TSF?

The competent person will perform several tests of the excavation to obtain consistent, supporting data along its depth and length. The soil is subject to change several times within the scope of an excavation and the moisture content will vary with weather and job conditions. The competent person must also determine the level of protection based on what conditions exist at the time of the test, and allow for changing conditions.

Ribbon Soil Test

Sloping

MAXIMUM ALLOWABLE SLOPES

SOIL TYPE	SLOPE (H:V)	ANGLE(º)
Stable Rock	Vertical	90º
Type A	3/4 : 1	53º
Type B	1 : 1	45º
Type C	1 1/2 : 1	34º

MAXIMUM ALLOWABLE SLOPE means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins and is expressed as the ratio of horizontal distance to vertical rise (**H:V**).

The tables and configurations within Appendix B may be used to a maximum depth of twenty (20') feet deep. Jobs more than twenty (20') feet in depth require the design of a sloping plan by a registered professional engineer (**RPE**). If configurations are used for depths less than 20 feet other than those found in Appendix B, they must also be designed by a registered professional engineer.

Shielding

The third method of providing a safe workplace in excavations is shielding. Shielding is different from shoring and sloping in that it does not prevent cave-ins. Instead, it protects the workers in the event of a cave-in. Its function is therefore somewhat similar to that of a bomb shelter.

Shields are simply devices that, when placed in an excavation, have sufficient structural strength to support the force of a cave-in should one occur. Shields take a number of different shapes and sizes. Most shields consist of two flat, parallel metal walls which are held apart by metal cross braces which are placed at the ends of the "**Box**" to allow for the installation of pipe within its interior dimensions. These boxes are used to greatest effect in what is known as "cut and cover" operations where a contractor excavates just enough trench to install the shield, then sets a joint of pipe, then excavates further, then pulls the shield forward to install another joint while the first is being backfilled. This method is extremely cost effective in that it is fast, safe, requires minimum excavation and minimum open trench. It has become the preferred method of laying pipe in most instances. While original shields were quite large, smaller shields have gained in popularity with public works maintenance crews and contractors working in shallow excavations because of their ease of use. Recently, round shields, made of corrugated metal have appeared. The sizes, shapes and possibilities for the applications of shields are endless. If they are to be used, however, several points must be borne in mind.

1. Shield construction is not covered by the standard. Users must rely on manufacturers' requirements. For this reason, it is critical that you know your supplier. Reputable manufacturers supply boxes designed by registered professional engineers, and the standard requires that they are certified for their applications. Do not make the mistake of having the neighborhood welder fabricate one. A user must know that their shield is appropriate for the situation.

2. Bent cross braces are not braces, they are hinges. Any bent of deformed structural member must be repaired or replaced according to the manufactures' guidelines.

3. The manufacturer must approve any modification to the shields.

4. Shields must be installed so as to prevent lateral movement in the event of a cave-in.

5. Shields may ride two feet above the bottom of an excavation, provided they are calculated to support the full depth of the excavation and there is no caving under or behind the shield.

6. Workers must enter and leave the shield in a protected manner, such as by ladder within the shield or a properly sloped ramp at the end.

7. Workers may not remain in the shield during its installation, removal or during vertical movement.

8. Do not forget about the open end of the shield if it exposes a wall of the excavation. The wall should be sloped, shored or shielded off to prevent a cave-in from the end.

9. If the excavation is deeper than the shield is tall, attached shields of the correct specifications may be used or the excavation may be sloped back to maximum allowable angle from a point 18 inches below the top of the shield.

Complete Rule and further instructions are located in TLC's Competent Person Course.

Inspections

Daily inspection of excavations, the adjacent areas and protective systems shall be made by the competent person for evidence of a situation that could result in a cave-in, indications of failure of protective systems, hazardous atmospheres or other hazardous conditions.

- All inspections shall be conducted by the competent person prior to the start of work and as needed throughout the shift.
- Inspections will be made after every rainstorm or any other increasing hazard.
- All documented inspections will be kept on file in the jobsite safety files and forwarded to the Safety Director weekly.
- A copy of the ***Daily Excavation Inspection*** form is located at the end of this program.

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.

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.

DAILY EXCAVATION CHECKLIST

Client		**Date**	
Project Name		**Approx. Temp.**	
Project Location		**Approx. Wind Dir.**	
Job Number		**Safety Rep**	
Excavation Depth & Width		**Soil Classification**	
Protective System Used			
Activities In Excavation			
Competent Person			

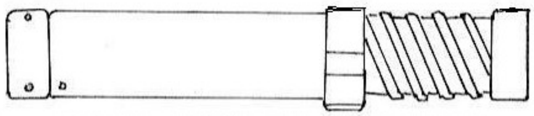
Excavation > 4 feet deep? ___Yes ___No

NOTE: **Trenches over 4 feet in depth are considered excavations. Any items marked *NO* on this form *MUST* be remediated prior to any employees entering the excavation.**

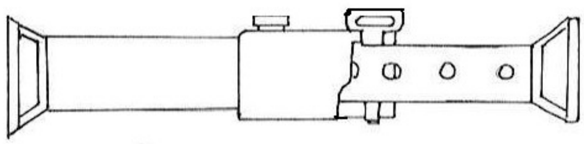
YES	NO	N/A	DESCRIPTION
			GENERAL
			Employees protected from cave-ins & loose rock/soil that could roll into the excavation
			Spoils, materials & equipment set back at least 2 feet from the edge of the excavation.
			Engineering designs for sheeting &/or manufacturer's data on trench box capabilities on site
			Adequate signs posted and barricades provided
			Training (toolbox meeting) conducted w/ employees prior to entering excavation
			UTILITIES
			Utility company contacted & given 24 hours notice &/or utilities already located & marked
			Overhead lines located, noted and reviewed with the operator
			Utility locations reviewed with the operator, & precautions taken to ensure contact does not occur
			Utilities crossing the excavation supported, and protected from falling materials
			Underground installations protected, supported or removed when excavation is open
			WET CONDITIONS
			Precautions taken to protect employees from water accumulation (continuous dewatering)
			Surface water or runoff diverted /controlled to prevent accumulation in the excavation
			Inspection made after every rainstorm or other hazard increasing occurrence

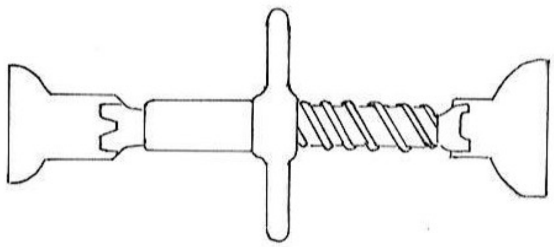
HAZARDOUS ATMOSPHERES			
			Air in the excavation tested for oxygen deficiency, combustibles, other contaminants
			Ventilation used in atmospheres that are oxygen rich/deficient &/or contains hazardous substances
			Ventilation provided to keep LEL below 10 %
			Emergency equipment available where hazardous atmospheres could or do exist
			Safety harness and lifeline used
			Supplied air necessary (if yes, contact safety department)
ENTRY & EXIT			
			Exit (i.e. ladder, sloped wall) no further than 25 feet from ANY employee
			Ladders secured and extend 3 feet above the edge of the trench
			Wood ramps constructed of uniform material thickness, cleated together @ the bottom
			Employees protected from cave-ins when entering or exiting the excavation

Explain how you have secured the site and made it safe to work inside (if possible)

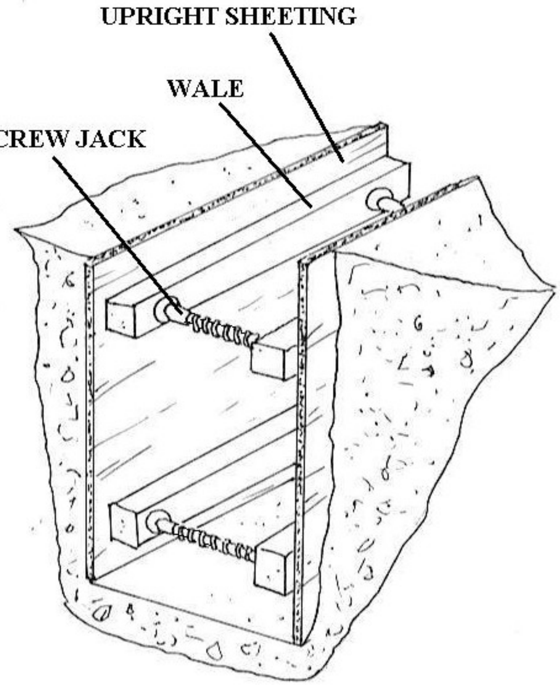


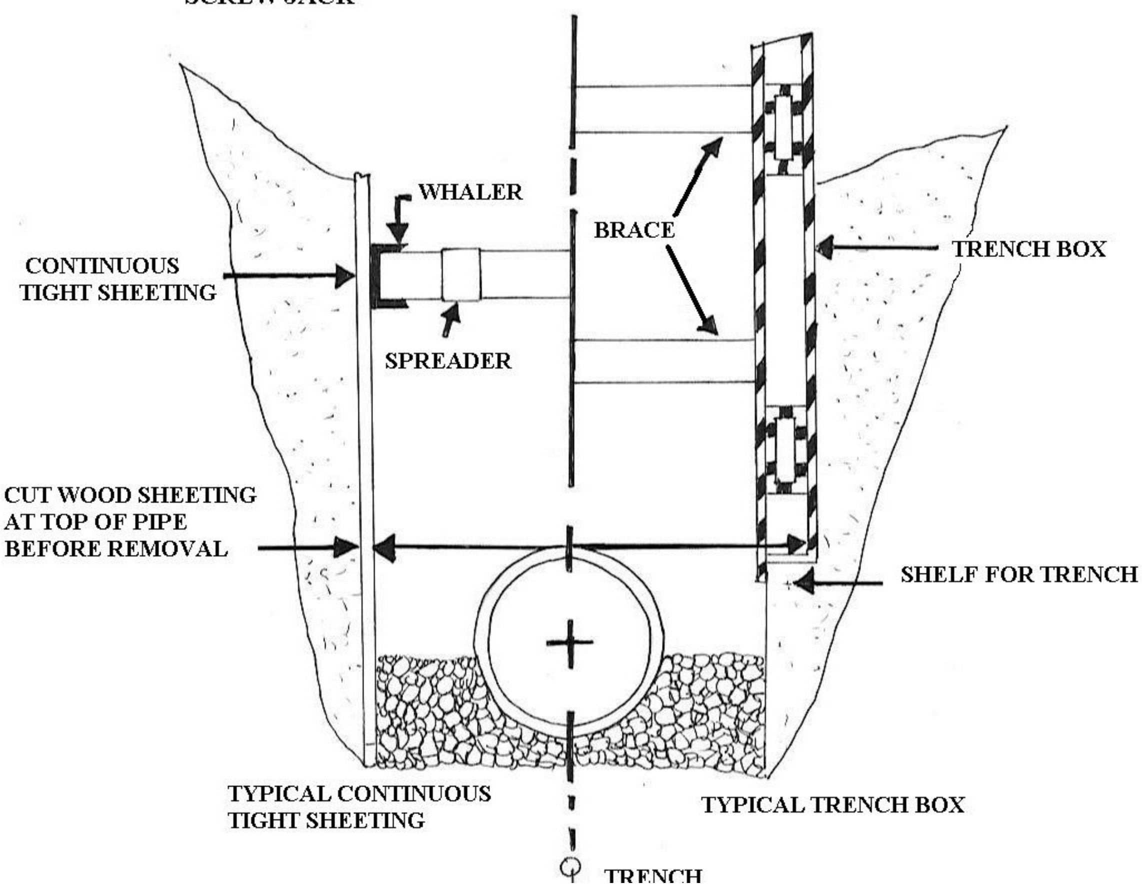
PNEUMATIC / HYDRAULIC JACKS

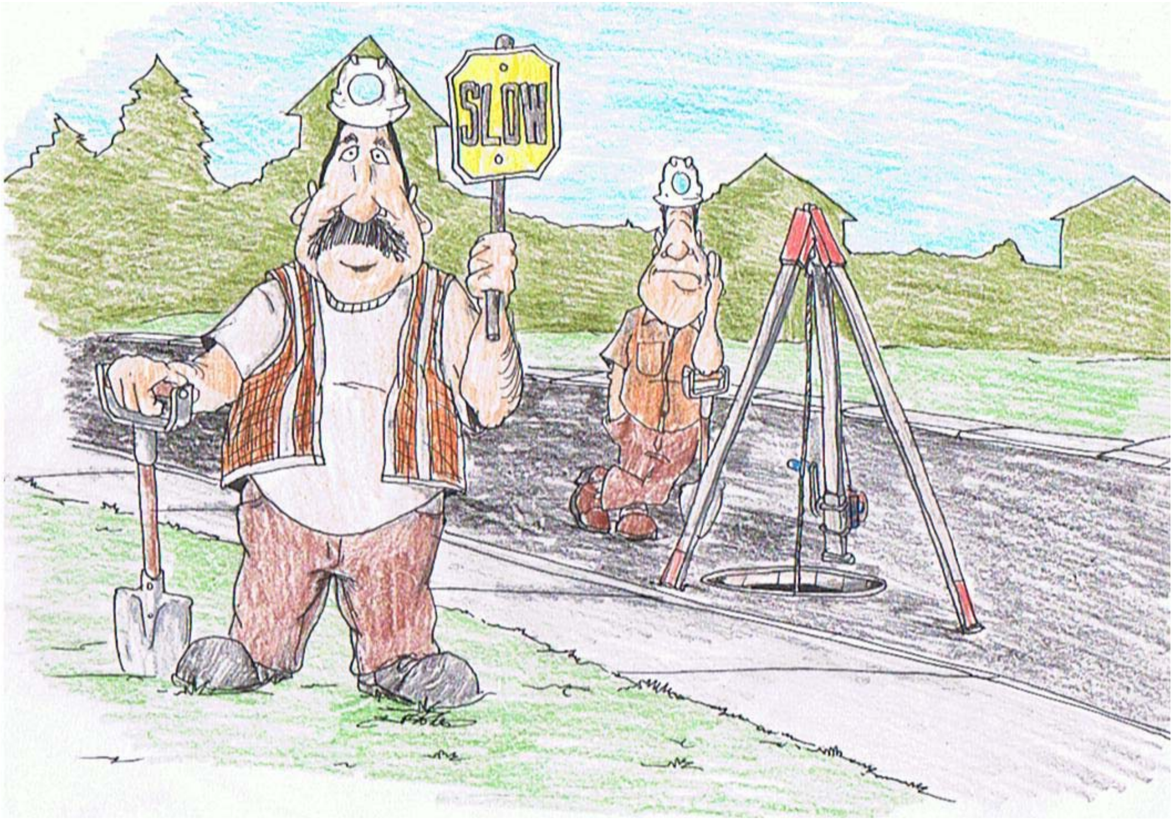




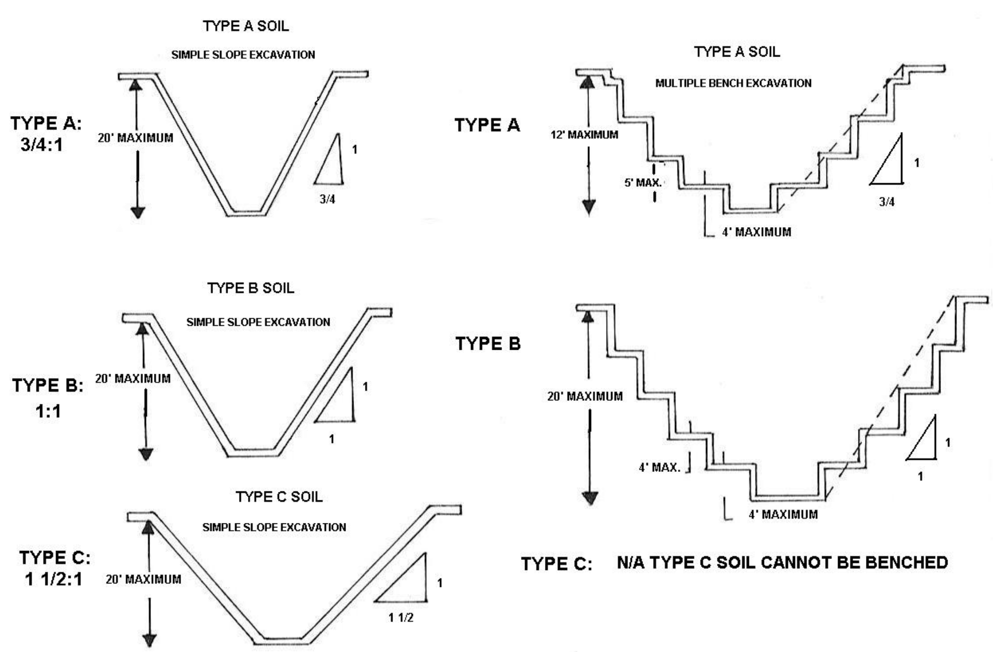
SCREW JACK







SLOPING **BENCHING**



One-call Center or Bluestakes

You are required to locate or call for proper buried utility locations before you dig or excavate. You will usually need a 48-hour notice before you excavate. Please check with your local one-call system.

Red marks mean-Electricity, Yellow marks-Gas, Blue marks-Water

Orange marks mean - Telephone & Fiber Optics

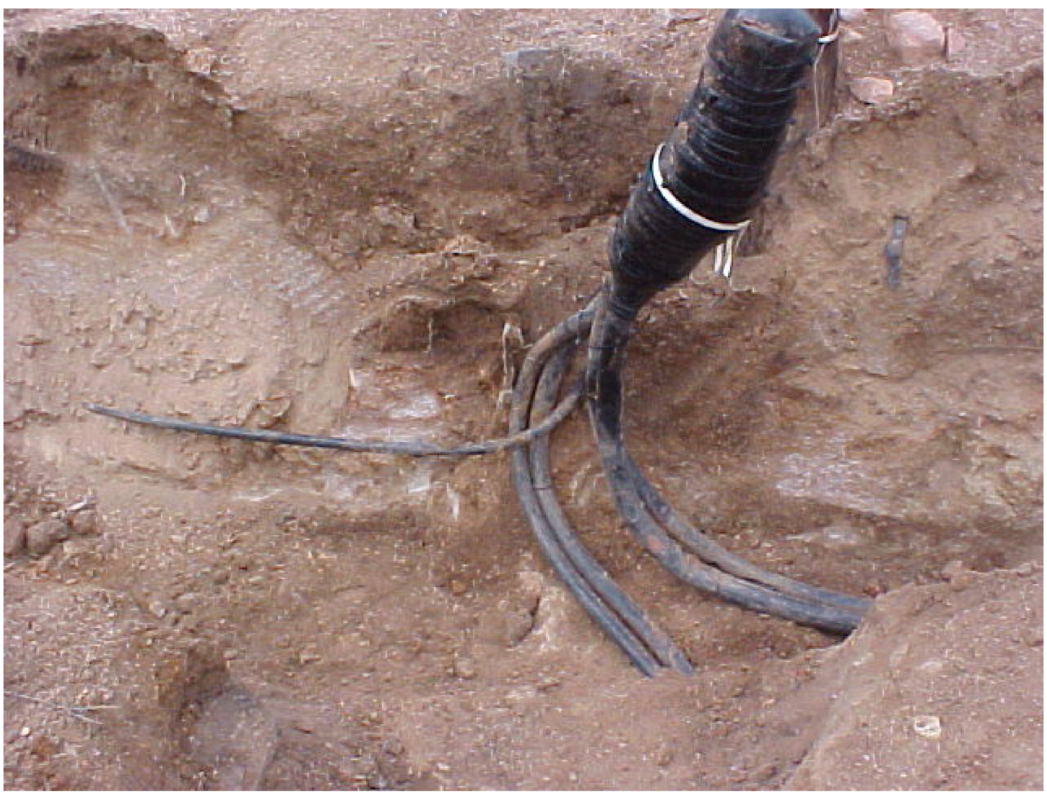
One Call Program

According to federal safety statistics, damage from unauthorized digging is the major cause of natural gas pipeline failures. To prevent excavation damage to all utilities, including pipelines, all 50 states have instituted "***One Call***" Programs. The programs provide telephone numbers for excavation contractors to call before excavation begins.

The one-call operator will notify a pipeline company of any planned excavation in the vicinity of its pipeline so that the company can flag the location of the pipeline and assign personnel to be present during excavation, if necessary.

In a related effort, a joint government-industry team has developed a public education program entitled "***Dig Safely***". The team involved representatives from the U.S. Department of Transportation, gas and liquid pipeline companies, distribution companies, excavators, the insurance industry, one-call systems and the telecommunications industry. This campaign provides information to the general public concerning underground utilities and the danger of unknowingly digging into buried lines and cables.

The program has posters, brochures and other printed materials available for use by interested organizations. For more information, contact **www.digsafely.com**.



Telephone Cables, nasty to dig around. It's almost as bad as electric lines.

One-Call Center, Underground Utilities

One Call Centers were established as a one-call notification system by underground facility owners to assist excavators with statutory requirements to notify underground facility owners prior to excavation. This damage prevention service is provided free of charge to any individual or company planning to excavate. By participating in the program and getting underground facilities located, you can:

- Comply with Federal Law
- Avoid Injuries
- Prevent costly damages and interruptions of facility services
- Save time and money
- Avoid hazards
- Eliminate construction delays

Color Codes for marking underground utility lines.

Red	**Electric Power**
Yellow	**Gas-Oil- Product Lines**
Orange	**Communication, Cable television**
Blue	**Water systems, slurry pipelines**
Green	**Sanitary sewer system**
Pink	**Temporary survey markings**

Example of a One-Call Center's Rules
Excavations: determining location of underground facilities; providing information; excavator marking; on-site representative; validity period of markings.

A. A person shall not make or begin any excavation in any public street, alley, right-of-way dedicated to the public use or utility easement or on any express or implied private property utility easement without first determining whether underground facilities will be encountered, and if so where they are located from each and every public utility, municipal corporation or other person having the right to bury such underground facilities within the public street, alley, right-of-way or utility easement and taking measures for control of the facilities in a careful and prudent manner.

B. Every public utility, municipal corporation or other person having the right to bury underground facilities shall file with the corporation commission the job title, address and telephone number of the person or persons from whom the necessary information may be obtained. Such person or persons shall be readily available during established business hours. The information on file shall also include the name, address and telephone number of each one-call notification center to which the owner of the facility belongs. Upon receipt of inquiry or notice from the excavator, the owner of the facility shall respond as promptly as practical, but in no event later than two days, by marking such facility with stakes, paint or in some customary manner. No person shall begin excavating before the location and marking are complete or the excavator is notified that marking is unnecessary.

C. On a timely request by the owner of a facility, the excavator shall mark the boundaries of the location requested to be excavated in accordance with a color code designated by the commission or by applicable custom or standard in the industry. A request under this subsection for excavator marking does not alter any other requirement of this section.

D. In performing the marking required by subsection B of this section, the owner of an underground facility installed after December 31, 1988 in a public street, alley or right-of–way dedicated to public use, but not including any express or implied private property utility easement, shall locate the facility by referring to installation records of the facility and utilizing one of the following methods:

1. Vertical line or facility markers.
2. Locator strip or locator wire.
3. Signs or permanent markers.
4. Electronic or magnetic location or tracing techniques.
5. Electronic or magnetic sensors or markers.
6. Metal sensors or sensing techniques.
7. Sonar techniques.
8. Underground electrical or radio transmitters.
9. Manual location techniques, including pot-holing.
10. Surface extensions of underground facilities.
11. Any other surface or subsurface location technique at least as accurate as the other marking methods in this subsection not prohibited by the commission or by federal or state law.

E. For an underground facility other than one installed after December 31, 1988, in a public street, alley or right-of-way dedicated to public use, in performing the marking required by subsection B of this section, the owner may refer to installation or other records relating to the facility to assist in locating the facility and shall locate the facility utilizing one of the methods listed under subsection D of this section.

If an underground facility owner is unable to complete the location and marking within the time period provided by subsection B of this section, the facility owner shall satisfy the requirements of this section by proving prompt notice of these facts to the excavator.

Assigning one or more representatives to be present on the excavation site at all pertinent times as requested by the excavator to provide facility location services until the facilities have been located and marked.

The underground facility owner shall bear all of its costs associated with assigning representatives. If representatives are assigned under this subsection, the excavator is not responsible or liable for damage or repair of the owner's underground facility while acting under the direction of an assigned representative of the owner, unless the damage or need for repair was caused by the excavator's negligence.

Lockout - Tagout Training Chapter
(LOTO) Lockout and Tagout

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 and 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's 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 tag-out 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 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.

Standard Operating Procedure (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 use of hasps, chains and valve covers with assigned individual locks.

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.

Release 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 have 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: 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 place his/her own lock and tag on the energy isolating device(s).

SOP: Management 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. However, the employee should leave the facility before removing his/her lock and tag, and the supervisor may remove the lock and tag. The supervisor must be assured that all tools have been removed, all guards have been replaced and all employees are free from any hazard before the lock and tag are removed and the machinery, equipment or process are returned to service. Notification of the employee who placed the lock is required prior to lock removal.

Contractors
Contractors working on our property and equipment must use this Lockout-Tagout procedure while servicing or maintaining equipment, machinery or processes.

Lockout - Tag out Safety Equipment
The employer will provide all Lockout-Tagout safety equipment and training to any employee that may need or work with electricity or powered equipment. Your supervisor will be able to provide any assistance or equipment.

Notice the chain for locking the wheel valve.

SAFETY SECTION 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. Has 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, and 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 is, the more unstable the soil is.

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 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 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 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.

BACKFLOW GLOSSARY

A

Absolute Pressure: 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).

Aerodynamics: The study of the flow of gases. The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law.

Aeronautics: The mathematics and mechanics of flying objects, in particular airplanes.

Air Break: A physical separation which may be a low inlet into the indirect waste receptor from the fixture, or device that is indirectly connected. You will most likely find an air break on waste fixtures or on non-potable lines. You should never allow an air break on an ice machine.

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

Altitude-Control Valve: If an overflow occurs on a storage tank, the operator should first check the altitude-control valve. Altitude-Control Valve is designed to, 1. Prevent overflows from the storage tank or reservoir, or 2. Maintain a constant water level as long as water pressure in the distribution system is adequate.

Angular Motion Formulas: Angular velocity can be expressed as (angular velocity = constant):

$\omega = \theta / t$ (2a)

where
ω= angular velocity (rad/s)
θ = angular displacement (rad)
t = time (s)

Angular velocity can be expressed as (angular acceleration = constant):
$\omega = \omega_o + \alpha t$ (2b)

where
ω_o = angular velocity at time zero (rad/s)
α = angular acceleration (rad/s^2)

Angular displacement can be expressed as (angular acceleration = constant):
$\theta = \omega_o t + 1/2 \alpha t^2$ (2c)

Combining 2a and 2c:
$\omega = (\omega_o^2 + 2 \alpha \theta)^{1/2}$

Angular acceleration can be expressed as:
$\alpha = d\omega / dt = d^2\theta / dt^2$ (2d)

where
$d\theta$ = change of angular displacement (rad)
dt = change in time (s)

Atmospheric Pressure: Pressure exerted by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute, 1 bar = 14.5psi.)

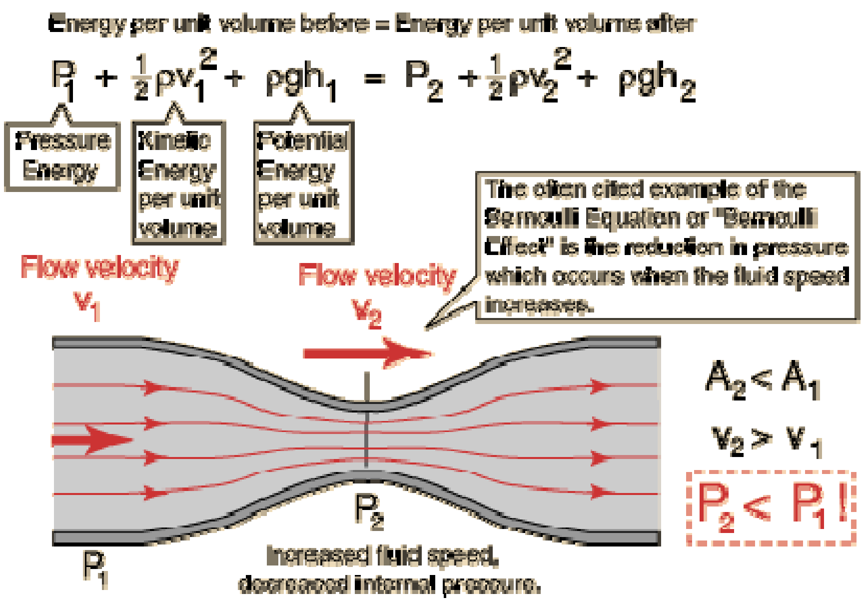
B

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

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

Backsiphonage: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point. Is a condition in which the pressure in the distribution system is less than atmospheric pressure. In other words, something is "sucked" into the system because the main is under a vacuum.

Bernoulli's Equation: Describes the behavior of moving fluids along a streamline. The Bernoulli Equation can be considered to be a statement of the conservation of energy principle appropriate for flowing fluids. The qualitative behavior that is usually labeled with the term "***Bernoulli effect***" is the lowering of fluid pressure in regions where the flow velocity is increased. This lowering of pressure in a constriction of a flow path may seem counterintuitive, but seems less so when you consider pressure to be energy density. In the high velocity flow through the constriction, kinetic energy must increase at the expense of pressure energy.



A special form of the Euler's equation derived along a fluid flow streamline is often called the **Bernoulli Equation.**

$$\frac{\partial}{\partial s}\left(\frac{v^2}{2}+\frac{p}{\rho}+g\cdot h\right)=0 \qquad (1)$$

where

v = flow speed

p = pressure

ρ = density

g = gravity

h = height

$$\frac{v^2}{2}+\frac{p}{\rho}+g\cdot h=\text{Constant} \qquad (2)$$

$$\frac{v^2}{2\cdot g}+\frac{p}{\gamma}+h=\text{Constant} \qquad (3)$$

where

$\gamma=\rho\cdot g$

$$\frac{\rho\cdot v^2}{2}+p=\text{Constant} \qquad (4)$$

$$\frac{\rho\cdot v^2}{2}=p_d \qquad (5)$$

$$\frac{\rho\cdot v_1^2}{2}+p_1=\frac{\rho\cdot v_2^2}{2}+p_2=\text{Constant} \qquad (6)$$

www.engineeringtoolbox.com

For steady state incompressible flow the Euler equation becomes (1). If we integrate (1) along the streamline it becomes (2). (2) can further be modified to (3) by dividing by gravity.

Head of Flow: Equation (3) is often referred to as the **head** because all elements have the unit of length.

Bernoulli's Equation Continued:
Dynamic Pressure
(2) and (3) are two forms of the Bernoulli Equation for steady state incompressible flow. If we assume that the gravitational body force is negligible, (3) can be written as (4). Both elements in the equation have the unit of pressure and it's common to refer the flow velocity component as the **dynamic pressure** of the fluid flow (5).

Since energy is conserved along the streamline, (4) can be expressed as (6). Using the equation we see that increasing the velocity of the flow will reduce the pressure, decreasing the velocity will increase the pressure.

This phenomena can be observed in a **venturi meter** where the pressure is reduced in the constriction area and regained after. It can also be observed in a **pitot tube** where the **stagnation** pressure is measured. The stagnation pressure is where the velocity component is zero.

Bernoulli's Equation Continued:

Pressurized Tank

If the tanks are pressurized so that product of gravity and height (g h) is much less than the pressure difference divided by the density, (e4) can be transformed to (e6).
The velocity out from the tanks depends mostly on the pressure difference.

Example - outlet velocity from a pressurized tank

The outlet velocity of a pressurized tank where

$p_1 = 0.2\ MN/m^2,\ p_2 = 0.1\ MN/m^2\ A_2/A_1 = 0.01,\ h = 10\ m$

can be calculated as
$V_2 = [(2/(1-(0.01)^2)\ (\ (0.2 - 0.1)x10^6\ /1x10^3 + 9.81\ x\ 10)]^{1/2} = \underline{19.9\ m/s}$

Coefficient of Discharge - Friction Coefficient

Due to friction the real velocity will be somewhat lower than this theoretical example. If we introduce a **friction coefficient** *c* (coefficient of discharge), (e5) can be expressed as (e5b). The coefficient of discharge can be determined experimentally. For a sharp edged opening it may be as low as 0.6. For smooth orifices it may be between 0.95 and 1.

Bingham Plastic Fluids: Bingham Plastic Fluids have a yield value which must be exceeded before it will start to flow like a fluid. From that point the viscosity will decrease with increase of agitation. Toothpaste, mayonnaise and tomato catsup are examples of such products.

Boundary Layer: The layer of fluid in the immediate vicinity of a bounding surface.

Bulk Modulus and Fluid Elasticity: An introduction to and a definition of the Bulk Modulus Elasticity commonly used to characterize the compressibility of fluids.

The Bulk Modulus Elasticity can be expressed as

$E = - dp / (dV / V)\ (1)$

where
E = bulk modulus elasticity
dp = differential change in pressure on the object
dV = differential change in volume of the object
V = initial volume of the object

The Bulk Modulus Elasticity can be alternatively expressed as

$E = - dp / (d\rho / \rho)\ (2)$

where
dρ = differential change in density of the object
ρ = initial density of the object

An increase in the pressure will decrease the volume (1). A decrease in the volume will increase the density (2).

- The SI unit of the bulk modulus elasticity is N/m^2 (Pa)
- The imperial (BG) unit is lb_f/in^2 (psi)

- 1 lb_f/in^2 (psi) = 6.894 10^3 N/m^2 (Pa)

A large Bulk Modulus indicates a relatively incompressible fluid.

Bulk Modulus for some common fluids can be found in the table below:

Bulk Modulus - *E*	Imperial Units - BG (psi, lb_f/in^2) x 10^5	SI Units (Pa, N/m^2) x 10^9
Carbon Tetrachloride	1.91	1.31
Ethyl Alcohol	1.54	1.06
Gasoline	1.9	1.3
Glycerin	6.56	4.52
Mercury	4.14	2.85
SAE 30 Oil	2.2	1.5
Seawater	3.39	2.35
Water	3.12	2.15

C

Capillarity: (or capillary action) The ability of a narrow tube to draw a liquid upwards against the force of gravity.

The height of liquid in a tube due to capillarity can be expressed as

$$h = 2 \sigma \cos\theta / (\rho g r) \quad (1)$$

where

h = height of liquid (ft, m)
σ = surface tension (lb/ft, N/m)
θ = contact angle
ρ = density of liquid (lb/ft³, kg/m³)
g = acceleration due to gravity (32.174 ft/s², 9.81 m/s²)
r = radius of tube (ft, m)

Cauchy Number: A dimensionless value useful for analyzing fluid flow dynamics problems where compressibility is a significant factor.
The Cauchy Number is the ratio between inertial and the compressibility force in a flow and can be expressed as

$$C = \rho v^2 / E \quad (1)$$

where

ρ = density (kg/m^3)
v = flow velocity (m/s)
E = bulk modulus elasticity (N/m^2)

The bulk modulus elasticity has the dimension pressure and is commonly used to characterize the compressibility of a fluid.

The Cauchy Number is the square root of the Mach Number

$M^2 = Ca$ *(3)*

where
C = Mach Number

Cavitation: Under the wrong condition, cavitation will reduce the components life time dramatically. Cavitation may occur when the local static pressure in a fluid reach a level below the vapor pressure of the liquid at the actual temperature. According to the Bernoulli Equation this may happen when the fluid accelerates in a control valve or around a pump impeller. The vaporization itself does not cause the damage - the damage happens when the vapor almost immediately collapses after evaporation when the velocity is decreased and pressure increased. Cavitation means that cavities are forming in the liquid that we are pumping. When these cavities form at the suction of the pump several things happen all at once: We experience a loss in capacity. We can no longer build the same head (pressure). The efficiency drops. The cavities or bubbles will collapse when they pass into the higher regions of pressure causing noise, vibration, and damage to many of the components. The cavities form for five basic reasons and it is common practice to lump all of them into the general classification of cavitation.

This is an error because we will learn that to correct each of these conditions we must understand why they occur and how to fix them. Here they are in no particular order: Vaporization, Air ingestion, Internal recirculation, Flow turbulence and finally the Vane Passing Syndrome.

Avoiding Cavitation

Cavitation can in general be avoided by:

- increasing the distance between the actual local static pressure in the fluid - and the vapor pressure of the fluid at the actual temperature

This can be done by:

- reengineering components initiating high speed velocities and low static pressures
- increasing the total or local static pressure in the system
- reducing the temperature of the fluid

Reengineering of Components Initiating High Speed Velocity and Low Static Pressure

Cavitation and damage can be avoided by using special components designed for the actual rough conditions.

- Conditions such as huge pressure drops can - with limitations - be handled by Multi Stage Control Valves
- Difficult pumping conditions - with fluid temperatures close to the vaporization temperature - can be handled with a special pump - working after another principle than the centrifugal pump.

Cavitation Continued: Increasing the Total or Local Pressure in the System
By increasing the total or local pressure in the system, the distance between the static pressure and the vaporization pressure is increased and vaporization and cavitation may be avoided.

The ratio between static pressure and the vaporization pressure, an indication of the possibility of vaporization, is often expressed by the Cavitation Number. Unfortunately it may not always be possible to increase the total static pressure due to system classifications or other limitations. Local static pressure in the component may then be increased by lowering the component in the system. Control valves and pumps should in general be positioned in the lowest part of the system to maximize the static head. This is common for boiler feeding pumps receiving hot condensate (water close to 100 ^{o}C) from a condensate receiver.

Cavitation Continued: Reducing the Temperature of the Fluid
The vaporization pressure is highly dependent on the fluid temperature. Water, our most common fluid, is an example:

Temperature (^{o}C)	Vapor Pressure (kN/m^2)
0	0.6
5	0.9
10	1.2
15	1.7
20	2.3
25	3.2
30	4.3
35	5.6
40	7.7
45	9.6
50	12.5
55	15.7
60	20
65	25
70	32.1
75	38.6
80	47.5
85	57.8
90	70
95	84.5
100	101.33

As we can see - the possibility of evaporation and cavitation increases dramatically with the water temperature.

Cavitation can be avoided by locating the components in the coldest part of the system. For example, it is common to locate the pumps in heating systems at the "cold" return lines. The situation is the same for control valves. Where it is possible they should be located on the cold side of heat exchangers.

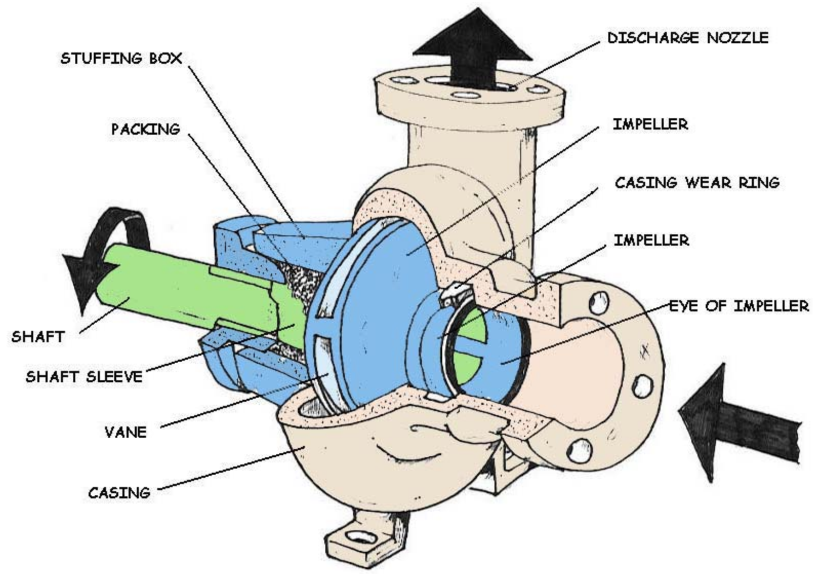
Cavitations Number: A "special edition" of the dimensionless Euler Number.

The Cavitations Number is useful for analyzing fluid flow dynamics problems where cavitations may occur. The Cavitations Number can be expressed as

$$Ca = (p_r - p_v) / 1/2 \rho v^2 \quad (1)$$

where
Ca = Cavitations number
p_r = reference pressure (Pa)
p_v = vapor pressure of the fluid (Pa)
ρ = density of the fluid (kg/m^3)
v = velocity of fluid (m/s)

Centrifugal Pump: A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.



Chezy Formula: Conduits flow and mean velocity. The Chezy formula can be used to calculate mean flow velocity in conduits and is expressed as

$$v = c (R S)^{1/2} \quad (1)$$

where
v = mean velocity (m/s, ft/s)
c = the Chezy roughness and conduit coefficient
R = hydraulic radius of the conduit (m, ft)
S = slope of the conduit (m/m, ft/ft)

In general the Chezy coefficient - *c* - is a function of the flow Reynolds Number - Re - and the relative roughness - *ε/R* - of the channel.
ε is the characteristic height of the roughness elements on the channel boundary.

Coanda Effect: The tendency of a stream of fluid to stay attached to a convex surface, rather than follow a straight line in its original direction.

Colebrook Equation: The friction coefficients used to calculate pressure loss (or major loss) in ducts, tubes and pipes can be calculated with the Colebrook equation.

$1 / \lambda^{1/2} = -2 \log ((2.51 / (Re\ \lambda^{1/2})) + ((k / d_h) / 3.72))$ *(1)*

where
λ = D'Arcy-Weisbach friction coefficient
Re = Reynolds Number
k = roughness of duct, pipe or tube surface (m, ft)
d_h = hydraulic diameter (m, ft)

The Colebrook equation is only valid at turbulent flow conditions.
Note that the friction coefficient is involved on both sides of the equation and that the equation must be solved by iteration.

The Colebrook equation is generic and can be used to calculate the friction coefficients in different kinds of fluid flows - air ventilation ducts, pipes and tubes with water or oil, compressed air and much more.

Common Pressure Measuring Devices: The Strain Gauge is a common measuring device used for a variety of changes such as head. As the pressure in the system changes, the diaphragm expands which changes the length of the wire attached. This change of length of the wire changes the Resistance of the wire, which is then converted to head. Float mechanisms, diaphragm elements, bubbler tubes, and direct electronic sensors are common types of level sensors.

Compressible Flow: We know that fluids are classified as Incompressible and Compressible fluids. Incompressible fluids do not undergo significant changes in density as they flow. In general, liquids are incompressible; water being an excellent example. In contrast compressible fluids do undergo density changes.

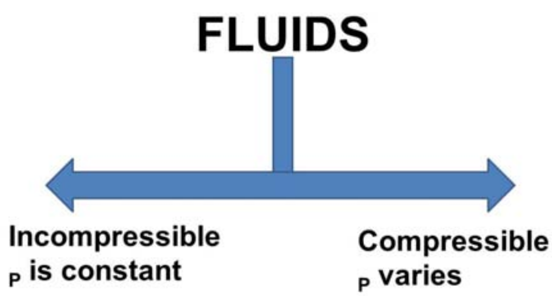
Gases are generally compressible; air being the most common compressible fluid we can find. Compressibility of gases leads to many interesting features such as shocks, which are absent for incompressible fluids. Gas dynamics is the discipline that studies the flow of compressible fluids and forms an important branch of Fluid Mechanics. In this book we give a broad introduction to the basics of compressible fluid flow.

In a compressible flow the compressibility of the fluid must be taken into account. The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law. Properties of **Gas Mixtures** - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density. The Individual and **Universal Gas Constant** - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Compression and Expansion of Gases: If the compression or expansion takes place under constant temperature conditions - the process is called **isothermal.** The isothermal process can on the basis of the Ideal Gas Law be expressed as:

p / ρ = constant (1)

where
p = absolute pressure
ρ = density



Confined Space Entry: Entry into a confined space requires that all entrants wear a harness and safety line. If an operator is working inside a storage tank and suddenly faints or has a serious problem, there should be two people outside standing by to remove the injured operator.

Conservation Laws: The conservation laws states that particular measurable properties of an isolated physical system does not change as the system evolves: Conservation of energy (including mass). Fluid Mechanics and Conservation of Mass - The law of conservation of mass states that mass can neither be created or destroyed.

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

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

Corrosion: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

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

D

Darcy-Weisbach Equation: The **pressure loss** (or major loss) in a pipe, tube or duct can be expressed with the D'Arcy-Weisbach equation:

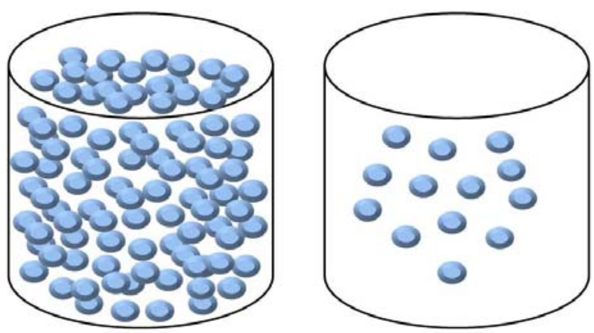
$\Delta p = \lambda (l / d_h) (\rho v^2 / 2)$ *(1)*

where
Δp *= pressure loss (Pa, N/m², lb_f/ft²)*
λ *= D'Arcy-Weisbach friction coefficient*
l *= length of duct or pipe (m, ft)*
d_h *= hydraulic diameter (m, ft)*
ρ *= density (kg/m³, lb/ft³)*

Note! Be aware that there are two alternative friction coefficients present in the literature. One is 1/4 of the other and (1) must be multiplied with four to achieve the correct result. This is important to verify when selecting friction coefficients from Moody diagrams.

Density: Is a physical property of matter, as each element and compound has a unique density associated with it.

Density defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume. For example: A rock is obviously more dense than a crumpled piece of paper of the same size. A Styrofoam cup is less dense than a ceramic cup. Density may also refer to how closely "packed" or "crowded" the material appears to be - again refer to the Styrofoam vs. ceramic cup. Take a look at the two boxes below.



Each box has the same volume. ***If each ball has the same mass, which box would weigh more? Why?***

The box that has more balls has more mass per unit of volume. This property of matter is called density. The density of a material helps to distinguish it from other materials. Since mass is usually expressed in grams and volume in cubic centimeters, density is expressed in grams/cubic centimeter. We can calculate density using the formula:

Density= Mass/Volume

The density can be expressed as

$\rho = m / V = 1 / v_g$ (1)

where
ρ = density (kg/m^3)
m = mass (kg)
V = volume (m^3)
v_g = specific volume (m^3/kg)

The SI units for density are kg/m^3. The imperial (BG) units are lb/ft^3 ($slugs/ft^3$). While people often use pounds per cubic foot as a measure of density in the U.S., pounds are really a measure of force, not mass. Slugs are the correct measure of mass. You can multiply slugs by 32.2 for a rough value in pounds. The higher the density, the tighter the particles are packed inside the substance. Density is a physical property constant at a given temperature and density can help to identify a substance.

Example - Use the Density to Identify the Material:
An unknown liquid substance has a mass of 18.5 g and occupies a volume of 23.4 ml. (milliliter).

The density can be calculated as

$$\rho = [18.5 (g) / 1000 (g/kg)] / [23.4 (ml) / 1000 (ml/l) 1000 (l/m^3)]$$
$$= 18.5\ 10^{-3} (kg) / 23.4\ 10^{-6} (m^3)$$
$$= \underline{790}\ kg/m^3$$

If we look up densities of some common substances, we can find that ethyl alcohol, or ethanol, has a density of <u>790</u> kg/m^3. Our unknown liquid may likely be ethyl alcohol!

Example - Use Density to Calculate the Mass of a Volume
The density of titanium is 4507 kg/m^3 . Calculate the mass of 0.17 m^3 titanium!

$$m = 0.17 (m^3) 4507 (kg/m^3)$$
$$= \underline{766.2}\ kg$$

Dilatant Fluids: Shear Thickening Fluids **or** Dilatant Fluids increase their viscosity with agitation. Some of these liquids can become almost solid within a pump or pipe line. With agitation, cream becomes butter and Candy compounds, clay slurries and similar heavily filled liquids do the same thing.

Disinfect: To kill and inhibit growth of harmful bacterial and viruses in drinking water.

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

Distribution System Water Quality: Can be adversely affected by improperly constructed or poorly located blowoffs of vacuum/air relief valves. Air relief valves in the distribution system lines must be placed in locations that cannot be flooded. This is to prevent water contamination. The common customer complaint of Milky Water or Entrained Air is sometimes solved by the installation of air relief valves. The venting of air is not a major concern when checking water levels in a storage tank. If the vent line on a ground level storage tank is closed or clogged up, a vacuum will develop in the tank may happen to the tank when the water level begins to lower.

Drag Coefficient: Used to express the drag of an object in moving fluid. Any object moving through a fluid will experience a drag - the net force in direction of flow due to the pressure and shear stress forces on the surface of the object.

The drag force can be expressed as:

$$F_d = c_d \; 1/2 \; \rho \; v^2 \; A \quad (1)$$

where
F_d = *drag force (N)*
c_d = *drag coefficient*
ρ = *density of fluid*
v = *flow velocity*
A = *characteristic frontal area of the body*

The drag coefficient is a function of several parameters as shape of the body, Reynolds Number for the flow, Froude number, Mach Number and Roughness of the Surface.
The characteristic frontal area - *A* - depends on the body.

Dynamic or Absolute Viscosity: The viscosity of a fluid is an important property in the analysis of liquid behavior and fluid motion near solid boundaries. The viscosity of a fluid is its resistance to shear or flow and is a measure of the adhesive/cohesive or frictional properties of a fluid. The resistance is caused by intermolecular friction exerted when layers of fluids attempts to slide by another.

Dynamic Pressure: Dynamic pressure is the component of fluid pressure that represents a fluids kinetic energy. The dynamic pressure is a defined property of a moving flow of gas or liquid and can be expressed as

$$p_d = 1/2 \; \rho \; v^2 \quad (1)$$

where
p_d = *dynamic pressure (Pa)*
ρ = *density of fluid* (kg/m^3)
v = *velocity (m/s)*

Dynamic, Absolute and Kinematic Viscosity: The viscosity of a fluid is an important property in the analysis of liquid behavior and fluid motion near solid boundaries. The viscosity is the fluid resistance to shear or flow and is a measure of the adhesive/cohesive or frictional fluid property. The resistance is caused by intermolecular friction exerted when layers of fluids attempts to slide by another.

Viscosity is a measure of a fluid's resistance to flow.

The knowledge of viscosity is needed for proper design of required temperatures for storage, pumping or injection of fluids.

Common used units for viscosity are
- CentiPoises (cp) = CentiStokes (cSt) × Density
- SSU[1] = Centistokes (cSt) × 4.55
- Degree Engler[1] × 7.45 = Centistokes (cSt)
- Seconds Redwood[1] × 0.2469 = Centistokes (cSt)

[1]centistokes greater than 50

There are two related measures of fluid viscosity - known as **dynamic** (**or absolute**) and **kinematic** viscosity.

Dynamic (absolute) Viscosity: The tangential force per unit area required to move one horizontal plane with respect to the other at unit velocity when maintained a unit distance apart by the fluid. The shearing stress between the layers of non-turbulent fluid moving in straight parallel lines can be defined for a Newtonian fluid as:

The dynamic or absolute viscosity can be expressed like

$$\tau = \mu \, dc/dy \quad (1)$$

where
τ = shearing stress
μ = dynamic viscosity

Equation (1) is known as the **Newton's Law of Friction**.

In the SI system the dynamic viscosity units are **$N\ s/m^2$**, **Pa s** or **kg/m s** where
- *1 Pa s = 1 N s/m^2 = 1 kg/m s*

The dynamic viscosity is also often expressed in the metric CGS (centimeter-gram-second) system as **g/cm.s**, **dyne.s/cm^2** or **poise (p)** where
- *1 poise = dyne s/cm^2 = g/cm s = 1/10 Pa s*

For practical use the Poise is to large and its usual divided by 100 into the smaller unit called the **centiPoise (cP)** where
- *1 p = 100 cP*

Water at 68.4°F (20.2°C) has an absolute viscosity of one - 1 - centiPoise.

E

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

Elevation Head: The energy possessed per unit weight of a fluid because of its elevation. 1 foot of water will produce .433 pounds of pressure head.

Energy: The ability to do work. Energy can exist in one of several forms, such as heat, light, mechanical, electrical, or chemical. Energy can be transferred to different forms. It also can exist in one of two states, either potential or kinetic.

Energy and Hydraulic Grade Line: The hydraulic grade and the energy line are graphical forms of the Bernoulli equation. For steady, in viscid, incompressible flow the total energy remains constant along a stream line as expressed through the Bernoulli

Equation:

$p + 1/2\ \rho\ v^2 + \gamma\ h$ = constant along a streamline (1)

where
p = static pressure (relative to the moving fluid)
ρ = density
γ = specific weight
v = flow velocity
g = acceleration of gravity
h = elevation height

Each term of this equation has the dimension *force per unit area* - psi, lb/ft^2 or N/m^2.

The Head

By dividing each term with the specific weight - $\gamma = \rho\ g$ - (1) can be transformed to express the "head":

$p / \gamma + v^2 / 2\ g + h$ = constant along a streamline = H (2)
where
H = the total head

Each term of this equation has the dimension length - ft, m.

The Total Head

(2) states that the sum of **pressure head** - p / γ -, **velocity head** - $v^2 / 2\ g$ - and **elevation head** - h - is constant along the stream line. This constant can be called **the total head** - H -.

The total head in a flow can be measured by the stagnation pressure using a pitot tube.

Energy and Hydraulic Grade Line Continued:

The Piezometric Head

The sum of pressure head - p / γ - and elevation head - h - is called **the piezometric head**. The piezometric head in a flow can be measured through an flat opening parallel to the flow.

Energy and Hydraulic Grade Line Continued:

The Energy Line

The Energy Line is a line that represents the total head available to the fluid and can be expressed as:

$EL = H = p / \gamma + v^2 / 2\ g + h$ = constant along a streamline (3)

where
EL = Energy Line

For a fluid flow without any losses due to friction (major losses) or components (minor losses) the energy line would be at a constant level. In the practical world the energy line decreases along the flow due to the losses.

A turbine in the flow will reduce the energy line and a pump or fan will increase the energy line.

The Hydraulic Grade Line
The Hydraulic Grade Line is a line that represent the total head available to the fluid minus the velocity head and can be expressed as:

$$HGL = p / \gamma + h \quad (4)$$

where
HGL = Hydraulic Grade Line

The hydraulic grade line lies one velocity head below the energy line.

Entrance Length and Developed Flow: Fluids need some length to develop the velocity profile after entering the pipe or after passing through components such as bends, valves, pumps, and turbines or similar.

The Entrance Length: The entrance length can be expressed with the dimensionless Entrance Length Number**:**

$$El = l_e / d \quad (1)$$

where
El = Entrance Length Number
l_e = length to fully developed velocity profile
d = tube or duct diameter

The Entrance Length Number for Laminar Flow
The Entrance length number correlation with the Reynolds Number for laminar flow can be expressed as:

$$El_{laminar} = 0.06\, Re \quad (2)$$

where
Re = Reynolds Number

The Entrance Length Number for Turbulent Flow
The Entrance length number correlation with the Reynolds Number for turbulent flow can be expressed as:

$$El_{turbulent} = 4.4\, Re^{1/6} \quad (3)$$

Entropy in Compressible Gas Flow: Calculating entropy in compressible gas flow
Entropy change in compressible gas flow can be expressed as

$ds = c_v \ln(T_2 / T_1) + R \ln(\rho_1 / \rho_2)$ (1)
or
$ds = c_p \ln(T_2 / T_1) - R \ln(p_2 / p_1)$ (2)

where
ds = entropy change
c_v *= specific heat capacity at a constant volume process*
c_p *= specific heat capacity at a constant pressure process*
T = absolute temperature
R = individual gas constant
ρ = density of gas
p = absolute pressure

Equation of Continuity: The Law of Conservation of Mass states that mass can be neither created nor destroyed. Using the Mass Conservation Law on a **steady flow** process - flow where the flow rate doesn't change over time - through a control volume where the stored mass in the control volume doesn't change - implements that inflow equals outflow. This statement is called **the Equation of Continuity.** Common application where **the Equation of Continuity** can be used are pipes, tubes and ducts with flowing fluids and gases, rivers, overall processes as power plants, diaries, logistics in general, roads, computer networks and semiconductor technology and more.

The Equation of Continuity and can be expressed as:

$$m = \rho_{i1} v_{i1} A_{i1} + \rho_{i2} v_{i2} A_{i2} +..+ \rho_{in} v_{in} A_{im}$$
$$= \rho_{o1} v_{o1} A_{o1} + \rho_{o2} v_{o2} A_{o2} +..+ \rho_{om} v_{om} A_{om} \quad (1)$$

where
m = mass flow rate (kg/s)
ρ = density (kg/m^3)
v = speed (m/s)
A = area (m^2)
With uniform density equation (1) can be modified to

$$q = v_{i1} A_{i1} + v_{i2} A_{i2} +..+ v_{in} A_{im}$$
$$= v_{o1} A_{o1} + v_{o2} A_{o2} +..+ v_{om} A_{om} \quad (2)$$

where
q = flow rate (m^3/s)
$\rho_{i1} = \rho_{i2} = . . = \rho_{in} = \rho_{o1} = \rho_{o2} = . .= \rho_{om}$

Example - Equation of Continuity
10 m^3/h of water flows through a pipe of 100 mm inside diameter. The pipe is reduced to an inside dimension of 80 mm. Using equation (2) the velocity in the 100 mm pipe can be calculated as

$$(10\ m^3/h)(1 / 3600\ h/s) = v_{100}\ (3.14 \times 0.1\ (m) \times 0.1\ (m) / 4)$$
or
$$v_{100} = (10\ m^3/h)(1 / 3600\ h/s) / (3.14 \times 0.1\ (m) \times 0.1\ (m) / 4)$$
$$= \underline{0.35}\ m/s$$

Using equation (2) the velocity in the 80 mm pipe can be calculated

$$(10\ m^3/h)(1 / 3600\ h/s) = v_{80}\ (3.14 \times 0.08\ (m) \times 0.08\ (m) / 4)$$

or
$v_{100} = (10\ m^3/h)(1 / 3600\ h/s) / (3.14 \times 0.08\ (m) \times 0.08\ (m) / 4)$
$= \underline{0.55}\ m/s$

Equation of Mechanical Energy: The Energy Equation is a statement of the first law of thermodynamics. The energy equation involves energy, heat transfer and work. With certain limitations the mechanical energy equation can be compared to the Bernoulli Equation and transferred to the Mechanical Energy Equation in Terms of Energy per Unit Mass.

The mechanical energy equation for a **pump or a fan** can be written in terms of **energy per unit mass**:

$$p_{in} / \rho + v_{in}^2 / 2 + g\ h_{in} + w_{shaft} = p_{out} / \rho + v_{out}^2 / 2 + g\ h_{out} + w_{loss} \quad (1)$$

where
p = *static pressure*
ρ = *density*
v = *flow velocity*
g = *acceleration of gravity*
h = *elevation height*
w_{shaft} = *net shaft energy inn per unit mass for a pump, fan or similar*
w_{loss} = *loss due to friction*

The energy equation is often used for incompressible flow problems and is called **the Mechanical Energy Equation** or **the Extended Bernoulli Equation**.

The mechanical energy equation for a **turbine** can be written as:

$$p_{in} / \rho + v_{in}^2 / 2 + g\ h_{in} = p_{out} / \rho + v_{out}^2 / 2 + g\ h_{out} + w_{shaft} + w_{loss} \quad (2)$$

where
w_{shaft} = *net shaft energy out per unit mass for a turbine or similar*

Equation (1) and (2) dimensions are
energy per unit mass ($ft^2/s^2 = ft\ lb/slug$ or $m^2/s^2 = N\ m/kg$)

Efficiency
According to (1) a larger amount of loss - w_{loss} - result in more shaft work required for the same rise of output energy. The efficiency of a **pump or fan process** can be expressed as:

$$\eta = (w_{shaft} - w_{loss}) / w_{shaft} \quad (3)$$

The efficiency of a **turbine process** can be expressed as:

$$\eta = w_{shaft} / (w_{shaft} + w_{loss}) \quad (4)$$

The Mechanical Energy Equation in Terms of Energy per Unit Volume
The mechanical energy equation for a **pump or a fan** (1) can also be written in terms of **energy per unit volume** by multiplying (1) with fluid density - ρ:

$p_{in} + \rho\ v_{in}^2 / 2 + \gamma\ h_{in} + \rho\ w_{shaft} = p_{out} + \rho\ v_{out}^2 / 2 + \gamma\ h_{out} + w_{loss}$ *(5)*

where
$\gamma = \rho\ g$ = *specific weight*

The dimensions of equation (5) are
energy per unit volume ($ft.lb/ft^3 = lb/ft^2$ or $N.m/m^3 = N/m^2$)

The Mechanical Energy Equation in Terms of Energy per Unit Weight involves Heads
The mechanical energy equation for a **pump or a fan** (1) can also be written in terms of **energy per unit weight** by dividing with gravity - *g*:

$p_{in} / \gamma + v_{in}^2 / 2\ g + h_{in} + h_{shaft} = p_{out} / \gamma + v_{out}^2 / 2\ g + h_{out} + h_{loss}$ *(6)*

where
$\gamma = \rho\ g$ = *specific weight*
$h_{shaft} = w_{shaft} / g$ = *net shaft energy head inn per unit mass for a pump, fan or similar*
$h_{loss} = w_{loss} / g$ = *loss head due to friction*

The dimensions of equation (6) are

energy per unit weight ($ft.lb/lb = ft$ or $N.m/N = m$)

Head is the energy per unit weight.

h_{shaft} can also be expressed as:
$h_{shaft} = w_{shaft} / g = W_{shaft} / m\ g = W_{shaft} / \gamma\ Q$ *(7)*

where
W_{shaft} = *shaft power*
m = mass flow rate
Q = volume flow rate

Example - Pumping Water
Water is pumped from an open tank at level zero to an open tank at level 10 ft. The pump adds four horsepowers to the water when pumping 2 ft^3/s.
Since $v_{in} = v_{out} = 0$, $p_{in} = p_{out} = 0$ and $h_{in} = 0$ - equation (6) can be modified to:

$h_{shaft} = h_{out} + h_{loss}$
or
$h_{loss} = h_{shaft} - h_{out}$ (8)

Equation (7) gives:

$h_{shaft} = W_{shaft} / \gamma\ Q = (4\ hp)(550\ ft.lb/s/hp) / (62.4\ lb/ft^3)(2\ ft^3/s) = 17.6\ ft$

- specific weight of water 62.4 lb/ft^3
- 1 hp (English horse power) = 550 ft. lb/s

Combined with (8):

h_{loss} = *(17.6 ft) - (10 ft) = 7.6 ft*

The pump efficiency can be calculated from (3) modified for head:

η = ((17.6 ft) - (7.6 ft)) / (17.6 ft)= 0.58

Equations in Fluid Mechanics: Common fluid mechanics equations - Bernoulli, conservation of energy, conservation of mass, pressure, Navier-Stokes, ideal gas law, Euler equations, Laplace equations, Darcy-Weisbach Equation and the following:

The Bernoulli Equation

- The Bernoulli Equation - A statement of the conservation of energy in a form useful for solving problems involving fluids. For a non-viscous, incompressible fluid in steady flow, the sum of pressure, potential and kinetic energies per unit volume is constant at any point.

Conservation laws

- The conservation laws states that particular measurable properties of an isolated physical system does not change as the system evolves.
- Conservation of energy (including mass)
- Fluid Mechanics and Conservation of Mass - The law of conservation of mass states that mass can neither be created nor destroyed.
- The Continuity Equation - The Continuity Equation is a statement that mass is conserved.

Darcy-Weisbach Equation

- Pressure Loss and Head Loss due to Friction in Ducts and Tubes - Major loss - head loss or pressure loss - due to friction in pipes and ducts.

Euler Equations

- In fluid dynamics, the Euler equations govern the motion of a compressible, inviscid fluid. They correspond to the Navier-Stokes equations with zero viscosity, although they are usually written in the form shown here because this emphasizes the fact that they directly represent conservation of mass, momentum, and energy.

Laplace's Equation

- The Laplace Equation describes the behavior of gravitational, electric, and fluid potentials.

Ideal Gas Law

- The Ideal Gas Law - For a perfect or ideal gas, the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law.
- Properties of Gas Mixtures - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density.
- The Individual and Universal Gas Constant - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Navier-Stokes Equations

- The motion of a non-turbulent, Newtonian fluid is governed by the Navier-Stokes equations. The equation can be used to model turbulent flow, where the fluid parameters are interpreted as time-averaged values.

Mechanical Energy Equation

- The Mechanical Energy Equation - The mechanical energy equation in Terms of Energy per Unit Mass, in Terms of Energy per Unit Volume and in Terms of Energy per Unit Weight involves Heads.

Pressure

- Static Pressure and Pressure Head in a Fluid - Pressure and pressure head in a static fluid.

Euler Equations: In fluid dynamics, the Euler equations govern the motion of a compressible, inviscid fluid. They correspond to the Navier-Stokes equations with zero viscosity, although they are usually written in the form shown here because this emphasizes the fact that they directly represent conservation of mass, momentum, and energy.

Euler Number: The Euler numbers, also called the secant numbers or zig numbers, are defined for $|x| < \pi/2$ by

$$\operatorname{sech} x - 1 \equiv -\frac{E_1^* x^2}{2!} + \frac{E_2^* x^4}{4!} - \frac{E_3^* x^6}{6!} + \ldots$$

$$\sec x - 1 \equiv \frac{E_1^* x^2}{2!} + \frac{E_2^* x^4}{4!} + \frac{E_3^* x^6}{6!} + \ldots,$$

where $\operatorname{sech}(z)$the hyperbolic secant and sec is the secant. Euler numbers give the number of odd alternating permutations and are related to Genocchi numbers. The base *e* of the natural logarithm is sometimes known as Euler's number. A different sort of Euler number, the Euler number of a finite complex K, is defined by

$$\chi(K) = \sum (-1)^p \operatorname{rank}(C_p(K)).$$

This Euler number is a topological invariant. To confuse matters further, the Euler characteristic is sometimes also called the "Euler number," and numbers produced by the prime-generating polynomial $n^2 - n + 41$are sometimes called "Euler numbers" (Flannery and Flannery 2000, p. 47).

F

Fecal Coliform: A group of bacteria that may indicate the presence of human or animal fecal matter in water.

Filtration: A series of processes that physically remove particles from water.

Flood Rim: The point of an object where the water would run over the edge of something and begin to cause a flood. See Air Break.

Fluids: A fluid is defined as a substance that continually deforms (flows) under an applied shear stress regardless of the magnitude of the applied stress. It is a subset of the phases of matter and includes liquids, gases, plasmas and, to some extent, plastic solids. Fluids are also divided into liquids and gases. Liquids form a free surface (that is, a surface not created by their container) while gases do not.

The distinction between solids and fluids is not so obvious. The distinction is made by evaluating the viscosity of the matter: for example silly putty can be considered either a solid or a fluid, depending on the time period over which it is observed. Fluids share the properties of not resisting deformation and the ability to flow (also described as their ability to take on the shape of their containers).

These properties are typically a function of their inability to support a shear stress in static equilibrium. While in a solid, stress is a function of strain, in a fluid, stress is a function of rate of strain. A consequence of this behavior is Pascal's law which entails the important role of pressure in characterizing a fluid's state. Based on how the stress depends on the rate of strain and its derivatives, fluids can be characterized as: Newtonian fluids: where stress is directly proportional to rate of strain, and Non-Newtonian fluids : where stress is proportional to rate of strain, its higher powers and derivatives (basically everything other than Newtonian fluid).

The behavior of fluids can be described by a set of partial differential equations, which are based on the conservation of mass, linear and angular momentum (Navier-Stokes equations) and energy. The study of fluids is fluid mechanics, which is subdivided into fluid dynamics and fluid statics depending on whether the fluid is in motion or not. Fluid **Related Information**: The Bernoulli Equation - A statement of the conservation of energy in a form useful for solving problems involving fluids. For a non-viscous, incompressible fluid in steady flow, the sum of pressure, potential and kinetic energies per unit volume is constant at any point. Equations in Fluid Mechanics - Continuity, Euler, Bernoulli, Dynamic and Total Pressure. Laminar, Transitional or Turbulent Flow? - It is important to know if the fluid flow is laminar, transitional or turbulent when calculating heat transfer or pressure and head loss.

Friction Head: 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.

G

Gas: A gas is one of the four major phases of matter (after solid and liquid, and followed by plasma) that subsequently appear as solid material when they are subjected to increasingly higher temperatures. Thus, as energy in the form of heat is added, a solid (e.g., ice) will first melt to become a liquid (e.g., water), which will then boil or evaporate to become a gas (e.g., water vapor). In some circumstances, a solid (e.g., "dry ice") can directly turn into a gas: this is called sublimation. If the gas is further heated, its atoms or molecules can become (wholly or partially) ionized, turning the gas into a plasma. Relater Gas Information: The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law. Properties of Gas Mixtures - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density. The Individual and Universal Gas Constant - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Gauge Pressure: Pressure differential above or below ambient atmospheric pressure.

H

Hazardous Atmosphere: An atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

Hazen-Williams Factor: Hazen-Williams factor for some common piping materials. Hazen-Williams coefficients are used in the Hazen-Williams equation for friction loss calculation in ducts and pipes.

Hazen-Williams Equation - Calculating Friction Head Loss in Water Pipes
Friction head loss (ft H2O per 100 ft pipe) in water pipes can be obtained by using the empirical Hazen-Williams equation. The Darcy-Weisbach equation with the Moody diagram are considered to be the most accurate model for estimating frictional head loss in steady pipe flow. Since the approach requires a not so efficient trial and error solution, an alternative empirical head loss calculation that does not require the trial and error solutions, as the Hazen-Williams equation, may be preferred:

$$f = 0.2083\ (100/c)^{1.852}\ q^{1.852} / d_h^{4.8655} \quad (1)$$

where
f = friction head loss in feet of water per 100 feet of pipe (ft_{h20}*/100 ft pipe)*
c = Hazen-Williams roughness constant
q = volume flow (gal/min)
d_h *= inside hydraulic diameter (inches)*

Note that the Hazen-Williams formula is empirical and lacks physical basis. Be aware that the roughness constants are based on "normal" condition with approximately 1 m/s (3 ft/sec).

The Hazen-Williams formula is not the only empirical formula available. Manning's formula is common for gravity driven flows in open channels.

The flow velocity may be calculated as:

$$v = 0.4087\ q / d_h^2$$

where
v = flow velocity (ft/s)

The Hazen-Williams formula can be assumed to be relatively accurate for piping systems where the Reynolds Number is above 10^5 (turbulent flow).

- 1 ft (foot) = 0.3048 m
- 1 in (inch) = 25.4 mm
- 1 gal (US)/min =6.30888×10^{-5} m^3/s = 0.0227 m^3/h = 0.0631 dm^3(liter)/s = 2.228×10^{-3} ft^3/s = 0.1337 ft^3/min = 0.8327 Imperial gal (UK)/min

Note! The Hazen-Williams formula gives accurate head loss due to friction for fluids with kinematic viscosity of approximately 1.1 cSt. More about fluids and kinematic viscosity.

The results for the formula are acceptable for cold water at 60^o F (15.6^o C) with kinematic viscosity 1.13 cSt. For hot water with a lower kinematic viscosity (0.55 cSt at 130^o F (54.4^o C)) the error will be significant. Since the Hazen Williams method is only valid for water flowing at ordinary temperatures between 40 to 75^o F, the Darcy Weisbach method should be used for other liquids or gases.

Head: The height of a column or body of fluid above a given point expressed in linear units. Head if often used to indicate gauge pressure. Pressure is equal to the height times the density of the liquid. The measure of the pressure of water expressed in feet of height of water. 1 psi = 2.31 feet of water. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

Hydraulics: Hydraulics is a branch of science and engineering concerned with the use of liquids to perform mechanical tasks.

Hydrodynamics: Hydrodynamics is the fluid dynamics applied to liquids, such as water, alcohol, and oil.

I

Ideal Gas: The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law. Properties of Gas Mixtures - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density. The Individual and Universal Gas Constant - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Isentropic Compression/Expansion Process: If the compression or expansion takes place under constant volume conditions - the process is called **isentropic.** The isentropic process on the basis of the Ideal Gas Law can be expressed as:

$$p / \rho^k = \text{constant} \quad (2)$$

where
$k = c_p / c_v$ *- the ratio of specific heats - the ratio of specific heat at constant pressure -* c_p *- to the specific heat at constant volume -* c_v

Irrigation: Water that is especially furnished to help provide and sustain the life of growing plants. It comes from ditches. It is sometimes treated with herbicides and pesticides to prevent the growth of weeds and the development of bugs in a lawn and a garden.

K

Kinematic Viscosity: The ratio of absolute or dynamic viscosity to density - a quantity in which no force is involved. Kinematic viscosity can be obtained by dividing the absolute viscosity of a fluid with its mass density as

$$v = \mu / \rho \quad (2)$$

where
v *= kinematic viscosity*
μ *= absolute or dynamic viscosity*
ρ *= density*

In the SI-system the theoretical unit is m^2/s or commonly used **Stoke (St)** where

- *1 St = 10^{-4} m^2/s*

Since the Stoke is an unpractical large unit, it is usual divided by 100 to give the unit called **Centistokes (cSt)** where

1 St = 100 cSt
1 cSt = 10^{-6} m^2/s

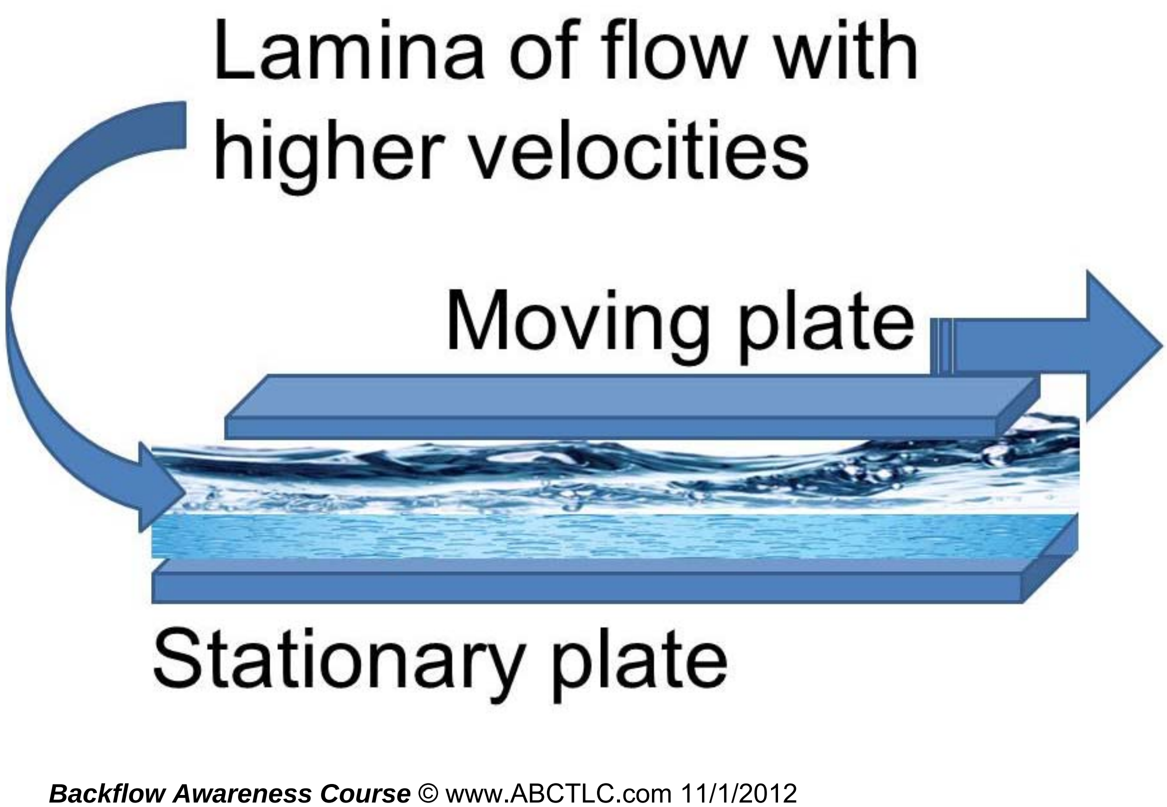
Since the specific gravity of water at 68.4°F (20.2°C) is almost one - 1, the kinematic viscosity of water at 68.4°F is for all practical purposes 1.0 cSt.

Kinetic Energy: The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head.

Knudsen Number: Used by modelers who wish to express a non-dimensionless speed.

L

Laminar Flow: The resistance to flow in a liquid can be characterized in terms of the viscosity of the fluid if the flow is smooth. In the case of a moving plate in a liquid, it is found that there is a layer or lamina which moves with the plate, and a layer which is essentially stationary if it is next to a stationary plate. There is a gradient of velocity as you move from the stationary to the moving plate, and the liquid tends to move in layers with successively higher speed. This is called laminar flow, or sometimes "streamlined" flow. Viscous resistance to flow can be modeled for laminar flow, but if the lamina break up into turbulence, it is very difficult to characterize the fluid flow.



The common application of laminar flow would be in the smooth flow of a viscous liquid through a tube or pipe. In that case, the velocity of flow varies from zero at the walls to a maximum along the centerline of the vessel. The flow profile of laminar flow in a tube can be calculated by dividing the flow into thin cylindrical elements and applying the viscous force to them. Laminar, Transitional or Turbulent Flow? - It is important to know if the fluid flow is laminar, transitional or turbulent when calculating heat transfer or pressure and head loss.

Laplace's Equation: Describes the behavior of gravitational, electric, and fluid potentials.

The scalar form of Laplace's equation is the partial differential equation

$$\nabla^2 \psi = 0, \quad (1)$$

where ∇^2 is the Laplacian.
Note that the operator ∇^2 is commonly written as Δ by mathematicians (Krantz 1999, p. 16).
Laplace's equation is a special case of the Helmholtz differential equation

$$\nabla^2 \psi + k^2 \psi = 0 \quad (2)$$

with $k = 0$, or Poisson's equation

$$\nabla^2 \psi = -4 \pi \rho \quad (3)$$

with $\rho = 0$.

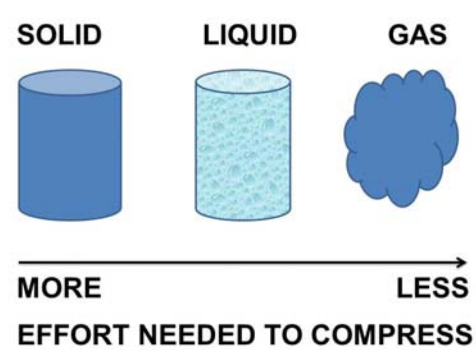
The vector Laplace's equation is given by

$$\nabla^2 \mathbf{F} = \mathbf{0}. \quad (4)$$

A function ψ which satisfies Laplace's equation is said to be harmonic. A solution to Laplace's equation has the property that the average value over a spherical surface is equal to the value at the center of the sphere (Gauss's harmonic function theorem). Solutions have no local maxima or minima. Because Laplace's equation is linear, the superposition of any two solutions is also a solution.

Lift (Force): Lift consists of the sum of all the aerodynamic forces normal to the direction of the external airflow.

Liquids: An in-between state of matter. They can be found in between the solid and gas states. They don't have to be made up of the same compounds. If you have a variety of materials in a liquid, it is called a solution. One characteristic of a liquid is that it will fill up the shape of a container. If you pour some water in a cup, it will fill up the bottom of the cup first and then fill the rest. The water will also take the shape of the cup.
It fills the bottom first because of **gravity**. The top part of a liquid will usually have a flat surface. That flat surface is because of gravity too. Putting an ice cube (solid) into a cup will leave you with a cube in the middle of the cup; the shape won't change until the ice becomes a liquid.



Another trait of liquids is that they are difficult to compress.

When you compress something, you take a certain amount and force it into a smaller space. Solids are very difficult to compress and gases are very easy. Liquids are in the middle but tend to be difficult. When you compress something, you force the atoms closer together. When pressure go up, substances are compressed. Liquids already have their atoms close together, so they are hard to compress. Many shock absorbers in cars compress liquids in tubes.

A special force keeps liquids together. Solids are stuck together and you have to force them apart. Gases bounce everywhere and they try to spread themselves out. Liquids actually want to stick together. There will always be the occasional evaporation where extra energy gets a molecule excited and the molecule leaves the system. Overall, liquids have **cohesive** (sticky) forces at work that hold the molecules together. Related Liquid Information: Equations in Fluid Mechanics - Continuity, Euler, Bernoulli, Dynamic and Total Pressure

M

Mach Number: When an object travels through a medium, then its Mach number is the ratio of the object's speed to the speed of sound in that medium.

Magnetic Flow Meter: Inspection of magnetic flow meter instrumentation should include checking for corrosion or insulation deterioration.

Manning Formula for Gravity Flow: Manning's equation can be used to calculate cross-sectional average velocity flow in open channels

$v = k_n/n\ R^{2/3}\ S^{1/2}$ *(1)*

where
v *= cross-sectional average velocity (ft/s, m/s)*
k_n *= 1.486 for English units and* k_n *= 1.0 for SI units*
A *= cross sectional area of flow (*ft^2*,* m^2*)*
n *= Manning coefficient of roughness*
R *= hydraulic radius (ft, m)*
S *= slope of pipe (ft/ft, m/m)*

The volume flow in the channel can be calculated as
$q = A\ v = A\ k_n/n\ R^{2/3}\ S^{1/2}$ *(2)*

where
q *= volume flow (*ft^3/s*,* m^3/s*)*
A *= cross-sectional area of flow (*ft^2*,* m^2*)*

Maximum Contamination Levels or (MCLs): The maximum allowable level of a contaminant that federal or state regulations allow in a public water system. If the MCL is exceeded, the water system must treat the water so that it meets the MCL. Or provide adequate backflow protection.

Mechanical Seal: A mechanical device used to control leakage from the stuffing box of a pump. Usually made of two flat surfaces, one of which rotates on the shaft. The two flat surfaces are of such tolerances as to prevent the passage of water between them.

Mg/L: milligrams per liter

Microbe, Microbial: Any minute, simple, single-celled form of life, especially one that causes disease.

Microbial Contaminants: Microscopic organisms present in untreated water that can cause waterborne diseases.

ML: milliliter

N

Navier-Stokes Equations: The motion of a non-turbulent, Newtonian fluid is governed by the Navier-Stokes equation. The equation can be used to model turbulent flow, where the fluid parameters are interpreted as time-averaged values.

Newtonian Fluid: Newtonian fluid (named for Isaac Newton) is a fluid that flows like water—its shear stress is linearly proportional to the velocity gradient in the direction perpendicular to the plane of shear. The constant of proportionality is known as the viscosity. Water is Newtonian, because it continues to exemplify fluid properties no matter how fast it is stirred or mixed.

Contrast this with a non-Newtonian fluid, in which stirring can leave a "hole" behind (that gradually fills up over time - this behavior is seen in materials such as pudding, or to a less rigorous extent, sand), or cause the fluid to become thinner, the drop in viscosity causing it to flow more (this is seen in non-drip paints). For a Newtonian fluid, the viscosity, by definition, depends only on temperature and pressure (and also the chemical composition of the fluid if the fluid is not a pure substance), not on the forces acting upon it. If the fluid is incompressible and viscosity is constant across the fluid, the equation governing the shear stress. Related Newtonian Information: A Fluid is Newtonian if viscosity is constant applied to shear force. Dynamic, Absolute and Kinematic Viscosity - An introduction to dynamic, absolute and kinematic viscosity and how to convert between CentiStokes (cSt), CentiPoises (cP), Saybolt Universal Seconds (SSU) and degree Engler.

Newton's Third Law: Newton's third law describes the forces acting on objects interacting with each other. Newton's third law can be expressed as

- *"If one object exerts a force **F** on another object, then the second object exerts an equal but opposite force **F** on the first object"*

Force is a convenient abstraction to represent mentally the pushing and pulling interaction between objects.

It is common to express forces as vectors with magnitude, direction and point of application. The net effect of two or more forces acting on the same point is the vector sum of the forces.

Non-Newtonian Fluid: Non-Newtonian fluid viscosity changes with the applied shear force.

O

Oxidizing: The process of breaking down organic wastes into simpler elemental forms or by products. Also used to separate combined chlorine and convert it into free chlorine.

P

Pascal's Law: A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

Pathogens: Disease-causing pathogens; waterborne pathogens. A pathogen is a bacterium, virus or parasite that causes or is capable of causing disease. Pathogens may contaminate water and cause waterborne disease.

pCi/L- ***picocuries per liter:*** A curie is the amount of radiation released by a set amount of a certain compound. A picocurie is one quadrillionth of a curie.

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

Pipeline Appurtenances: Pressure reducers, bends, valves, regulators (which are a type of valve), etc.

Peak Demand: The maximum momentary load placed on a water treatment plant, pumping station or distribution system is the Peak Demand.

Pipe Velocities: For calculating fluid pipe velocity.

Imperial units

A fluids flow velocity in pipes can be calculated with Imperial or American units as

$v = 0.4085\, q / d^2$ *(1)*

where

v = velocity (ft/s)

q = volume flow (US gal. /min)

d = pipe inside diameter (inches)

SI units

A fluids flow velocity in pipes can be calculated with SI units as

$v = 1.274\, q / d^2$ *(2)*

where

v = velocity (m/s)

q = volume flow (m^3/s)

d = pipe inside diameter (m)

Pollution: To make something unclean or impure. Some states will have a definition of pollution that relates to non-health related water problems, like taste and odors. See Contaminated.

Positive Flow Report-back Signal: When a pump receives a signal to start, a light will typically be illuminated on the control panel indicating that the pump is running. In order to be sure that the pump is actually pumping water, a Positive flow report-back signal should be installed on the control panel.

Potable: Good water which is safe for drinking or cooking purposes. Non-Potable: A liquid or water that is not approved for drinking.

Potential Energy: The energy that a body has by virtue of its position or state enabling it to do work.

PPM: Abbreviation for parts per million.

Prandtl Number: The Prandtl Number is a dimensionless number approximating the ratio of momentum diffusivity and thermal diffusivity and can be expressed as

Pr = v / α (1)
where
Pr = Prandtl's number
v = kinematic viscosity (Pa s)
α = thermal diffusivity (W/m K)

The Prandtl number can alternatively be expressed as

$Pr = \mu\ c_p / k$ *(2)*

where
μ = absolute or dynamic viscosity (kg/m s, cP)
c_p *= specific heat capacity (J/kg K, Btu/(lb* ^{o}*F))*
k = thermal conductivity (W/m K, Btu/(h $ft^2\ ^{o}F/ft$*))*
The Prandtl Number is often used in heat transfer and free and forced convection calculations.

Pressure: An introduction to pressure - the definition and presentation of common units as psi and Pa and the relationship between them.

The pressure in a fluid is defined as
"the normal force per unit area exerted on an imaginary or real plane surface in a fluid or a gas"

The equation for pressure can expressed as:
p = F / A (1)

where
p = pressure [lb/in^2 *(psi) or* lb/ft^2 *(psf),* N/m^2 *or* kg/ms^2 *(Pa)]*
F = force [[1)], N]
A = area [in^2 *or* ft^2*,* m^2*]*
[1)] In the English Engineering System special care must be taken for the force unit. The basic unit for mass is the pound mass (lb_m) and the unit for the force is the pound (lb) or pound force (lb_f).

Absolute Pressure
The **absolute pressure** - p_a - is measured relative to the *absolute zero pressure* - the pressure that would occur at absolute vacuum.

Gauge Pressure
A **gauge** is often used to measure the pressure difference between a system and the surrounding atmosphere. This pressure is often called the **gauge pressure** and can be expressed as

$p_g = p_a - p_o$ *(2)*

where
p_g = *gauge pressure*
p_o = *atmospheric pressure*

Atmospheric Pressure
The atmospheric pressure is the pressure in the surrounding air. It varies with temperature and altitude above sea level.

Standard Atmospheric Pressure
The **Standard Atmospheric Pressure** (atm) is used as a reference for gas densities and volumes. The Standard Atmospheric Pressure is defined at sea-level at 273^{o}K (0^{o}C) and is **1.01325 bar** or 101325 Pa (absolute). The temperature of 293^{o}K (20^{o}C) is also used.

In imperial units the Standard Atmospheric Pressure is 14.696 psi.
- *1 atm = 1.01325 bar = 101.3 kPa = 14.696 psi (lb_f/in^2)= 760 mmHg =10.33 mH_2O = 760 torr = 29.92 in Hg = 1013 mbar = 1.0332 kg_f/cm^2 = 33.90 ftH_2O*

Pressure Head: The height to which liquid can be raised by a given pressure.

Pressure Regulation Valves: Control water pressure and operate by restricting flows. They are used to deliver water from a high pressure to a low-pressure system. The pressure downstream from the valve regulates the amount of flow. Usually, these valves are of the globe design and have a spring-loaded diaphragm that sets the size of the opening.

Pressure Units: Since 1 Pa is a small pressure unit, the unit hectopascal (hPa) is widely used, especially in meteorology. The unit kilopascal (kPa) is commonly used designing technical applications like HVAC systems, piping systems and similar.
- *1 hectopascal = 100 pascal = 1 millibar*
- *1 kilopascal = 1000 pascal*

Some Pressure Levels
- 10 Pa - The pressure at a depth of 1 mm of water
- 1 kPa - Approximately the pressure exerted by a 10 g mass on a 1 cm^2 area
- 10 kPa - The pressure at a depth of 1 m of water, or
  the drop in air pressure when going from sea level to 1000 m elevation
- 10 MPa - A "high pressure" washer forces the water out of the nozzles at this pressure
- 10 GPa - This pressure forms diamonds

Some Alternative Units of Pressure

- *1 bar - 100,000 Pa*
- *1 millibar - 100 Pa*
- *1 atmosphere - 101,325 Pa*
- *1 mm Hg - 133 Pa*
- *1 inch Hg - 3,386 Pa*

A **torr** (torr) is named after Torricelli and is the pressure produced by a column of mercury 1 mm high equals to 1/760th of an atmosphere. 1 atm = 760 torr = 14.696 psi

Pounds per square inch (psi) was common in U.K. but has now been replaced in almost every country except in the U.S. by the SI units. The Normal atmospheric pressure is 14.696 psi, meaning that a column of air on one square inch in area rising from the Earth's atmosphere to space weighs 14.696 pounds.

The **bar** (bar) is common in the industry. One bar is 100,000 Pa, and for most practical purposes can be approximated to one atmosphere even if

1 Bar = 0.9869 atm

There are 1,000 **millibar** (mbar) in one bar, a unit common in meteorology.

1 millibar = 0.001 bar = 0.750 torr = 100 Pa

R

Residual Disinfection/Protection: A required level of disinfectant that remains in treated water to ensure disinfection protection and prevent recontamination throughout the distribution system (i.e., pipes).

Reynolds Number: The Reynolds number is used to determine whether a flow is laminar or turbulent. The Reynolds Number is a non-dimensional parameter defined by the ratio of dynamic pressure (ρu^2) and shearing stress ($\mu u / L$) - and can be expressed as

$$Re = (\rho u^2) / (\mu u / L)$$
$$= \rho u L / \mu$$
$$= u L / v \quad (1)$$

where

Re = Reynolds Number (non-dimensional)

ρ = *density* (kg/m^3, lb_m/ft^3)

u = *velocity (m/s, ft/s)*

μ = *dynamic viscosity* (Ns/m^2, $lb_m/s\ ft$)

L = *characteristic length (m, ft)*

v = *kinematic viscosity* (m^2/s, ft^2/s)

Richardson Number: A dimensionless number that expresses the ratio of potential to kinetic energy.

S

Sanitizer: A chemical which disinfects (kills bacteria), kills algae and oxidizes organic matter.

Saybolt Universal Seconds (or SUS, SSU): Saybolt Universal Seconds (or SUS) is used to measure viscosity. The efflux time is Saybolt Universal Seconds (SUS) required for 60 milliliters of a petroleum product to flow through the calibrated orifice of a Saybolt Universal viscometer, under carefully controlled temperature and as prescribed by test method ASTM D 88. This method has largely been replaced by the kinematic viscosity method. Saybolt Universal Seconds is also called the SSU number (Seconds Saybolt Universal) or SSF number (Saybolt Seconds Furol).

Kinematic viscosity versus dynamic or absolute viscosity can be expressed as

$v = 4.63\ \mu / SG$ *(3)*
where
v *= kinematic viscosity (SSU)*
μ *= dynamic or absolute viscosity (cP)*

Scale: Crust of calcium carbonate, the result of unbalanced pool water. Hard insoluble minerals deposited (usually calcium bicarbonate) which forms on pool and spa surfaces and clog filters, heaters and pumps. Scale is caused by high calcium hardness and/or high pH. You will often find major scale deposits inside a backflow prevention assembly.

Shock: Also known as superchlorination or break point chlorination. Ridding a pool of organic waste through oxidization by the addition of significant quantities of a halogen.

Shock Wave: A shock wave is a strong pressure wave produced by explosions or other phenomena that create violent changes in pressure.

Solder: A fusible alloy used to join metallic parts. Solder for potable water pipes shall be lead-free.

Sound Barrier: The sound barrier is the apparent physical boundary stopping large objects from becoming supersonic.

Specific Gravity: The Specific Gravity - *SG* - is a dimensionless unit defined as the ratio of density of the material to the density of water at a specified temperature. Specific Gravity can be expressed as

$SG = = \rho / \rho_{H2O}$ *(3)*

where
SG *= specific gravity*
ρ *= density of fluid or substance* (kg/m^3)
ρ_{H2O} *= density of water* (kg/m^3)

It is common to use the density of water at 4^o C (39^oF) as a reference - at this point the density of water is at the highest. Since Specific Weight is dimensionless it has the same value in the metric SI system as in the imperial English system (BG). At the reference point the Specific Gravity has same numerically value as density.

Example - Specific Gravity

If the density of iron is 7850 kg/m^3, 7.85 grams per cubic millimeter, 7.85 kilograms per liter, or 7.85 metric tons per cubic meter - the specific gravity of iron is:

$SG = 7850\ kg/m^3 / 1000\ kg/m^3$

$= \underline{7.85}$

(the density of water is 1000 kg/m^3)

Specific Weight: Specific Weight is defined as weight per unit volume. Weight is a **force**.

- Mass and Weight - the difference! - What is weight and what is mass? An explanation of the difference between weight and mass.

Specific Weight can be expressed as

$\gamma = \rho g$ *(2)*

where

γ *= specific weight* (kN/m^3)

g *= acceleration of gravity* (m/s^2)

The SI-units of specific weight are kN/m^3. The imperial units are lb/ft^3. The local acceleration *g* is under normal conditions 9.807 m/s^2 in SI-units and 32.174 ft/s^2 in imperial units.

Example - Specific Weight Water

Specific weight for water at 60 ^oF is 62.4 lb/ft^3 in imperial units and 9.80 kN/m^3 in SI-units.

Example - Specific Weight Some other Materials

Product	Specific Weight - γ	
	Imperial Units (lb/ft^3)	SI Units (kN/m^3)
Ethyl Alcohol	49.3	7.74
Gasoline	42.5	6.67
Glycerin	78.6	12.4
Mercury	847	133
SAE 20 Oil	57	8.95
Seawater	64	10.1
Water	62.4	9.80

Static Head: The height of a column or body of fluid above a given point

Static Pressure: The pressure in a fluid at rest.

Static Pressure and Pressure Head in Fluids: The pressure indicates the normal force per unit area at a given point acting on a given plane. Since there is no shearing stresses present in a fluid at rest - the pressure in a fluid is independent of direction.

For fluids - liquids or gases - at rest the pressure gradient in the vertical direction depends only on the specific weight of the fluid.

How pressure changes with elevation can be expressed as

$dp = - \gamma\, dz$ (1)

where
dp = change in pressure
dz = change in height
γ = specific weight

The pressure gradient in vertical direction is negative - the pressure decrease upwards.

Specific Weight: Specific Weight can be expressed as:

$\gamma = \rho\, g$ (2)

where
γ = specific weight
g = acceleration of gravity

In general the specific weight - γ - is constant for fluids. For gases the specific weight - γ - varies with the elevation.

Static Pressure in a Fluid: For an incompressible fluid - as a liquid - the pressure difference between two elevations can be expressed as:

$p_2 - p_1 = - \gamma\, (z_2 - z_1)$ (3)

where
p_2 = pressure at level 2
p_1 = pressure at level 1
z_2 = level 2
z_1 = level 1

(3) can be transformed to:

$p_1 - p_2 = \gamma\, (z_2 - z_1)$ (4)
or
$p_1 - p_2 = \gamma\, h$ (5)

where
$h = z_2 - z_1$ difference in elevation - the depth down from location z_2.
or
$p_1 = \gamma\, h + p_2$ (6)

Static Pressure and Pressure Head in Fluids Continued:

The Pressure Head

(6) can be transformed to:

$h = (p_2 - p_1) / \gamma$ (6)

h express **the pressure head** - the height of a column of fluid of specific weight - γ - required to give a pressure difference of ($p_2 - p_1$).

Example - Pressure Head

A pressure difference of 5 psi (lbf/in^2) is equivalent to

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 62.4 (lb/ft^3) = <u>11.6</u> ft of water

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 847 (lb/ft^3) = <u>0.85</u> ft of mercury

when specific weight of water is 62.4 (lb/ft^3) and specific weight of mercury is 847 (lb/ft^3).

Streamline - Stream Function: A streamline is the path that an imaginary particle would follow if it was embedded in the flow.

Strouhal Number: A quantity describing oscillating flow mechanisms. The Strouhal Number is a dimensionless value useful for analyzing oscillating, unsteady fluid flow dynamics problems.

The Strouhal Number can be expressed as

$$St = \omega l / v \quad (1)$$

where
St = Strouhal Number
ω = oscillation frequency
l = characteristic length
v = flow velocity

The Strouhal Number represents a measure of the ratio of inertial forces due to the unsteadiness of the flow or local acceleration to the inertial forces due to changes in velocity from one point to another in the flow field.

The vortices observed behind a stone in a river, or measured behind the obstruction in a vortex flow meter, illustrate these principles.

Stuffing Box: That portion of the pump which houses the packing or mechanical seal.

Submerged: To cover with water or liquid substance.

Supersonic Flow: Flow with speed above the speed of sound, 1,225 km/h at sea level, is said to be supersonic.

Surface Tension: Surface tension is a force within the surface layer of a liquid that causes the layer to behave as an elastic sheet. The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension. The molecules at the surface do not have other like molecules on all sides of them and consequently they cohere more strongly to those directly associated with them on the surface. This forms a surface "film" which makes it more difficult to move an object through the surface than to move it when it is completely submersed. Surface tension is typically measured in dynes/cm, the force in dynes required to break a film of length 1 cm. Equivalently, it can be stated as surface energy in ergs per square centimeter. Water at 20°C has a surface tension of 72.8 dynes/cm compared to 22.3 for ethyl alcohol and 465 for mercury.

Surface tension is typically measured in *dynes/cm* or *N/m*.

Liquid	Surface Tension	
	N/m	dynes/cm
Ethyl Alcohol	0.0223	22.3
Mercury	0.465	465
Water 20°C	0.0728	72.75
Water 100°C	0.0599	58.9

Surface tension is the energy required to stretch a unit change of a surface area. Surface tension will form a drop of liquid to a sphere since the sphere offers the smallest area for a definite volume.

Surface tension can be defined as

$\sigma = F_s / l$ *(1)*

where
σ = surface tension (N/m)
F_s = stretching force (N)
l = unit length (m)

Alternative Units
Alternatively, surface tension is typically measured in dynes/cm, which is
- the force in dynes required to break a film of length 1 cm

or as surface energy J/m^2 or alternatively ergs per square centimeter.
- 1 dynes/cm = 0.001 N/m = 0.0000685 lb_f/ft = 0.571 10^{-5} lb_f/in = 0.0022 poundal/ft = 0.00018 poundal/in = 1.0 mN/m = 0.001 J/m^2 = 1.0 erg/cm^2 = 0.00010197 kg_f/m

Common Imperial units used are lb/ft and lb/in.
Water surface tension at different temperatures can be taken from the table below:

Temperature (°C)	Surface Tension - σ - (N/m)
0	0.0757
10	0.0742
20	0.0728
30	0.0712
40	0.0696
50	0.0679
60	0.0662
70	0.0644
80	0.0626
90	0.0608
100	0.0588

Surface Tension of some common Fluids

- benzene : 0.0289 (N/m)
- diethyl ether : 0.0728 (N/m)
- carbon tetrachloride : 0.027 (N/m)
- chloroform : 0.0271 (N/m)
- ethanol : 0.0221 (N/m)
- ethylene glycol : 0.0477 (N/m)
- glycerol : 0.064 (N/m)
- mercury : 0.425 (N/m)
- methanol : 0.0227 (N/m)
- propanol : 0.0237 (N/m)
- toluene : 0.0284 (N/m)
- water at $20^{o}C$: 0.0729 (N/m)

Surge Tanks: Surge tanks can be used to control Water Hammer. A limitation of hydropneumatic tanks is that they do not provide much storage to meet peak demands during power outages and you have very limited time to do repairs on equipment.

T

Telemetering Systems: The following are common pressure sensing devices: Helical Sensor, Bourdon Tube, and Bellows Sensor. The most frequent problem that affects a liquid pressure-sensing device is air accumulation at the sensor. A diaphragm element being used as a level sensor would be used in conjunction with a pressure sensor. Devices must often transmit more than one signal. You can use several types of systems including: Polling, Scanning and Multiplexing. Transmitting equipment requires installation where temperature will not exceed 130 degrees F.

Thixotropic Fluids: Shear Thinning Fluids or **Thixotropic Fluids** reduce their viscosity as agitation or pressure is increased at a constant temperature. Ketchup and mayonnaise are examples of thixotropic materials. They appear thick or viscous but are possible to pump quite easily.

Transonic: Flow with speed at velocities just below and above the speed of sound is said to be transonic.

Turbidity: A measure of the cloudiness of water caused by suspended particles.

U

U-Tube Manometer: Pressure measuring devices using liquid columns in vertical or inclined tubes are called manometers. One of the most common is the water filled u-tube manometer used to measure pressure difference in pitot or orifices located in the airflow in air handling or ventilation systems.

V

Valve: A device that opens and closes to regulate the flow of liquids. Faucets, hose bibs, and Ball are examples of valves.

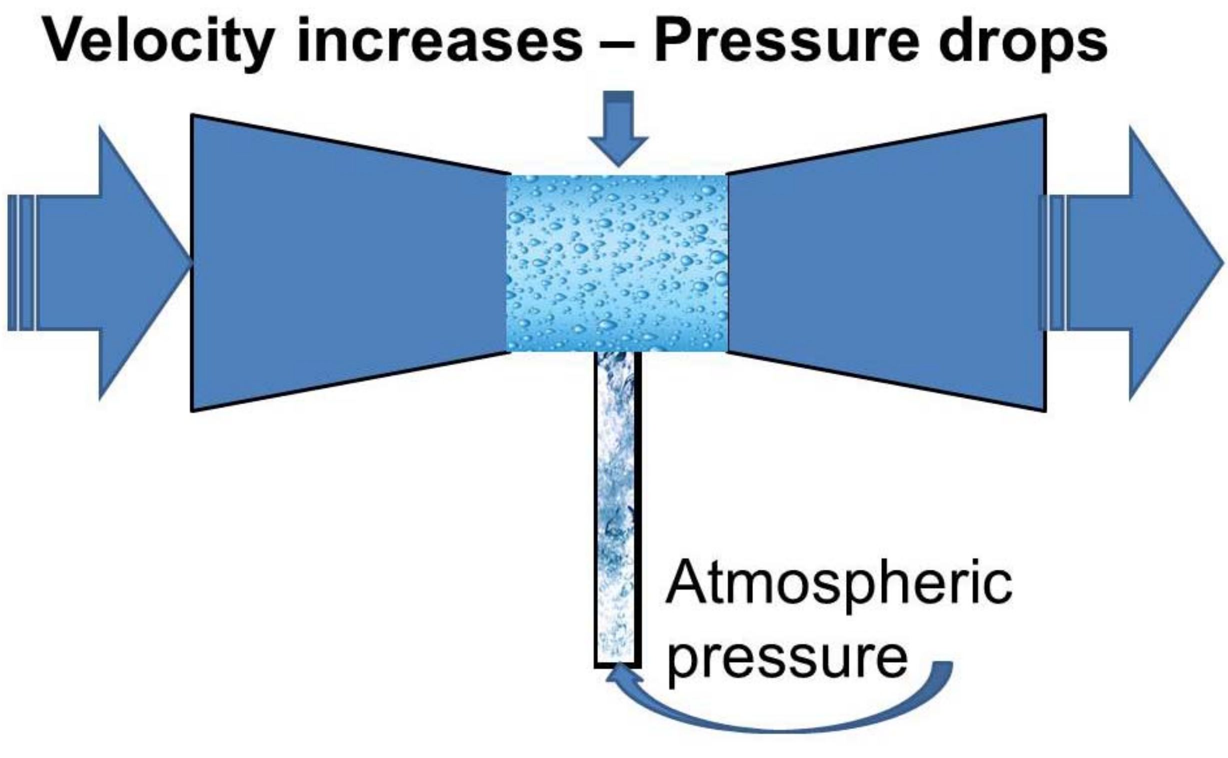
Vane: That portion of an impeller which throws the water toward the volute.

Vapor Pressure: For a particular substance at any given temperature there is a pressure at which the vapor of that substance is in equilibrium with its liquid or solid forms.

Velocity Head: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.

Venturi: A system for speeding the flow of the fluid, by constricting it in a cone-shaped tube. Venturi are used to measure the speed of a fluid, by measuring the pressure changes from one point to another along the venture. A venturi can also be used to inject a liquid or a gas into another liquid. A pump forces the liquid flow through a tube connected to:

- A venturi to increase the speed of the fluid (restriction of the pipe diameter)
- A short piece of tube connected to the gas source
- A second venturi that decrease the speed of the fluid (the pipe diameter increase again)
- After the first venturi the pressure in the pipe is lower, so the gas is sucked in the pipe. Then the mixture enters the second venturi and slow down. At the end of the system a mixture of gas and liquid appears and the pressure rise again to its normal level in the pipe.
- This technique is used for ozone injection in water.



The newest injector design causes complete mixing of injected materials (air, ozone or chemicals), eliminating the need for other in-line mixers. Venturi injectors have no moving parts and are maintenance free. They operate effectively over a wide range of pressures (from 1 to 250 psi) and require only a minimum pressure difference to initiate the vacuum at the suction part. Venturis are often built in thermoplastics (PVC, PE, PVDF), stainless steel or other metals.

The cavitation effect at the injection chamber provides an instantaneous mixing, creating thousands of very tiny bubbles of gas in the liquid. The small bubbles provide and increased gas exposure to the liquid surface area, increasing the effectiveness of the process (i.e. ozonation).

Vibration: A force that is present on construction sites and must be considered. The vibrations caused by backhoes, dump trucks, compactors and traffic on job sites can be substantial.

Viscosity: Informally, viscosity is the quantity that describes a fluid's resistance to flow. Fluids resist the relative motion of immersed objects through them as well as to the motion of layers with differing velocities within them. Formally, viscosity (represented by the symbol η "eta") is the ratio of the shearing stress (F/A) to the velocity gradient ($\Delta v_x/\Delta z$ or dv_x/dz) in a fluid.

$$\eta = \left(\frac{F}{A}\right) \div \left(\frac{\Delta v_x}{\Delta z}\right) \quad \text{or} \quad \eta = \left(\frac{F}{A}\right) \div \left(\frac{dv_x}{dz}\right)$$

The more usual form of this relationship, called Newton's equation, states that the resulting shear of a fluid is directly proportional to the force applied and inversely proportional to its viscosity. The similarity to Newton's second law of motion ($F = ma$) should be apparent.

$$\frac{F}{A} = \eta \frac{\Delta v_x}{\Delta z} \quad \text{or} \quad \frac{F}{A} = \eta \frac{dv_x}{dz}$$

$$\Updownarrow \qquad\qquad \Updownarrow$$

$$F = m\frac{\Delta v}{\Delta t} \quad \text{or} \quad F = m\frac{dv}{dt}$$

The SI unit of viscosity is the pascal second [Pa·s], which has no special name. Despite its self-proclaimed title as an international system, the International System of Units has had very little international impact on viscosity. The pascal second is rarely used in scientific and technical publications today. The most common unit of viscosity is the dyne second per square centimeter [dyne·s/cm^2], which is given the name poise [P] after the French physiologist Jean Louis Poiseuille (1799-1869). Ten poise equal one pascal second [Pa·s] making the centipoise [cP] and millipascal second [mPa·s] identical.

1 pascal second = 10 poise = 1,000 millipascal second
1 centipoise = 1 millipascal second

There are actually two quantities that are called viscosity. The quantity defined above is sometimes called dynamic viscosity, absolute viscosity, or simple viscosity to distinguish it from the other quantity, but is usually just called viscosity. The other quantity called kinematic viscosity (represented by the symbol v "nu") is the ratio of the viscosity of a fluid to its density.

$$v = \frac{\eta}{\rho}$$

Kinematic viscosity is a measure of the resistive flow of a fluid under the influence of gravity. It is frequently measured using a device called a capillary viscometer -- basically a graduated can with a narrow tube at the bottom. When two fluids of equal volume are placed in identical capillary viscometers and allowed to flow under the influence of gravity, a viscous fluid takes longer than a less viscous fluid to flow through the tube. Capillary viscometers are discussed in more detail later in this section. The SI unit of kinematic viscosity is the square meter per second [m^2/s], which has no special name. This unit is so large that it is rarely used. A more common unit of kinematic viscosity is the square centimeter per second [cm^2/s], which is given the name stoke [St] after the English scientist George Stoke. This unit is also a bit too large and so the most common unit is probably the square millimeter per second [mm^2/s] or centistoke [cSt].

Viscosity and Reference Temperatures: The viscosity of a fluid is highly temperature dependent and for either dynamic or kinematic viscosity to be meaningful, the **reference temperature** must be quoted. In ISO 8217 the reference temperature for a residual fluid is 100^{o}C. For a distillate fluid the reference temperature is 40^{o}C.

- For a liquid - the kinematic viscosity will **decrease** with higher temperature.
- For a gas - the kinematic viscosity will **increase** with higher temperature.

Volute: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharged by the impeller.

Vorticity: Vorticity is defined as the circulation per unit area at a point in the flow field.

Vortex: A vortex is a whirlpool in the water.

W

Water Freezing: The effects of water freezing in storage tanks can be minimized by alternating water levels in the tank.

Water Storage Facility Inspection: During an inspection of your water storage facility, you should inspect the Cathodic protection system including checking the anode's condition and the connections. The concentration of polyphosphates that is used for corrosion control in storage tanks is typically 5 mg/L or less. External corrosion of steel water storage facilities can be reduced with Zinc or aluminum coatings. All storage facilities should be regularly sampled to determine the quality of water that enters and leaves the facility. One tool or piece of measuring equipment is the Jackson turbidimeter, which is a method to measure cloudiness in water.

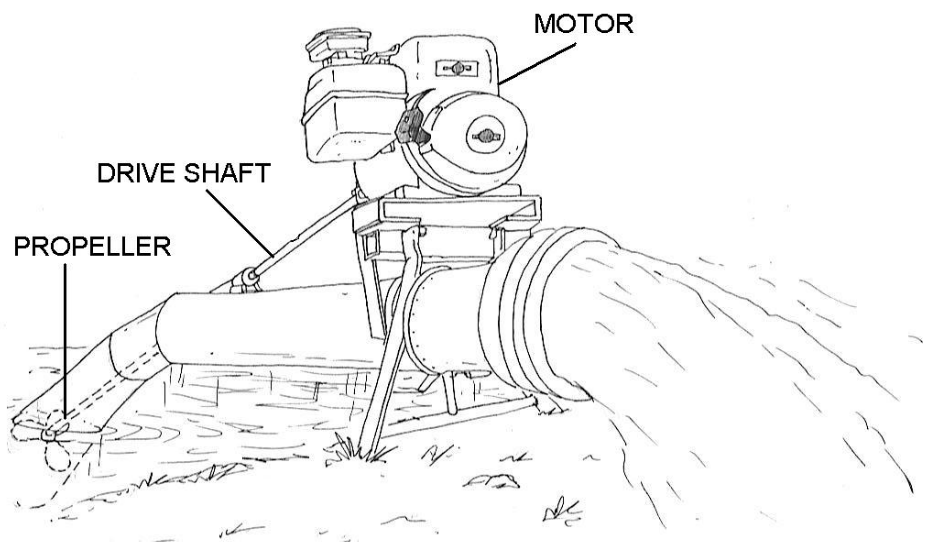
Wave Drag: Wave drag refers to a sudden and very powerful drag that appears on aircrafts flying at high-subsonic speeds.

Water Purveyor: The individuals or organization responsible to help provide, supply, and furnish quality water to a community.

Water Works: All of the pipes, pumps, reservoirs, dams and buildings that make up a water system.

Waterborne Diseases: A disease, caused by a virus, bacterium, protozoan, or other microorganism, capable of being transmitted by water (e.g., typhoid fever, cholera, amoebic dysentery, gastroenteritis).

Weber Number: A dimensionless value useful for analyzing fluid flows where there is an interface between two different fluids. Since the Weber Number represents an index of the inertial force to the surface tension force acting on a fluid element, it can be useful analyzing thin films flows and the formation of droplets and bubbles.



Appendixes and Charts

Density of Common Liquids

The density of some common liquids can be found in the table below:

Liquid	Temperature - *t* - (^{o}C)	Density - *ρ* - (kg/m^3)
Acetic Acid	25	1049
Acetone	25	785
Acetonitrile	20	782
Alcohol, ethyl	25	785
Alcohol, methyl	25	787
Alcohol, propyl	25	780
Ammonia (aqua)	25	823
Aniline	25	1019
Automobile oils	15	880 - 940
Beer (varies)	10	1010
Benzene	25	874
Benzyl	15	1230
Brine	15	1230
Bromine	25	3120
Butyric Acid	20	959
Butane	25	599
n-Butyl Acetate	20	880
n-Butyl Alcohol	20	810
n-Butylhloride	20	886
Caproic acid	25	921
Carbolic acid	15	956
Carbon disulfide	25	1261
Carbon tetrachloride	25	1584
Carene	25	857
Castor oil	25	956
Chloride	25	1560
Chlorobenzene	20	1106
Chloroform	20	1489
Chloroform	25	1465
Citric acid	25	1660
Coconut oil	15	924
Cotton seed oil	15	926
Cresol	25	1024
Creosote	15	1067
Crude oil, 48^{o} API	60^{o}F	790

Crude oil, 40° API	60°F	825
Crude oil, 35.6° API	60°F	847
Crude oil, 32.6° API	60°F	862
Crude oil, California	60°F	915
Crude oil, Mexican	60°F	973
Crude oil, Texas	60°F	873
Cumene	25	860
Cyclohexane	20	779
Cyclopentane	20	745
Decane	25	726
Diesel fuel oil 20 to 60	15	820 - 950
Diethyl ether	20	714
o-Dichlorobenzene	20	1306
Dichloromethane	20	1326
Diethylene glycol	15	1120
Dichloromethane	20	1326
Dimethyl Acetamide	20	942
N,N-Dimethylformamide	20	949
Dimethyl Sulfoxide	20	1100
Dodecane	25	755
Ethane	-89	570
Ether	25	73
Ethylamine	16	681
Ethyl Acetate	20	901
Ethyl Alcohol	20	789
Ethyl Ether	20	713
Ethylene Dichloride	20	1253
Ethylene glycol	25	1097
Fluorine refrigerant R-12	25	1311
Formaldehyde	45	812
Formic acid 10%oncentration	20	1025
Formic acid 80%oncentration	20	1221
Freon - 11	21	1490
Freon - 21	21	1370
Fuel oil	60°F	890
Furan	25	1416
Furforol	25	1155
Gasoline, natural	60°F	711
Gasoline, Vehicle	60°F	737
Gas oils	60°F	890
Glucose	60°F	1350 - 1440
Glycerin	25	1259

Glycerol	25	1126
Heptane	25	676
Hexane	25	655
Hexanol	25	811
Hexene	25	671
Hydrazine	25	795
Iodine	25	4927
Ionene	25	932
Isobutyl Alcohol	20	802
Iso-Octane	20	692
Isopropyl Alcohol	20	785
Isopropyl Myristate	20	853
Kerosene	60^{o}F	817
Linolenic Acid	25	897
Linseed oil	25	929
Methane	-164	465
Methanol	20	791
Methyl Isoamyl Ketone	20	888
Methyl Isobutyl Ketone	20	801
Methyl n-Propyl Ketone	20	808
Methyl t-Butyl Ether	20	741
N-Methylpyrrolidone	20	1030
Methyl Ethyl Ketone	20	805
Milk	15	1020 - 1050
Naphtha	15	665
Naphtha, wood	25	960
Napthalene	25	820
Ocimene	25	798
Octane	15	918
Olive oil	20	800 - 920
Oxygen (liquid)	-183	1140
Palmitic Acid	25	851
Pentane	20	626
Pentane	25	625
Petroleum Ether	20	640
Petrol, natural	60^{o}F	711
Petrol, Vehicle	60^{o}F	737
Phenol	25	1072
Phosgene	0	1378
Phytadiene	25	823
Pinene	25	857
Propane	-40	583

Propane, R-290	25	494
Propanol	25	804
Propylenearbonate	20	1201
Propylene	25	514
Propylene glycol	25	965
Pyridine	25	979
Pyrrole	25	966
Rape seed oil	20	920
Resorcinol	25	1269
Rosin oil	15	980
Sea water	25	1025
Silane	25	718
Silicone oil		760
Sodium Hydroxide (caustic soda)	15	1250
Sorbaldehyde	25	895
Soya bean oil	15	924 - 928
Stearic Acid	25	891
Sulfuric Acid 95%onc.	20	1839
Sugar solution 68 brix	15	1338
Sunflower oil	20	920
Styrene	25	903
Terpinene	25	847
Tetrahydrofuran	20	888
Toluene	20	867
Toluene	25	862
Triethylamine	20	728
Trifluoroacetic Acid	20	1489
Turpentine	25	868
Water - pure	4	1000
Water - sea	77^oF	1022
Whale oil	15	925
o-Xylene	20	880

1 kg/m^3 = 0.001 g/cm^3 = 0.0005780 oz/in^3 = 0.16036 oz/gal (Imperial) = 0.1335 oz/gal (U.S.) = 0.0624 lb/ft^3 = 0.000036127 lb/in^3 = 1.6856 lb/yd^3 = 0.010022 lb/gal (Imperial) = 0.008345 lb/gal (U.S) = 0.0007525 ton/yd^3

Dynamic or Absolute Viscosity Units Converting Table

The table below can be used to convert between common dynamic or absolute viscosity units.

Multiply by	Convert to				
Convert from	Poiseuille (Pa s)	Poise (dyne s/ cm^2 = g / cm s)	centiPoise	kg / m h	kg_f s / m^2
Poiseuille (Pa s)	1	10	10^3	3.63 10^3	0.102
Poise (dyne s / cm^2 = g / cm s)	0.1	1	100	360	0.0102
centiPoise	0.001	0.01	1	3.6	0.00012
kg / m h	2.78 10^{-4}	0.00278	0.0278	1	2.83 10^{-5}
kg_f s / m^2	9.81	98.1	9.81 10^3	3.53 10^4	1
lb_f s / $inch^2$	6.89 10^3	6.89 10^4	6.89 10^6	2.48 10^7	703
lb_f s / ft^2	47.9	479	4.79 10^4	1.72 10^5	0.0488
lb_f h / ft^2	1.72 10^5	1.72 10^6	1.72 10^8	6.21 10^8	1.76 10^4
lb / ft s	1.49	14.9	1.49 10^3	5.36 10^3	0.152
lb / ft h	4.13 10^{-4}	0.00413	0.413	1.49	4.22 10^{-5}

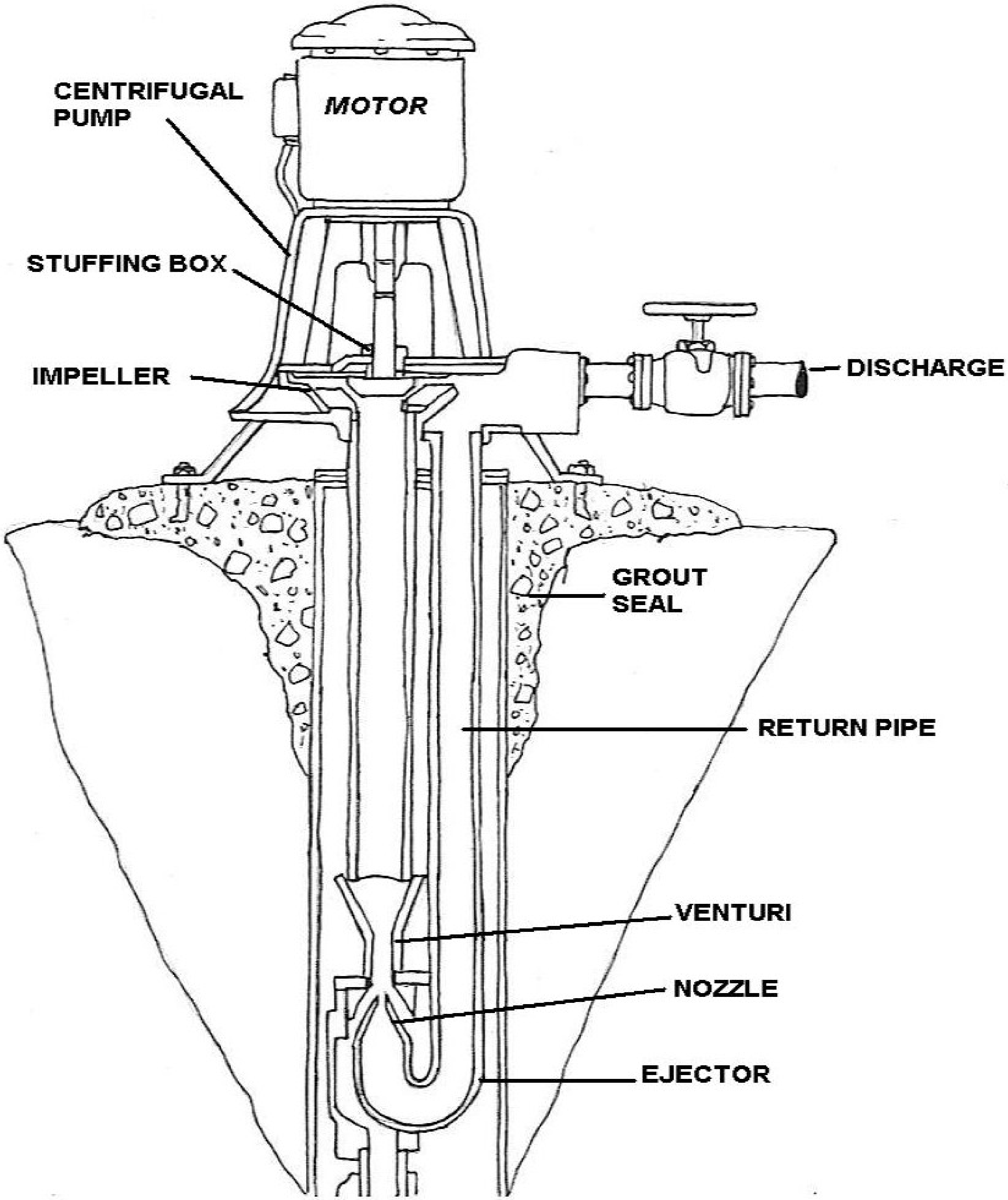
Multiply by	Convert to				
Convert from	lb_f s / $inch^2$	lb_f s / ft^2	lb_f h / ft^2	lb / ft s	lb / ft h
Poiseuille (Pa s)	1.45 10^{-4}	0.0209	5.8 10^{-6}	0.672	2.42 10^3
Poise (dyne s / cm^2 = g / cm s)	1.45 10^{-5}	0.00209	5.8 10^{-7}	0.0672	242
centiPoise	1.45 10^{-7}	2.9 10^{-5}	5.8 10^{-9}	0.000672	2.42
kg / m h	4.03 10^{-8}	5.8 10^{-6}	1.61 10^{-9}	0.000187	0.672
kg_f s / m^2	0.00142	20.5	5.69 10^{-5}	6.59	2.37 10^4
lb_f s / $inch^2$	1	144	0.04	4.63 10^3	1.67 10^7
lb_f s / ft^2	0.00694	1	0.000278	32.2	1.16 10^5
lb_f h / ft^2	25	3.6 10^3	1	1.16 10^5	4.17 10^8
lb / ft s	0.000216	0.0311	8.63 10^{-6}	1	3.6 10^3
lb / ft h	6 10-^{8}	1.16 10^5	2.4 10^{-9}	0.000278	1

Friction Loss Chart

The table below can be used to indicate the friction loss - feet of liquid per 100 feet of pipe - in standard schedule 40 steel pipes.

Pipe Size (inches)	Flow Rate		Kinematic Viscosity - SSU					
	(gpm)	(l/s)	31 (Water)	100 (~Cream)	200 (~Vegetable oil)	400 (~SAE 10 oil)	800 (~Tomato juice)	1500 (~SAE 30 oil)
1/2	3	0.19	10.0	25.7	54.4	108.0	218.0	411.0
3/4	3	0.19	2.5	8.5	17.5	35.5	71.0	131.0
	5	0.32	6.3	14.1	29.3	59.0	117.0	219.0
1	3	0.19	0.8	3.2	6.6	13.4	26.6	50.0
	5	0.32	1.9	5.3	11.0	22.4	44.0	83.0
	10	0.63	6.9	11.2	22.4	45.0	89.0	165.0
	15	0.95	14.6	26.0	34.0	67.0	137.0	
	20	1.26	25.1	46	46.0	90.0	180.0	
1 1/4	5	0.32	0.5	1.8	3.7	7.6	14.8	26.0
	10	0.63	1.8	3.6	7.5	14.9	30.0	55.0
	15	0.95	3.7	6.4	11.3	22.4	45.0	84.0
1 1/2	10	0.63	0.8	1.9	4.2	8.1	16.5	31.0
	15	0.95	1.7	2.8	6.2	12.4	25.0	46.0
	20	1.26	2.9	5.3	8.1	16.2	33.0	61.0
	30	1.9	6.3	11.6	12.2	24.3	50.0	91.0
	40	2.5	10.8	19.6	20.8	32.0	65.0	121.0
2	20	1.26	0.9	1.5	3.0	6.0	11.9	22.4
	30	1.9	1.8	3.2	4.4	9.0	17.8	33.0
	40	2.5	3.1	5.8	5.8	11.8	24.0	44.0
	60	3.8	6.6	11.6	13.4	17.8	36.0	67.0
	80	5.0	1.6	3.0	3.2	4.8	9.7	18.3
2 1/2	30	1.9	0.8	1.4	2.2	4.4	8.8	16.6
	40	2.5	1.3	2.5	3.0	5.8	11.8	22.2
	60	3.8	2.7	5.1	5.5	8.8	17.8	34.0
	80	5.0	4.7	8.3	9.7	11.8	24.0	44.0
	100	6.3	7.1	12.2	14.1	14.8	29.0	55.0
3	60	3.8	0.9	1.8	1.8	3.7	7.3	13.8
	100	6.3	2.4	4.4	5.1	6.2	12.1	23.0
	125	7.9	3.6	6.5	7.8	8.1	15.3	29.0
	150	9.5	5.1	9.2	10.4	11.5	18.4	35.0
	175	11.0	6.9	11.7	13.8	15.8	21.4	40.0
	200	12.6	8.9	15.0	17.8	20.3	25.0	46.0
4	80	5.0	0.4	0.8	0.8	1.7	3.3	6.2
	100	6.3	0.6	1.2	1.3	2.1	4.1	7.8

	125	7.9	0.9	1.8	2.1	2.6	5.2	9.8
	150	9.5	1.3	2.4	2.9	3.1	6.2	11.5
	175	11.0	1.8	3.2	4.0	4.0	7.4	13.7
	200	12.6	2.3	4.2	5.1	5.1	8.3	15.5
	250	15.8	3.5	6.0	7.4	8.0	10.2	19.4
6	125	7.9	0.1	0.3	0.3	0.52	1.0	1.9
	150	9.5	0.2	0.3	0.4	0.6	1.2	2.3
	175	11.0	0.2	0.4	0.5	0.7	1.4	2.6
	200	12.6	0.3	0.6	0.7	0.8	1.6	3.0
	250	15.8	0.5	0.8	1.0	1.0	2.1	3.7
	300	18.9	1.1	8.5	10.0	11.6	12.4	23.0
	400	25.2	1.1	1.9	2.3	2.8	3.2	6.0
8	250	15.8	0.1	0.2	0.3	0.4	0.7	1.2
	300	18.9	0.3	1.2	1.4	1.5	2.5	4.6
	400	25.2	0.3	0.5	0.6	0.7	1.1	2.0
10	300	18.9	0.1	0.3	0.4	0.4	0.8	1.5
	400	25.2	0.1	0.2	0.2	0.2	0.4	0.8



Hazen-Williams Coefficients

Hazen-Williams factor for some common piping materials. Hazen-Williams coefficients are used in the Hazen-Williams equation for friction loss calculation in ducts and pipes. Coefficients for some common materials used in ducts and pipes can be found in the table below:

Material	Hazen-Williams Coefficient *- C -*
Asbestos Cement	140
Brass	130 - 140
Brick sewer	100
Cast-Iron - new unlined (CIP)	130
Cast-Iron 10 years old	107 - 113
Cast-Iron 20 years old	89 - 100
Cast-Iron 30 years old	75 - 90
Cast-Iron 40 years old	64-83
Cast-Iron, asphalt coated	100
Cast-Iron, cement lined	140
Cast-Iron, bituminous lined	140
Cast-Iron, wrought plain	100
Concrete	100 - 140
Copper or Brass	130 - 140
Ductile Iron Pipe (DIP)	140
Fiber	140
Galvanized iron	120
Glass	130
Lead	130 - 140
Plastic	130 - 150
Polyethylene, PE, PEH	150
PVC, CPVC	150
Smooth Pipes	140
Steel new unlined	140 - 150
Steel	
Steel, welded and seamless	100
Steel, interior riveted, no projecting rivets	100
Steel, projecting girth rivets	100
Steel, vitrified, spiral-riveted	90 - 100
Steel, corrugated	60
Tin	130
Vitrified Clays	110
Wood Stave	110 - 120

Pressure Head

A pressure difference of 5 psi (lbf/in^2) is equivalent to

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 62.4 (lb/ft^3) = 11.6 ft of water

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 847 (lb/ft^3) = 0.85 ft of mercury

When specific weight of water is 62.4 (lb/ft^3) and specific weight of mercury is 847 (lb/ft^3).

Heads at different velocities can be taken from the table below:

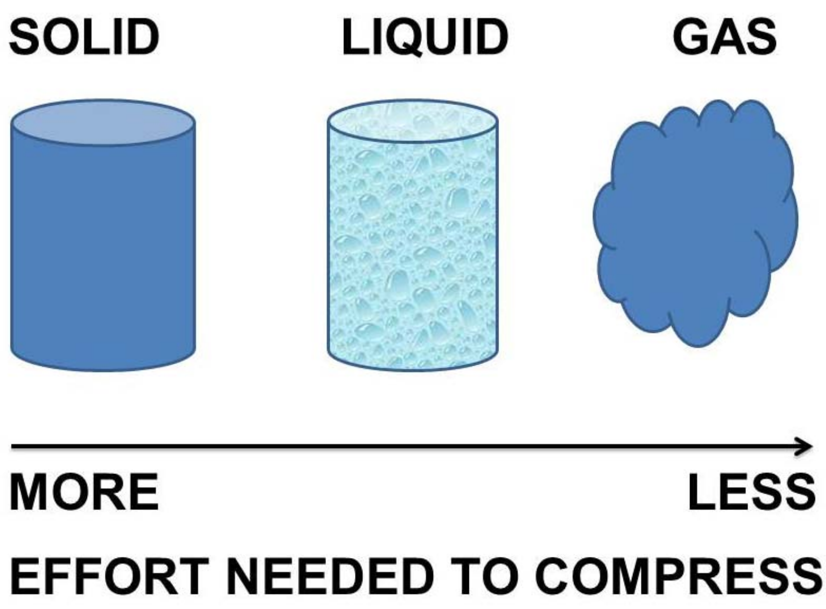
Velocity (ft/sec)	Head Water (ft)
0.5	0.004
1.0	0.016
1.5	0035
2.0	0.062
2.5	0.097
3.0	0.140
3.5	0.190
4.0	0.248
4.5	0.314
5.0	0.389
5.5	0.470
6.0	0.560
6.5	0.657
7.0	0.762
7.5	0.875
8.0	0.995
8.5	1.123
9.0	1.259
9.5	1.403
10.0	1.555
11.0	1.881
12.0	2.239
13.0	2.627
14.0	3.047
15.0	3.498
16.0	3.980
17.0	4.493
18.0	5.037
19.0	5.613
20.0	6.219
21.0	6.856
22.0	7.525

1 ft (foot) = 0.3048 m = 12 in = 0.3333 yd.

Thermal Properties of Water

Temperature - t - (^oC)	Absolute pressure - p - (kN/m^2)	Density - ρ - (kg/m^3)	Specific volume - v - ($m^3/kgx10^{-3}$)	Specific Heat - c_p - (kJ/kgK)	Specific entropy - e - (kJ/kgK)
0	0.6	1000	100	4.217	0
5	0.9	1000	100	4.204	0.075
10	1.2	1000	100	4.193	0.150
15	1.7	999	100	4.186	0.223
20	2.3	998	100	4.182	0.296
25	3.2	997	100	4.181	0.367
30	4.3	996	100	4.179	0.438
35	5.6	994	101	4.178	0.505
40	7.7	991	101	4.179	0.581
45	9.6	990	101	4.181	0.637
50	12.5	988	101	4.182	0.707
55	15.7	986	101	4.183	0.767
60	20.0	980	102	4.185	0.832
65	25.0	979	102	4.188	0.893
70	31.3	978	102	4.190	0.966
75	38.6	975	103	4.194	1.016
80	47.5	971	103	4.197	1.076
85	57.8	969	103	4.203	1.134
90	70.0	962	104	4.205	1.192
95	84.5	962	104	4.213	1.250
100	101.33	962	104	4.216	1.307
105	121	955	105	4.226	1.382
110	143	951	105	4.233	1.418
115	169	947	106	4.240	1.473
120	199	943	106	4.240	1.527
125	228	939	106	4.254	1.565
130	270	935	107	4.270	1.635
135	313	931	107	4.280	1.687
140	361	926	108	4.290	1.739
145	416	922	108	4.300	1.790
150	477	918	109	4.310	1.842
155	543	912	110	4.335	1.892
160	618	907	110	4.350	1.942
165	701	902	111	4.364	1.992
170	792	897	111	4.380	2.041
175	890	893	112	4.389	2.090

180	1000	887	113	4.420	2.138
185	1120	882	113	4.444	2.187
190	1260	876	114	4.460	2.236
195	1400	870	115	4.404	2.282
200	1550	863	116	4.497	2.329
220					
225	2550	834	120	4.648	2.569
240					
250	3990	800	125	4.867	2.797
260					
275	5950	756	132	5.202	3.022
300	8600	714	140	5.769	3.256
325	12130	654	153	6.861	3.501
350	16540	575	174	10.10	3.781
360	18680	526	190	14.60	3.921



Viscosity Converting Chart

The viscosity of a fluid is its resistance to shear or flow, and is a measure of the fluid's adhesive/ cohesive or frictional properties. This arises because of the internal molecular friction within the fluid producing the frictional drag effect. There are two related measures of fluid viscosity which are known as **dynamic** and **kinematic** viscosity.

Dynamic viscosity is also termed "**absolute viscosity**" and is the tangential force per unit area required to move one horizontal plane with respect to the other at unit velocity when maintained a unit distance apart by the fluid.

Centipoise (CPS) Millipascal (mPas)	Poise (P)	Centistokes (cSt)	Stokes (S)	Saybolt Seconds Universal (SSU)
1	0.01	1	0.01	31
2	0.02	2	0.02	34
4	0.04	4	0.04	38
7	0.07	7	0.07	47
10	0.1	10	0.1	60
15	0.15	15	0.15	80
20	0.2	20	0.2	100
25	0.24	25	0.24	130
30	0.3	30	0.3	160
40	0.4	40	0.4	210
50	0.5	50	0.5	260
60	0.6	60	0.6	320
70	0.7	70	0.7	370
80	0.8	80	0.8	430
90	0.9	90	0.9	480
100	1	100	1	530
120	1.2	120	1.2	580
140	1.4	140	1.4	690
160	1.6	160	1.6	790
180	1.8	180	1.8	900
200	2	200	2	1000
220	2.2	220	2.2	1100
240	2.4	240	2.4	1200
260	2.6	260	2.6	1280
280	2.8	280	2.8	1380
300	3	300	3	1475
320	3.2	320	3.2	1530

340	3.4	340	3.4	1630
360	3.6	360	3.6	1730
380	3.8	380	3.8	1850
400	4	400	4	1950
420	4.2	420	4.2	2050
440	4.4	440	4.4	2160
460	4.6	460	4.6	2270
480	4.8	480	4.8	2380
500	5	500	5	2480
550	5.5	550	5.5	2660
600	6	600	6	2900
700	7	700	7	3380
800	8	800	8	3880
900	9	900	9	4300
1000	10	1000	10	4600
1100	11	1100	11	5200
1200	12	1200	12	5620
1300	13	1300	13	6100
1400	14	1400	14	6480
1500	15	1500	15	7000
1600	16	1600	16	7500
1700	17	1700	17	8000
1800	18	1800	18	8500
1900	19	1900	19	9000
2000	20	2000	20	9400
2100	21	2100	21	9850
2200	22	2200	22	10300
2300	23	2300	23	10750
2400	24	2400	24	11200

Various Flow Section Channels and their Geometric Relationships:
Area, wetted perimeter and hydraulic diameter for some common geometric sections like
- rectangular channels
- trapezoidal channels
- triangular channels
- circular channels.

Rectangular Channel
Flow Area
Flow area of a rectangular channel can be expressed as
A = b h (1)

where
A = flow area (m^2, in^2)
b = width of channel (m, in)
h = height of flow (m, in)

Wetted Perimeter
Wetted perimeter of a rectangular channel can be expressed as
P = b + 2 h (1b)

where
P = wetted perimeter (m, in)

Hydraulic Radius
Hydraulic radius of a rectangular channel can be expressed as
$R_h = b\ h / (b + 2\ y)$ *(1c)*

where
R_h *= hydraulic radius (m, in)*

Trapezoidal Channel
Flow Area
Flow area of a trapezoidal channel can be expressed as
A = (a + z h) h (2)

where
z = see figure above (m, in)

Wetted Perimeter
Wetted perimeter of a trapezoidal channel can be expressed as
$P = a + 2\ h\ (1 + z^2)^{1/2}$ *(2b)*

Hydraulic Radius
Hydraulic radius of a trapezoidal channel can be expressed as
$R_h = (a + z\ h)\ h / a + 2\ h\ (1 + z^2)^{1/2}$ *(2c)*

Triangular Channel

Flow Area

Flow area of a triangular channel can be expressed as

$A = z h^2$ *(3)*

where

z = see figure above (m, in)

Wetted Perimeter

Wetted perimeter of a triangular channel can be expressed as

$P = 2 h (1 + z^2)^{1/2}$ *(3b)*

Hydraulic Radius

Hydraulic radius of a triangular channel can be expressed as

$R_h = z h / 2 (1 + z^2)^{1/2}$ *(3c)*

Circular Channel

Flow Area

Flow area of a circular channel can be expressed as

$A = D^2/4 (\alpha - \sin(2 \alpha)/2)$ *(4)*

where

D = diameter of channel

$\alpha = \cos^{-1}(1 - h/r)$

Wetted Perimeter

Wetted perimeter of a circular channel can be expressed as

$P = \alpha D$ *(4b)*

Hydraulic Radius

Hydraulic radius of a circular channel can be expressed as

$R_h = D/8 [1 - \sin(2 \alpha) / (2 \alpha)]$ *(4c)*

Velocity Head: Velocity head can be expressed as

$h = v^2/2g$ *(1)*

where

v = velocity (ft, m)

g = acceleration of gravity (32.174 ft/s², 9.81 m/s²)

Heads at different velocities can be taken from the table below:

Velocity - *v* - (ft/sec)	Velocity Head - $v^2/2g$ - (ft Water)
0.5	0.004
1.0	0.016
1.5	0035
2.0	0.062
2.5	0.097
3.0	0.140
3.5	0.190
4.0	0.248
4.5	0.314
5.0	0.389
5.5	0.470
6.0	0.560
6.5	0.657
7.0	0.762
7.5	0.875
8.0	0.995
8.5	1.123
9.0	1.259
9.5	1.403
10.0	1.555
11.0	1.881
12.0	2.239
13.0	2.627
14.0	3.047
15.0	3.498
16.0	3.980
17.0	4.493
18.0	5.037
19.0	5.613
20.0	6.219
21.0	6.856
22.0	7.525

Some Commonly used Thermal Properties for Water

- Density at 4 °C - 1,000 kg/m^3, 62.43 Lbs./Cu.Ft., 8.33 Lbs./Gal., 0.1337 Cu.Ft./Gal.
- Freezing temperature - 0 °C
- Boiling temperature - 100 °C
- Latent heat of melting - 334 kJ/kg
- Latent heat of evaporation - 2,270 kJ/kg
- Critical temperature - 380 - 386 °C
- Critical pressure - 23.520 kN/m^2
- Specific heat capacity water - 4.187 kJ/kgK
- Specific heat capacity ice - 2.108 kJ/kgK
- Specific heat capacity water vapor - 1.996 kJ/kgK
- Thermal expansion from 4 °C to 100 °C - $4.2x10^{-2}$

Bulk modulus elasticity - 2,068,500 kN/m^2

Reynolds Number

Turbulent or laminar flow is determined by the dimensionless **Reynolds Number.**

The Reynolds number is important in analyzing any type of flow when there is substantial velocity gradient (i.e., shear.) It indicates the relative significance of the viscous effect compared to the inertia effect. The Reynolds number is proportional to inertial force divided by viscous force.

A definition of the Reynolds' Number:
The flow is

- **laminar** if Re < 2300
- **transient** if 2300 < Re < 4000
- **turbulent** if 4000 < Re

The table below shows Reynolds Number for one liter of water flowing through pipes of different dimensions:

Pipe Size										
(inches)	1	1 ?	2	3	4	6	8	10	12	18
(mm)	25	40	50	75	100	150	200	250	300	450
Reynolds number with **one (1) liter/min**	835	550	420	280	210	140	105	85	70	46
Reynolds number with **one (1) gal/min**	3800	2500	1900	1270	950	630	475	380	320	210

Linear Motion Formulas

Velocity can be expressed as (velocity = constant):

$v = s / t$ *(1a)*

where
v *= velocity (m/s, ft/s)*
s *= linear displacement (m, ft)*
t *= time (s)*

Velocity can be expressed as (acceleration = constant):
$v = V_0 + a t$ *(1b)*

where
V_0 *= linear velocity at time zero (m/s, ft/s)*

Linear displacement can be expressed as (acceleration = constant):
$s = V_0 t + 1/2 a t^2$ *(1c)*

Combining 1a and 1c to express velocity
$v = (V_0^2 + 2 a s)^{1/2}$ *(1d)*

Velocity can be expressed as (velocity variable)
$v = ds / dt$ *(1f)*

where
ds *= change of displacement (m, ft)*
dt *= change in time (s)*

Acceleration can be expressed as
$a = dv / dt$ *(1g)*

where
dv *= change in velocity (m/s, ft/s)*

Water - Dynamic and Kinematic Viscosity

Dynamic and Kinematic Viscosity of Water in Imperial Units (BG units):

Temperature *- t -* *(°F)*	Dynamic Viscosity *- μ -* *10^{-5} (lbs./ft²)*	Kinematic Viscosity *- ν -* *10^{-5} (ft²/s)*
32	3.732	1.924
40	3.228	1.664
50	2.730	1.407
60	2.344	1.210
70	2.034	1.052
80	1.791	0.926
90	1.500	0.823
100	1.423	0.738
120	1.164	0.607
140	0.974	0.511
160	0.832	0.439
180	0.721	0.383
200	0.634	0.339
212	0.589	0.317

Dynamic and Kinematic Viscosity of Water in SI Units:

Temperature *- t -* *(°C)*	Dynamic Viscosity *- μ -* *10^{-3} (N.s/m²)*	Kinematic Viscosity *- ν -* *10^{-6} (m²/s)*
0	1.787	1.787
5	1.519	1.519
10	1.307	1.307
20	1.002	1.004
30	0.798	0.801
40	0.653	0.658
50	0.547	0.553
60	0.467	0.475
70	0.404	0.413
80	0.355	0.365
90	0.315	0.326
100	0.282	0.294

Water and Speed of Sound

Speed of sound in water at temperatures between 32 - 212^{o}F (0-100^{o}C) - imperial and SI units

Speed of Sound in Water - in imperial units (BG units)

Temperature - *t* - (^{o}F)	Speed of Sound - *c* - (ft/s)
32	4,603
40	4,672
50	4,748
60	4,814
70	4,871
80	4,919
90	4,960
100	4,995
120	5,049
140	5,091
160	5,101
180	5,095
200	5,089
212	5,062

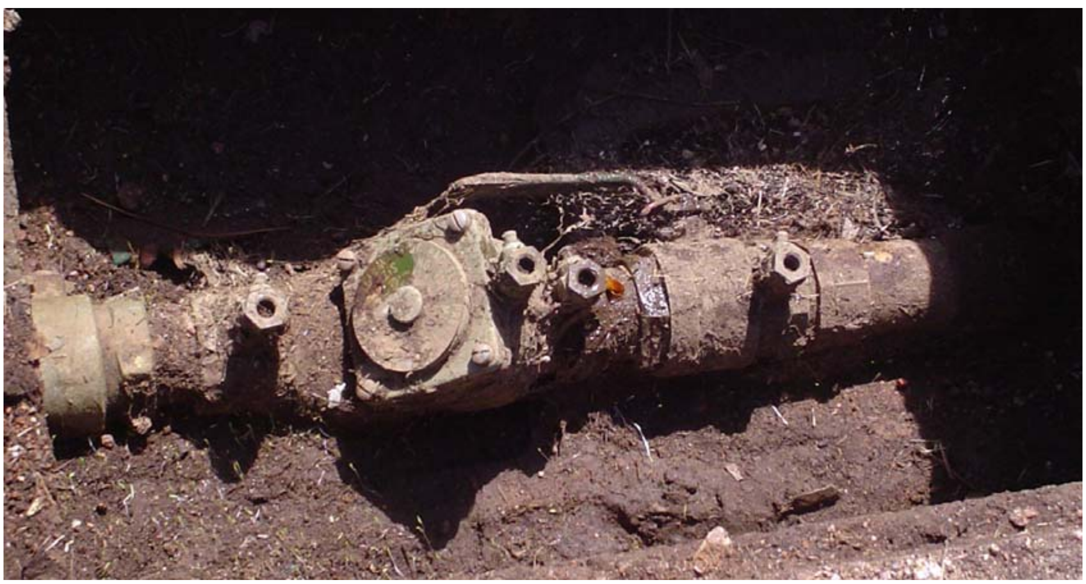
Speed of Sound in Water - in SI units

Temperature - *t* - (^{o}C)	Speed of Sound - *c* - (m/s)
0	1,403
5	1,427
10	1,447
20	1,481
30	1,507
40	1,526
50	1,541
60	1,552
70	1,555
80	1,555
90	1,550
100	1,543

Math Conversion Factors

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
1 Gallon of Water = 8.34 lbs/gallon
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 = 1Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of Water
62.38 Pounds = 1 Cubic Foot of Water



Another RP buried inside a water meter box, broken shut-offs and not tested for over 20 years. The best thing to do is rip out this assembly and install a completely new assembly above ground and test the assembly. Careful to document the location, serial number and other information for the water provider. The owner of the backflow preventer will feel ripped-off because he did not realize the potential hazard, so you need to carefully and skillfully explain the necessity of the replacement and relocation. Often, your water provider will support you in a correct decision but sometimes, these “officials” don’t know or don’t care about the condition or location of assemblies. I have seen water providers do the dumbest things and the next day, change their minds and blame the tester for the problem. CWA! Document everything and prepare to be underbid and held accountable.

Backflow Awareness CEU Training Course Practice Exam

The focus of this course is a basic understanding of Backflow Prevention/Cross-Connection. This course is **NOT** designed to certify you as a General Tester or a Cross-Connection Specialist.

Practice Exam, the final assignment is a 200 multiple choice question examination. You can find a copy of the final assignment on TLC's website under the Assignment page, both in Adobe Acrobat and Microsoft Word formats.

1. Define the term BACKFLOW.

2. Define the term BACKPRESSURE.

3. Define the term BACKSIPHONAGE.

4. Why is backflow a concern?

5. Do you believe backflow is a reasonable concern to you? Why?

6. When should a water supplier require a backflow-prevention assembly to be installed?

Define the following abbreviations:

7. AG

8. RP

9. PVB

10. DC

11. What does your State use for a reference or standard for determining what type of backflow assembly can be used? Please provide the name/title or reference of this Rule or Regulation.

12. What State agency is responsible for backflow protection?

13. Are single family residences in your State required to have a backflow assembly?

14. What is the standard or description for an Air Gap?

15. Give one example of an Air Gap that you have seen.

16. Give two examples of how a PVB can be used.

17. Give one example of a backflow prevention assembly, manufactures name, model number, and type of assembly.

18. Explain Pascal's Law.

19. Explain Bernoulli’s Principle.

20. Explain in detail a backflow/cross-connection occurrence. If you are unfamiliar with a backflow/cross-connection occurrence, please use the library or the Internet and you will be able to find several occurrences. We would prefer an actual report of a backflow occurrence that you know of or have seen.

21. How could the previous backflow /cross-connection event or incident have been prevented? Explain in detail. 100 word minimum.

22. Do you believe that backflow prevention is reasonable? Explain why in 100 words.

23. Do you believe that backflow prevention is unreasonable or could be excessive in some way? Explain why in less than 100 words.

24. Have you learned anything about backflow or your State Rule? How would you improve the Rules?

25. What is meant by the expression “**Closed-Loop**” commonly caused by placing a RP on a service line?

26. Do Firelines need backflow prevention assemblies? Explain

27. Does backflow in any way relate to your profession? Explain in detail. 100 word minimum

A happy TLC student at our hands-on backflow awareness class.