VALVES AND FITTINGS

CONTINUING EDUCATION

PROFESSIONAL DEVELOPMENT COURSE

Technical Learning College

Printing and Saving Instructions

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

You can complete the course by viewing the course on your computer or you can print it out. This course booklet does not have the assignment (the test). Please visit our website and download the assignment (the test).

Printing Instructions: Once you have purchased the program, we will give you permission to print this document. If you are going to print this document, it was designed to be printed double-sided or duplexed but can be printed single-sided.

You can obtain a printed version from TLC for an additional $129.95 plus shipping charges.

Internet Link to Assignment…
http://www.abctlc.com/downloads/PDF/ValveandFittingsAss.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. Do not solely trust our list for it may be outdated. It is your sole responsibility to ensure this course is accepted for credit. No refunds.

Professional Engineers: most states will accept our courses for credit but we do not official list the States or Agencies.

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All downloads are electronically tracked and monitored for security purposes.

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

Do not solely depend on TLC's Approval list for it may be outdated.

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

Responsibility

This course contains EPA's federal rule requirements. Please be aware that each state implements drinking water/wastewater/safety regulations that may be more stringent than EPA's or OSHA's regulations.

Check with your state environmental agency for more information. You are solely responsible in ensuring that you abide with your jurisdiction or agency's rules and regulations.

Important Information about this Manual

This manual has been prepared to educate operators in the general education of valves, valve system design, valve operation, and hydraulic principles including basic mechanical training and different valve related applications. For most students, the study of valving and hydraulics is quite large, requiring a major effort to bring it under control.

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 hydraulic equipment, 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.

Contributing Editors

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

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

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

Technical Learning College's Scope and Function

Welcome to the Program,

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

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

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

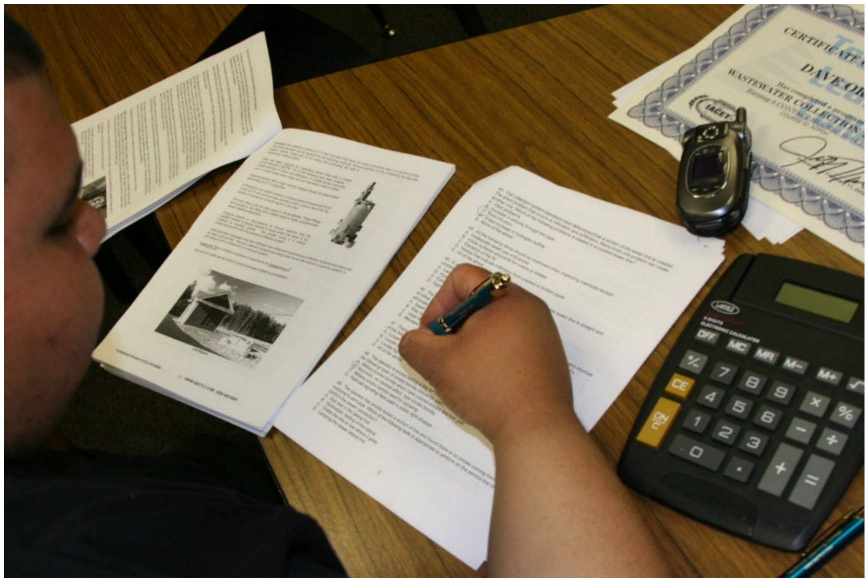
Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling; i.e.,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

Flexible Learning
At TLC, there are no scheduled online sessions or passwords you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus based student. You 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.

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

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

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



We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail. If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of $50.

Contact Numbers

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

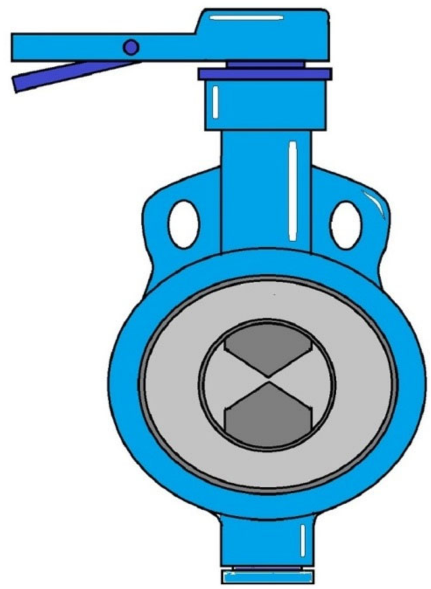
CEU Course Description

VALVES AND FITTINGS CEU TRAINING COURSE

This short technical continuing education course will address the EPA Lead reduction rule in relation to fittings and valves. This course will cover the new lead reduction requirements of the Safe Drinking Water Act and general water distribution and hydraulic principles.

Statement of Need

All water treatment and distribution system operators must know the new EPA Lead reduction rule and how it applies to valves and fittings in order to provide safe drinking water to the public. This course will cover the basic requirements of the Safe Drinking Water Act and general water pipefitting, water distribution and hydraulic principles.



1. Students will be able to understand, identify and explain the EPA Reduction of Lead in Drinking Water Rule and related information.

2. Students will be able to understand, identify and explain various distribution pipe installation materials, methods and disinfection procedures.

3. Students will be able to understand, identify and explain common joints and fittings installation materials, methods and disinfection procedures.

4. Students will be able to understand, identify and explain backflow concerns, methods, assemblies and cross-connections prevention methods.

5. Students will be able to understand, identify and explain commonly found water treat/distribution valves and operating procedures.

6. Students will be able to understand, identify and explain related pipeline hydraulic procedures, principles and terms related to water production and water carrying methods.

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.

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

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 a unique number will be assigned to the student.

Instructions for Assignment
The ***Valves and Fittings*** CEU training course uses a multiple choice type answer key. You can find a copy of the answer key in the front of the assignment 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.

Disclaimer and Security Notice
The student shall understand that it their responsibility to ensure that this CEU course is either approved or accepted in my State for CEU credit. The student shall understand and follow State laws and rules concerning distance learning courses and understand these rules change on a frequent basis and will not hold Technical Learning College responsible for any changes. The student shall understand that this type of study program deals with dangerous conditions and will not hold Technical Learning College, Technical Learning Consultants, Inc. (TLC) liable for any errors or omissions or advice contained in this CEU education training course or for any violation or injury caused by this CEU education training course material. The student shall contact TLC if they need help or assistance and double-check to ensure my registration page and assignment has been received and graded.

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 ***Valves and Fittings*** 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 your responsibility to give the completion certificate to the appropriate agencies.

You will have 90 days from receipt of this manual to complete 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 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,

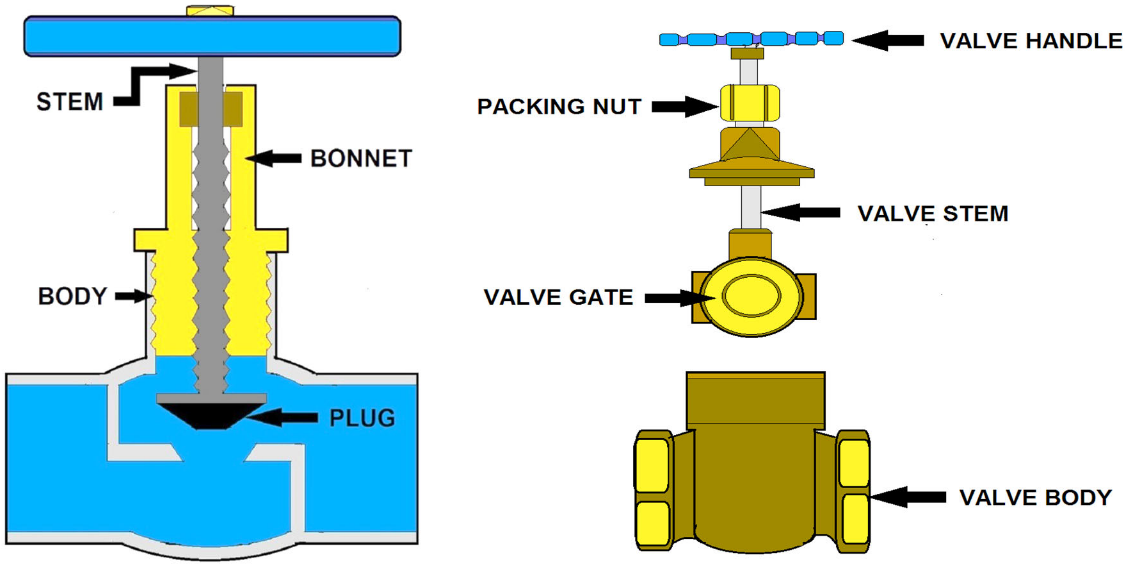
To provide a forum in which students can exchange experiences and ideas related to environmental education,

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.

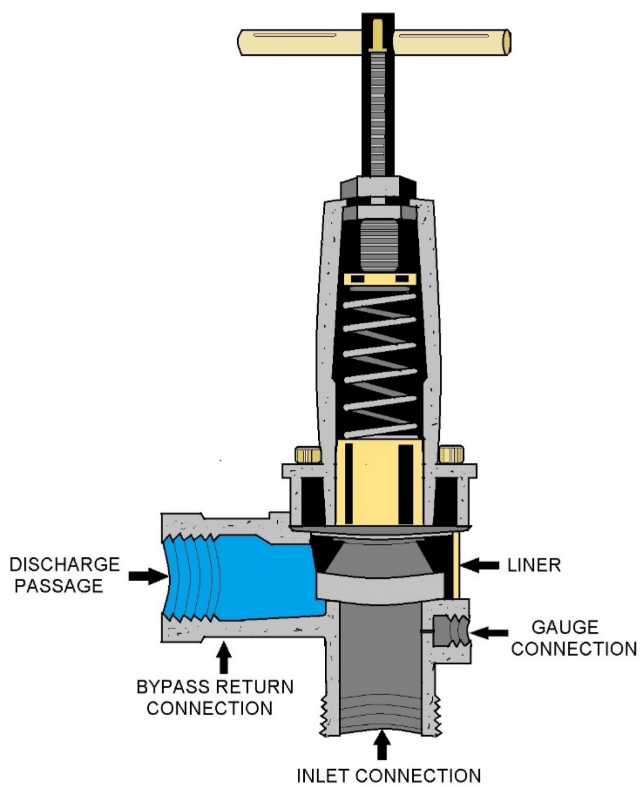
Please call TLC if you need any assistance with this course or assignment.

Always check with your State agency to see if this course is accepted.

TLC Toll Free (866) 557-1746



GLOBE AND WHEEL VALVES



PRESSURE RELIEF VALVE

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Course Introduction

A **water supply system** or **distribution system** is a system of engineered hydrologic and hydraulic components which provide water supply. A water supply system typically includes:

1. A raw water collection point (above or below ground) where the water accumulates, such as a lake, a river, or groundwater from an underground aquifer. Raw water may be transferred using uncovered ground-level aqueducts, covered tunnels or underground water pipes to water treatment facilities.
2. Water treatment facilities. Treated water is transferred using water pipes (usually underground). We will examine these water pipe and valves.
3. Water storage facilities such as reservoirs, water tanks, or water towers. Smaller water systems may store the water in cisterns or pressure vessels. Tall buildings may also need to store water locally in pressure vessels in order for the water to reach the upper floors.
4. Additional water pressurizing components such as pumping stations may need to be situated at the outlet of underground or above ground reservoirs or cisterns (if gravity flow is impractical).
5. A interconnecting pipe network for distribution of water to the consumers (which may be private houses or industrial, commercial or institution establishments) and other usage points (such as fire hydrants). We will examine these components in detail.
6. Connections to the sewer collection system (underground pipes, or aboveground ditches in some developing countries) are generally found downstream of the water consumers, but the sewer system is considered to be a separate system, rather than part of the water supply system.

Corrosion

As water passes through the distribution system, the water quality can degrade by chemical reactions and biological processes. Corrosion of metal pipe materials in the distribution system can cause the release of metals into the water with undesirable aesthetic and health effects. Release of iron from unlined iron pipes can result in customer reports of "red water" at the tap.

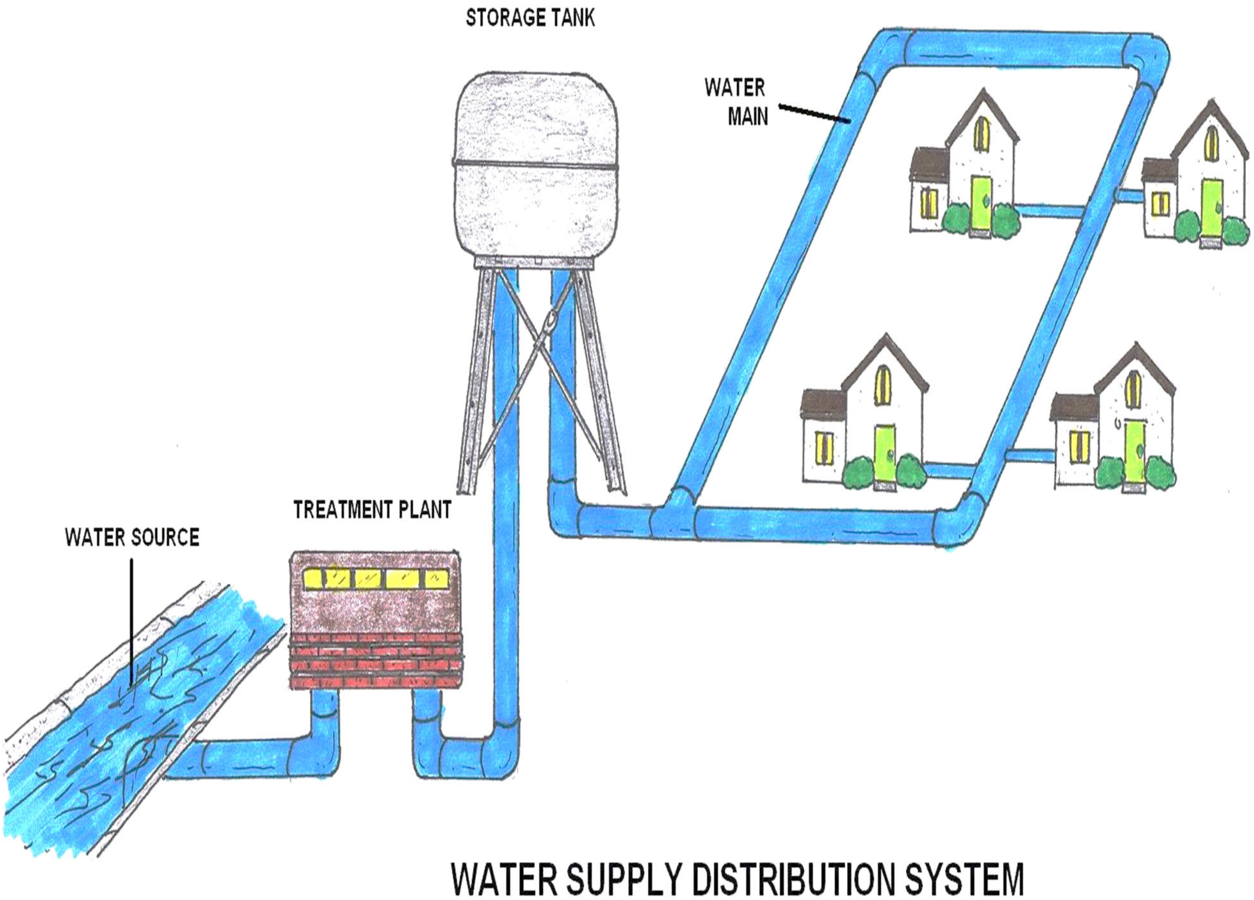
Release of copper from copper pipes can result in customer reports of "blue water" and/or a metallic taste.

Release of lead can occur from the solder used to join copper pipe together or from brass fixtures. Copper and lead levels at the consumer's tap are regulated to protect consumer health.

Utilities will often adjust the chemistry of the water before distribution to minimize its corrosiveness. The simplest adjustment involves control of pH and alkalinity to produce a water that tends to passivate corrosion by depositing a layer of calcium carbonate. Corrosion inhibitors are often added to reduce release of metals into the water. Common corrosion inhibitors added to the water are phosphates and silicates.

Maintenance of a biologically safe drinking water is another goal in water distribution. Typically, a chlorine based disinfectant, such as sodium hypochlorite or monochloramine is added to the water as it leaves the treatment plant. Booster stations can be placed within the distribution system to ensure that all areas of the distribution system have adequate sustained levels of disinfection.

Normal day for distribution workers.

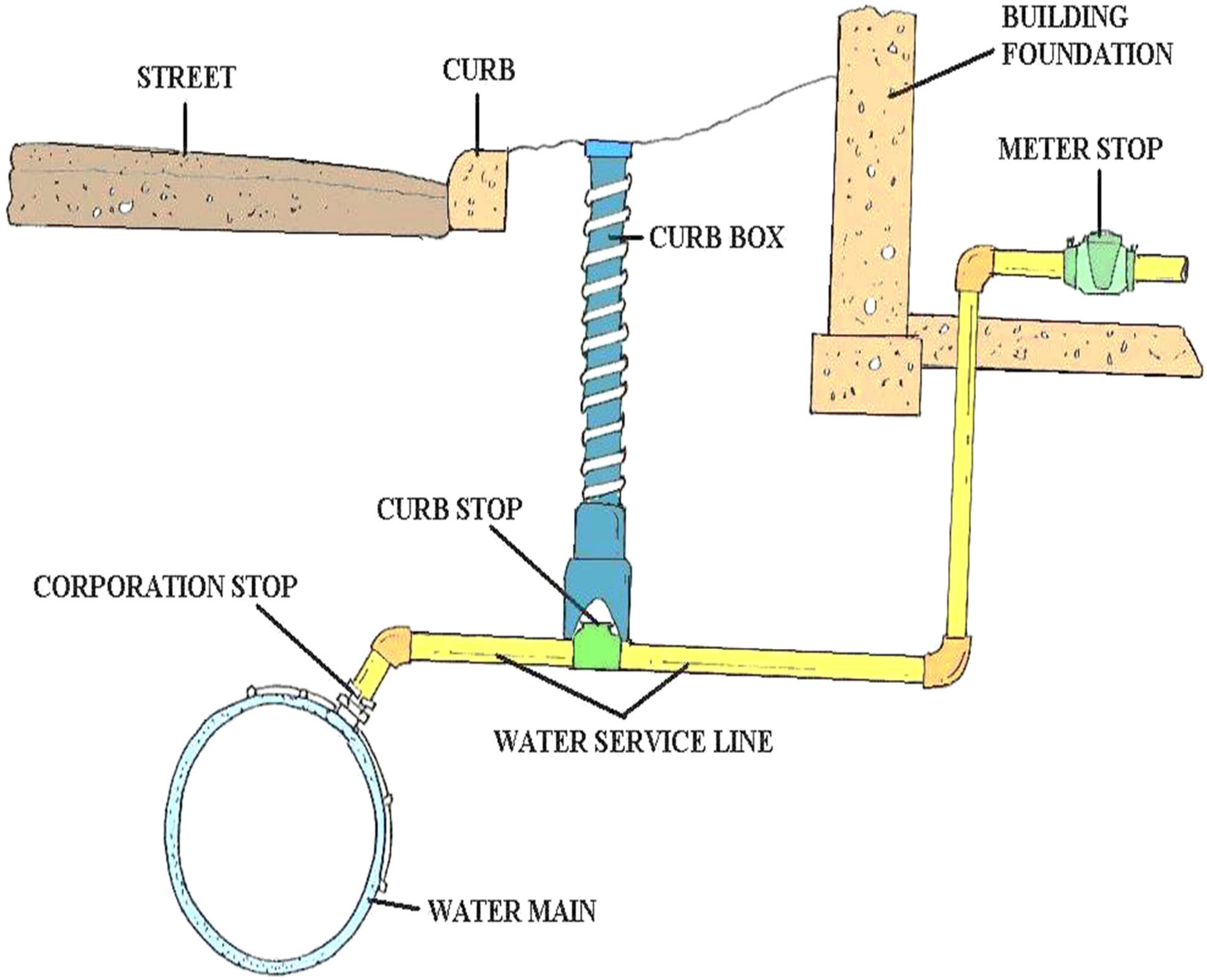


Schematic of a Large Transmission Distribution System

The diagram above shows a typical large main or transmission distribution system. The water flows from the treatment plant into a storage reservoir. Although not every system will have a storage reservoir, it is advisable to separate stored water and source water in order to have better hydraulic flows and a more dependable system. In this case, we have an elevated storage tank.

From the storage reservoir, water flows or is pumped as needed out into the mains which carry large quantities of water toward the customer. Water is diverted to feed fire hydrants off smaller mains. Other water flows from the mains into the service lines which carry the water to the customers.

Booster stations are used to pump water where the water pressure is lower than in the rest of the system. Meters measure the flow of water through the system located at customer services.



What Is the Distribution Purpose?

The water distribution system is the essential link between the water supply source and the consumer. It is not just the main that runs down your street, quite the contrary. It is an elaborate conveyance system that allows water to be moved through miles of piping before reaching your tap.

Pumps allow water to move through the system; valves allow water pressure and flow direction to be regulated along the way.

The Water Distribution is generally responsible for the maintenance of water mains, water services, fire hydrants, water valves and backflow devices located within your City's/Water Provider's service area. In short, the Distribution Division ensures that treated water is delivered to your tap.

New EPA Rules for Distribution
Reduction of Lead in Drinking Water Act

Congress passed Public Law 111-380 or The Reduction of Lead in Drinking Water Act, in 2010. It went into effect Jan. 4, 2014, which means municipalities, water districts and developers who work with and pay for water infrastructure need to be preparing.

Lead, a metal found in natural deposits, is commonly used in household plumbing materials and water service lines. The greatest exposure to lead is swallowing or breathing in lead paint chips and dust.

But lead in drinking water can also cause a variety of adverse health effects. In babies and children, exposure to lead in drinking water above the action level can result in delays in physical and mental development, along with slight deficits in attention span and learning abilities. In adults, it can cause increases in blood pressure. Adults who drink this water over many years could develop kidney problems or high blood pressure.

Lead is rarely found in source water, but enters tap water through corrosion of plumbing materials. Homes built before 1986 are more likely to have lead pipes, fixtures and solder. However, new homes are also at risk: even legally "lead-free" plumbing may contain up to 8 percent lead. The most common problem is with brass or chrome-plated brass faucets and fixtures which can leach significant amounts of lead into the water, especially hot water.

Congress enacted the Reduction of Lead in Drinking Water Act on January 4, 2011, to amend Section 1417 of the Safe Drinking Water Act (SDWA) regarding the use and introduction into commerce of lead pipes, plumbing fittings or fixtures, solder and flux. The Act established an effective date of January 4, 2014, which provided a three-year timeframe for affected parties to transition to the new requirements.

Pervasive Environmental Contaminant
Lead is a pervasive environmental contaminant. The adverse health effects of lead exposure in children and adults are well documented, and no safe blood lead threshold in children has been identified. Lead can be ingested from various sources, including lead paint and house dust contaminated by lead paint, as well as soil, drinking water, and food. The concentration of lead, total amount of lead consumed, and duration of lead exposure influence the severity of health effects. Because lead accumulates in the body, all sources of lead should be controlled or eliminated to prevent childhood lead poisoning.

Beginning in the 1970s, lead concentrations in air, tap water, food, dust, and soil began to be substantially reduced, resulting in significantly reduced blood lead levels (BLLs) in children throughout the United States. However, children are still being exposed to lead, and many of these children live in housing built before the 1978 ban on lead-based residential paint. These homes might contain lead paint hazards, as well as drinking water service lines made from lead, lead solder, or plumbing materials that contain lead. Adequate corrosion control reduces the leaching of lead plumbing components or solder into drinking water.

The majority of public water utilities are in compliance with the Safe Drinking Water Act Lead and Copper Rule (LCR) of 1991.

However, some children are still exposed to lead in drinking water. EPA is reviewing LCR, and additional changes to the rule are expected that will further protect public health. Childhood lead poisoning prevention programs should be made aware of the results of local public water system lead monitoring measurement under LCR and consider drinking water as a potential cause of increased BLLs, especially when other sources of lead exposure are not identified.

This review describes a selection of peer-reviewed publications on childhood lead poisoning, sources of lead exposure for adults and children, particularly children aged <6 years, and LCR. What is known and unknown about tap water as a source of lead exposure is summarized, and ways that children might be exposed to lead in drinking water are identified.

This report does not provide a comprehensive review of the current scientific literature but builds on other comprehensive reviews, including the *Toxicological Profile for Lead* and the 2005 CDC statement *Preventing Lead Poisoning Among Young Children*). When investigating cases of children with BLLs at or above the reference value established as the 97.5 percentile of the distribution of BLLs in U.S. children aged 1–5 years, drinking water should be considered as a source. The recent recommendations from the CDC Advisory Committee on Childhood Lead Poisoning Prevention to reduce or eliminate lead sources for children before they are exposed underscore the need to reduce lead concentrations in drinking water as much as possible.

Background

Lead is a relatively corrosion-resistant, dense, ductile, and malleable metal that has been used by humans for at least 5,000 years. During this time, lead production has increased from an estimated 10 tons per year to 1,000,000 tons per year, accompanying population and economic growth. The estimated average BLL for Native Americans before European settlement in the Americas was calculated as 0.016 *µ*g/dL. During 1999–2004, the estimated average BLL was 1.9 *µ*g/dL for the non-institutionalized population aged 1–5 years in the United States, approximately 100 times higher than ancient background levels, indicating that substantial sources of lead exposure exist in the environment.

January 4, 2014

On January 4, 2014, the "Reduction of Lead in Drinking Water Act" becomes effective nationwide. This amendment to the 1974 Safe Drinking Water Act reduces the allowable lead content of drinking water pipes, pipe fittings and other plumbing fixtures. Specifically, as of January 4, 2014, it shall be illegal to install pipes, pipe fittings, and other plumbing fixtures that are not "lead free." "Lead free" is defined as restricting the permissible levels of lead in the wetted surfaces of pipes, pipe fittings, other plumbing fittings and fixtures to a weighted average of not more than 0.25%.

This new requirement does not apply to pipes, pipe fittings, plumbing fittings or fixtures that are used exclusively for non-potable services such as manufacturing, industrial processing, irrigation, outdoor watering, or any other uses where water is not anticipated to be used for human consumption.

The law also excludes toilets, bidets, urinals, fill valves, flushometer valves, tub fillers, shower valves, service saddles, or water distribution main gate valves that are 2 inches in diameter or larger.

Accordingly, effective January 4, 2014, only accepted products that are "lead free" may be utilized with regards to any plumbing providing water for human consumption (unless meeting the exception outlined above). Installers and inspectors may check their products to determine if they meet these requirements by looking to see if the products are certified to the following standards:

A. NSF/ANSI 61-G;
B. NSF/ANSI 61, section 9-G; OR
C. Both NSF/ANSI 61 AND NSF/ANSI 372.

As existing products may still be utilized for non-potable purposes. The burden of following these requirements shall be on installers. Plumbing inspectors (who will be covering these requirements in continuing education) shall have the right to question installers, who must be able to prove that no non-compliant products are installed on or after January 4, 2014.

What does the law say?
It reduces the maximum amount of lead that can be used in the wetted surfaces of service brass from 8 percent to 0.25 percent. It prohibits the sale of traditional brass pipe fittings, valves and meters for potable water applications as well as their installation after Jan. 4, 2014.

Does The Reduction of Lead in Drinking Water Act apply to all water infrastructure?
No. Service brass used in industrial or non-potable infrastructure is exempt from the law. Also, the law only applies to wetted surfaces. Saddles and other exterior pipe are also exempt.

Are there any exceptions to the New Regulations?
Exceptions to the new lead-free law include: pipes, pipe fittings, plumbing fittings, or fixtures, including backflow preventers, that are used exclusively for non-potable services such as manufacturing, industrial processing, irrigation, outdoor watering, or any other uses where the water is not anticipated to be used for human consumption. In addition, toilets, bidets, urinals, fill valves, flushometer valves, tub fillers, shower valves, service saddles, or water distribution main gate valves that are 2 inches in diameter or larger are excluded from the new lead-free law.

Who does the New Regulations apply to?
If you use or introduce into commerce any pipe, valves, plumbing fittings or fixtures, solder, or flux intended to convey or dispense water for human consumption, your products must comply with the law. Additionally, if you introduce into commerce solder or flux, your products must comply with the law.

If I am a homeowner, how do I know my water system is lead-free?
Many manufacturers have already complied with the January 4th, 2014 implementation date of the federal “Reduction of Lead in Drinking Water Act.” Even without federal certification requirements regarding the lead content of plumbing products, California’s mandate for third-party certification will be followed by most manufacturers seeking a single approval path that covers both federal and state requirements. For that reason, it is important to use and install only clearly marked low-lead products.

If you are a homeowner and are concerned about potential lead exposure from your private water system, have your water tested by a state certified water testing laboratory in your area.

Is there a difference between low-lead and no-lead brass?
No. There are several terms flying around to refer to the low-lead service brass products – no lead, lead free, low lead, and others. They all refer to the same products: service brass with 0.25 percent or less lead on wetter surfaces.

How are the new alloys different?
Functionally, there is almost no difference. For water utilities and contractors working with the material, it will handle just like traditional service brass. The difference is in the manufacturing. Lead has traditionally been used to fill gaps, seal the surface and create a smooth pipe interior that doesn't have gaps or pits where debris can settle and erode the metal.

Instead of lead, manufacturers will have to use different and more expensive materials and take more care in the manufacturing process. That means the cost of the new low-lead brass will be 25 to 40 percent higher than traditional brass pipe fittings and meters.

What are the biggest concerns for developers, municipalities and water districts?
There are two big concerns that should inspire anyone responsible for laying water infrastructure to act soon. If you have inventory of traditional services brass, now is the time to find a place to use it. Work ahead on projects if you can because that inventory will be wasted if you don't use it before January 2014.

The second concern is cost. If you don't have an inventory of traditional brass but you have upcoming projects, this might be the ideal time to start them. Order traditional brass pipe fittings and meters from suppliers who are offering their traditional service brass at steep discounts ahead of the new law. After the law goes into effect, service brass costs will skyrocket and significantly increase your costs.

Lead-free Alternatives
There are several materials that utilities should consider when selecting a lead-free meter alternative. Various options include epoxy coated ductile and cast iron, stainless steel, low lead bronze and composite.

When choosing a lead-free alternative material, utilities must consider traditional meter requirements such as strong flow capability and durability. However, the difference between lead-free and zero lead meters should also be considered. Some "lead-free" meters contain as much as 0.25 percent lead.

While a 0.25 percentage of lead in meters allows utilities to meet current regulations, implementing these "lead-free" meters could put utilities at risk for the cost of another meter change out should future regulations require complete lead elimination from water meters.

Most water meters are expected to last more than 20 years, meaning that the next amendment to SDWA could come before the meter fleet must be replaced. This could be potentially devastating for utility companies still using older systems should completely lead-free meters become mandated.

Composite Meters
Composite meters are one example of a zero lead alternative that is not susceptible to future no-lead regulations. This meter material is also gaining popularity due to its strength and cost stability. Composite meters do not depend on metal pricing fluctuations and, more importantly, have zero lead as opposed to low lead or even bronze meters.

Made of materials that have already proven their strength and durability in the automotive and valve industries, composite meters boast longevity and resistance to corrosion from aggressive water and from the chlorinated chemicals used to make water drinkable. Composite meters are also equipped to withstand the pressure required to maintain a water system.

Composite meters are constructed using a blend of plastic and fiberglass. When compared to bronze water meter products, composites are lighter and require less time and energy to manufacture, ship and install. Composite meters attached with composite threads have been found to eliminate the "friction feeling" typically experienced with metal threads and metal couplings, facilitating easier installation.

Through comprehensive testing, composite meters have demonstrated a burst pressure that is significantly greater than bronze and an equal longevity. Composite technology today allows for better, more environmentally friendly composite products that will last up to 25 years in residential applications. Manufacturers have a wide range of "lead-free" or zero lead products on the market and it is critical that utilities consider all of their options when selecting a new fleet of meters.

Most importantly, everyone deserves access to safe, clean water. It is essential that manufacturers continually develop and deliver products that meet the highest standards for safety, quality, reliability and accuracy to ensure availability to, and conservation of, this most precious resource.

Lead in Drinking Water
Lead is unlikely to be present in source water unless a specific source of contamination exists. However, lead has long been used in the plumbing materials and solder that are in contact with drinking water as it is transported from its source into homes. Lead leaches into tap water through the corrosion of plumbing materials that contain lead.

The greater the concentration of lead in drinking water and the greater amount of lead-contaminated drinking water consumed, the greater the exposure to lead. In children, lead in drinking water has been associated both with BLLs ≥10 μg/dL as well as levels that are higher than the U.S. GM level for children (1.4 μg/dL) but are <10 μg/dL.

History of Studies on Lead in Water
In 1793, the Duke of Württemberg, Germany, warned against the use of lead in drinking water pipes, and in 1878, lead pipes were outlawed in the area as a result of concerns about the adverse health effects of lead in water. In the United States, the adverse health consequences of lead-contaminated water were recognized as early as 1845. A survey conducted in 1924 in the United States indicated that lead service lines were more prevalent in New England, the Midwest, Montana, New York, Oklahoma, and Texas.

A nationwide survey conducted in 1990 indicated that 3.3 million lead service lines were in use, and the areas where they were most likely to be used were, again, the Midwestern and northeastern regions of the United States. This survey also estimated that approximately 61,000 lead service lines had been removed through voluntary programs during the previous 10 years.

Research on exposure to lead in water increased as concern about the topic increased, and efforts were made to establish a level of lead in water that, at the time of the studies, was considered acceptable. A 1972 study in Edinburgh, Scotland, obtained 949 first-flush water samples (i.e., samples of water from the tap that have been standing in the plumbing pipes for at least 6 hours) matched with 949 BLLs, as well as 205 running water samples matched to 205 BLLs . No dose-response relationship could be determined when comparing BLLs with four levels of lead in both first-flush water and in running water (<0.24 *µ*mol/L; 0.24–0.47 *µ*mol/L; 0.48–1.43 *µ*mol/l; and ≥1.44 *µ*mol/L).

The study concluded that the findings challenged whether it was necessary to lower the water lead concentration to <100 ppb, which at that time was the acceptable concentration established by the World Health Organization. However, the study also reported that low levels of environmental lead exposure could have adverse health effects; therefore, knowing the degree of lead exposure from household water relative to other sources is important. Another study, in 1976, of 129 randomly selected homes in Caernarvonshire, England, reported a similar finding, describing the relationship between blood and water lead as slight.

Monitoring and Reporting
To ensure that drinking water supplied by **all** public water supply systems as defined by the EPA meet Federal and State requirements, water system operators are required to collect samples regularly and have the water tested. The regulations specify minimum sampling frequencies, sampling locations, testing procedures, methods of keeping records, and frequency of reporting to the State. The regulations also mandate special reporting procedures to be followed if a contaminant exceeds an MCL.

All systems must provide periodic monitoring for microbiological contaminants and some chemical contaminants. The frequency of sampling and the chemicals that must be tested for depend on the physical size of the water system, the water source, and the history of analyses. General sampling procedures are covered in more detail under the topic of Public Health Considerations to follow.

State policies vary on providing laboratory services. Some States have laboratory facilities available to perform all required analyses or, in some cases, a certain number of the required analyses for a system. In most States, there is a charge for all or some of the laboratory services. Sample analyses that are required and cannot be performed by a State laboratory must be taken or sent to a State-certified private laboratory.

If the analysis of a sample exceeds an MCL, resampling is required, and the State should be contacted immediately for special instructions. There is always the possibility that such a sample was caused by a sampling or laboratory error, but it must be handled as though it actually was caused by contamination of the water supply.

The results of all water analyses must be periodically sent to the State of origin.

Failure to have the required analysis performed or to report the results to the State usually will result in the water system being required to provide PN. States typically have special forms for submitting data, and specify a number of days following the end of the monitoring period by which the form is due.

General Disinfection Requirements
Disinfection is absolutely required for all water systems using surface water sources. Various chemicals other than chlorine can be used for treatment of surface water, but as the water enters the distribution system, it must carry a continuous chlorine residual that will be retained throughout the distribution system. Water samples from points on the distribution system must be analyzed periodically to make sure an adequate chlorine residual is being maintained.

In spite of the fact that use of chlorine has almost completely eliminated occurrences of waterborne diseases in the United States, there is no concern for byproducts formed when chlorine reacts with naturally occurring substances in raw water (such as decaying vegetation containing humic and fulvic acids).

The first group of byproduct chemicals identified was tri-halo-methane (THM), a group of organic chemicals that are known carcinogens (cancer-forming) to some animals, so they are assumed also to be carcinogenic to humans. Other byproducts of disinfection have been identified that may be harmful, and there also is concern now that disinfectants themselves may cause some adverse health reactions.

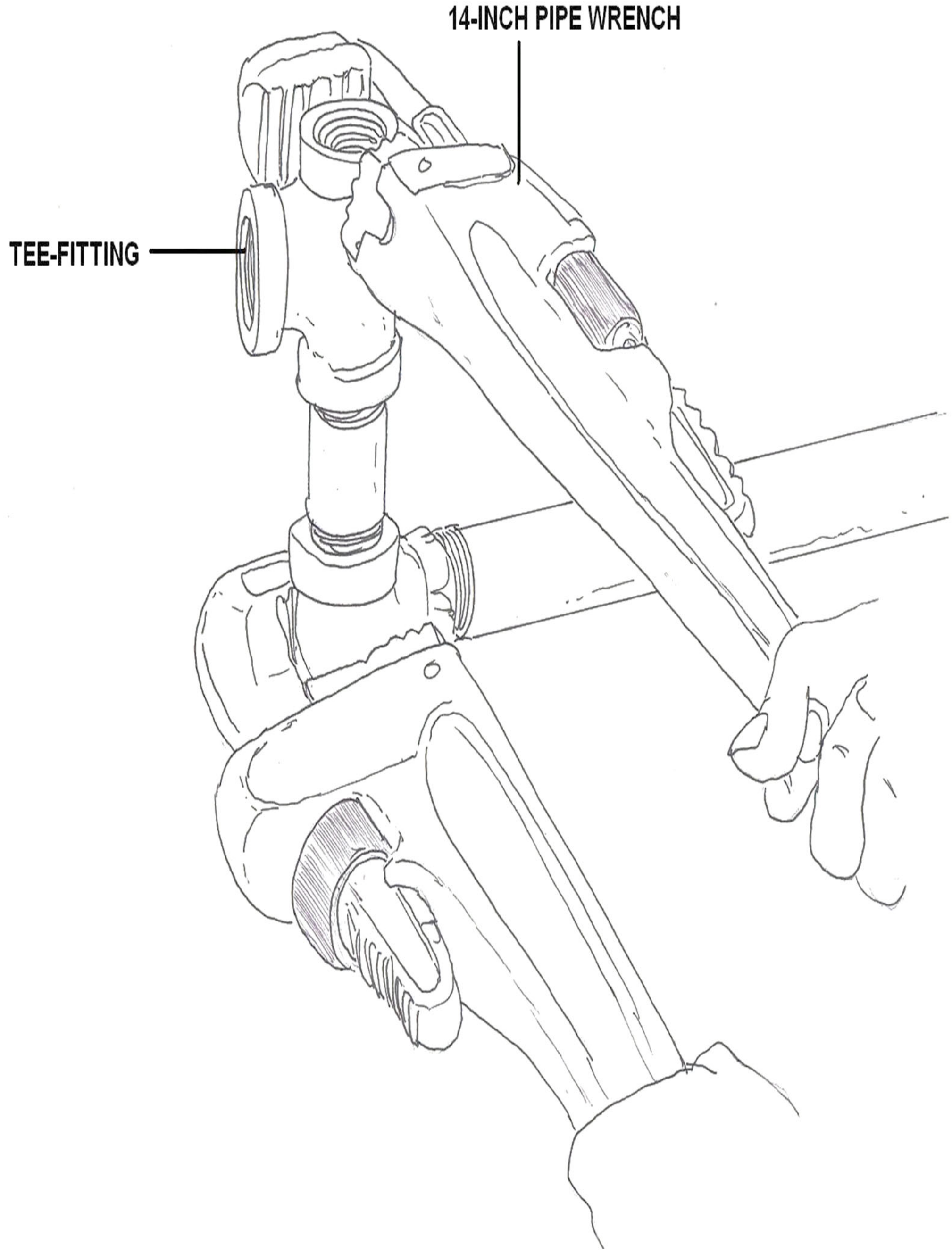
Consumer Confidence Reports
One of the very significant provisions of the 1996 SDWA amendments is the consumer confidence report (CCR) requirement. The purpose of the CCR is to provide all water customers with basic facts regarding their drinking water so that individuals can make decisions about water consumption based on their personal health. This directive has been likened to the requirement that packaged food companies disclose what is in their food product.

The reports must be prepared yearly by every community water supply system. Water systems serving more than 10,000 people must mail the report to customers. Small systems must notify customers as directed by the State primacy agency. Beginning in the year 2000, reports were to be delivered by July 1 of the calendar year.

A water system that only distributes purchased water (i.e., a satellite system) must prepare the report for their consumers. Information on the source water and chemical analyses must be furnished to the satellite system by the system selling the water (parent company).

Some States are preparing much of the information for their water systems, but the system operator still must add local information.

Templates for preparing a report also are available from the American Water Works Association (AWWA) and the National Rural Water Association (NRWA). Water system operators should keep in mind that CCRs provide an opportunity to educate consumers about the sources and quality of their drinking water. Educated consumers are more likely to help protect drinking water sources and be more understanding of the need to upgrade the water system to make their drinking water safe.


14-INCH PIPE WRENCH
TEE-FITTING

Distribution System Water Quality Problems

Turbidity

Turbidity is caused by particles suspended in water. These particles scatter or reflect light rays, making the water appear cloudy. Turbidity is expressed in nephelometric turbidity units (ntu) and a reading in excess of 5 ntu is generally noticeable to water system customers.

Besides the appearance being unpleasant to customers, turbidity in water is significant from a public health standpoint because suspended particles could shelter micro-organisms from the disinfectant and allow them to still be viable when they reach the customer.

EPA regulations direct that, for most water systems, the turbidity of water entering the distribution system must be equal or less than 0.5 ntu in at least 95 percent of the measurements taken each month. At no time may the turbidity exceed 5 ntu.

Turbidity changes in the distribution system can indicate developing problems. Increases in turbidity may be caused by changes in velocity or inadequate flushing following main replacement.

Hardness

Hardness is a measure of the concentration of calcium and magnesium in water. Water hardness usually comes from water contacting rock formations, such as water from wells in limestone formations. Soft ground water may occur where topsoil is thin and limestone formations are sparse or absent. Most surface water is of medium hardness.

Hard and soft water are both satisfactory for human consumption, but customers may object to very hard water because of the scale it forms in plumbing fixtures and on cooking utensils. Hardness is also a problem for some industrial and commercial users because of scale buildup in boilers and other equipment.

Water generally is considered most satisfactory for household use when the hardness is between 75 and 100 mg/L as calcium carbonate (CaCO3).

Water with 300 mg/L of hardness usually is considered **hard**.

Very soft water of 30 mg/L or less is found in some section of the United States. Soft water usually is quite corrosive, and may have to be treated to reduce the corrosivity.

Iron
Iron occurs naturally in rocks and soils and is one of the most abundant elements. It occurs in two forms. Ferrous iron (Fe2) is in a dissolved state, and water containing ferrous iron is colorless. Ferric iron (Fe3) has been oxidized, and water containing it is rust-colored. Water from some well sources contains significant levels of dissolved iron, which is colorless, but rapidly turns brown as air reaches the water and oxidizes the iron.

There are no known harmful effects to humans from drinking water containing iron, but NSDWR suggest a limit of 0.5 mg/L. At high levels, the staining of plumbing fixtures and clothing becomes objectionable. Iron also provides nutrient source for some bacteria that grow in distribution systems and wells. Iron bacteria, such as Gallionella, cause red water, tastes and odors, clogged pipes, and pump failure.

Whenever tests on water samples show increased iron concentrations between the point where water enters the distribution system and the consumer's tap, either corrosion, iron bacteria, or both are probably taking place. If the problem is caused by bacteria, flushing mains, shock chlorination, and carrying increased residual chlorine are alternatives to consider.

Manganese
Manganese in ground water creates problems similar to iron. It does not usually discolor the water, but will stain washed clothes and plumbing fixtures black; this is very unpopular with customers. Consumption of manganese has no known harmful effects on humans, but the NSDWR recommend a concentration not to exceed 0.05 mg/L to avoid customer complaints.

Water Quality Safeguards
The **critical** safeguard for water distribution system operations are

- continuous positive pressure in the mains; 20 pounds per square inch (psi) minimum residual pressure is recommended;
- maintenance of chlorine residual;
- cross-connection control; and
- frequent testing.

Continuous positive pressure as recommended above is absolutely necessary to prevent back siphonage and the entry of contaminants into the water system. This can be achieved primarily by maintaining an adequate water supply and storage capable of meeting peak water demands. If water demands are so great during peak demand periods that pressure declines in parts of the systems, either water use must be restricted or the water system must be upgraded to be capable of supplying more water.

System pressure also may be reduced during a main break because of the large amount of escaping water. The best safeguards against having serious pressure loss during a main break are to have adequate system storage and to be well-organized to shut down the leaking section of water main swiftly. The later involves having personnel on call at all time to respond to emergencies, knowing where all the valves are, and having a valve exercise program so that valves are sure to operate when needed.

The ultimate proof of the bacteriological safety of the water in the distribution system comes through frequent sampling.

Samples collected to meet State requirements should be considered a minimum. Additional samples should be collected following construction and repair work as well as in response to customer complaints that could be the result of water system contamination.

A distribution system can become contaminated from an outside source by accident or intention in the framework of the world climate today.

Contamination problems need to be identified and appropriate action taken immediately after detection.

The design and evaluation of municipal water supply systems is based on both theoretical and applied hydraulics. Hydraulics is the branch of science that defines the mathematical laws of liquids at rest and in motion. This text material is confined to fundamental principles and what is generally referred to as **applied hydraulics**.

These fundamentals are essential for understanding many of the considerations involved in the design of a municipal water supply system, the periodic testing of water systems, and the proper evaluation of water systems to assess a given community's water supply with respect to providing adequate water supplies.

A municipal water supply system has the objective of providing an adequate and reliable water supply to meet the following demands:

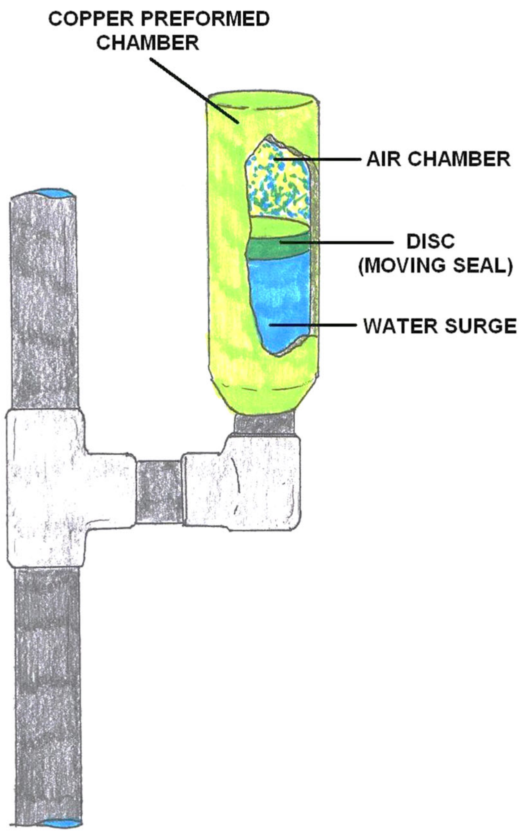
- residential occupancy water consumption;
- commercial occupancy water consumption;
- industrial occupancy consumption;
- municipal and educational building use;
- Needed Fire Flows (NFFs) that are available from a planned location of fire hydrants throughout the municipality; and
- water for special community needs that include parks and recreation, street cleaning, decorative water fountains, sale of water to contractors through metered water from fire hydrants, etc.

The primary objective of the following material is to present the fundamental concept of hydraulics applied to municipal water systems, in order for municipal officials and fire officials to better understand the design and evaluation of public-sector water delivery systems.

Some fundamental hydraulic problems are provided to establish principles used to meet the above objective. A number of tables and charts are provided for future reference by the user of this material in actually working with a specific water supply system.

Reference

Water Supply Systems• Vol. II: Evaluation Methods October 2008 FEMA U.S. Fire Administration Harry E. Hickey, Ph.D.



WATER HAMMER ARRESTER

A hydropneumatic device similar in principle to a shock absorber called a 'Water Hammer Arrestor' can be installed between the water pipe and the machine, to absorb the shock and stop the banging.

Water hammer has caused many water main breaks, accidents and even fatalities, but usually damage is limited to breakage of pipes or appendages.

An engineer should always assess the risk of a pipeline burst. Pipelines transporting hazardous liquids or gases warrant special care in design, construction, and operation.

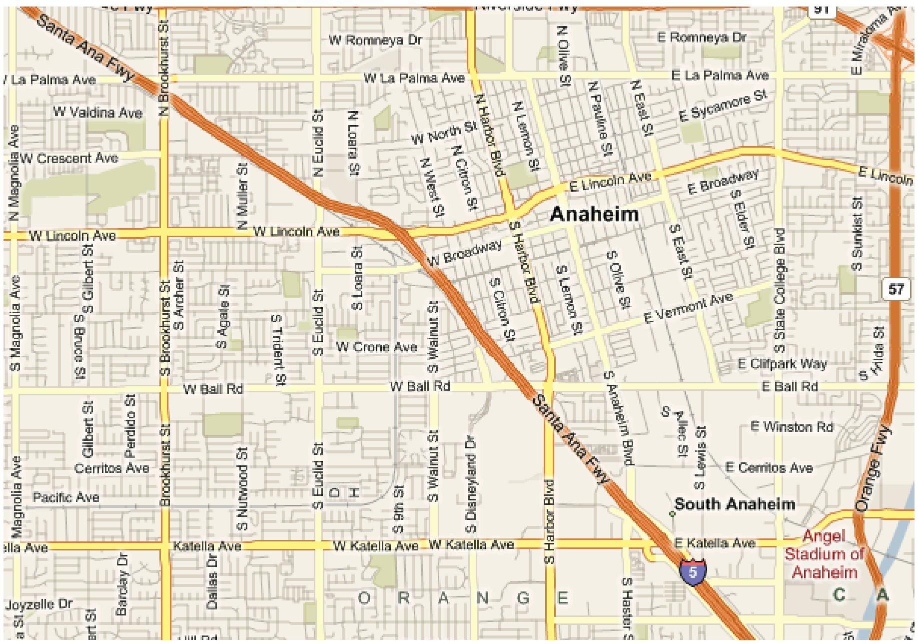
Distribution Section
System Layouts

There are three general ways systems are laid out to deliver water (picture your quarter section layouts). They include:

A. Tree systems

B. Loop or Grid systems

C. Dead-end systems - ***Undesirable, taste and odor problems.***



Tree System
Older water systems frequently were expanded without planning and developed into a treelike system. This consists of a single main that decreases in size as it leaves the source and progresses through the area originally served. Smaller pipelines branch off the main and divide again, much like the trunk and branches of a tree.

A treelike system is not desirable because the size of the old main limits the expansion of the system needed to meet increasing demands. In addition, there are many dead ends in the system where water remains for long periods, causing undesirable tastes and odors in nearby service lines.

The most reliable means to provide water for firefighting is by designing redundancy into the system. There are several advantages gained by laying out water mains in a loop or grid, with feeder and distributor mains interconnecting at roadway intersections and other regular intervals.

Friction Loss

Water will still be distributed through the system if a single section fails. The damaged section can be isolated and the remainder of the system will still carry water.

Water supplied to fire hydrants will feed from multiple directions. Thus during periods of peak fire flow demand, there will be less impact from "friction loss" in water mains as the velocity within any given section of main will be less since several mains will be sharing the supply.

Rust and debris from cleaning a steel main.

A temporary blow-off at a dead-end line.

Water System Supply Component
It is necessary to understand the types of community water supply systems and the arrangement of components prior to discussing the evaluation concepts associated with them.

There are two basic types of water supply systems:
1. Gravity-feed system.
2. Pressure-feed system, where pressure is developed by stationary pumps.

Each of these basic types of supply systems can be subdivided according to the type of potable water and nonpotable water in storage:
- reservoirs that hold nonpotable water for gravity feed;
- elevated tanks, standpipe tanks, and impounding tanks that store potable or finished water for gravity feed;
- pumping stations that are supplied by ground-water sources: lake, river, ponds, etc.; and
- pump(s) at well sites.

In any of the above systems, pumps may be used to pump nonpotable water to a filtration system or purifying system, followed by pumping potable water to holding tanks or directly into the water supply distribution system.

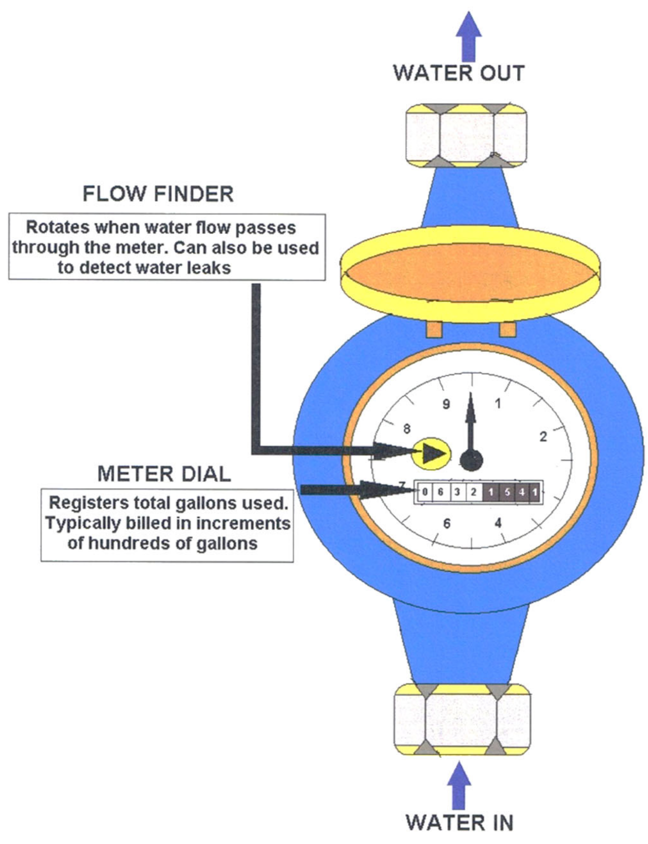
Water Meters

It is important to account for the water produced and supplied. A master meter should be installed on each source, with service meters placed at each point of use. These should be read and recorded periodically.

Totals from the master meters should be compared to totals from the service meters to compute the amount of water lost in the distribution system. This information is important in locating and eliminating leaks and unauthorized taps.

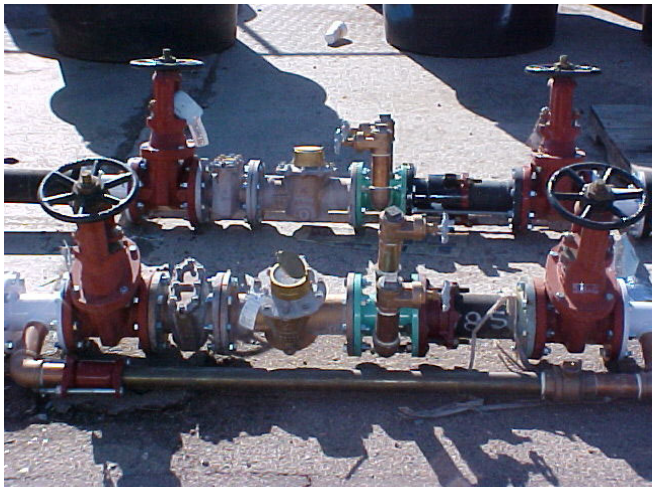
Losses of 10 to 20 percent are not uncommon in many distribution systems. Also, it has been shown that a system which is not metered is likely to have a water usage up to three times as great as a metered system.

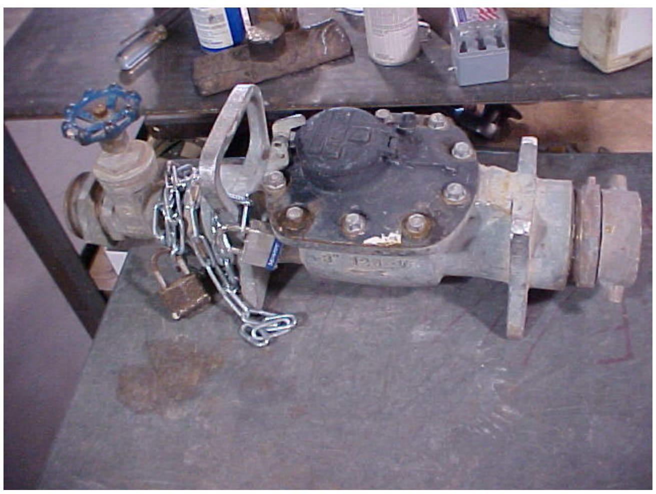
Un-metered water users tend to water freely and have little incentive to repair plumbing leaks.

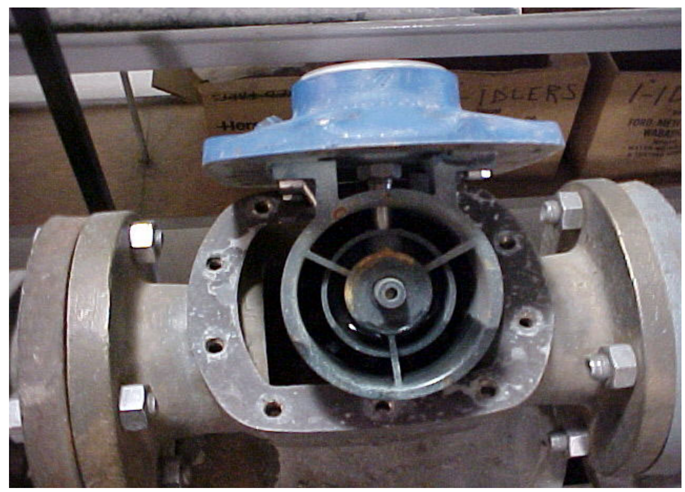


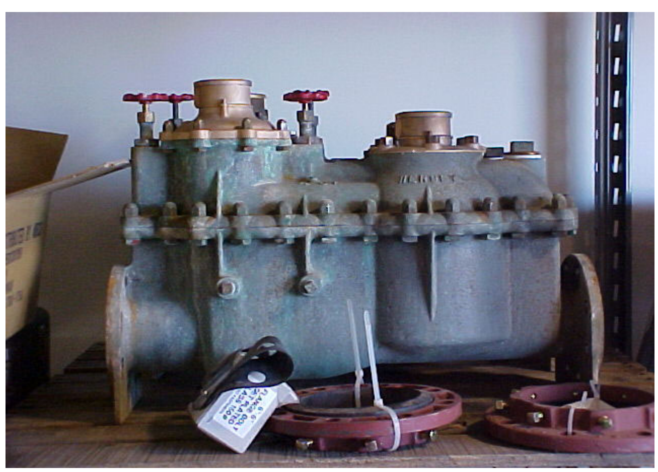
RESIDENTIAL WATER METER (3/4")

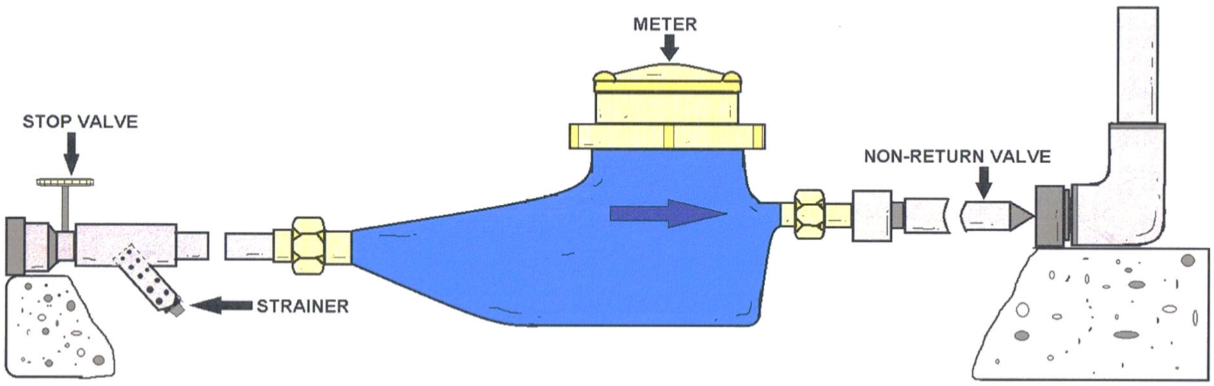
Water Meters
Record the flow of water in a part of the distribution system.
Bypass, Compound, Turbine or Propeller meters.







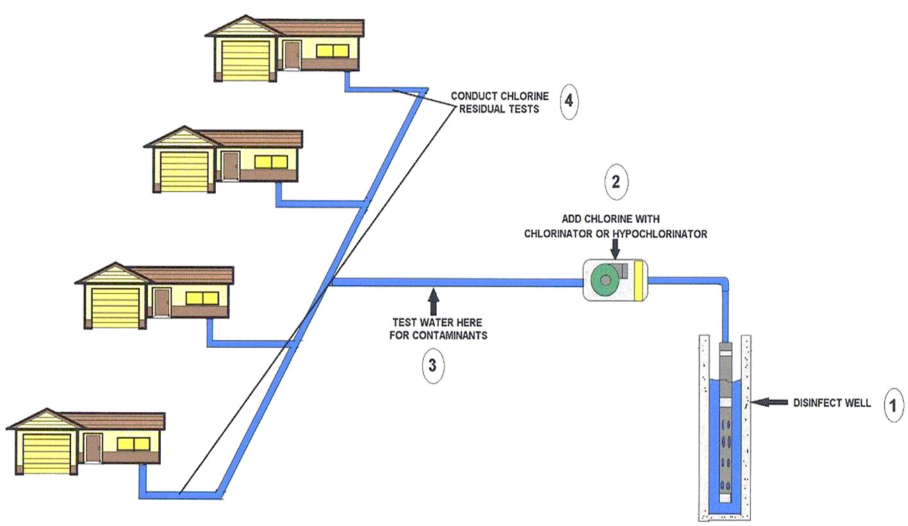




WATER METER

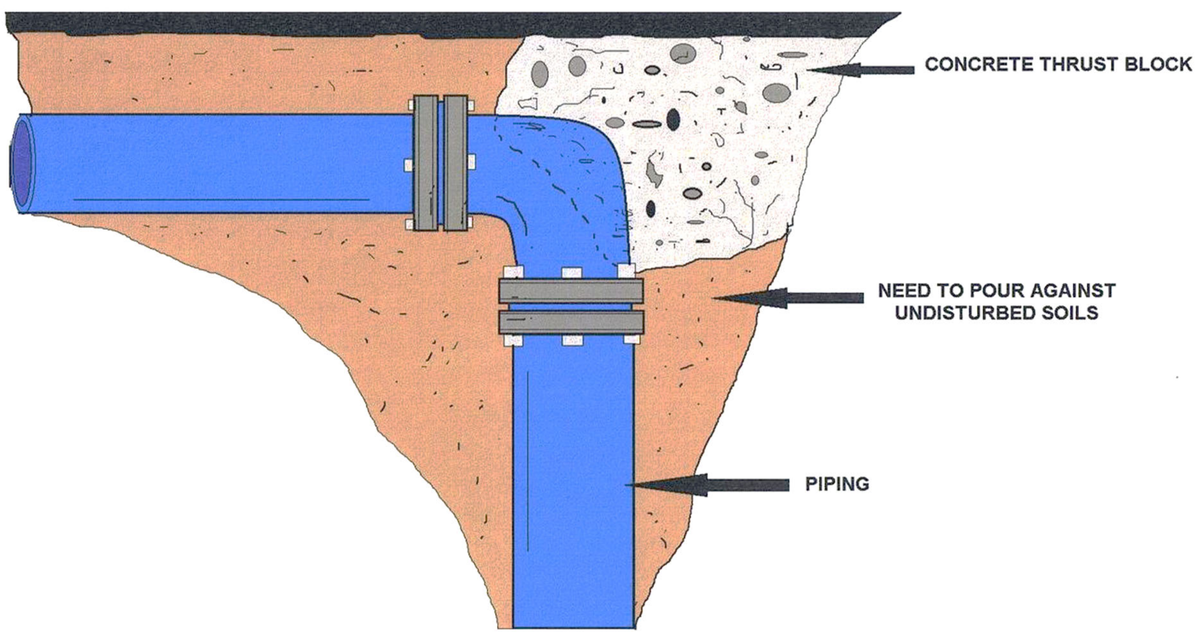
In many developed countries water meters are used to measure the volume of water used by residential and commercial building that are supplied with water by a public water supply system. Water meters can also be used at the water source, well, or throughout a water system to determine flow through that portion of the system. In most of the world water meters measure flow in Cubic meters (m^3) or liters but in the USA and some other countries water meters are calibrated in cubic feet ($ft.^3$), or US gallons on a mechanical or electronic register. Some electronic meter registers can display rate-of-flow in addition to total usage.

There are several types of water meters in common use. Selection is based on different flow measurement methods, the type of end user, the required flow rates, and accuracy requirements. In North America, standards for manufacturing of water meters are made by the American Water Works Association.



STARTING UP A WELL

Wear appropriate personal protective equipment (PPE) as required by the task being performed and as required per OSHA regulations. Ensure a spotter is used if there are overhead power lines, underground utilities or tight working conditions in the work area. Verify the competent person is on site.

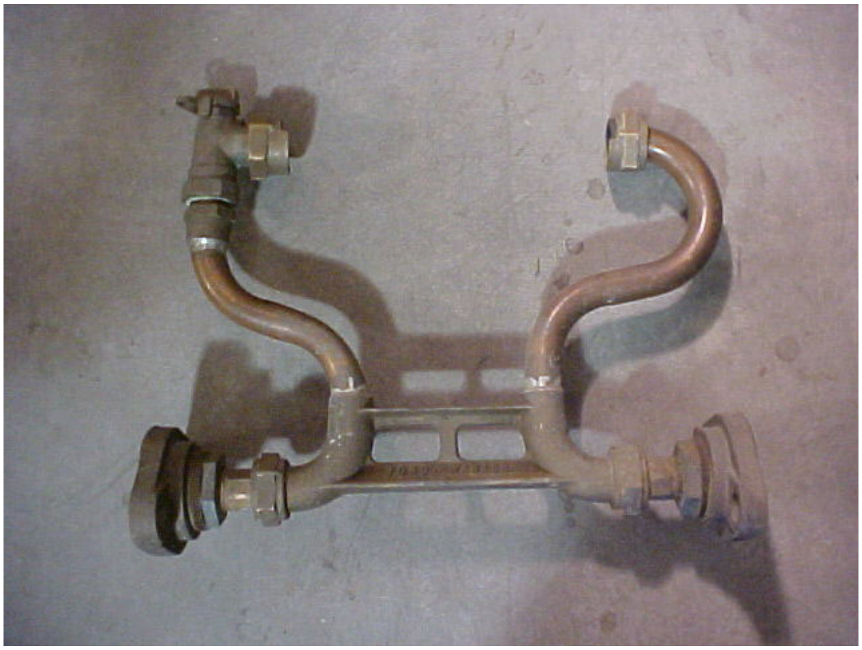


TYPICAL THRUST BLOCK

Ensure policies and procedures will be followed when excavating across foreign utilities and other underground structures. Ensure that the competent person *is available* while any trenching/excavation work is being performed. Ensure that benching, sloping, and shoring practices are followed when necessary. Ensure proper protection and support of existing utilities and structures.

Service Connections

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



Water Meter Re-setter, Riser, or sometimes referred to as a copper yoke.

Common distribution fittings. Single check, Poly Pig, 1 inch repair clamp, 4 inch full circle clamp, T- Bolt and a corp. and bronze saddle.

Types of Pipes Used in the Distribution Field

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

Plastic Pipe (PVC)
This is currently the most common type of pipe used in distribution systems. It is available in diameters of 1/2" and larger, and in lengths of 10', 20', and 40'. A main advantage is its light weight, allowing for easy installation. A disadvantage is its inability to withstand shock loads. Since it is non-metallic, a tracer wire must be installed with the PVC water main so that it can be located after burial. The National Sanitation Foundation (NSF) currently lists most brands of PVC pipe as being acceptable for potable water use. This information should be stamped on the outside of the pipe, along with working pressure and temperature, diameter and pipe manufacturer. PVC pipe will have the highest C Factor of all the above pipes. The higher the C factor the smoother the pipe.

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

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

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

Various types and sizes of coupons or tap cut-outs. You will want to date and collect these cut-outs to determine the condition of the pipe or measure the corrosion.

Cast Iron (CIP)

This is another type of piping material that has been in use for a long time. It is found in diameters from 3" to 48". Advantages of this material are its long life, durability and ability to withstand working pressures up to 350 psi. Disadvantages include the fact that it is heavy, difficult to install and does not withstand shock loading. Although it is not currently the material of choice, there is still a lot of it in the ground.

Ductile Iron Pipe (DIP)

This was developed to overcome the breakage problems associated with cast iron pipe. It can be purchased in 4" to 45" diameters and lengths of 18' to 20'. Its main advantage is that it is nearly indestructible by internal or external pressures. It is manufactured by injecting magnesium into molten cast iron. It is sometimes protected from highly corrosive soils by wrapping the pipe in plastic sheeting prior to installation. This practice can greatly extend the life of this type of pipe.

Steel Pipe

This pipe is often used in water treatment plants and pump stations. It is available in various diameters and in 20' or 21' lengths. Its main advantage is the ability to form it into a variety of shapes. It also exhibits good yielding and shock resistance. It has a smooth interior surface and can withstand pressures up to 250 psi.

A disadvantage is that it is easily corroded by both soil and water. To reduce corrosion problems, steel pipe is usually galvanized or dipped in coal-tar enamel and wrapped with coal-tar impregnated felt. At present, however, coal-tar products are undergoing scrutiny from a health standpoint and it is recommended that the appropriate regulatory agencies be contacted prior to use of this material.

Asbestos Cement Pipe (ACP)

This pipe is manufactured from Portland cement, long fibrous asbestos and silica. It is available in diameters from 3" to 36" and in 13' lengths. Its main advantages are its ability to withstand corrosion and its excellent hydraulic flow characteristics due to its smoothness. A major disadvantage is that it is brittle and is easily broken during construction or by shock loading. There is some concern regarding the possible release of asbestos fibers in corrosive water and there has been much debate over the health effects of ingested asbestos. Of greater certainty, however, is the danger posed by inhalation of asbestos fibers.

Asbestos is considered a hazardous material, and precautionary measures must be taken to protect water utility workers when cutting, tapping or otherwise handling this type of pipe.

Galvanized Pipe

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

Copper Pipe or Tubing

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.

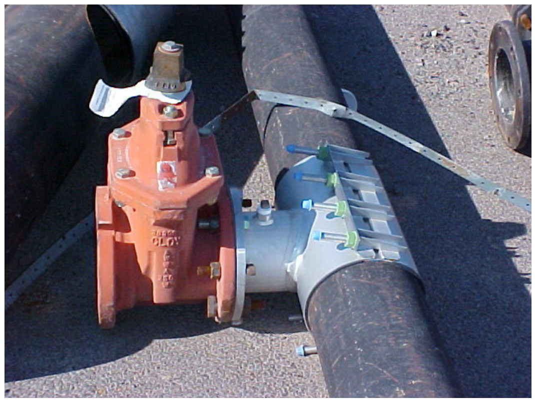
Copper Tubing Crimpers. Great if you are unable to get a shut-down. Just place this dude on the pipe. The problem is to fix that crimp when you are finished with the leak. They need to invent an uncrimper.

A normal day for a water distribution worker.

Distribution Joints and Fittings Sub-Section

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

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



Tapping Sleeve

Customers are not inconvenienced by having their water turned off is one of the reason we utilize pressure taps or hot taps. Some of you are lucky to punch a hole with a ball-peen hammer.

A Gate Valve is used to isolate sections of water mains. Not to be used to throttle or regulate the flow. A Globe valve should be used to regulate the flow. Be sure to chlorinate or disinfect all distribution parts such as valves and piping!

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

Couplings
The three common types of couplings are straight coupling, reducer, and eccentric reducer. The STRAIGHT COUPLING is for joining two lengths of pipe in a straight run that do not require additional fittings. A run is that portion of a pipe or fitting continuing in a straight line in the direction of flow.

A REDUCER is used to join two pipes of different sizes. The ECCENTRIC REDUCER (also called a BELL REDUCER) has two female (inside) threads of different sizes with centers so designed that when they are joined, the two pieces of pipe will not be in line with each other, but they can be installed to provide optimum drainage of the line.

Elbows (OR ELLS) 90° AND 45°

These fittings (fig. 8-5, close to middle of figure) are used to change the direction of the pipe either 90 or 45 degrees. REGULAR elbows have female threads at both outlets. STREET elbows change the direction of a pipe in a closed space where it would be impossible or impractical to use an elbow and nipple. 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 is.

Nipples

A nipple is a short length of pipe (12 in. or less) with a male thread on each end. It is used for extension from a fitting. At times, you may use the DIELECTRIC or INSULATING TYPE of fittings. These fittings connect underground tanks or hot-water tanks. They are also used with pipes of dissimilar metals. These help slow down corrosion that starts inside the pipe and works to the outside of the pipe.

Do not heat or solder dielectric fittings. You may melt the plastic coating on them.

Zinc is a coating on the outside and inside of pipes to slow corrosion. This process is called "Galvanization".

Tees

A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs. A common type of pipe tee is the STRAIGHT tee, which has a straight-through portion and a 90-degree takeoff on one side.

All three openings of the straight tee are of the same size. Another common type is the REDUCING tee, similar to the straight tee just described, except that one of the threaded openings is of a different size than the other.

Notice the type of pipe connection device.
This is known as a "Restraining Flange".

Unions

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

Disinfection of Repaired Pipeline Sections

You should recognize that the protection of the public health of its water customers is the primary role of a water provider. Accordingly, the disinfection of all repaired water appurtenances is paramount to the return of the water system to its' normal operation mode. Prior to initiating the disinfection process, a thorough cleaning of all repaired pipes and or reservoirs must be accomplished. The following table indicates the amount of Sodium Hypochlorite and Calcium Hypochlorite that is necessary to disinfect 100,000 gallons of water.

DISINFECTION TABLE
For 100,000 Gallons Of Water

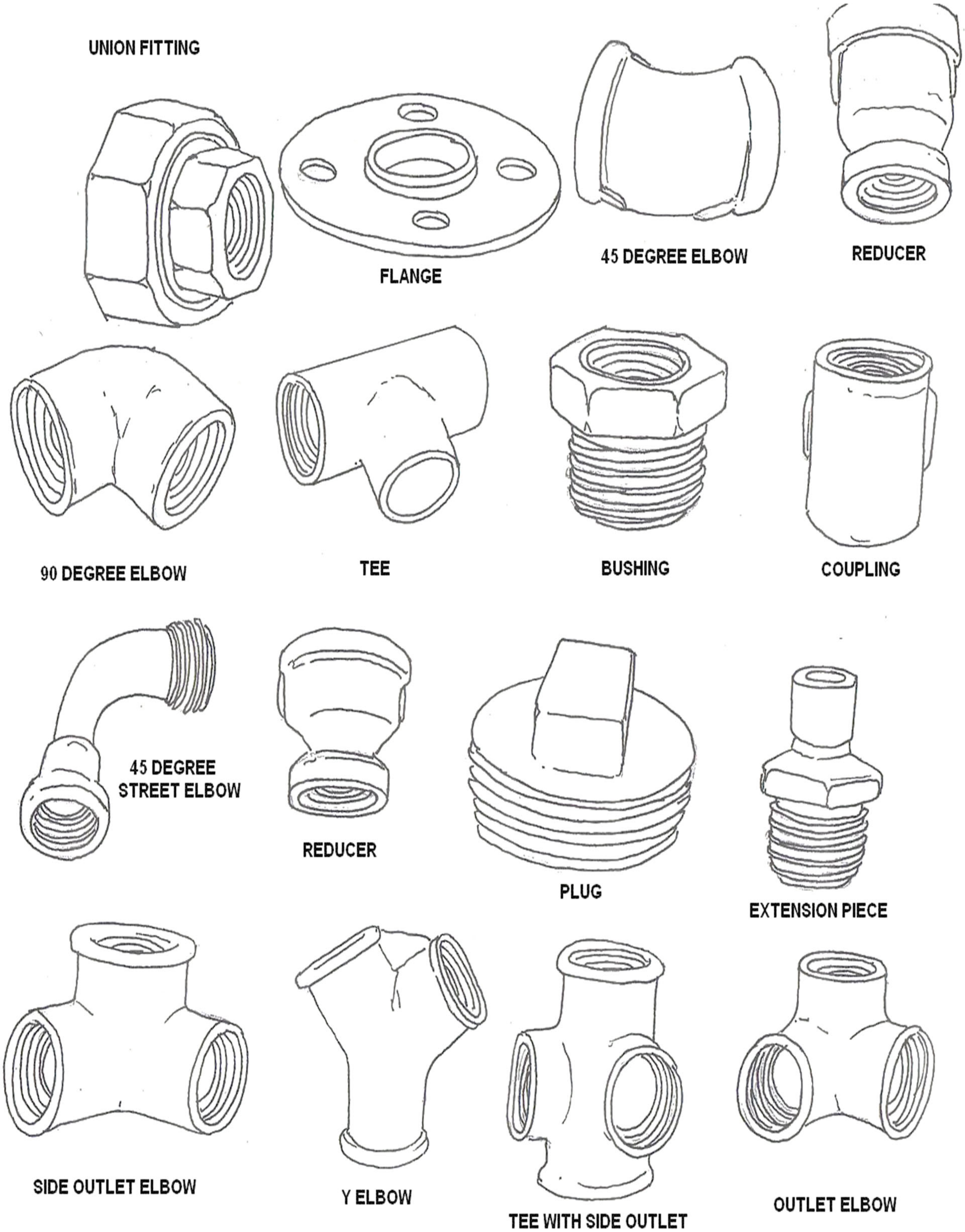
Desired Chlorine Dose in MG/L	Pounds of Liquid Chlorine Required	Gallons of Sodium Hypo Chlorite Required 5% Available Chlorine	10% Available Chlorine	15% Available Chlorine	Pounds of Calcium Hypo Chlorite Required. 65% Available
2	1.7	3.9	2.0	1.3	2.6
10	8.3	19.4	9.9	12.8	12.8
50	42	97	49.6	64	64

Spare Parts Inventory

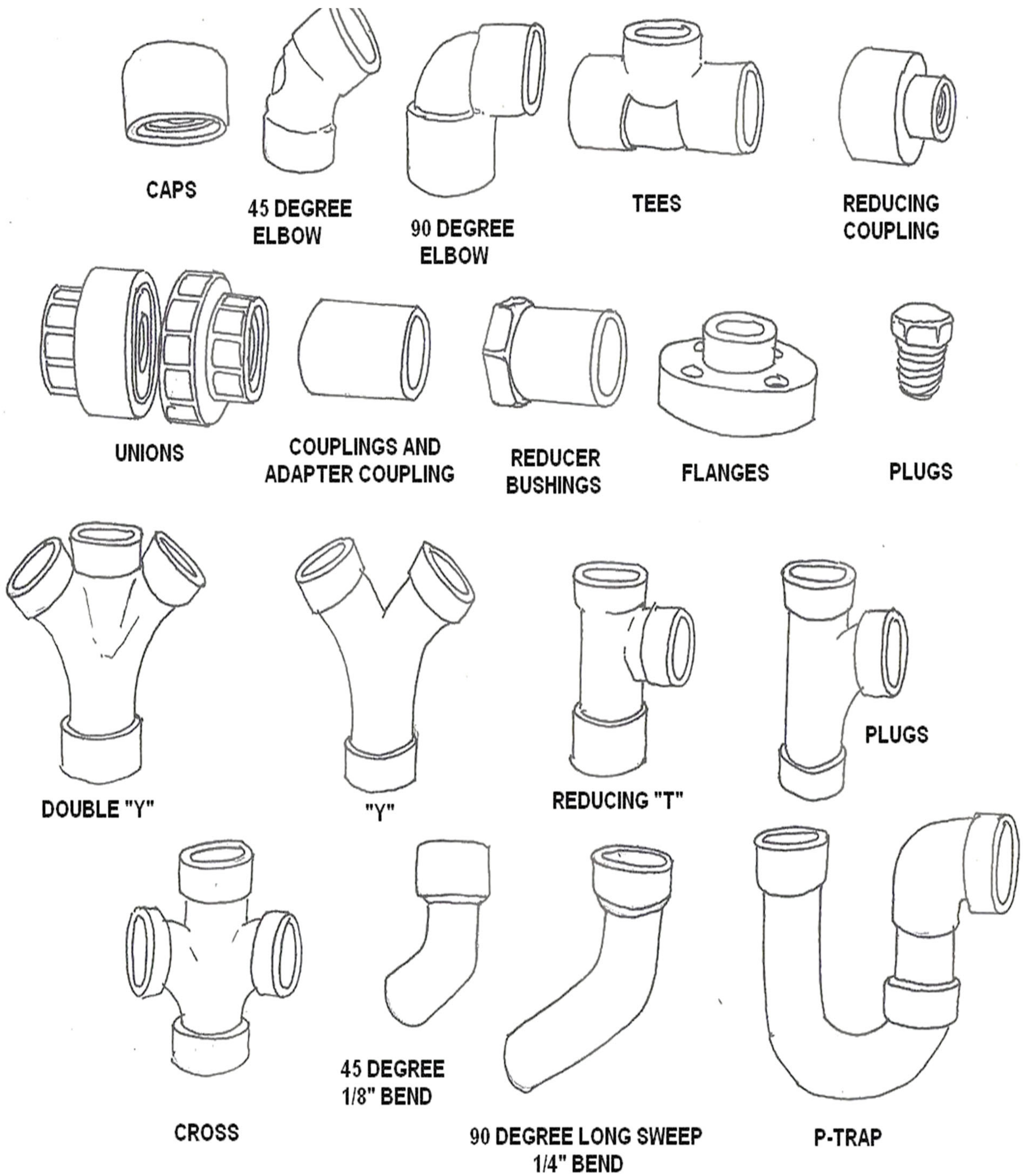
You should maintain a complete inventory of spare parts for the maintenance and repair of all water transmission and distribution lines. The water lines in the system range in size between ¾ inch and 16 inches in diameter.

Additionally, you should maintain spare motor controls, pump ends, and motors for all wells and booster stations.

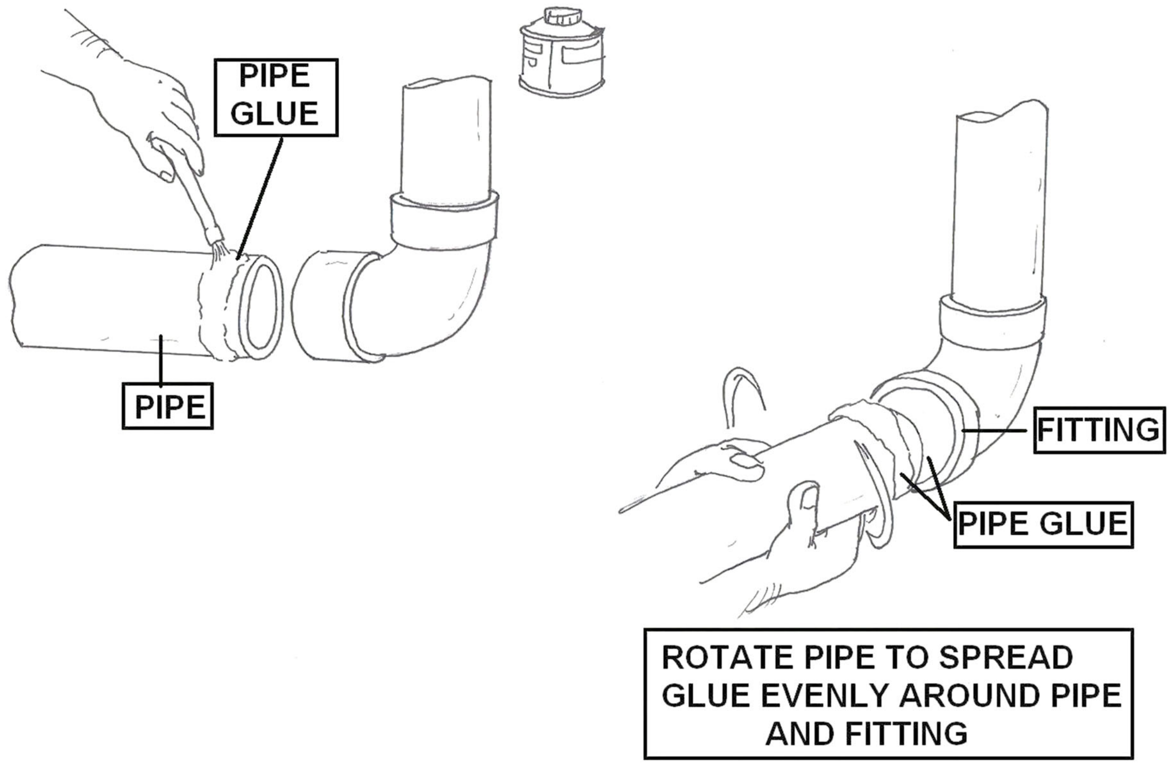
Water system personnel can repair the entire range of water lines without assistance from outside contractors. Stand-by warehouse personnel should be available twenty four hours per day to assist in the delivery of spare parts in instances requiring emergency repair.



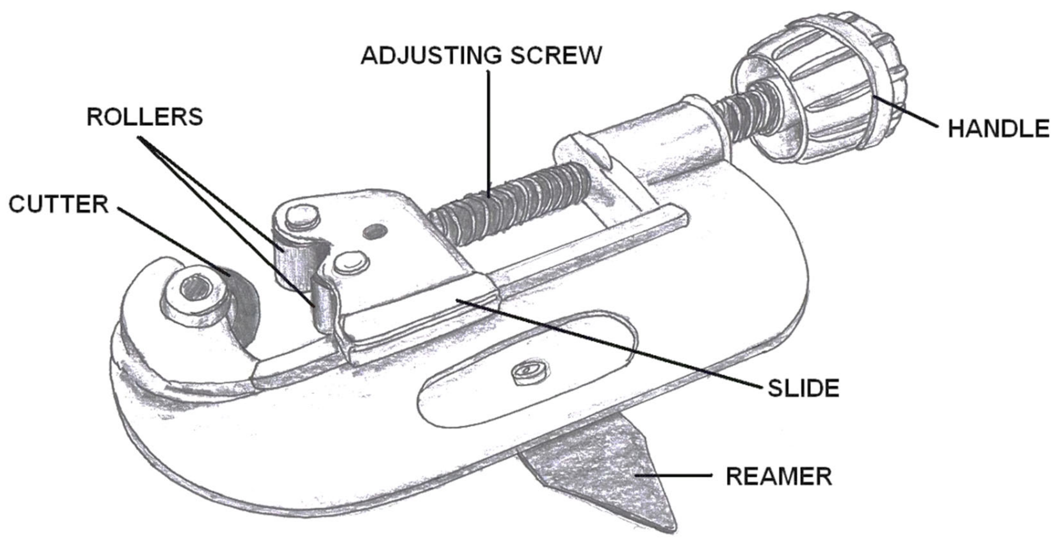
THREADED PIPE FITTINGS



DRAIN –WASTE –VENT FITTINGS



SOLVENT WELDING



TUBING CUTTER

Water Main Installation Sub-Section

Installation of new or replacement pipe sections should be in accordance with good construction practices. The line must be buried a minimum of 30" below the ground surface to prevent freezing. The line must be bedded and backfilled properly insuring protection from weather and surface loadings. Also, thrust blocking (*Kickers*) at all bends, tees, and valves is essential to hold the pipe in place and prevent separation of line sections. Thrust blocking is not necessary if the pipe is welded.

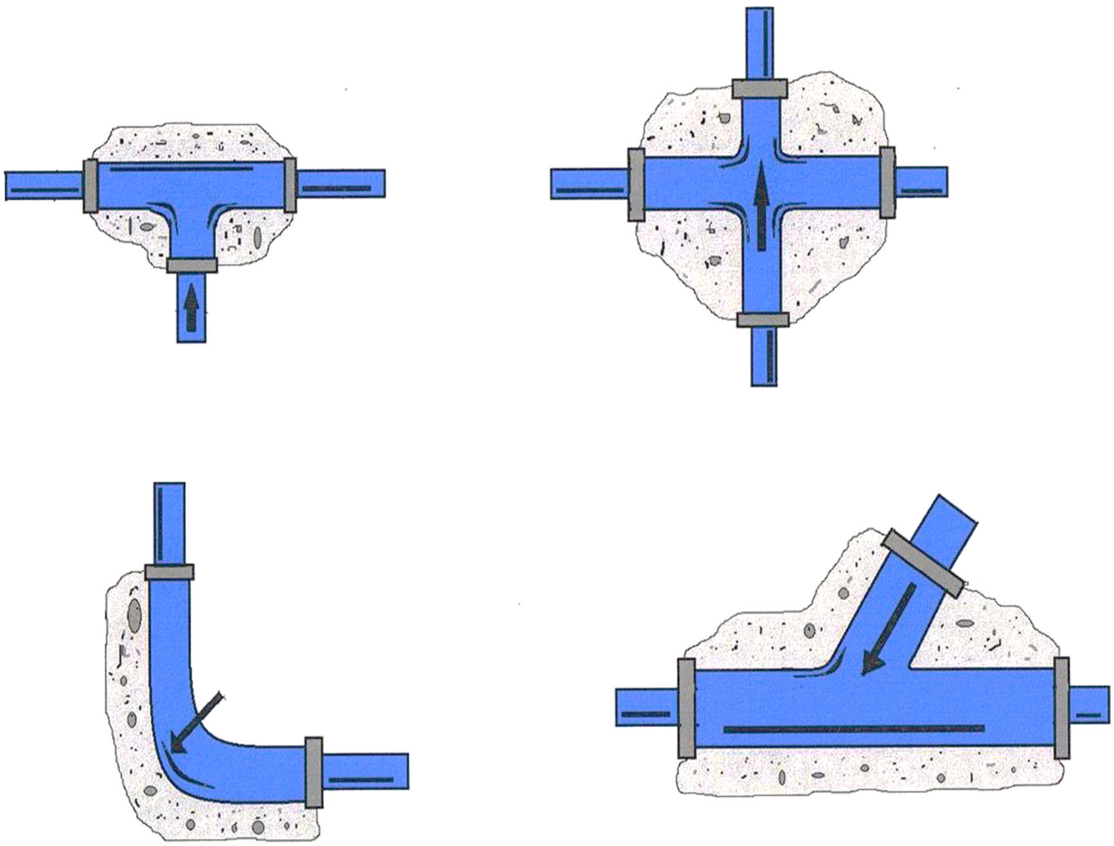
Disinfection of new installations or repaired sections is required prior to placing them in service. This can be accomplished by filling the line with a 25 mg/1 free chlorine solution and allowing it to stand for 24 hours. Valves and fittings used in the waterworks industry are made of cast iron, steel, brass, stainless and fiberglass. Enough gate valves should be placed throughout the system to enable problem areas (leaks, etc.) to be isolated and repaired with minimal service disruption. Air relief valves should be installed at high points in the system. Valves should be installed with valve boxes and covers. Regardless of the type of pipe installed, certain maintenance routines should be performed on the distribution system to maintain water quality and optimal service. These programs should be scheduled and performed on a regular basis.

Flushing at blowoffs on dead end lines and at fire hydrants throughout the system should be done at least twice per year. Flushing is needed to remove stagnant water in dead ends and to remove accumulated sediment that results from turbidity, iron, manganese, etc. This should also help minimize customer complaints of water quality. Flushing should always be done from the source to the ends of the system. Affected customers should be notified of this process in advance. To do an adequate job of flushing, the flow should reach a velocity of at least 2.5 feet per second, known as the “minimum cleansing velocity” of the system (at hydrant locations).

These tests are important to determine the adequacy of the distribution system in transmitting water, particularly during days of peak demand. Also, these tests can help determine if pipe capacity is decreasing over time due to internal corrosion or deposits. Pressure tests should be done at various locations in the distribution system several times per year. This helps to monitor the performance of the system and alert the operator to problems such as leaks or internal deposits. It is sometimes advantageous to have certain points in the system continuously monitored to provide a constant evaluation of the system.

Preventative Maintenance (PM)

Preventative maintenance can extend the life of any water pipeline. Pipes can deteriorate on the inside as a result of corrosion and on the outside as a result of aggressive soil and moisture. The Water Department should maintain an intense leak detection program to effectively reduce operating costs and provide revenue savings by reducing lost and unaccounted for water. Leaks can originate in joints and fittings or any corroded portion of a pipeline. Additionally, leaks will undermine the pavement and water soak the area around the leaking section of pipeline. When leaks are discovered, they are repaired within twenty four hours after properly locating all underground utilities through the Underground Service Alert or “***Blue Stake*”** procedure.



THRUST BLOACKING COMMON LOCATIONS

Leak Detection Methods

Leak detection is critical for finding difficult to locate leaks. There are many devices to choose from. All of these devices magnify the sound of the leak to pin-point the area of damage. Plastic pipe is the most difficult and copper is the easiest to locate.

These men are listing to a stop to find a difficult leak. Some hydrophones magnify the sound and others use a meter to locate the leak. Many old-timers use a short piece of copper tubing and have good results.

In this photograph, we see two men checking the results of a hydrophone. In areas of thick blacktop, it is difficult to locate small service leaks and slow water main breaks. A hydrophone is a microphone designed to be used underwater for recording or listening to underwater sound.

Most hydrophones are based on a piezoelectric transducer that generates electricity when subjected to a pressure change.

Such piezoelectric materials or transducers can convert a sound signal into an electrical signal since sound is a pressure wave. Some transducers can also serve as a projector, but not all have this capability, and may be destroyed if used in such a manner.

A hydrophone can "listen" to sound in air, but will be less sensitive due to its design as having a good acoustic impedance match to water, which is a denser fluid than air.

Likewise, a microphone can be buried in the ground, or immersed in water if it is put in a waterproof container, but will give similarly poor performance due to the similarly bad acoustic impedance match.

Understanding a Plastic Water Main Break

Generally speaking, water main breaks are much more intense that service leaks. This scenario with examine a hairline crack caused by poor installation. The water main was laid on a sharp rock without proper bedding. A slight water main leak is often confused with a service line leak and can be difficult to find.

In this case, a sewer vactor was utilized to expedite removal of water and spoil. Utilizing a vactor is a great tool, but is dangerous. It is easy to lose tools and injure personnel if the vactor is not properly managed. The vactor is powerful enough to lift large stones and even a 200 pound man.

In this photograph, a plastic water main is discovered; there is a red wire under the main for bluestaking purposes. The hair-line crack is about a foot long, so it will be necessary to cut out about 4 feet to make sure the water main will not leak in the future.

Any work with a chainsaw or powersaw should include proper safety equipment including proper eye protection, face shield, and hearing protection. The blue pipe is an eight inch plastic C900 and will be utilized for the repair.

You will notice the blue Hymax coupling is being utilized instead of a clamp or flex coupling. This coupling is easy to use and has only two bolts and a special two-part gasket for odd size pipe.

Water Service Pipe Installation (*Homeowner Side Guidelines*)

a) **Underground Water Service.**
Water service pipe shall be installed outside the foundation wall.

1) Water service and building drain or building sewer may be installed in separate trenches with a minimum of 10 feet horizontal separation. Such installation shall use material listed in Approved Materials for Building Sewer and Approved Materials for Water Service Pipe, provided that such material is specific for this type of installation.

2) The water service and the building drain or building sewer may be installed in the same trench provided that the water service is placed on a solid shelf a minimum of 18 inches above the building drain or building sewer. For such installation, the building sewer shall be of material listed in Approved Building Drainage/Vent Pipe for a building drain.

3) The minimum depth for any water service pipe shall be at least 36 inches or the maximum frost penetration of the local area, whichever is of greater depth.

4) No water service pipe shall be installed or permitted outside of a building or in an exterior wall unless provisions are made to protect such pipe from freezing.

b) Potable Water Piping and Sanitary Sewer Crossing Installation Requirements.
1) Where it is necessary for the potable water piping to pass above or below a sanitary sewer, such piping shall be installed with a minimum vertical separation of 18 inches for a distance of 10 feet on either side from the center of the sanitary sewer.

2) Where it is necessary for the potable water piping to pass beneath a sanitary sewer or drain, the sanitary sewer or drain shall be constructed of materials as specified in Approved Building Drainage/Vent Pipe for building drains, and shall extend on each side of the crossing to a distance of at least 10 feet as measured at right angles to the water line.

3) **Wet/Dry Bore:**
When it is not possible to comply with subsection (b)(1) or (2), a pressure rated pipe approved for building drain material shall encase the water service pipe. The casing pipe shall be sealed with a casing seal and extend 10 feet on either side of the center of the sanitary sewer pipe. The sleeve or case shall be at least 2 times the size of the water service.

c) When it is not possible to comply with subsection (a) or (b), the Department shall be contacted for consideration of alternative methods.

d) Stop-And-Waste Valve. Combination stop-and-waste valves and cocks shall not be installed in an underground potable water pipe. Frost free hydrants and fire hydrants shall not be considered stop-and-waste valves.

Potable Water Pumping and Storage Equipment

a) Pumps and Other Appliances. Potable water pumps, tanks, filters, and all other appliances and devices shall be protected against contamination.

b) Water Supply Tanks. Potable water supply tanks shall be properly covered to prevent contamination of the water supply. Soil or waste lines shall not pass directly over such tanks.

c) Cleaning, Painting, Repairing Water Tanks. A potable water supply tank used for domestic purposes shall not be lined, painted or repaired with any material which affects either the taste or the potability of the water. Tanks shall be disconnected from the system during such operations to prevent any foreign substance from entering the system.

Potable Water Supply Tanks and Auxiliary Pressure Tanks

a) When the water pressure from the public water supply main is insufficient during periods of peak flow or due to the building height to supply all fixtures, the rate of supply shall be supplemented by a gravity tank or auxiliary pressure (booster) system. Auxiliary pressure systems shall not substitute for adequate sizing of water distribution piping within the building.

b) Support. All water supply tanks shall be supported in accordance with local building codes or other regulations that apply.

c) Tank Supply Inlet and Outlet. The water supply inlet to the tank shall have a minimum air gap of at least six (6) inches. The supply outlet shall be a minimum of four (4) inches above the bottom of the tank.

d) Overflow For Water Supply Tanks. Overflow pipes for gravity tanks shall be indirectly connected to the drainage system with an air gap of at least six (6) inches. Overflow pipes shall be full sized, unrestricted and screened with 24-mesh per inch stainless steel or bronze screen.

e) Size of Overflow. Overflow drains for gravity water supply tanks shall have an area of at least twice the size of the supply pipe.

f) Drains. Water supply tanks shall be provided with valved drain lines located at their lowest point and discharge through an indirect waste with an air gap of twice the diameter of the drain line. Such drain line and valve shall have no restrictions and need not exceed two (2) inches in diameter.

g) Gravity and Suction Tanks. Tanks used for potable water supply or to supply fire-fighting equipment only shall be equipped with tight, overlapping covers which are rodent and insect proof. Such tanks shall be vented with a return bend (turned down) pipe having an area at least one-half (1/2) the area of the tank outlet pipe, and the vent opening shall be covered with a stainless steel or bronze screen of at least 24-mesh per inch.

h) Pressure Tanks. Pressure tanks used for supplying water to the water distribution system, or to supply standpipes for fire equipment only, shall be equipped with a vacuum relief valve located on top of the tank. An air inlet of this device shall be covered with a stainless steel or bronze screen of at least 24-mesh per inch.

Water Supply Control Valves and Meter

a) A full-port shut-off valve shall be located near the curb or property line and immediately inside the building, either on the inlet or outlet side of the water meter. When underground, this valve shall be located in a stop box or meter vault.

b) The utility meter may be installed outside in an accessible meter vault or within the building. The meter shall have unions on the inlet/outlet openings, but is not required to have a shut-off valve on the inlet side of the meter if it is inside a building. A full-port valve with an open area at least that of the water service shall be provided for all meters.

c) Tank Controls. Supply lines taken from pressure or gravity tanks shall be valved at or near their source.

d) Water Heating Equipment. A shut-off valve shall be provided in the cold water branch line within 5 feet of each water storage tank or each water heater.

e) Separate Controls for Each Family Unit. In multiple family dwellings, the water service or water distribution pipe to each family unit shall be controlled by an arrangement of shut-off valves which permits each group of fixtures and each individual fixture to be shut off without interference with the water supply to any other family unit or portion of the building. The location of such valves shall be uniform in each family unit of a multiple family dwelling.

f) Buildings Other Than Dwellings. In all buildings other than dwellings and health care facilities as specified in subsection (g) of this Section, shut-off valves shall be installed to permit the water supply to all equipment and/or fixtures in each separate room to be shut off without interfering with the water supply to any other room or portion of the building. For plumbing equipment or fixtures that are installed back-to-back in adjacent rooms, e.g., in adjacent restrooms, a common shut-off valve may be used to shut off the water supply to the back-to-back fixtures in no more than 2 adjacent rooms.

g) Health Care Facilities. In the residence rooms of health care facilities the water distribution pipe to each resident unit or back-to-back rooms shall be controlled by an arrangement of line valves that permits each group of fixtures, and each individual fixture, to be shut off without interference with the water supply to any other unit or portion of the building.

Flushing/Disinfection of Potable Water System
New or repaired potable water systems shall be flushed or disinfected prior to use as follows:

a) Chlorinated Water Supply. If the potable water supply serving the water supply system is chlorinated, e.g., a community water system, the water supply system, or appropriate repaired portion, shall be flushed with clean, potable water until no dirty water appears at the point of outlet.

b) Non-Chlorinated Water Supply. The pipe system shall be flushed with clean, potable water until no dirty water appears at the point of outlet.

1) The system (or part thereof) shall be filled with a chlorine solution containing at least 50 parts per million of chlorine, shall be valved off and allowed to stand for 24 hours; or the system (or part thereof) shall be filled with a chlorine solution containing at least 200 parts per million of chlorine and be allowed to stand for three (3) hours.

2) Following the required contact (standing) time, the system shall be flushed with clean, potable water until the chlorine level in the water discharging from the system is within acceptable limits for potable water, i.e., generally until the water has no detectable chlorine odor.

3) To ensure that the water supplied by the water system is safe for drinking, a bacteriological examination of a water sample taken from the water supply system shall be secured. This examination shall be performed by a laboratory certified in accordance with 35 Ill. Adm. Code 183. The chlorine residual in any water sample collected for such examination must not exceed four (4) parts per million (or 4 milligrams/liter) for a reliable laboratory result. If such examination reveals that contamination still persists in the system, the procedure outlined above for disinfection shall be repeated.

Water Service Sizing
a) Water Service Pipe Sizing. The water service pipe from the street main (including the tap) to the water distribution system for the building shall be sized in accordance with Appendix A, Tables M, N, O, P and Q. Water service pipe and fittings shall be at least ¾ inch diameter. Plastic water pipe shall be rated at a minimum of 160 psi at 73.4°F. If flushometers or other devices requiring a high rate of water flow are used, the water service pipe shall be designed and installed to provide this additional flow.

b) Demand Load. The calculation of the water service demand load for a building shall be based on the total number and types of fixtures installed in the building, assuming the simultaneous use of such fixtures.

c) Unused sections of water service or water distribution piping ("dead ends"), where the water in the piping may become stagnant, are prohibited. A developed length of more than 2 feet shall be considered a dead end.

Design of a Building Water Distribution System

a) Design and Installation. The design and installation of the hot and cold water building distribution systems shall provide a volume of water at the required rates and pressures to ensure the safe, efficient and satisfactory operation of fixtures, fittings, appliances and other connected devices during periods of peak use. No distribution pipe or pipes shall be installed or permitted outside of a building or in an exterior wall unless provisions are made to protect such pipe from freezing, including but not limited to wrap-on insulation or heat tape tracer line or wire.

b) Size of Water Distribution Pipes. The fixture supply for each fixture shall be at least the minimum size provided in Appendix A, Table D. The size of all other water distribution pipes shall be determined by calculating the water supply demand (in water supply fixture units) for that portion of the water distribution system served by the pipe. Using Appendix A, Tables M, N, O, P and Q, the cumulative water supply demand or load shall be calculated for all fixtures, piping, valves and fittings served by the water distribution pipe, and the pipe shall meet the minimum size provided in Appendix A, Table N or O, as applicable. Exception: As an alternative to using Tables M, N, O, P and Q to design and size the piping in the water distribution system, the system may be designed and sized employing current engineering practices, provided the design/plans are approved in writing by an Illinois licensed professional engineer, an Illinois licensed architect or an individual Certified in Plumbing Engineering (C.I.P.E.) by the American Society of Plumbing Engineers and approved in writing by the Department.

c) Minimum Water Pressure. The minimum constant water service pressure on the discharge side of the water meter shall be (at least) 20 p.s.i.; and the minimum constant water pressure at each fixture shall be at least 8 p.s.i. or the minimum recommended by the fixture manufacturer.

d) Auxiliary Pressure. Supplementary Tank. If the pressure in the system is below the minimum 8 p.s.i. at the highest water outlet when the flow in the system is at peak demand, an automatically controlled pressure tank or gravity tank of a capacity to supply sections of the building installation which are too high to be supplied directly from the public water main shall be installed.

e) Low Pressure Cut-Off. When a booster pump except those used for fire protection is used on an auxiliary pressure system, there shall be installed a low-pressure cut-off switch on the booster pump to prevent the creation of pressures less than 5 p.s.i. on the suction side of the pump. A shut-off valve shall be installed on the suction side of the water system and within 5 feet from the pump suction inlet, and a pressure gauge shall be installed between the shut-off valve and pump.

f) Water Hammer. All building water supply systems shall be provided with air chambers or approved mechanical devices or water hammer arrestors to absorb high pressures. Water pressure absorbers shall be installed at the ends of long pipe runs or near batteries of fixtures.

1) Air Chambers. Where an air chamber is installed in a fixture supply, it shall be at least 12 inches in length and the same diameter as the fixture supply. An air chamber with a volume equivalent to one with the dimension listed above may also be used. Where an

air chamber is installed in a riser, it shall be at least 24 inches in length and at least the same size as the riser.

2) Mechanical Devices. Where a mechanical device or water hammer arrestor is used, the manufacturer's specifications for location and installation shall be followed.

g) Excessive Static Water Pressure.
1) When water main pressure exceeds 80 p.s.i., a pressure reducing valve and a strainer with a by-pass relief valve shall be installed in the water service pipe near the entrance to the building to reduce the water pressure to 80 p.s.i. or lower, except where the water service pipe supplies water directly to a water pressure booster system, an elevated water tank, or to pumps provided in connection with a hydropneumatic or elevated water supply tank system. Sill cocks and outside hydrants may be left on full water main pressure.

2) When the water pressure exceeds 80 p.s.i. at any plumbing fixture, a pressure reducing valve, pressure gauge and a strainer with a by-pass relief valve shall be installed in a water supply pipe serving the fixture to reduce the water pressure at the fixture to 80 p.s.i. or lower.

h) Approval of Auxiliary Pressure Systems. Whenever in any building, structure, or premises receiving its potable water supply from the public water system, a pump or any other device for increasing the water pressure is to be installed, plans of such installation shall be approved by the Department prior to installation in accordance with Section 890.1940.

i) Variable Street Pressures. When the water main has a wide fluctuation in pressure, the water distribution system shall be designed for minimum pressure available at the main.

Hot Water Supply and Distribution

a) All water heaters shall comply with the requirements of Appendix A, Table A, (Approved Standards for Plumbing Appliances/Appurtenances/Devices), and ASHRAE 90 Standards. Hot water storage tanks shall meet construction requirements of ASME, AGA, or UL listed in Appendix A, Table A (Approved Standards for Plumbing Appliances/ Appurtenances/Devices), as appropriate. Hot water supply boilers with heat input in excess of 200,000 BTU per hour, water temperature in excess of 200° F, or capacity in excess of 120 gallons must also comply with the requirements of the Boiler and Pressure Vessel Safety Rules and Regulations. Smaller water storage tanks that are not subject to ASME requirements shall be constructed of durable materials and constructed to withstand 150 p.s.i.

1) All equipment used for heating and storage of hot water shall bear the marking of an approved testing agency certifying that it has been tested and approved and listed as meeting the requirements of the applicable standard. Listing by Underwriters Laboratories, American Gas Association or National Board of Boiler and Pressure Vessel Inspectors, or the ASME Standard shall constitute evidence of conformance with these standards.

2) A solar-heated system shall use a double-walled heat exchanger which is exposed or vented to the atmosphere between the walls.

3) Heat exchangers may be of single wall construction if a non-toxic transfer fluid with no conditioning chemicals in the system is used, or if a pressure gradient monitor system is installed to isolate the heat exchanger from the potable water system. If pressure on the potable water side reaches a pressure less than 10 p.s.i. above the toxic transfer fluid pressure, an audible alarm shall be activated.

4) Heat exchangers using a toxic transfer fluid or having conditioning chemicals in the system shall be separated from the potable water by double wall construction. There shall be an air gap open to the atmosphere between the two walls. Where the boiler (heating chamber) operates in excess of 65 p.s.i., the requirements of subsection (a)(5) of this Section shall also apply.

5) No heat exchanger will be permitted on any boiler system operating in excess of 65 p.s.i., or high temperature hot water system operating in excess of 250°F, or any steam boiler operating with a pressure in excess of 50 p.s.i., unless:

A) the heat exchanger is double-walled; and

B) the heat exchanger has an air gap open to the atmosphere between the 2 walls; and

C) the heat exchanger has a pressure gradient monitor system with a "fail-safe to off" switch installed to isolate the heat exchanger from the potable cold or hot water system. If pressure on the potable water side reaches a pressure less than 20 p.s.i. above the pressure of the transfer fluid or steam and a pressure reducing valve is installed on the inlet to the heat exchanger with a setting 20 p.s.i. lower than the potable water pressure at the heat exchanger, an audible alarm shall be activated and the heat exchanger shall be automatically shut off until the alarm and heat exchanger can be reset manually.

6) Any boiler using toxic chemicals shall have a label with a minimum size of 5 inches X 5 inches attached to the boiler in a conspicuous place. The label shall read as follows:

WARNING
Chemicals and additives used to treat the boiler feed water in this boiler are not approved for potable water. The steam or hot water produced by this boiler is not potable. If the steam or hot water produced by this boiler is used to heat water, the water will not be considered potable if the steam and potable water are mixed.

7) Indirect, External, Submerged Coils. Indirect, external, tankless or submerged coils used in heating water shall be equipped with a thermostatic mixing valve or valves when not connected to a storage tank. A pressure relief valve shall be installed on the cold water inlet of the tank. A properly sized temperature and pressure relief valve, based upon the energy input rating of the coils, shall be installed on the tempered line with the temperature sensing element immersed in the tempered water line as close as possible to the mixing valve.

8) Direct Fired Instantaneous Heaters. (Storage tank of more than 64 fluid ounces.) Direct fired instantaneous water heaters shall be equipped with a thermostatic mixing valve or valves which conform to ASSE 1017-1999. A pressure relief valve shall be installed on or adjacent to the heater. A properly sized temperature and pressure relief valve, based upon the energy input rating of the heater, shall be installed on the tempered line with the temperature sensing element immersed in the tempered water line as close as possible to the mixing valve.

9) Water Heaters Used for Space Heating. Any water heater to be used for space heating, in addition to hot water supply, must conform to ANSI Z21.10.1a-1991, shall be constructed for continuous use, and the piping for space heating shall be conducted to a proper terminal heating device.

A) A thermostatic mixing valve, conforming to ASSE 1017-1999, shall be installed on the hot water line to the plumbing fixtures. (The mixing valve shall be set to prevent temperatures exceeding 120°F from reaching the plumbing fixtures.)

B) A single check valve shall be installed in the cold water line supplying the water heater. (This will prevent hot water backing up from the heating unit to the plumbing fixtures.)

C) A properly sized and approved expansion tank shall be located on the outlet side of the check valve in the water heater's cold water supply with no shut-off valve between the heater and expansion tank.

D) Valves (manual, automatic) supplying hot water to the heat transfer unit for space heating shall have a minimum of a 1 inch orifice. (This will prohibit potable water from standing in the heat transfer unit when not in use.) This does not prohibit full shut off/isolation valves on either side of the pump within a heat transfer unit, as needed, to permit the servicing of the pump.

E) The water heater instructions shall have a statement specifying that piping and components connected to the water heater for the space heating application shall be suitable for use with potable water, and the water heater shall not exceed a developed length of more than 25 feet from the heating coil.

F) A statement specifying that toxic chemicals, such as those used for boiler treatment, shall not be introduced into the potable water used for space heating shall be included in the instructions. A label with the following words shall be firmly attached to any water heater used for space heating: "DO NOT INJECT TOXIC MATERIALS INTO THIS TANK."

G) A statement specifying that a water heater which will be used to supply potable water shall not be connected to any heating system or components previously used with a non-potable water heating appliance shall be included in the installation instructions.

H) Each water heater shall bear a statement on the rating plate as follows: "SUITABLE FOR POTABLE WATER HEATING AND SPACE HEATING."

10) Point-of-Use Instantaneous Water Heaters. Point-of-use instantaneous water heaters (high temperature, non-storage or storage of 64 fluid ounces or less, non-pressurized relative to atmosphere) shall meet the following requirements:

A) Units intended to deliver water temperatures exceeding 110°F, or with no mechanical or electrical temperature limiting device must have the faucet located at least 3 inches from the 110°F hot water or cold water faucet. All such faucet outlets shall have labels clearly and conspicuously indicating extremely hot water.

B) Units intended to deliver water temperatures 110°F or less shall have an internal burnout element or shall have a factory set thermostat that is not adjustable to higher than 110°F.

C) All pressurized point-of-use water heaters shall also have provisions as a part of the unit to provide temperature and pressure relief. Valves shall be set to relieve at 20°F above the intended water temperature and at 125 p.s.i. or at 15 p.s.i. below the pressure rating of the lowest rated part of the assembly, whichever is lower.

11) Steam Heat. All water heaters including storage heaters, instantaneous shell and tube heat exchangers, steam injection heaters and any other device using steam to heat water for potable use shall meet the following requirements:

A) All chemicals and additives used to treat the boiler feed water in a boiler supplying steam to heat potable water must be proper for use with potable water. Where such approved chemicals and additives are used with steam boilers generating at 15 p.s.i. or less, or are used with pressure reducing stations with pressure relief valves set at 15 p.s.i. or less downstream from the pressure reducing valves, single wall heat exchangers may be used.

B) Steam injection heaters must be supplied with steam from a generator or boiler which uses only United States Food and Drug Administration (FDA) approved additives or chemicals.

C) The following warning label with a minimum size of 5 inches X 5 inches shall be permanently attached to each steam injection heater:

"If the chemicals used to treat the feed water to provide steam for this steam injection water heater are not approved for potable water, the hot water from this heater shall not be considered potable. Therefore, each cross connection between the hot water and cold water connections to or from this heater must be provided with a device to prevent the backflow of hot water or steam condensate into the potable water supply."

D) The following warning label with a minimum size of 5 inches X 5 inches shall be permanently attached on the front of any boiler providing steam to direct injection steam hot water heaters:

"If the chemicals used to treat the boiler feed water in this boiler are not approved for potable water, the steam produced by this boiler cannot be considered potable. Therefore, if steam from this boiler is used to heat water, the water shall not be considered potable and any cross connections between the hot water produced and a potable water supply must be provided with a device to prevent the backflow of the non-potable hot water into the potable water supply."

b) Water Heaters – Food Service. Water heaters installed and utilized in food service establishments with dishwashing machines shall comply with National Sanitation Foundation (NSF) Standard.

c) With the exception of special water heaters used for space heating in addition to hot water supply, as provided in subsection (a)(9) of this Section, water that leaves the potable water system for heating, cooling, use in equipment or other similar uses shall not be returned to the potable water distribution system. When such water is discharged to the building drainage system it shall be discharged through a fixed air gap.

Safety Devices

a) All equipment used for heating water or storing hot water shall be provided, at the time of installation of such equipment, with an appropriate relief valve or valves to protect against excessive or unsafe temperature and/or pressure. This shall be achieved by installing either a pressure relief valve and a temperature relief valve or by installing a combination pressure-temperature relief valve.

b) Pressure and Temperature Relief Valves.

1) Pressure Relief Valves. Pressure relief valves shall have an ASME relief rating to meet the pressure conditions specified on the equipment served. They shall be installed in the cold water supply line to the heating equipment served, except where scale formation from hard water may be encountered, in which case they shall be installed in the hot water supply line from the heating equipment served. There shall not be a shut-off valve between the pressure relief valve and the tank. Except where an alternate design is approved by the Department in writing pursuant to Section 890.140(a)(2) or 890.1940, the pressure relief valve must be set to open at a maximum of the working pressure rating of the water heater, but shall not exceed 150 p.s.i. Each pressure relief valve shall have a test lever.

2) Temperature Relief Valves. Temperature relief valves shall bear an American Gas Association (AGA) relief rating, expressed in British Thermal Units (BTU) of heat input per hour, for the equipment served. They shall be installed so that the temperature sensing element is immersed in the hottest water within the top 6 inches of the tank. The valve shall be set to open full when the stored water temperature is 210^{O}F.

c) Combination Pressure-Temperature Relief Valves.

1) Combination pressure-temperature relief valves shall comply with the applicable requirements as listed in Appendix A, Table A (Approved Standards for Plumbing Appliances/Appurtenances/Devices) for individual pressure and individual temperature relief valves, and shall be installed so that the temperature sensing element is immersed in the hottest water within the top 6 inches of the tank and have a test lever.

2) A check valve or shut-off valve shall not be installed between any safety device and the hot water equipment, nor shall there be any shut-off valve in the discharge pipe from the relief valve.

3) Energy cut-off devices shall not be used in lieu of subsections (c)(1) and (2) of this Section and shall be of a design to properly serve the intended use of the plumbing appliance, appurtenance or device. Exception: Instantaneous cut-off devices are exempted or may be used.

d) Relief Discharge Outlet.

1) A relief discharge outlet shall be indirectly connected to waste. The discharge pipe from the relief valve shall not be located so as to create a safety hazard or to discharge in such a way as to cause damage to the building or its contents. The relief valve shall not discharge through a wall into the outside atmosphere or where there is a possibility of freezing.

2) No reduced coupling, valve or any other restriction shall be installed in the discharge line of any relief valve that would impede the flow of discharge. The discharge line shall be installed from the relief valve to within 6 inches of the floor or receptor and the end of such line shall not be threaded.

3) Any piping used for discharge from the relief valve shall be of metallic material and conform with the requirements of Appendix A, Table A (Approved Materials for Water Distribution Pipe) for potable water piping and shall drain continuously downward to the outlet.

4) The discharge piping shall discharge indirectly into a floor drain, hub drain, service sink, sump or a trapped and vented P-trap which is located in the same room as the water heater. (See Sections 890.1010 and 890.1050(a), (b) and (c).) The trap must have a deep seal to protect against evaporation or shall be fed by means of a priming device designed and installed for that purpose. (The use of light grade oil in the trap will retard evaporation.)

e) Pressure Marking – Hot Water Storage Tank. Hot water storage tanks shall be permanently marked in an accessible place with the maximum allowable working pressure.

f) Vacuum Relief Valve. Where a hot water storage tank or water heater is located at an elevation above the fixture outlets in the hot water system, or if the storage tank or water heater is bottom fed, a vacuum relief valve as listed in Appendix A, Table A (Approved Standards for Plumbing Appliances/Appurtenances/Devices) shall be installed on the storage tank or heater.

g) Multiple Temperature Hot Water Systems. Such systems shall be provided with thermostatic mixing valves to properly control the desired temperatures.

Types of Joints

a) Caulked joints. Caulked joints for (drain, waste and vent systems only) cast iron hub-and-spigot pipe shall be firmly packed with oakum or hemp and filled with molten lead at least one inch deep and be firmly caulked not to extend more than 1" below the rim of the hub. Paint, varnish, or other coatings shall not be permitted on the jointing material until after a plumbing inspector has been given the opportunity to test and approve or disapprove the joint.

b) Threaded/Screwed Joints. Threaded joints shall conform to American National Taper Pipe Thread, ASME B.1.20.1-1983 (General Purpose). All burrs shall be removed; pipe ends shall be reamed or filed to size of the bore and all chips shall be removed. Pipe joints compound shall be insoluble in water and non-toxic.

c) Wiped Joints. Joints in lead pipe or fittings, or between lead pipe fittings and brass or copper pipe ferrules, solder nipples, or traps shall be full-wiped joints. Wiped joints shall have exposed surface on each side of the joint at least ¾" and at least as thick as the material being joined. Wall or floor flange lead-wiped joints shall be made by using a lead ring or flange placed behind the joints at the wall or floor. Joints between lead pipe and cast iron, steel or wrought iron shall be made by means of a caulking ferrule, soldering nipple, or bushing. Note: Lead joints and lead fixtures have been banned.

d) Soldered Joints. The surface to be soldered shall be cleaned bright. The joints shall be properly fluxed (lead free) and made with approved lead free solder conforming to ASTM Standard B32-1989. Joints in copper water tubing shall be made with approved cast bronze or wrought copper pressure fittings, properly soldered together. All solders or flux containing more than 0.2% lead shall bear a warning label which states that the solder or flux is not approved for private or potable water use as required by Section 4 of the federal Hazardous Substances Act (15 USC 1263). Use of this product in the making of joints or fittings in any private or public potable water system is prohibited. No part of a DWV (drain, waste and vent) system shall be joined or fitted with a solder or flux containing more than 0.2% lead. Note: Lead joints and lead fixtures have been banned.

e) Flared Joints. Flared joints for plastic pipe and tubing and soft copper water tubing shall be made with approved fittings. The tubing shall be expanded with a proper flaring tool.

f) Hot-Poured Joints. Hot-poured compound for clay or concrete sewer pipe shall not be water absorbent and when poured against a dry surface shall have a bond of at least 100 pounds per square inch (p.s.i.). All surfaces of the joint shall be cleaned and dried before pouring. If wet surfaces are unavoidable, a suitable primer such as oil or tar shall be applied. The compound shall not soften sufficiently to destroy effectiveness of the joint when subjected to a temperature of 160ºF, and not be soluble in any of the waste carried by the drainage system. Approximately 25 percent of the joint space at the base of the socket shall be filled with jute or hemp. A pouring collar rope or other device shall be used to hold the hot compound during pouring. Each joint shall be poured in one operation until the joint is filled. Joints shall not be tested until one hour after pouring. Note: Lead joints and lead fixtures have been banned.

g) Precast Joints. Precast collars shall be formed in both the spigot and bell of the pipe in advance of use. Prior to making joint contact, surfaces shall be cleaned. When the spigot end is inserted in the collar, it shall bind before contacting the base of the socket.

h) Brazed Joints. Brazed joints shall be made by first cleaning the surface to be joined down to the base metal, applying flux approved for such joints and for the filler metal to be used, and making the joints by heating to a temperature sufficient to melt the approved brazing filler metal on contact. An extracted mechanical joint may be made in copper tube types K or L only for water distribution. The joint shall be made with a mechanical extraction tool and joined by brazing. To prevent the branch tube from being inserted beyond the depth of the extracted joint, depth stops shall be provided. This joint shall be for above ground use only.

i) Cement Mortar Joints. Except for repairs, cement mortar joints are prohibited.

j) Burned Lead (Welded). (For drain, waste and vent system only) Every burned (welded) joint shall be made in such manner that the 2 or more sections to be joined shall be uniformly fused together into one continuous piece. The thickness of the weld shall be at least as thick as the lead being joined. Note: Lead joints and lead fixtures have been banned.

k) Bituminized Fiber Pipe Joints. Joints in bituminized fiber pipe shall be made with tapered type couplings of the same composition as the pipe. Joints between bituminized fiber pipe and metal pipe shall be made by means of an adaptor coupling caulked as required in subsection (a) of this Section.

Plastic Pipe Joints

1) Every joint in plastic piping shall be made with approved fittings by either solvent welded or fusion welded connections, compression fittings, approved insert fittings, metal clamps and screws of corrosion resistant material, or threaded joints.

2) Joints and Fittings in Plastic Pipe. Potable water piping fittings and joints shall be in accordance with the manufacturer's recommendations.

A) Polyethylene (PE) pipe shall be installed only with compression fittings, insert and clamp type fittings or thermal welded joints and fittings. All clamps shall be of corrosion resistant material. The inside diameter (I.D.) of any insert fitting shall not be less than the minimum allowable size for water service/distribution piping.

B) Polyvinyl chloride (PVC) pipe shall be installed with solvent welded or flanged joints only. The pipe shall not be threaded. Transition to metallic or other piping shall be made with the use of adaptor fittings. The fittings shall be molded from polyvinyl chloride. The primer and solvent cement used shall be in accordance with the manufacturer's recommendation for polyvinyl chloride piping.

C) Polybutylene (PB) pipe shall be installed only with insert and clamp type fittings, compression type, flanged type, or thermal welded joints and fittings. All clamps shall be of corrosion resistant material. The inside diameter (I.D.) of any insert fitting shall not be less than the minimum allowable size for water service/distribution piping.

3) Joints in Plastic Drainage. Joints in plastic drainage piping or vent piping within a building shall be solvent welded. Threaded or flanged joints may be used with adaptor fittings. The solvent cement shall be specific for the type of piping material. O-ring expansion joints are acceptable if accessible.

m) Ground Joint Connections. Ground joint connections (when accessible) may be used on the inlet or outlet side of a fixture trap or within the trap seal. Ground joint connections shall not be used in any inaccessible drainage piping.

n) No-Hub Soil Pipe Joints. Shielded joints for no-hub cast iron soil pipe shall be made with an elastomeric gasket covered by either a stainless steel shield secured by 2 or more stainless steel bands or clamps, or covered by cast iron couplings secured with stainless steel nuts and bolts. When a stainless steel shield is used, the shield and clamps shall be corrosion resistant and homogeneous throughout.

Compression Type Joints.
1) Compression type joints for hub and spigot cast iron soil pipe shall be made with neoprene insert gaskets in accordance with ASTM C564. The pipe shall comply with the specifications contained in ASTM A-74 with regard to hub and spigot dimensions and tolerances.

2) Compression type joints for copper water tube or brass tube shall be made with brass ferrules and ground joint connections.

p) Grooved Type Mechanical Couplings.
1) Cut grooved type mechanical couplings, fittings and valves used on standard weight galvanized steel pipe, cast iron pipe or ductile iron pipe shall comply with the grooving dimensions of the AWWA specifications C606-78, limited to water distribution piping and downspout pipe above ground.

2) Rolled grooved type mechanical couplings, fittings and valves used on standard weight galvanized steel pipe or type K or L copper tubing shall comply with the manufacturer's standard, limited to water distribution piping above ground. Fittings, couplings and valves shall be compatible with the pipe material. Transition adapters shall be dielectric type.

3) Gaskets for use with potable water piping shall be fabricated from material that is non-toxic, durable and impervious.

q) Copper Press Fittings. Copper press fittings for joining copper water tubing shall have an elastomeric o-ring that forms the joint. The fitting shall be made by pressing the socket joint under pressure in accordance with the manufacturer's installation requirements and NSF Standard 61.

Tightness Joints and Connections

Joints and connections shall be gas-tight and water-tight.

Special Joints

a) Copper Tubing to Screwed Pipe Joints. Joints from copper tubing to threaded pipe shall be made by the use of a cast bronze or wrought copper adaptor fitting. The joint between copper tubing and the fitting shall be soldered or, if flared or compression, must be accessible.

b) Welding or Brazing. Brazing or welding shall be in accordance with the provisions of Section 6 of the Code for Pressure Piping, ANSI B.3.1 and ANSI B.3.L.1.

c) Slip Joints. In drainage and water piping, slip joints may be used on the inlet side of the trap or in the trap seal, and on the exposed fixture supply. Slip joints shall not be used in any inaccessible piping. Push-on angle stop valves are permitted, provided they meet the following specifications: they are installed by being pushed onto copper or CPVC; they are mechanically secured by metal tabs which grip the piping; they are sealed with o-rings; and they are capable of withstanding a water pressure of 150 pounds per square inch and a temperature of 210 degrees Fahrenheit.

d) Expansion Joints. Expansion joints must be accessible and may be used where necessary to provide for expansion or contraction of the piping. The expansion joint material shall conform to the type piping on which it is installed.

e) Compression type couplings shall not be used in unexposed water piping except for water services, water meter yokes and stop box connections.

f) Grooved Type Mechanical Couplings. Grooved type mechanical couplings, in accordance with Section 890.320(p), may be used in potable water and roof drainpiping. Such couplings shall not be used in waste, soil or vent piping.

g) Plastic Pipe to Non-Plastic Pipe Joints. Joints between plastic pipe and non-plastic pipe shall be made only by one of the following methods:

1) Pressure piping.

A) Approved insert fittings.

B) Threaded adaptors.

C) Flanges.

D) Flared fittings.

2) Non-pressure piping - Drain Waste Vent (DWV)

A) Caulked lead joints with caulked adaptors.

B) No-hub soil pipe shielded couplings with approved adaptor having a raised bead.

C) Compression type joints for hub and spigot cast iron pipe.

D) Threaded adaptors.

Use of Joints

a) Clay Sewer Pipe. Joints in vitrified clay pipe or between such pipe and metal pipe shall be made with a neoprene gasket and stainless steel bands.

b) Concrete Sewer Pipe. Joints in concrete sewer pipe or between such pipe and metal pipe shall be made with a neoprene gasket and stainless steel bands.

c) Cast Iron Pipe. A joint in cast iron water supply pipe shall be made in accordance with Section 890.320(a) and (b) or shall be a mechanical joint.

d) Screw Pipe to Cast Iron. Joints between wrought iron, steel, brass, or copper pipe, and cast iron pipe shall be either caulked or threaded joints which are made as provided in Section 890.320 (a) or (b) and shall be made with proper adaptor fittings.

e) Lead to Cast Iron, Wrought Iron or Steel. Joints between lead and cast iron, wrought iron, or steel pipe shall be made by means of wiped joints to a caulking ferrule, soldering nipple, or brushing.

f) Copper Water Tube. Joints in copper tubing shall be made with cast bronze or wrought copper pressure fittings, properly soldered or brazed, or by means of compression or flared joints. Flared joints and compression fittings shall not be installed underground except for water services, water meter yokes and stop box connections.

g) Plastic Pipe. Joints between plastic pipe and non-plastic material shall be made only with an appropriate type adaptor.

1) Plastic-Commingling. There shall be no commingling of plastic materials within the same plumbing system except through the use of proper adaptors.

2) Plastic Pipe. Plastic pipe shall not be installed in any tunnel or chase that contains uninsulated hot water, hot air or steam piping which causes the ambient air temperature in the tunnel or chase to exceed 180ºF.

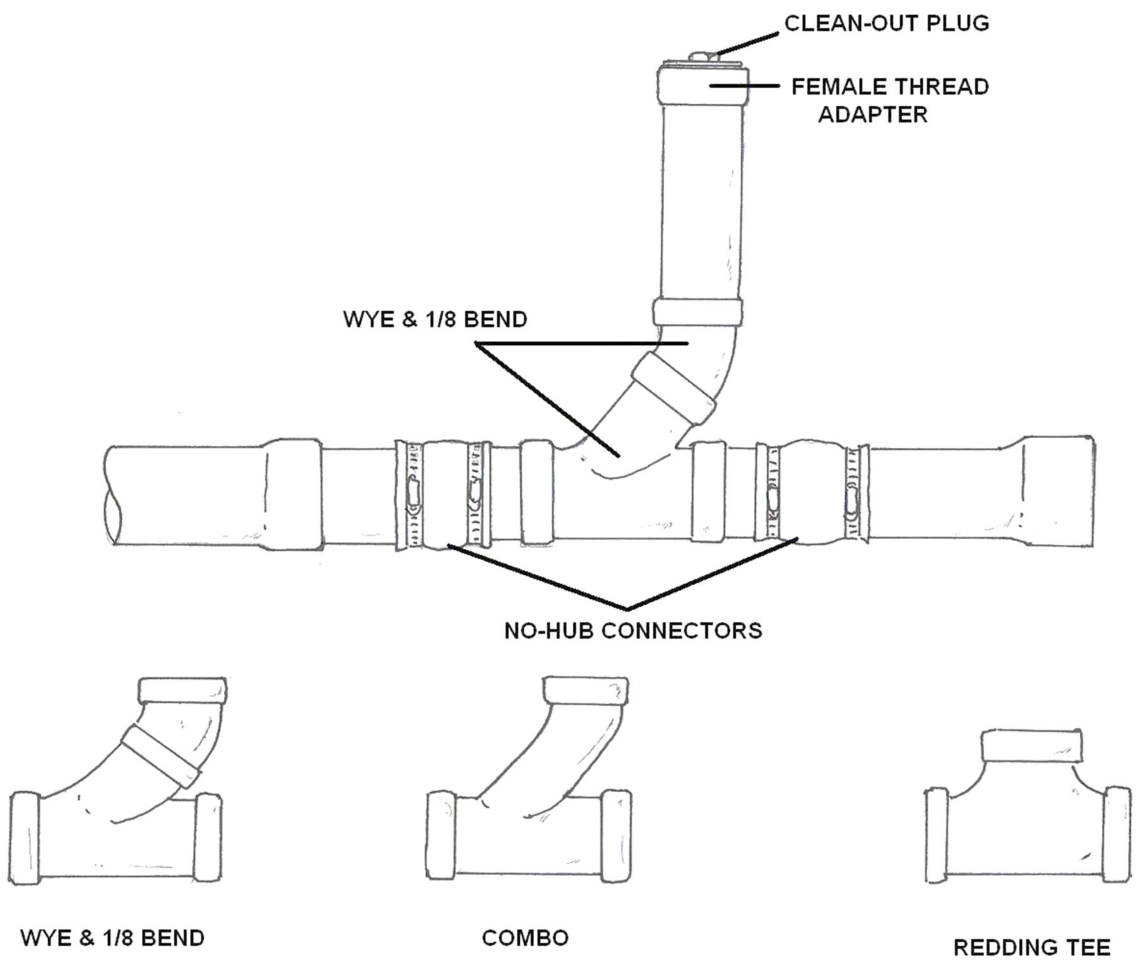
h) Building Sewer Connections. An elastomeric coupling seal conforming to ASTM C 425 (1988), ASTM C 443 (1985), ASTM C 564 (1988), ASTM D 4161 (1986), ASTM F 477 (1985), or ASTM D 3139 (1989), ASTM D 3212 (1989), or ASTM D 412 (1980) tests may be used to adapt any 2 building sewer pipes for different materials or size changes. The flexible couplings shall be attached to the pipe with stainless steel clamps or bolts. The manufacturer's recommended method of installation shall be followed.

Unions

Unions may be used in the drainage and venting system when accessibly located above ground. Unions shall be installed in a water supply system within 5 feet of regulating equipment, water heaters, water conditioning tanks, water conditioning equipment, pumps, and similar equipment which may require service by removal or replacement. Where small equipment may be unscrewed, only one union shall be required.

a) Drainage System. Unions may be used in the trap seal and on the inlet and outlet side of the trap. Unions shall have metal to metal seats except that plastic unions may have plastic to plastic seats.

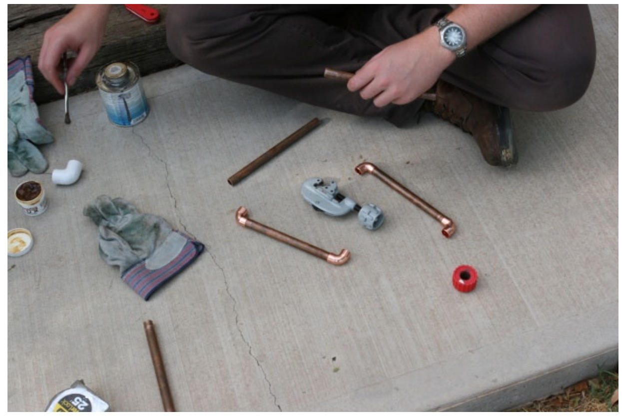
b) Water Supply System. Unions in the water supply system shall be metal to metal with ground seats, except that plastic to metal unions may utilize durable, non-toxic, impervious gaskets. Unions between copper pipe/tubing and dissimilar metals shall either be made with a brass converter fitting or be a dielectric type union.



DRAIN WASTE WYES

Plumbing Repairs Sub-Section

Faucets
Today, most faucets can be categorized as being washerless (port-type faucets), or of the Compression (washer) type.



Repairing Faucets
There are a few different types and combinations of faucets: single-handle or two-handled shut-offs that are compression or washerless (cartridge, ball or disc mechanism).

A compression faucet stops water by tightening down a rubber washer to block water flow.

A washerless faucet uses a rotating mechanism -- like a ball or valve -- to open and shut water flow.

A compression faucet usually has threaded brass stems that open/close firmly. A cartridge faucet has brass or plastic valves with holes in them and operate more easily.

Tips Before You Start

- Close the sink drain to avoid losing any parts.
- After locating the leak, shut off both water supplies before removing any parts.
- Tape wrench jaws to avoid marring the faucet's finish.
- Write down and/or lay out parts to remember their order.
- Buy a repair kit that includes a special adjusting ring wrench, seals, springs and O-rings rather than one or two pieces. Washer assortment kits may also be better than more expensive single washer packaging.
- If the faucet still leaks after installing a kit, the outer housing is probably cracked and buying a new faucet is probably the only way to fix the leak.

Washerless Faucets
Washerless faucets can be either single handle or the two handle type. In washerless faucets, the control of the water flow is done by a replaceable cartridge or arrangement of seals that allow water flow when the holes or ports are lined up in the proper configuration.

Giving the handle an extra hard twist to stop water flow will be ineffective. This type of faucet does not use compression strength to stop water flow.

Various Seats and Stems. Here is a money maker.

A washer-less faucet does not mean it will never leak, but rather because of the way it is designed, the parts will last much longer, as their design minimizes friction and wear.

When repairing this type of faucet or requesting service on one, it is vital that you know the brand name, or have a sample of the part you require, as there are hundreds of faucet cartridges and parts kits on the market today.

Compression Faucets
Like sink and lavatory faucets, wall mounted faucets fall into two categories: compression and non-compression types. Two-handle compression types feature O-rings and washers that you can replace. The non-compression version usually has a single handle pull-on, push off configuration, with a cartridge assembly beneath, when it leaks, the whole cartridge assembly usually requires replacement**.**

In a compression type faucet, you will find the conventional setup - a faucet washer on the end of the stern. Replacing the washer usually will correct a dripping faucet.

However, when removing the stem, always check the seat inside the faucet body - the brass ring that the washer grinds against. The faucet seat can be worn or grooved, making the washer replacement ineffective within days. The washer and seat are the two parts of a compression type faucet that receive the greatest amount of wear. It is not difficult to replace a washer. First, shut off the water supply.

Usually, the shut-off valve is under the sink in the kitchen, or in the bathroom, under the lavatory basin. If there is none, shut off the branch-line valve in the basement or the main valve where the water supply enters the house.

Pad a smooth jawed wrench with a cloth, then, using the padded wrench, unscrew the large packing nut and turn out the faucet stem. Then, with a screw driver that fits the screw slot closely, remove the screw from the bottom of the stem and pry out the worn washer. If the screw is tight or stubborn, tap its head lightly or apply penetrating oil (WD-40).

Troubleshooting Section for Distribution System

Problem

1. Dirty water complaints
2. Red water complaints
3. No or low water pressure
4. Excessive water usage.

Possible Cause

1A. Localized accumulations of debris, solids/particulates in distribution mains
1B. Cross connection between water system and another system carrying non-potable water.
2A. Iron content of water from source is high. Iron precipitates in mains and accumulates.
2B. Cast iron, ductile iron, or steel mains are corroding causing “rust” in the water.
3A. Source of supply, storage or pumping station interrupted.
3B. System cannot supply demands.
3C. Service line, meter, or connections shutoff, or clogged with debris.
3D. Broken or leaking distribution pipes.
3E. Valve in system closed or broken.
4A. More connections have been added to the system.
4B. Excessive leakage (>15% of production)is occurring, meters are not installed or not registering properly.
4C. Illegal connections have been made.

Possible Solution

1A. Collect and preserve samples for analysis if needed. Isolate affected part of main and flush.
1B. Collect and preserve samples for analysis if needed. Conduct survey of system for cross connections. Contact State Drinking Water Agency.
2A. Collect and test water samples from water source and location of complaints for iron. If high at both sites, contact regulatory agency, TA provider, consulting engineer or water conditioning company for assistance with iron removal treatment.
2B. Collect and analyze samples for iron and corrosion parameters. Contact State Drinking Water Agency , TA provider, consulting engineer or water conditioning company for assistance with corrosion control treatment.
3A. Check source, storage and pumping stations. Correct or repair as needed.
3B. Check to see if demands are unusually high. If so, try to reduce demand.
Contact State Drinking Water Agency, TA provider or consulting engineer.
3C. Investigate and open or unclog service.
3D. Locate and repair break or leak.
3E. Check and open closed isolation and pressure-reducing valves. Repair or contact contractor if valves are broken.
4A. Compare increase in usage over time with new connections added over same period. If correlation evident take action to curtail demand or increase capacity if needed. Contact State Drinking Water Agency , TA provider or consulting engineer.
4B. Conduct a water audit to determine the cause. If leakage, contact regulatory agency, and consulting engineer or leak detection contractor.
4C. Conduct survey to identify connections.

Minimum Storage

Minimum storage available for public fire protection should be examined in terms of the type of distribution system. It may be helpful to refer to the figures illustrating basic types of water systems. Every water system for communities over 50 population has to have a water storage component in order to provide even minimum fire protection water supplies

On this matter, the *Grading Schedule* states that the average daily **minimum** water storage maintained is the **maximum** amount that can be credited. This concept can be understood through the following explanation.

The amount of water in storage for a given distribution system is constantly changing due to residential, business, and industrial consumption and, as needed, fire-flow consumption. As previously identified, consumption varies by the time of the day and the day of the week. Consequently, finished water (referring to water that has been suitably treated to meet EPA Safe Drinking Water Standards), in storage also varies by the time of day and the day of the week. The insurance community grading process is interested in the **average** minimum storage as a benchmark for both water system adequacy and reliability.

To determine minimum storage, it is necessary to maintain **accurate** records on storage facilities including clear wells, standpipe tanks, and gravity tanks. Chart recorders linked to each storage facility typically are used to cover the capacity range of the specific storage tank.

The recorded minimum amount of water in storage for each day is expressed in gallons or millions of gallons.

For each year being evaluated, all daily minimum amounts are totaled and divided by 365 days to provide the average minimum water in storage. This is the amount of water credited as available for consumer consumption and fire flow at any given time. Obviously, consumer consumption does not stop when there is a fire in the community.

The ISO *Grading Schedule* does specify some conditions and exceptions to the concept of minimum storage:

- The absolute minimum water supply under extreme dry weather conditions should not be considered; this is a judgment item.
- Only the portion of water in storage that can be delivered at the required pressure of 20 psi at representative tests sites is to be considered.
- Water loss due to a pipe rupture should not be considered in the evaluation.
- Water supply available during periods when water tanks are being cleaned and painted has to be carefully evaluated by an ISO field representative.
- It should be recognized that direct pumping systems from treated water supplies, or nonpotable water that is treated during the pumping process, generally are limited by both water storage and pumping capacity. The pumping limitation is discussed below.

Municipal Stationary Pumps
Municipal pumps may interface with a water distribution system supply in several ways. Some of these ways are illustrated above. The most common uses of pumps at the supply works follow:

- Pumps take water from an impounding source (lakes, rivers, streams, etc.) and send the water through pipes to a filtration/treatment plant.
- Pumps take treated water from clear wells and pump directly into the water delivery system piping network.
- Pumps take treated water from clear wells and pump to elevated or standpipe tanks.
- Pumps take water from wells and pump it through purifiers and then to the water distribution system.
- The Grading Schedule indicates that stationary municipal pumps should be credited at their effective capacities when delivering at normal operating pressures as specified by the pump manufacturer. This information needs to be taken from the manufacturer's pump specification plate and manufacturer's pump curves. This information is to be available at the water supply works. Each water supply pump needs to be tested annually to match points on the manufacturer's pump curve with actual flow capability.

The **actual** flow capability of one or more pumps at the supply works may be limited by the following factors:

- size and length of the suction pipe to the pump;
- filter arrangements;
- Venturi fittings for chlorinators, water softeners, fluorides, and other additives;
- head loss characteristics on the discharge side of the pumps; and
- minimum stored water capacity may limit pump capability when pumping from this source.

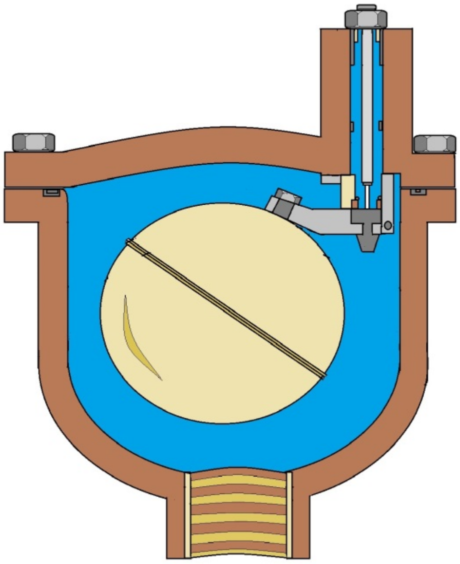
The following explanatory information should be of assistance in the determination of creditable pump capacity:

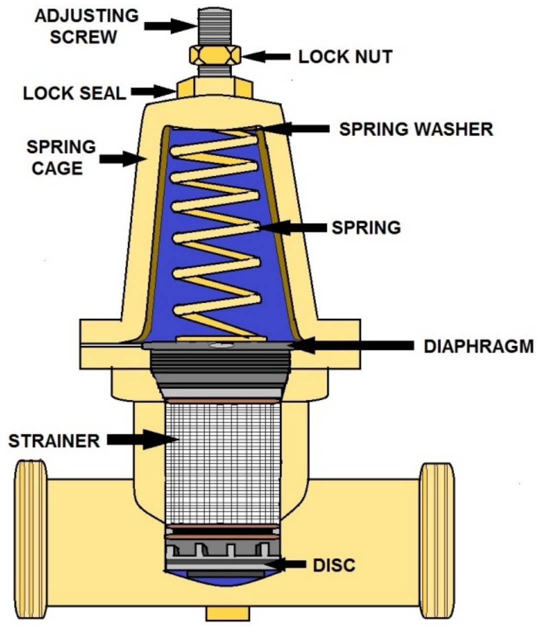
- The total pumping capacity should be the sum of **all** pump facilities available at the test location expressed in gpm.
- When there are two or more pump lifts in a series, the effective pump capacity is the capacity of the lift with the lowest total capacity.
- When the same pumps can operate in two or more lifts, they are to be credited in each lift to determine the lift with the lowest total capacity.

Reference

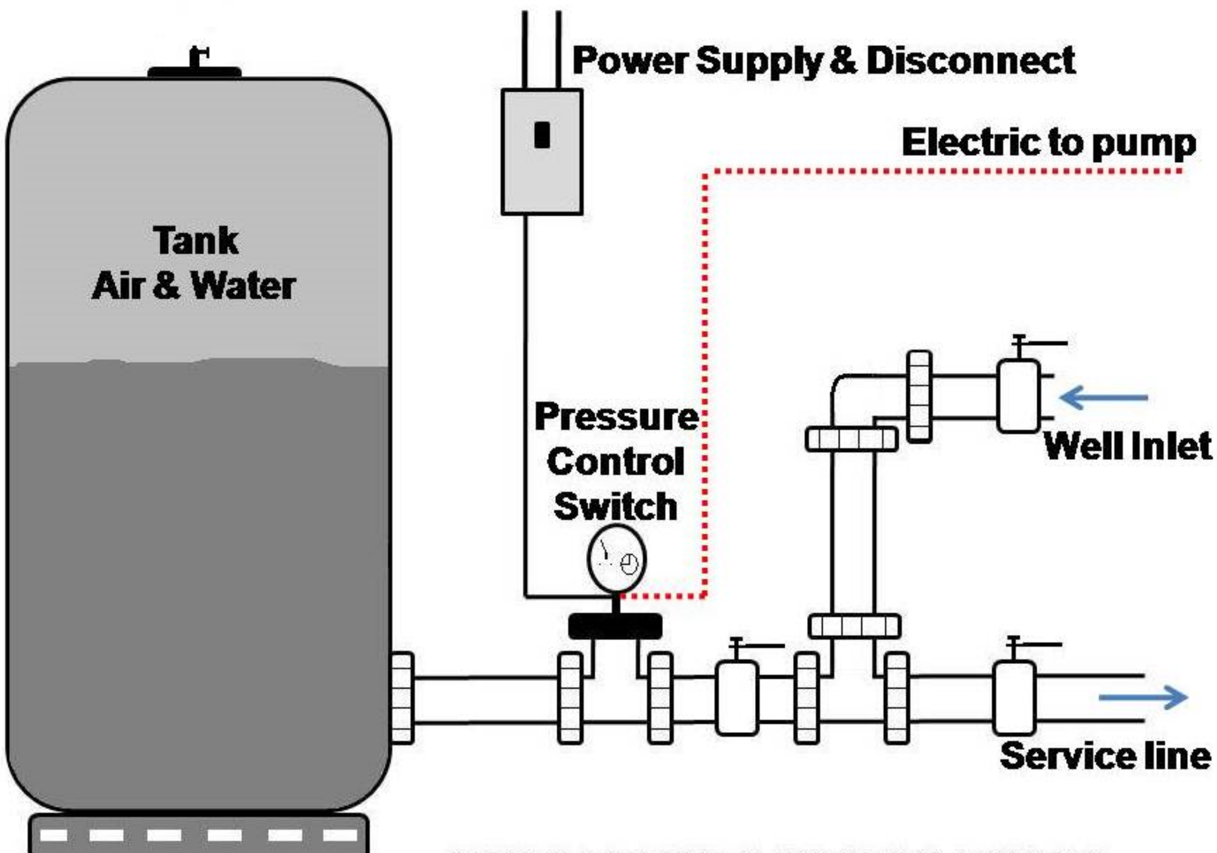
Water Supply Systems• Vol. II: Evaluation Methods October 2008 FEMA U.S. Fire Administration Harry E. Hickey, Ph.D.

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

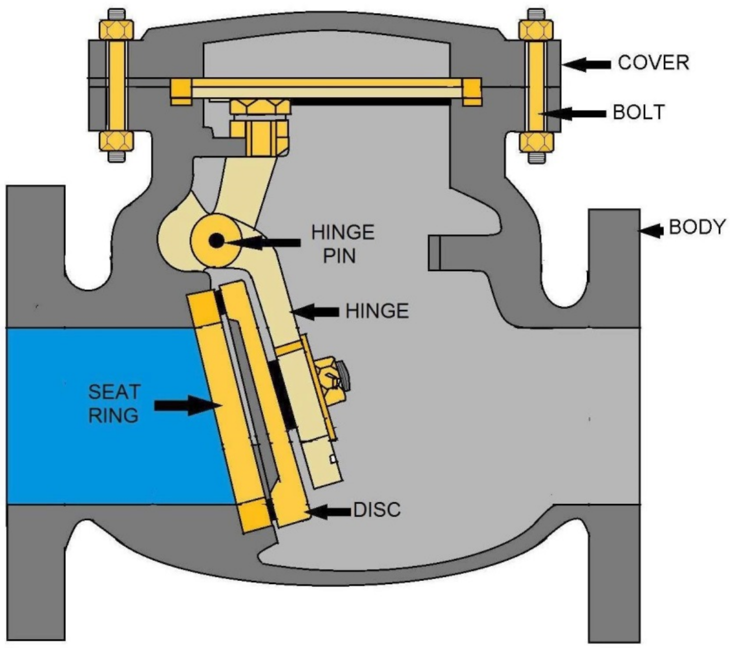




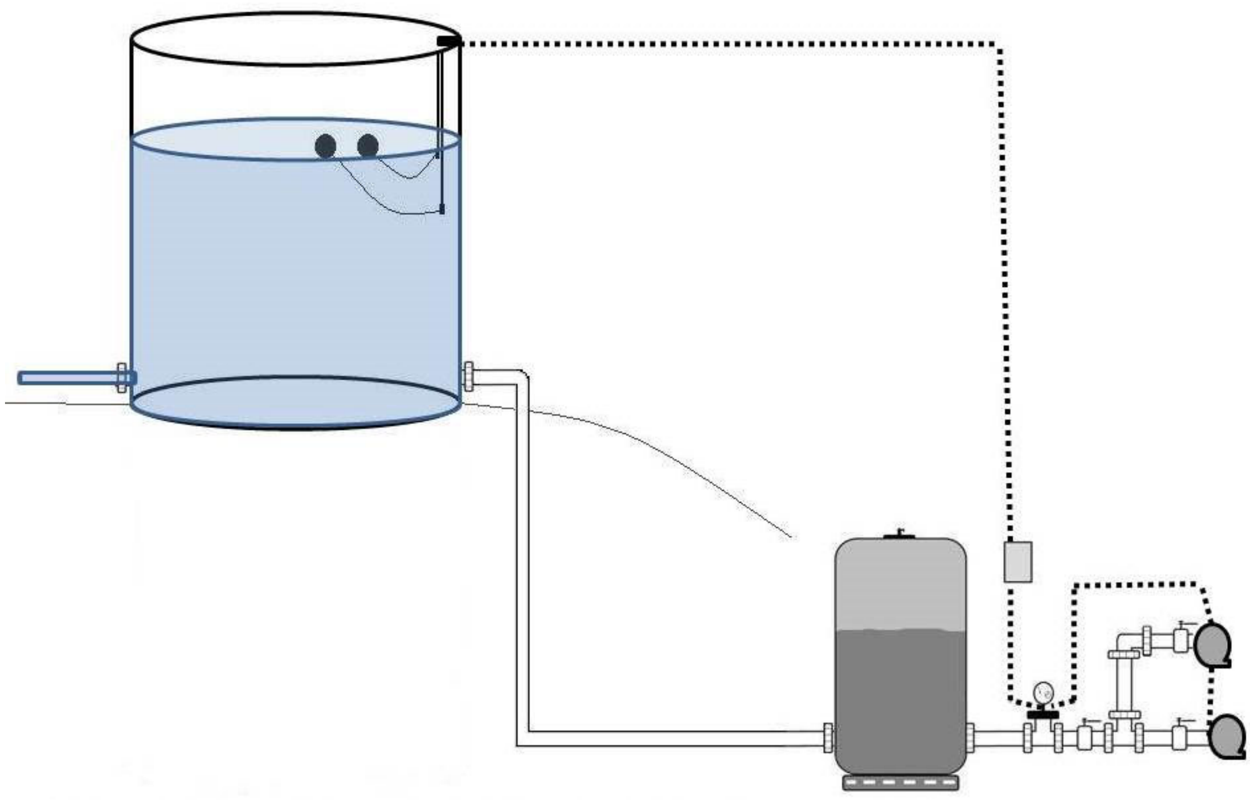
AIR RELIEF AND PRESSURE REDUCING VALVE EXAMPLES



HYDROPNEUMATIC TANK



CHECK VALVE EXAMPLE



HYDROPNEUMATIC & STORAGE TANK DIAGRAM

Service Pumping Station

High-level service pumps may be needed to:
a. Pump water up to service areas that have higher elevations than other areas of a community.
b. Fill gravity tanks that float on the water supply distribution system.
c. When service pumping stations are used to distribute water, and no water storage is provided, the pumps force water directly into the water mains. From a water system evaluation perspective, there is no outlet for the water except as it furnishes consumer consumption for actual fire flows. Variable speed pumps or multiple pumps may be required to provide adequate water delivery service because of fluctuating demands.

The efficiency and expense of this pumping equipment needs to be considered carefully. For example, it is a disadvantage that the peak power demand of the water plant is likely to occur during periods of high electrical consumption, and thus increase power costs. Furthermore, systems with little or no storage should be provided with standby electrical generating capability or pumps driven directly by internal combustion engines. These standby generators and engines needs to be tested routinely (e.g., several hours per week).

An extremely important element in a water distribution system is water storage. System storage facilities have a far-reaching effect on a system's ability to provide adequate consumer consumption during periods of high demand while meeting fire protection requirements. The two common storage methods are ground-level storage and elevated storage.

The primary emphasis is to evaluate the impact of fire-flow requirements on water storage capacity. Storage capacity is aggregated into three categories:

1) equalization,
2) fire demand, and
3) reserve storage.

Reserve storage corresponds to capacity that is not used for either a joint equalization or simply fire-flow demand and includes both ineffective storage and emergency (other than fire) storage. In order to develop a general relationship, the following assumptions were made

- The tank or reservoir is completely and instantaneously mixed during the fill cycle.
- The storage facility operates with a 12-hour draw and 12-hour fill cycle at constant fill and draw rate with the water level variation over the full range of the equalization storage volume.
- The water level in the tank is at its maximum level at the start of the draw cycle and again at the end of the fill cycle.

Determining Existing Community Water Supply Adequacy and Reliability
A community water supply system is one of the most important factors in both public and private fire protection. Fire departments and fire protection engineers, as well as those responsible for the design, operation, and maintenance of water systems, are concerned with two aspects of the total water supply system: its adequacy and its reliability.

Adequacy, in the case of a water system supplying water for normal consumer consumption and for fire protection, means having the capability of simultaneously supplying water for maximum consumption demands plus water that may be needed to combat and extinguish a major fire within the area served by the water system. Adequacy concerns itself with sufficient flow and pressure on all installed fire hydrants on the water system; the minimum residual pressure on each fire hydrant under flow conditions is to be 20 pounds per square inch (psi) residual pressure.

Reliability of a community water system is having the capability of supplying the maximum daily consumption plus a required fire-flow demand, even in the event of a malfunction or the outage of important system components, such as a pipeline break, valve failure, power outage, or stationary pump outage. Reliability is a more subjective evaluation and requires both a **what-if** look at the water system and a determination of what to do about the **what-if** happening.

Today, the reliability of community water systems has to be extended to the consideration that the water supply sources maybe contaminated through terrorist operations or depleted through overt operations.

This topic examines the objectives of water supply testing, using fire hydrants to determine water supply capability throughout a given water distribution system, some applications of fundamental hydraulics, flow test procedures, and graphical solutions to test for water flow problems. The results of this type of analysis are essential to understanding a given water system's capability to provide both consumer consumption and needed fires flows at representative locations throughout the built areas of the community.

Municipal water supply systems are concerned with two classifications of water storage.

1. Raw water storage: Water supplies that are used to feed water to a filtration and treatment plant for purification in order to produce **finished water** that is used for domestic purposes including drinking water is classified as **raw water**. Raw water sources from streams, rivers, ponds, lakes, and even reservoirs are **not suitable** for any domestic purposes including water for cooking, bathing, and especially drinking. The one exception is individual well water that has been chlorinated and disinfected for individual household use in accordance with individual State Public Health regulations.

Extreme caution: Raw water or any water supply that has not been treated to Environmental Protection Agency (EPA) standards **is not** to be pumped into fire hydrants attached to a municipal water system. During the summer drought conditions of 2005 in the Middle Atlantic States, there were reports where community fire departments were pumping water from creeks and ponds into small water systems because there was no water in the reservoirs to supply the water piping system. This is considered a very dangerous situation, and such practices present serious health risks to persons using these water supplies.

Furthermore, all components of the water system are required by either State or Federal regulations to be completely disinfected along with biological testing before the water system can be placed back in service to provide treated water for human consumption.

A more positive approach to raw water supplies is to use raw water holding basins, ponds, or reservoirs as an alternative water supply source to meet unusual demand on the water system, including a major fire, situations when the main water supply is low, or any other emergency situation requiring large volumes of water such as a primary or secondary water main break. These raw water sources should be arranged so that the water flows by gravity, if possible, to the water treatment plant. If the terrain in the area of the treatment plant does not permit this height differential, then arrangements need to be made for stationary pumps, or even fire department pumpers to pump water from the raw water source to the water treatment plant.

2. Finished water storage: The most common type of water storage on a municipal water system is the use of clear wells on the outboard side of water treatment plants, ground-level water-storage tanks and elevated water-storage tanks to store **finished water** that is suitable for domestic consumption. Therefore, an extremely important element in a water distribution system is **finished water storage**. Water system **storage facilities** have far-reaching effects on a given system's ability to provide adequate consumer consumption plus adequate water supplies for meeting fire-flow demand in addition to consumer consumption. The two common finished water storage methods 1) ground-level storage, and 2) elevated storage, are presented below. Emphasis is placed on the relative merits of both methods.

Functions of Distribution Storage
Storage within a distribution system enables the system to process water at times when treatment facilities otherwise would be idle. It is then possible to distribute and store water at one or more locations in the service area that are closer to the user.

1. Advantages.
The principal advantages of distribution storage include the fact that storage equalizes demands on supply sources, production works, and transmission and distribution mains. As a result, the sizes or capacities of these elements need not be so large. Additionally, system flows and pressures are improved and stabilized to better serve the customers throughout the service area. Finally, reserve supplies are provided in the distribution system for emergencies, such as firefighting and power outages.

2. Meeting system demands and required fire flow.
The location, capacity, and elevation (if in fact elevated) of distribution storage are closely associated with system demands and the variations in demand that occur throughout the day in different parts of the distribution system. System demands can be determined only after a careful analysis of an entire distribution system. However, some general rules may serve as a guide to such analysis.

Elevated and Ground-Level Storage
Storage within the distribution system normally is provided in one of two ways: elevated storage or ground storage with high-service pumping. It should be noted that elevated storage provides the best, most reliable, and most useful form of storage, particularly for structural fire suppression.

Elevated Storage
Properly sized elevated water tanks provide dedicated fire storage and are used to maintain constant pressure on the water supply distribution system.

Domestic water supplies are regularly fed to the system from the top 10 to 15 feet of water in the elevated tanks. As the water level in the tank drops, the tank controls call for additional high-service pumps to start in order to satisfy the system demand and refill the tanks.

The high-service pumps are constant-speed units, which can operate at their highest efficiency point virtually all the time. The remaining water in the tanks (70 to 75 percent) normally is held in reserve as dedicated fire storage. This reserve will feed into the system automatically as the fire-flow demand and the domestic use at a specific time exceed the capacity of the system's high-service pumps.

Ground Storage

Since water kept in ground storage is not under any significant pressure, it must be delivered to the point of use by pumping equipment. This arrangement limits the water distribution system's effectiveness for fire suppression in three ways:

1. There must be sufficient excess pumping capacity to deliver the peak demand for normal uses as well as any fire demand, which requires a generally unused investment in pumping capacity. The pumps are activated periodically to redistribute the water in the holding tank to avoid stagnation of the water.

2. Standby power sources and standby pumping systems must be maintained at all times because the system cannot function without the pumps.

3. The distribution lines to all points in the water distribution system must be significantly oversized to handle peak delivery use plus fire flow, no matter where the fire might occur near one or more fire hydrants on the piping system.

However, in hilly areas it is frequently possible to install ground reservoirs at sufficient elevation so that the water would "float" on the distribution system. This eliminates the need for pumps at the ground-storage facility. If the desired overflow elevation can be achieved on a hill, a considerably larger storage capacity can be installed when compared to an elevated tank. This may result in placement of the storage facility on a hill in a less desirable location. Such a placement would provide larger storage capacity than could be achieved by an elevated storage tank(s), or it should provide the equivalent storage more economically.

When ground-level storage is used in areas of high fire risks, the energy that would be needed to deliver the water is lost on the initial delivery of water to the tank. The water supply must be re-pumped and re-pressurized with the consequent addition of more standby generators and more standby pumps. In addition, the system's high-service pumps must be either variable speed or controlled by discharge valves to maintain constant system pressures.

This equipment is expensive, uses additional electrical power, and requires extensive operation and maintenance. Frequently, the additional capital costs for pumps, generators, and backup systems, and the long-term energy costs, significantly increase the costs of a ground-storage system.

Pumping For Distribution Storage

There are two types of water supply distribution storage as defined above:
1. Ground-level storage.
2. Elevated storage.

There also are two types of pumping supply systems. Both of the concepts are expanded upon below. One is a direct pumping system, in which the instantaneous system demand is met by pumping with no elevated storage provided. The second type is an indirect system in which the pumping station lifts water to a reservoir or elevated storage tank, which **floats** on the water system, based on demand, and provides system pressure by the gravity method.

1. Direct pumping.
The direct pumping system is considered obsolete today, although there are some systems of this type still in existence. Variable-speed pumping units operated off of direct system pressure are also in use in some communities. Hydropneumatic tanks at the pumping station provide some storage capability.

These tanks permit the pumping station pumps to start and stop, based on a variable system pressure preset by controls operating off of the storage tank.

2. Indirect pumping.
In an indirect system, the pumping station is not associated with the demands of the major load center. It is operated from the water level difference in the reservoir or elevated storage tank, enabling the prescribed water level in the tank to be maintained. The majority of systems have an elevated storage tank or a reservoir on high ground floating on the water system. This arrangement permits the pumping station to operate at a uniform rate, with the storage either making up or absorbing the difference between station discharge and system demand.

Supply Works
A water system supply works evaluation examines the amount of potable water that can be delivered to the distribution system piping, often called the water mains. This evaluation considers a number of factors that affect the supply capacity:

- minimum storage of water;
- municipal water supply pumps;
- water filters and treatment facilities to provide potable water; and
- emergency water supplies.

Two special topics, Water System Supplies and Fire Department Supplies also are evaluated here. These topics are of importance to all communities, especially those that have relatively poor water delivery capability, or cities that have areas where the available water supply does not meet NFF.

Furthermore, these two topics are most important for fire protection to areas that are beyond 1,000 feet of a recognized fire hydrant (i.e., a fire hydrant that delivers a minimum of 250 gpm for a 2-hour duration).

Evaluation of Municipal Water Storage
Two variations of distribution storage design affect the operation and reliability of a water system's fire suppression capabilities. These two variations involve placement of the storage between the supply point and the major load center or beyond the major load center. A numerical analysis of the following storage designs is presented to provide comparisons and contrasting approaches to the issue of not providing water storage or providing water storage in one of two different design approaches:

- System A: a pumping station to the major center of demand on the water system (load) with **no** elevated storage tank;
- System B: a pumping station to the major center of demand with an elevated storage tank between the supply and the demand point; and
- System C: a pumping station to the major center of water demand with an elevated storage tank beyond the demand point.

1. System criteria.
a. Normal minimum working pressure in the distribution system should be approximately 50 pounds per square inch (psi) and not less than 35 psi during a maximum hour. A normal working pressure in most systems will vary between 50 to 56 psi.
b. Systems must be designed to maintain a minimum pressure of 20 psi at ground level at all points in the water distribution system under fire flow conditions.
c. The maximum daily demand is considered to be 1.5 times the average daily demand.
d. The maximum hourly demand is considered to be 2.25 times the average daily demand.

References
Water Supply Systems• Vol. II: Evaluation Methods October 2008 FEMA U.S. Fire Administration Harry E. Hickey, Ph.D.

EPA Office of Water (4601M), Office of Ground Water and Drinking Water, Distribution System Issue Paper, Finished Water Storage Facilities

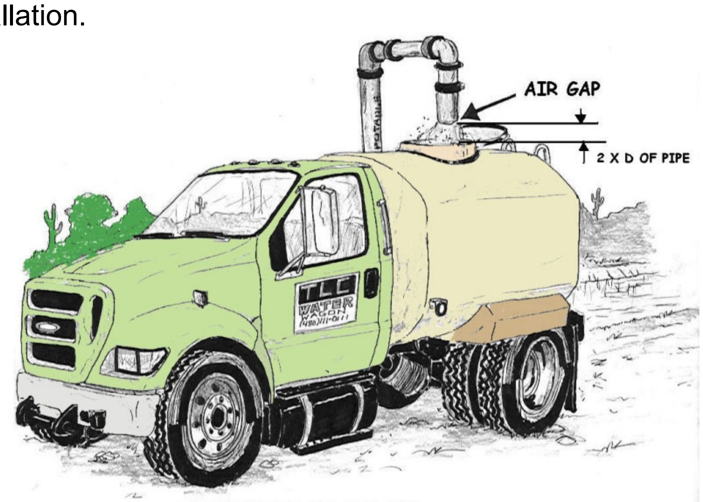
Backflow Section

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 (**EPA**.) 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 EPA.

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.



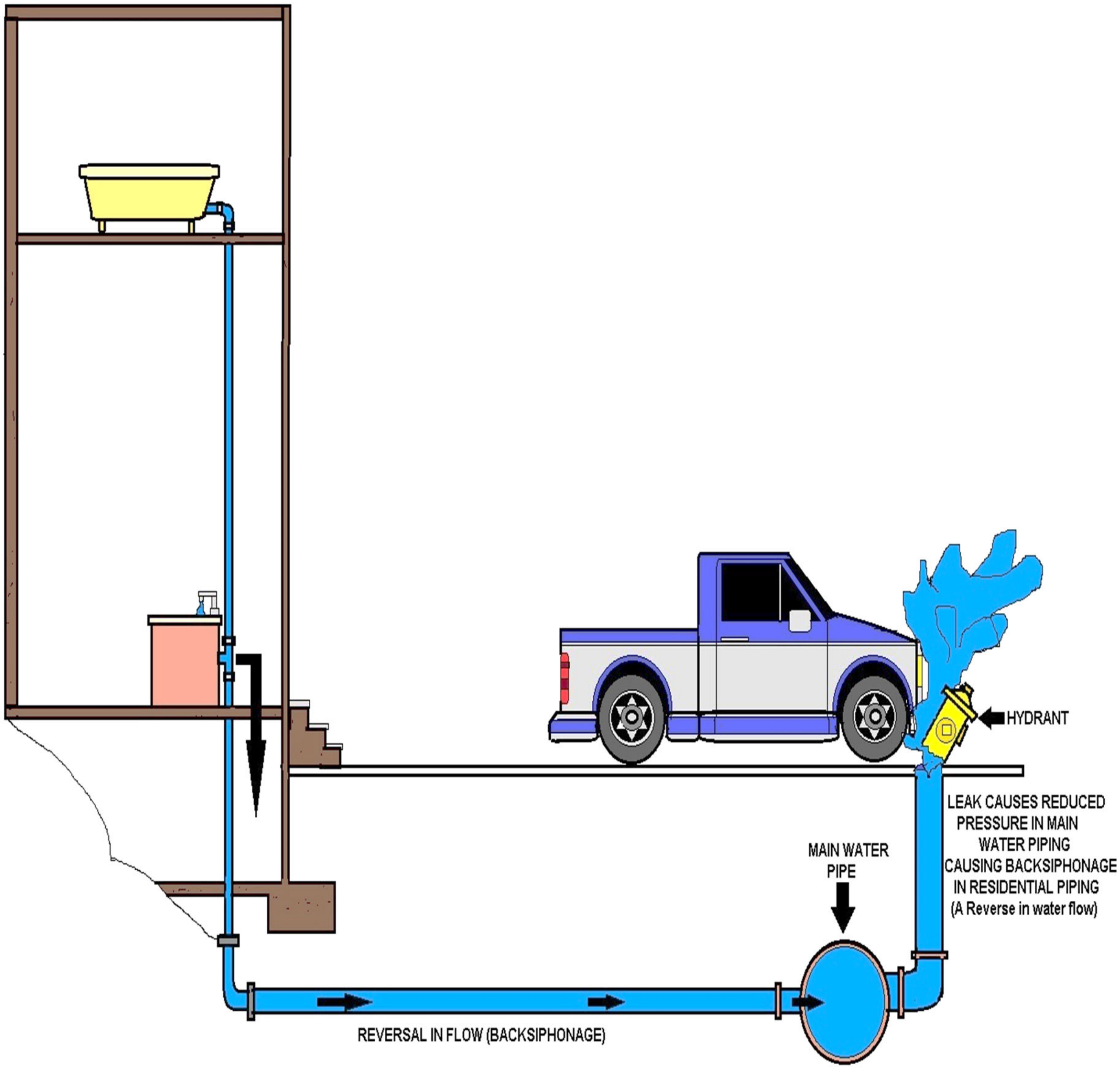
EXAMPLE OF AN AIR GAP

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 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.



BACKSIPHONAGE EXAMPLE DIAGRAM

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

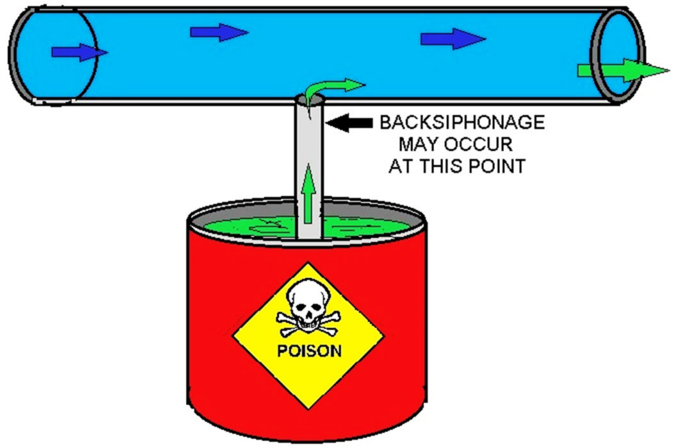
The chief plumbing inspector in a large southern city received a telephone call advising that blood was coming from drinking fountains at a mortuary (i.e., a funeral home). Plumbing and health inspectors went to the scene and found evidence that blood had been circulating in the potable water system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

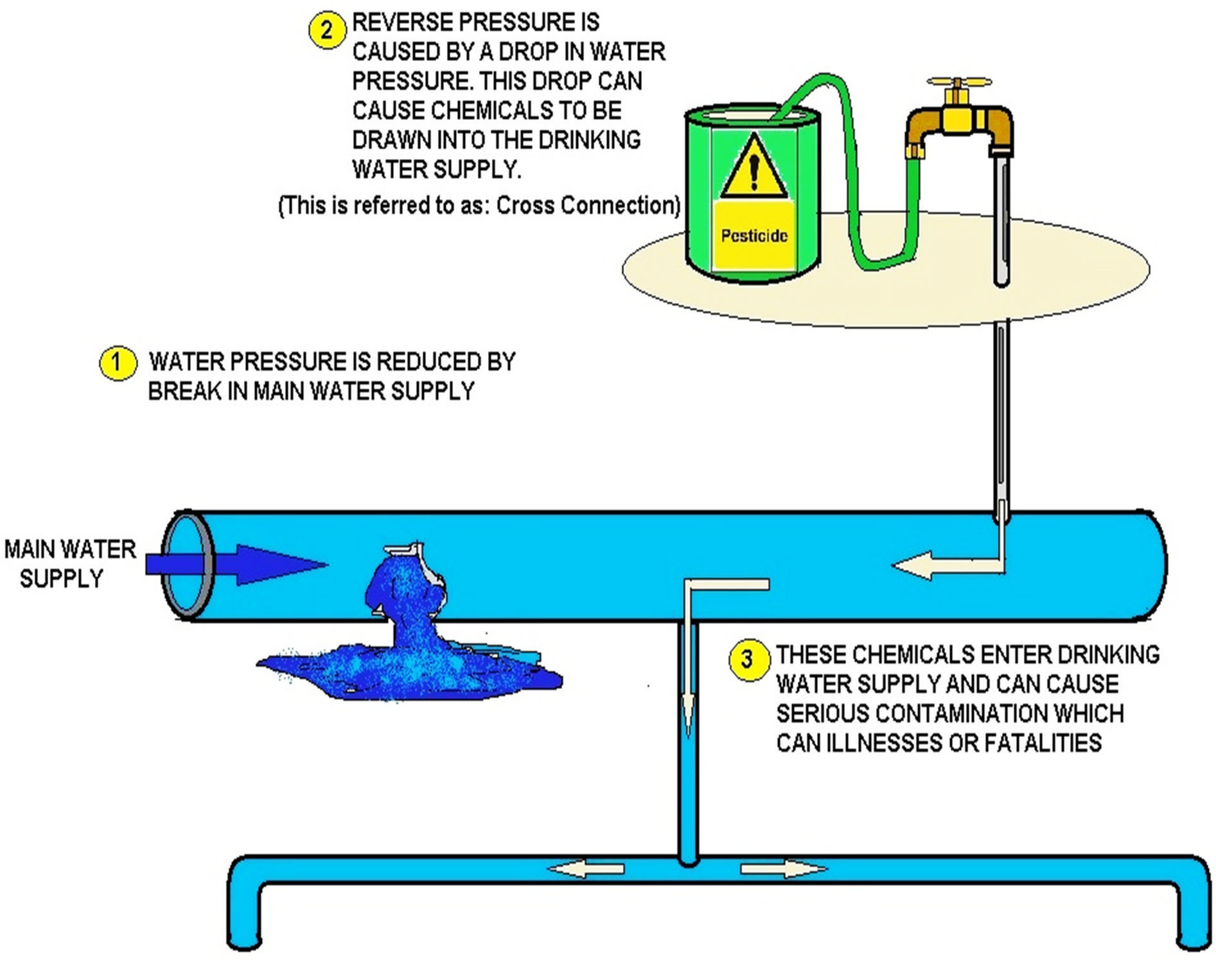
The funeral home had been using a hydraulic aspirator to drain fluids from bodies as part of the embalming process. The aspirator was directly connected to a faucet at a sink in the embalming room.

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



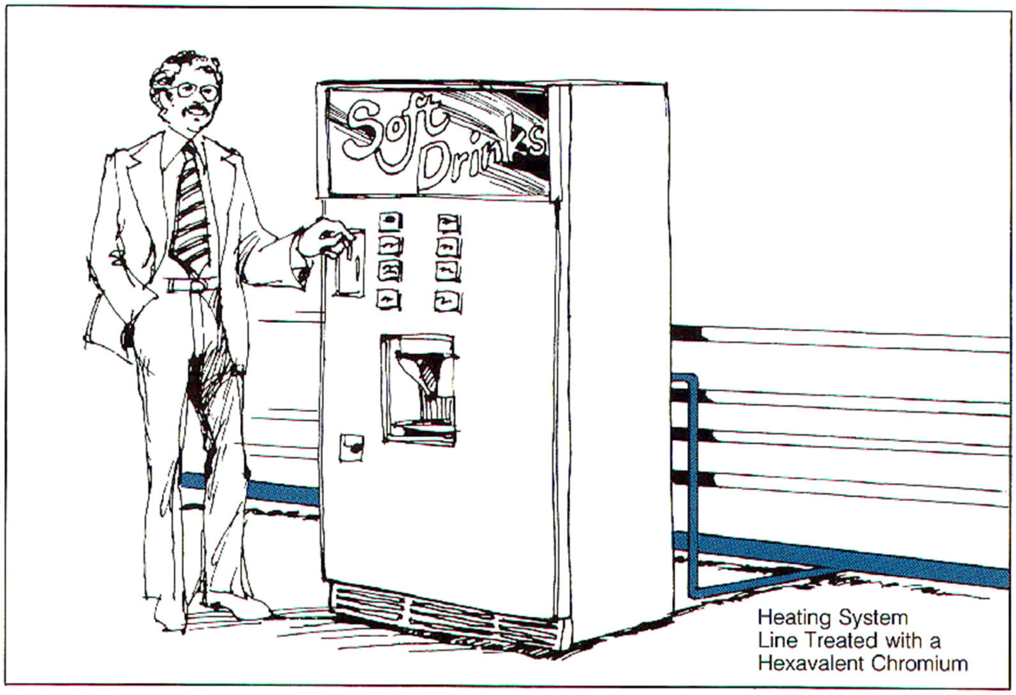
ASPIRATOR EFFECT- BACKSIPHONAGE DIAGRAM #2



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.

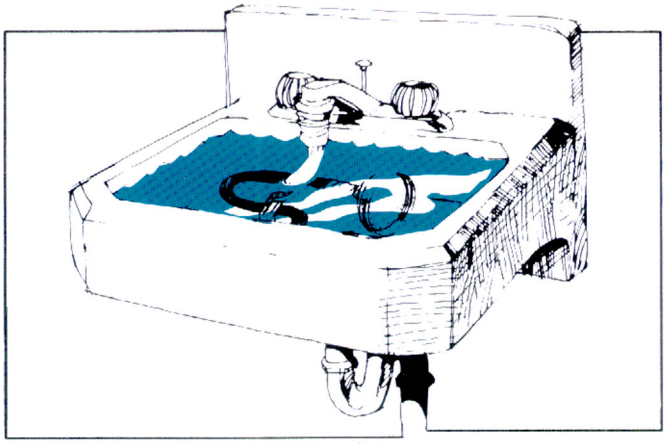


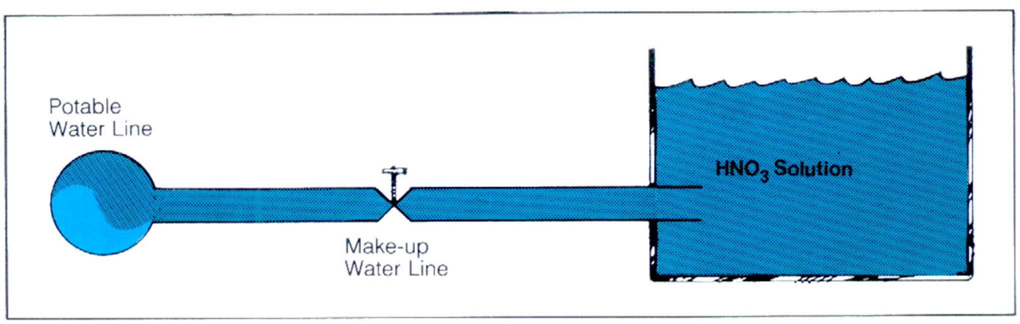
Several cross-connection have been made to soda machines, the one to worry about is when you have a copper water line hooked to CO_2 without a backflow preventer.

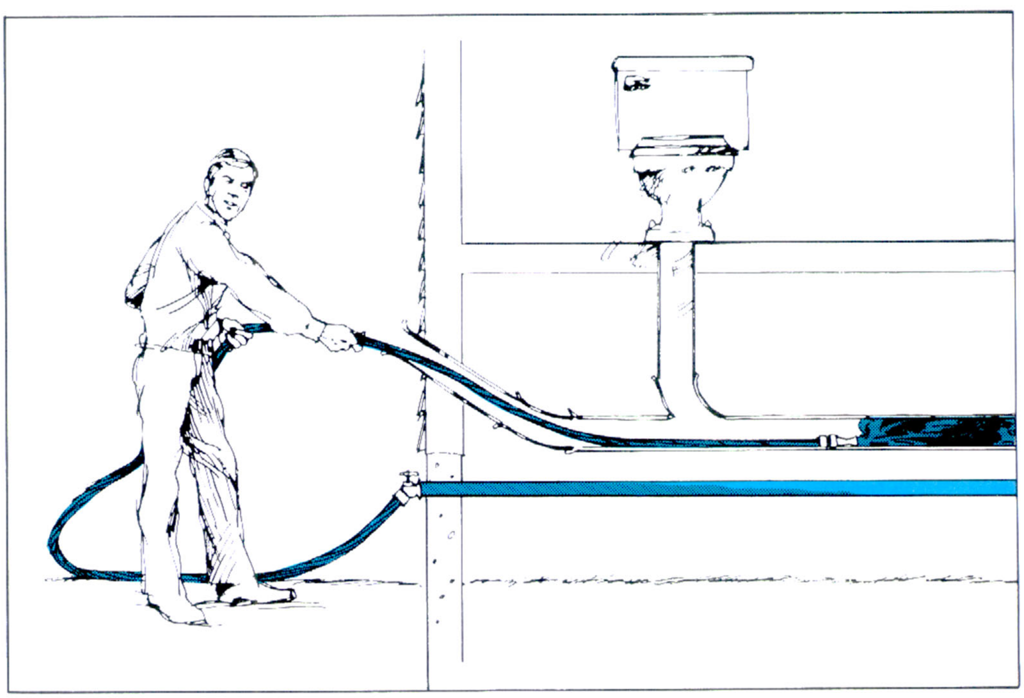
The reason is that the CO_2 will mix in the water and create copper carbonic acid, which is deadly.

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



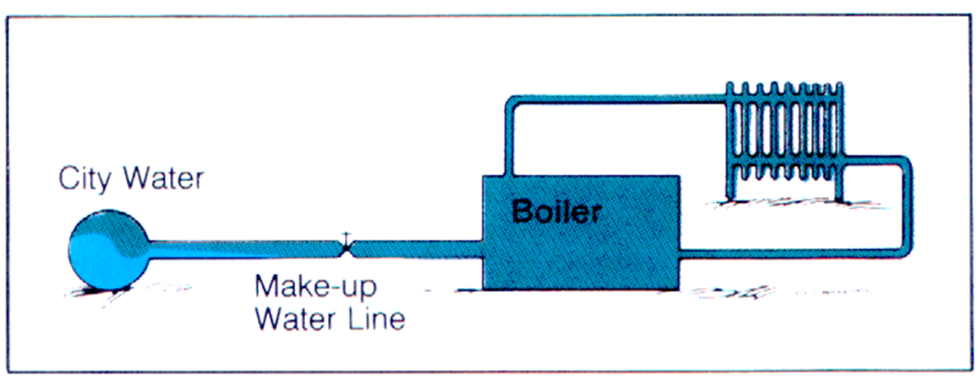




Backflow

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

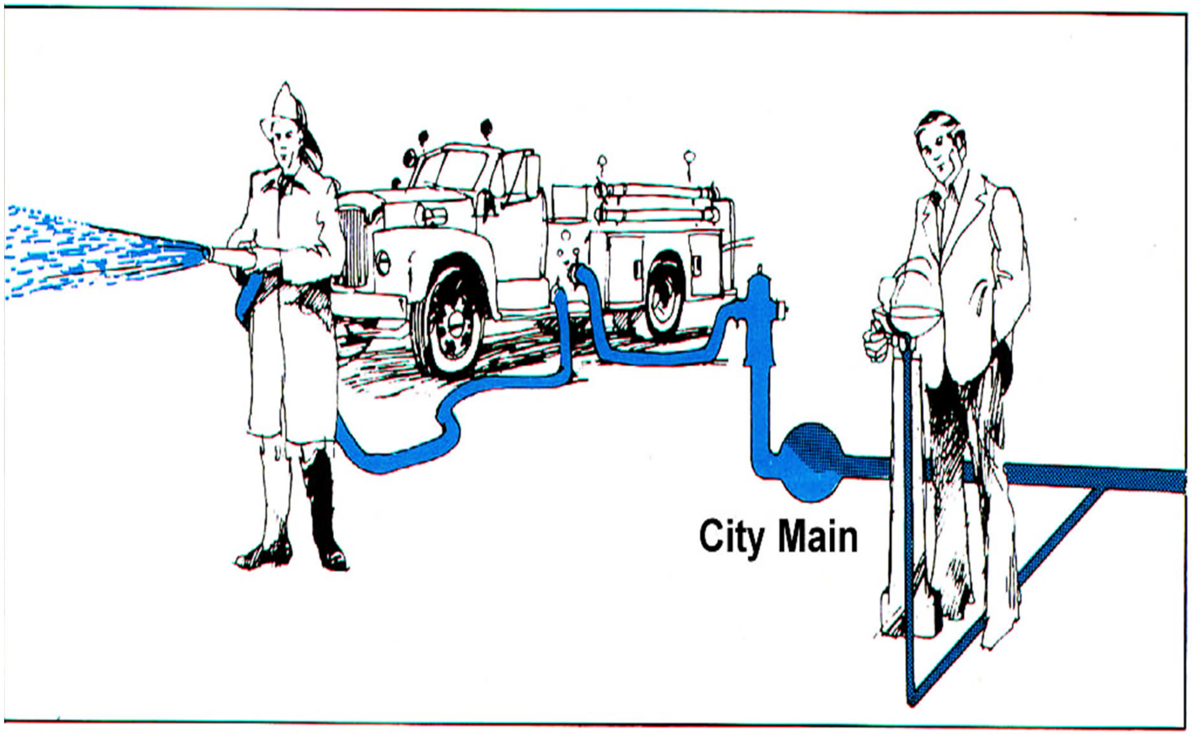


Example of backpressure being caused by heat.

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 firefighting, 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 building with pumps.

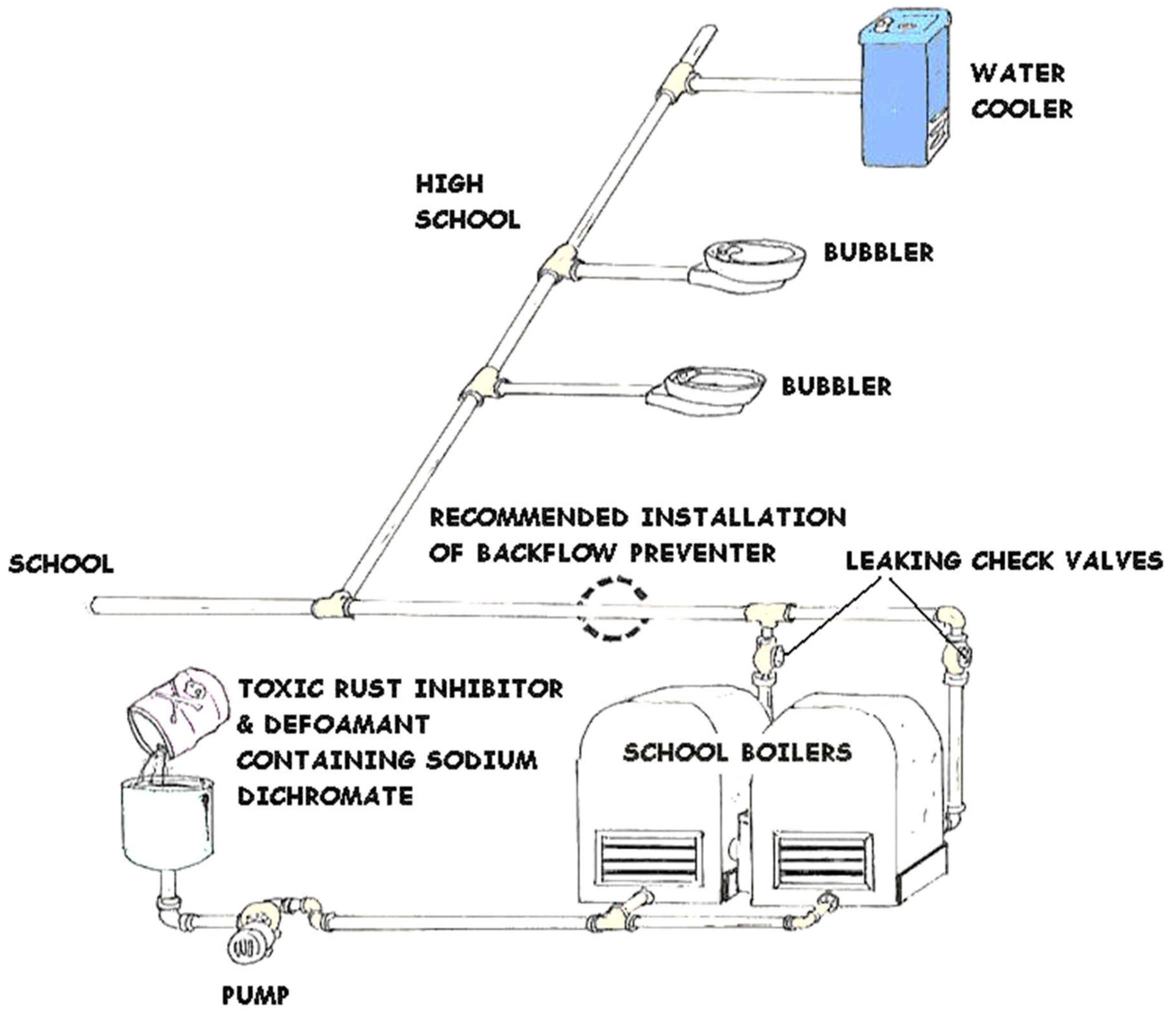
A good example is the pressure exerted by a building that is 100 feet tall is about 43 PSI; the water main feeding the building is at 35 PSI. The water will flow back to the water main.

Never drink water or coffee inside a funeral home, vet clinic or hospital. Think about the plumbing system!

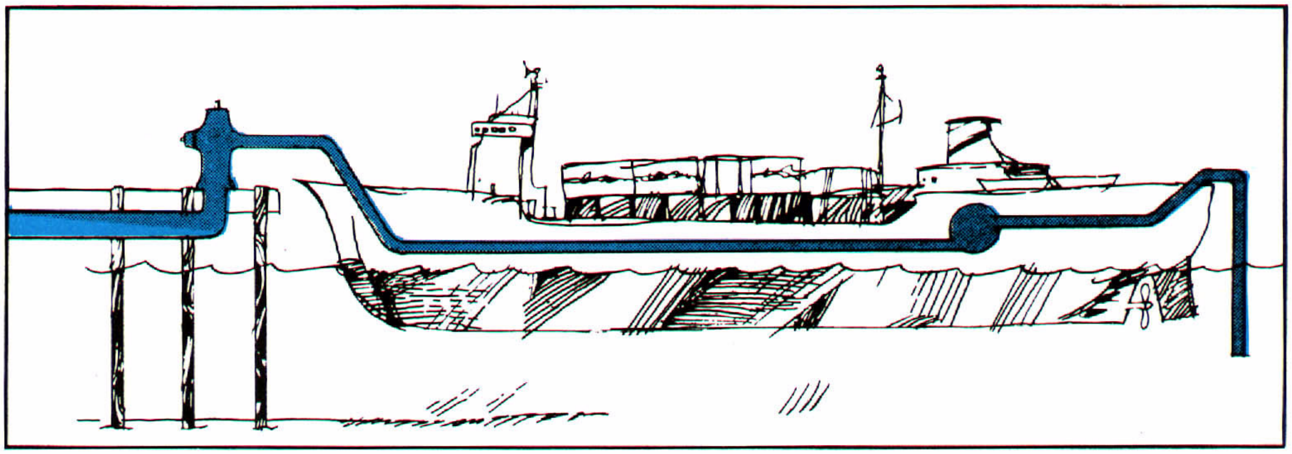
Backpressure

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, firefighting, 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.

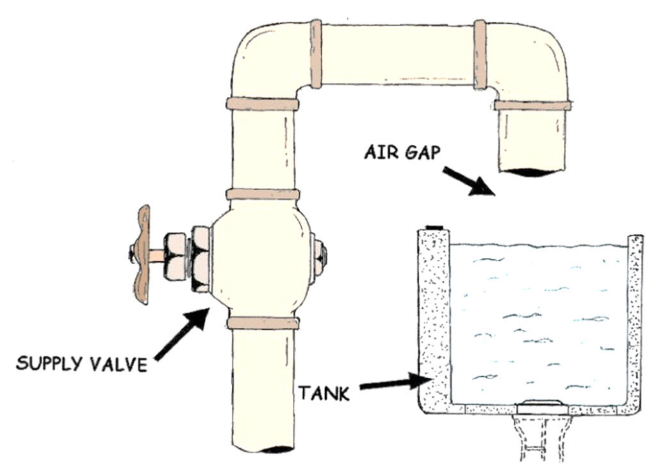
Second, the plumbing arrangement must be considered.

Third, it must be determined whether protection is needed at the water meter or at a location within the facility.

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.



Which of these ice machine drains have an approved air gap?

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.

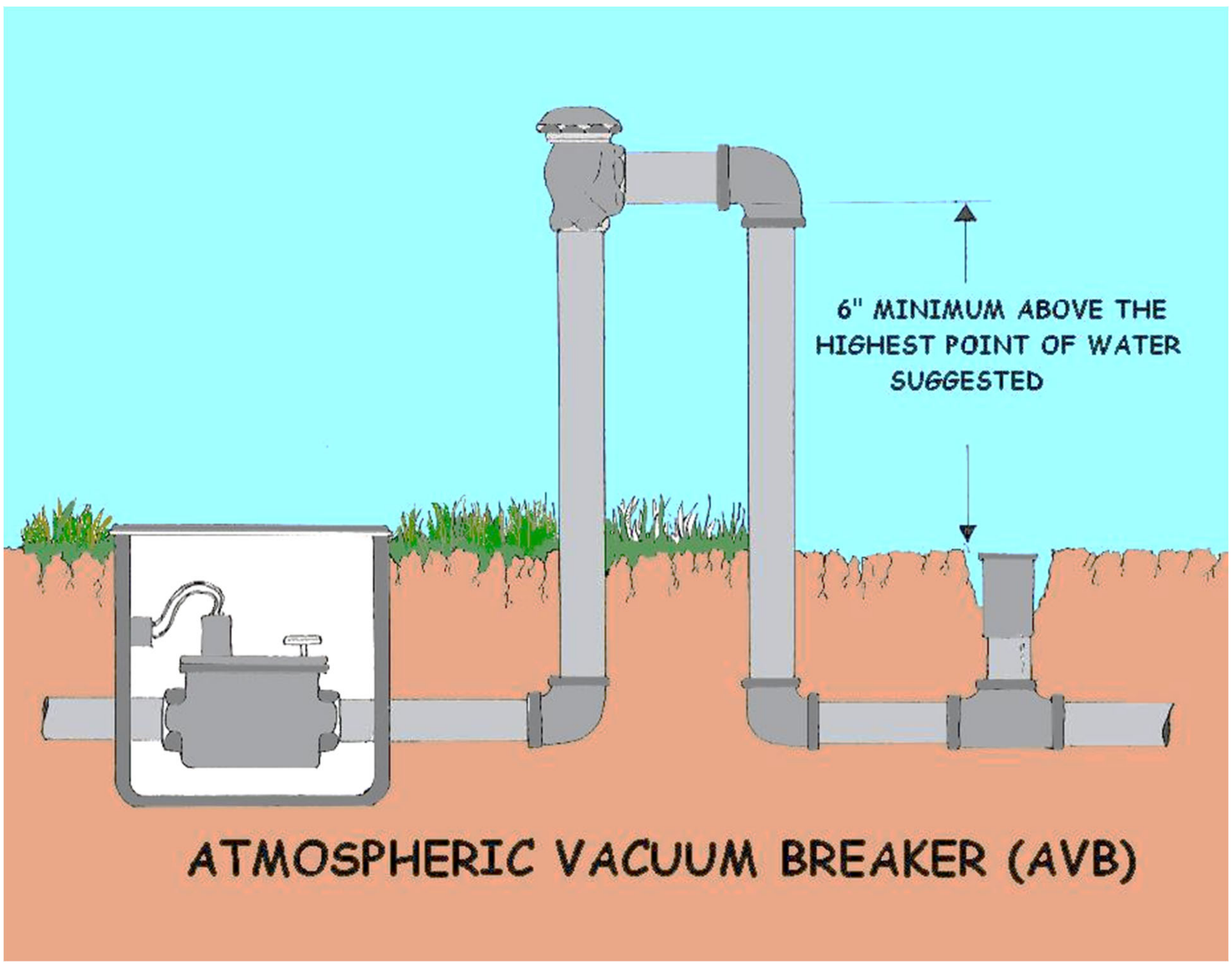
However, this method of prevention can be circumvented if the supply pipe is extended.

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, non-pressurized connections)

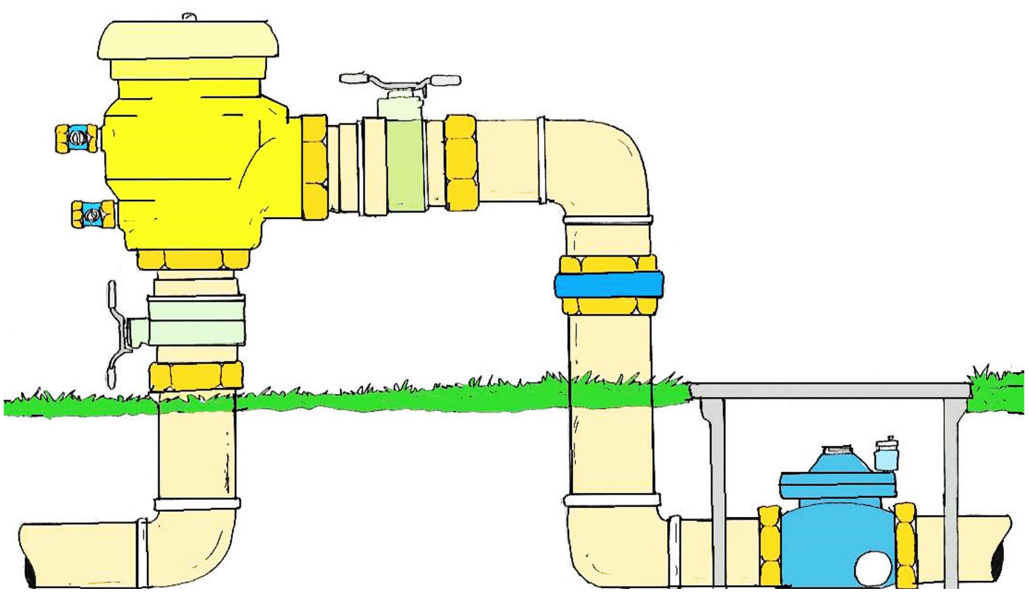
(Note: hazard relates to the water purveyor's risk assessment; plumbing codes may allow AVB for high hazard fixture isolation).



Pressure Vacuum Breaker Assembly (PVB)

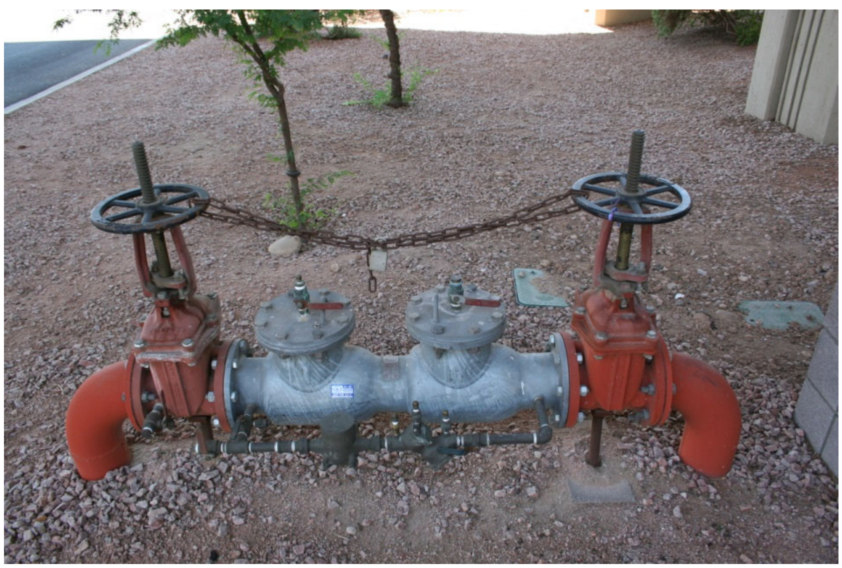
The Pressure Vacuum Breaker Assembly consists of a spring loaded check valve, an independently operating air inlet valve, two resilient seated shutoff valves, and two properly located resilient seated test cocks. It shall be installed as a unit as shipped by the manufacturer. The air inlet valve is internally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

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.

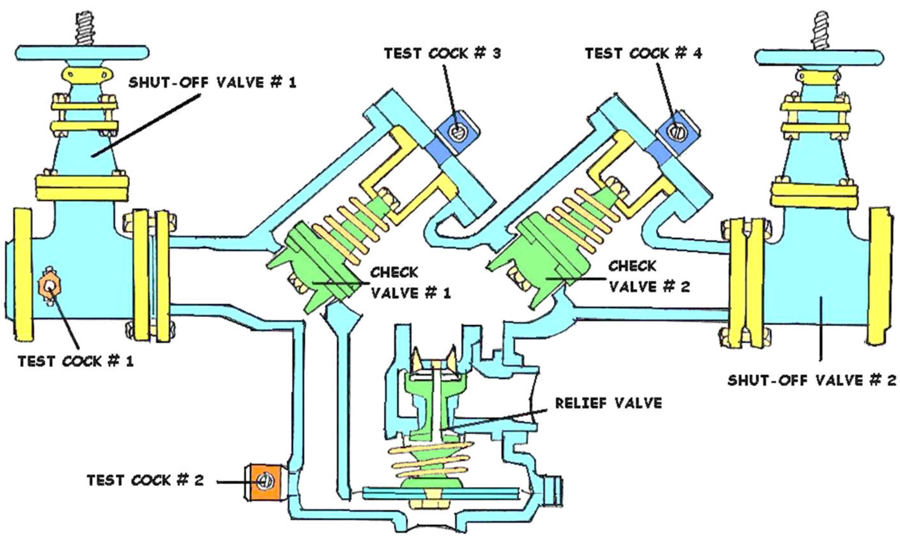


Reduced Pressure Backflow Assembly (RP)

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.



REDUCED-PRESSURE BACKFLOW ASSEMBLY

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.

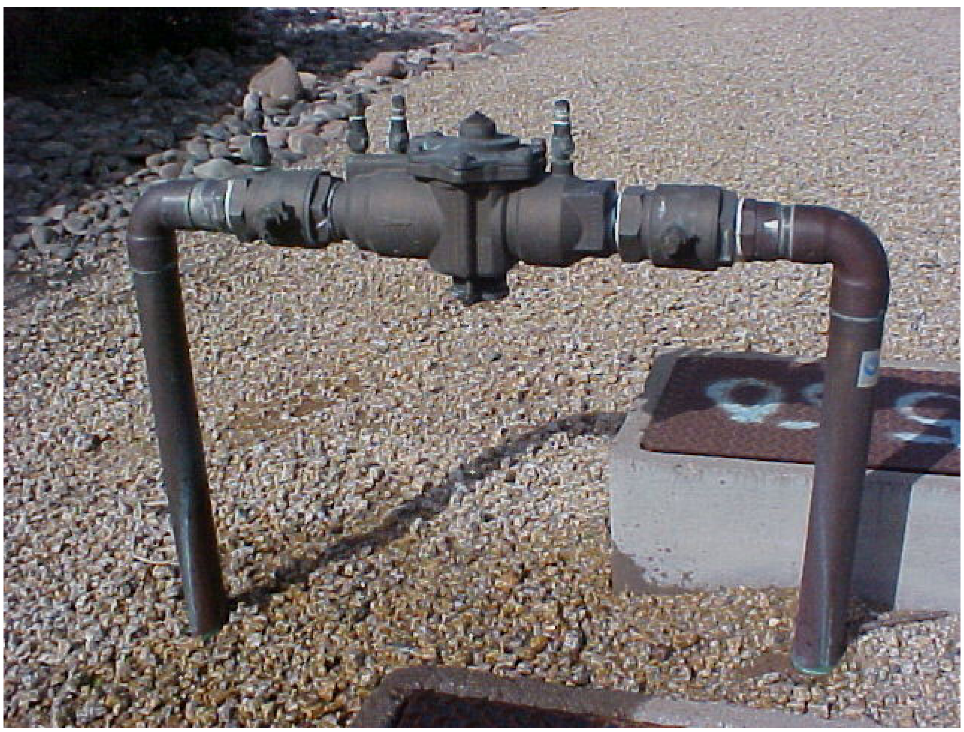
Why do Backflow Preventors have to be Tested Periodically?

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.

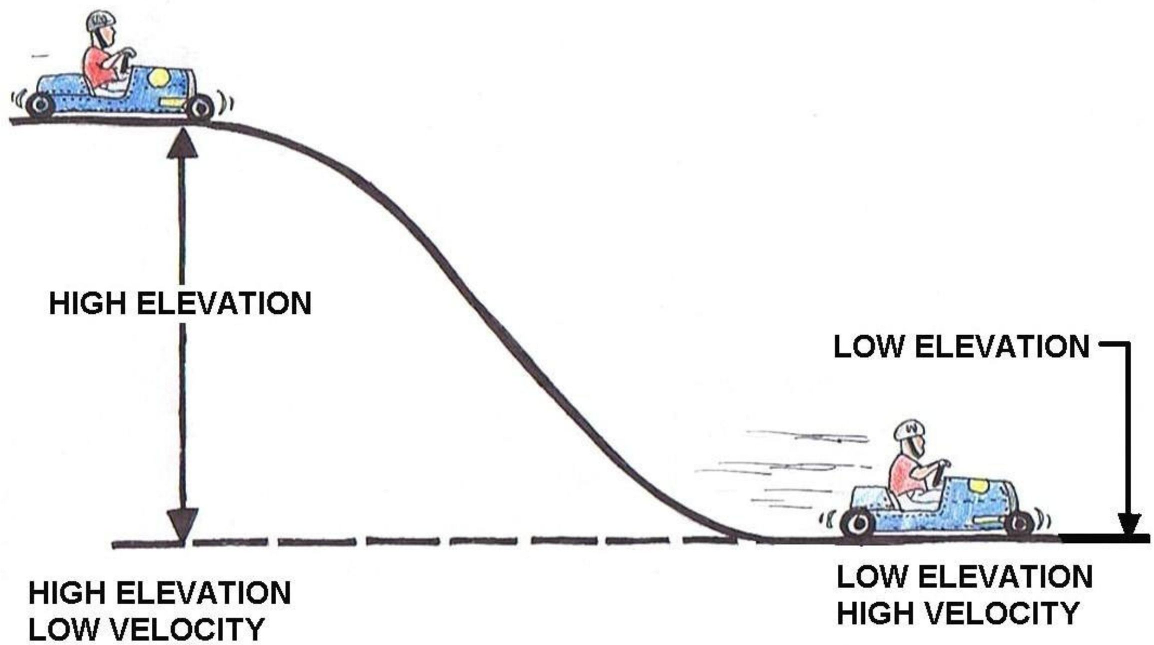
A visual check of air gaps is sufficient, but mechanical backflow preventors have to be tested with properly calibrated gauge equipment.

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 that 1 or 2 minutes any more than that, there is a problem, a piece of debris or a stuck check is causing this RP's hydraulic relief port to dump.



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.

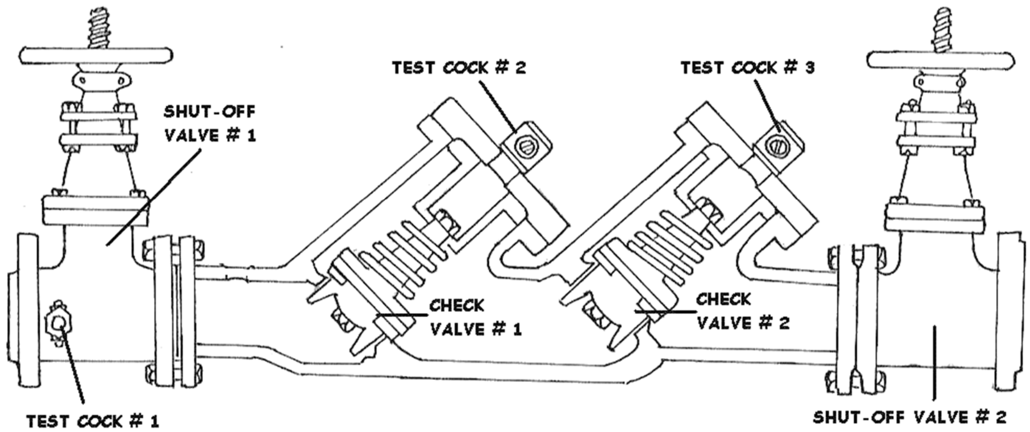
This is known as the principle of conservation of energy at work which is also Bernoulli's law. This is similar to the soapbox derby car in the illustration at the top of a hill. At the top or point, the elevation of the soapbox derby car is high and the velocity low. At the bottom the elevation is low 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.

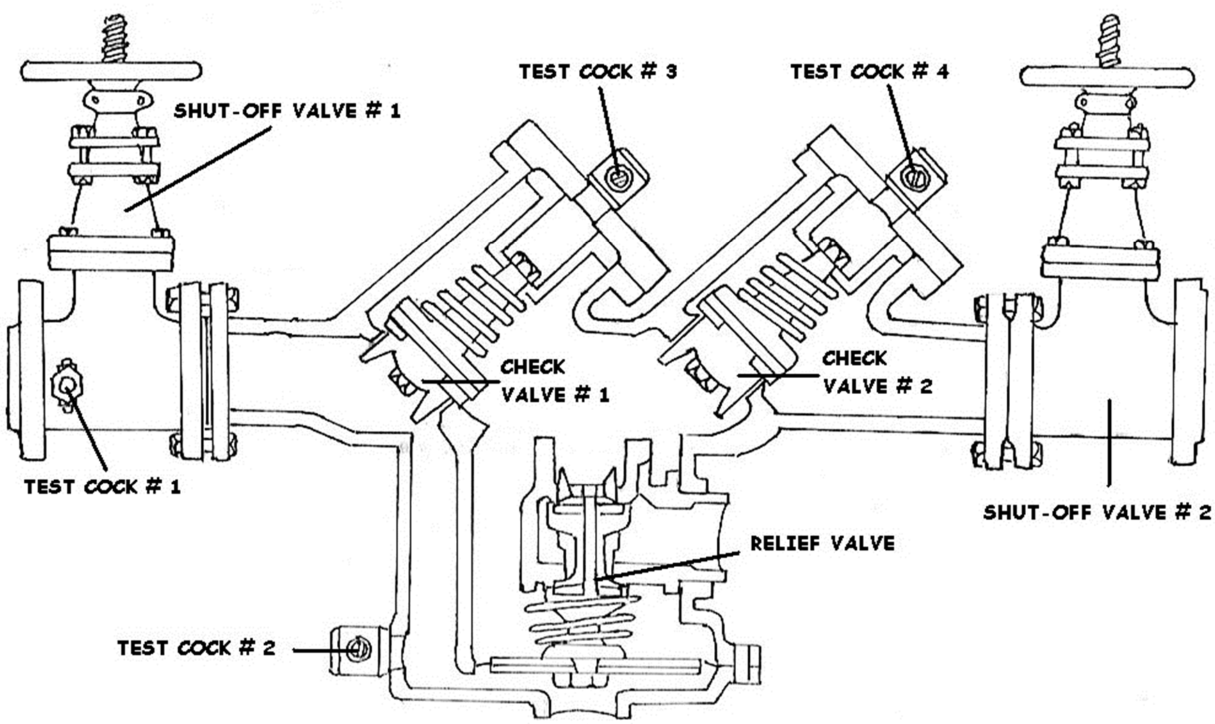
If you ever need to prove for a need for backflow protection, visit your local fair grounds or trailer park. I guarantee that you'll find all you need at the concession stand and most health departments and plumbing officials either do not know or could care less.

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.

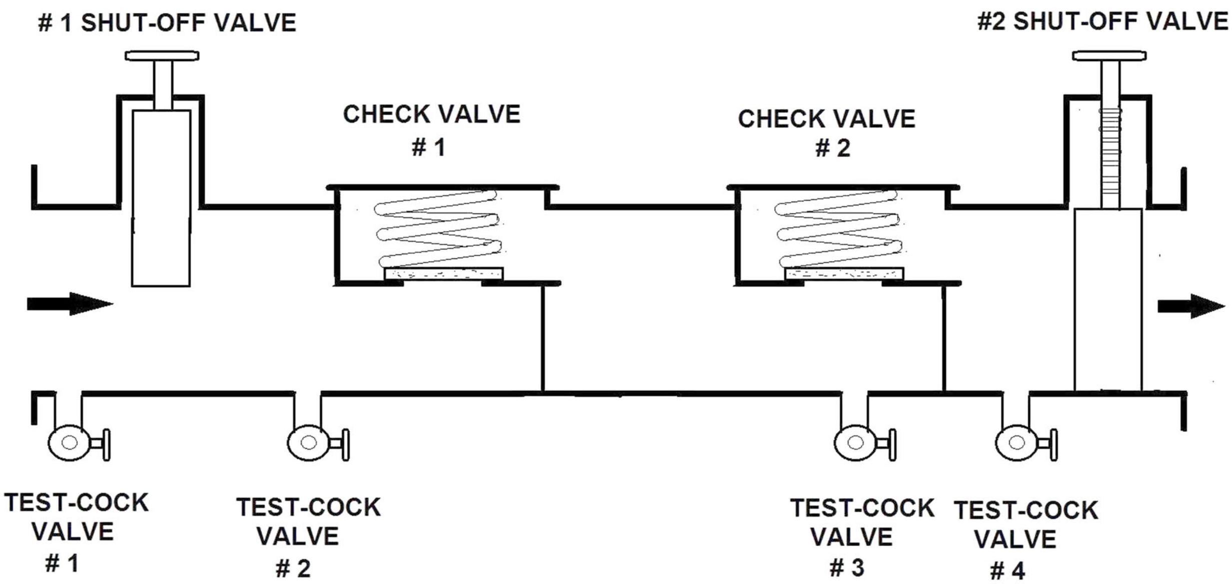
What is backflow? ***Reverse flow condition.***
Backflow is the undesirable reversal of flow of nonpotable water or other substances through a cross-connection and into the piping of a public water system or consumer's potable water system. There are two types of backflow--**backpressure** and **backsiphonage.**



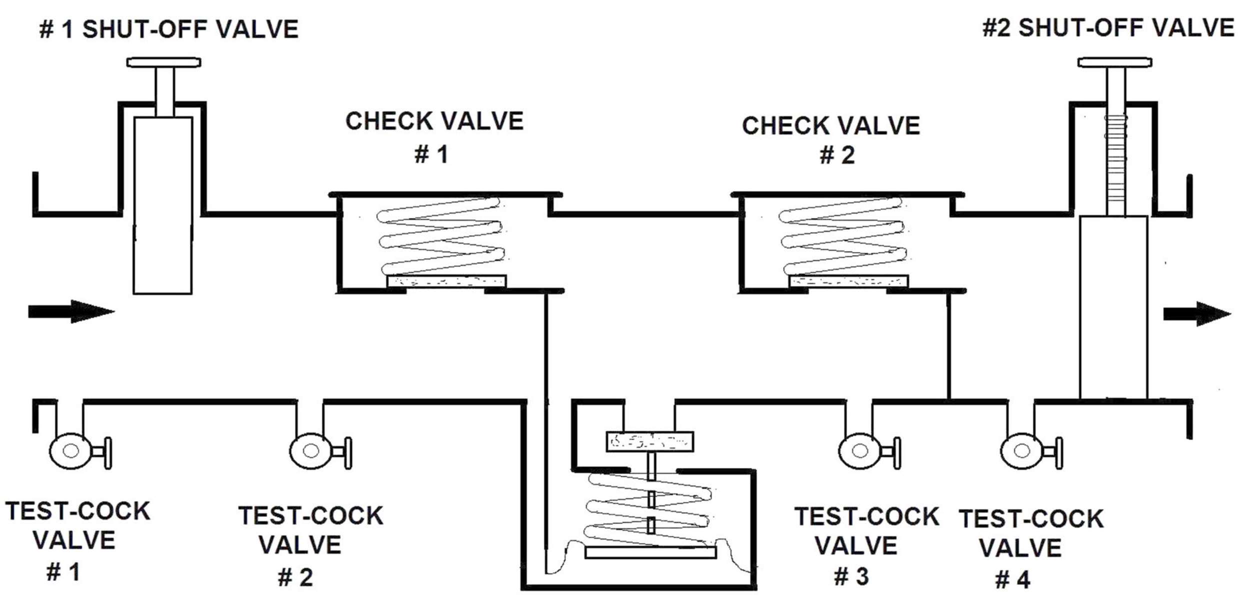
DOUBLE-CHECK BACKFLOW ASSEMBLY



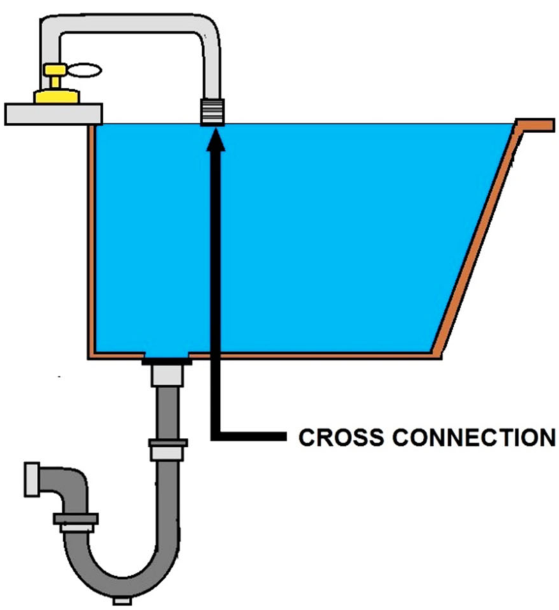
REDUCED PRESSURE BACKFLOW ASSEMBLY

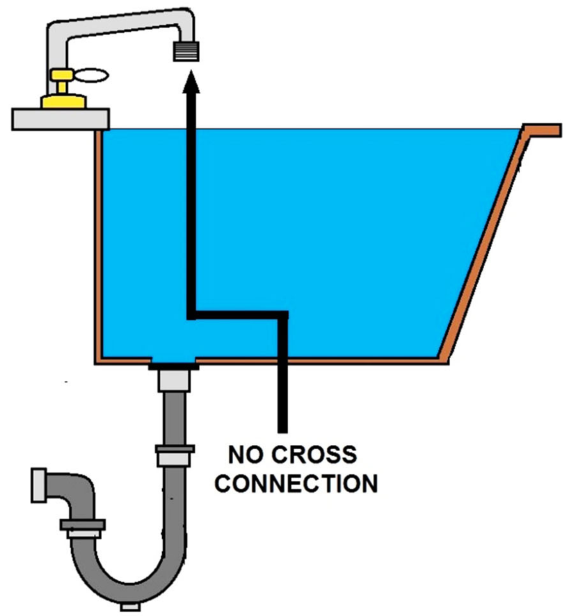


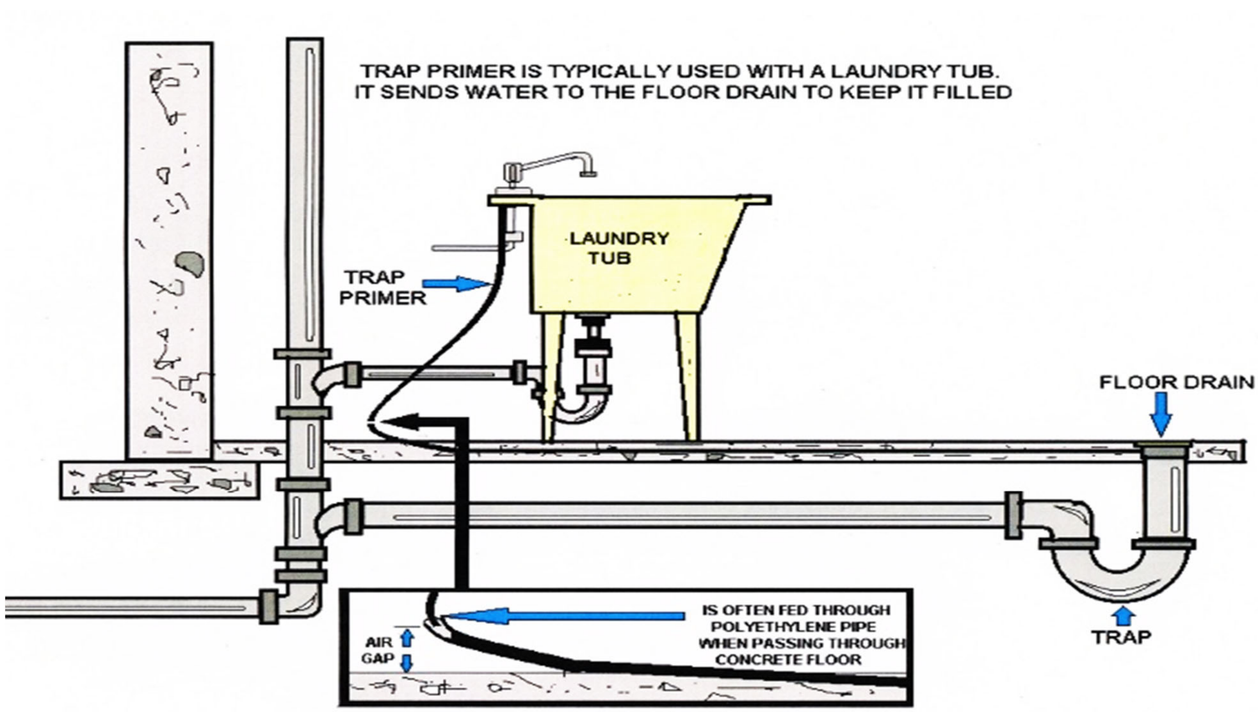
DOUBLE-CHECK INTERNAL VIEW



REDUCED PRESSURE PRINCIPLE BACKLFOW ASSEMBLY INTERNAL VIEW







INTENTIONAL CROSS-CONNECTION- TRAP PRIMER

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 firefighting 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).

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, firefighting, 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 firefighting, 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.

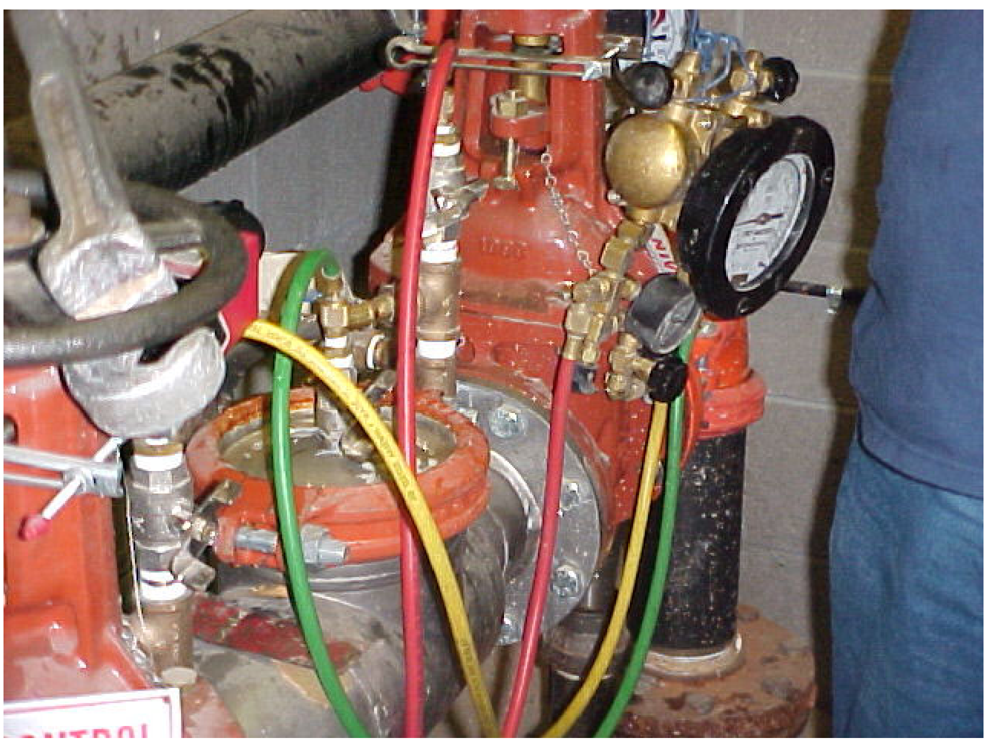
5. RP: An RP or reduced pressure principle backflow prevention assembly is a mechanical backflow preventer that consists of two independently acting, spring-loaded check valves with a hydraulically operating, mechanically independent, spring-loaded pressure differential relief valve between the check 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 non-health 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 non-health 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 non-health 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.

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



Water Storage Section - Common Hydraulic Terms

Head
The height of a column or body of fluid above a given point expressed in linear units. Head is often used to indicate gauge pressure. Pressure is equal to the height times the density of the liquid.

Head, Friction
The head required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type, and conditions of conductors and fittings, and the fluid characteristics.

Head, Static
The height of a column or body of fluid above a given point.

Hydraulics
Engineering science pertaining to liquid pressure and flow.

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

Pascal's Law
A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

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

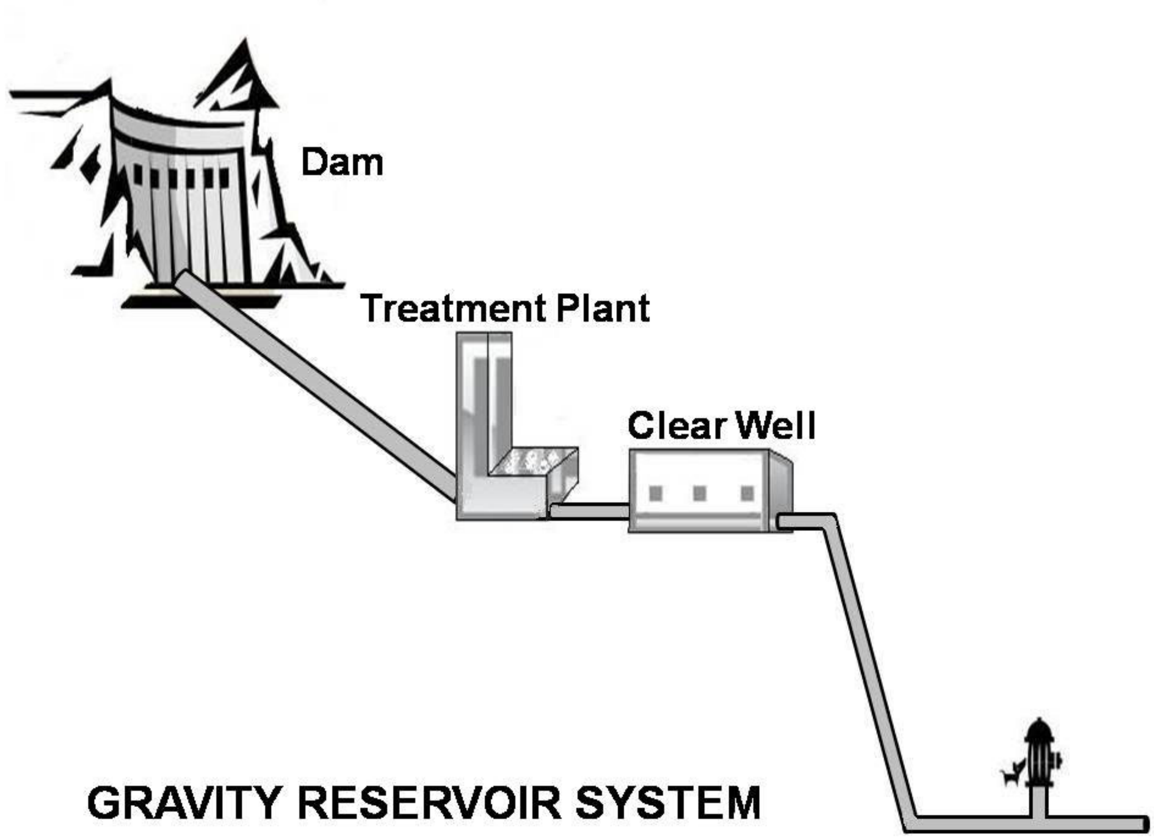
Pressure, Absolute
The pressure above zone absolute, i.e. the sum of atmospheric and gauge pressure. In vacuum related work it is usually expressed in millimeters of mercury. (mmHg).

Pressure, Atmospheric
Pressure exerted by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute, 1 bar = 14.5 psi.)

Pressure, Gauge
Pressure differential above or below ambient atmospheric pressure.

Pressure, Static
The pressure in a fluid at rest.

System Operation Section



System design depends on the area that you live. Some areas may only serve residents on a part time basis and water will sit for long periods of time, while other areas may have a combination of peaks and valleys with short and long distances of service.

Before you design the system you need to ask yourself some basic questions.

1. ***What is the source of water?***
2. ***What is the population?***
3. ***What kind of storage will I need for high demand and emergencies?***
4. ***How will the pressure be maintained?***

System Elements
The elements of a water distribution system include: distribution mains, arterial mains, storage reservoirs, and system accessories. These elements and accessories are described as follows:

Distribution mains are the pipelines that make up the distribution system. Their function is to carry water from the water source or treatment works to users.

Arterial mains are distribution mains of large size. They are interconnected with smaller distribution mains to form a complete gridiron system.

Storage reservoirs are structures used to store water. They also equalize the supply or pressure in the distribution system. A common example of a storage reservoir is an aboveground water storage tank.

Commonly found system accessories include the following:
Booster stations are used to increase water pressure from storage tanks for low-pressure mains.

Valves control the flow of water in the distribution system by isolating areas for repair or by regulating system flow or pressure. We will explore this component later in this course.

Water Entering the Distribution System
There are two basic types of pipe layout for delivering water to consumer taps and to supply water to individual fire hydrants. The preferred method is to loop the entire service area with a primary feeder main; the size is determined by hydraulic analysis. Interior to the ring main are cross-connected secondary feeders provided along the major streets in the community. Interior water mains that essentially provide water to residential areas are cross-connected to the secondary feeders.

The advantages of this type of pipe system layout are twofold:
1) the water to every service location or demand point is supplied from two directions, which is considered to be the most efficient hydraulic design to minimize pipe sizes; and

2) in the event that a pipe section is out of service for cleaning, breakage from an accident, tapping for service extension, or whatever reason, water can be supplied to any demand point from a different travel path. In older community water systems a single primary feeder supplies secondary feeders and distributor pipes along block fronts in a branched layout configuration where at any demand point water is supplied from one direction only.

This arrangement decreases the reliability of a water system significantly and has a tendency to decrease fire flow capability for larger scale fires. The capability of water main systems for meeting fire flow criteria can be determined only by semiannual fire flow tests.

Specific Considerations
A number of water system features need to be examined more specifically in relation to providing adequate and reliable water supplies for fire protection. The following topics need to be considered carefully in the evaluation of any given water supply system, not only for consumer consumption but especially for meeting model building code required water supplies and/or the ISO's NFF for public-sector fire protection.

Distribution System Storage
An extremely important element in a water distribution system is water storage. System storage facilities have a far-reaching effect on a water system's ability to provide adequate and reliable water supplies for domestic needs and especially for fire protection. Storage within a distribution system enables the system to process water at times when treatment facilities otherwise would be idle. It then is possible to distribute and store water at one or more locations in the service area which are closer to the end user, and provide the needed volume of water at a minimum of 20 psi residual pressure on fire hydrants to meet fire flow demands. The considerations presented below need to be evaluated carefully for any given municipal water delivery system.

1. Advantages: The principal advantages of distribution storage include the fact that storage equalizes demands on supply sources, production works, plus transmission and distribution mains. As a result, the sizes or capacities of these elements need not be so large. Additional system flows and pressures are improved and stabilized to better serve the customers throughout the service area. Finally, reserve supplies are provided in the distribution system for emergencies, such as fire suppression and power outages.

2. Meeting system demands and required/NFF: In the evaluation of both existing and needed water supply storage, it is essential to consider the location, capacity, and elevation (if elevated) of distribution storage in relation to system demands and the variation of demands that occur throughout the day in different parts of the system. System demands can be determined only after a careful analysis of an entire distribution system. However, some general rules may serve as a guide to such an analysis. Such data are of great assistance in determining the adequacy of storage capacities.

This type of analysis needs to be performed for each water system because each has its own requirements. Studies show that it is more advantageous to provide several smaller storage units in different parts of the water system than to provide an equivalent capacity at a central location. Smaller pipelines are required to serve decentralized storage and, other things being equal, a lower flow-line elevation and pumping head or pressure results.

3. Comparing and contrasting ground storage and elevated storage: Storage within the distribution system network normally is provided in one of two ways: ground-level storage with high-service pumping, and elevated storage. It is noted by the AWWA that elevated storage provides the best, most reliable and most useful form of storage, particularly for fire protection.

a. Ground-level storage: Since water kept in ground-level storage is not under pressure, it must be delivered to the point of use by pumping equipment. This arrangement limits water system effectiveness for fire protection in three ways: 1) There must be sufficient excess pumping capacity to deliver the peak demand for normal uses as well as any fire demands; 2) Standby power sources and standby pumping units must be maintained at all times because the system cannot function without the pumps; and 3) The distribution lines at all points in the system must be significantly oversized to handle peak delivery use plus fire flow, no matter where a fire might occur.

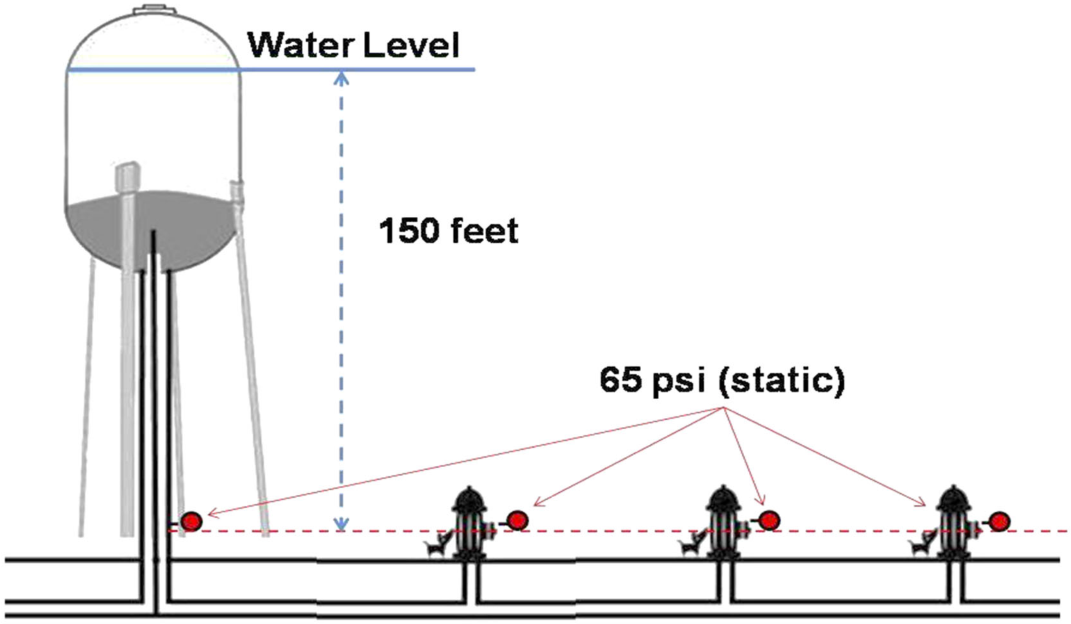
b. Elevated storage: Properly sized elevated water tanks provide dedicated fire storage and are used to maintain constant system pressure. Where elevated tanks are used, ground storage tanks **may** still be required to provide water to the water treatment plant based on the type of system design. However, the size of the ground storage tank(s) can be reduced to the minimum required to treat the water adequately, usually in the 300,000- to 500,000-gallon range. The elevated storage tanks are used to store treated water to provide water directly to the water distribution system. What needs to be evaluated with elevated storage is that the water supply is fed to the distribution system from the top 10 to 15 feet of water in the elevated tank(s). The high-service pumps are constant-speed pump units, which can operate at their highest efficiency point virtually all the time. The remaining water in the tanks (70 to 75 percent) normally is held in reserve as dedicated fire storage. When domestic consumption is at a minimum during a 24-hour period, water in the gravity tank is recycled with fresh treated water to eliminate aging of the water in the holding tank.

4. Pumping for distribution storage: The two types of distribution storage (i.e., ground level and elevated) have, in turn, two types of pumping systems that need to be evaluated on a performance basis. One is a direct pumping system, in which the instantaneous system demand is met by pumping with no elevation storage provided. The second type is an indirect system in which the pumping station lifts water to a reservoir or elevated storage tank, which floats on the water system and provides system pressure by gravity.

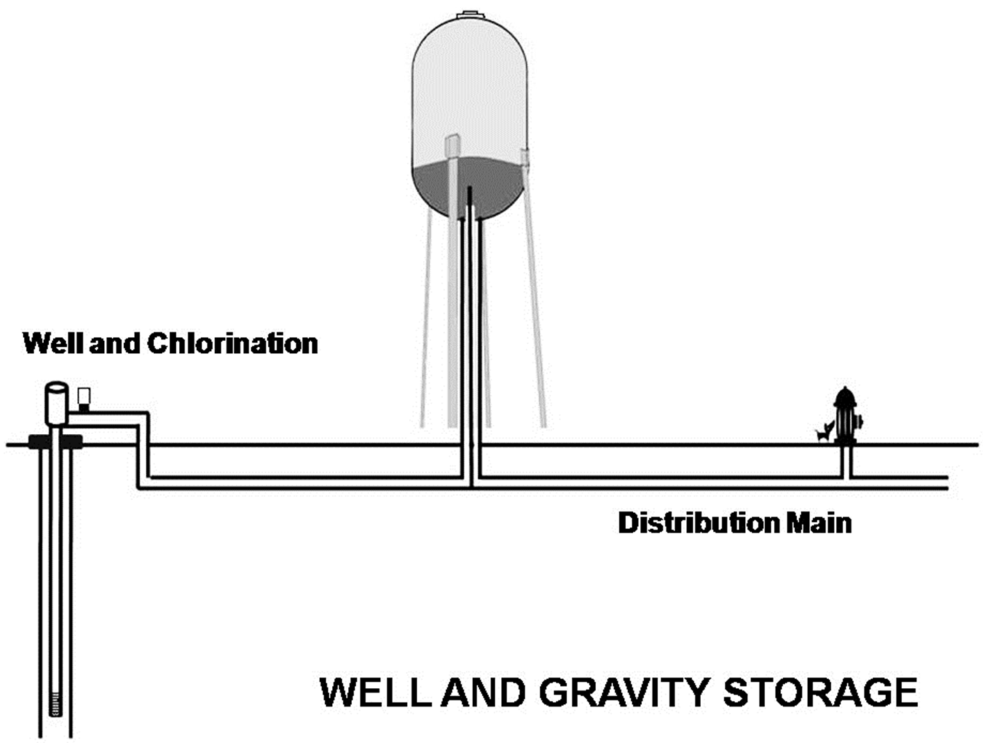
Some comments on each Pumping System are in Order:

a. Direct pumping: The direct pumping system is being phased out for municipal water delivery systems primarily because of operating costs. However, many older systems, especially for smaller communities, still exist. Variable-speed pumping units operated off direct system pressure are also in use in some communities. Hydropneumatic tanks at the pumping station provide some storage. These tanks permit the pumping-station pumps to start and stop, based on a variable-system pressure preset by controls operating off of the tank.

b. Indirect pumping: In an indirect system, the pumping station is not associated with the demands of the major load center. It is operated from the water level difference in the reservoir or elevated storage tank, enabling the prescribed water level in the tank to be maintained. The majority of systems have an elevated storage tank or reservoir on high ground floating on the system. This arrangement permits the pumping station to operate at a uniform rate, with the storage either making up or absorbing the difference between station discharge and system demand.

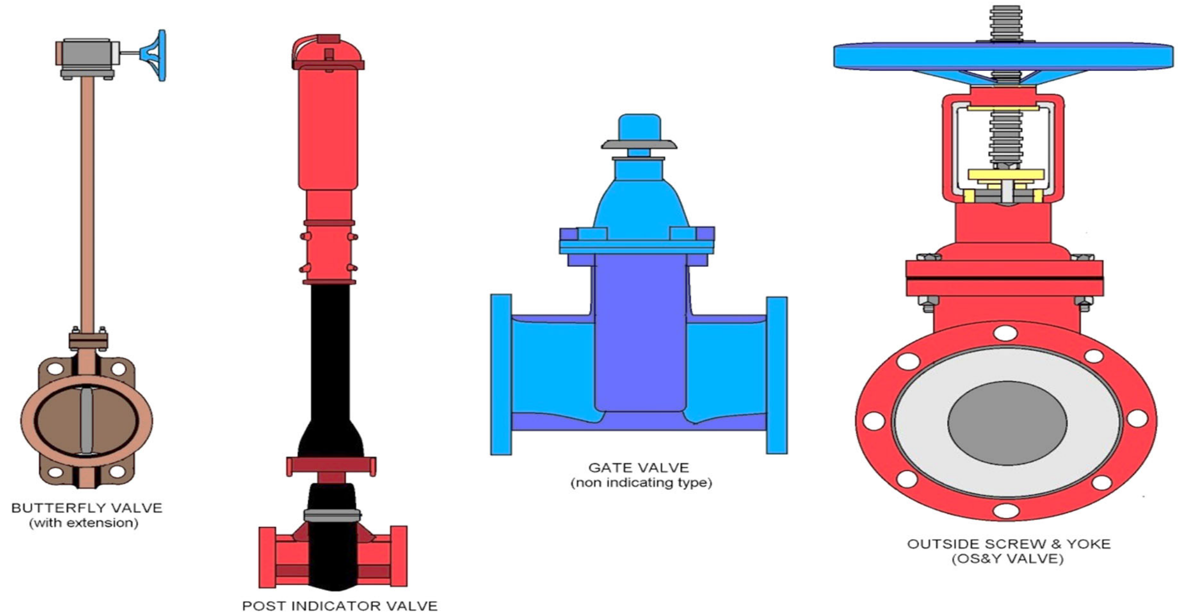


ELEVATED GRAVITY STORAGE TANK

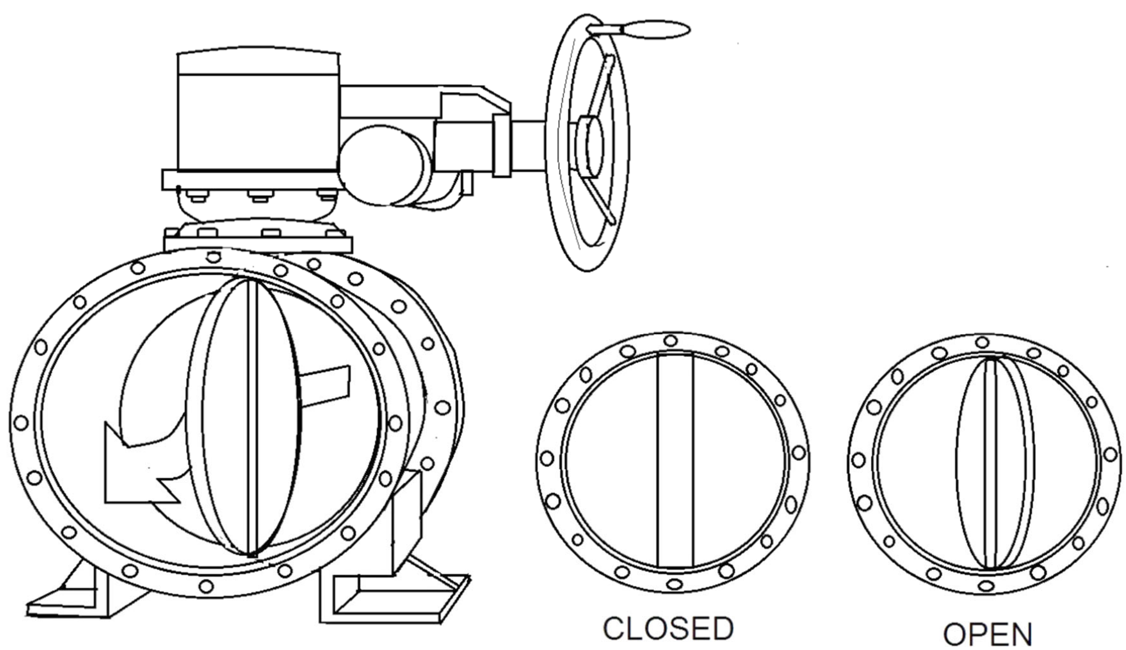


WELL AND GRAVITY STORAGE

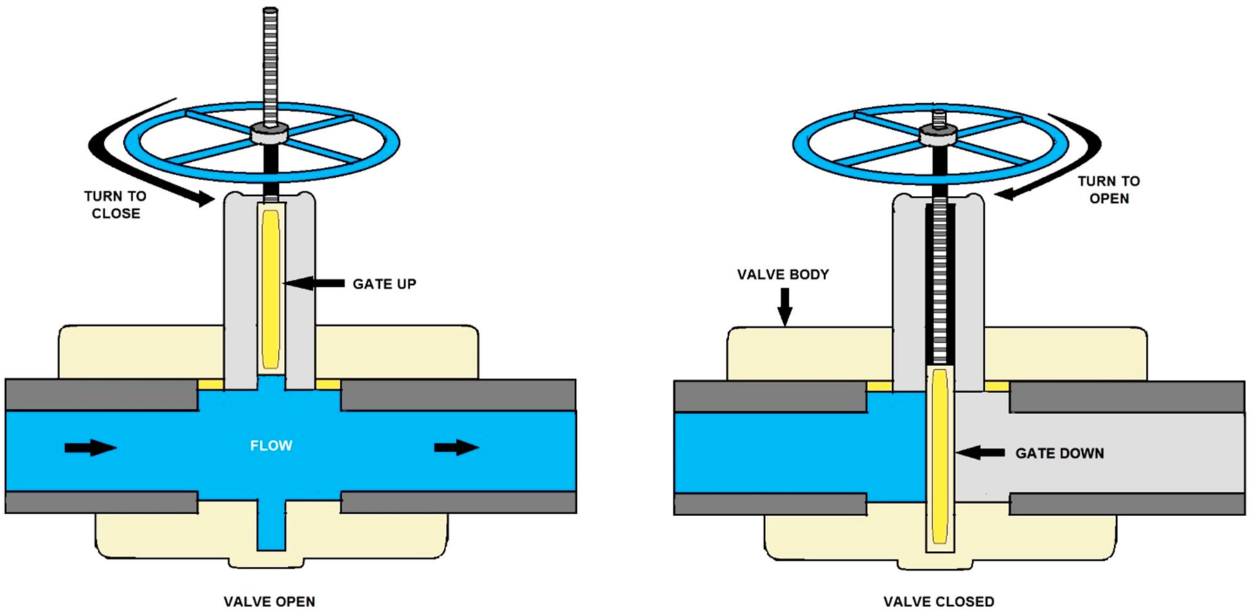
Valve Section



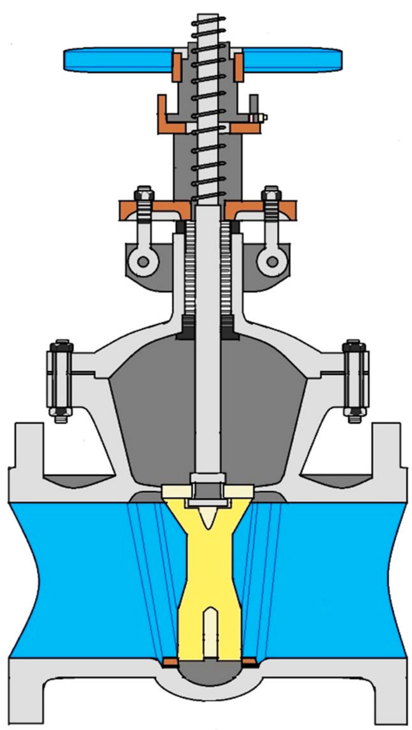
COMMOMLY FOUND VALVE TYPES

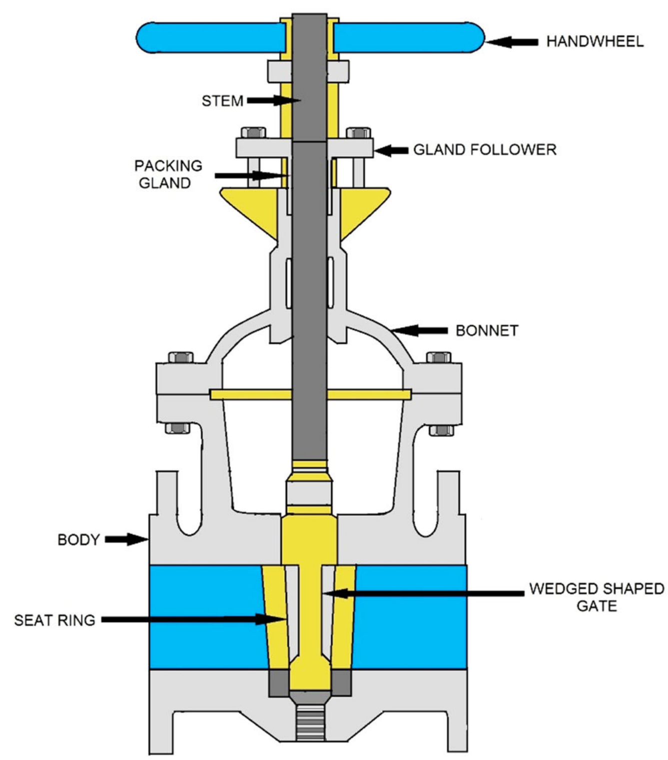


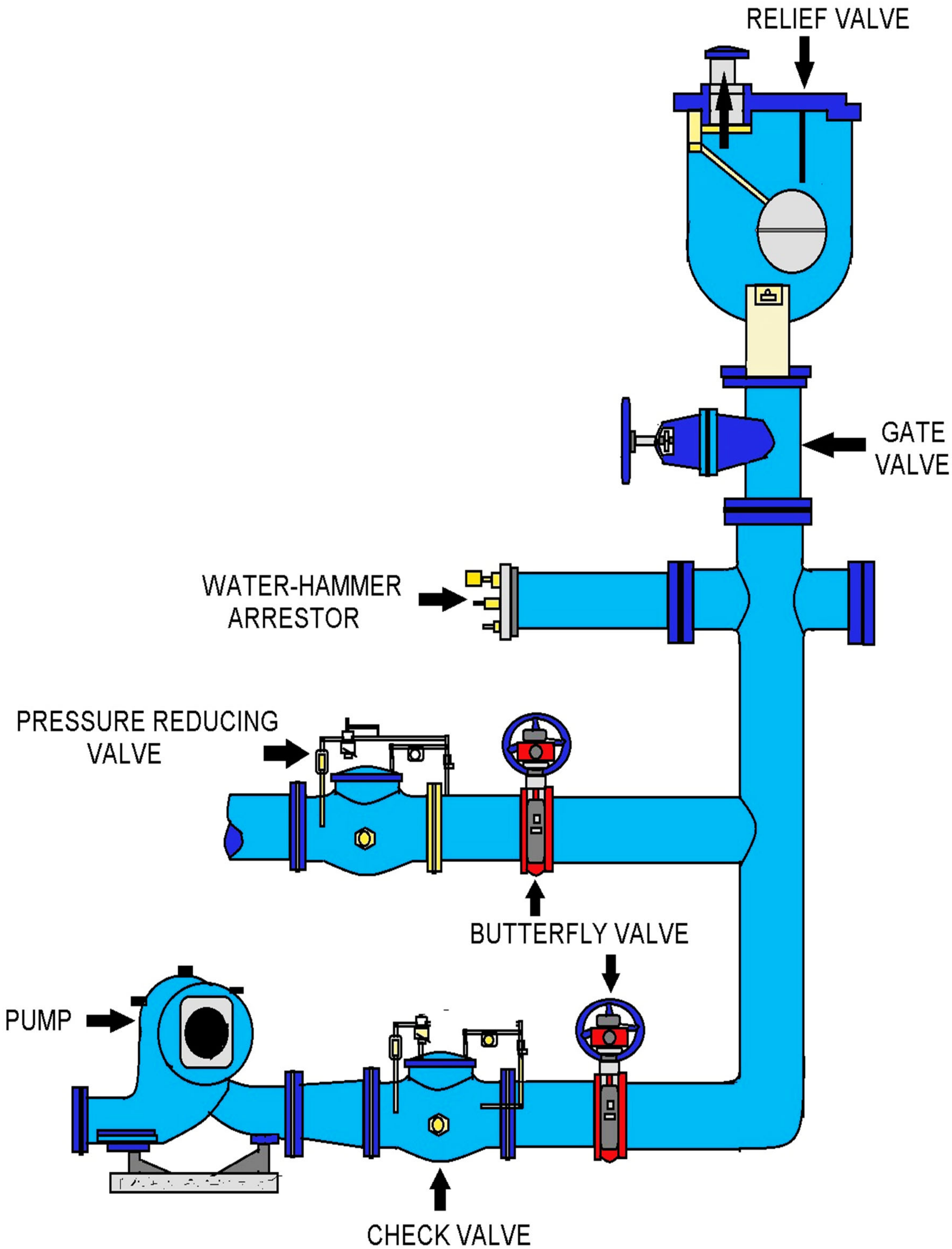
BUTTERFLY VALVE DIAGRAM



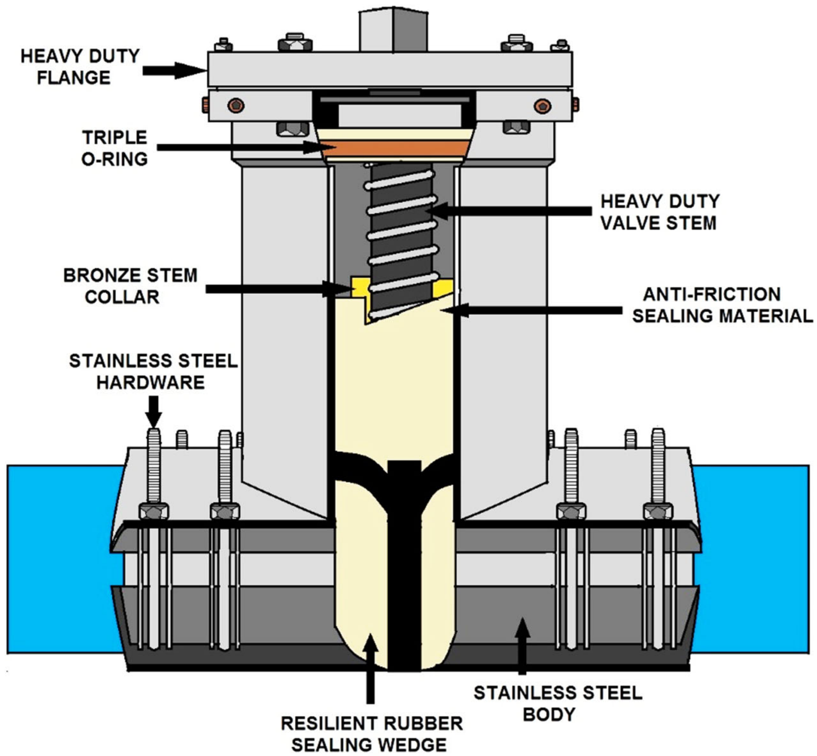
OS&Y VALVE DIAGRAM



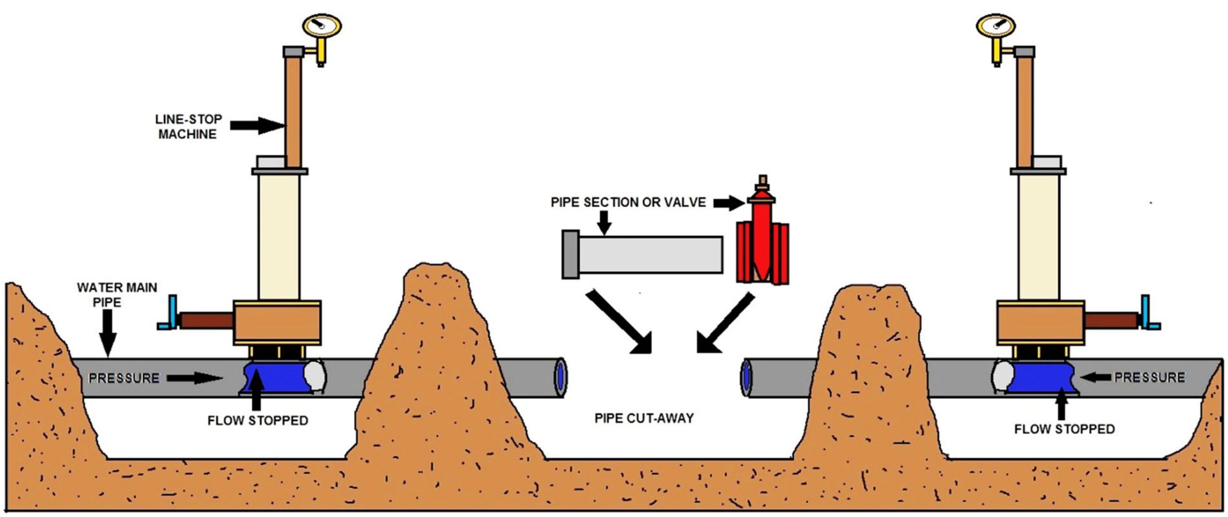




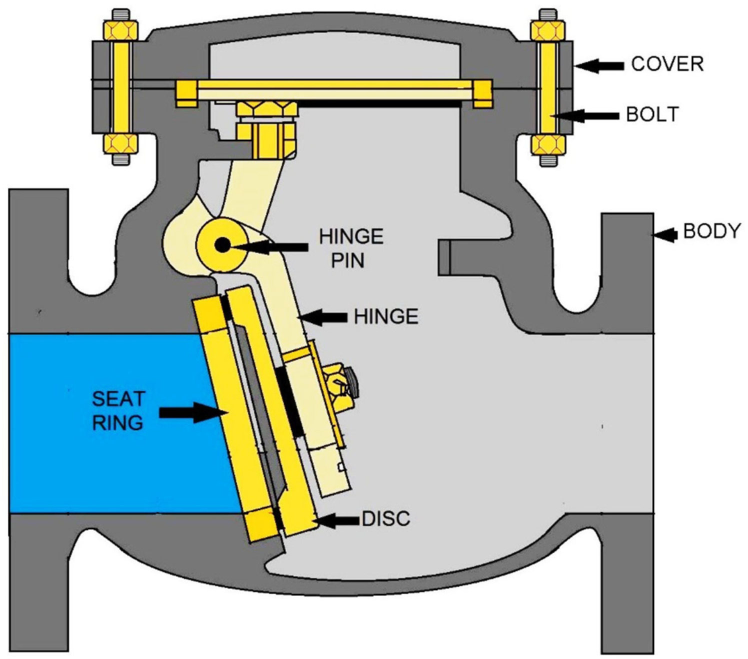
AIR RELIEF VALVE INSTALLATION DIAGRAM



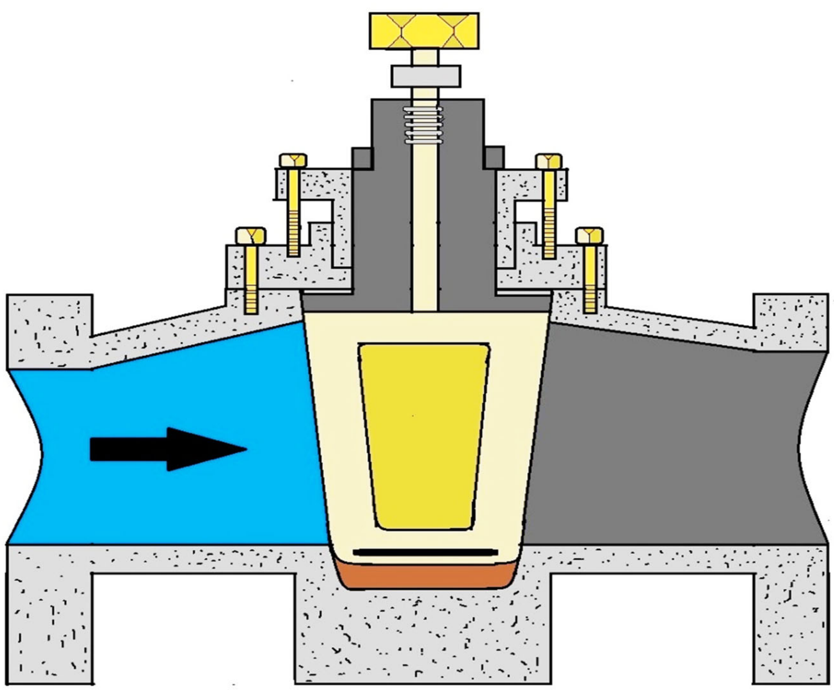
INSTA-VALVE



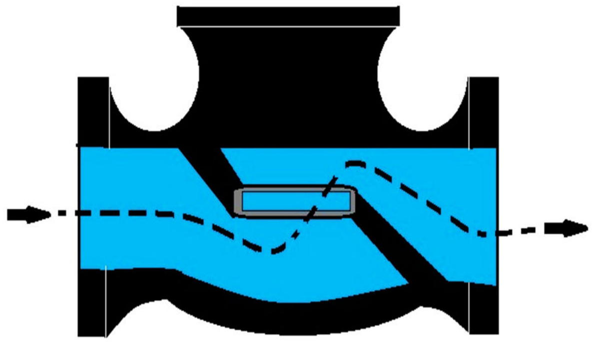
INSERTION OR HOT TAP VALVE INSTALLATION DIAGRAM



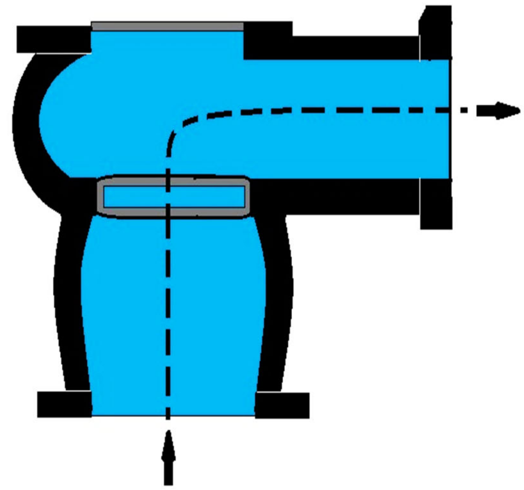
CHECK VALVE DIAGRAM



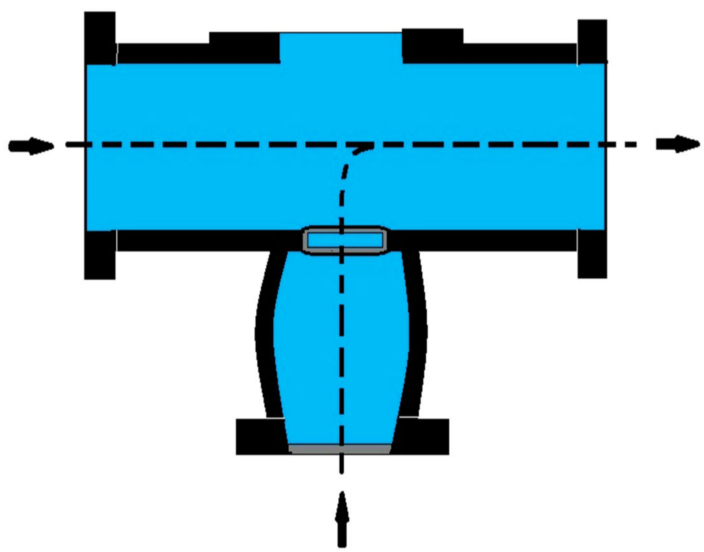
PLUG VALVE DIAGRAM



STRAIGHT-FLOW



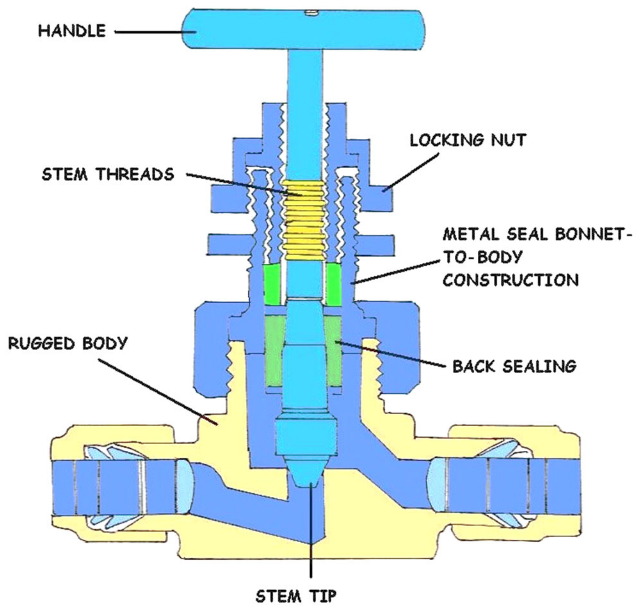
ANGLE-FLOW



CROSS-FLOW

GLOBE VALVE CONFIGURATIONS

Purpose of Valves



NEEDLE VALVE DIAGRAM

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

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

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

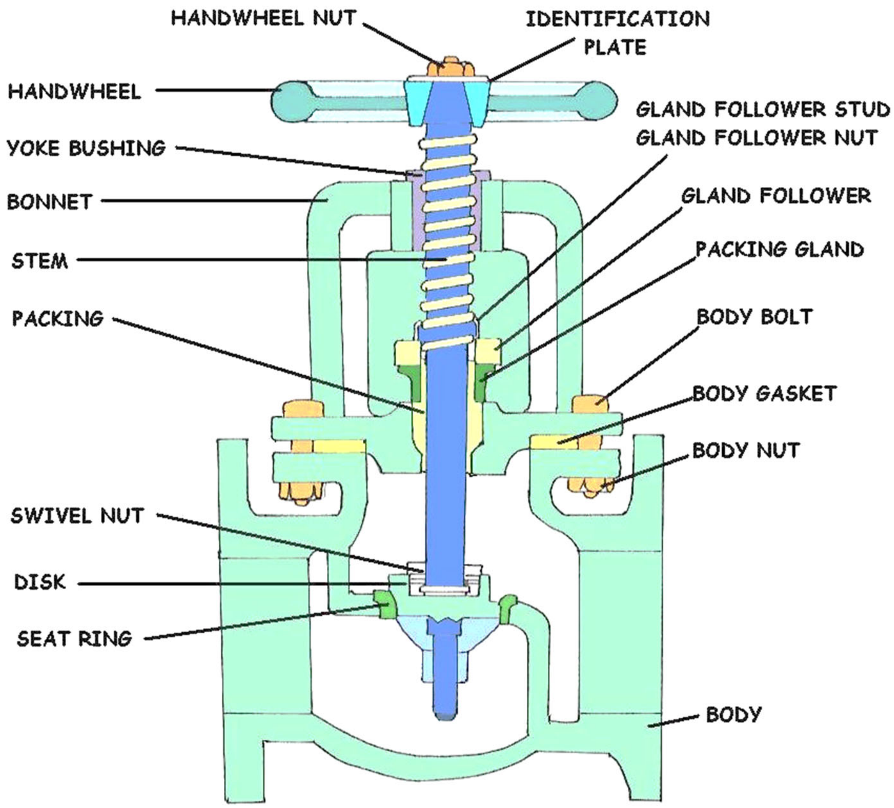
At intersections of distribution mains, the number of valves required is normally one less than the number of radiating mains. The valve omitted from the line is usually the one that principally supplies flow to the intersection. Shutoff valves should be installed in standardized locations (that is,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

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

Classification of Valves

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

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



Gate valves are used when a straight-line flow of fluid and minimum flow restriction are needed. Gate valves are so-named because the part that either stops or allows flow through the valve acts somewhat like a gate.

The gate is usually wedge-shaped. When the valve is wide open, the gate is fully drawn up into the valve bonnet. This leaves an opening for flow through the valve the same size as the pipe in which the valve is installed.

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

The Singing Key

Dr. Rusty recommends that you listen to the Valve Key when shutting down a Gate valve. You will easily hear it sing as you shut the water off or leak by. It is very easy to create a water hammer when opening or closing a Gate valve. Always take your time when operating a Gate valve or any valve. I know that most of you will not listen to me and you will end up breaking plastic water services and customer's water lines at first. Next, you'll move up to water main breaks. We like to blame the Fire Department or Street Sweepers for water hammers, and they should be blamed, but most water hammers are created by water personnel. Yes, I said it. A great example is watching a rookie shut down or open a fire hydrant. These young rookies like to turn the hydrant on or off as fast as possible, like the Firemen do. Pretty soon, the hydrant starts chattering and pumping. The ground feels like an earthquake and the rookie pretends that nothing is happening. We've all done this and if you haven't, you've probably never worked in the field.

Problems

Valve Jammed Open

Dr. Rusty recommends that opened valves should not be jammed-tight on the backseat.

Always back the valve-off a quarter turn from the fully opened position.

Note that motor operated valves coast inevitably to the backseat by tripping on a limit switch. Valves should not be back seated on torque.

Valve Jammed Closed

Variations in the temperature and/or pressure of the working fluid are often the cause of a valve failing to open.

Thermal binding can occur in high temperature situations depending on the seat and wedge material, length of exposure and closing torque applied. Thermal binding can cause galling on the valve sealing surfaces as well as on the guides.

A valve can lock in the closed position when high pressure enters the cavity and has no way to escape. This is known as over-pressurization.

If Excessive Torque is Needed to Work the Valve

Variations in the temperature and/or pressure of the working fluid are often the cause of a valve failing to open.

Thermal binding can occur in high temperature situations depending on the seat and wedge material, length of exposure and closing torque applied. Thermal binding can cause galling on the valve sealing surfaces as well as on the guides. A valve can lock in the closed position when high pressure enters the cavity and has no way to escape. This is known as over-pressurization. We will cover this in a later section.

Single direction sealing gate valves have a nameplate on the side of the valve that has a relief hole or pressure equalizer. This should be the high pressure side when the valve is closed.

Gate valve storage procedures. Always store a gate valve with the gate up or opened. Not like this photograph. Sunlight destroys the rubbers with ultraviolet radiation. Dr. Rusty recommends that you keep the valves covered and clean. We are professionals and must remember the final outcome. We provide drinking water to the public. Notice the two different styles of flange fittings.

Knife Gate Valve

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

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

Ductile pipe cement-lined iron pipe. I've seen thousands of dollars of pipe that is dropped or moved with the front bucket of a backhoe and destroyed. This destroys the interior protection of the pipe, causing leaks which will start within in a short period of time, just a few years. I know that some of you welcome this as job security. Always protect and store all types of pipe covered and in a pipe rack. This goes for the proper storage of rubbers as well.

Flex Coupling--sometimes referred to as a Dayton; used to join pipes or to "cut-in a valve." You will learn that you can use different sizes to join pipe or even file out the inside diameter to adjust to larger pipes like ACP. This flex coupling only has three bolts. I like four or more for work with larger pipe work.

Dr. Rusty's trick, when working on a water line, I like to turn the valves on slowly to fill the water main as the flex couplings are being tightened. This allows the air to escape and for you to find leaks. It also allows debris in the main to flush out.

Here is a four-way pipe cutting tool used for iron pipe. Be careful not to break the wheels by over-tightening. I personally like 4-Ways because of the nice cut. You will learn to recognize the distinct snap of cut pipe. The only drawback to these cutters is cutting a small section out of the main.

You may need to make two or three more cuts and break the section out with a cocking hammer. It will easily cut ductile, galvanized, and even plastic. Plastic pipe cutters utilize sharper cutting wheels. Rookies like to thread the pipe rather than cut the pipe and break the cutting wheel doing it. It is fun to watch and good to tease these rookies about it.

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

Piping and Valve Arrangement

The primary feeders, sometimes called arterial mains, form the skeleton of the distribution system. They are located so that large quantities of water can be carried from the pumping plant to and from the storage tanks and the distribution system.

Primary feeders should be arranged in several interlocking loops, with the mains not more than 3,000 feet apart. Looping allows continuous service as previously identified through the rest of the primary mains, even when one portion is shut down temporarily for repairs. Under normal conditions, looping also allows supply from two directions for large fire flows. Large feeders and long feeders should be equipped with **blow-off valves** at low points and **air relief valves** at high points. Valves should be placed so that a pipe break will affect water service **only** in the immediate area of the break.

The secondary feeders carry large quantities of water from the primary feeders to points in the system in order to provide for normal domestic consumption supply and fire suppression. They form smaller loops within the loops of the primary mains by running from one primary feeder to another. Secondary feeders should be spaced only about three blocks apart, or a maximum of 1,500 feet. This spacing allows concentration of large amounts of water for firefighting without excessive head loss and resulting low pressure.

Small distribution mains (i.e., distributors) are to form a grid over the area to be served. They supply water to residential taps and fire hydrants along residential block fronts throughout areas with this occupancy classification. In no case should the pipe size be less than 6 inches in diameter. Larger size pipes may be needed in residential areas for multiple occupancy buildings. In this case, pipe sizing is based on the sum of the peak day water use plus fire-flow requirements. Where there are multiple-occupancy buildings of more than one floor, required pipe sizing is almost always controlled by the fire-flow requirement.

Water distribution piping should be sized and spaced to meet design flow. The minimum size water main for providing fire protection and serving fire hydrants is 6 inches in diameter.

Values Commonly Used in Distribution Piping
Appurtenance Minimum Standard

Lines
Smallest pipes in network 6 inch
Smallest branching pipes (dead ends) 8 inch
Largest spacing of 6” grid (8” pipe used beyond this value) 600 ft.
Smallest pipes in high-value district 8 inch
Smallest pipes on principal streets in central district 12 inch
Largest spacing of supply mains or feeders 3,000 ft.

Valves
Spacing in single and dual main systems:
Largest spacing on long branches 800 ft.
Largest spacing in high-value district 500 ft.
Fire hydrant locations.

All areas served by a water distribution system should have fire hydrants installed in locations and with spacing for fire department use. The following method of locating fire hydrants should be observed in the United States.

Briefly summarized, the procedure examines a representative fire-risk location and a computed NFF at that location. The first determination is that a recognized fire hydrant be within 1,000 feet of the fire risk, as fire hose is laid from the fire hydrant to the fire risk. A recognized fire hydrant on a municipal water system must flow a minimum of 250 gpm at 20 psi residual pressure for 2 hours.

The actual flow capability from each fire hydrant in the vicinity of the fire risk is limited by the distance to the fire risk as follows: Credit is awarded up to 1,000 gpm from each hydrant within 300 feet of the fire-risk building; 670 gpm from hydrants within 301 to 600 feet of the fire-risk building; and 250 gpm from hydrants within 601 to 1,000 feet of the fire-risk building.

Furthermore, the water utility should review hydrant spacing or representative fire risks in the community with the responsible first-due fire company because the supply hose capacity on fire apparatus may limit the credit assigned by ISO to this item in the *Fire Suppression Rating Schedule.*

The pipe connecting the fire hydrant to the water main is call the **hydrant branch** or **lateral**. Every lateral needs to have an installed valve to enable the water utility to isolate the fire hydrant for repair or general maintenance.

In addition, fire department use typically requires a maximum lineal distance between fire hydrants along street fronts in commercial and congested built-up areas of 300 feet, and 600 feet for light single-family residential areas. Good practice calls for fire hydrants at intersections, in the middle of a block where the NFF equals or exceeds 1,200 gpm, and at the end of dead-end streets.

Summary Statement on Water Supply Distribution
Water supply distribution systems are rather straightforward to evaluate in small communities with a population range up 5,000. The proper evaluation of water supplies and distribution for larger communities, up to cities over 100,000 population, is no simple thing.

Water system maps that are kept current and electronic graph records for all of the water supply that enters the distribution system are **essential** to establish an understanding of actual supply versus consumption on an hourly basis, daily basis, monthly basis, and yearly basis.

If this information is not in place, the first step to the evaluation of a water system is to put in place a records management system, and then to pay close attention to this system. The water utility has the responsibility to keep public officials, especially fire officials, apprised of the current conditions of the water system. This topic paints the **big picture** for developing and maintaining a comprehensive evaluation of a water system.

Valve Terms

Here are some of the common valves and related information.

Air and Vacuum relief valve: Both of these functions are in one valve. These valves can combine three functions; they can allow large amounts of air to escape during the filling of a pipeline, permits air to enter a pipeline that is being drained and allow entrained air to escape while a line is operating under pressure. Distribution system water quality can be adversely affected by improperly constructed or poorly located blowoffs of vacuum/air relief valves. Air relief valves in the distribution system lines must be placed in locations that cannot be flooded. This is to prevent water contamination. The common customer complaint of Milky Water is sometimes solved by the installation of these air relief valves.

Altitude valve: Are often used on supply lines to elevated tanks or standpipes. These close automatically when the tank is full and open when the pressure on the inlet side is less than that on the tank side of the valve. These valves control the high water level and prevent overflow. 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.

Butterfly valve: Has a movable disc as large as the full bore opening of the valve.

Check valve: Are often used on the discharge side of pumps to prevent backflow.

Gate valve: Is a linear valve used to isolate sections of the water main, to permit emergency repairs without interruption of water service to customers.

Pressure sustaining valve: Maintains constant downstream pressure regardless of fluctuating demand. The valve is usually a globe design controlled by a diaphragm with the diaphragm assembly being the only moving part in the valve. Can also be used as an automatic flow-control valve.

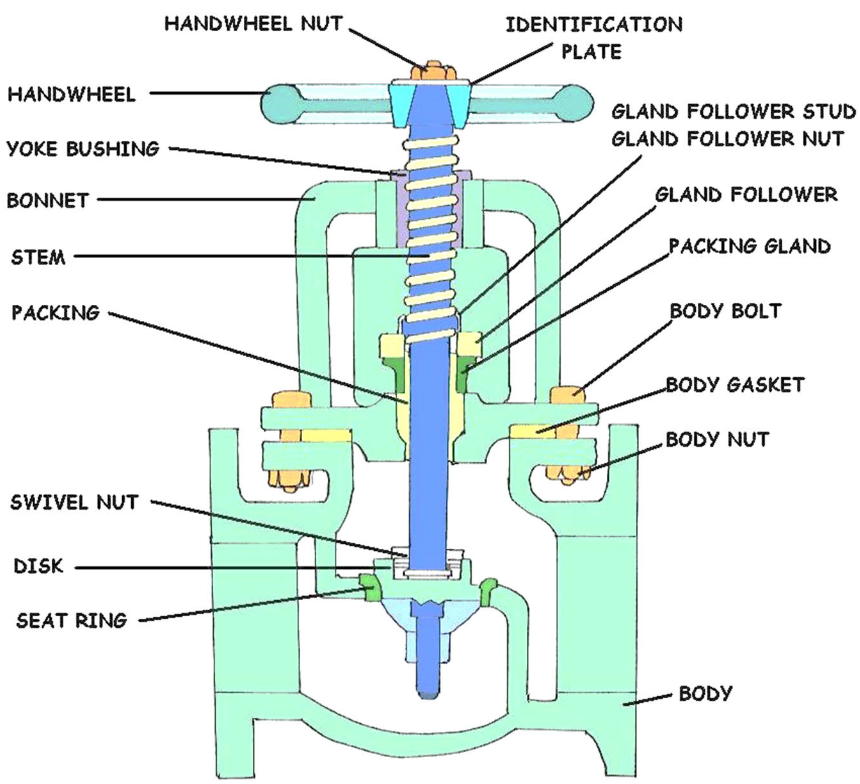
Pressure regulating valve: A valve that controls water pressure by restricting flows. The pressure downstream of the valve regulates the amount of flow. Usually these valves are of the globe valve design. **P**ressure **R**egulation **V**alves control water pressure and operate by restricting flows. They are used to deliver water from a high pressure to a low-pressure system. The pressure downstream from the valve regulates the amount of flow. Usually, these valves are of the globe design and have a spring-loaded diaphragm that sets the size of the opening.

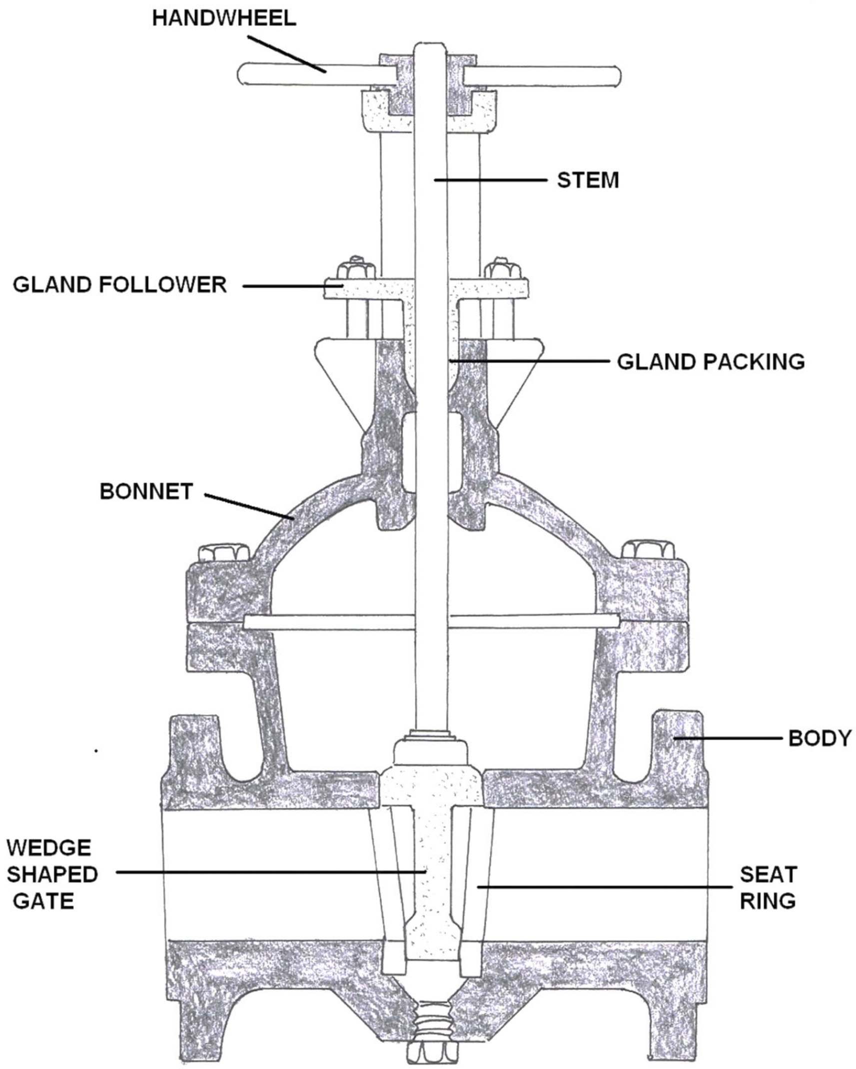
Pressure relief: The simplest type of surge pressure relief is a pressure relief valve. These valves respond to pressure variations at their inlets.

What screen size and protection should air vacuum release valves have above and below ground?
Vents should be screened to keep out birds and animals that may contaminate the water. A screen with1/4 mesh openings is required. Some vents have flap valves that will operate to relive excess pressure or vacuum if the screen becomes blocked.

What types of water contamination problems could result from improper installation of air vacuum and relief valves?

All overflow, blow off, or cleanout pipes should be turned downward to prevent entrance of rain and should have removable #24-mesh screens to prevent the entrance of birds, insects, rodents, and contaminating materials.

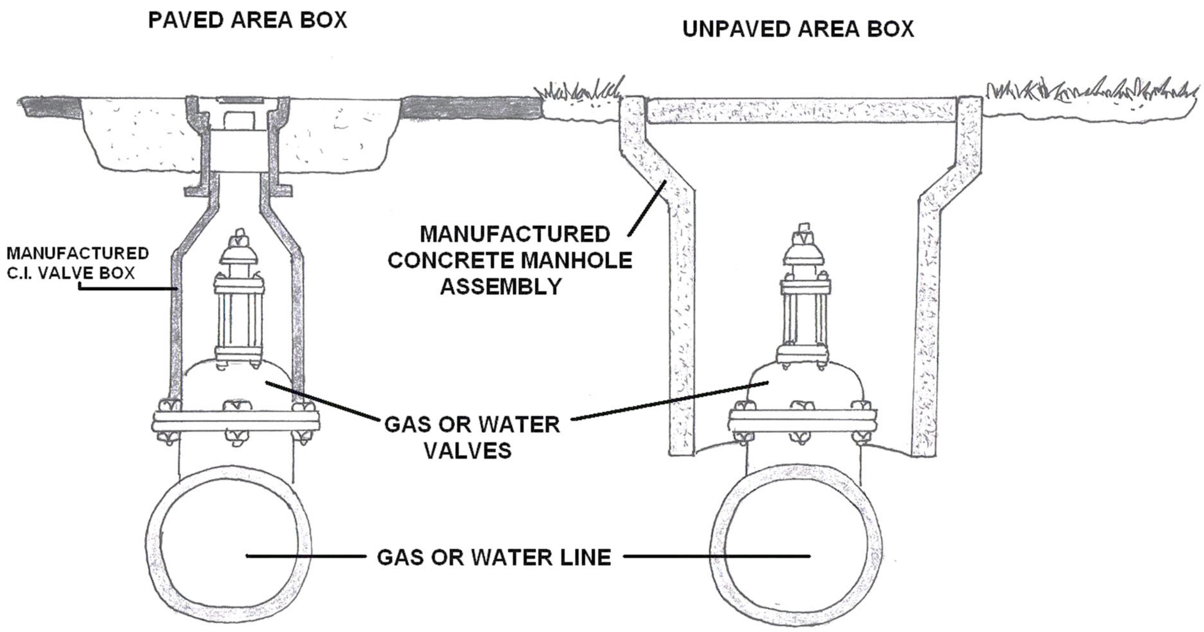




GATE VALVE DIAGRAM

Gate valves are characterized as having either a rising or a non-rising stem. Rising stems provide a visual indication of valve position because the stem is attached to the gate such that the gate and stem rise and lower together as the valve is operated. Non-rising stem valves may have a pointer threaded onto the upper end of the stem to indicate valve position, since the gate travels up or down the stem on the threads without raising or lowering the stem. Non-rising stems are used underground or where vertical space is limited.

Bonnets provide leak-proof closure for the valve body. Gate valves may have a screw-in, union, or bolted bonnet. Screw-in bonnet is the simplest, offering a durable, pressure-tight seal. Union bonnet is suitable for applications requiring frequent inspection and cleaning. It also gives the body added strength. Bolted bonnet is used for larger valves and higher pressure applications.



TYPICAL VALVE BOX INSTALLATION DETAIL

Generally Accepted Valve Installation Information

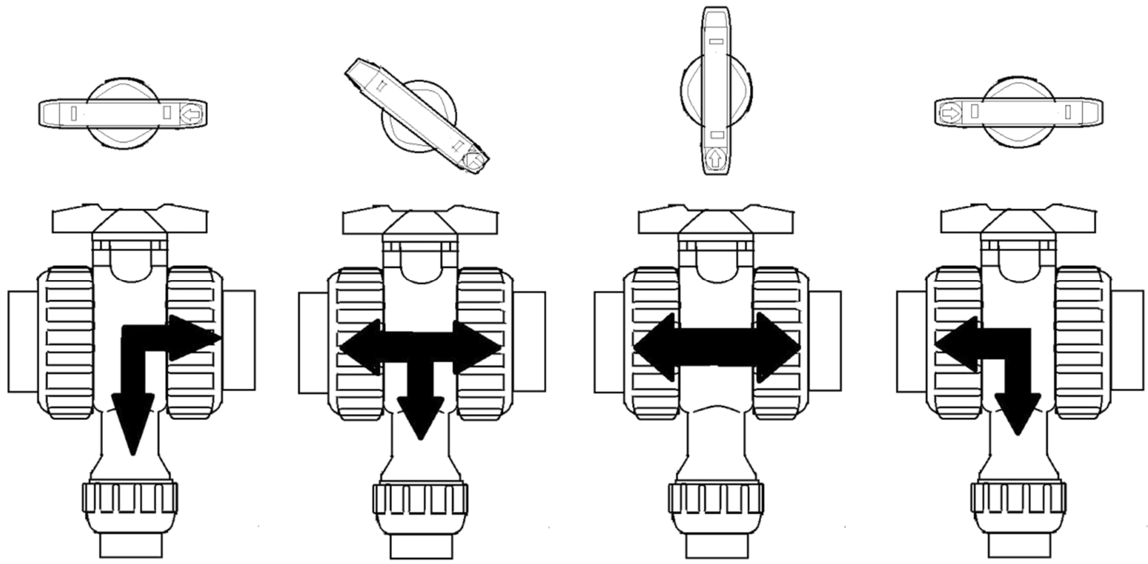
A. Gate valves shall conform with the requirements of AWWA Standard Specification for gate valves for ordinary water works service No. C-500. They shall be iron body, bronze mounted, parallel seat, double disc valves with bronze wedging devices. The valves shall be non-rising stem, open to the left, and shall be equipped with standard two inch square operating nuts. Valves shall be equipped with "O" ring packing.

B. A cast iron valve box, with lid marked "water," and a valve marker post shall be furnished with each gate valve, except marker posts shall not be furnished with hydrant auxiliary valves. -

C. All valves shall be approved by the water superintendent. Contractors shall furnish the location of the nearest point at which replacement working parts are stocked.

D. Gate valves used with asbestos-cement pipe shall be hub end, MJ, Ring-Tite, or Flanged, as shown on plans.

Rotary Valve Sub-Section



GLOBE VALVE CONFIGURATIONS #2

Globe Valve *Rotary Valve*
Primarily used for flow regulation, and works similar to a faucet. They are rare to find in most distribution systems, but can be found at treatment plants. Always follow standard safety procedures when working on a valve.

Most Globes have compact **OS & Y** type, bolted bonnet, rising stems with renewable seat rings. The disc results with most advanced design features provide the ultimate in dependable, economical flow control.

Globe valves should usually be installed with the inlet below the valve seat. For severe throttling service, the valve may be installed so that the flow enters over the top of the seat and goes down through it. Note that in this arrangement, the packings will be constantly pressurized. If the valve is to be installed near throttling service, verify with an outside contractor or a skilled valve technician. Globe valves, per se, are not suitable for throttling service.

The valve should be welded onto the line with the disc in the fully closed position. Leaving it even partially open can cause distortion and leaking. Allow time for the weld to cool before operating the valve the first time in the pipeline.

The preferred orientation of a globe valve is upright. The valve may be installed in other orientations, but any deviation from vertical is a compromise. Installation upside down is not recommended because it can cause dirt to accumulate in the bonnet.

Globe Valve Problems and Solutions

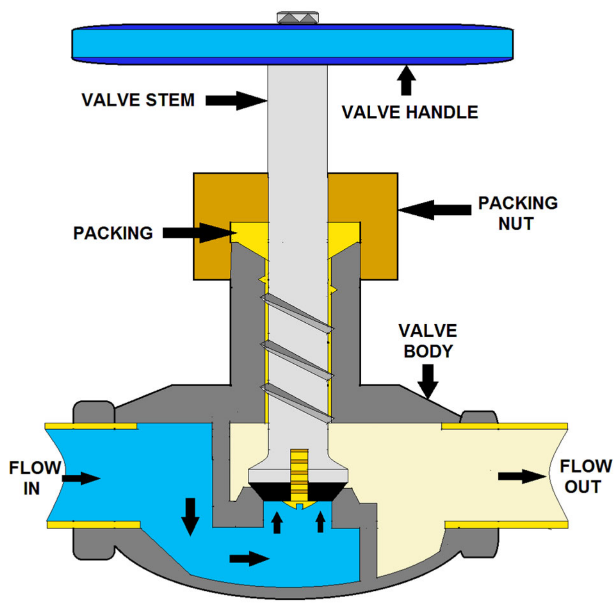
If the valve stem is improperly lubricated or damaged--Disassemble the valve and inspect the stem. Acceptable deviation from theoretical centerline created by joining center points of the ends of the stem is 0.005"/ft of stem. Inspect the threads for any visible signs of damage.

Small grooves less than 0.005" can be polished with an Emory cloth. Contact specialized services or an outside contractor if run-out is unacceptable or large grooves are discovered on the surface of the stem.

If the valve packing compression is too tight--Verify the packing bolt torque and adjust if necessary.

Foreign debris is trapped on threads and/or in the packing area.--This is a common problem when valves are installed outdoors in sandy areas and the areas not cleaned before operating.

Always inspect threads and packing area for particle obstructions; even seemingly small amounts of sand trapped on the drive can completely stop large valves from cycling.



GLOBE VALVE

The valve may stop abruptly when a cycle is attempted. With the line pressure removed from the valve, disconnect the actuator, gear operator or handwheel and inspect the drive nut, stem, bearings and yoke bushing. Contaminated parts should be cleaned with a lint-free cloth using alcohol, varsol or equivalent. All parts should be re-lubricated before re-assembled. If the valves are installed outdoors in a sandy area, it may be desirable to cover the valves with jackets.

If the valve components are faulty or damaged--contact specialized services or an outside contractor.

If the valve's handwheel is too small--Increasing the size of the handwheel will reduce the amount of torque required to operate the valve. If a larger handwheel is installed, the person operating the valve must be careful not to over-torque the valve when closing it.

Bellow Seal Valve

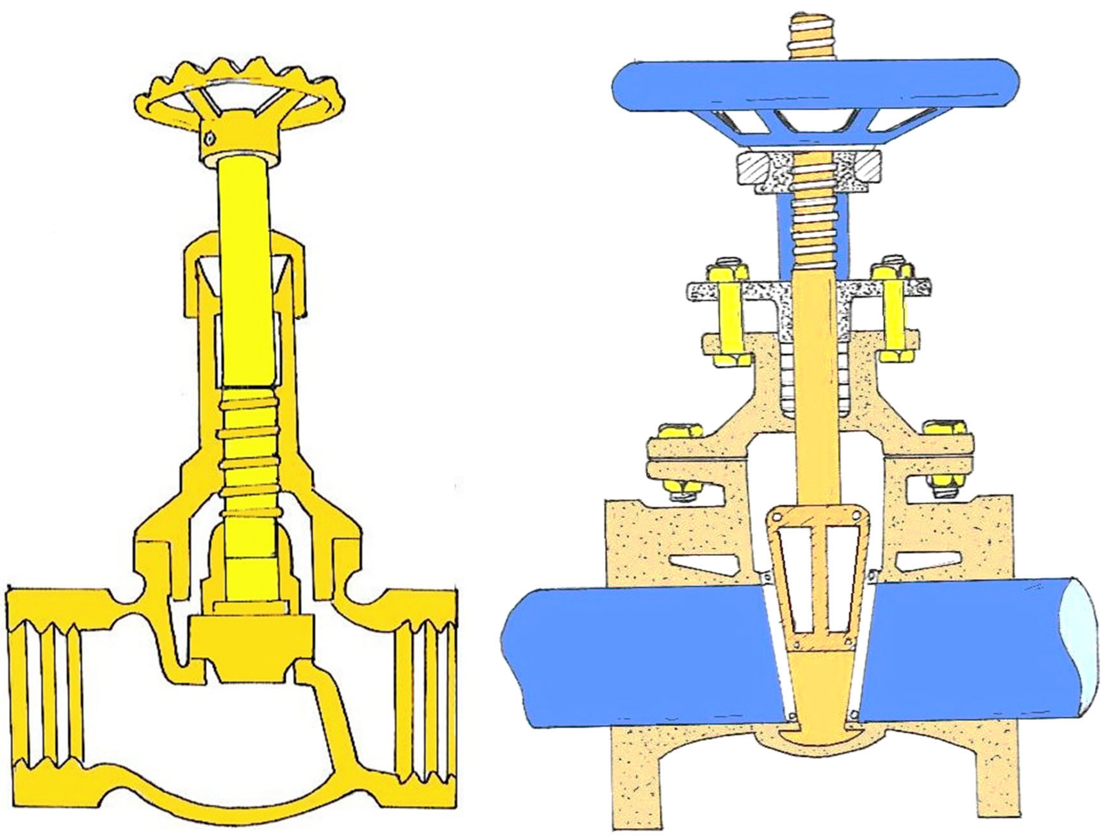
Always follow standard safety procedures when working on a valve.

Bellows seal valves provide a complete hermetic seal of the working fluid. They are used in applications where zero leakage of the working fluid into the environment is permitted.

Bellows seal valves are specially modified versions of the standard valves. The installation information that applies to gate and globe valves will apply to bellows seal valves.

A packing leak signifies that the bellows has ruptured or the bellows-assembly weld has a crack. Dr. Rusty does not recommend repairing or reusing a damaged bellows.

Instead, Dr. Rusty suggests replacing the entire bonnet assembly including bellows and stem.



GLOBE VALVE VS RISTING STEM GATE VALVE

Pressure Sustaining Valve
Pressure sustaining valves are used to sustain the system pressure to a predetermined maximum level. The applications balance the pressure distribution throughout the whole system by maintaining the minimum pressure for high altitude users. Pressure sustaining valves are also used to prevent discharging of the pipe system when any user starts to operate. More in a few more pages.

Pressure Reducing Valve
Pressure reducing valves maintain a predetermined outlet pressure which remains steady and unaffected by either changing of inlet pressure and/or various demands. Pressure Reducing Valves are self-contained control valves which do not require external power. More in a few more pages.

Insertion Valves *Rotary Valve*
You know sometimes you can obtain a shut down and you have two choices. Do it hot or cut in an insertion or inserting valve. An Insertion valve is normally a Gate Valve that is made to be installed on a hot water main. A few years ago, this was a serious feat. First, you had to pour ten yards of mud or cement and come back and cut the valve in. No longer. The Insertion valve machine and tap works like a tapping sleeve. The only difference is that the tap points up and not to the side. I recommend that any major system budget money to purchase this equipment. It will pay for itself on the first job. Otherwise, contract the work out. You can see in the photograph a manually operated tapping machine. I prefer the electric. Note: see the sweet shoring shield set-up. It is rare to see a nice shoring job.

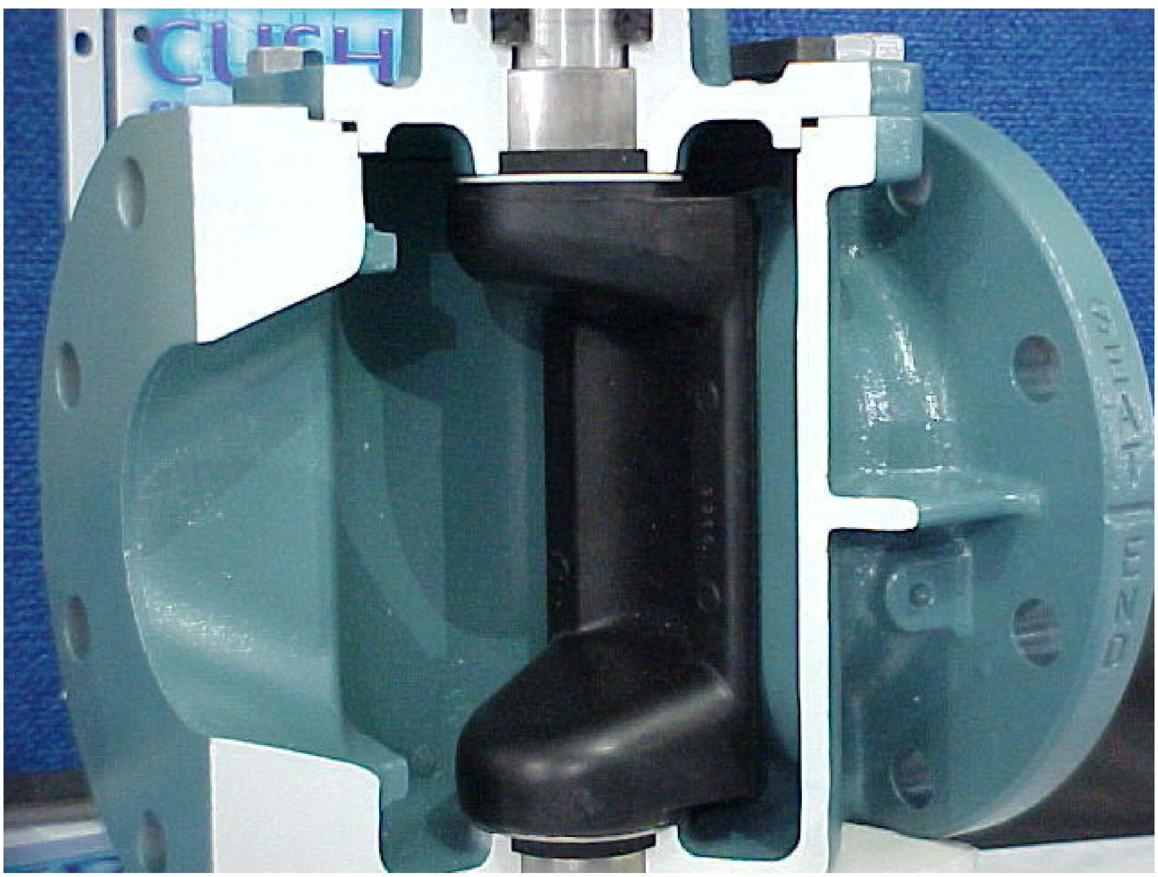
Hydro-Stop valve insertion machine

Needle Valves *Rotary Valve*

A needle valve, as shown on the right, is used to make relatively fine adjustments in the amount of fluid flow. The distinguishing characteristic of a needle valve is the long, tapered, needle- like point on the end of the valve stem. This "needle" acts as a disk. The longer part of the needle is smaller than the orifice in the valve seat and passes through the orifice before the needle seats. This arrangement permits a very gradual increase or decrease in the size of the opening. Needle valves are often used as component parts of other, more complicated valves. For example, they are used in some types of reducing valves.

Plug Valves *Rotary Valve*

Plug valves are extremely versatile valves that are found widely in low-pressure sanitary and industrial applications, especially petroleum pipelines, chemical processing and related fields, and power plants. They are high capacity valves that can be used for directional flow control, even in moderate vacuum systems. They can safely and efficiently handle gas and liquid fuel, and extreme temperature flow, such as boiler feed water, condensate, and similar elements. They can also be used to regulate the flow of liquids containing suspended solids (slurries).



Cut-away of a Plug Valve.

Angle Stops *Rotary Valve*

When working in tight areas, you sometimes need a tight fitting valve. This is an excellent place for an Angle Stop or Angle valve. If you ever have to jump an Angle valve on hot, first dismantle the bottom compression fitting and the rubber and slide it on the water line. Sometimes the bottom compression fitting will have a set-screw and some operators like to tighten it to the pipe or service before jumping the stop. Either way, it will work. Always have a helper if jumping any service larger than 1 inch.

Ball or Corporation Stop *Rotary Valve* ***Small Valves 2 inches and smaller***

Most commonly found on customer or water meters. All small backflow assemblies will have two Ball valves. It is the valve that is either fully on or fully off; and the one that you use to test the abilities of a water service rookie. The Corp is usually found at the water main on a saddle. Some people say that the purpose of the Corp is to regulate the service. I don't like that explanation. No one likes to dig up the street to regulate the service and Ball valves are only to be used fully on or fully off.

Most ball valves are the quick-acting type. They require only a 90-degree turn to either completely open or close the valve. However, many are operated by planetary gears. This type of gearing allows the use of a relatively small handwheel and operating force to operate a fairly large valve. Always follow standard safety procedures when working on a valve.

The gearing does, however, increase the operating time for the valve. Some ball valves also contain a swing check located within the ball to give the valve a check valve feature. The brass ball valve is often used for house appliance and industry appliance, the size range is 1/4"-4". Brass or zinc is common for body, brass or iron for stem, brass or iron for ball, aluminum, stainless steel, or iron for handle including a Teflon seal in the ball housing.

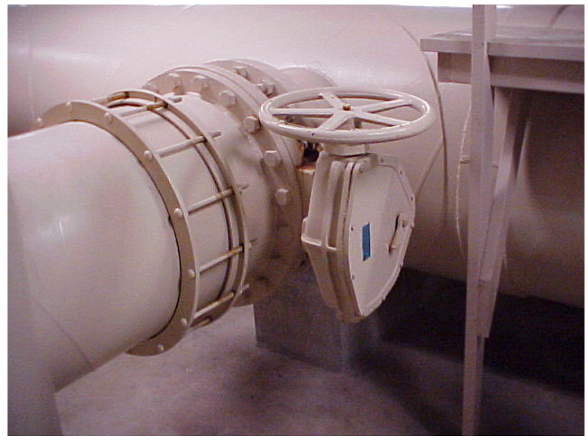
Flush the pipeline before installing the valve. Debris allowed to remain in the pipeline (such as weld spatters, welding rods, bricks, tools, etc.) can damage the valve. After installation, cycle the valve a minimum of three times and re-torque bolts as required. Ensure that the valve is in the open position and the inside of the body bore of the valve body/body end is coated with a suitable spatter guard.

Butterfly Valve *Rotary Valve*

Usually a huge water valve found in both treatment plants and throughout the distribution system. If the valve is not broken, it is relatively easy to operate. It is usually accompanied with a Gate valve used as a by-pass to prevent water hammer. When I was a Valve man, it seemed that every Bypass valve was broken closed when near a Butterfly valve.

These are rotary type of valves usually found on large transmission lines. They may also have an additional valve beside it known as a "***bypass valve***" to prevent a water hammer.

Some of these valves can require 300-600 turns to open or close. Most Valvemen (or the politically correct term "Valve Operators") will use a machine to open or close a Butterfly Valve. The machine will count the turns required to open or close the valve.

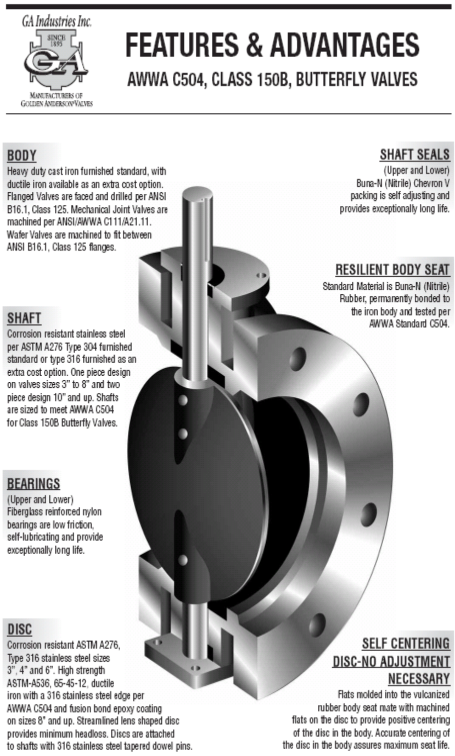


Butterfly valves should be installed with the valve shaft horizontal or inclined from vertical. Always follow standard safety procedures when working on a valve.

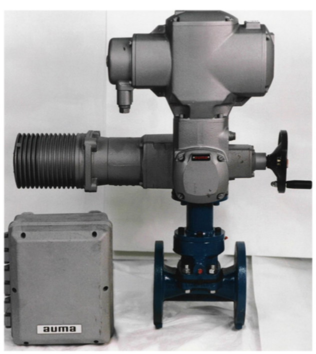
The valve should be mounted in the preferred direction, with the "HP" marking. Thermal insulation of the valve body is recommended for operating temperatures above 392°F (200°C). The valve should be installed in the closed position to ensure that the laminated seal in the disc is not damaged during installation.

If the pipe is lined, make sure that the valve disc does not contact the pipe lining during the opening stroke. Contact with lining can damage the valve disc.

54 inch Butterfly valve on a huge transmission line. Nice job but no shoring, no ladder or valve blocking.



ACTUATION METHODS



- Standard Handwheel
- Chainwheel Operated
- Square Nut
- Pneumatic
- Electric

Butterfly Valve Problems

A butterfly valve may have jerky operation for the following reasons:

If the packing is too tight--Loosen the packing torque until it is only hand tight. Tighten to the required level and then cycle the valve. Re-tighten, if required. CAUTION: Always follow safety instructions when operating on valve.

If the shaft seals are dirty or worn out--Clean or replace components, as per assembly-disassembly procedure. CAUTION: Always follow safety instructions when operating on a valve.

If the shaft is bent or warped--The shaft must be replaced. Remove valve from service and contact an outside contractor or your expert fix-it person.

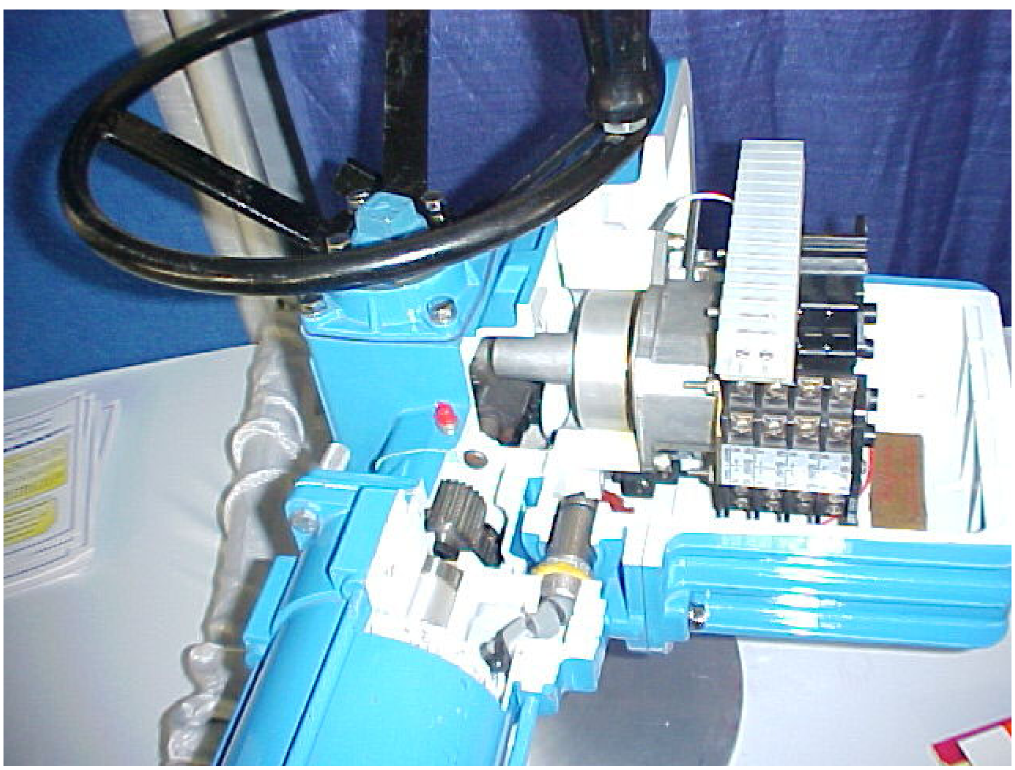
If the valve has a pneumatic actuator, the air supply may be inadequate--Increase the air supply pressure to standard operating level. Any combination of the following may prevent the valve shaft from rotating:

If the actuator is not working--Replace or repair the actuator as required. Please contact specialized services or an outside contractor for assistance.

If the valve is packed with debris--Cycle the valve and then flush to remove debris. A full cleaning may be required if flushing the valve does not improve valve shaft rotation. Flush or clean valve to remove the debris.

A broken 54-inch Butterfly and a worker inside the water main preparing the interior surface. Notice, this is a Permit Required Confined Space. Hot work permit is also required. Side note, there is a plastic version of the 54 and 60 inch Butterfly valve.

Here at a water treatment plant, we can see both valve actuators control devices and Butterfly valves as well. Bottom photograph is a cut-away of an actuator and mechanism.

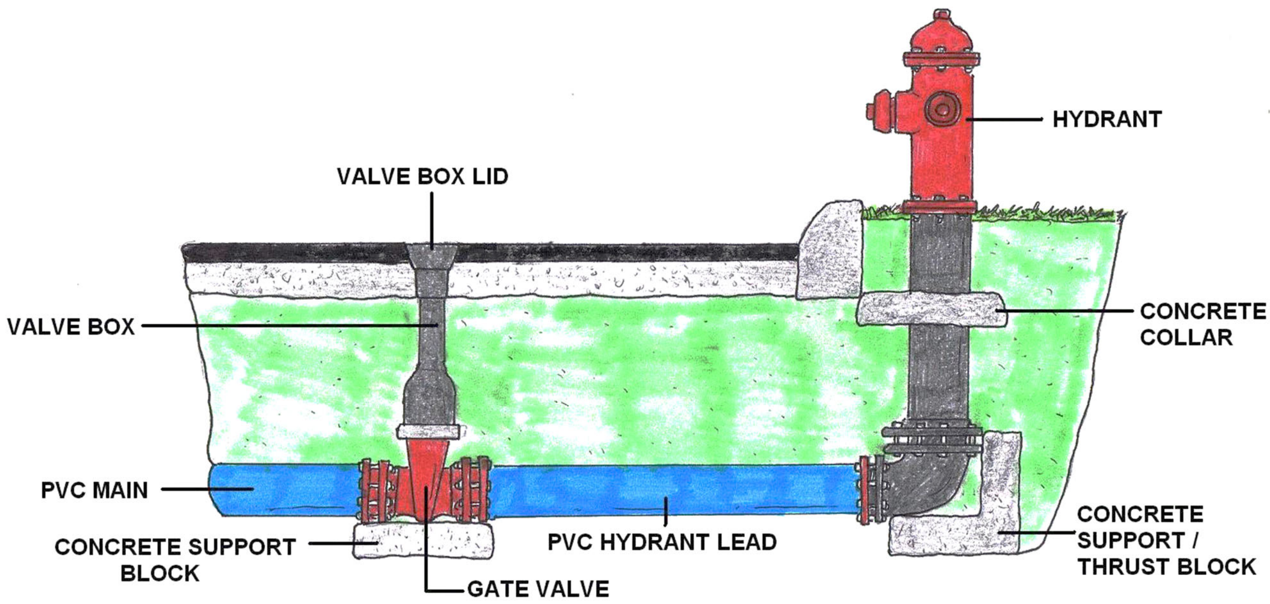


Valve Exercising Sub-Section

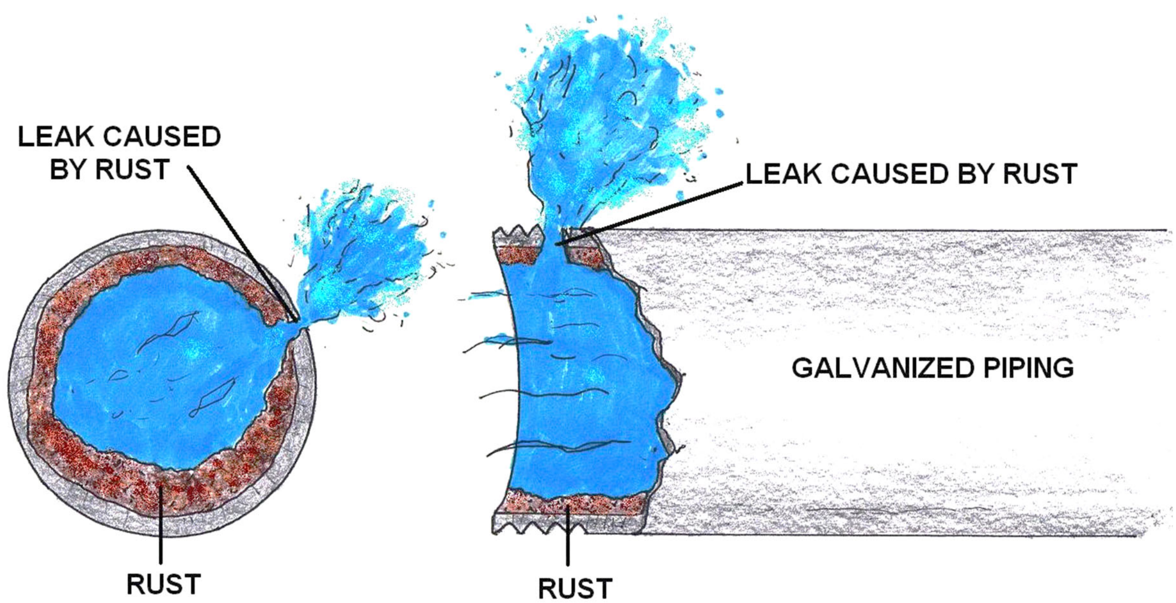
Valve exercising should be done once per year (especially main line valves) to detect malfunctioning valves and to prevent valves from becoming inoperable due to freezing or build-up of rust or corrosion. A valve inspection should include drawing valve location maps to show distances (ties) to the valves from specific reference points (telephone poles, stonelines, etc.).

Hydrants are designed to allow water from the distribution system to be used for fire-fighting purposes.

Bottom of a dry barrel fire hydrant--there is a drainage hole on the back of this hydrant, sometimes referred to as a "weep hole". Below is an "Airport Runway" type of hydrant. These are difficult to find.



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



Evaluating Fire Water Main Capacity

The following elements comprise a water distribution system used to supply water to commerce, industry, residences, and fire hydrants:

- primary distribution pipe heading from the supply works;
- secondary feeder pipe looping around the major sections of the city
- distribution pipe laid along individual streets that should interconnect with the secondary feeders; and
- distribution pipe laid along individual streets.

The flow capability, or hydraulic characteristic, of water mains is used to determine the amount of water available at fire hydrants located near NFF sites. Fire-flow tests are conducted on one, or a set, of fire hydrants to measure the flow at a 20 psi residual pressure. These measured flows can be compared to NFFs at the same locations. Water tests need to be conducted and recorded for each NFF risk site.

The *Grading Schedule* adds the following instruction:
If tests are made on two or more systems or service levels at the same location, credit will be given for the sum of the test results on each system, or service, up to the limit of the supply, for the flow duration.

The concept of available fire flow for **different** durations will be covered in the following review.

Evaluating Fire Hydrant Distribution
The *Grading Schedule* provides the following information (that is not directly quoted): A review is conducted at each fire hydrant within 1,000 feet of a representative test site location (i.e., fire risk) measured as fire hose can be laid by fire apparatus in order to satisfy the determined NFF.

Proximity of fire hydrant distribution to NFF sites or fire-risk sites is the third factor in determining water system capability. Credit for fire hydrants is expressed in gpm, based on measured distance from the building site as established above. The flow and distance relationship is as follows:

Credit Up To: Distance From the Risk Site
1,000 gpm Within 300 ft of site location
670 gpm Within 301 ft to 600 ft of site location
250 gpm Within 601 ft to 1,000 ft of site location
The maximum credit for a fire hydrant is to be limited by the number and size of the outlets as follows:

Hydrant Outlets Maximum Credit
At least one pumper outlet 1,000 gpm
Two or more hose outlets 750 gpm
One hose outlet only 500 gpm

Flow Test Objectives

Fire hydrant flow tests conducted on public water supply systems are done for several reasons: 1) to determine the rate at which water is available at specific locations within a given distribution system;

2) to use flow-test data between two fire hydrants on the same water main to determine a pipe coefficient or to determine if control valves are completely open;

3) to determine water availability at the end of an existing pipeline for the determination of pipeline extensions;

4) for determining the need for booster pump applications;

5) to verify or calibrate the accuracy of water distribution system models; and

6) to determine a water flow and pressure profile where the water system supplies an automatic sprinkler system. The flow-test data may be used for the evaluation of new developments that would be supplied by the water system and for evaluating tradeoffs for providing water supplies for public fire protection and/or private fire protection in the form of automatic sprinkler systems.

Of particular interest to fire departments and insurance companies is the rate and quantity at which water is available to concentrated high-value areas, such as shopping centers, industrial parks, high-rise high-tech buildings, institutional buildings, and residential areas. Also see National Fire Protection Association (NFPA) 25, *Standard for Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, which outlines testing requirements for private fire hydrants.

Fire hydrant flow tests should not be attempted until all the operational characteristics of a water system are known. Results may differ substantially, depending on the operation of pumping equipment, water levels in the system's storage facilities, rates of consumption, and points of demand on the water system.

Even though it is possible to conduct accurate tests within acceptable tolerances, often the results obtained will vary from day to day, and even at different periods during the same day, because of the many variables involved.

Basic Hydraulic Concepts

Persons involved in water supply testing and flow testing from fire hydrants need to understand some of the fundamentals of water as a fluid flowing through pipe and flowing out of orifices such as an outlet on a fire hydrant.

The Hazen-Williams Formula for evaluating water flow though pipes is the most practical and usable formula for analyzing water supply systems in relation to providing effective water supplies for fire protection. Many standards published by the NFPA, including those on sprinklers, water spray systems, and suburban and rural water supplies, make direct reference to the Hazen-Williams Formula for pipe configuration calculations.

It is the formula of choice for water system operators and field engineers to measure pressure loss in pipe sections and to verify the "c" value or the coefficient of roughness on the interior of pipe walls which signals a reduction in the actual pipe diameter.

The **Hazen-Williams Formula** is used widely for pipe flow problems involving municipal water supply system evaluations and sprinkler system piping design layout and evaluation. This is an empirical formula that evolved for water test work over a period of 30 years and is considered to be valid today for water distribution system analysis. The formula is presented as follows:

P=4.52xQ1.85/c1.85xd4.87

Where:

P=pressure loss in psi per foot of pipe, often referred to as friction loss.

Q=flow of water in U.S. gallons of water per minute expressed as gpm.

c=roughness coefficient to be used with this formula; see further explanation below.

d=the actual internal diameter of the pipe; for practical hydraulics the published diameter of the pipe is used, not the actual manufacturers' diameter. (A given brand of 6-inch pipe has an actual internal diameter of 5.871, which is indistinguishable from field hydraulic problems.)

NOTE: on a special understanding the correct use of this formula: If the constant for the pipe which is now an acceptable constant for all pipe from the perspective of practical hydraulics is canceled out, and the coefficient of roughness (c) is canceled out, and the diameter of the pipe being tested remains constant (i.e., all 8-inch pipe), it too can be canceled out.

The remaining equation now reads

psi loss varies as Q1.85

This concept is very important because it permit preparing Log graphs that are based on this equation. This is useful for plotting flow data to show the relationship between flow and pressure loss through pipelines without doing a lot of mathematical calculations.

Cautions To Be Observed When Field Testing

Opening a fire hydrant rapidly can cause a negative pressure fluctuation. Therefore, fire hydrants should be opened slowly until fully opened. Closing the hydrants is more critical, and it must be done very slowly until after the flow is diminished to about 20 percent of the full flow. Closing a hydrant rapidly causes a pressure surge, or water hammer; this could cause weakened water mains to **fail.**

Fire hydrants should be opened and closed one at a time to minimize the effect on the water distribution system. Dry-barrel hydrants must be opened fully because the drain valve mechanism operates with the main valve. A partially opened fire hydrant **could** force water thorough the drain outlets under pressure, eroding the thrust block support from behind the fire hydrant. After the test, the hydrant barrel should be drained before tightening the outlet-nozzle cap; a tight outlet-nozzle cap could prevent proper drainage and possibly cause ice blockage in either the upper or lower barrels.

Gauge measurements should be taken only when the water is running clear, because sediment could damage the instruments.

Summary

This topic is about conducting evaluations of municipal water systems by conducting water supply tests at regular intervals; semiannually is recommended. Most important is the concept of preparing a *Water Flow Test Summary Sheet* for each test location, along with the information discussed above. These sheets are very important for monitoring the municipal water system at specific locations over time. When flow curves at the same location over succeeding tests do not match, there is a need to know why they do not match and identified problems need immediate attention.

Responding fire companies to specific fire risks need to have current information about water supplies. Therefore, all first-due fire companies should have a set of flow test sheets to make informed decisions on fire suppression tactics. This type of evaluation should be part of any cost reduction program.

Common Valve Operation Problems

Valve stem is improperly lubricated or damaged--I always like to find a bent brass stem. Just a small bend will make most valves difficult to operate. This also applies to misplaced valve boxes. It is best to disassemble the valve and inspect the stem. Acceptable deviation from theoretical centerline created by joining center points of the ends of the stem is 0.005"/ft of stem. Inspect the threads for any visible signs of damage. Small grooves less than 0.005" can be polished with an Emory cloth. Contact specialized services or an outside contractor if run-out is unacceptable or large grooves are discovered on the surface of the stem.

Valve packing compression is too tight--Verify the packing bolt torque and adjust if necessary.

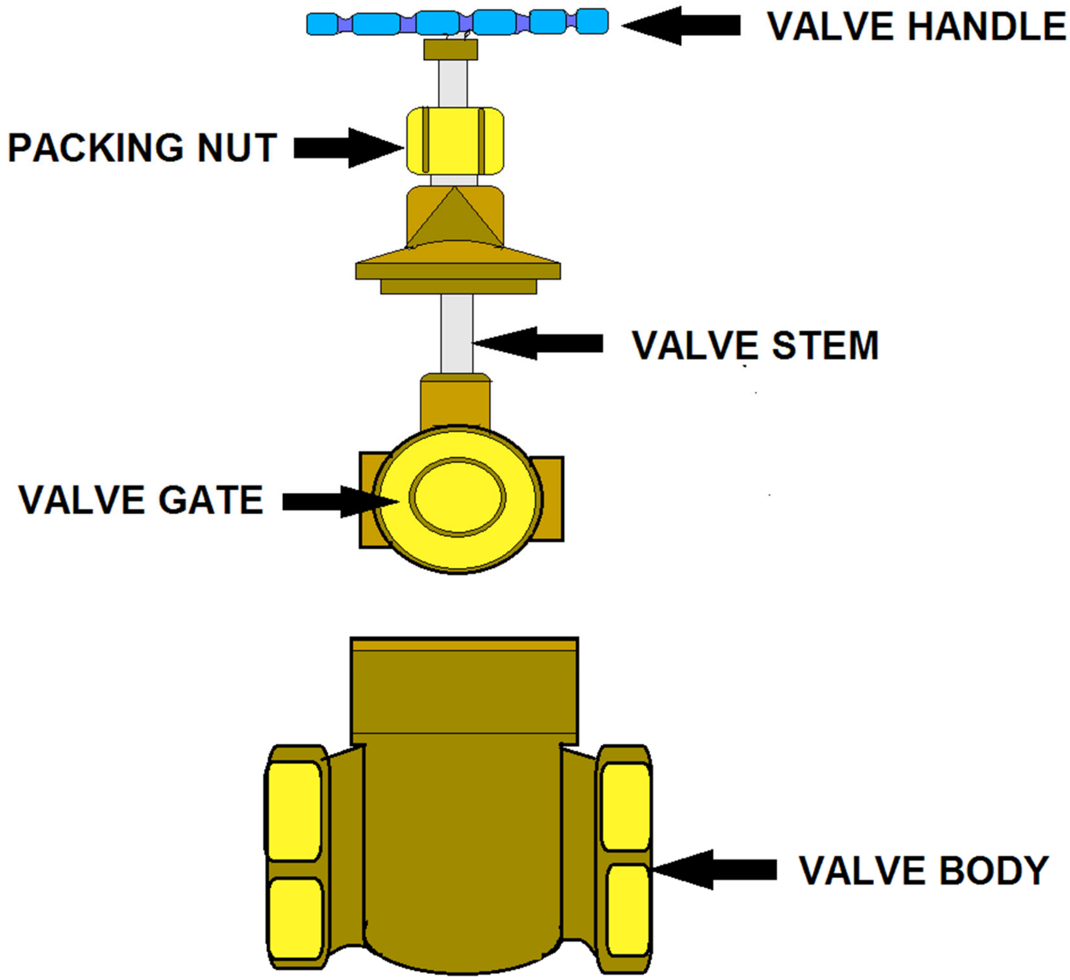
Foreign debris is trapped on threads and/or in the packing area. This is a common problem when valves are installed outdoors in sandy areas and in areas not cleaned before operating. Always inspect threads and packing area for particle obstructions; even seemingly small amounts of sand trapped on the drive can completely stop large valves from cycling. The valve may stop abruptly when a cycle is attempted. With the line pressure removed from the valve, disconnect the actuator, gear operator or handwheel and inspect the drive nut, stem, bearings and yoke bushing.

Contaminated parts should be cleaned with a lint-free cloth using alcohol, varsol or equivalent. All parts should be re-lubricated before re-assembly. If the valves are installed outdoors in a sandy area, it may be desirable to cover the valves with jackets.

Valve components are faulty or damaged--If you suspect that the valve components are damaged or faulty, contact the supply house or warehouse. Most valve salesmen will try to keep your business and do whatever possible to do so. In the last ten years only one manufacturer did not replace a faulty valve. It is one of the largest makers of water valves and blew me off. It was clearly a bad valve to begin with. Sad part of this story is that the large American valve companies have to deal with aggressive Chinese valve companies that will make things right to keep your business. Most of these valves that I have seen are great for most water and wastewater work. They have nice finishes and even come in stainless steel--Probably made from recycled American cars. I just hate to switch over to anything other than American but I guess we are living in a Global market.

The handwheel is too small--Increasing the size of the handwheel will reduce the amount of torque required to operate the valve. If a larger handwheel is installed, the person operating the valve must be careful not to over-torque the valve when closing it. Most Valve operators will have a set of special keys for the operation of most valves but a small wheel can present problems as well as no hand wheel.

Dr. Rusty's commentary. Over the years and at most systems, it seems that the institutional knowledge that most of the old timers have is priceless and under appreciated by most management. The reason I say this is most experienced Valvemen or Valve Operators know their system better than any map or GIS system.



WHEEL VALVE DIAGRAM

Slam, Surge and Water Hammer

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

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

The Effects of Water Hammer And Pulsations

Quick closing valves, positive displacement pumps, and vertical pipe runs can create damaging pressure spikes, leading to blown diaphragms, seals and gaskets, and also destroyed meters and gauges. Liquid, for all practical purposes, is not compressible; any energy that is applied to it is instantly transmitted. This energy becomes dynamic in nature when a force such as a quick closing valve or a pump applies velocity to the fluid.

Surge (Water Hammer)

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

For this reason, most pipe-sizing charts recommend keeping the flow velocity at or below 5 ft/s (1.5 m/s). If the pipe is suddenly closed at the outlet (downstream), the mass of water before the closure is still moving forward with some velocity, building up a high pressure and shock waves. In domestic plumbing this is experienced as a loud bang resembling a hammering noise. Water hammer can cause pipelines to break or even explode if the pressure is high enough. Air traps or stand pipes (open at the top) are sometimes added as dampers to water systems to provide a cushion to absorb the force of moving water in order to prevent damage to the system. (At some hydroelectric generating stations, what appears to be a water tower is actually one of these devices.) The water hammer principle can be used to create a simple water pump called a hydraulic ram.

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

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

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

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

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

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

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

Total Pressure = 437.5 + 50 = 487.5 psi

Pulsation

Pulsation generally occurs when a liquid's motive force is generated by reciprocating or peristaltic positive displacement pumps. It is most commonly caused by the acceleration and deceleration of the pumped fluid. This uncontrolled energy appears as pressure spikes. Vibration is the visible example of pulsation and is the culprit that usually leads the way to component failure. Unlike centrifugal pumps (which produce normally non-damaging high-frequency but low-amplitude pulses), the amplitude is the problem because it's the pressure spike.

The peak, instantaneous pressure required to accelerate the liquid in the pipe line can be greater than ten (10) times the steady state flow pressure produced by a centrifugal pump. Damage to seals gauges, diaphragms, valves and joints in piping result from the pressure spikes created by the pulsating flow.

Remedy

Suggest that you install a pulsation dampener or surge tank. Dampeners provide the most cost efficient and effective choice to prevent the damaging effects of pulsation. A surge suppressor is in design essentially the same as pulsation dampener. The difference primarily lies in sizing and pressurizing.

The most current pulsation dampener design is the hydro-pneumatic dampener, consisting of a pressure vessel containing a compressed gas, generally air or Nitrogen separated from the process liquid by a bladder or diaphragm.

Actuators and Control Devices

Directional control valves route the fluid to the desired actuator. They usually consist of a spool inside a cast iron or steel housing. The spool slides to different positions in the housing, and intersecting grooves and channels route the fluid based on the spool's position.

The spool has a central (neutral) position maintained with springs; in this position the supply fluid is blocked, or returned to tank. Sliding the spool to one side routes the hydraulic fluid to an actuator and provides a return path from the actuator to the tank. When the spool is moved to the opposite direction the supply and return paths are switched. When the spool is allowed to return to the neutral (center) position the actuator fluid paths are blocked, locking it in position.

Directional control valves are usually designed to be stackable, with one valve for each hydraulic cylinder, and one fluid input supplying all the valves in the stack.

Tolerances are very tight in order to handle the high pressure and avoid leaking, spools typically have a clearance with the housing of less than a thousandth of an inch. The valve block will be mounted to the machine's frame with a three point pattern to avoid distorting the valve block and jamming the valve's sensitive components.

The spool position may be actuated by mechanical levers, hydraulic pilot pressure, or solenoids which push the spool left or right. A seal allows part of the spool to protrude outside the housing, where it is accessible to the actuator.

The main valve block is usually a stack of off the shelf directional control valves chosen by flow capacity and performance. Some valves are designed to be proportional (flow rate proportional to valve position), while others may be simply on-off. The control valve is one of the most expensive and sensitive parts of a hydraulic circuit.

Pressure reducing valves reduce the supply pressure as needed for various circuits. Pressure relief valves are used in several places in hydraulic machinery: on the return circuit to maintain a small amount of pressure for brakes, pilot lines, etc.; on hydraulic cylinders, to prevent overloading and hydraulic line/seal rupture; on the hydraulic reservoir, to maintain a small positive pressure which excludes moisture and contamination.

Sequence valves control the sequence of hydraulic circuits; to insure that one hydraulic cylinder is fully extended before another starts its stroke, for example. Shuttle valves provide a logical function.

Check valves are one way valves, allowing an accumulator to charge and maintain its pressure after the machine is turned off, for example.

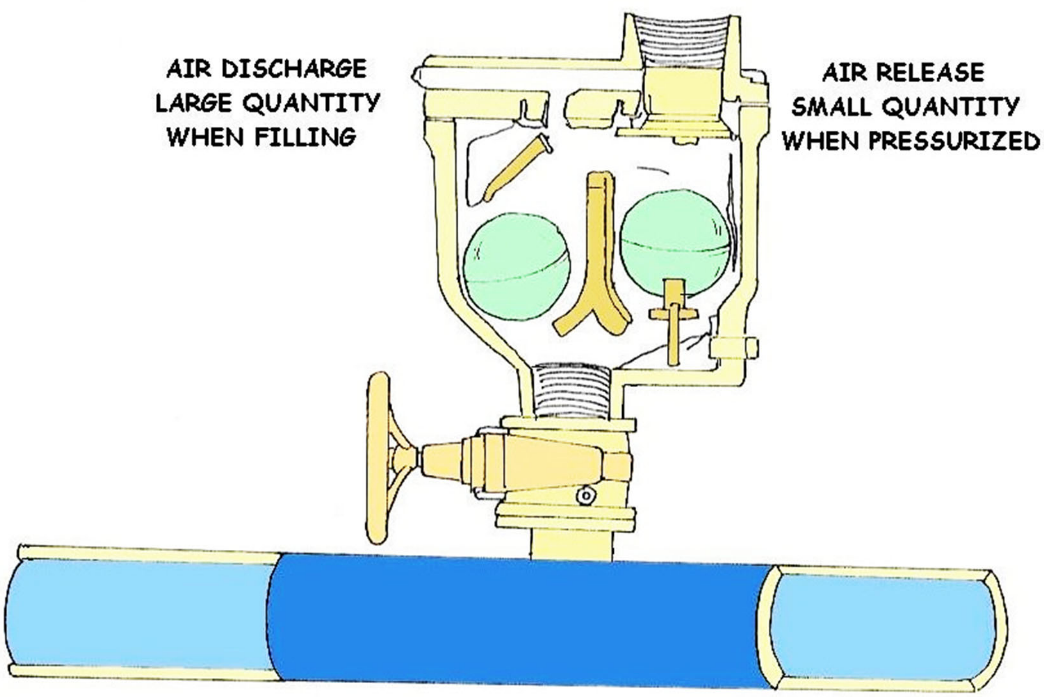
Pilot controlled Check valves are one way valves that can be opened (for both directions) by a foreign pressure signal. For instance, if the load should not be held by the check valve anymore. Often the foreign pressure comes from the other pipe that is connected to the motor or cylinder.

Counterbalance Valves
A counterbalance valve is, in fact, a special type of pilot controlled check valve. Whereas the check valve is open or closed, the counterbalance valve acts a bit like a pilot controlled flow control.

Cartridge valves are in fact the inner part of a check valve; they are off the shelf components with a standardized envelope, making them easy to populate a proprietary valve block. They are available in many configurations: on/off, proportional, pressure relief, etc. They generally screw into a valve block and are electrically controlled to provide logic and automated functions.

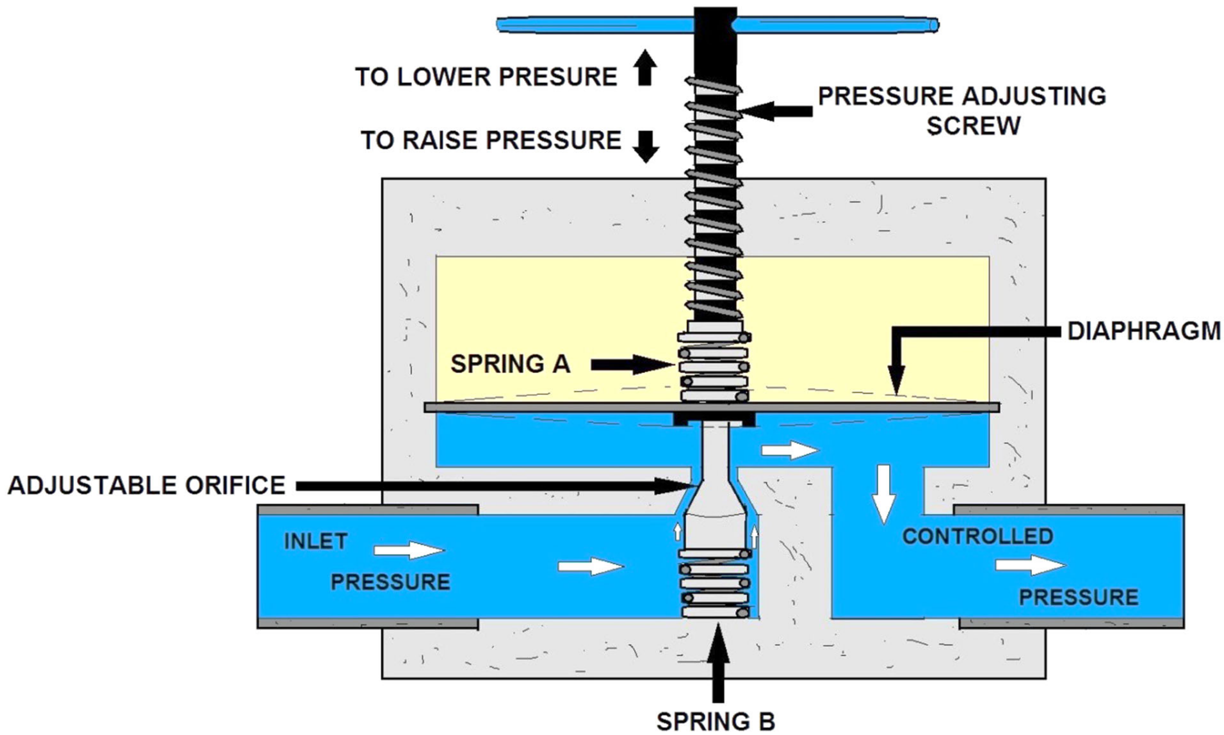
Hydraulic fuses are in-line safety devices designed to automatically seal off a hydraulic line if pressure becomes too low, or safely vent fluid if pressure becomes too high.

Auxiliary Valves
Complex hydraulic systems will usually have auxiliary valve blocks to handle various duties unseen to the operator, such as accumulator charging, cooling fan operation, air conditioning power, etc... They are usually custom valves designed for a particular machine, and may consist of a metal block drilled with ports and channels. Cartridge valves are threaded into the ports and may be electrically controlled by switches or a microprocessor to route fluid power as needed.



COMBINATION AIR RELIEF VALVE

Pressure Reducing Valves - *Rotary Valve*



PRESSURE – REGULATION VALVE DIAGRAM

Pressure Relief Valve

Pressure relief valves are used to release excess pressure that may develop as a result of a sudden change in the velocity of the water flowing in the pipe.

PRVs assist in a variety of functions, from keeping system pressures safely below a desired upper limit to maintaining a set pressure in part of a circuit. Types include relief, reducing, sequence, counterbalance, and unloading. All of these are normally closed valves, except for reducing valves, which are normally open. For most of these valves, a restriction is necessary to produce the required pressure control. One exception is the externally piloted unloading valve, which depends on an external signal for its actuation.

The most practical components for maintaining secondary, lower pressure in a hydraulic system are pressure-reducing valves. Pressure-reducing valves are normally open, 2-way valves that close when subjected to sufficient downstream pressure. There are two types: direct acting and pilot operated.

Direct acting - A pressure-reducing valve limits the maximum pressure available in the secondary circuit regardless of pressure changes in the main circuit, as long as the work load generates no back flow into the reducing valve port, in which case the valve will close.

The pressure-sensing signal comes from the downstream side (secondary circuit). This valve, in effect, operates in reverse fashion from a relief valve (which senses pressure from the inlet and is normally closed). As pressure rises in the secondary circuit, hydraulic force acts on area A of the valve, closing it partly. Spring force opposes the hydraulic force, so that only enough oil flows past the valve to supply the secondary circuit at the desired pressure. The spring setting is adjustable.

When outlet pressure reaches that of the valve setting, the valve closes except for a small quantity of oil that bleeds from the low-pressure side of the valve, usually through an orifice in the spool, through the spring chamber, to the reservoir.

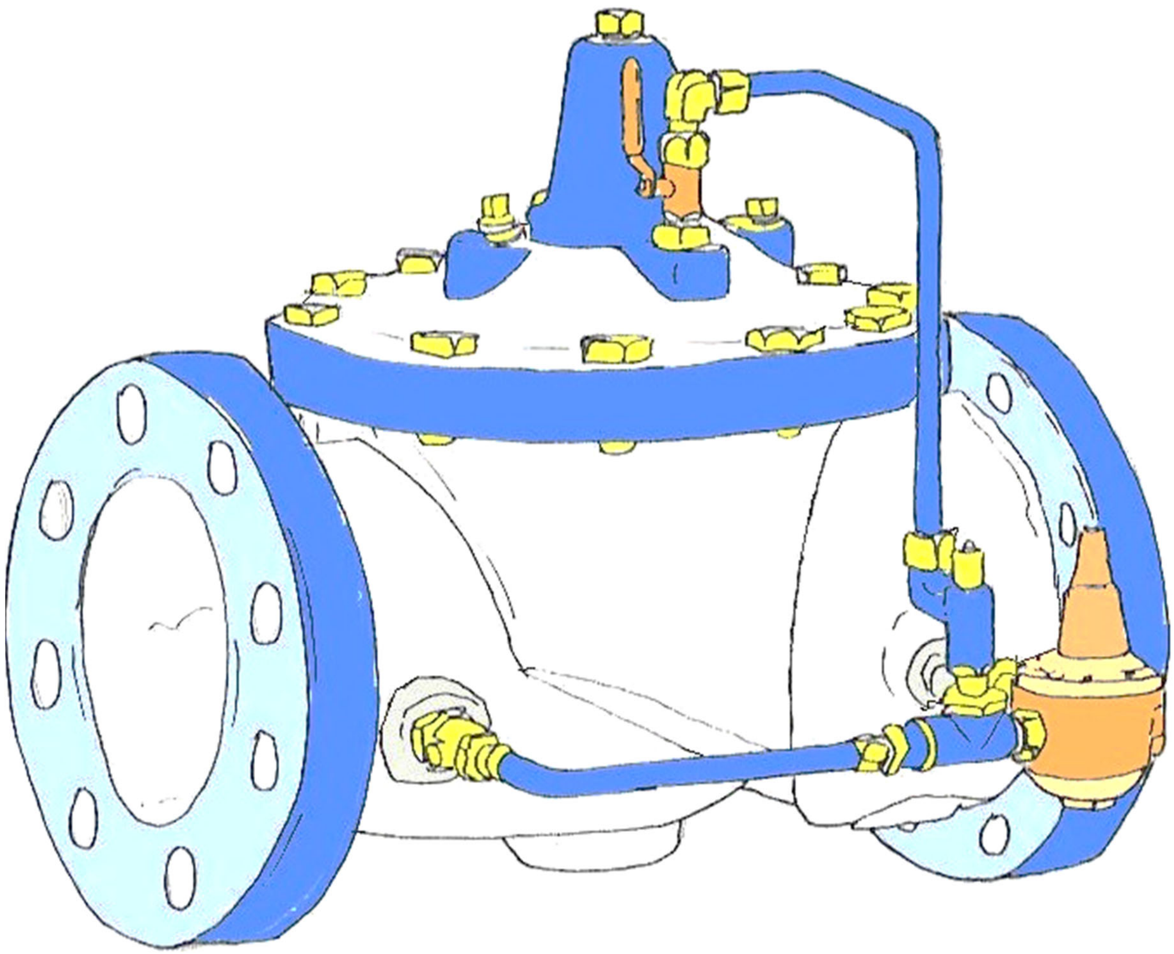
Should the valve close fully, leakage past the spool could cause pressure build-up in the secondary circuit. To avoid this, a bleed passage to the reservoir keeps it slightly open, preventing a rise in downstream pressure above the valve setting. The drain passage returns leakage flow to reservoir. (Valves with built-in relieving capability also are available to eliminate the need for this orifice.)

Constant and Fixed Pressure Reduction
Constant-pressure-reducing valves supply a preset pressure, regardless of main circuit pressure, as long as pressure in the main circuit is higher than that in the secondary. These valves balance secondary-circuit pressure against the force exerted by an adjustable spring which tries to open the valve. When pressure in the secondary circuit drops, spring force opens the valve enough to increase pressure and keep a constant reduced pressure in the secondary circuit. Fixed pressure reducing valves supply a fixed amount of pressure reduction regardless of the pressure in the main circuit. For instance, assume a valve is set to provide reduction of 250 psi.

If main system pressure is 2,750 psi, reduced pressure will be 2,500 psi; if main pressure is 2,000 psi, reduced pressure will be 1,750 psi. This valve operates by balancing the force exerted by the pressure in the main circuit against the sum of the forces exerted by secondary circuit pressure and the spring. Because the pressurized areas on both sides of the poppet are equal, the fixed reduction is that exerted by the spring.

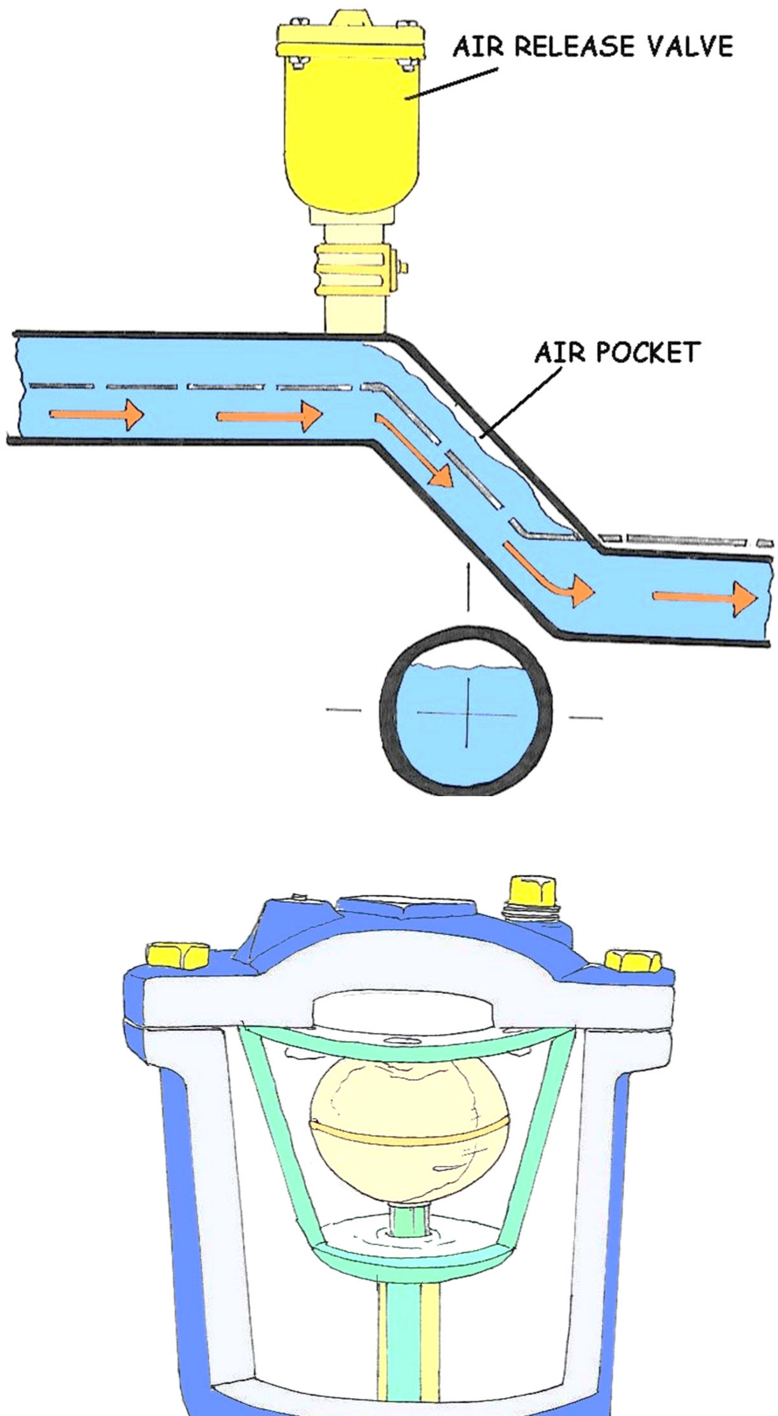
How do Pressure Relief Valves Operate?
Most pressure relief valves consist of a main valve and pilot control system. The basic main Cla-Val valve is called a Hytrol Valve. Often a small box can be connected to an existing pilot PRV valve to control the main Pressure Reducing Valve on the pipe network. This single box contains both the control electronics and an integral data logger to save the cost and space of having both a controller and a separate data logger.

There are basically two types of PRV controllers, either time-based (to reduce the pipe pressure at low demand times, e.g. at night) or flow modulated controllers which can realize leakage savings throughout the day and night (by adjusting the pressure according to the demand to prevent excessive pressure at any time of the day or night).

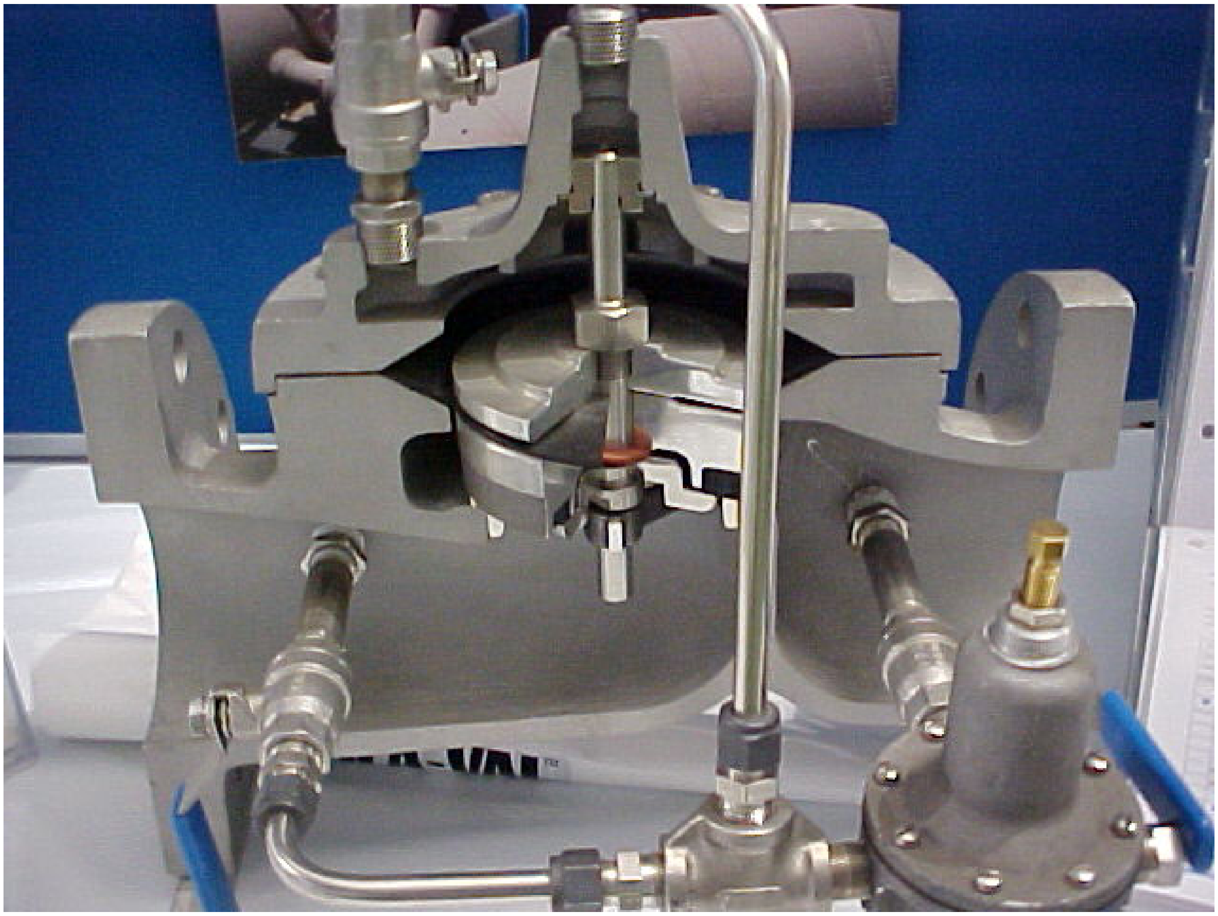


PRESSURE REDUCING VALVE EXAMPLE

When no pressure is in the valve, the spring and the weight of the diaphragm assembly holds the valve closed.

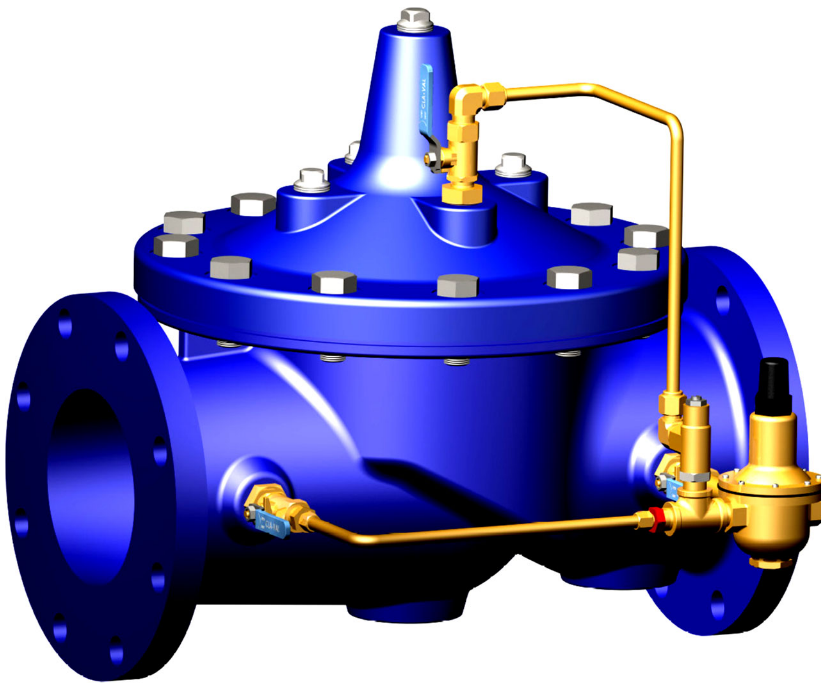


COMBINATION AIR RELIEF VALVE DIAGRAM #2

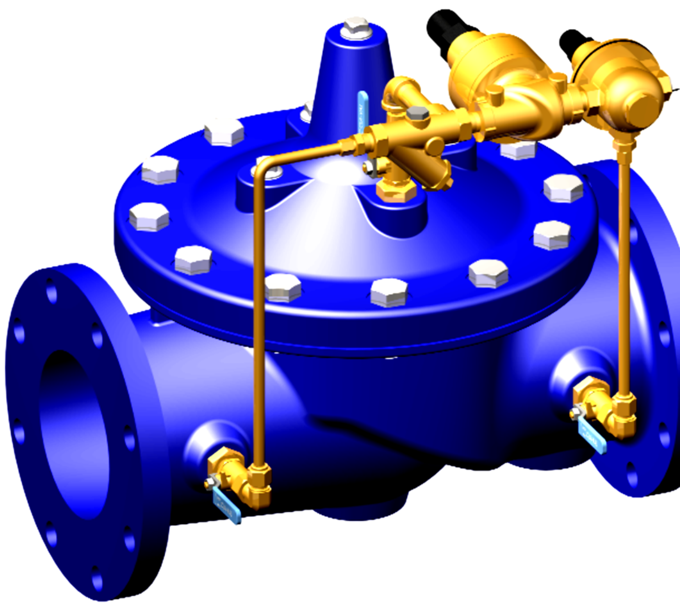


Municipal water distribution systems often have widely varying flow rates ranging from 7:00 am peak demand (or even fire-flow) to minimal 2:00am demand. One valve size cannot accurately control the wide range of flows.

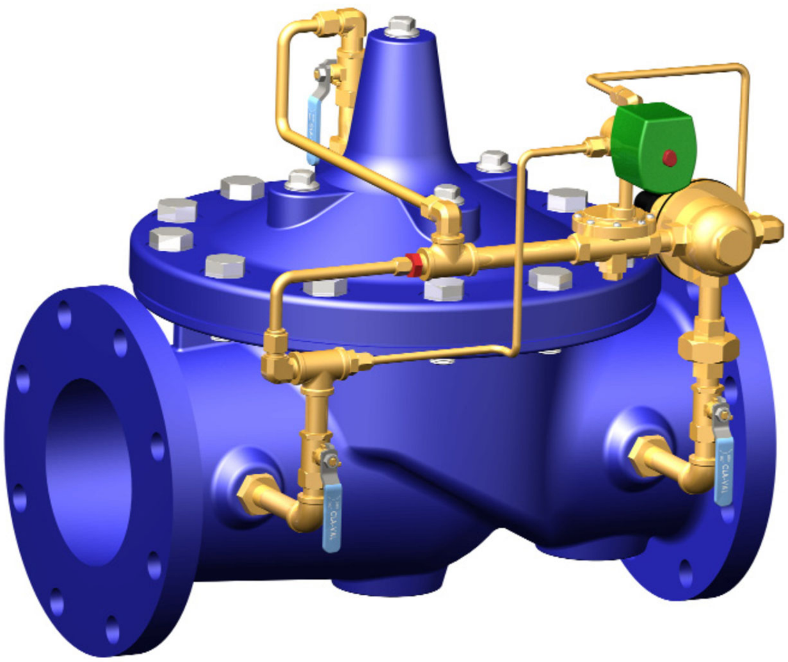
A low flow bypass pressure reducing valve is often used to control pressure at the low flow conditions. Both valves are open at maximum flow demand. The small valve is set at a slightly higher pressure than the larger valve.



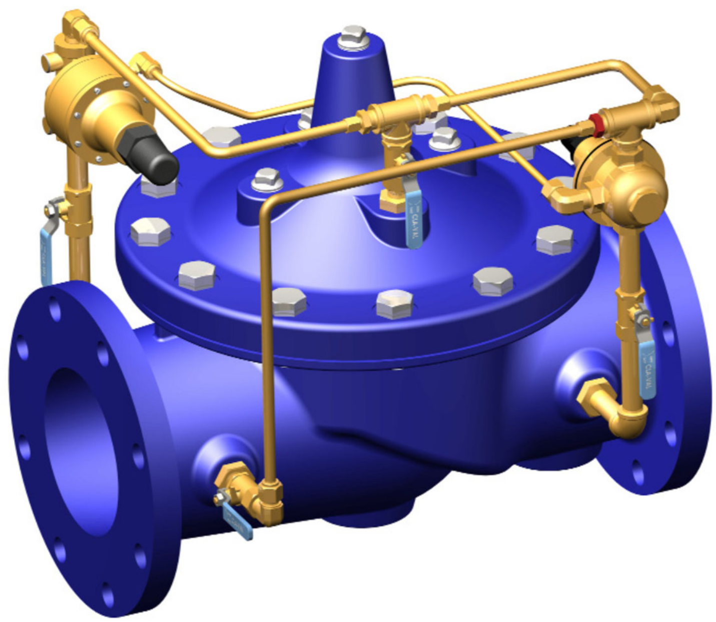
Pressure Reducing Valve
- Holds downstream pressure to a pre-determined limit.
- Optional check feature.
- Fully supported frictionless diaphragm.



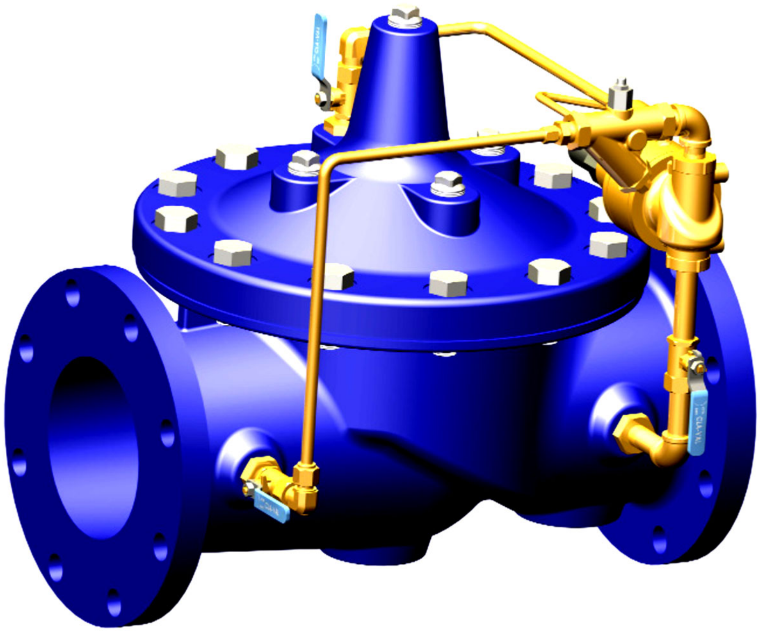
Pressure Reducing/Pressure Sustaining Control Valve
- Maintains downstream pressure regardless of fluctuating demand and sustains upstream pressure to a pre-set minimum.
- Optional check feature.



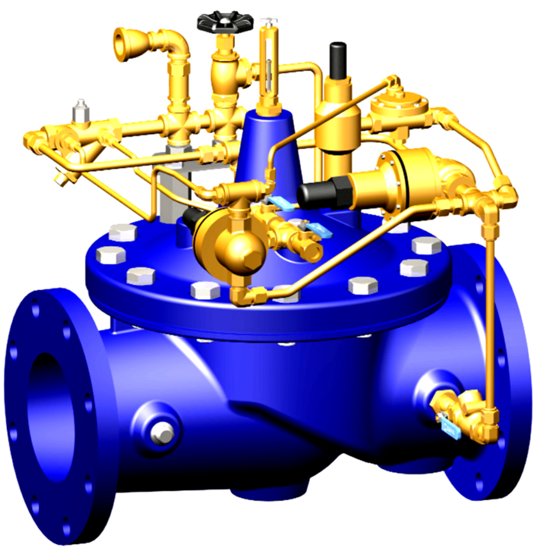
Pressure Reducing & Solenoid Shut-Off Valve Cla-Val 93 Series
• Ideal for reducing high transmission line pressures to lower distribution system pressures.
• Solenoid can be remotely activated.



Pressure Reducing & Surge Control Valve Cla-Val 94 Series
• Integral surge pilot opens to prevent rapid pressure increases.
• Optional check feature.

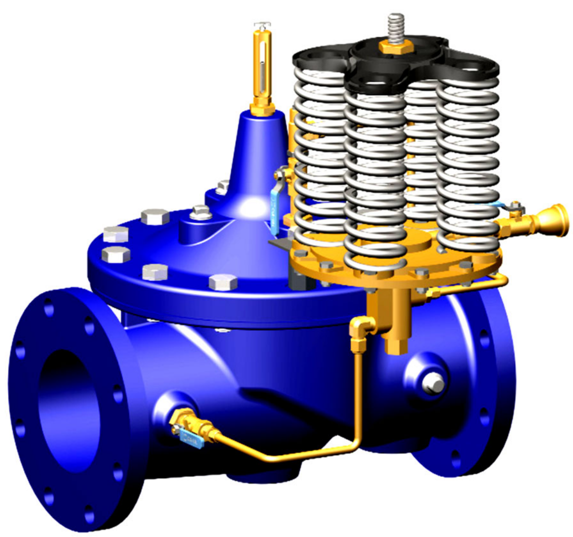


Pressure Relief/Pressure Sustaining Valve Cla-Val 50 Series
• Completely automatic operation.
• Accurate pressure control.
• Fast opening maintains line pressure.
• Slow closing prevents surges.
• Optional check feature.

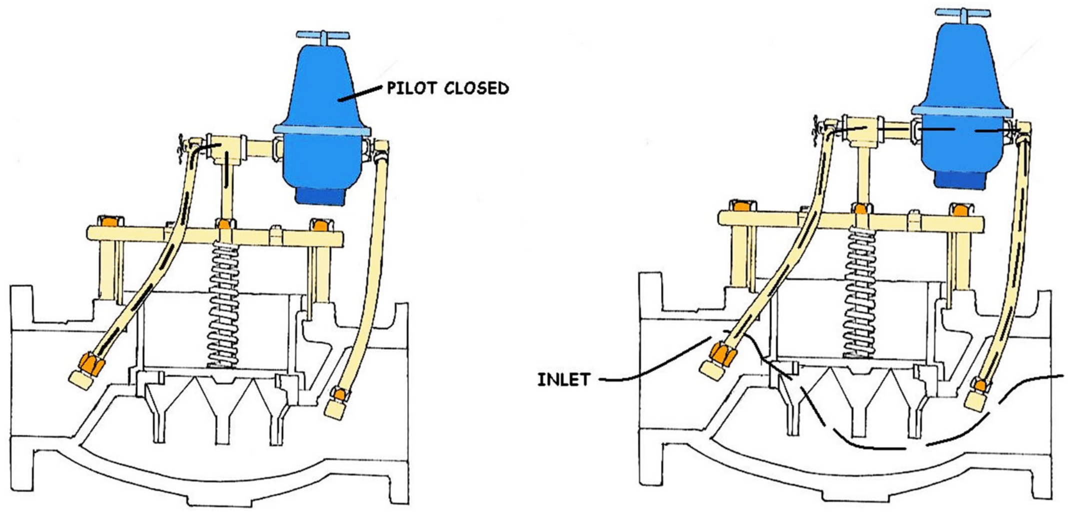


Surge Anticipator Valve Cla-Val 52 Series
• Protects pumping equipment and pipelines from damage caused by rapid flow velocity changes.
• Opens on initial low pressure wave.
• Closes slowly to prevent subsequent surges.

Float Valve Cla-Val 124 Series
- Accurate and repeatable level control in tanks to pre-set high and low points
- Reliable drip-tight shut-off.
- On-Off non-modulating action.
- Use Model 428-01 for modulating service.



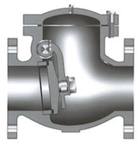
Altitude Control Valve Cla-Val 210 Series
- Provides accurate and repeatable tank level control.
- Optional check valve feature.
- Delayed opening option available.
- One-way and two-way flow pilot systems available.



REDUCED PRESSURE VALVE OPERATION
LEFT SIDE -VALVE CLOSED, RIGHT SIDE VALVE OPENED

Related In-Plant Valves

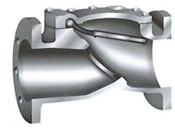
COMMONLY USED PUMP CHECK VALVES



Plain Swing check valve

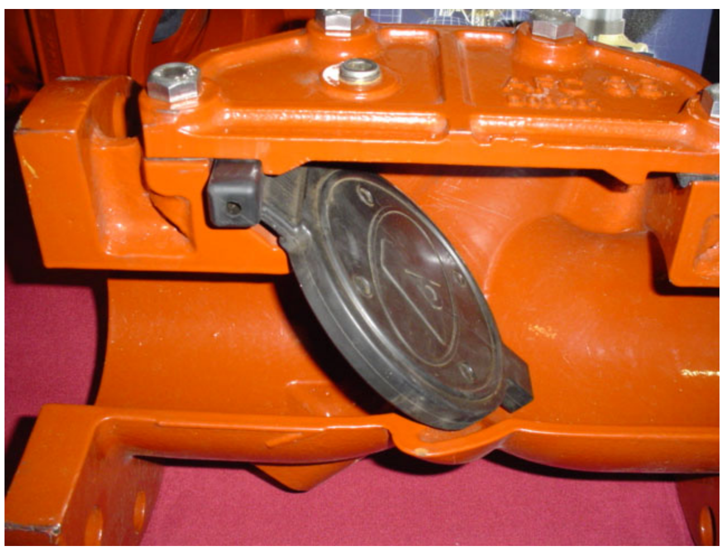
Lever and Spring Swing check valve

Lever and Weight Swing check valve



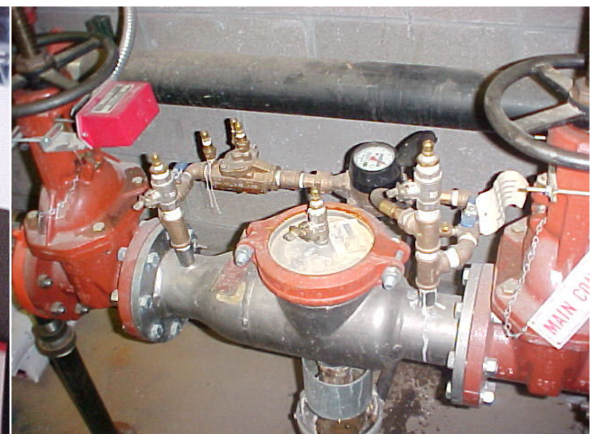
Rubber Flapper Swing check valve

Surge Relief valves are not usually employed due to short pipe runs in the plant.



A beautiful swing check valve. Swing checks need to be maintained. I hate finding a swing check that is both buried and forgotten, rusted in place or, my favorite, the check was removed.

Check Valves are not backflow preventors. The big difference is a legal term, “Backflow Prevention Assembly” that means two independent mechanical acting check valves with two independent shut offs which are checked annually by a certified general tester. We will explore the differences later. If I had to use a check valve, I would choose plastic and would check this device every six months because I don’t trust them. Why? Because everything that is mechanical is subject to failure. The bottom left photograph--a cut-away of a handsome spring loaded check valve. Right photograph--this looks like a check valve but really is a RP backflow preventer. Notice the smaller one in the background. Very bottom--A fireline check valve. This is probably the most political valve I can think of. Yes, I said political. Fire regulations are a whole new empire to work inside.



Hydraulic Principles Section

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.

The word "hydraulics" originates from the Greek word ὑδραυλικός (*hydraulikos*) which in turn originates from ὕδωρ (*hydor*, Greek for water) and αὐλός (*aulos*, meaning pipe).

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.

Free surface hydraulics is the branch of hydraulics dealing with free surface flow, such as occurring in rivers, canals, lakes, estuaries and seas. Its sub-field **open channel flow** studies the flow in open channels.

Hydrokinetics
Hydrokinetics is the science of water in motion. When a fire hydrant is opened with a cap removed from a discharge spout, the flowing water is a hydrodynamics problem. Hydrodynamics is a general term associated with the science of forces exerted on the pipe wall when water is flowing through a pipe, or the flowing pressure when a quantity of water is discharging from an open pipe or from an orifice device connected to the pipe, such as a fire hydrant opening. The potential energy (i.e., static pressure) becomes kinetic energy (i.e., residual pressure). The weight of the water based on the elevation head supply at the fire hydrant causes the water to move through the piping system and out of the fire hydrant discharge opening. Calculating the water supply and the pipe to supply fire hydrants is also a problem of hydrokinetics.

Fluid Mechanics
Fluid mechanics is the branch of physics that studies fluids (liquids, gases, and plasmas) and the forces on them. Fluid mechanics can be divided into fluid statics, the study of fluids at rest; fluid kinematics, the study of fluids in motion; and fluid dynamics, the study of the effect of forces on fluid motion. It is a branch of continuum mechanics, a subject which models matter without using the information that it is made out of atoms, that is, it models matter from a macroscopic

viewpoint rather than from a microscopic viewpoint. Fluid mechanics, especially fluid dynamics, is an active field of research with many unsolved or partly solved problems.

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.

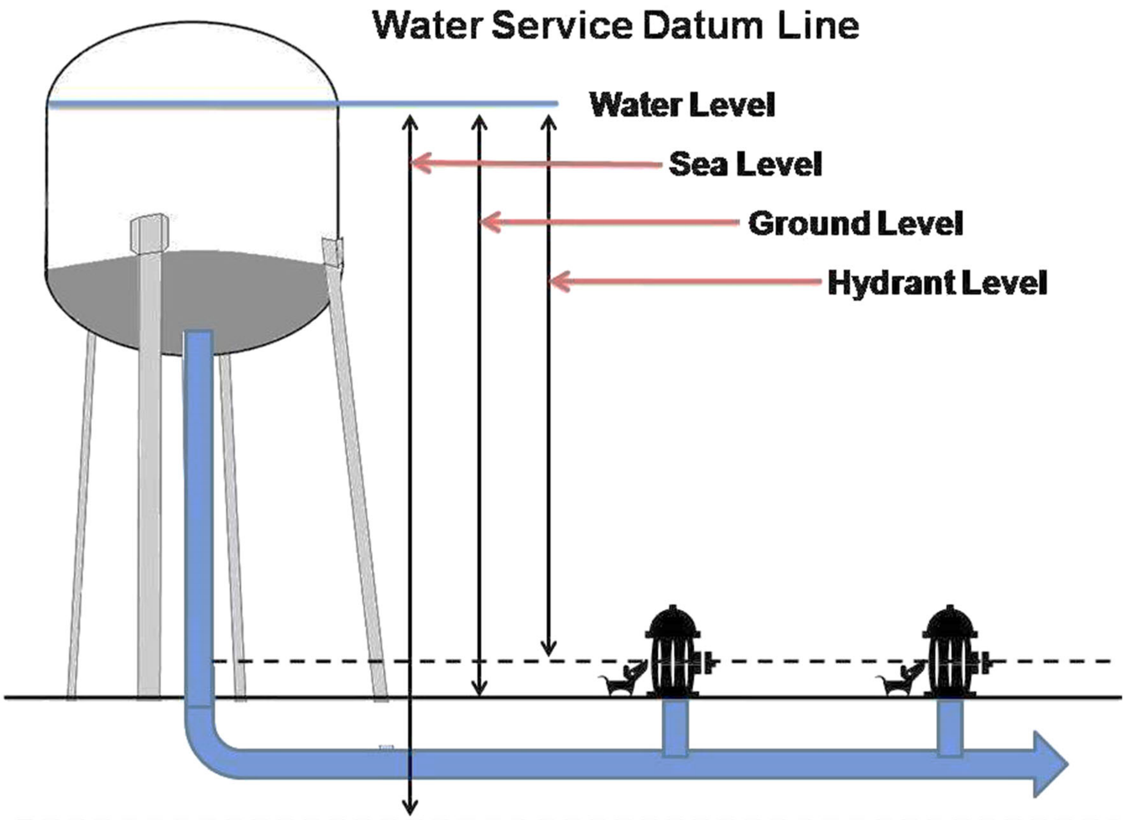
Geology has now shown us clearly that there are substances which can resist shearing forces over short time intervals, and appear to be typical solids, but which flow like liquids over long time intervals. Such materials include wax and pitch, ice, and even rock.

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.

Physical Characteristics of Water
Water is the only fluid considered in this text material. Therefore, it is important to define its physical characteristics and properties that affect hydraulic calculations involving both public and private water supply systems. The following characteristics should be considered for all calculations involving water supply systems.



Datum Line
A datum line is a line designating the potential energy of water; also a line that serves as the basis for mathematical computations. Water is a colorless liquid that takes the shape of the container in which it is placed. The top surface of the water seeks its own level and, therefore, is flat for practical considerations. The top level of the water in a container is often referred to as the **surface datum line**. The measurement is given in feet above sea level, or some other reference point.

Note that the underground pipe reference line may change with time if water is being used from the holding tank. In hydrokinetic problems, the water surface datum line is often referenced as the potential energy line. Storage is an important component in almost all distribution systems. It can serve the following purposes):

Equalization
Demands in a water system generally vary over the course of the day while water utilities prefer to operate their treatment facilities at a relatively constant rate. Distribution system water tanks and reservoirs frequently operate in fill-and-draw operation over the course of the day, thus providing the storage to accommodate the constant variations in water supply and demand. However, time-of-day variations in energy pricing may influence when wells and pumps are operated.

Pressure maintenance
The water level in tanks and reservoirs largely determine the pressure in areas served by a storage facility. In order to provide sufficient pressure in many situations, particularly at the top of the pressure zone, the water level in a storage facility must be maintained within a specific range.

Fire storage
Required or NFFs can be provided through a combination of fire storage in water tanks and reservoirs or through larger transmission lines and increased treatment capacities. In many water systems it appears that fire storage is the more economical means of meeting fire flow requirements. Dedicated water in storage for fire protection needs to be recycled weekly to prevent excessive aging and sedimentation. This can be done by bringing the tank “on line” and refilling from the top using a total flow meter to replenish the gallons of water drained from the tank. This technique keeps the tank 90 percent full at all times.

Emergency storage
In addition to fires, other emergencies such as power outages, equipment failures, water main breaks, and temporary loss of water supply facilities can result in insufficient water supply within the distribution system. Storage provides a mechanism for providing water under such emergency conditions.

In order to accommodate the various purposes of a water tank or reservoir, they are generally designed with a given amount of capacity targeted to each of the following specific uses:

- equalization storage: storage used to allow for normal fill and draw patterns;
- ineffective (passive) storage: storage used to provide the minimum pressure requirements;
- fire storage: storage to meet sufficient, required, or NFFs; and
- emergency storage: storage reserved for emergencies other than fires.

The actual storage requirements in each of these categories vary in different storage facilities based on local regulations, operating conditions, and hydraulic conditions. It should be understood that at some water utilities, fire storage and emergency storage maybe combined, based on the assumption that both fires and other emergencies are rare events and the simultaneous occurrence of fires and other emergencies is unlikely. With the added consideration of potential terrorist threats, the probability of simultaneous events may need to be considered in contingency planning for large city water supply systems.

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.

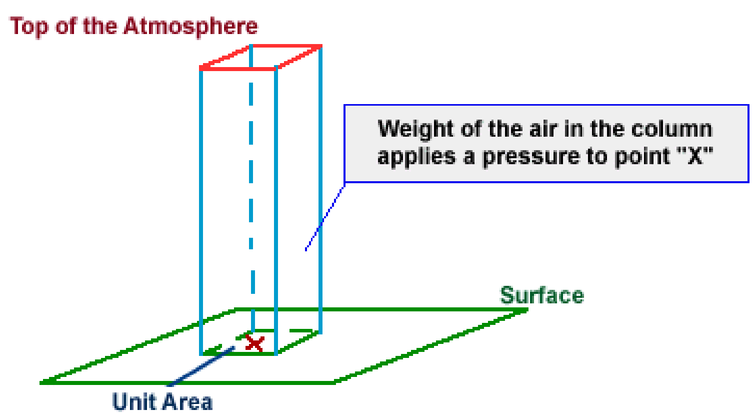
If a column of air 1-inch square extending all the way to the "***top***" of the atmosphere could be weighed, this column of air would weigh approximately 14.7 pounds at sea level. Thus, atmospheric pressure at sea level is approximately 14.7 psi.

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.



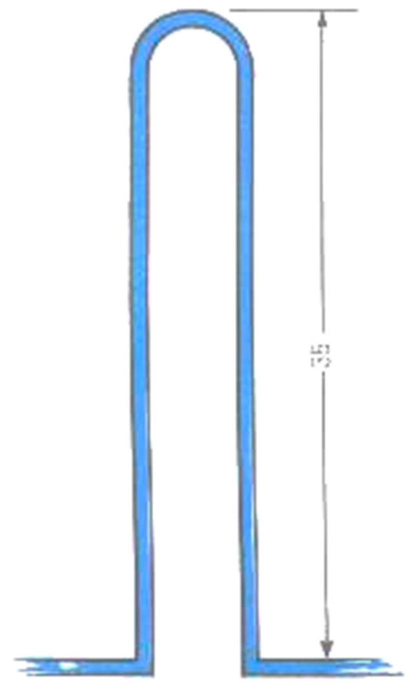
It is impossible to make a pressure measurement on the earth's surface unless it is made relative to atmospheric pressure. Therefore, a reference can be established at the atmospheric pressure level.

If the pressure one wishes to measure is at the same level, there will be zero pressure relative to atmospheric pressure. Pressure gauges, piezometers, and other pressure-flow measuring devices indicate **gauge** pressure.

Atmospheric pressure is equal to zero pressure on a gauge, often abbreviated as psig on gauges calibrated to register pounds per square inch.

Gauge pressures are positive if greater than atmospheric, and negative if less than atmospheric, or measured down from the atmospheric reference. Negative pressure also is called a vacuum.

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.

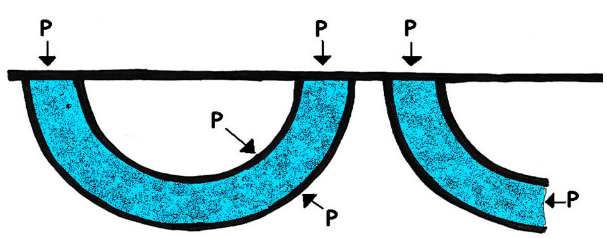
Absolute pressure is the total pressure.

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 –CURTAIN RINGS

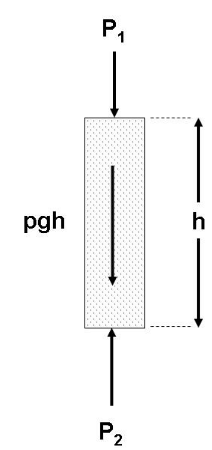
A fluid, therefore, is a substance that cannot exert any permanent forces tangential to a boundary. Any force that it exerts on a boundary must be normal to the boundary. Such a force is proportional to the area on which it is exerted, and is called a pressure. We can imagine any surface in a fluid as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



Increase of Pressure with Depth

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

This is simply 2117 / 62.4 = 33.9 ft of water. This is the maximum height to which water can be raised by a suction pump, or, more correctly, can be supported by atmospheric pressure. Professor James Thomson (brother of William Thomson, Lord Kelvin) illustrated the equality of pressure by a "curtain-ring" analogy shown in the diagram. A section of the toroid was identified, imagined to be solidified, and its equilibrium was analyzed.

The forces exerted on the curved surfaces have no component along the normal to a plane section, so the pressures at any two points of a plane must be equal, since the fluid represented by the curtain ring was in equilibrium.

The diagram illustrates the equality of pressures in orthogonal directions. This can be extended to any direction whatever, so Pascal's Principle is established. This demonstration is similar to the usual one using a triangular prism and considering the forces on the end and lateral faces separately.

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.

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).

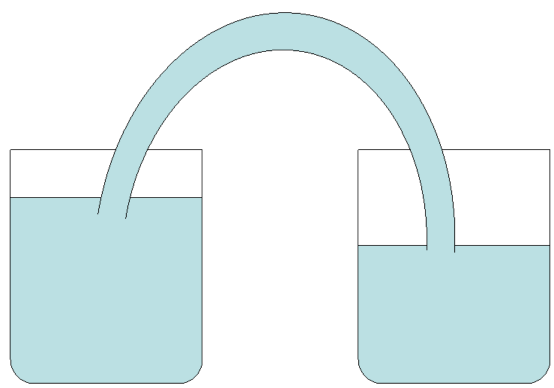
Vacuum

A perfect vacuum is a space entirely devoid of gas, liquids, and solids. The literature on this subject indicates that only the National Aeronautics and Space Administration (NASA) in space has ever succeeded in exhausting all the air from a closed vessel.

This applies to suction pipes on stationary fire pumps. Therefore, the word **vacuum** actually means **practical vacuum**, and is measured by the amount of this pressure below the prevailing atmospheric pressure. Vacuum is measured by **gauges** graduated in inches of mercury (Hg).

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.

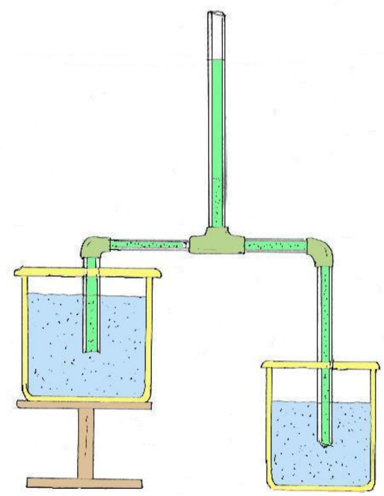
In a partial vacuum, the pressure would range from slightly less than 14.7 psia (0 psig) to slightly greater than 0 psia (-14.7 psig). Backsiphonage results from atmospheric pressure exerted on a liquid, forcing it toward a supply system that is under a vacuum.



Siphon

More on 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.


PASCAL'S SIPHON

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.

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.

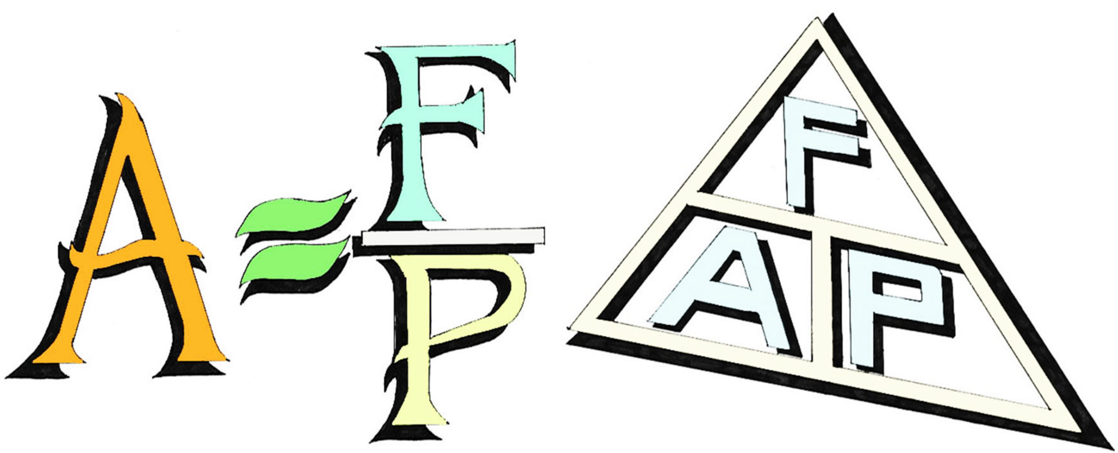
Pressure and Force
Pressure is the force that pushes water through pipes. Water pressure determines the flow of water from the tap. If pressure is not sufficient then the flow can reduce to a trickle and it will take a long time to fill a kettle or a cistern.

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:

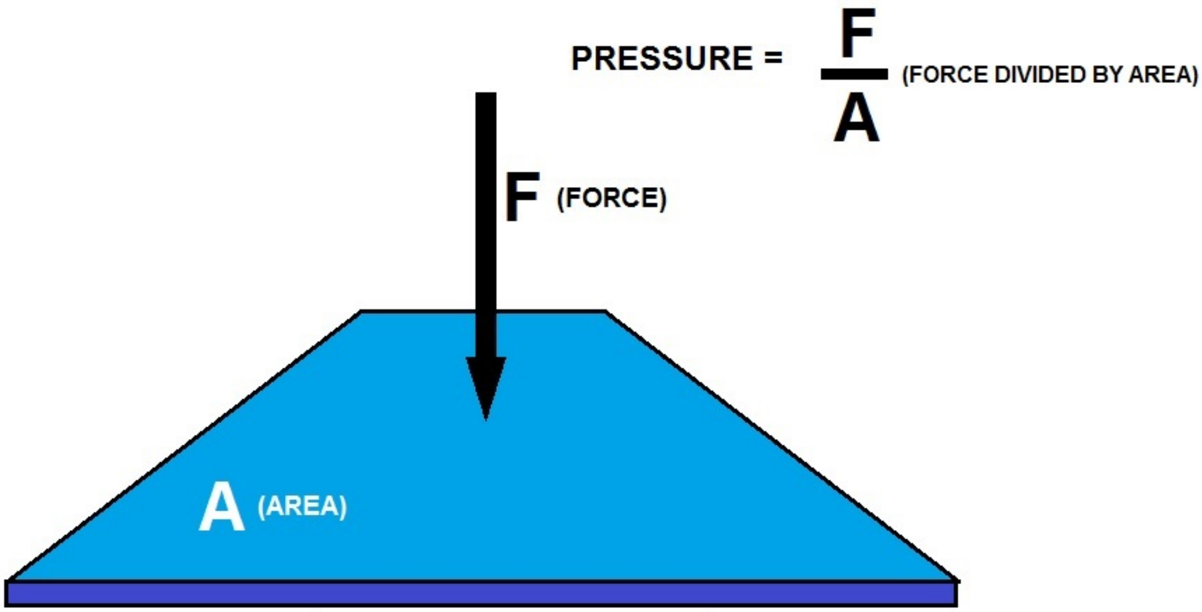


DANIEL BERNOULLI (1700-1782)

Daniel Bernoulli was born in Groningen, in the Netherlands, into a family of distinguished mathematicians. The Bernoulli family came originally from Antwerp, at that time in the Spanish Netherlands, but emigrated to escape the Spanish persecution of the Huguenots. After a brief period in Frankfurt the family moved to Basel, in Switzerland.

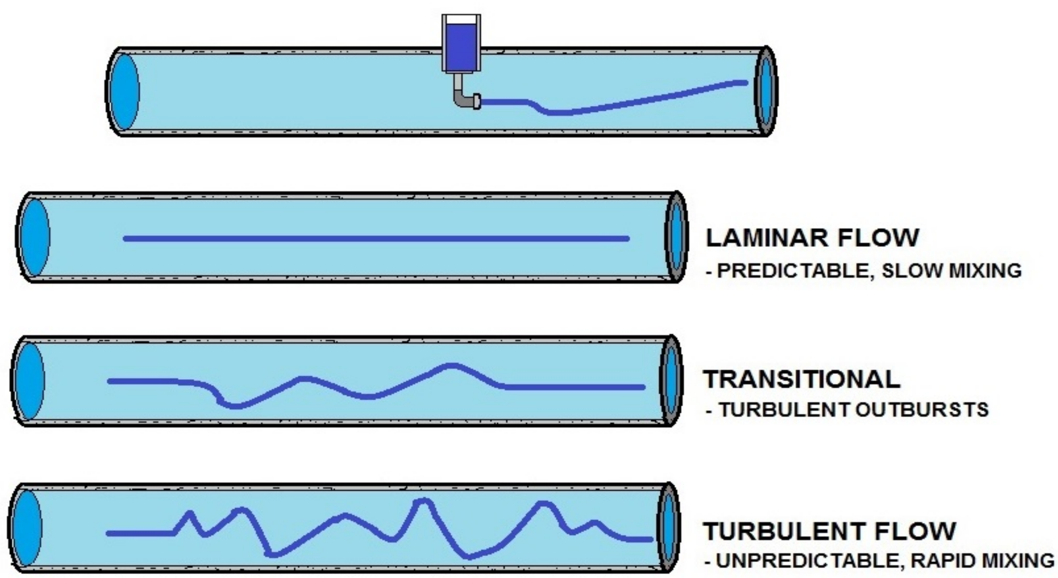
Daniel was the son of Johann Bernoulli (one of the "early developers" of calculus), nephew of Jakob Bernoulli (who "was the first to discover the theory of probability"), and older brother of Johann II. Daniel Bernoulli was described by W. W. Rouse Ball as "by far the ablest of the younger Bernoullis". He is said to have had a bad relationship with his father, Johann. Upon both of them entering and tying for first place in a scientific contest at the University of Paris, Johann, unable to bear the "shame" of being compared as Daniel's equal, banned Daniel from his house. Johann Bernoulli also plagiarized some key ideas from Daniel's book *Hydrodynamica* in his own book *Hydraulica* which he backdated to before *Hydrodynamica*. Despite Daniel's attempts at reconciliation, his father carried the grudge until his death.

When Daniel was seven, his younger brother Johann II Bernoulli was born. Around schooling age, his father, Johann Bernoulli, encouraged him to study business, there being poor rewards awaiting a mathematician. However, Daniel refused, because he wanted to study mathematics. He later gave in to his father's wish and studied business.

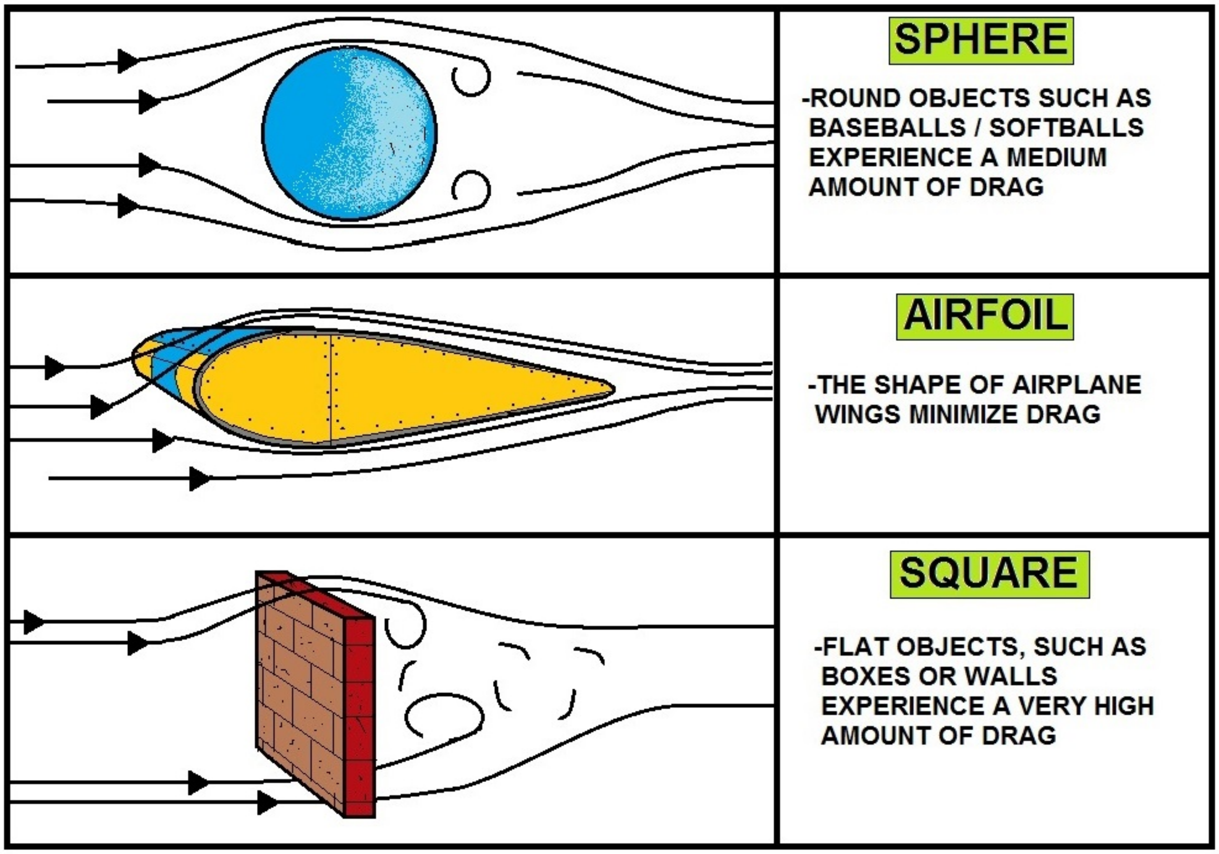


WHAT IS PRESSURE?

PRESSURE IS THE AMOUNT OF FORCE ACTING ON A SPECIFIC AREA AND IS EQUAL TO THE FORCE DIVIDED BY THE AREA

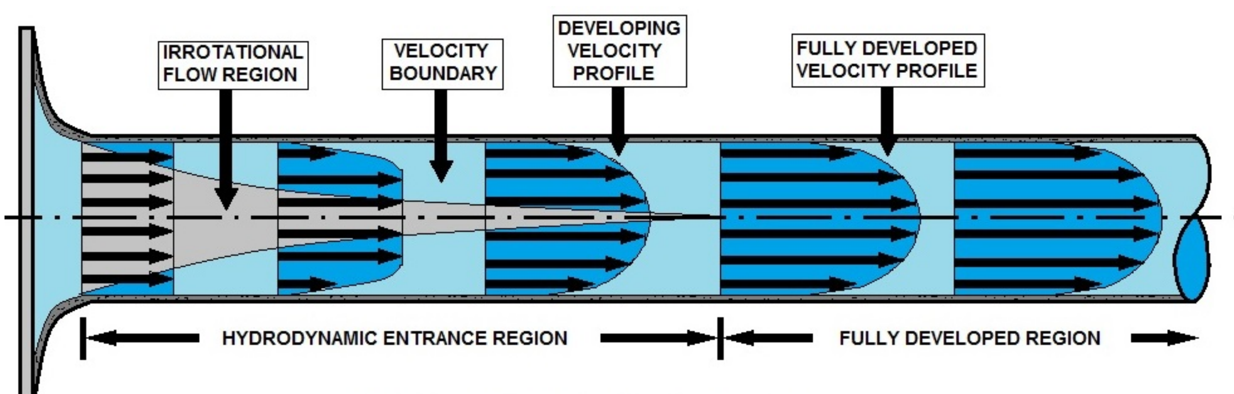


FLOW CHARACTERISTICS IN PIPING



DRAG FORCE (VISCOUS)

- THIS IS THE FORCE OF FRICTION CAUSED BY FLOWING FLUID
- IN THE OPPOSITE DIRECTION TO THE MOVEMENT OF FLUID



BREAKDOWN OF WATER FLOW IN A PIPE

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 center 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; see on right). He also showed that air had weight, and how much force it did require to separate 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 as shown, 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/cm2. 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/cm2, 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/cm2.

A kilogram-force per square centimeter is 981,000 dyne/cm2, 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.

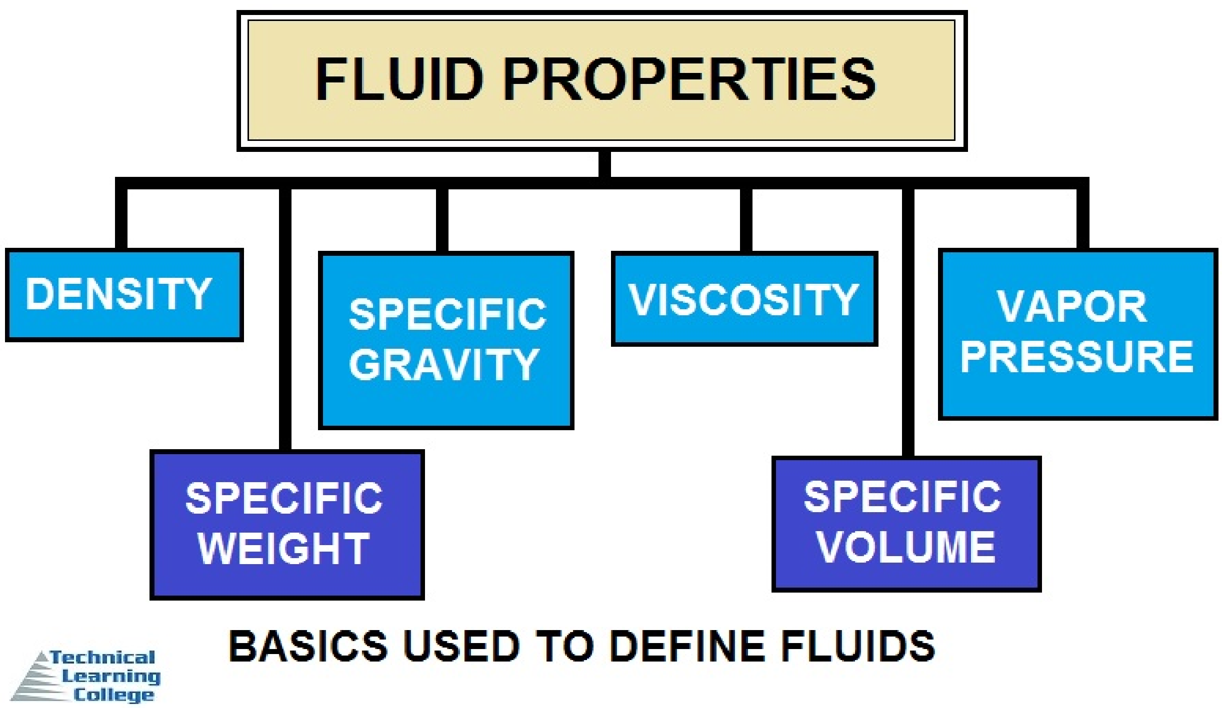
To see what happens in this case, we can make use of the ideal gas equation of state, $p = \rho RT/M$, and assume that the temperature T is constant. Then the change of pressure in a change of altitude dh is $dp = -\rho g\, dh = -(pM/RT)\, gdh$, or $dp/p = -(Mg/RT)\, dh$.

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 $p = p0\exp(-Mgh/RT)$.

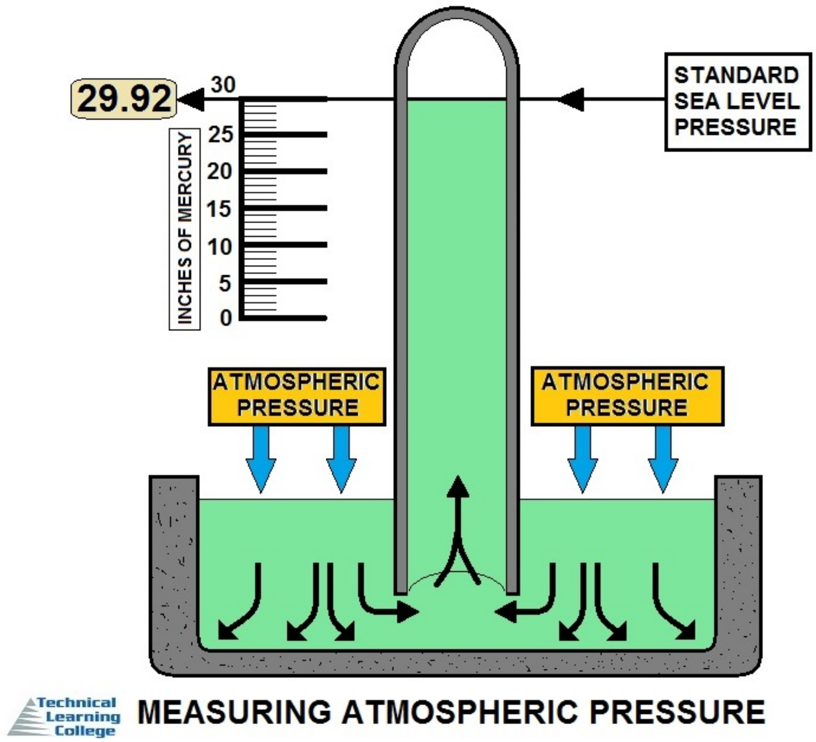
In an isothermal atmosphere, the pressure decreases exponentially. The quantity $H = RT/Mg$ is called the "height of the homogeneous atmosphere" or the scale height, and is about 8 km at T = 273K.

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 the 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.

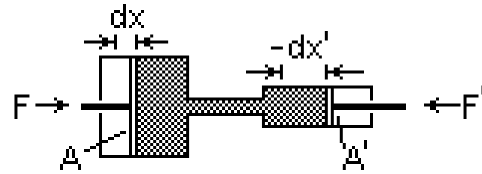
In fact, altitude is quite a problem in meteorology, since pressures must be measured at a common level to be meaningful.

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.

The Hydraulic Lever

A cylinder and piston is a chamber of variable volume, a mechanism for transforming pressure to force.



Hydraulic Lever

If A is the area of the cylinder, and p the pressure of the fluid in it, then F = pA is the force on the piston. If the piston moves outwards a distance dx, then the change in volume is dV = A dx.

The work done by the fluid in this displacement is dW = F dx = pA dx = p dV. If the movement is slow enough that inertia and viscosity forces are negligible, then hydrostatics will still be valid. A process for which this is true is called quasi-static. Now consider two cylinders, possibly of different areas A and A', connected with each other and filled with fluid. For simplicity, suppose that there are no gravitational forces.

Then the pressure is the same, p, in both cylinders. If the fluid is incompressible, then dV + dV' = 0, so that dW = p dV + p dV' = F dx + F' dx' = 0. This says the work done on one piston is equal to the work done by the other piston: the conservation of energy. The ratio of the forces on the pistons is F' / F = A' / A, the same as the ratio of the areas, and the ratios of the displacements dx' / dx = F / F' = A / A' is in the inverse ratio of the areas. This mechanism is the hydrostatic analogue of the lever, and is the basis of hydraulic activation.

Bramah Hydraulic Press

The most famous application of this principle is the Bramah hydraulic press, invented by Joseph Bramah (1748-1814), who also invented many other useful machines, including a lock and a toilet. Now, it was not very remarkable to see the possibility of a hydraulic press; what was remarkable was to find a way to seal the large cylinder properly.

This was the crucial problem that Bramah solved by his leather seal that was held against the cylinder and the piston by the hydraulic pressure itself. In the presence of gravity, p' = p + ρgh, where h is the difference in elevation of the two cylinders. Now, p' dV' = -dV (p + ρgh) =-p dV - (ρ dV) gh, or the net work done in the process is p' dV' + p dV = -dM gh, where dM is the mass of fluid displaced from the lower cylinder to the upper cylinder. Again, energy is conserved if we take into account the potential energy of the fluid. Pumps are seen to fall within the province of hydrostatics if their operation is quasi-static, which means that dynamic or inertia forces are negligible.

Pascal’s Law

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

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

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

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

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

Gravity

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

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

Static Pressure

Static pressure exists in addition to any dynamic factors that may also be present at the same time. Pascal’s law states that a pressure set up in a fluid acts equally in all directions and at right angles to the containing surfaces. This covers the situation only for fluids at rest or practically at rest. It is true only for the factors making up static head.

Obviously, when velocity becomes a factor it must have a direction, and as previously explained, the force related to the velocity must also have a direction, so that Pascal's law alone does not apply to the dynamic factors of fluid power.

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

Volume and Velocity of Flow

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

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

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

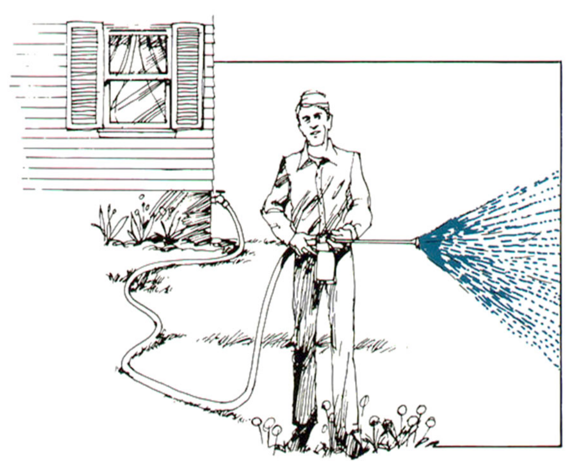
Bernoulli's Principle

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

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

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

Action of a spray atomizer→

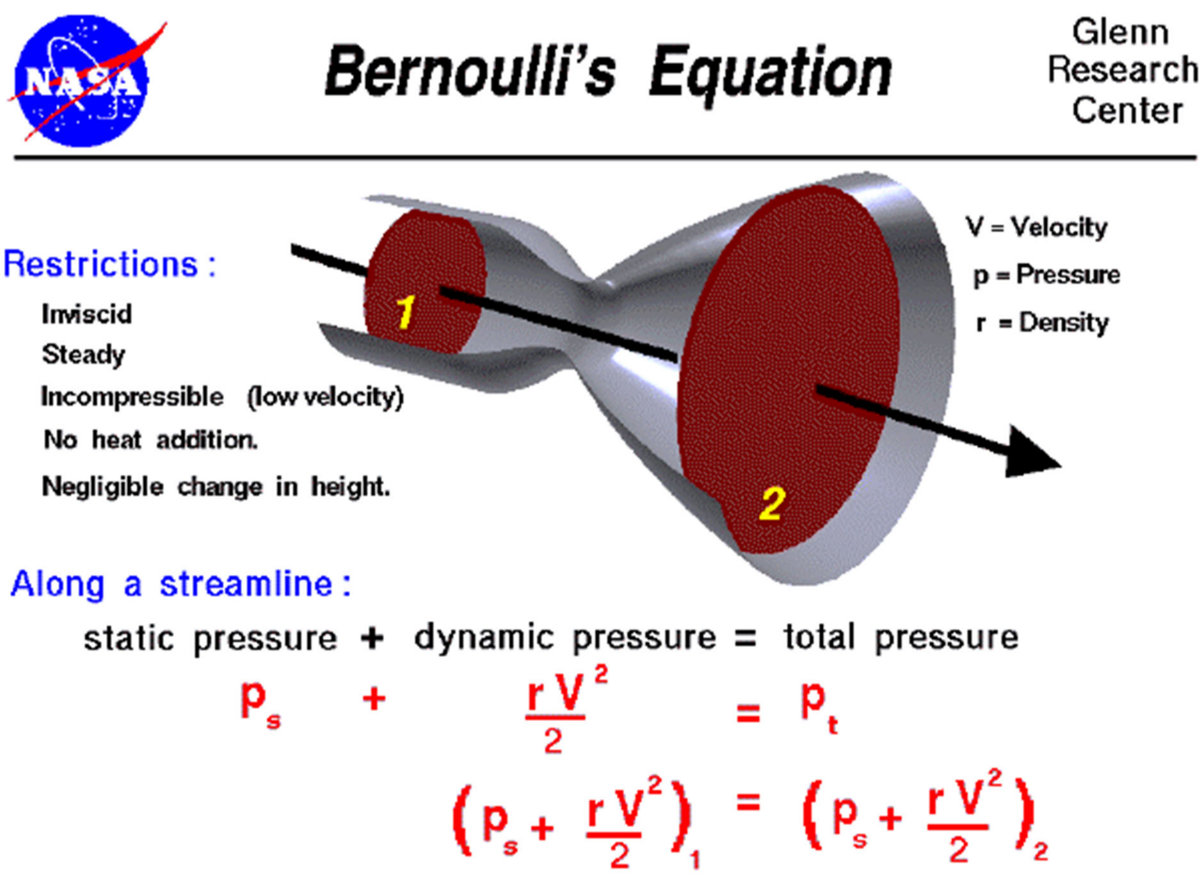


Bernoulli's principle also tells us why windows tend to explode, rather than implode in hurricanes: the very high speed of the air just outside the window causes the pressure just outside to be much less than the pressure inside, where the air is still.

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.



BLAISE PASCAL (1623-1662)

Blaise Pascal 19 June 1623 – 19 August 1662) was a French mathematician, physicist, inventor, writer and Christian philosopher. He was a child prodigy who was educated by his father, a tax collector in Rouen. Pascal's earliest work was in the natural and applied sciences where he made important contributions to the study of fluids, and clarified the concepts of pressure and vacuum by generalizing the work of Evangelista Torricelli. Pascal also wrote in defense of the scientific method.

In 1642, while still a teenager, he started some pioneering work on calculating machines. After three years of effort and fifty prototypes, he invented the mechanical calculator. He built 20 of these machines (called Pascal's calculator and later pascaline) in the following ten years. Pascal was an important mathematician, helping create two major new areas of research: he wrote a significant treatise on the subject of projective geometry at the age of 16, and later corresponded with Pierre de Fermat on probability theory, strongly influencing the development of modern economics and social science. Following Galileo and Torricelli, in 1646 he refuted Aristotle's followers who insisted that nature abhors a vacuum. Pascal's results caused many disputes before being accepted.

In 1646, he and his sister Jacqueline identified with the religious movement within Catholicism known by its detractors as Jansenism. His father died in 1651. Following a mystical experience in late 1654, he had his "second conversion", abandoned his scientific work, and devoted himself to philosophy and theology. His two most famous works date from this period: the *Lettres provinciales* and the *Pensées*, the former set in the conflict between Jansenists and Jesuits. In this year, he also wrote an important treatise on the arithmetical triangle. Between 1658 and 1659 he wrote on the cycloid and its use in calculating the volume of solids. Pascal had poor health especially after his 18th year and his death came just two months after his 39th birthday.

The Bernoulli Theorem

The work of John Bernoulli in 1772 was a continuing exposition on the theory of water in conduits. The basic principle that Bernoulli discovered is the one most often used in hydraulics and is generally described as the law of conservation of water energy, or simply Bernoulli's Theorem. It is one of the most fundamental and far-reaching statements concerning fluid mechanics and it applies Newton's law of conservation of energy to the flow of water. It is stated in the equation:

$$V12/2g+P1/w+Z1=V22/2g+P2/w+Z2$$

The values in this equation are defined as follows: V is the velocity in ft/sec; g is the acceleration of gravity which is 32.2 ft/sec2; P is pressure in lb/ft^2; Z is elevation head in feet; and w is the specific weight of the fluid in lb/ft^3.

Essentially, the equation states that the total head is equal to the pressure head plus the velocity head plus the static head at reference point 1; and this relationship holds at all other points in a continuous fluid medium. It stands to reason that this includes water. Since all terms in the above equation are given in units of head (feet), each term in the expression is called respectively, velocity head, pressure head, and potential head. Elevation head and pressure head are related directly to the potential energy of a given water system. The potential energy may be considered as the difference in height or head through which the quantity of water can flow from an established elevation level to one or more defined flow points.

As a first concept, consider the relationship of potential head for the first two fire hydrants between the gravity tank and the warehouse. Since Z1 = Z2 because they are at the same elevation level or datum line, the two terms cancel out of the analysis of flow at each hydrant reference point. Therefore, the Bernoulli Equation can be written to express flow energy with reference to hydrants 1 and 2; the basic equation now can be referenced as the following formula:

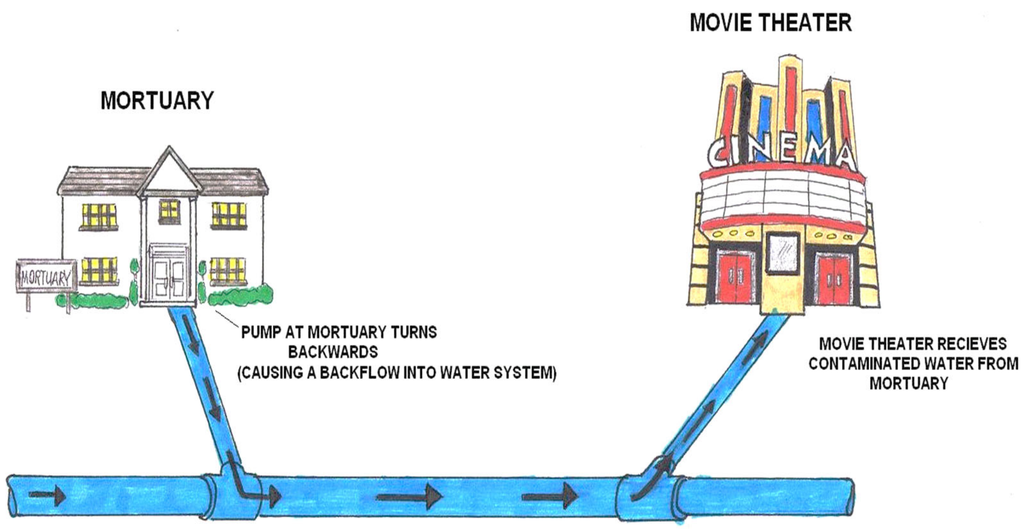
$$V12/2g=V22/2g+H(L)$$

Where: *H(L)* is treated as energy loss to the resistance of a given quantity of water flow between the two fire hydrants. Head loss may be defined broadly as friction loss, although friction loss is influenced by a number of factors. In summary, it should be noted that at hydrant 1, head pressures, *H(p)*=V12 /2g (velocity head as a function of kinetic energy) + the pressure intensity, *P/w*. Therefore the total energy at hydrant 1 is a function of the velocity head and the pressure head intensity.

Based upon the illustrations developed to this point, it should be noted that the head pressure has been created by gravitational force due to the weight of water contained in the gravity tank. The term total head pressure is used synonymously with total pressure intensity.

Different types of pumps or pressure tanks can be used to create pressure head and velocity head in contrast to the influence of gravity.

Without adequate and reliable water supplies at fire hydrants to protect fire risks, the best-trained firefighters with the best of equipment have only a very limited opportunity of protecting lives in a building fire and confining, controlling to the area of origin, and extinguishing a hostile fire. Therefore, it is essential that community officials, from the highest ranking administrator/ manager, to the water department superintendent or an equal authority, and the ranking fire chief, provide means and opportunity to monitor the community water system's performance capability constantly.



Backflow - Backsiphonage Situation

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.

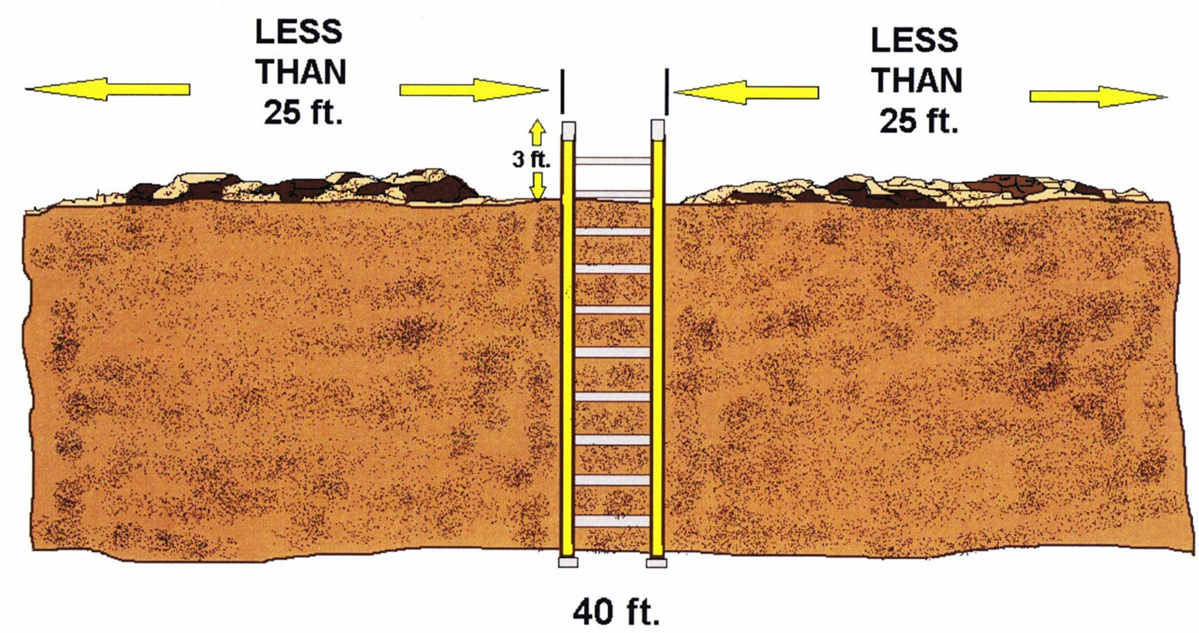
When funeral home personnel used the aspirator during a period of low water pressure, the potable water system at the funeral home became contaminated. Instead of body fluids flowing into the wastewater system, they were drawn in the opposite direction–into the potable water system.

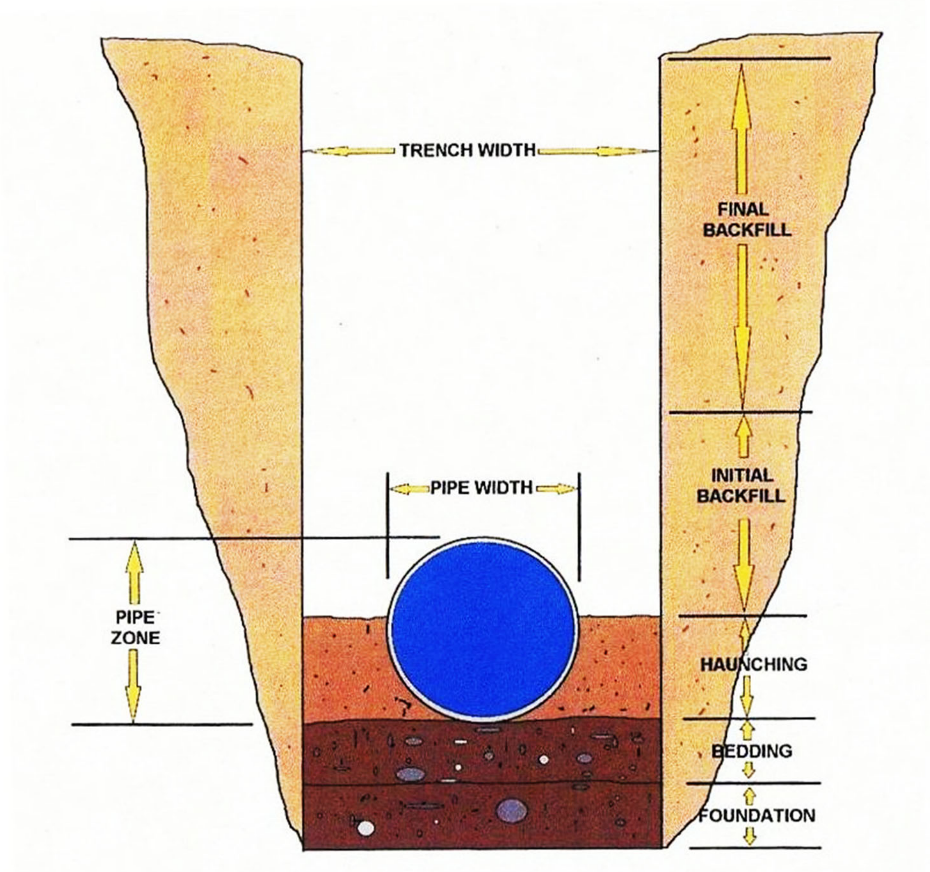
U.S. Environmental Protection Agency, Cross-Connection Control Manual, 1989

Safety Section

Competent Person: One who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees. They have authorization to take prompt corrective measures to eliminate hazards.

The Competent Person also is trained and knowledgeable about soil analysis and the use of protective systems.





CROSS-SECTION OF A TRENCH

Lockout - Tagout Training Sub-Section
(LOTO)

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

Definitions
Authorized (Qualified) Employees are the only ones certified to lock and tagout equipment or machinery. Whether an employee is considered to be qualified will depend upon various circumstances in the workplace. It is likely for an individual to be considered "**qualified**" with regard to certain equipment in the workplace, but "unqualified" as to other equipment.

An employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person, is considered to be "**qualified**" for the performance of those duties.

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

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

Training
Authorized Employees Training **Example**

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

The training will consist of the following:

- Review of General Procedures.
- Review of Specific Procedures for machinery, equipment and processes.
- Location and use of Specific Procedures.
- Procedures when questions arise.

Affected Employee Training

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

Other Employee Training

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

Preparation for Lock and Tagout Procedures

A Lockout - Tagout survey will be conducted to locate and identify all energy sources to verify which switches or valves supply energy to machinery and equipment. Dual or redundant controls will need to be removed. A Tagout Schedule will be developed for each piece of equipment and machinery. This schedule describes the energy sources, location of disconnects, type of disconnect, special hazards and special safety procedures. The schedule will be reviewed each time to ensure employees properly lock and tag out equipment and machinery. If a Tagout Schedule does not exist for a particular piece of equipment, machinery and process, one must be developed prior to conducting a Lockout - Tagout. As repairs and/or renovations of existing electrical systems are made, standardized controls will be used. It is your departmental supervisor's responsibility to ensure that a schedule is made.

Routine Maintenance & Machine Adjustments

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

SOP: General Lock and Tag out Procedures

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

Preparation for Shutdown

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

Machine or Equipment Shutdown
The machine or equipment will be turned off or shut down using the specific procedures for that specific machine. An orderly shutdown will be utilized to avoid any additional or increased hazards to employees as a result of equipment de-energization. If the machinery, equipment or process is in operation, follow normal stopping procedures (depress stop button, open toggle switch, etc.). Move switch or panel arms to "**Off**" or "**Open**" positions and close all valves or other energy isolating devices so that the energy source(s) is disconnected or isolated from the machinery or equipment.

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

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

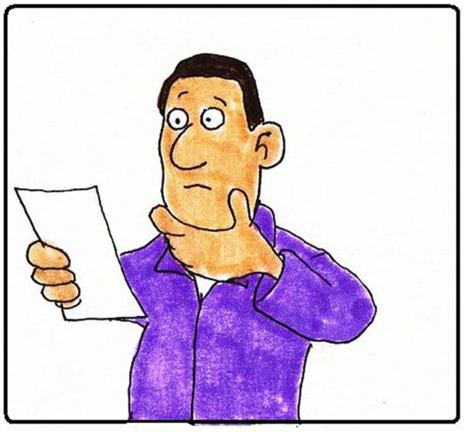
Where tagout devices are used they will be affixed in such a manner that will clearly state that the operation or the movement of energy isolating devices from the "safe" or "off" positions is prohibited.

The tagout devices will be attached to the same point a lock would be attached. If the tag cannot be affixed at that point, the tag will be located as close as possible to the device in a position that will be immediately obvious to anyone attempting to operate the device. Lock and tag out all energy devices by the use of hasps, chains and valve covers with assigned individual lock(s).

Stored Energy
Following the application of the lockout or tagout devices to the energy isolating devices, all potential or residual energy will be relieved, disconnected, restrained, and otherwise rendered safe. Where the re-accumulation of stored energy to a hazardous energy level is possible, verification of isolation will be continued until the maintenance or servicing is complete. Stored energy (capacitors, springs, elevated members, rotating fly wheels, and hydraulic/air/gas/steam systems) must be relieved or restrained by grounding, repositioning, blocking and/or bleeding the system.

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

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



READ THE SAFETY DATA SHEET

WEAR PROPER PPE

HANDLING CHEMICALS

Confined Space Safety Sub-Section

Definition of Confined Spaces Requiring an Entry Permit

A Confined space:

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

Confined Spaces are
-large enough to allow entry of any body part, and
-limited or restricted entry or exit, and
-not designed for continuous employee occupancy.

Permit Required Confined Spaces are confined spaces that have any of the following
-potential hazardous atmosphere
-material inside that may engulf or trap you
-internal design that could trap or asphyxiate you
-any other serious safety or health hazard

Entry Permits are required before you enter any "**Permit Required Confined Space**"

Hazards include
- Fire & Explosion
- Engulfment
- Asphyxiation
- Entrapment
- Slips & Falls
- Electric Shock
- Noise & Vibration
- Chemical Exposure
- Toxic Atmospheres
- Thermal / Chemical Burns

Engineering Controls
- ❑ Ventilation
- ❑ Locked Access
- ❑ Lighting

Administrative Controls
- ❑ Controlled Access
- ❑ Hazard Assessments
- ❑ Entry Permits & Procedures
- ❑ Signs & Lockout Tagout
- ❑ Training

Smart Safety Rules

Know what you are getting into.

Know how to get out in an emergency.

Know the hazards & how they are controlled.

Only authorized & trained personnel may enter a Confined Space or act as an attendant.

No smoking in Confined Space or near entrance or exit area.

Attendant must be present at all times.

Constant visual or voice communication must be maintained between the attendant and entrants.

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

Air and oxygen Monitoring is required before entering a Permit-Required Confined Space.

Ventilation & oxygen monitoring is required when welding is performed.

Confined Space

Purpose
The Confined Space Entry Program is provided to protect authorized employees that will enter confined spaces and may be exposed to hazardous atmospheres, engulfment in materials, conditions which may trap or asphyxiate due to converging or sloping walls, or contains any other safety or health hazards. **Reference**: OSHA-Permit-Required Confined Spaces (29 CFR 1910.146).

Scope ***Example***
You are required to recognize the dangers and hazards associated with Confined Spaces, and this program is designed to assist you in the safety of and compliance with the OSHA standards associated with such.

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

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

Permit required confined space (permit space), is a confined space that has one or more of the following characteristics:
1. Contains or has a potential to contain a hazardous atmosphere.
2. Contains a material that has the potential for engulfing an entrant.
3. Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly covering walls or by a floor which slopes downward and tapers to a smaller cross-section.
4. Contains any other recognized serious safety or health hazard.

Each Permit-Required Confined Space will be marked
"Confined Space - Entry Permit Required".
CONFINED SPACE

Permitted Confined Space Entry Program

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, entrants, supervisors.

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

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

4. Constant visual or voice communication will be maintained between the safety watchman or 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**).

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

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 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 ensure 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 and 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.
- ✓ Not to perform duties that might interfere with the attendants' primary duty to monitor and protect the entrants.

Take the following action 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, use the proper equipment, and observe the entry procedures and permit.

EXAMPLE OF A CONFINED SPACE ENTRY DANGER SIGN

Other Excavation and Confined Space 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 chemicals 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.

Carbon Monoxide

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. Carbon monoxide is an insidious toxic gas because of its poor warning properties. Early stages of CO intoxication are nausea and headache. Carbon monoxide may be fatal at 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.

Carbon monoxide 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. Carbon monoxide 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.

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.

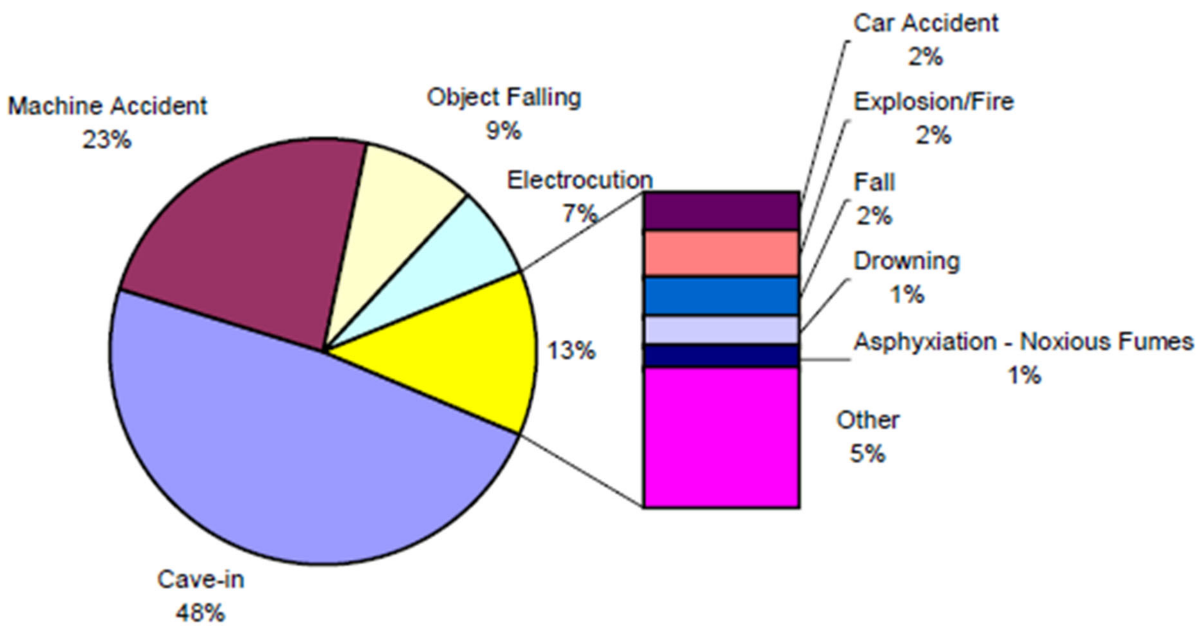
A secondary irritant is one that may produce systemic toxic effects in addition to surface irritation.

Examples of secondary irritants include benzene, carbon tetrachloride, ethyl chloride, trichloroethane, trichloroethylene, and chloropropene. Irritant gases vary widely among all areas of industrial activity.

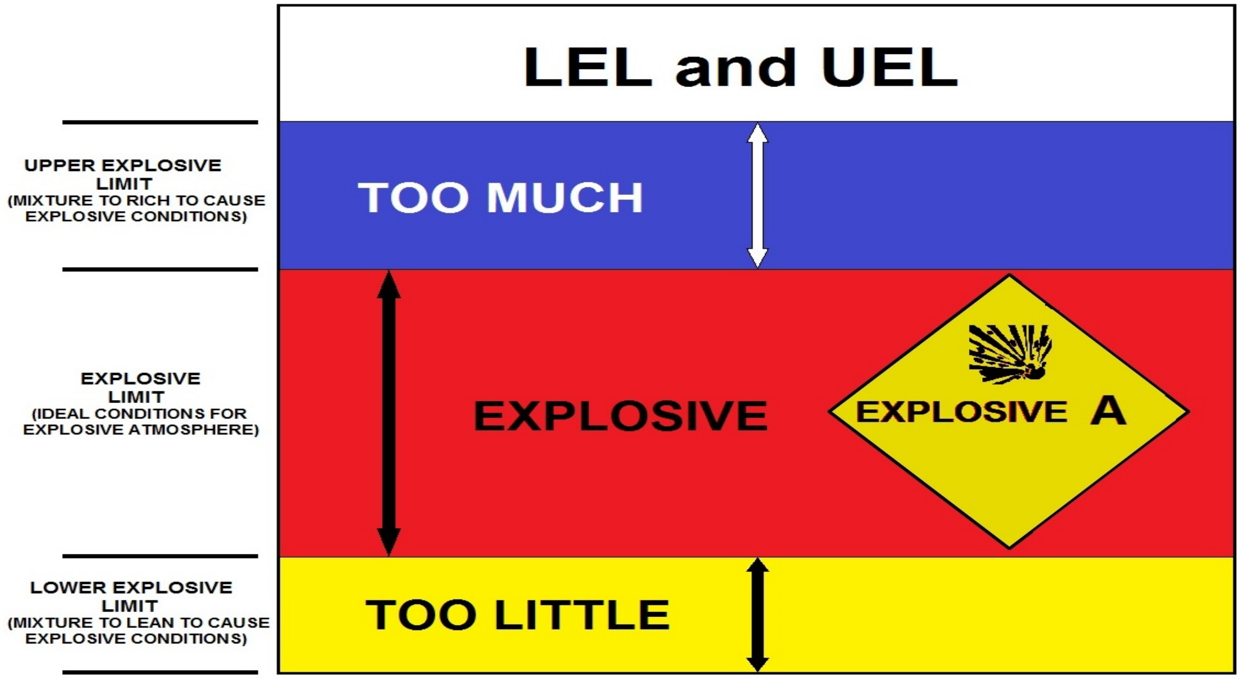
They can be found in plastics plants, chemical plants, the petroleum industry, tanneries, refrigeration industries, paint manufacturing, and mining operations. Prolonged exposure at irritant or corrosive concentrations in a confined space may produce little or no evidence of irritation. This may result 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.

COMMON HAZARDOUS GASES THAT MAY BE PRESENT IN CONFINED SPACE					
SUBSTANCE *	8-HOUR TIME-WEIGHTED AVERAGE (TWA)	15-MINUTE SHORT-TERM EXPOSURE LIMIT (STEL)	CEILING LIMIT (Never To Be Exceeded)	IMMEDIATELY DANGEROUS TO LIFE AND HEALTH (IDLH)	RECOMMENDED ALARM SETTINGS (Low / High)
AMMONIA	25 ppm	35 ppm	—	300 ppm	13 ppm / 25 ppm
CARBON MONOXIDE	25 ppm	100 ppm	—	1200 ppm	13 ppm / 25 ppm
CHLORINE	0.5 ppm	1 ppm	—	10 ppm	0.25 ppm / 0.5 ppm
HYDROGEN SULFIDE	—	—	10 ppm	100 ppm	5 ppm / 10 ppm
METHANE	1000 ppm	—	—	—	500 ppm / 1000 ppm
NITROGEN DIOXIDE	—	—	1 ppm	20 ppm	0.5 ppm / 1 ppm
SULFUR DIOXIDE	2 ppm	5 ppm	—	100 ppm	1 ppm / 2 ppm
OXYGEN	—	—	—	—	20.5 % of Atmosphere
LOWER EXPLOSIVE LIMIT (LEL)	—	—	—	—	5 % LEL

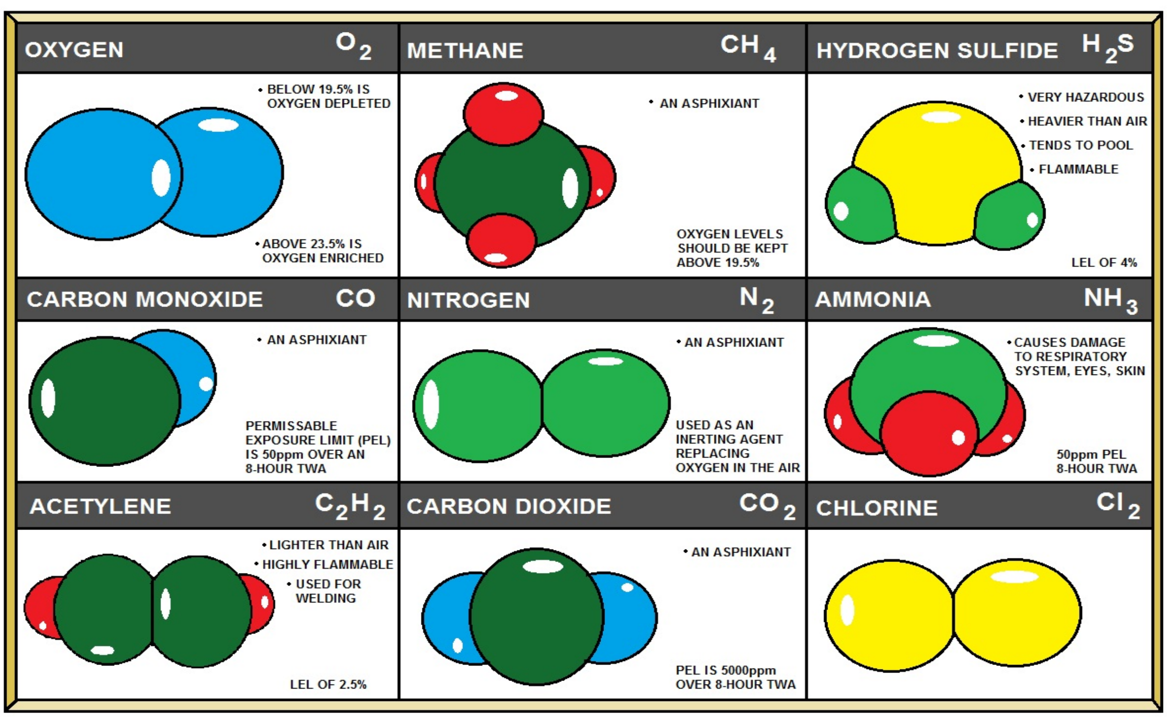
EXAMPLE OF A CHART OF CONFINED SPACE GASES



CAUSES OF OCCUPATIONAL RELATED DEATH



UNDERSTANDING UPPER (UEL) & LOWER (LEL) EXPLOSIVE LIMITS



COMMON GASES THAT CAN BE FOUND IN CONFINED SPACE

Confined Space Hazards

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Manholes
Throughout the construction site, manholes are commonplace. As means of entry into and exit from vaults, tanks, pits, and so forth, manholes perform a necessary function. However, these confined spaces may present serious hazards which could cause injuries and fatalities.

A variety of hazards are associated with manholes. To begin with, the manhole could be a dangerous trap into which the worker could fall. Often covers are removed and not replaced, or else they are not provided in the first place.

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

Asbestos Awareness Training Introduction

Employers must provide asbestos awareness training, including training required by local enforcement agencies (LEA) where applicable, to all employees who may be exposed to airborne concentrations of asbestos at or above the permissible exposure limit (PEL) and/or excursion limit.

The following rules or standards regulate asbestos:

- ✓ 1910.1001 applies to all occupational exposures to asbestos in all industries covered by the Occupational Safety and Health Act.
- ✓ 1915.1001 applies to the shipbuilding industry.
- ✓ 1926.1101 applies to the construction industry. The construction industry includes the alteration, repair, painting, and decorating of a facility that contains asbestos. This regulation also has standards for the housekeeping and custodial duties of asbestos-containing material (ACM).
- ✓ 40 CFR 763, subpart G applies to asbestos-abatement projects by employers of state and local government employees not covered by the OSHA standards. These standards follow the 1910.1001 standards.
- ✓ 40 CFR 61 (asbestos NESHAP) applies to facilities that mill, manufacture, or use asbestos. This standard also applies to the demolition of any facility and the renovation of facilities that contain friable asbestos.

Worker's Exposure to Asbestos

OSHA first regulated worker's exposure to asbestos in 1971 under the general workers standard (29 CFR 1910.1001). OSHA later followed with specific standards for the construction and shipbuilding industry.

Then, EPA's Worker Protection Rule (40 CFR Part 763, Subpart G) extended the OSHA standards to state and local employees performing asbestos work who are not covered by the OSHA asbestos standards, or by a state OSHA plan.

The rule parallels OSHA requirements and covers medical examinations, air monitoring and reporting, personal protective equipment, work practices, and recordkeeping.

Finally, EPA published the National Emission Standard for Hazardous Air Pollutants (NESHAP) for asbestos, which regulates the release of asbestos fibers during activities involving the handling of asbestos.

The basis for these modules is the Environmental Protection Agency's (EPA) Model Accreditation Plan (MAP), which follows the OSHA training standards. EPA's MAP represents the first comprehensive governmental standard spelling out exactly what a person needs to know to perform a particular task.

Using a chisel and keeping the ACP wet in order to cut the pipe, if possible Duct tape the pipe before cutting it.

Training Requirements
Both EPA and OSHA require workers to be aware of the dangers in being exposed to asbestos, the proper handling of asbestos to reduce exposure, and information on the medical surveillance program requirements. OSHA requires any person that may be exposed to asbestos above the permissible exposure limit, while EPA regulations dictate training based upon the quantity of ACM to be disturbed.

In a successful training program:

- ✓ Employees must be trained when first assigned to a job or an area that meets or exceeds exposure limits or for major fiber releases.
- ✓ Training must be repeated at least once a year.
- ✓ Employees must be able to understand the training.

However, EPA does not require an Operation and Maintenance (**O&M**) plan for asbestos activities of less than three linear or three square feet. The Agency also does not require the work to be done by accredited workers under these circumstances.

Common Asbestos Acronyms

AHERA - The Asbestos Hazard Emergency Response Act, passed by Congress in 1986

ASHARA - Asbestos School Hazard Abatement Reauthorization Act

CAA - Clean Air Act

CERCLA - The Comprehensive Environmental Response Compensation and Liability Act. Also known as the "**Superfund**."

EPA - The United States Environmental Protection Agency

EHSD - Environmental Health and Safety Division, U.S. EPA

CAA - Clean Air Act

CFR - Code of Federal Regulations

FR - Federal Register

NARS - National Asbestos Registry System

NESHAP - The National Emission Standard for Hazardous Air Pollutants found in Title 40 CFR Part 61 promulgated under Section 112 of the Clean Air Act.

NIOSH - National Institute for Occupational Safety and Health

NIST - National Institute of Standards and Technology

NVLAP - National Voluntary Laboratory Accreditation Program

OSHA - Occupational Safety & Health Administration

PLM - Polarized Light Microscopy

TEM - Transmission Electron Microscopy

TSCA - Toxic Substance Control Act

Asbestos is an Excellent …

Heat Stability
Asbestos will maintain its structural integrity at temperatures well above 800 F. The melting point is at about 2800 F

Thermal Insulation
The fibers have a relatively large surface area, along with numerous pores, and cracks. This allows for a low heat transfer. This makes it useful as an insulator in homes and machinery. The large surface area also absorbs water making it practical as pipe insulator to prevent sweating.

Chemical Resistance
The amphiboles are resistant to aqueous media and chemical attack. They also show high resistance to acids. This makes this class of asbestos useful for battery packing. Chrysotile is significantly less resistant to chemical destruction.

Sound Absorption
Asbestos have a large internal volume, large surface area, and the fibers are flexible. This makes it ideal for the absorption of sound energy. It is often uses to help acoustics.

Workers removing Asbestos wrapped Pipe

Intro to Asbestos

OSHA requires that employees who may be exposed to dangerous levels of asbestos must be made aware of the hazards and how to protect themselves. Employees must be told where in their workplace they can find copies of all applicable asbestos standards. Employers must provide any employee with the opportunity to review the regulations if they so desire. It is an employee's right to have access to the regulations.

What Is Asbestos?
Asbestos is the name given to a number of naturally occurring fibrous silicate minerals that have been mined for their useful properties such as thermal insulation, chemical and thermal stability, and high tensile strength. The three most common types of asbestos are: a) chrysotile, b) amosite and c) crocidolite. Chrysotile, also known as white asbestos and a member of the Serpentine mineral group is the commonest. Asbestos can only be identified under a microscope.

Asbestos differs from other minerals in its crystal development. The crystal formation of asbestos is in the form of long thin fibers. Asbestos is divided into two mineral groups **Serpentine** and **Amphibole**. The division between the two types of asbestos is based upon the crystalline structure.

Serpentines have a sheet or layered structure where amphiboles have a chain-like structure. As the only member of the serpentine group, Chrysotile (A, B) is the most common type of asbestos found in buildings. Chrysotile makes up approximately 90%-95% of all asbestos contained in buildings in the United States.

Unlike most minerals, which turn into dust particles when crushed, asbestos breaks up into fine fibers that are too small to be seen by the human eye. Often, individual fibers are mixed with a material that binds them together, producing asbestos-containing material (ACM).

Health Effects of Asbestos Exposure
Asbestos is the largest single cause of fatal disease and ill-health caused by work in Great Britain. Although almost all the deaths and ill health related to asbestos today are due to exposures that happened several decades ago, if you work with asbestos, or come into contact with it as a result of repair and maintenance work, you need to be particularly careful.

Asbestos can be found in most buildings built between 1950 and 1980, as insulation and lagging. It is still used in some brake pads and clutch linings and can be met in vehicle servicing and repair.

Asbestos-Related Health Problems
Some people exposed to asbestos develop asbestos-related health problems; some do not. Once inhaled, asbestos fibers can easily penetrate body tissues. They may be deposited and retained in the airways and lung tissue. Because asbestos fibers remain in the body, each exposure increases the likelihood of developing an asbestos-related disease. Asbestos-related diseases may not appear until years after exposure. A medical examination that includes a medical history, breathing capacity test, and chest X ray may detect problems early.

Many substances have a "safe dose" or an exposure that is unlikely to cause any harm. Above the safe dose, a health effect is expected.

This concept is known as a dose response. As the dose increases, so does the expected severity of the health effect.

However, in the case of asbestos, scientists have not determined a "safe dose" or threshold level for exposure to airborne asbestos. Still, the less exposure a person receives over a lifetime, the less likely it is that that person will develop an asbestos-related health problem.

In addition to breathing it, ingesting asbestos may also be harmful to you, but the consequences of this type of exposure have not been clearly documented. People who touch asbestos may get a rash similar to the rash caused by fiberglass. While the effects of skin exposure to asbestos have not been scientifically documented, it is best to minimize all contact with asbestos.

Asbestos was used in approximately 3,000 products. Two-thirds of this total (2,000) was used in construction products. Appendix A includes a short list of products where asbestos may be found.

OSHA's Asbestos Standard

Employees must receive asbestos training when they are assigned to work in an area with the risk of exposure to asbestos. The training includes asbestos hazards and how to reduce them. More than one standard may apply to a particular assignment. Employees must be told where in their workplace they can find copies of all the applicable asbestos standards.

Reducing Exposure
Prohibited Activities
Employees should never eat, drink, smoke, chew tobacco or gum, or apply makeup in regulated areas. These activities can greatly increase an employee's exposure to asbestos fibers.

Work Practices
Each employee who will be working with asbestos must be trained in the proper work practices for the job being done. Training must include hands-on experience. OSHA recommends specific procedures to prevent release of asbestos fibers depending on the type of action being done and the class of work. ***General work procedures include:***

- ✓ Never cut, hammer, or otherwise damage ACM.
- ✓ Don't sand flooring materials that contain asbestos.
- ✓ Don't burnish or dry-buff floors containing asbestos unless there's enough finish to prevent the pad from contacting the ACM.
- ✓ Don't use compressed air to remove asbestos or ACM without using a ventilation system to capture the dust.
- ✓ Use enclosures, impermeable sleeves, HEPA vacuums, etc., when working on automotive brakes and clutches.
- ✓ Use wet methods, wetting agents, or removal encapsulation to control fiber release during handling, mixing, removal, cutting, or cleanup**.**

OSHA also specifies the work practices by the class of work being performed in shipyard and construction. These practices are highly specific, and the proper training is essential to worker health. ***Some of the work procedures include the use of:***

- ✓ Negative-pressure enclosures
- ✓ Glove bag systems
- ✓ Glove box systems
- ✓ Water spray process systems
- ✓ Walk-in or mini-enclosures

Wetting asbestos keeps fibers out of the air. Handle, mix, apply, remove, cut, and score asbestos while it's wet. Certain asbestos-containing products may not be removed from their shipping containers unless they're wet, enclosed, or ventilated.

The products include:

- ✓ Asbestos cement
- ✓ Mortar
- ✓ Coating
- ✓ Grout
- ✓ Plaster

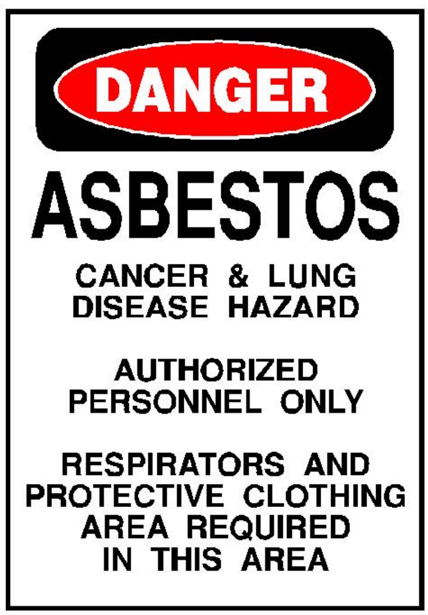
Regulated Areas
A regulated area is an area where the airborne concentration of asbestos exceeds or is likely to exceed the PEL (either the TWA or the excursion limit). The OSHA shipbuilding and construction standards further demarcate a regulated area by what class of asbestos work is being conducted. Class I, II, and III asbestos work must be done in a regulated area by accredited personnel.

EPA determines that an area is regulated by whether the activity constitutes a major or minor fiber release. A major fiber release requires restricted entry into the area and the posting of signs to prevent entry into the area by persons other than those necessary to perform the response action. Whenever possible, restricted areas should get a negative-pressure enclosure before removal or demolition activities commence. Employers must mark off any regulated areas from the rest of the workplace in a way that employees can recognize and avoid the area or take the appropriate precautions before entering. Only accredited employees are allowed access to regulated areas. Each person entering a regulated area must be supplied with and required to use a respirator.

Eating, drinking, smoking, or chewing tobacco or gum should be prohibited in these areas. No one may apply cosmetics in a regulated area.

Warning Signs
Warning signs must be posted in regulated areas. Signs should include the following cautions:

DANGER-ASBESTOS
CANCER AND LUNG DISEASE HAZARD
AUTHORIZED PERSONNEL ONLY
RESPIRATORS AND PROTECTIVE CLOTHING ARE REQUIRED IN THIS AREA



Respirators

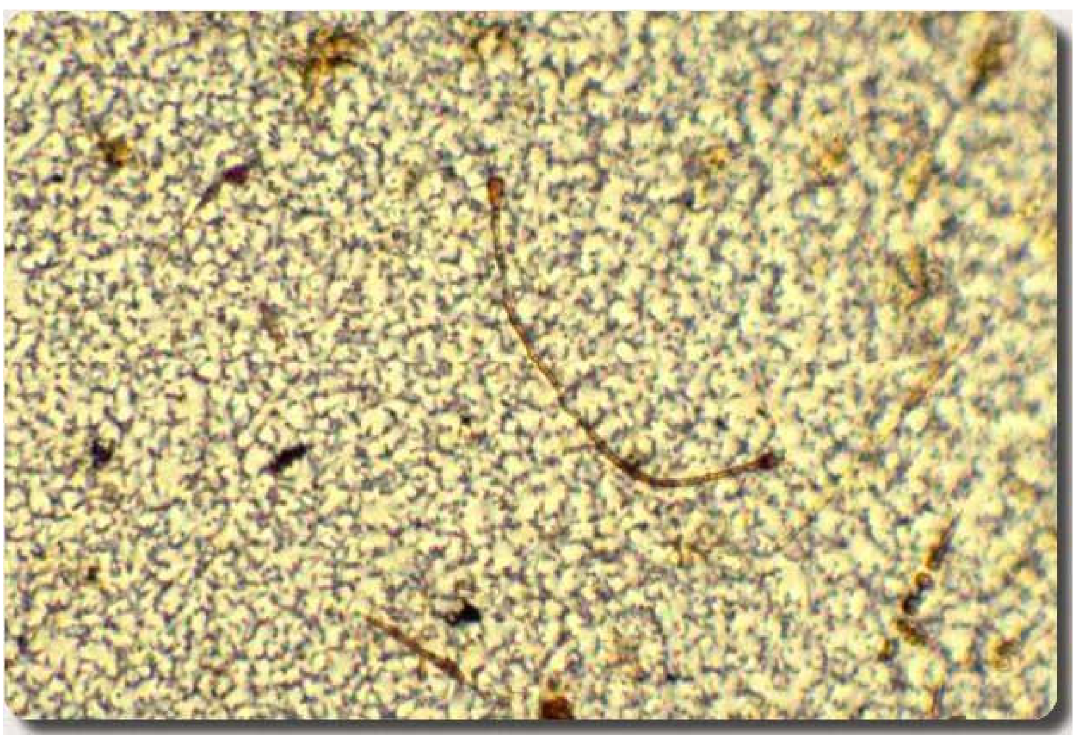
OSHA's respirator standard (29 CFR 1910.134) requires that:

- ✓ The correct respirator be specified for each job
- ✓ The employer have written procedures on the safe use of respirators in "dangerous atmospheres that might be encountered in normal operations or in emergencies"
- ✓ Someone stand by a worker using a respirator and stay in communication so that rescue can be provided promptly if needed
- ✓ In some such situations, workers wearing respirators also wear safety harnesses or lines

For certain limited operations, when all feasible engineering and work practices cannot reduce the employee exposure to below the TWA or excursion limits (i.e., 0.1 f/cc and 1.0 f/cc respectively), the employer must reduce exposure to asbestos to 0.5 f/cc over an 8-hour period or 2.5 f/cc for 30 minutes, or less and require employees to use the appropriate respirator.

The operations that will likely require respirator use include: coupling cutoff in primary asbestos cement pipe manufacturing; sanding in primary and secondary asbestos cement sheet manufacturing; grinding in primary and secondary friction product manufacturing; carding and spinning in dry textile processes; and grinding and sanding in primary plastics manufacturing.

Even though the area may be above the TWA, employers must reduce employee exposure to asbestos below the TWA or excursion limit



A photo of a lung that was exposed to asbestos and developed cancer.

Protective Clothing

Employees exposed to asbestos above the TWA or excursion limit, or where the possibility of eye irritation exists, must use appropriate protective work clothing and equipment. The employer must provide the protection at no cost to the employee. ***Protective clothing includes:***

- ✓ **Coveralls or similar full-body work clothing**
- ✓ **Gloves, head coverings, and foot coverings**
- ✓ **Face shields, vented goggles, or other appropriate PPE that complies with 29 CFR 1910.133**

Change rooms must be provided for the removal of any protective clothing that is contaminated with asbestos. Employees cannot take contaminated work clothing out of the change room, except for laundering, maintenance, or disposal. All contaminated work clothing must be stored in closed containers that prevent dispersion of the asbestos.

Contaminated clothing may only be transported only in sealed impermeable bags or other closed, impermeable containers, with all appropriate labels.

Employers must provide employees who work with asbestos in areas where the airborne exposure to asbestos is above the TWA and/or excursion limit with:

- ✓ **Change rooms equipped with two separate lockers or storage facilities to prevent contamination of the employee's street clothes with fibers from PPE.**
- ✓ **Showers.**
- ✓ **Lunchroom facilities that have a positive pressure, filtered air supply, and are readily accessible. Never enter the lunchroom in protective clothing that may be contaminated with asbestos.**

Anyone working with asbestos should carefully wash his or her hands and face prior to eating, drinking, or smoking.

Engineering Controls
Local exhaust ventilation and dust collection systems are very important, especially when you use tools such as saws, drills, scorers, and abrasive wheels that could release asbestos fibers into the air. ***The following is allowable exposure control equipment:***

- ✓ Automatic bag-opening equipment
- ✓ Exhaust systems to collect air in closed containers
- ✓ Dust collection and cleaning systems
- ✓ Hoods to cover operations that release fibers
- ✓ Tools with exhaust systems or wet sprays
- ✓ Shrouds for tools such as grinders

Whenever the engineering and work practices are insufficient to control asbestos fibers, employees must supplement the controls with respiratory protection.

Decontamination Areas

Decontamination areas are a source of secondary exposure to asbestos. Follow the decontamination procedures for the site to prevent asbestos on protective clothing from becoming airborne. Always enter or exit the regulated area through the decontamination area.

When leaving a regulated area, employees should enter the decontamination area through the equipment room. There, they should remove all asbestos material on the protective clothing by using an HEPA-filtered vacuum. Employees must not remove their respirators while in the equipment room. All protective clothing must be removed and put into labeled clothing bags. Employees then must leave the equipment room, remove their respirator, and shower before entering a clean room.

Housekeeping Requirements

OSHA regulates housekeeping activities under both the general industry standard and the construction standard. The general industry standard applies to routine housekeeping activities in facilities where the asbestos material is whole. If the housekeeping activities are for the cleanup of construction-related activities, the more stringent construction standard must be followed. Generally, both standards require similar precautions:

- ✓ Maintain all surfaces as free as possible from ACM waste and dust.
- ✓ Do not clean surfaces using compressed air.
- ✓ Use HEPA-filtered vacuuming equipment.
- ✓ Use wet cleaning or HEPA vacuuming whenever possible. Dry sweeping and shoveling is a last resort.
- ✓ Sanding of asbestos floors is prohibited.
- ✓ Stripping of finish from asbestos flooring may only be done using low-abrasion pads at less than 300 rpm and wet methods.
- ✓ Buffing is allowed only if sufficient finish remains to prevent the pads from contacting the ACM.

The construction standard also requires:

- ✓ All asbestos waste must be collected and disposed of in sealed, labeled, impermeable bags or similar containers.
- ✓ Waste and dust from areas with accessible TSI or surfacing ACM may not be dusted or dry swept except by using an HEPA-filtered vacuum and all material placed in a leak-tight container.

Cleanup Procedures

Keep all surfaces free of asbestos-containing dust and waste. Clean up all asbestos releases as soon as possible. Use HEPA vacuums—not compressed air—to clean up ACM. Shovel, sweep, or use other dry methods only when vacuuming or wet cleaning is impossible.

Avoid activities that might release fibers. For instance, don't cut through pipe insulation or hammer nails or drill holes in ceilings that might contain asbestos.

Asbestos Wastes (EPA Waste information in next section)

Use the same asbestos safety precautions when handling asbestos waste. It's best to wet these wastes. Place them in labeled, sealed, leakproof containers for careful and proper disposal. ***Examples of asbestos waste include:***

- ✓ **Empty asbestos containers**
- ✓ **Manufacturing cuttings or trimmings**
- ✓ **Materials that are swept or vacuumed up (including vacuum bags or filters)**
- ✓ **Fireproofing**
- ✓ **Insulation**

Any shipment of asbestos waste must conform to the U.S. Department of Transportation (**DOT**) regulations for the transportation of hazardous materials. In general, the material must be placed in a proper poly-lined container that is leakproof and labeled with the correct DOT name for the asbestos waste.

The waste must be transported in a covered vehicle to an EPA-approved landfill. When shipping the waste, the shipping facility must offer the proper placards to the driver of the transport vehicle. The vehicle must have the proper placards on all sides. Once delivered to the landfill, the waste must be covered with at least 6 inches of fill within 24 hours.

For each load of asbestos waste that is regulated under the asbestos NESHAP, the employer must maintain a waste shipment record (WSR). The WSR must contain the following information:

- ✓ Name, address, and telephone number of the waste generator
- ✓ Name and address of the local, state, or EPA regional office responsible for administering the asbestos NESHAP program
- ✓ Quantity of waste in cubic meters (or cubic yards)
- ✓ Name and telephone number of the disposal site operator
- ✓ Name and physical site location of the disposal site
- ✓ Date transported
- ✓ Name, address, and telephone number of the transporter(s)
- ✓ Certification that the contents meet all government regulations for transport by highways

Summary

Reducing asbestos exposure is both the employer's and the employee's concern. Do not take shortcuts to save time. Any exposure to asbestos is potentially harmful.

The OSHA standard on asbestos requires that your employer make you aware of the hazards of exposure and how to protect yourself.

- ✓ Use engineering controls, work practices, and procedures that can reduce your exposure.
- ✓ Learn and be able to use emergency and cleanup procedures.
- ✓ Know when to use respirators and protective clothing; learn to use and dispose of them properly.
- ✓ Proper waste disposal has as important a role in reducing exposure as engineering and work practice controls.

Friable and Non-Friable Asbestos

What is friable asbestos-containing material?
Friable ACM is any material containing more than one percent asbestos (as determined by Polarized Light Microscopy) that, when dry, may be crumbled, pulverized, or reduced to powder by hand pressure.

What is non-friable ACM?
Non-friable ACM is any material containing more than one percent asbestos (as determined by Polarized Light Microscopy) that, when dry, cannot be crumbled, pulverized, or reduced to powder by hand pressure. Under the Asbestos NESHAP, non-friable ACM is divided into two categories.

Category I non-friable ACM are asbestos-containing resilient floor coverings (commonly known as vinyl asbestos tile (**VAT**)), asphalt roofing products, packings and gaskets. These materials rarely become friable. All other non-friable ACM are considered category II non-friable ACM.

Must I remove category I non-friable material prior to demolition or renovation?
Under normal circumstances, category I non-friable materials need not be removed prior to demolition or renovation, because generally these materials do not release significant amounts of asbestos fibers, even when damaged. This is not, however, a hard and fast rule. If category I materials have become friable or are in poor condition, they must be removed.

Also, if you sand, grind, abrade, drill, cut or chip any non-friable materials, including category I materials, you must treat the material as friable, if more than the jurisdictional amount is involved.

Must I remove category II non-friable materials prior to demolition or renovation?
These materials should be evaluated on a case-by-case basis. If category II non-friable materials are likely to become crushed, pulverized or reduced to powder during demolition or renovation, they should be removed before demolition or renovation begin.

For example, A/C (asbestos cement) siding on a building that is going to be demolished with a wrecking ball should be removed, because it is likely that the siding will be pulverized by the wrecking ball.

Does non-friable waste, if broken, damaged, etc., have to be wetted and contained?
Non-friable ACM that has been damaged during a demolition or renovation operation such that some portions of the material are crumbled, pulverized or reduced to powder is covered by the Asbestos NESHAP if the facility contains more than the threshold amount of RACM.

However, category II non-friable ACM that has a high probability of being damaged by the demolition or renovation forces expected to act on the materials such that it will be crumbled, pulverized, or reduced to powder must be removed prior to the demolition or renovation operation. It is the owner's or operator's responsibility to make these determinations.

Transport and Disposal

How should I handle bulk waste from a facility that contained RACM and that was not found until after demolition began?
The demolition debris must be treated as asbestos-containing waste. Adequately wet the demolition debris until collected for disposal and during loading, transport it in covered vehicles and emit no visible emissions to the outside air as required by 61.150. The waste must be deposited at an acceptable waste disposal site.

Can I transport bulk asbestos waste without placing it in containers as long as I keep the waste pile wet?
No. After wetting, seal all asbestos-containing waste material in leak-tight containers while wet and label with the appropriate signs and labels. If the waste will not fit into containers, it must be placed in leak-tight wrapping.

However, for facilities that are demolished without removing the RACM and for ordered demolitions, the material must be adequately wet after the demolition has occurred and again when loading the material for transport to a disposal site. RACM covered by this paragraph may be transported in bulk without being placed in leak-tight containers or wrapping.

How should I label asbestos-containing waste that is being taken away from the facility?
You should label the containers or wrapped materials with the name of the waste generator and the location at which the waste was generated. An OSHA warning label must also be used.

Does EPA license landfills for asbestos waste?
The EPA does not license asbestos landfills under the Clean Air Act.. However, it has established asbestos disposal requirements for active and inactive disposal sites under the NESHAP, and general requirements for solid waste disposal under the Resource Conservation and Recovery Act (**RCRA**). In addition, State and/or local agencies usually require asbestos landfills to be approved or licensed.

Where can I obtain a list of licensed landfills?
State and local agencies which require handling or licensing procedures can supply a list of "**approved**" or licensed asbestos disposal sites upon request. Solid waste control agencies are listed in local telephone directories under State, county or city headings.

What should the owner or operator of a waste disposal site do if it is determined that there is a discrepancy between the amount of waste that left the facility and the amount of waste that was delivered to the site?
The waste site owner or operator must contact the demolition/renovation owner or operator, and attempt to reconcile the discrepancy. If they cannot do so within 15 days after the waste was received, the waste site owner or operator must notify both the delegated agency responsible for the facility from which the waste was removed, and the delegated agency responsible for the area in which the waste was disposed.

Can water be considered "six-inch compacted non-asbestos cover"? In other words, could asbestos covered components be dropped in the ocean?
No.

Monitoring and Sampling

Does the NESHAP regulation require air monitoring during renovation or removal?
No.

Does the Asbestos NESHAP regulation require me to inspect my property for asbestos?
No, not unless demolition or renovation is planned. The only Federal regulation which requires general inspections are the AHERA regulations, which mandate that schools must be inspected for asbestos. The NESHAP regulation requires that you inspect for asbestos before demolition or renovation.

What is the acceptable exposure/ambient air standard for asbestos?
EPA does not specify an acceptable exposure/ambient air standard.

What is a bulk sample?
A bulk sample is a solid quantity of insulation, floor tile, building material, etc., that is suspected of containing asbestos fibers that will be analyzed for the presence and quantity of asbestos.

Will EPA test my building for asbestos for me?
No. Owners and operators are responsible for getting their buildings tested.

Does EPA accredit laboratories that test for asbestos?
No. EPA, under 40 CFR Part 763, requires local education agencies to use laboratories accredited by the National Institute of Standards and Technology (NIST) in its National Voluntary Laboratory Accreditation Program (NVLAP). It is recommended for NESHAP related projects that NIST accredited laboratories be used.

How can I find someone to do the testing?
NIST publishes a yearly listing of accredited laboratories enrolled in the NVLAP. Then, on a quarterly basis NIST publishes updates to the master list detailing labs newly accredited, labs which have had their accreditation suspended, etc.

Contact NIST NVLAP for a current listing of accredited labs. The NIST NVLAP number is listed at the end of this pamphlet, along with other contact numbers.

How do laboratories analyze bulk samples?
Laboratories analyze bulk samples a number of ways. Most laboratories use Polarized Light Microscopy (**PLM**). Some laboratories use Transmission Electron Microscopy (**TEM**). However, there is currently no published method for bulk analysis using TEM.

How much does it cost to have a bulk sample analyzed?
The cost varies with the method. The cost of PLM analysis ranges from $20.00 to $100.00. The average cost is $30.00. TEM analysis is more expensive.

Inspections

Does an inspector have the right to enter any facility and the containment area?
Yes. All inspectors have the right under the Clean Air Act to inspect any facility and the containment area. Inspectors are trained and equipped to do this safely.

If I can see ACM dust inside the containment area or inside a glovebag, is this a violation of the Asbestos NESHAP?
The observation of ACM dust will be used as evidence of a violation of the "**adequately wet**" requirement. This is consistent with the definition of adequately wet that requires enough wetting "**to prevent the release of particulates**."

Is visible asbestos-containing debris on the ground outside a removal job considered a "visible emission," and a violation of the NESHAP?
Yes. Dry friable asbestos insulation on the ground violates the "**adequately wet**" requirement, and can be considered evidence of a visible emission.

Is it appropriate for an inspector to open any bags outside the designated contaminated area?
Yes. The inspector may open any bags outside the designated contaminated area to inspect them. The inspector may use a glovebag or other control techniques. The inspector will then properly reseal the bag, or request that the operator do so.

Must an inspector witness improper removal of more than 160 square feet or 260 linear feet of asbestos-containing material to prove a violation of the NESHAP regulation?
No. First, the inspector must gather information about the quantity of asbestos to prove that the project is subject to the NESHAP standards. Second, the inspector must prove that there has been improper removal. The two tasks are distinct from each other.

Are inspectors required to have medical examinations to ensure that they are medically fit to wear respirators?
Yes. Several Federal provisions under OSHA, EHSD, and NIOSH require people to be examined by a doctor and pronounced physically fit before they are permitted to wear respirators.

Must inspectors have personnel monitoring conducted on them during inspections to comply with OSHA requirements for workers?
No. The inspectors do not have to comply with the work practice safety standards required by OSHA for personnel monitoring.

Do inspectors need to follow facility training requirements including fit testing?
No.

Training

Do contractors and employees need to be accredited?
As of November, 1991 the Asbestos NESHAP requires a person trained in the provisions of this rule and the means of complying with them to be on-site when asbestos-containing material is stripped, removed or disturbed. Under AHERA, all contractors and employees involved in the removal and disposal of asbestos-containing material from schools must be accredited. Additionally, many States require that all workers be accredited before they remove asbestos from any facility.

How can I qualify as an asbestos contractor/worker/consultant under AHERA?
You must attend and pass an EPA accredited training course. A list of training courses approved by EPA is published quarterly in the Federal Register, and is available through the TSCA hotline.

The TSCA number is printed at the end of this pamphlet, along with other contact numbers. Contact your State or local agency for more information.

Do supervisors need to be trained?
Beginning on November 20, 1991, the Asbestos NESHAP requires at least one trained supervisor to be present at any site at which RACM is stripped, removed, or otherwise disturbed at any facility which is being demolished or renovated and is regulated by NESHAP. Evidence of the training must be posted and made available for inspection at the demolition or renovation site. Training includes, at a minimum: applicability, notification, material identification, control procedures, waste disposal, reporting and record keeping, asbestos hazards and worker protection.

Completion of an AHERA accredited course constitutes adequate training. Every 2 years the trained individual is required to receive refresher training. Information about both the training and refresher courses is available through EPA or delegated State or local agencies.

Violations and Penalties
What will happen if I violate the Asbestos NESHAP?
Sanctions vary. In some cases, Notices of Deficiency (**NOD**) -- written warnings -- or Notices of Violation (**NOV's**) are issued to owners or operators who violate notification requirements. Or, depending upon the offense, EPA recommends fines up to $25,000 per day per violation.

Violators of the work practice or disposal standards may be subject to either written warnings, administrative orders or civil penalties up to $25,000 per day per violation, depending upon the seriousness of the violation. EPA may also bring criminal charges against violators. Some owners and operators who have knowingly violated the Asbestos NESHAP have been sentenced to prison terms.

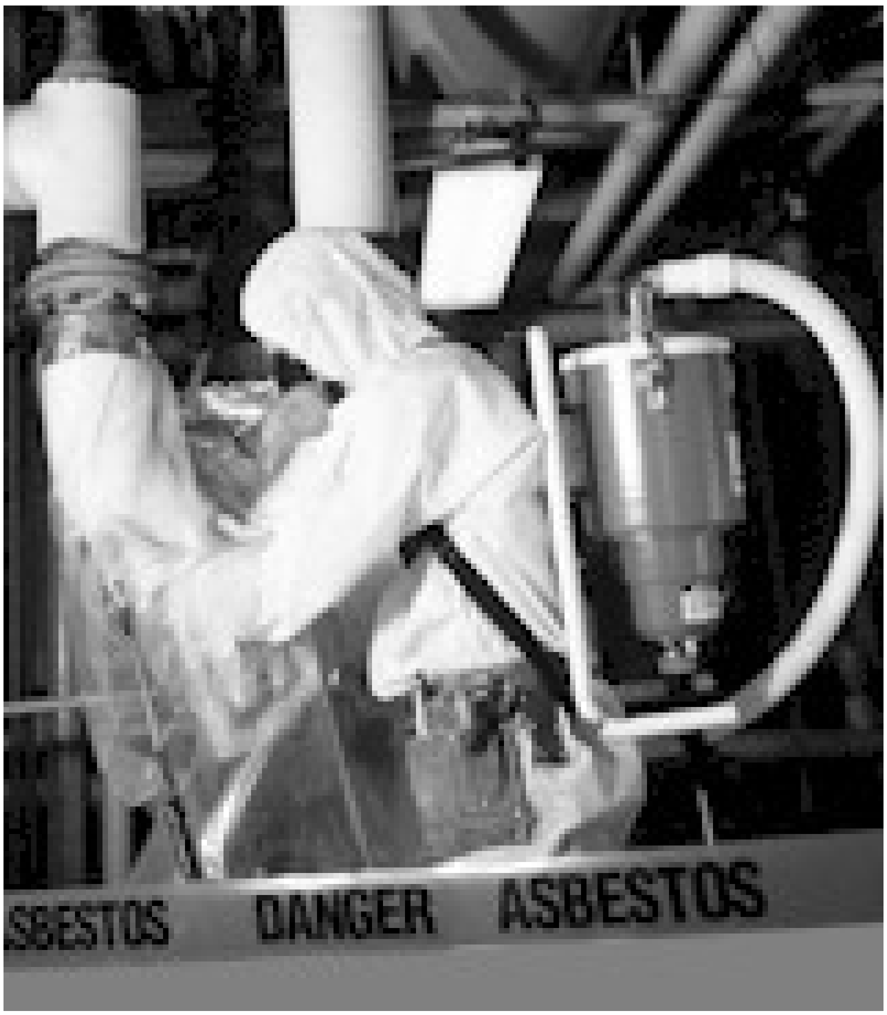
For more information on penalties and enforcement, see the EPA Public Information Document entitled "**Asbestos NESHAP Enforcement**."

What is the maximum penalty which can be assessed for NESHAP violations?
$25,000 per day, per violation, with no absolute maximum. However, some NESHAP violators may also be liable under CERCLA, and if so, the maximum penalty may be much higher.
How are penalties calculated?

Penalties are computed on a case-by-case basis. The amount of asbestos involved, the number of previous violations, the duration of the offense, the economic benefit that accrued to the owner or operator as a result of the violation, and similar considerations are taken into account.

What is "contractor listing?"
Contractors who have shown a pattern of violation, or who have been convicted of a criminal violation, may be placed on a list of violators who are prohibited from contracting for any jobs involving Federal money (grants, contracts, sub-grants, etc.).

Can a corporation that has changed its name, but is owned by an individual who has been listed be subject to contractor listing?
Yes.



Asbestos Hazard Emergency Response Act (AHERA)
Regulation: 40 CFR 763 Subpart E, Appendix C

Applicability

This session summarizes the training requirements under the U.S. Environmental Protection Agency's (EPA) Model Accreditation Plan (MAP). Any person who remediates friable asbestos-containing building material (ACBM) from schools or public or commercial buildings must be accredited by EPA or an EPA-approved state program.

MAP does not require the accreditation of persons removing ACBM from detached residential single-family homes or residential apartment (including condominiums) buildings of less than 10 units. However, some states require all asbestos removal to be done by accredited personnel. **Note:** Only approved training providers, with EPA or state-approved instructors may provide MAP accreditation training.

Worker Training Requirements

A person must be accredited as a worker to carry out any of the following activities with respect to friable ACBM in a school or public and commercial building:

- ✓ A response action other than a small-scale short-duration (**SSSD**) activity
- ✓ A maintenance activity that disturbs friable ACBM other than an SSSD activity
- ✓ A response action for a major fiber-release episode

All persons seeking accreditation as asbestos-abatement workers must complete an EPA- or EPA-state approved four-day training course. The four-day worker training course must include lectures, demonstrations, at least 14 hours of hands-on training, individual respirator fit testing, course review, and an examination.

Hands-on training must permit workers to have actual experience performing tasks associated with asbestos abatement. A person who is otherwise accredited as a contractor/supervisor may perform in the role of a worker without possessing separate accreditation as a worker.

Contractor/Supervisor Training Requirements

A person must be accredited as a contractor/supervisor to supervise any of the following activities with respect to friable ACBM in a school or public and commercial building:

- ✓ A response action other than an SSSD activity
- ✓ A maintenance activity that disturbs friable ACBM other than an SSSD activity
- ✓ A response action for a major fiber release-episode.

All persons seeking accreditation as asbestos-abatement contractors/supervisors must complete an EPA or EPA-state approved five-day training course. The training course must include lectures, demonstrations, at least 14 hours of hands-on training, individual respirator fit testing, course review, and a written examination.

Hands-on training must permit supervisors to have actual experience performing tasks associated with asbestos abatement. EPA recommends the use of audiovisual materials to complement the lectures where appropriate.

Asbestos abatement supervisors include those persons who provide supervision and direction to workers performing response actions. Supervisors include people who serve as foreman, working foreman, or lead person pursuant to collective bargaining agreements.

At least one supervisor is required to be at the worksite at all times while response actions are being conducted. Asbestos workers must have access to accredited supervisors throughout the duration of the project.

Inspector Training Requirements
Any person who inspects schools or public and commercial buildings for ACBM must complete an EPA- or EPA-state approved course for accreditation. An inspector must complete a three-day training course that includes:

- ✓ Background information on asbestos
- ✓ Potential health effects related to asbestos exposure
- ✓ The function and qualifications of an inspector
- ✓ Legal liabilities and defenses
- ✓ Understanding building systems
- ✓ Proper notification to employees, the public, or building occupants of inspections
- ✓ Pre-inspection planning and review of previous inspection records
- ✓ Inspecting for friable and non-friable material
- ✓ Bulk sampling and documentation of asbestos
- ✓ Inspector respirator and personal protective equipment (**PPE**)
- ✓ Recordkeeping and report writing
- ✓ Regulatory review

The training must include at least four hours of hands-on training, individual respirator fit-testing, a course review, a written exam, and a field trip. The field trip must include a simulated building walk-through inspection, on-site discussion about information gathering, proper sampling locations, on-site practice in physical assessment, followed by classroom discussion.

Management Planner Training Requirements
Anyone who prepares management plans for schools must have EPA accreditation as a management planner. Management planners must already possess a current and valid inspector accreditation prior to seeking accreditation as a management planner. The management accreditation course must include:

- ✓ **A course overview**
- ✓ **Evaluation and interpretation of survey results**
- ✓ **Hazard assessment**
- ✓ **Legal implications associated with asbestos removal**
- ✓ **Evaluation and selection of control options**
- ✓ **The role of other professionals, such as industrial hygienist, architects, and engineers**
- ✓ **Developing an operation and maintenance plan**
- ✓ **Regulatory review**
- ✓ **Recordkeeping for management planners**
- ✓ **Submitting management plans**
- ✓ **Financing abatement actions**
- ✓ **Course review**

Project Designer Training Requirements

A person must be accredited as a project designer to design any of the following activities with respect to friable ACBM in a school or public or commercial building:

- ✓ A response action other than an SSSD activity
- ✓ A maintenance activity that disturbs friable ACBM other than an SSSD activity
- ✓ A response action for a major fiber release episode

To be accredited as a project designer, the person must complete a minimum three-day training course. The training must include demonstrations and lectures on the following material:

- ✓ Background on asbestos
- ✓ Potential health effects related to asbestos exposure
- ✓ An overview of abatement construction projects
- ✓ Safety system design specifications
- ✓ Employee PPE
- ✓ Hazards encountered during abatement activity and how to deal with them
- ✓ Fiber aerodynamics and how to control fibers
- ✓ Design abatement solutions
- ✓ Final clearance process
- ✓ Budget/cost estimating
- ✓ Written abatement specifications
- ✓ Preparing abatement drawings
- ✓ Contract preparation and administration
- ✓ Legal liabilities and defenses
- ✓ Information on asbestos-free replacement products
- ✓ Role of other consultants
- ✓ Special design procedures for occupied buildings
- ✓ All relevant regulatory requirements

The course must also include a field trip to an abatement site or other building site for an on-site discussion of abatement design and building walk-through inspection, a course review, and a written exam.

Examinations

Each state requires a state-approved closed-book examination of anyone seeking accreditation after completion of the initial training course. The state may also include demonstration testing as part of the examination. Anyone seeking initial accreditation in a specific discipline (for example, worker, contractor/supervisor) must pass the examination for that discipline in order to receive accreditation.

Since a state may develop its own examination or have providers of training courses develop examinations, you must check with your state's particular requirements. Each examination must adequately cover the topics included in the training course for that discipline.

Certificate

Each person who completes a training course, passes the required examination, and fulfills whatever other requirements the state imposes must receive an accreditation certificate in a specific discipline. The certificate must include:

- ✓ A unique certification number
- ✓ Name of the accredited person
- ✓ Discipline of the training course completed
- ✓ Dates of the training course
- ✓ Date of the examination
- ✓ Expiration of the accreditation (one year from the date of the examination)
- ✓ The name, address, and telephone number of the training provider that issued the certificate
- ✓ A statement that the person receiving the certificate has completed the requisite training for the asbestos certification under the Toxic Substance Control Act Title II.

Continuing Education

For all disciplines, a state's accreditation program includes annual continuing education as follows:

- ✓ Workers—one full day of refresher training
- ✓ Contractor/supervisors—one full day of refresher training
- ✓ Inspectors—one-half day of refresher training
- ✓ Management planners—one-half day of inspector training and one-half day of training for management planners
- ✓ Project designers—one full day of fresher training
- ✓ Refresher training must address the specifics of each discipline and may not be combined with any other training course. Refresher training extends the accreditation for one year from the date of the refresher course. States may require full re-accreditation after a specific interval (e.g., every five years).

Recordkeeping Requirements for Trainers

All approved trainers of accredited asbestos training courses must comply with the following minimum recordkeeping requirements:

- ✓ **Training course materials.** Trainers must retain copies of all instructional materials used in the delivery of the classroom training, such as student manuals, instructor notebooks, and handouts.
- ✓ **Instructor qualifications.** Trainers must retain copies of all instructors' resumes, and the documentation approving each instructor as issued by either EPA or your state. Either EPA or your state must approve instructors before they may teach courses for accreditation purposes. The trainer must notify EPA or the state in advance whenever course instructors are changed. Records must accurately identify the instructors who taught each particular course for each date that a course was offered.
- ✓ **Examinations.** Trainers must document that each person who receives an accreditation certificate for an initial training course has achieved a passing score on the examination.
- ✓ **Accreditation certificates**. Trainers must maintain records that document the names of all persons who have been awarded certificates, their certificate numbers, the disciplines for which accreditation was conferred, training and expiration dates, and the training location.
- ✓ **Verification of certificate information**. EPA recommends that trainers of refresher training courses confirm that their students possess valid accreditation before granting course admission.
- ✓ **Records retention and access.** Trainers must maintain all required records for a minimum of three years.

Types of EPA Accreditation
EPA MAP training requires the following persons to be accredited:

- ✓ Workers
- ✓ Supervisors/contractors
- ✓ Inspectors
- ✓ Management planners
- ✓ Project designers

Each of these requires separate training courses and certifications. Certification is valid for one year before refresher training is required.

Training Session
Asbestos is a durable, fire-retardant, corrosion-resistant mineral compound that breaks up into fine, light fibers invisible to the naked eye.

The term "**friable asbestos**" describes asbestos that is dry and crumbly, capable of being reduced to dust by hand pressure. The use of asbestos ranges from paper products and brake linings to floor tiles and insulation.

Potential Health Effects Related to Exposure
Intact and undisturbed asbestos-containing material (**ACM**) does not pose a health risk. Asbestos becomes a problem when, because of damage, disturbance, or deterioration, fibers are released into the air.

Asbestos fibers can cause serious health problems. If inhaled, these tiny fibers can disrupt normal functions of the lungs. Exposure increases the risk of developing lung cancer, mesothelioma, or asbestosis. It can take anywhere from 20 to 30 years after the first exposure for the first symptoms to occur. Workers who held jobs in industries such as shipbuilding, mining, milling, and fabricating have experienced severe health problems from exposure.

Trainees must receive an explanation of the nature of asbestos-related diseases. Include in your session explanations of:

- ✓ Routes of exposure
- ✓ The dangers of cigarette smoking and asbestos exposure
- ✓ The latency periods for asbestos-related diseases (20 to 30 years)
- ✓ The relationship of asbestos exposure to asbestosis, lung cancer, mesothelioma, and cancers of other organs

Respirators
In general industry and construction, the level of exposure determines what type of respirator is required; the standards specify the respirator to be used. Demonstrate how different respirators work and have workers try them on. In addition, review the following with the trainees:

- ✓ The components of a proper respiratory protection program
- ✓ Selection and use of PPE
- ✓ Use, storage, and handling of non-disposable clothing
- ✓ Regulations covering PPE
- ✓ Classes and characteristics of respirator types
- ✓ Limitations of respirators
- ✓ Proper selection and inspection
- ✓ Storing procedures for respirators
- ✓ Methods for field testing of the face piece to face seal (positive- and negative-pressure fit checks)
- ✓ Fit testing procedures

For a more in-depth review, see PPE: Respirator Use, PPE: Protective Clothing and PPE: Eye and Face.

Work Practices
Workers should have actual experience performing tasks associated with asbestos abatement. Be prepared to demonstrate and have workers perform some or all of the following relevant tasks:

- ✓ Proper work practices for asbestos abatement activities, including descriptions of proper construction
- ✓ Maintenance of barriers and decontamination enclosure systems
- ✓ Positioning of warning signs
- ✓ Lockout of electrical and ventilation systems
- ✓ Proper working techniques for minimizing fiber release
- ✓ Use of wet methods
- ✓ Use of negative-pressure exhaust ventilation equipment
- ✓ Use of high-efficiency particulate air (HEPA) vacuums
- ✓ Proper cleanup and disposal procedures
- ✓ Work practices for removal, encapsulation, enclosure, and repair of friable ACM
- ✓ Emergency procedures for sudden releases
- ✓ Potential exposure situations
- ✓ Transport and disposal procedures
- ✓ Recommended and prohibited work practices

Personal Hygiene
Following abatement work, employees must wash their hands and face prior to eating, drinking, or smoking. Employees may not enter lunchroom facilities wearing protective work clothing or carrying equipment unless surface fibers have been removed from the clothing or equipment.
Discuss all of the following when explaining personal hygiene:

- ✓ Entry and exit procedures for the work area
- ✓ Use of showers
- ✓ Avoidance of eating, drinking, smoking, and chewing (gum or tobacco) in the work area
- ✓ Potential for family exposures

Additional Safety Hazards
In addition to personal hygiene, you should briefly discuss the following possible hazards encountered during abatement activities and how to deal with them:

- ✓ Electrical hazards
- ✓ Heat stress
- ✓ Air contaminants other than asbestos
- ✓ Fire and explosion hazards
- ✓ Scaffold and ladder hazards
- ✓ Slips, trips, and falls
- ✓ Confined spaces

For a more in-depth review, see PPE: Respirator Use, PPE: Protective Clothing and PPE: Eye and Face.

Summary

- ✓ The potential health effects related to asbestos exposure include lung cancer, mesothelioma, and cancers of other organs.
- ✓ Although asbestos is hazardous, human risk of asbestos disease depends upon exposure.
- ✓ Removal is often not the best course of action to reduce asbestos exposure. In fact, an improper removal can create a dangerous situation where none previously existed.
- ✓ Respirators have limitations of protection. Make sure your respirator is inspected, stored, and maintained properly.
- ✓ Employees must wash their hands and face prior to eating, drinking, or smoking.
- ✓ Smoking is not allowed in work areas exposed to asbestos.
- ✓ Each employee must enter and exit the asbestos-regulated area through the decontamination area.

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/s²)*

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
dθ = 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.)

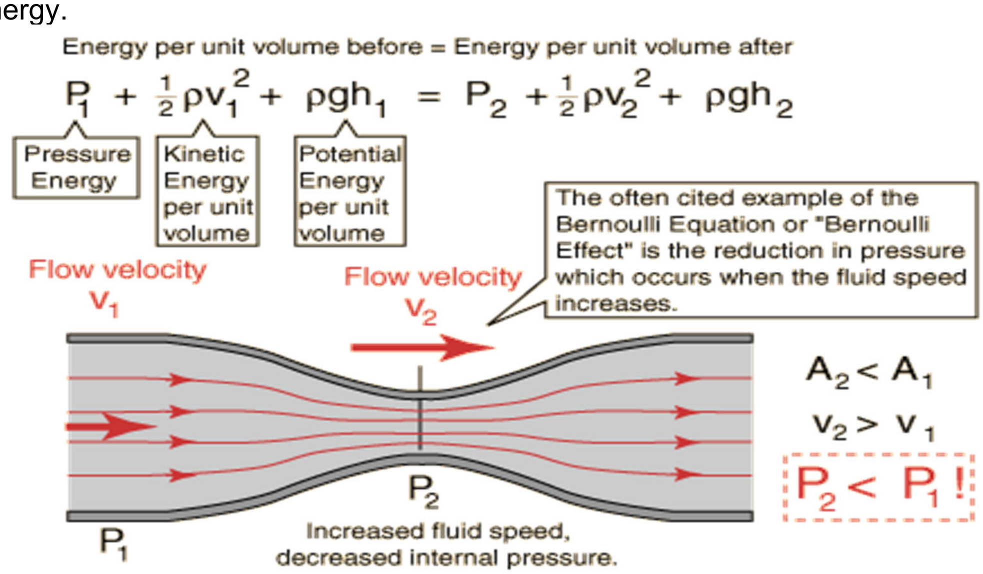
B

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

$\gamma=\rho\cdot g$

$$\frac{\rho\cdot v^2}{2}+p=\text{Constant} \qquad (4)$$

$$\frac{\rho\cdot v^2}{2}=p_d \qquad (5)$$

$$\frac{\rho\cdot v_1^2}{2}+p_1=\frac{\rho\cdot v_2^2}{2}+p_2=\text{Constant} \qquad (6)$$

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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

$h = 2\ \sigma\ \cos\theta\ /\ (\rho\ g\ r)$ *(1)*

where

h = *height of liquid (ft, m)*

σ = *surface tension (lb/ft, N/m)*

θ = *contact angle*

ρ = *density of liquid* (lb/ft^3, kg/m^3)

g = *acceleration due to gravity* (32.174 ft/s^2, 9.81 m/s^2)

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

$C = \rho v^2 / E$ (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 ^oC) 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 (^oC)	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.

$$1 / \lambda^{1/2} = -2 \log \left(\left(2.51 / (Re\, \lambda^{1/2})\right) + \left((k / d_h) / 3.72\right) \right) \quad (1)$$

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.

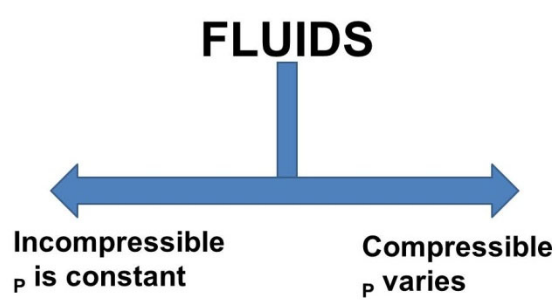
Compressible Flow: We know that fluids are classified as Incompressible and Compressible fluids. Incompressible fluids do not undergo significant changes in density as they flow. In general, liquids are incompressible; water being an excellent example. In contrast compressible fluids do undergo density 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)*

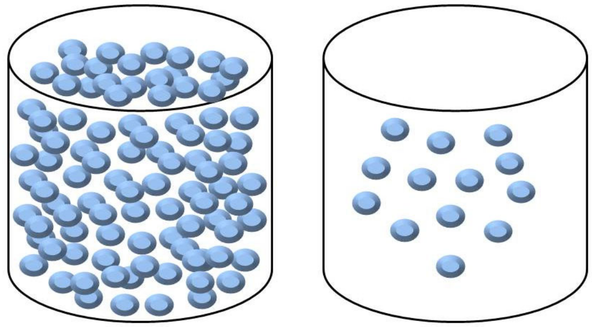
where
Δp *= pressure loss (Pa,* N/m^2*,* lb_f/ft^2*)*
λ *= D'Arcy-Weisbach friction coefficient*
l *= length of duct or pipe (m, ft)*
d_h *= hydraulic diameter (m, ft)*
ρ *= density (*kg/m^3*,* lb/ft^3*)*

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 790 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:

$$F_d = c_d\ 1/2\ \rho\ v^2\ A\ (1)$$

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

$p_d = 1/2\, \rho\, v^2$ (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

$\tau = \mu\ dc/dy$ (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^{o}F (20.2^{o}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:

$$p + 1/2\ \rho\ v^2 + \gamma\ h = \text{constant along a streamline} \quad (1)$$

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":

$$p / \gamma + v^2 / 2\ g + h = \text{constant along a streamline} = H \quad (2)$$

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:

$$EL = H = p / \gamma + v^2 / 2\ g + h = \text{constant along a streamline} \quad (3)$$

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:

$HGL = p / \gamma + h$ (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:**

$El = l_e / d$ (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:

$El_{laminar} = 0.06\ Re$ (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:

$El_{turbulent} = 4.4\ Re^{1/6}$ (3)

Entropy in Compressible Gas Flow: Calculating entropy in compressible gas flow
Entropy change in compressible gas flow can be expressed as

$$ds = c_v \ln(T_2 / T_1) + R \ln(\rho_1 / \rho_2) \quad (1)$$

or

$$ds = c_p \ln(T_2 / T_1) - R \ln(p_2 / p_1) \quad (2)$$

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 x 0.1 (m) x 0.1 (m) / 4)
or
v_{100} = (10 m^3/h)(1 / 3600 h/s) / (3.14 x 0.1 (m) x 0.1 (m) / 4)
= <u>0.35</u> 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 x 0.08 (m) x 0.08 (m) / 4)
or
v_{100} = (10 m^3/h)(1 / 3600 h/s) / (3.14 x 0.08 (m) x 0.08 (m) / 4)
= <u>0.55</u> 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:

$$p_{in} + \rho\, v_{in}^2 / 2 + \gamma\, h_{in} + \rho\, w_{shaft} = p_{out} + \rho\, v_{out}^2 / 2 + \gamma\, h_{out} + w_{loss} \quad (5)$$

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:

$$p_{in} / \gamma + v_{in}^2 / 2\, g + h_{in} + h_{shaft} = p_{out} / \gamma + v_{out}^2 / 2\, g + h_{out} + h_{loss} \quad (6)$$

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:
$h_{shaft} = w_{shaft} / g = W_{shaft} / m\, g = W_{shaft} / \gamma\, Q \quad (7)$
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:
$\eta = ((17.6 ft) - (7.6 ft)) / (17.6 ft) = 0.58$

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:

$p / \rho^k = constant$ *(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

$v = \mu / \rho$ *(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

$1\ St = 100\ cSt$
$1\ cSt = 10^{-6}\ m^2/s$

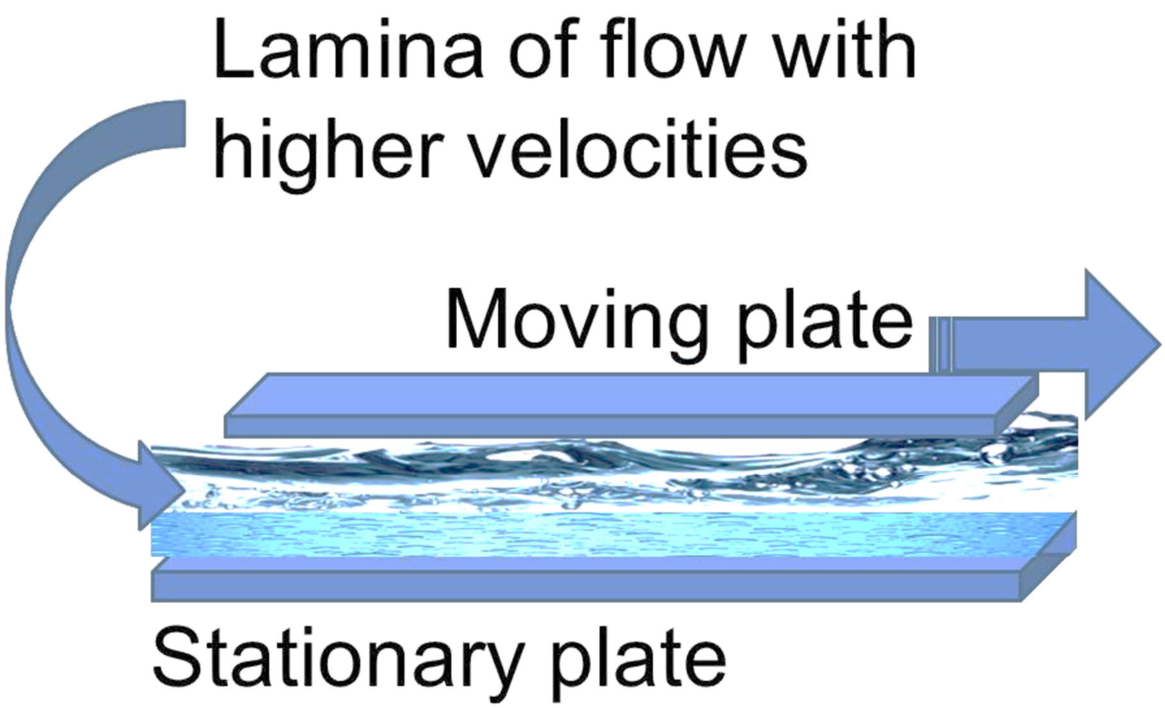
Since the specific gravity of water at 68.4°F (20.2°C) is almost one - 1, the kinematic viscosity of water at 68.4°F is for all practical purposes 1.0 cSt.

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 $\rho = 0$.

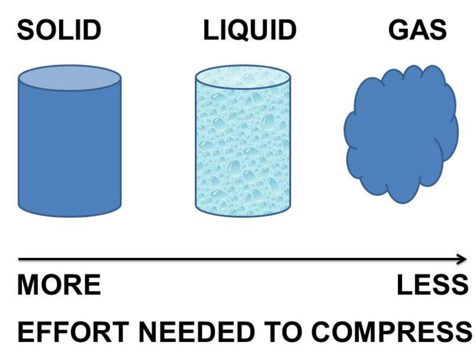
The vector Laplace's equation is given by

$$\nabla^2 \mathbf{F} = \mathbf{0}. \quad (4)$$

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

$Pr = v / \alpha$ *(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 ^oF))*
k = *thermal conductivity (W/m K, Btu/(h ft^2 ^oF/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°K (0°C) and is **1.01325 bar** or 101325 Pa (absolute). The temperature of 293°K (20°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

$$dp = - \gamma \, dz \quad (1)$$

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:

$$\gamma = \rho \, g \quad (2)$$

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)*

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) = 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).

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

$St = \omega l / v$ *(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

$$\sigma = F_s / l \quad (1)$$

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°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.

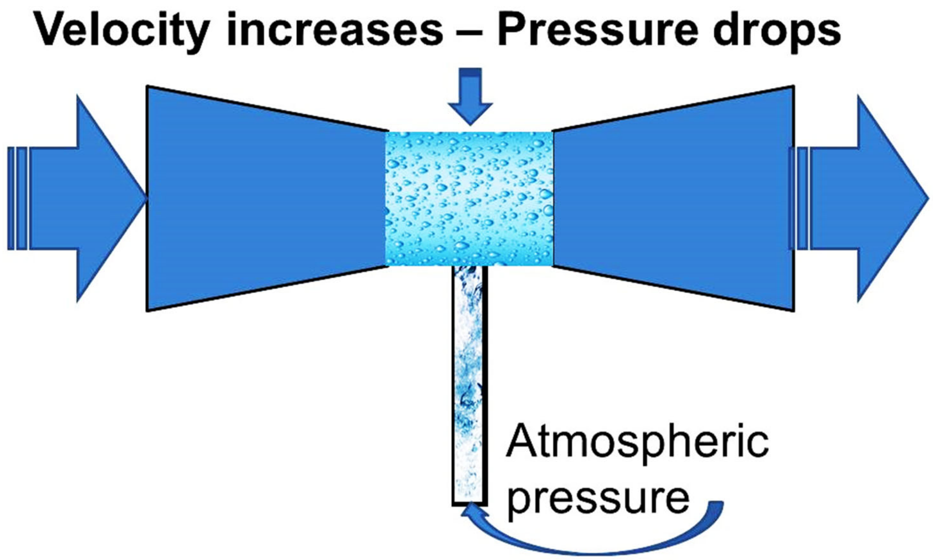
Velocity Head: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.

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°C. For a distillate fluid the reference temperature is 40°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.

Appendixes and Charts

Density of Common Liquids

The density of some common liquids can be found in the table below:

Liquid	Temperature - *t* - (ºC)	Density - *ρ* - (kg/m³)
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, 48º API	60ºF	790
Crude oil, 40º API	60ºF	825
Crude oil, 35.6º API	60ºF	847
Crude oil, 32.6º API	60ºF	862
Crude oil, California	60ºF	915
Crude oil, Mexican	60ºF	973
Crude oil, Texas	60ºF	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	60ºF	890
Furan	25	1416
Furforol	25	1155
Gasoline, natural	60ºF	711
Gasoline, Vehicle	60ºF	737

Gas oils	60ºF	890
Glucose	60ºF	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	60ºF	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	60ºF	711
Petrol, Vehicle	60ºF	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
Sulphuric 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	77ºF	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) = <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).

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

Thermal Properties of Water

Temperature - *t* - (°C)	Absolute pressure - *p* - (kN/m²)	Density - *ρ* - (kg/m³)	Specific volume - *v* - (m³/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

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 ^{o}C - 1,000 kg/m^3, 62.43 Lbs./Cu.Ft, 8.33 Lbs./Gal., 0.1337 Cu.Ft./Gal.
- Freezing temperature - 0 ^{o}C
- Boiling temperature - 100 ^{o}C
- Latent heat of melting - 334 kJ/kg
- Latent heat of evaporation - 2,270 kJ/kg
- Critical temperature - 380 - 386 ^{o}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 ^{o}C to 100 ^{o}C - 4.2x10^{-2}
- Bulk modulus elasticity - 2,068,500 kN/m^2
- 1 ft (foot) = 0.3048 m = 12 in = 0.3333 yd

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} (lb.s/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
2.54 CM =Inch
1 Gallon of Water = 8.34 Pounds
1 mg/L = 1 PPM
17.1 mg/L = 1 Grain/Gallon
1% = 10,000 mg/L
694 Gallons per Minute = MGD
1.55 Cubic Feet per Second = 1 MGD
60 Seconds = 1 Minute
1440 Minutes = 1 Day
.746 kW = 1 Horsepower

LENGTH
12 Inches = 1 Foot
3 Feet = 1 Yard
5280 Feet = 1 Mile

AREA
144 Square Inches = 1 Square Foot
43,560 Square Feet = 1 Acre

VOLUME
1000 Milliliters = 1 Liter
3.785 Liters = 1 Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of Water
62.38 Pounds = 1 Cubic Foot of Water

Dimensions

SQUARE: Area (sq. ft.) = Length X Width
Volume (cu. ft.) = Length (ft) X Width (ft) X Height (ft)

CIRCLE: Area (sq. ft.) = 3.14 X Radius (ft) X Radius (ft)

CYLINDER: Volume (Cu. ft) = 3.14 X Radius (ft) X Radius (ft) X Depth (ft)

PIPE VOLUME: .785 X Diameter ^{2} X Length = ? To obtain gallons multiply by 7.48

SPHERE: $\frac{(3.14)\ (\text{Diameter})^3}{(6)}$

Circumference = 3.14 X Diameter

General Conversions
Flowrate

Multiply	—>	to get
to get	**<—**	**Divide**
cc/min	1	mL/min
cfm (ft^3/min)	28.31	L/min
cfm (ft^3/min)	1.699	m^3/hr
cfh (ft^3/hr)	472	mL/min
cfh (ft^3/hr)	0.125	GPM
GPH	63.1	mL/min
GPH	0.134	cfh
GPM	0.227	m^3/hr
GPM	3.785	L/min

POUNDS PER DAY= Concentration (mg/L) X Flow (MG) X 8.34
***AKA* Solids Applied Formula** = Flow X Dose X 8.34

TEMPERATURE: ^{0}F = (^{0}C X 9/5) + 32 9/5 =1.8
^{0}C = (^{0}F - 32) X 5/9 5/9 = .555

CONCENTRATION: Conc. (A) X Volume (A) = Conc. (B) X Volume (B)

FLOW RATE (Q): Q = A X V (**Q**uantity = **A**rea X **V**elocity)

FLOW RATE (gpm): Flow Rate (gpm) = $\frac{2.83 \text{ (Diameter, in)}^2 \text{ (Distance, in)}}{\text{Height, in}}$

VELOCITY = $\frac{\text{Distance (ft)}}{\text{Time (Sec)}}$

N = Manning's Coefficient of Roughness
R = Hydraulic Radius (ft.)
S = Slope of Sewer (ft/ft.)

HYDRAULIC RADIUS (ft) = $\frac{\text{Cross Sectional Area of Flow (ft)}}{\text{Wetted pipe Perimeter (ft)}}$

MIXTURE STRENGTH (%) = $\frac{\text{(Volume 1, gal) (Strength 1, \%) + (Volume 2, gal) (Strength 2,\%)}}{\text{(Volume 1, gal) + (Volume 2, gal)}}$

INJURY FREQUENCY RATE = $\frac{\text{(Number of Injuries) 1,000,000}}{\text{Number of hours worked per year}}$

HYDRAULIC RADIUS (ft) = $\frac{\text{Flow Area (ft. 2)}}{\text{Wetted Perimeter (ft.)}}$

References

Several Photographs and Reference were provided by
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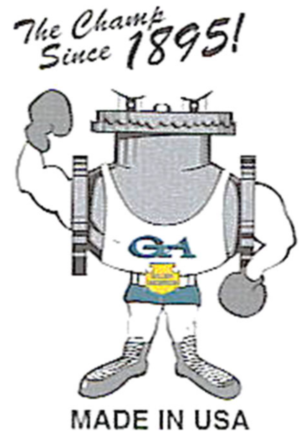

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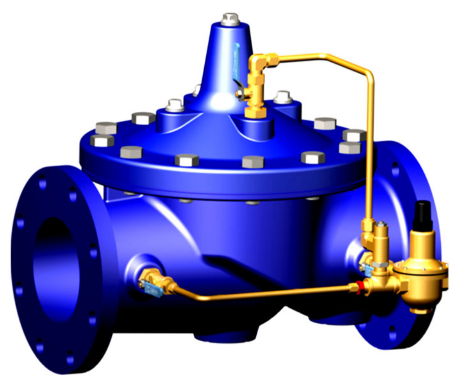

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EPA Office of Water (4601M), Office of Ground Water and Drinking Water, Distribution System Issue Paper, Finished Water Storage Facilities

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