VALVE CONTROLS

CONTINUING EDUCATION

PROFESSIONAL DEVELOPMENT COURSE

6 PDHs, 6 TUs, 6 CEHs or .5 CEUs upon completion

Technical Learning College

Printing and Saving Instructions

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

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

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

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

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

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

Internet Link to Assignment…
http://www.tlch2o.com/PDF/ValveControlAss.pdf

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

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

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

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

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**), 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. makes no warranty, guarantee or representation as to the absolute correctness or appropriateness of the information in this manual and assumes no responsibility in connection with the implementation of this information.

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

CEU Course Description

VALVE CONTROLS CEU TRAINING COURSE

This short technical continuing education course will address the function, application and selection of various valves (control devices) used in every stage of the water treatment cycle from raw water intake to the treated wastewater discharge. This course will cover criteria for selecting and applying check valves, air relief, automatic valves on wells, in raw water pumping stations, in the water treatment plant, and in potable water storage and distribution systems as well as in sewage lift stations, on force mains, in wastewater treatment plants, on effluent and reuse pumping. Of the 83 different TLC courses, this course is designed for the sixth grade reading level for Operators that do not have upper level reading skills.

This course will also review basic hydraulic fundamentals and principles, i.e. water hammer, head, and pressure. Following this short course, the student will develop an understanding of the different classifications and uses of commonly found valves. This training course will present several familiar topics in valve related installations and problems encountered. ***You will not need any other materials for this course.***

Prerequisites: None

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

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

Instructions for Assignment
The ***Valve Controls*** CEU training course uses a multiple choice type answer key. You can find a copy of the answer key in the back of this course manual or in Word format on TLC's website under the Assignment Page. You can also find complete course support under the Assignment Page.

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

Feedback Mechanism (examination procedures)
Each student will receive a feedback form as part of their study packet. You will be able to find this form in the rear of the course or lesson.

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

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

Required Texts
The ***Valve Controls*** 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.

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

You will have 90 days from receipt of this manual to complete it in order to receive your Continuing Education Units (**CEUs**) or Professional Development Hours (**PDHs**). A score of 70% or better is necessary to pass this course. If you should need any assistance, please email all concerns and the final test to: info@tlch2o.com.

A Ball Stop with my favorite copper fitting, a flare fitting. It is difficult to find and even harder to find a person that knows how to flare copper correctly. I personally think that this may be the best copper fitting of all time, even stronger than sweating.

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 an Instructor if you need any assistance with this course or assignment. We can also come to your facility. Always check with your State agency to see if this course is accepted.

Toll Free (866) 557-1746

TLC can come to your facility and provide classroom instruction. To date, we have trained over 10,000 operators. We like to utilize hands-on training as well as distance based training. Let us know how we can serve you. Your business is very important to us. Send us your questions; we have over 13 Instructors to answer your questions.

TABLE OF CONTENTS

Common Hydraulic Terms

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

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

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

Hydraulics
Engineering science pertaining to liquid pressure and flow.

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

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

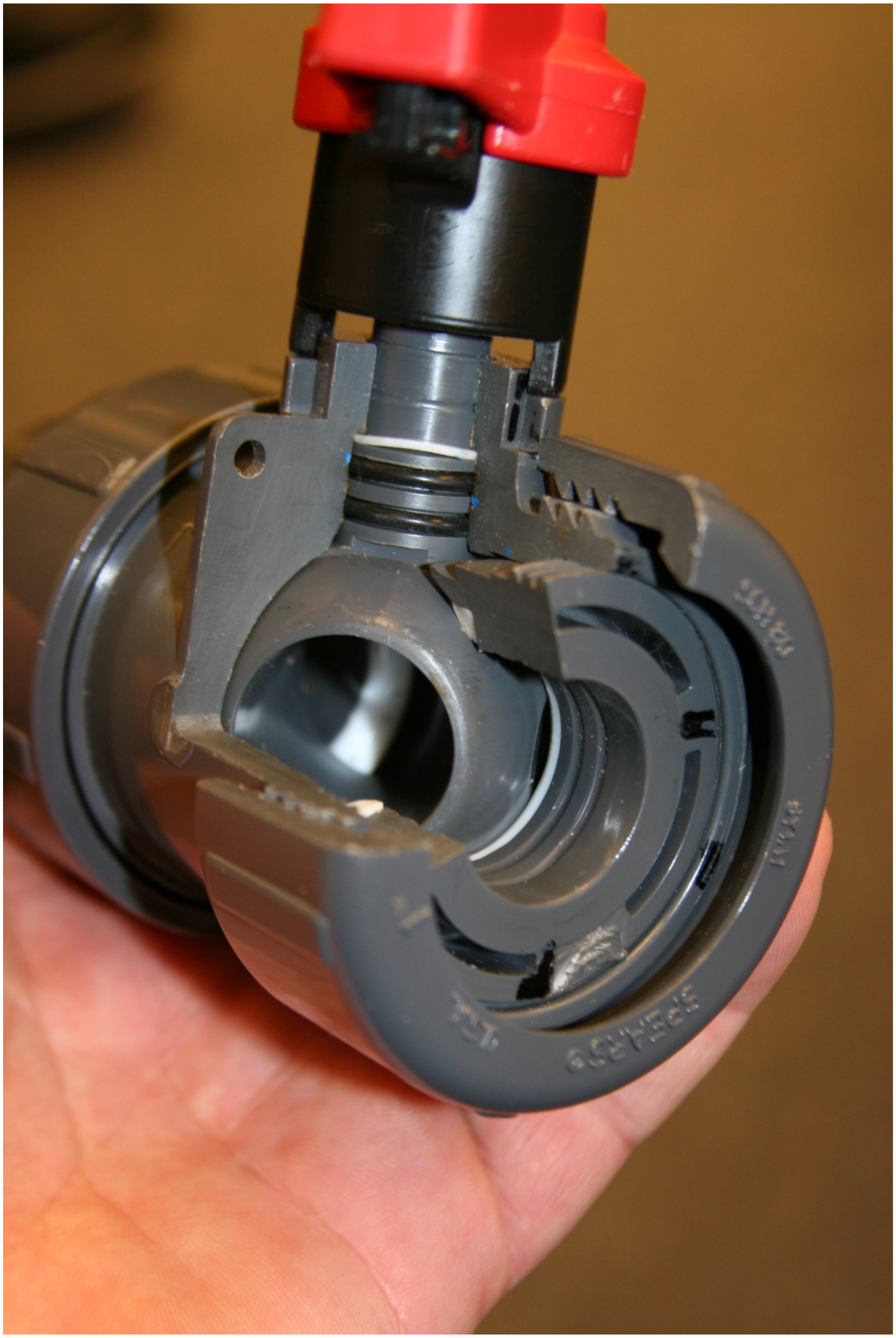
Pressure
The application of continuous force by one body upon another that it is touching; compression. Force per unit area, usually expressed in pounds per square inch (Pascal or bar).

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

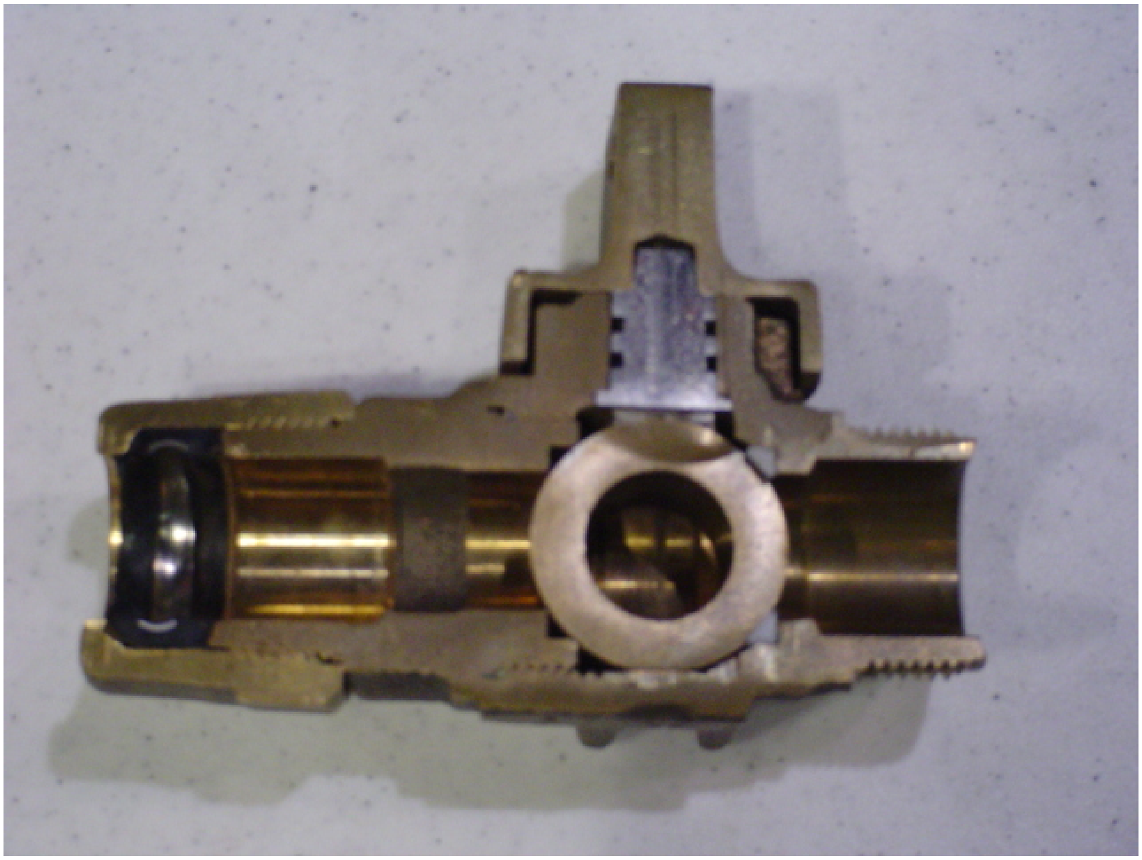
Pressure, Atmospheric
Pressure exported by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute, 1 bar = 14.5psi.)

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

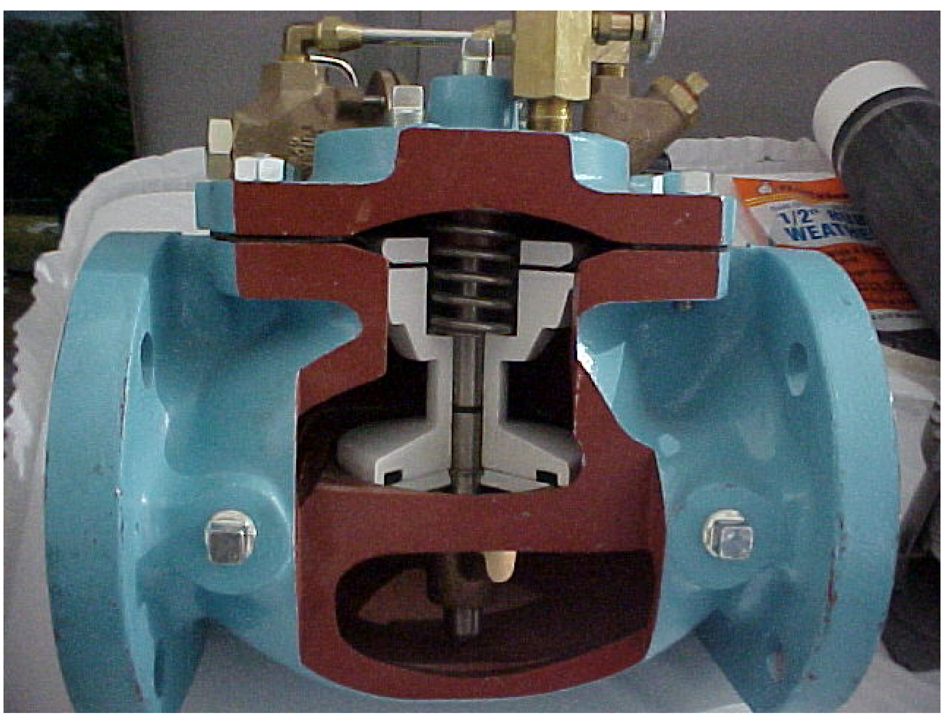
Pressure, Static
The pressure in a fluid at rest.



A cut away of a ball valve. The ball is made of plastic in this valve. The balls are not perfectly round but are egg shaped or elongated to make a good seal.



Above, a cut away of a brass Ball valve. Below a PRV.



Introduction to Water System Valves

System design depends on the area that you live. You may be a flatlander, like in Texas, and the services could be spread out for miles. You may live in the Rocky Mountain area and have many fluctuating elevations. 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.

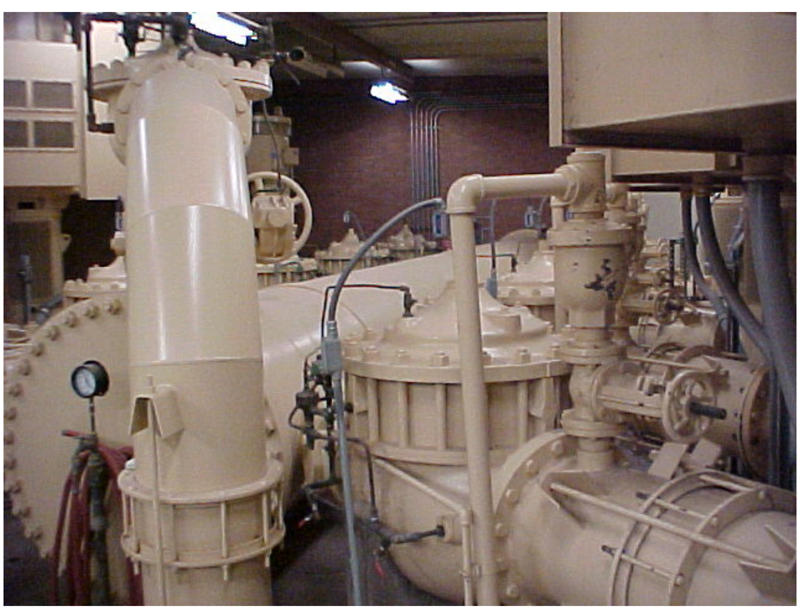
1. ***What is the source of water?***
2. ***What is the population?***
3. ***What kind of storage will I need for high demand and emergencies?***
4. ***How will the pressure be maintained?***

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

STORAGE RESERVOIRS 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.

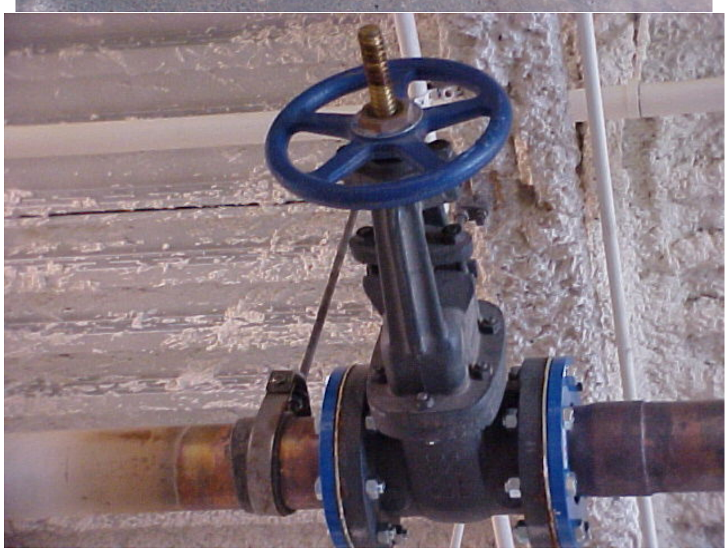


The inside of a booster pump station, notice the PRV with air relief valve.

Commonly found s*ystem 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.



Two different styles of Gate Valves. Top photograph is valve ready for a valve replacement. Bottom photograph is OS&Y commonly found on fire lines.
(Outside Screw and Yoke) As the gate is lifted or opened, the stem will rise.

Gate valves should be used in the distribution system for main line isolation.

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. ***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.

Always remember to use shoring and proper safety equipment when working underground. You should also wear your hard hats as well. We are professionals and need to look like it. Bottom photograph is two nitwits going to be killed. 15 feet deep and no way out. Let's think before doing work.

Distribution Valves

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

Valves should be installed at intervals not greater than 5,000 feet in long supply lines, and 1,500 foot 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.



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.

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.

Here is a nasty 4 inch broken gate valve with serious Tuberculation. The valve is broken closed. The rust particles are sharp and can easily cut the water service worker. The flange bolts or Tee bolts were cut off to replace this valve. The rubber gasket will leave a black ink like stain on your clothes and in the water line as well. You will see lots of nasty stuff in the top portion of a valve. Some engineers or big shots refer to this area of the valve as the “Angular space”. If they really knew that this space contained nasty particles or debris and sediment they would never visit your Yard or facility again.

One practice that I am not sure about is the common procedure of only removing the bonnet or removing the guts of a closed valve and keeping the valve body on the line. I guess that sometimes this practice is necessary, and I don’t like removing the guts and packing of cement and a redwood plug in the stem hole but it happens. Dr. Rusty’s advice, when working on wastewater and water valves is difficult practice because of mud, debris and because water lines are under pressure, but be super careful of rust particles cutting your skin. Get in line at the Doctor’s or Health Provider’s facility and get all of your shots. Especially Tetanus and Hepatitis. Some of you will need Rabies as well, not because of the water but because of your wild animal make-up. I know some of you will fight this but the facts are that you will probably be infected with something nasty. Dr. Rusty recommends that you protect yourself, others around you and the public.

Notice the corrosion inside this cast iron main.

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

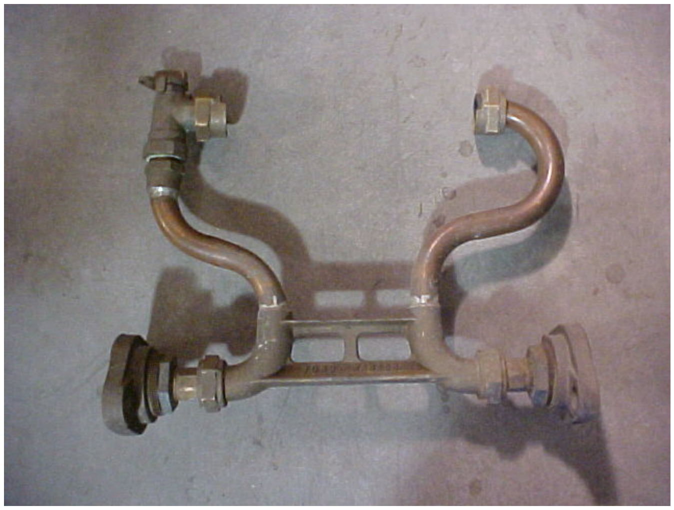
Gate valve storage procedures. Dr. Rusty recommends to always store a gate valve with the gate up or opened. Not like this picture. Sunlight will give the rubbers a good shot of Vitamin D and a sunburn, destroying the rubbers with ultraviolet radiation. I like to keep the valves covered and clean and I want you to do the same. I know that some of you don't care because these valves are so darn heavy and bother-some. 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.

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



Water Meter Re-setter, Riser, or sometimes referred to as a copper yoke. There is also a cast iron version which is best broken off with two sledge or cocking hammers when it’s time to replace or retrofit the service. You almost always replace a yoke stop hot. A Yoke stop is an Angle Stop most of the time but I’ve seen a nasty galvanized valve that is also used in this situation.

Common distribution fittings: Single check, Poly Pig, 1 inch repair clamp, 4 inch full circle clamp, T- Bolt and a corp. and saddle. Note from Dr. Rusty, Single checks are not a backflow assembly and will probably stick open over time. I know that most systems will pay for these but unless you replace or test these checks, they will not hold up. Most fitting salesmen will not tell you this little tidbit. Notice the Corp, it is a ball type valve.

Ductile pipe cement-lined iron pipe. I've seen thousands of dollars of pipe that is dropped or moved with the front bucket of a backhoe and destroyed. This destroys the interior protection of the pipe, causing leaks which will start in a few years. I know that some of you welcome this as job security. These nitwits need job security, but water professionals do not need crappy work to keep them employed. Always protect and store all types of pipe covered 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. It is fun to watch and good to tease these rookies about it. Especially if they have just finished jumping a stop with the valve closed or no ball. Good times for sure in the crazy Distribution field.

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

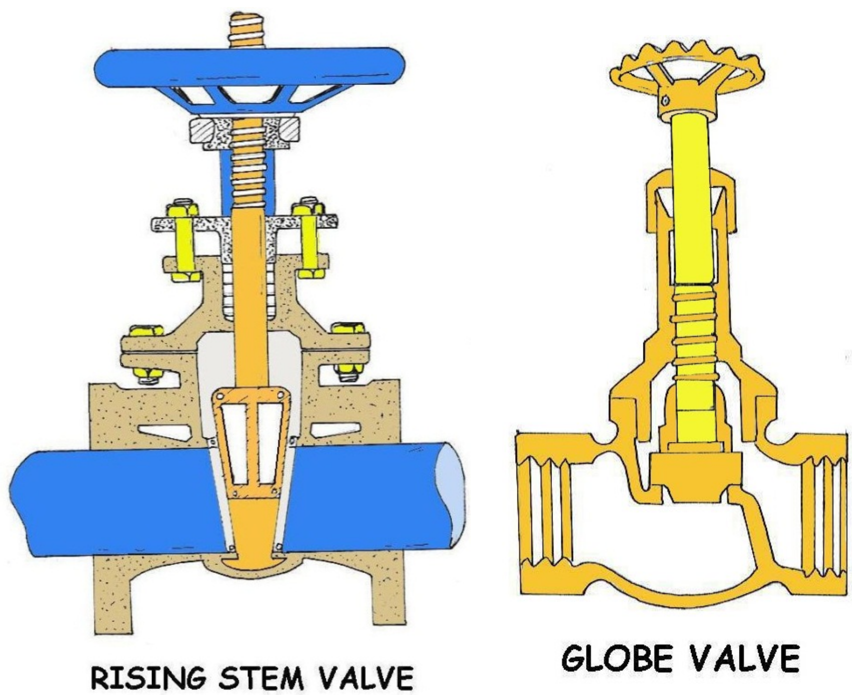
Top photograph, two gate valves blew out, you can see the kickers or thrust blocks in the back ground. Bottom photograph, a tapping machine and a new gate valve. These tapping machines are very, very expensive. I can't believe the cost of a new one. Even buying a used one will set you back more than a new car.

Common Rotary Valves

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 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 being 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.

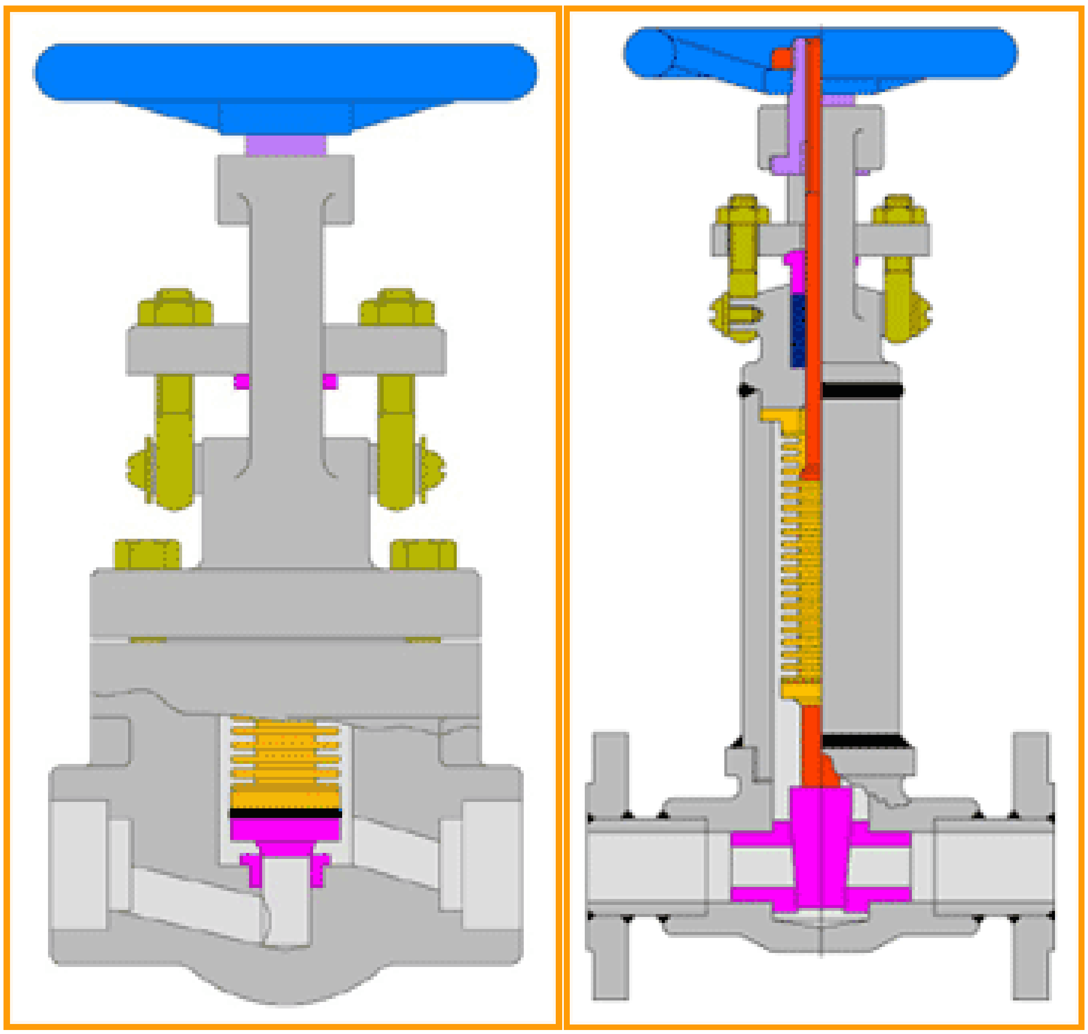
Bellow Seal Valve

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.



Bellow's style Globe on left, Gate on right

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.

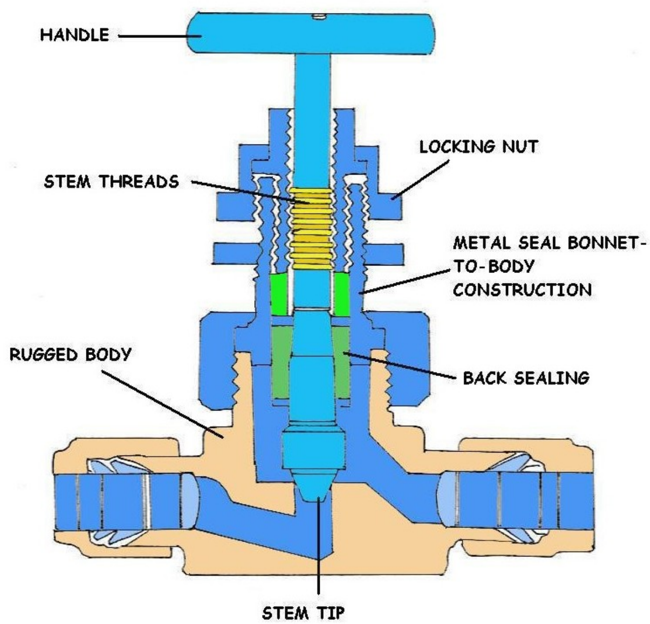
Insertion Valves *Rotary Valve*

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*

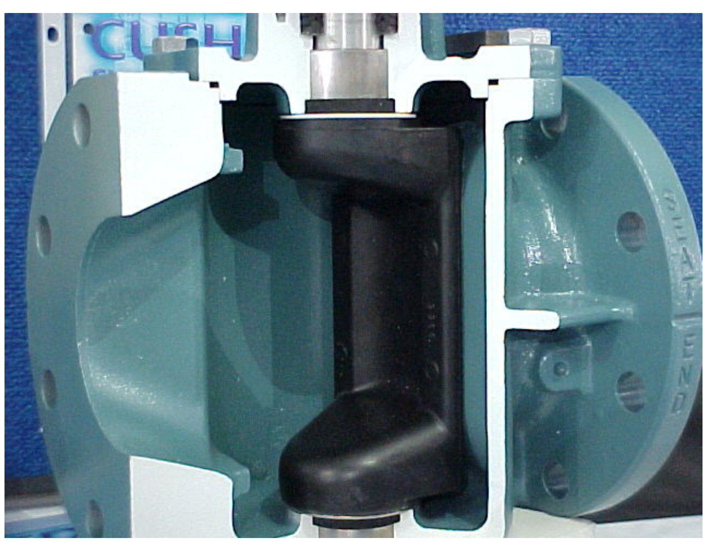
A needle valve, as shown on the right, is used to make relatively fine adjustments in the amount of fluid flow. The distinguishing characteristic of a needle valve is the long, tapered, needle- like point on the end of the valve stem. This "needle" acts as a disk. The longer part of the needle is smaller 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.



NEEDLE VALVE

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 Stop *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.

Get in there and jump that corp!

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 best trick is to remove the ball from the Ball valve and have a rookie ***Jump a Stop***. 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.

Bird’s eye view of the coveted stainless steel ball**.**

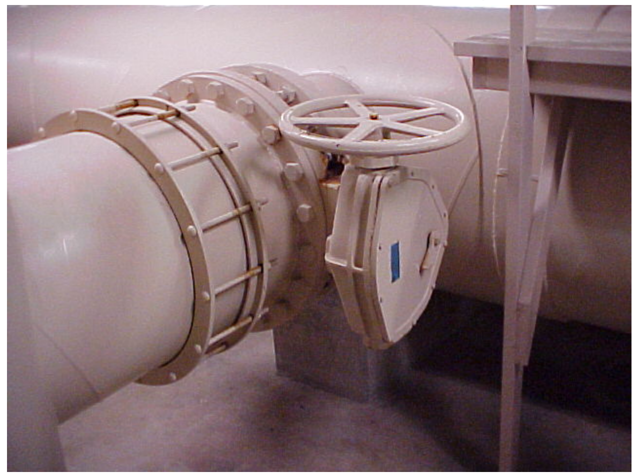
Removing the ball is very difficult. I think they use a robot to tighten the rear nut to keep you from removing it. I recommend that you always use pipe dope or Teflon tape when installing a Stop. I know a lot of you think that brass or bronze will make up the slack, but pipe dope, or Teflon dope or tape makes a nicer job and makes for an easier removal.

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.

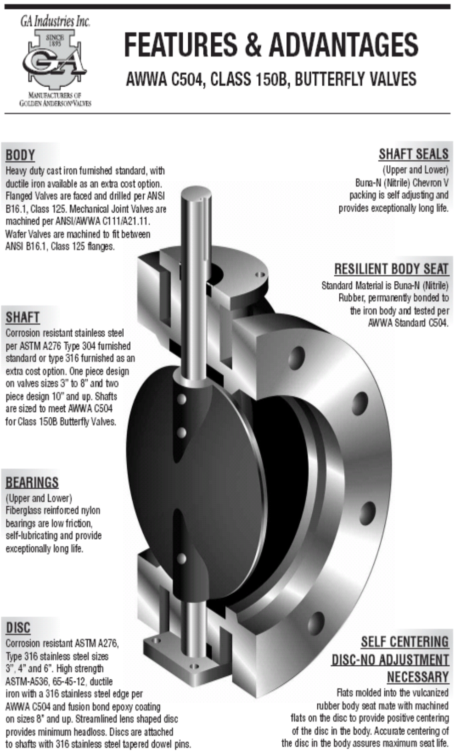


Butterfly valves should be installed with the valve shaft horizontal or inclined from vertical. Always follow standard safety procedures when working on a valve.

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.



GA Industries Inc.

SINCE 1895

MANUFACTURERS OF GOLDEN ANDERSON VALVES

FEATURES & ADVANTAGES

AWWA C504, CLASS 150B, BUTTERFLY VALVES

BODY
Heavy duty cast iron furnished standard, with ductile iron available as an extra cost option. Flanged Valves are faced and drilled per ANSI B16.1, Class 125. Mechanical Joint Valves are machined per ANSI/AWWA C111/A21.11. Wafer Valves are machined to fit between ANSI B16.1, Class 125 flanges.

SHAFT SEALS
(Upper and Lower)
Buna-N (Nitrile) Chevron V packing is self adjusting and provides exceptionally long life.

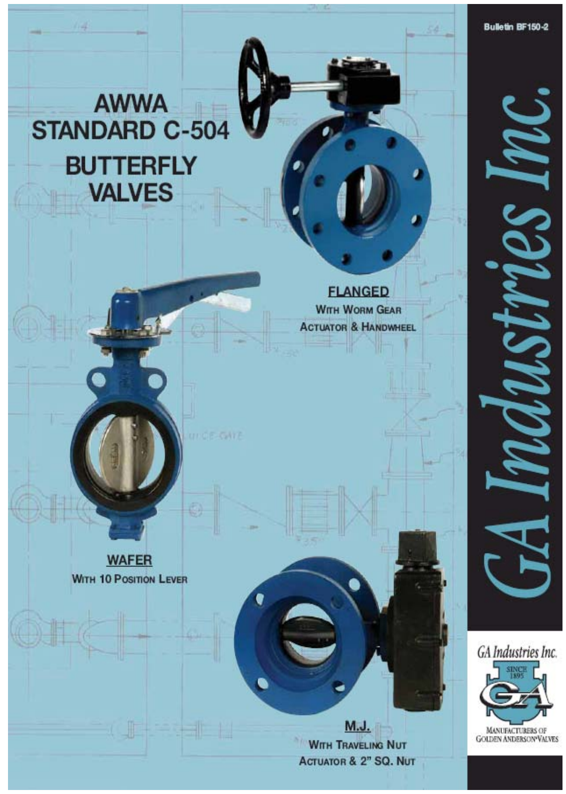
RESILIENT BODY SEAT
Standard Material is Buna-N (Nitrile) Rubber, permanently bonded to the iron body and tested per AWWA Standard C504.

SHAFT
Corrosion resistant stainless steel per ASTM A276 Type 304 furnished standard or type 316 furnished as an extra cost option. One piece design on valves sizes 3" to 8" and two piece design 10" and up. Shafts are sized to meet AWWA C504 for Class 150B Butterfly Valves.

BEARINGS
(Upper and Lower)
Fiberglass reinforced nylon bearings are low friction, self-lubricating and provide exceptionally long life.

DISC
Corrosion resistant ASTM A276, Type 316 stainless steel sizes 3", 4" and 6". High strength ASTM-A536, 65-45-12, ductile iron with a 316 stainless steel edge per AWWA C504 and fusion bond epoxy coating on sizes 8" and up. Streamlined lens shaped disc provides minimum headloss. Discs are attached to shafts with 316 stainless steel tapered dowel pins.

SELF CENTERING DISC-NO ADJUSTMENT NECESSARY
Flats molded into the vulcanized rubber body seat mate with machined flats on the disc to provide positive centering of the disc in the body. Accurate centering of the disc in the body assures maximum seat life.



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.

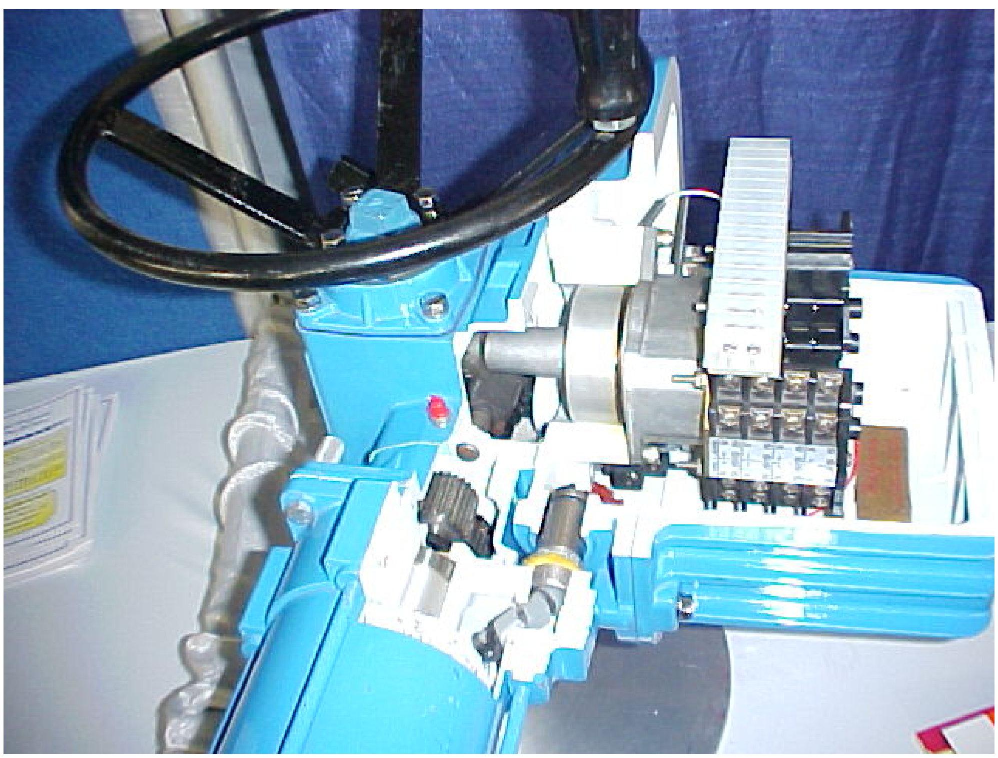
If the valve has a pneumatic actuator, the air supply may be inadequate--Increase the air supply pressure to standard operating level. Any combination of the following may prevent the valve shaft from rotating:

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.



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 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.

Pressure reducing valves reduce the supply pressure as needed for various circuits.
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.

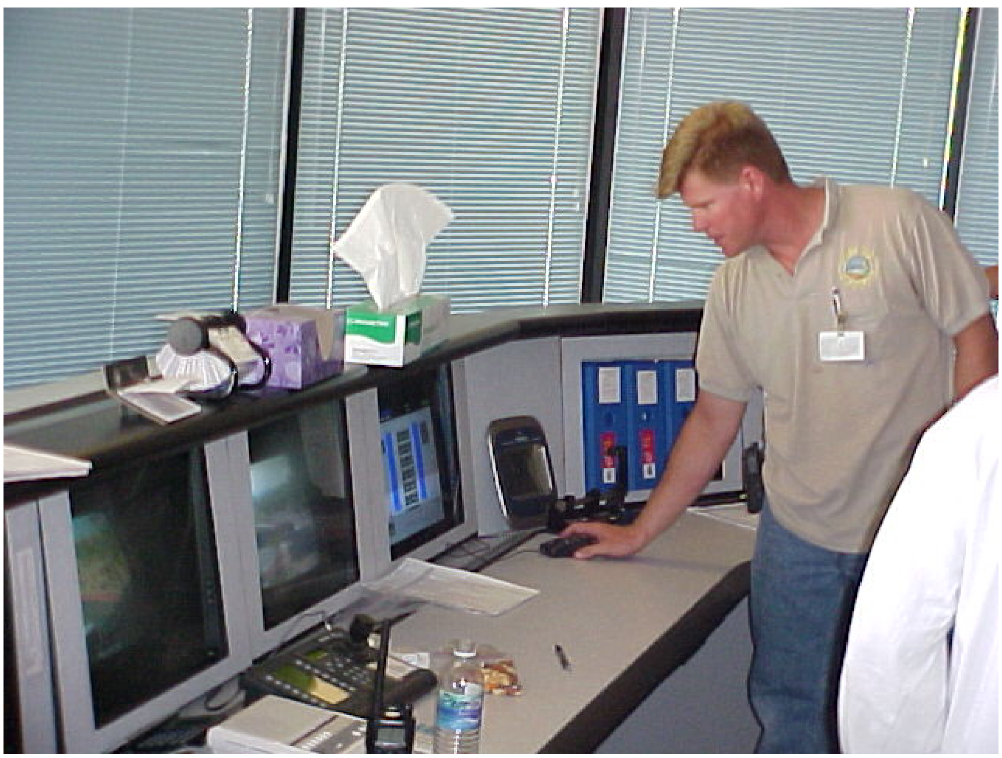
Check valves are one way valves, allowing an accumulator to charge and maintain its pressure after the machine is turned off, for example.

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 with drilled 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.



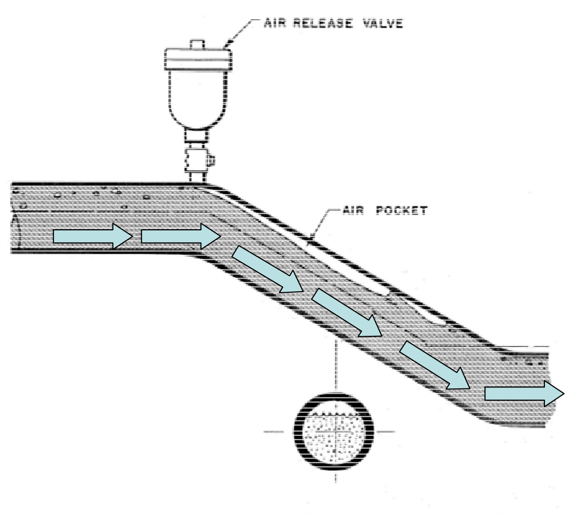
Here is an Operator who utilizes electronic or SCADA control of the valves at a modern treatment facility. Push a button at work and live a good life. This is one of my favorite students of all time. He has been coming to TLC classes for ten years and has climbed all the way to the top. I am very proud of his work as well as that of all my students.

Why use automatic air valves?

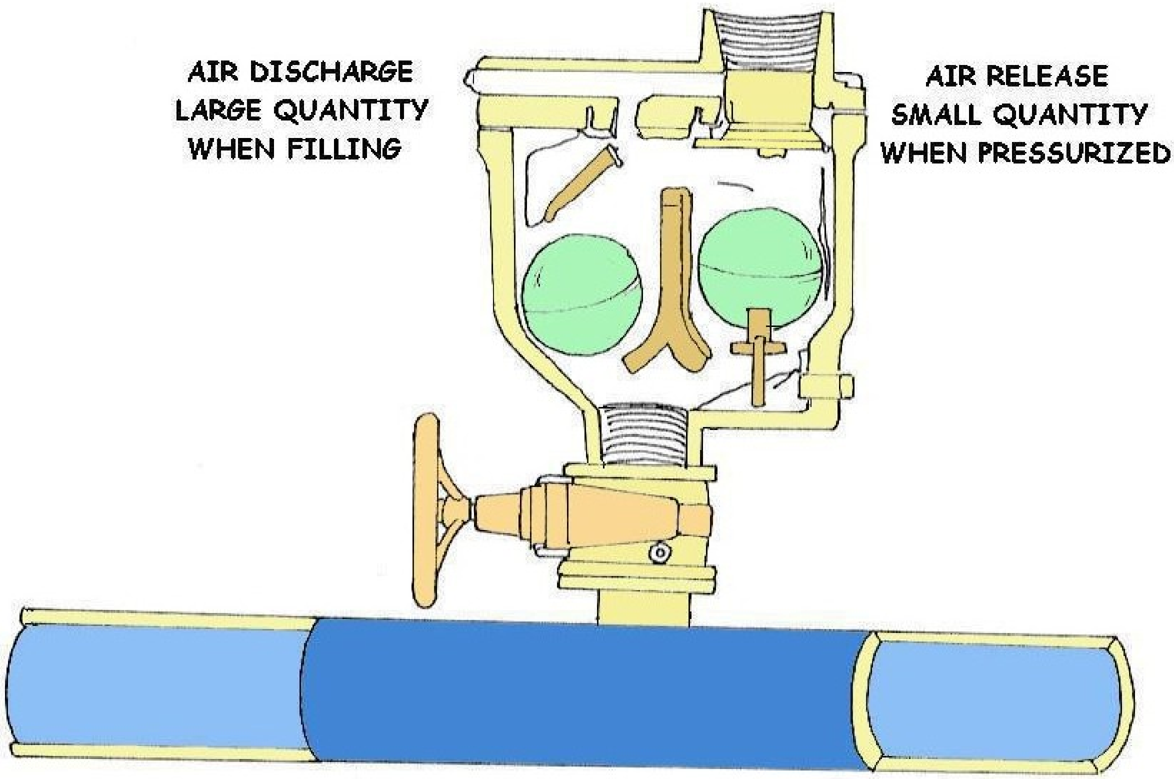
- ❑ **Increase flow capacity**
- ❑ **Reduce pumping costs (less electricity)**
- ❑ **Lessen the effect of water hammer.**
- ❑ **Prevent vacuum damage, such as pipeline collapse, seal failure, contamination and cross connection.**
- ❑ **Keep the lines full to reduce corrosion of the pipe.**

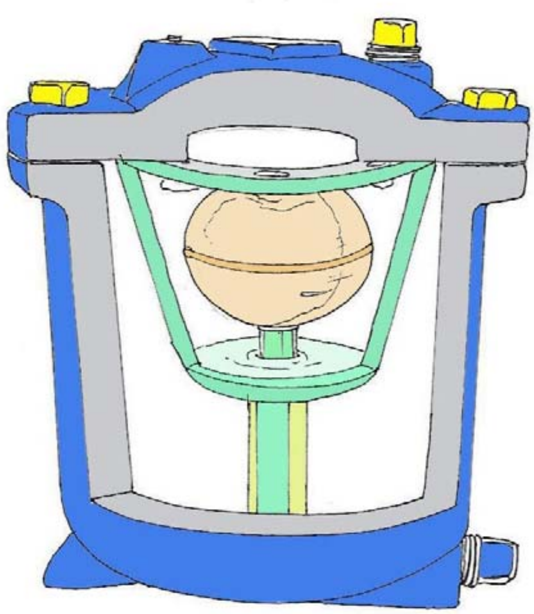
Air pockets reduce the cross sectional area of the pipe available to transmit the fluid, similar to partially closed valves. The velocity will increase at all air pockets and therefore the system head loss also increases.

The flow in the pipeline will push the air pocket down the pipe. The location of air valves should be at the point of the anticipated air pocket during flowing conditions.

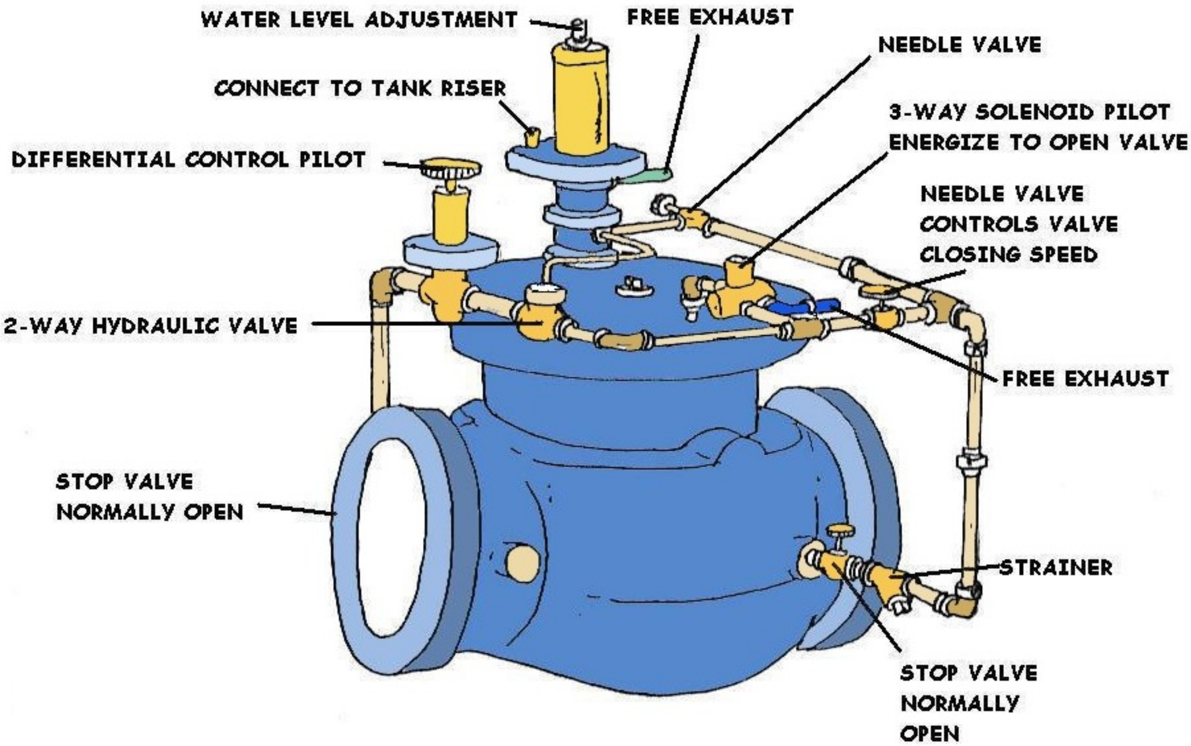


COMBINATION AIR VALVE

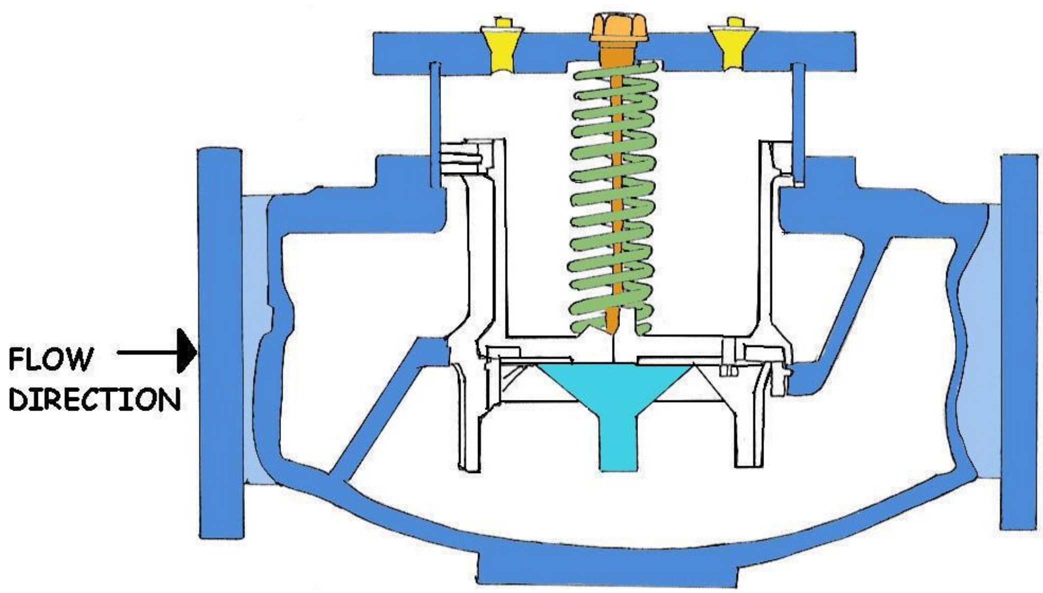




INTERNAL VIEW OF COMBINATION AIR VALVE

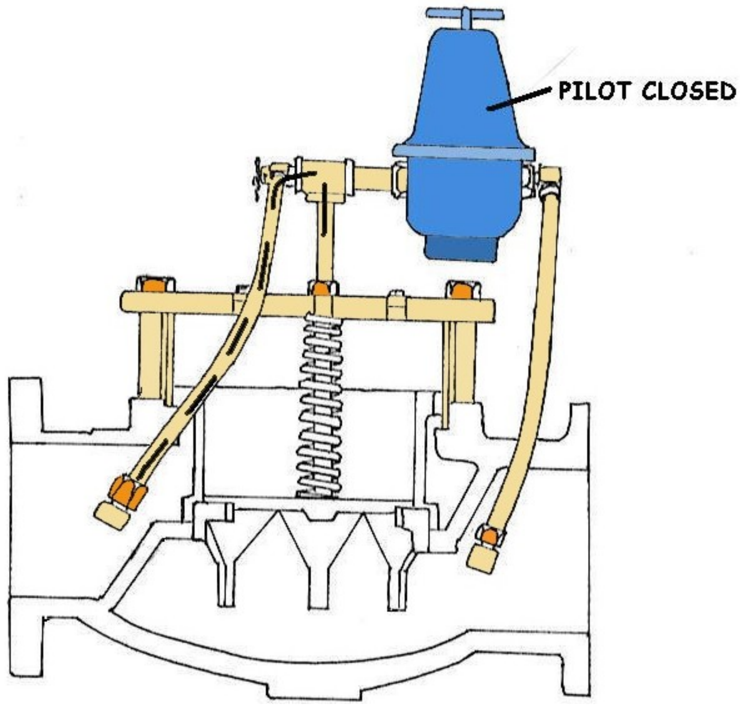


ALTITUDE CONTROL VALVE

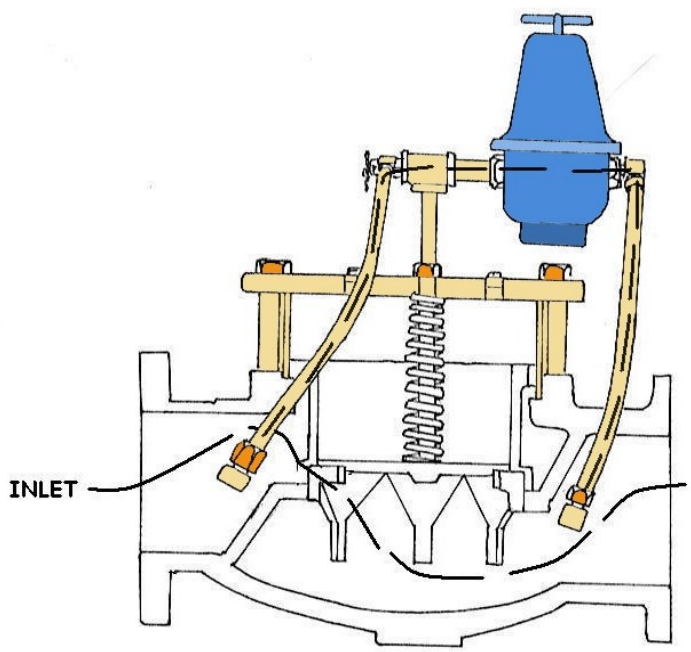


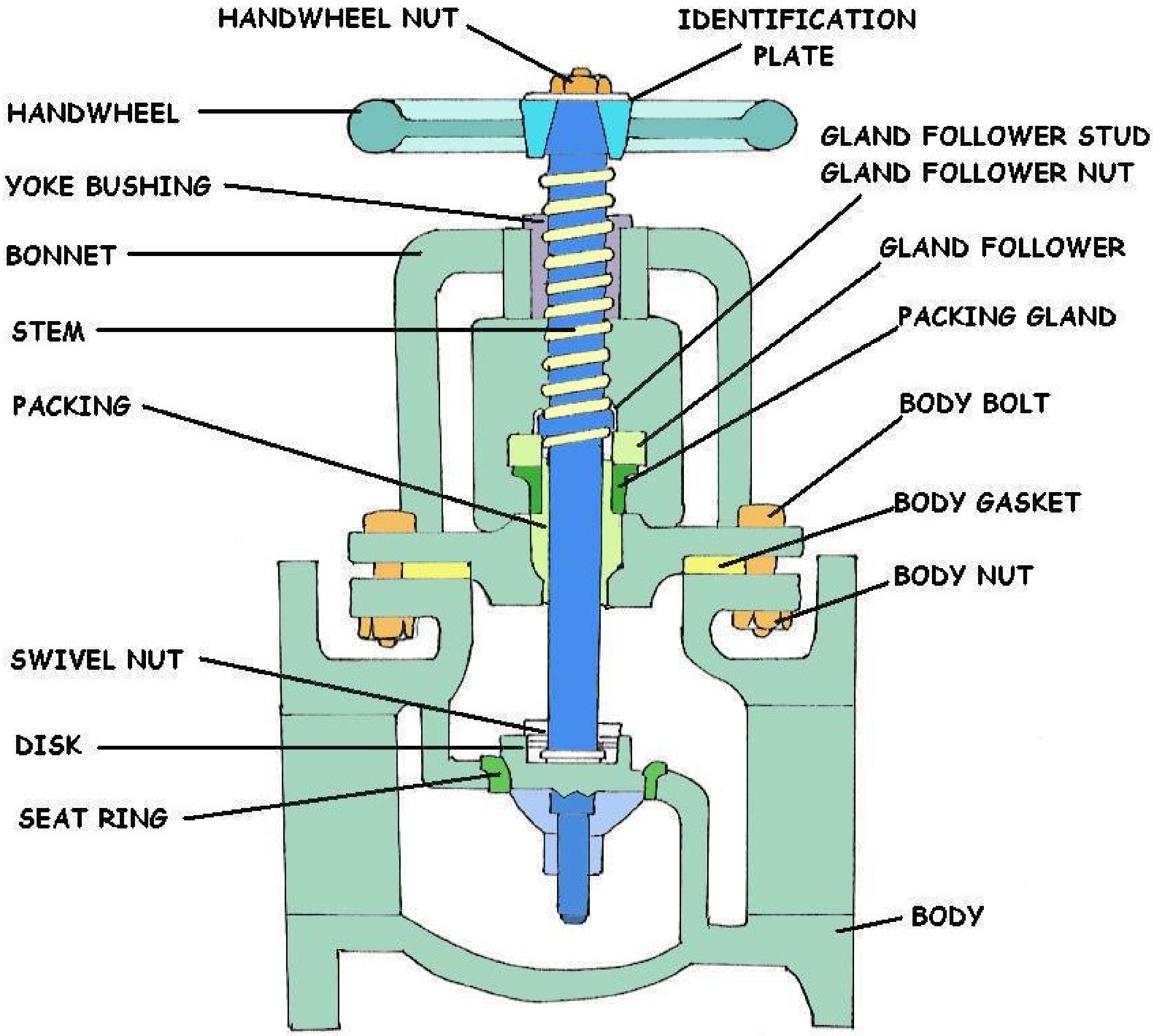
FLANGED GLOBE STYLE PRESSURE REDUCING VALVE

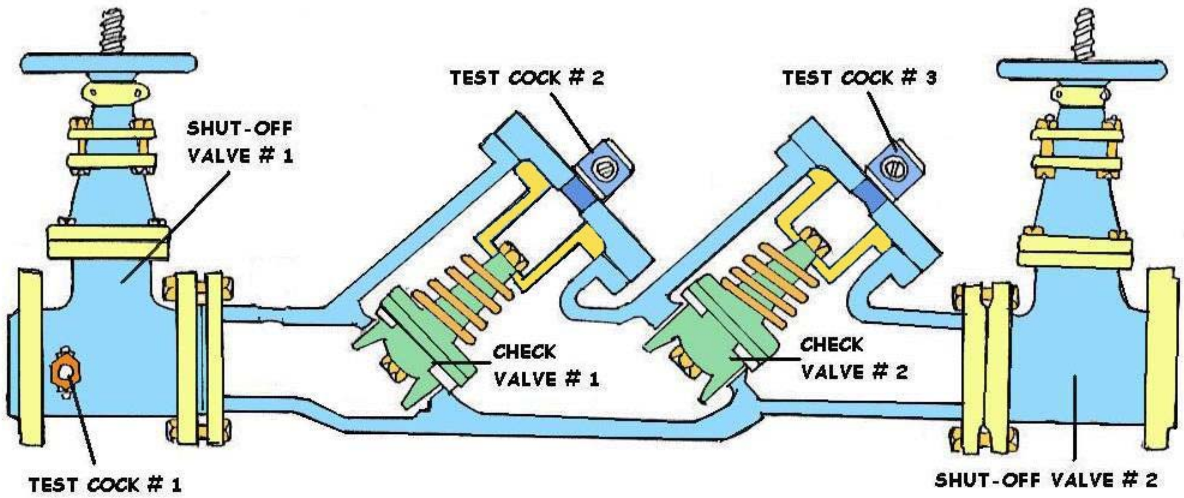
REDUCED PRESSURE VALVE OPERATION
(VALVE CLOSED)



REDUCED PRESSURE VALVE OPERATION
(VALVE OPEN)

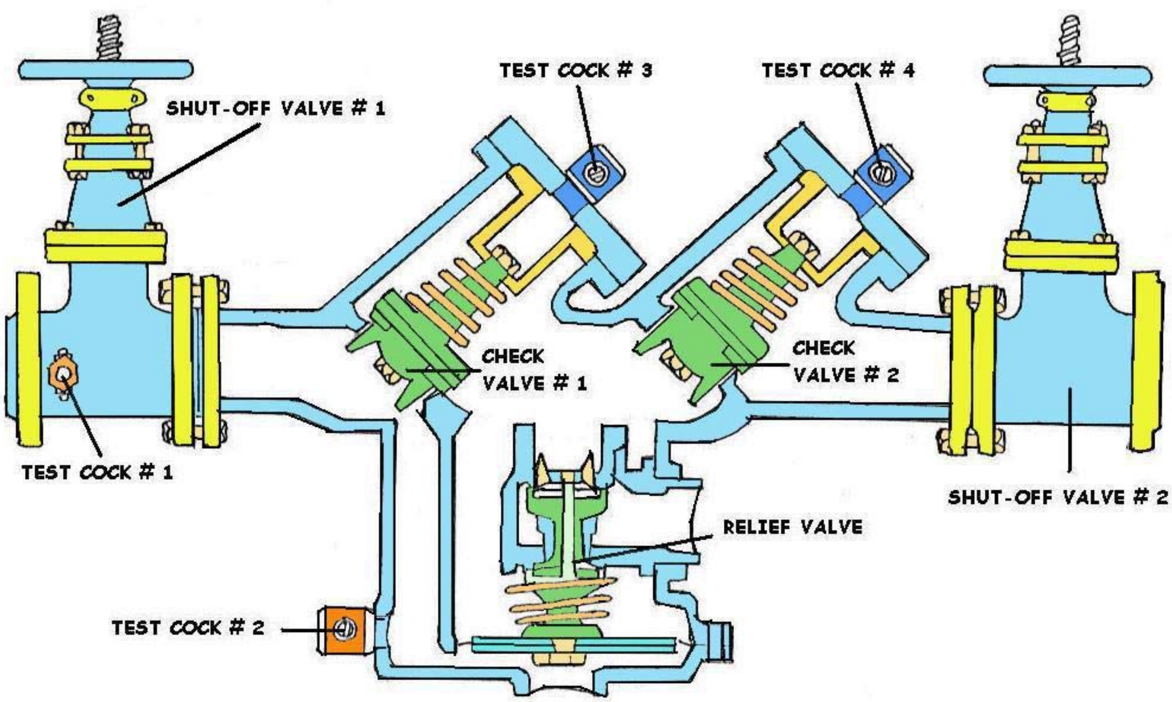



HANDWHEEL NUT
IDENTIFICATION PLATE
HANDWHEEL
GLAND FOLLOWER STUD
GLAND FOLLOWER NUT
YOKE BUSHING
BONNET
GLAND FOLLOWER
STEM
PACKING GLAND
PACKING
BODY BOLT
BODY GASKET
BODY NUT
SWIVEL NUT
DISK
SEAT RING
BODY



DOUBLE-CHECK BACKFLOW ASSEMBLY

REDUCED-PRESSURE BACKFLOW ASSEMBLY



Pressure Reducing Valves *Rotary Valve*

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.

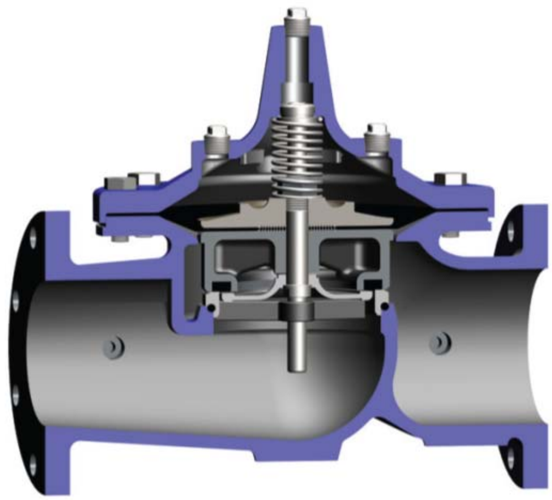
When outlet pressure reaches that of the valve setting, the valve closes, except for a small quantity of oil that bleeds from the low-pressure side of the valve, usually through an orifice in the spool, through the spring chamber, to the reservoir. Should the valve close fully, leakage past the spool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

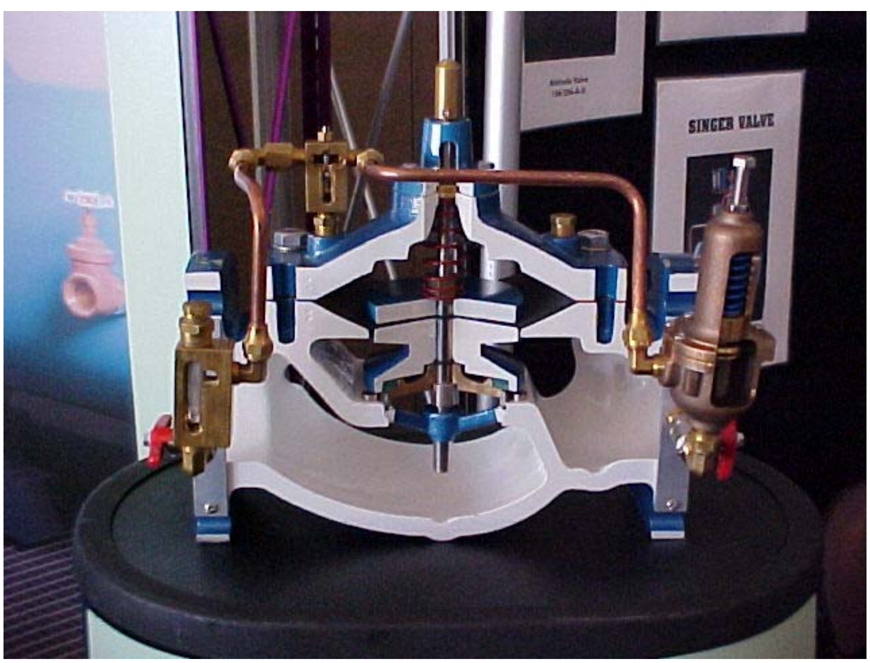
This valve operates by balancing the force exerted by the pressure in the main circuit against the sum of the forces exerted by secondary circuit pressure and the spring. Because the pressurized areas on both sides of the poppet are equal, the fixed reduction is that exerted by the spring.

How do Pressure Relief Valves Operate?

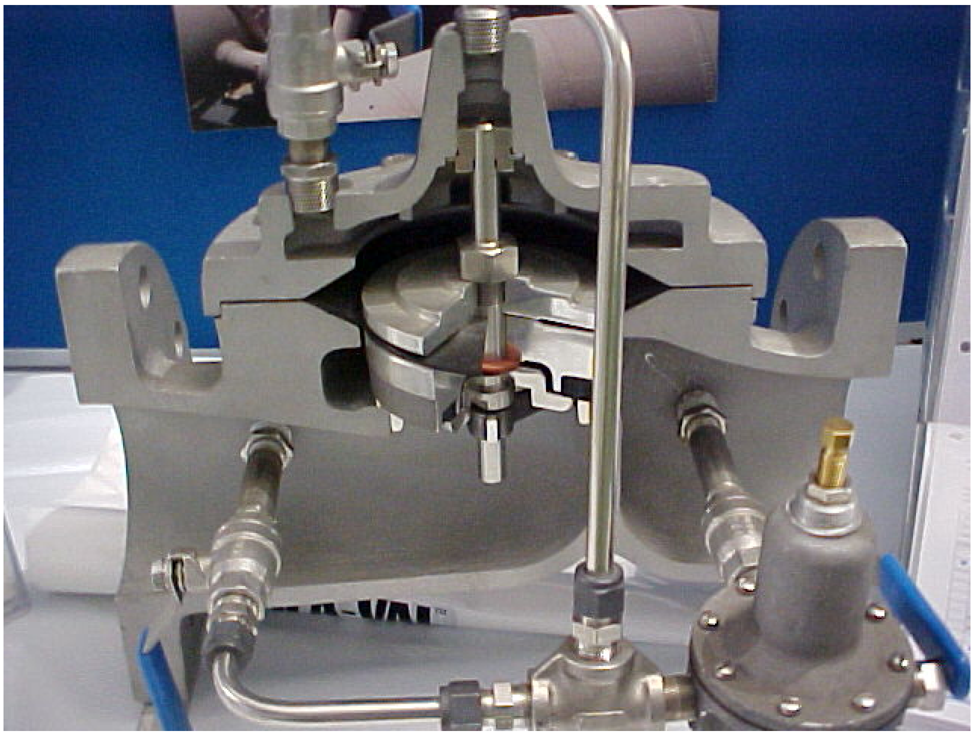
Most pressure relief valves consist of a main valve and pilot control system. The basic main Cla-Val valve is called a Hytrol Valve.



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



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).



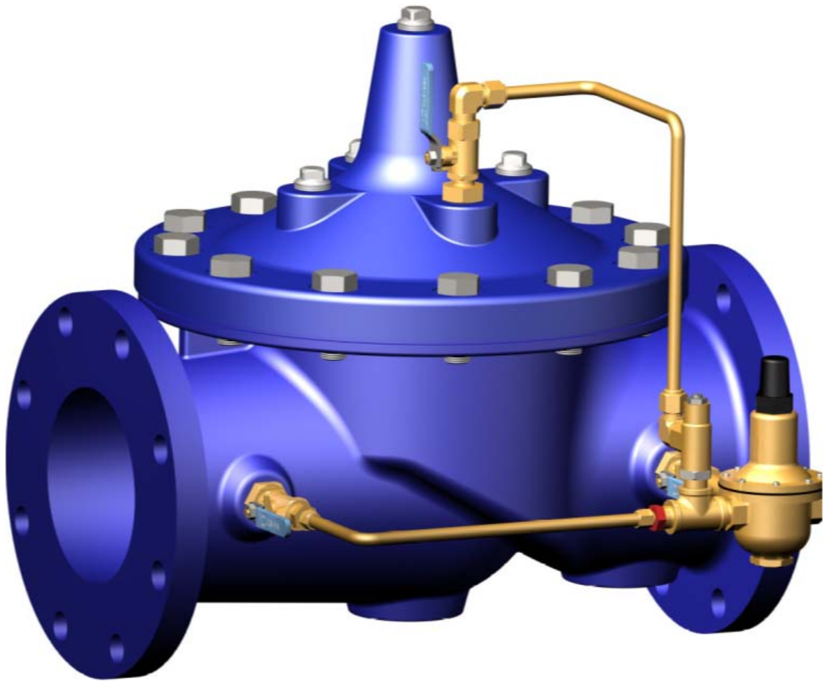
Hydraulics is a branch of engineering concerned mainly with moving liquids. The term is applied commonly to the study of the mechanical properties of water, other liquids, and even gases when the effects of compressibility are small.

Hydraulics can be divided into two areas, hydrostatics and hydrokinetics.

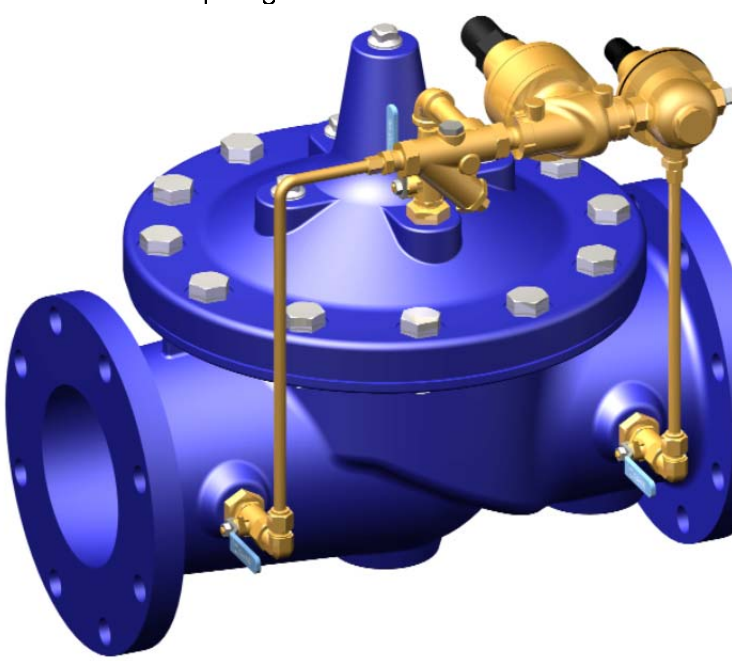
The word hydraulics is based on the Greek word for air, and originally covered the study of the spirit at rest and in motion.

Use of the word hydraulics 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.

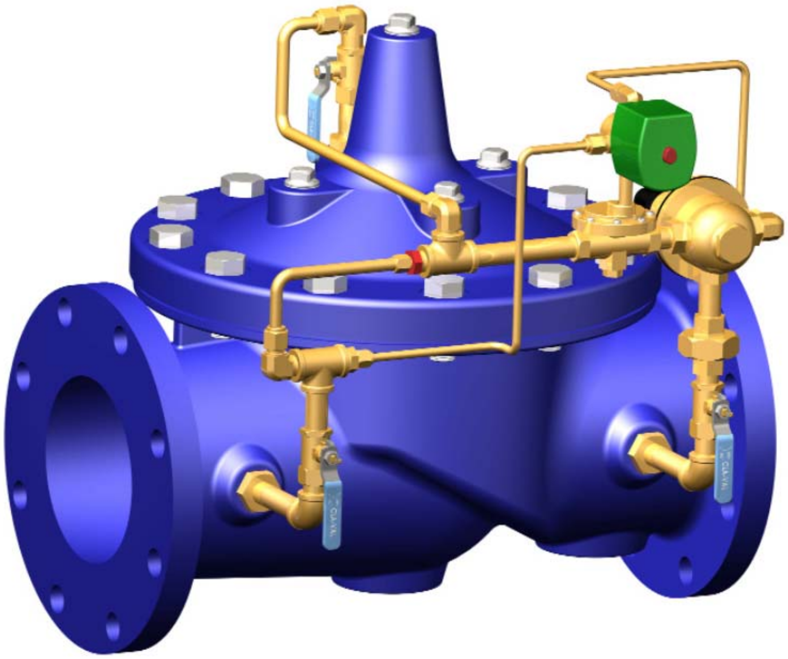
Hydrostatics, the consideration of liquids at rest, involves problems of buoyancy and flotation, pressure on dams and submerged devices, and hydraulic presses. The relative incompressibility of liquids is one of its basic principles.



Pressure Reducing Valve Cla-Val 90 Series
• Holds downstream pressure to a pre-determined limit.
• Optional check feature.
• Fully supported frictionless diaphragm.

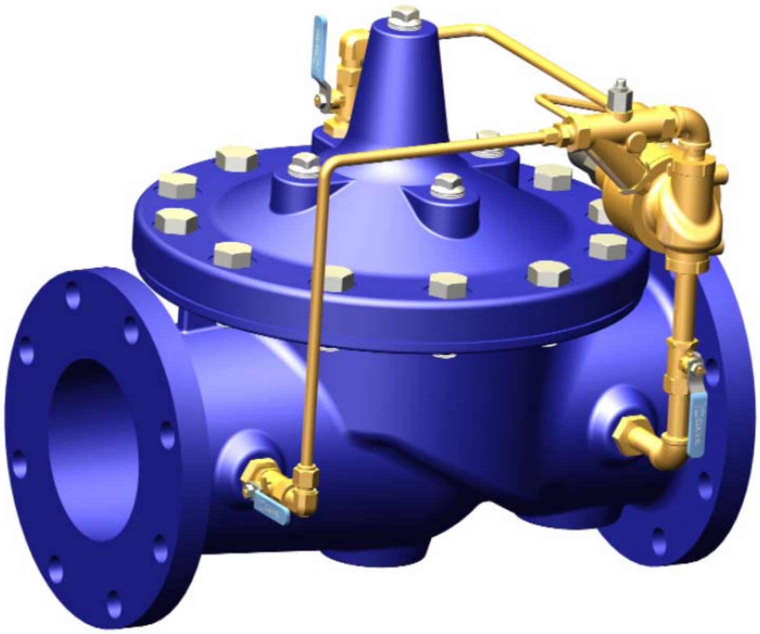


Pressure Reducing/Pressure Sustaining Control Valve Cla-Val 92 Series
• Maintains downstream pressure regardless of fluctuating demand and sustains upstream pressure to a pre-set minimum.
• Optional check feature.



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.



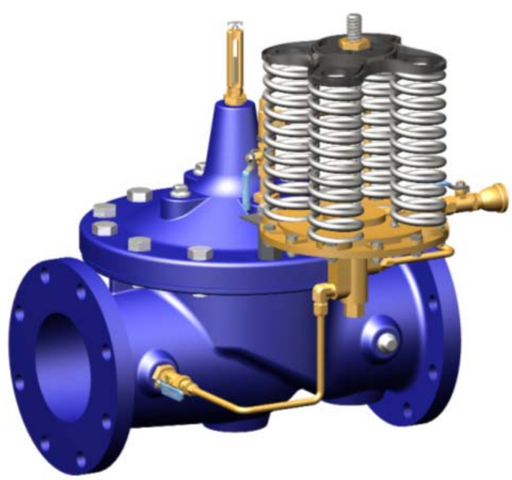
Pressure Relief/Pressure Sustaining Valve Cla-Val 50 Series

• 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

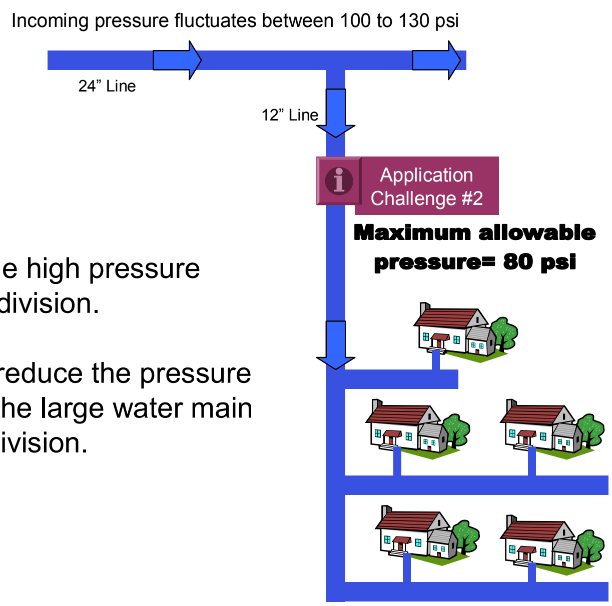
• Protects pumping equipment and pipelines from damage caused by rapid flow velocity changes.
• Opens on initial low pressure wave.
• Closes slowly to prevent subsequent surges.

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.

Water Distribution System Application Challenge #2

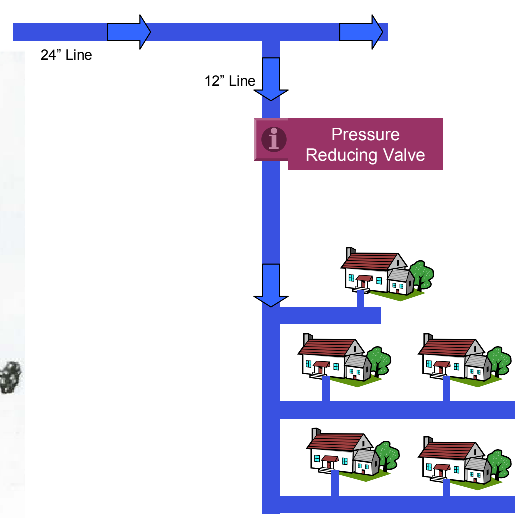


A small branch line tee's off a large high pressure water main to feed water to a subdivision.

Automatically (without electricity) reduce the pressure from a range of 100 to 130 psi in the large water main to not exceed 80 psi into the subdivision.

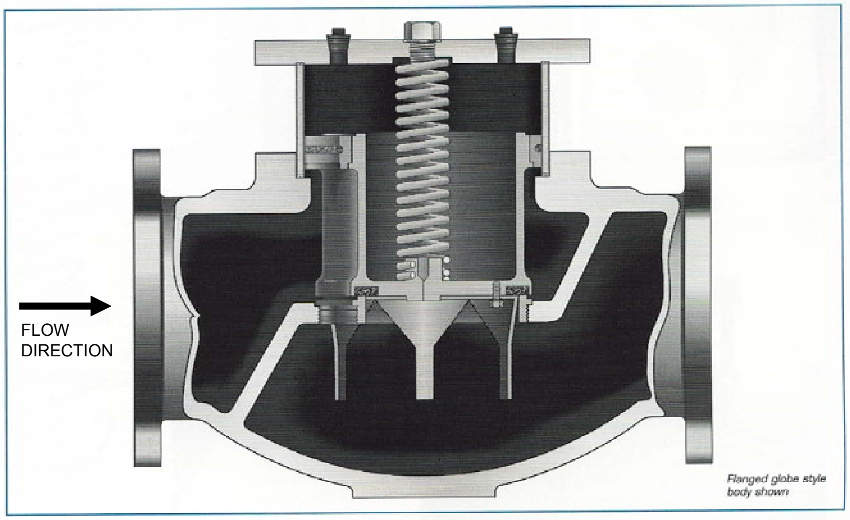
Proposed Solution

A Pressure Reducing Valve will reduce a higher variable upstream pressure to a uniform maximum downstream pressure by throttling in response to changes in the downstream pressure which result from changes in flow demand.



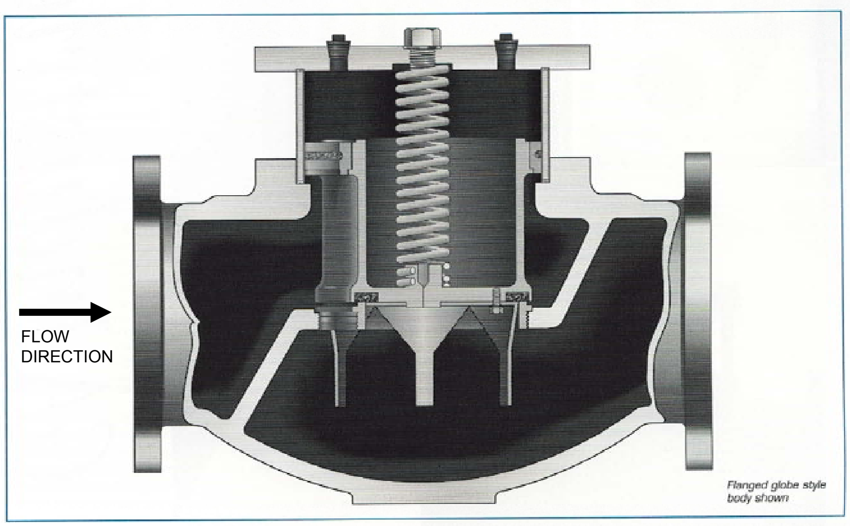
SERIES 2000 Features

1. Full-ported for high capacity
2. Stainless trim - Standard
3. Stainless steel vee-ports for precise low flow control
4. 1- $1/_2$" through 3" - Screwed NPT connections 2" through 12"- 125# Flanged connections
5. Globe or angle body, both use identical internal parts
6. Only one moving part
7. No rubber diaphragms to fatigue, rot, rupture or fail.
8. Drop-tight closure
9. Streamlined body for low inherent headloss
10. 100% tested for reliability
11. Easily maintained in the line
12. Many options available



SERIES 2000 Features

1. Full-ported for high capacity
2. Stainless trim - Standard
3. Stainless steel vee-ports for precise low flow control
4. 1- $1/_2$" through 3" - Screwed NPT connections 2" through 12"- 125# Flanged connections
5. Globe or angle body, both use identical internal parts
6. Only one moving part
7. No rubber diaphragms to fatigue, rot, rupture or fail.
8. Drop-tight closure
9. Streamlined body for low inherent headloss
10. 100% tested for reliability
11. Easily maintained in the line
12. Many options available



Pressure Reducing Valve Operation

SERIES 2000 pressure reducing valves will throttle to maintain a steady downstream pressure as set by the pilot spring adjustment. The valve will close drip-tight when the downstream pressure exceeds the pilot setting.

VALVE CLOSED

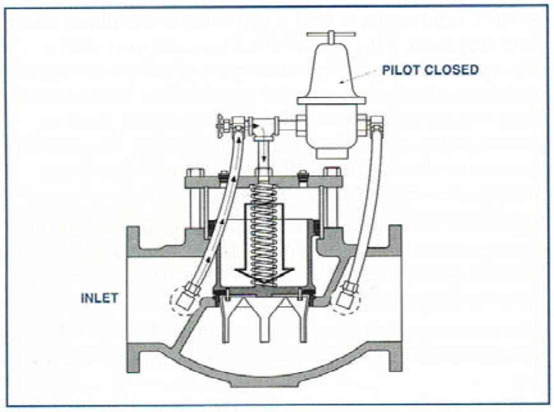


Figure 1. Valve closed when downstream pressure exceeds pilot setting

The valve is installed with flow "over the seat." Inlet pressure is conveyed to the top of the piston by means of a small pilot line and a closing speed control needle valve. Downstream pressure is applied to the underside of the pilot valve's diaphragm and is opposed by the pilot's adjusting spring. The pilot closes when the downstream pressure exceeds the adjusting spring set point, allowing inlet pressure to build on the upper surface of the piston and hold the main valve closed.

VALVE OPEN

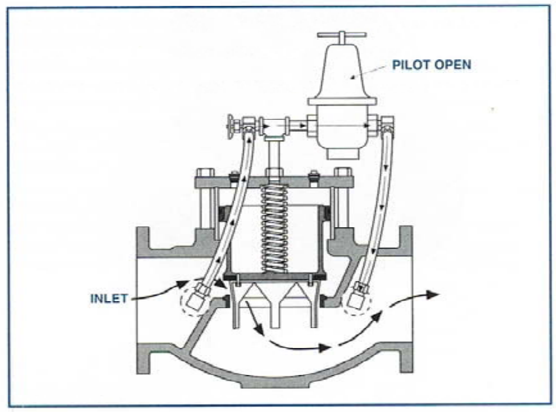
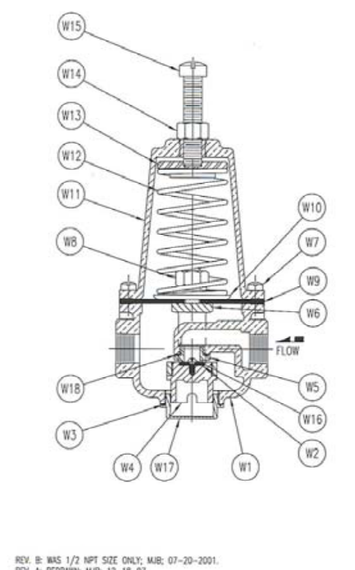


Figure 2. Valve throttles to satisfy demand at setting of pilot

Should downstream pressure fall to the setting of the pilot spring, the pilot opens and allows flow from above the piston to the downstream side of the valve at a faster rate than can be applied through the inlet needle valve. This reduces the pressure on the upper surface of the piston so that inlet pressure, which is constantly applied to the underside of the piston, lifts the piston and opens the main valve. The pilot "throttles" the main valve, allowing sufficient flow to match demand in order to maintain the downstream pressure as determined by the pilot setting.



PILOT PARTS	
W1	PILOT BODY
W2	RENEWABLE SEAT
W3	BOTTOM CAP SEAL
W4	SEAT HOLDER
W5	SEAT RING
W6	YOKE
W7	CHAMBER SCREWS
W8	DIAPHRAGM NUT
W9	DIAPHRAGM
W10	DIAPHRAGM WASHER
W11	SPRING CHAMBER
W12	SPRING
W13	SPRING WASHER
W14	STEM LOCKNUT
W15	ADJUSTING SCREW
W16	SEAT SCREW
W17	BOTTOM CAP
W18	SEAT GASKET

REV. B: WAS 1/2 NPT SIZE ONLY; MJB; 07-20-2001.
REV. A: REDRAWN; MJB; 12-18-97.

GA INDUSTRIES, INC.	STANDARD TOLERANCES (UNLESS OTHERWISE NOTED)	REFERENCES	SCALE: NONE	DRAWN BY: RLD
1/2 - 2" NPT PRESSURE REDUCING PILOT VALVE	FINISHED SURFACES ONLY DIMENSIONS SHOWN IN INCHES .X = ±.02 .XX = ±.01 .XXX = ±.002 FRACTIONS ±1/64" ANGLES ±1° FINISH [illegible]	SERIAL NO.	EFFECTIVE DATE: 10-2-78	APPR. BY
		FIG. NUMBER 43223	FILE D1	DRAWING NO. D-1035 REV. B

Related In Plant Valves

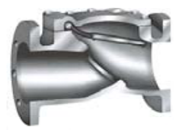
Plant Pump Check Valves

COMMONLY USED PUMP CHECK VALVES

Plain Swing
check valve

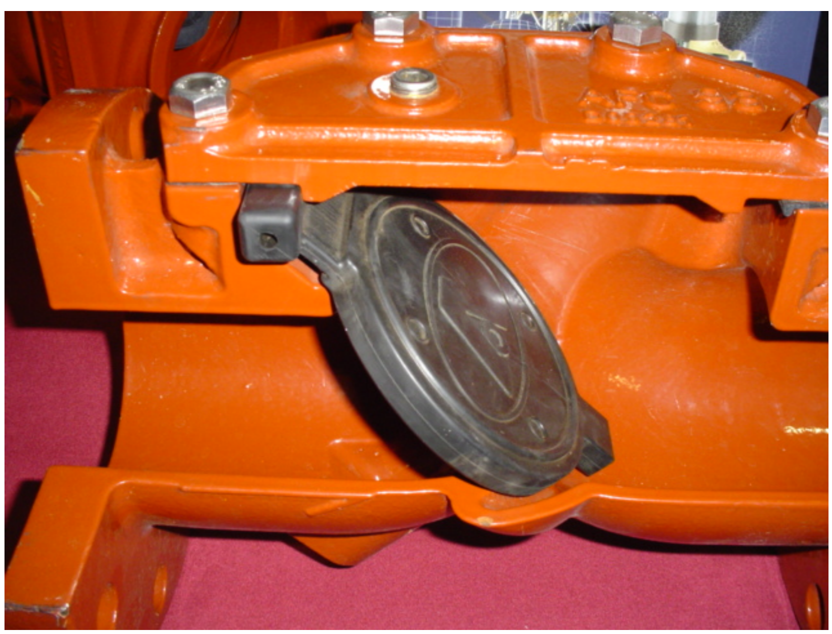
Lever and Spring
Swing check valve

Lever and Weight
Swing check valve



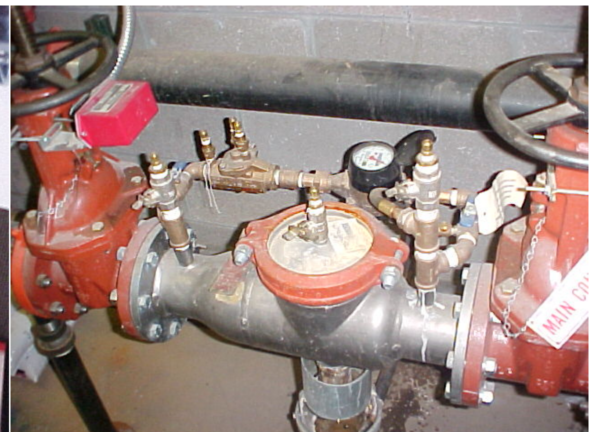
Rubber Flapper
Swing check valve

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

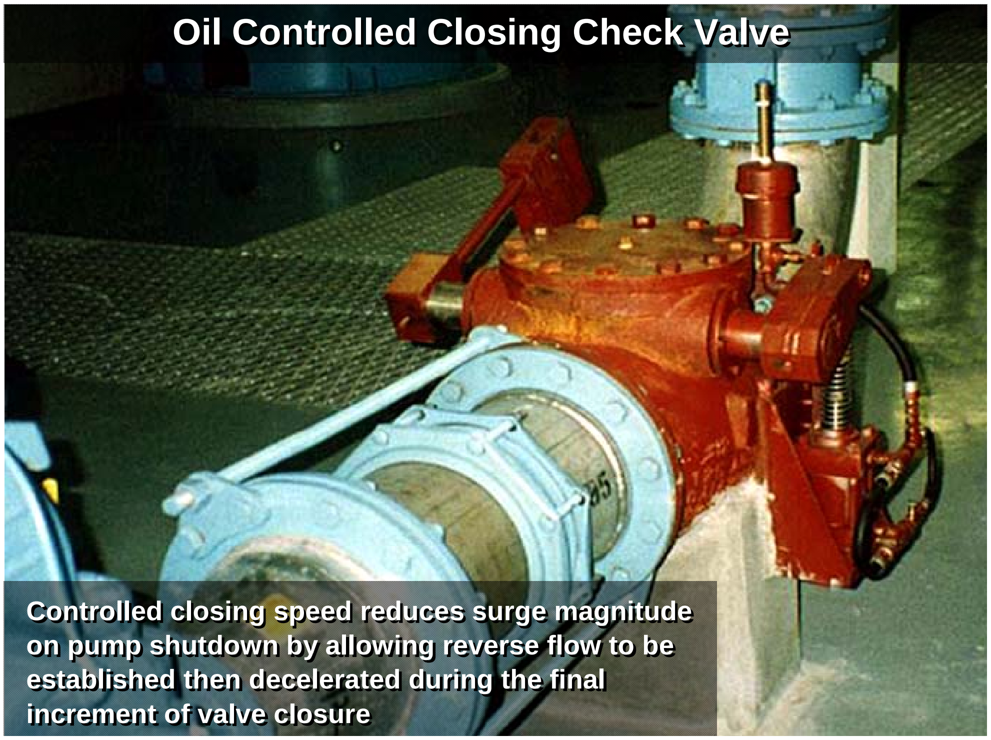


A beautiful swing check valve. Swing checks need to be maintained. I hate finding a swing check that is either buried and/or forgotten, rusted in place or, my favorite, the check was removed. Yes, folks, you too will find these three conditions. Send me a photograph if you do. I love stories and photographs from the field.

Check Valves are not backflow preventors. The big difference is a legal term that means two independent mechanical acting check valves with two shut offs which is 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 it every six months because I don't trust them. Why? Because everything that is mechanical is subject to failure. Lots of nasties in the water too. 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 preventor. 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 in.



Wastewater Section

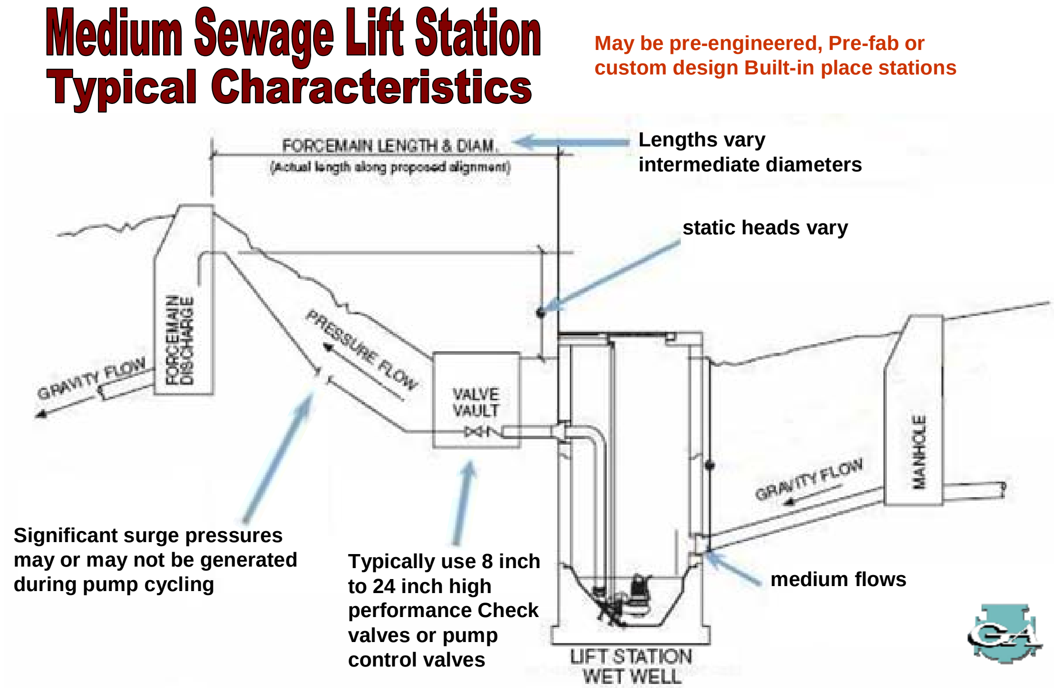


Wastewater valves are widely used in different industries like dairy, food, pharmaceutical, medical and chemical industries to name a few.

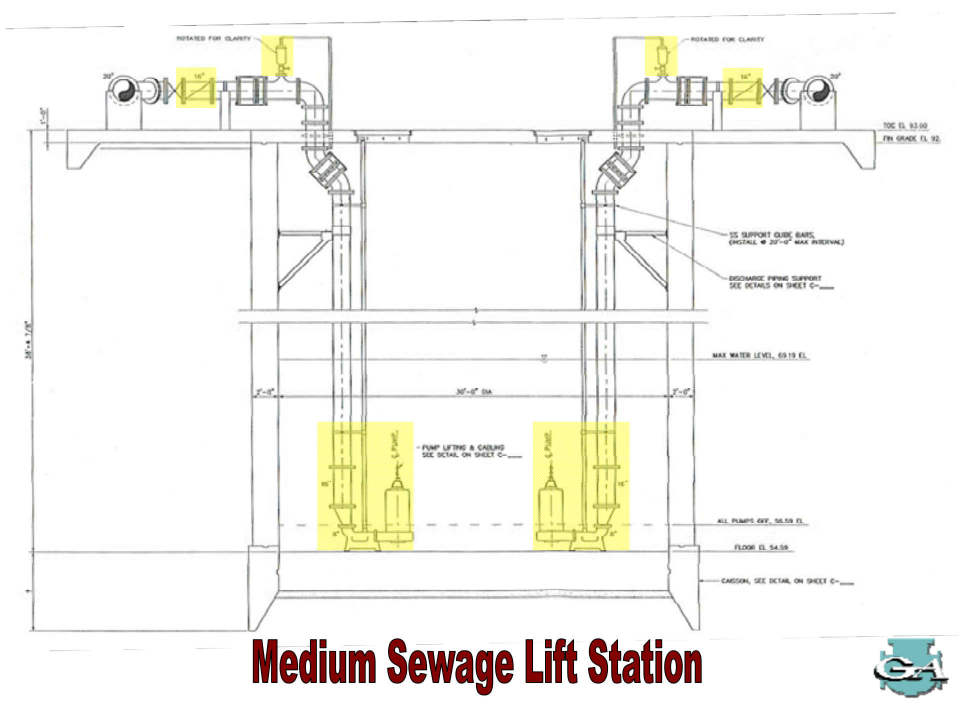
These sanitary valves perform various features like easy cleaning, crevice free, and polish contact surfaces. Types among these sanitary valves can be seen in the form of sanitary ball valves, sanitary sewer valves, sanitary butterfly valves, sanitary check valves, sanitary globe valves and many other such sanitary valves.

Variations among these sanitary valves can also be seen in their working pressure and operating temperature. These sanitary valves carry gas and liquid media or liquid with suspended solids. Metals like brass, bronze, copper, cast iron, ductile iron, stainless steel, and steel are used in the manufacture of these sanitary valves to ensure that they have a longer life.

Lift Station



(Hint: If your pump station is too big to unload with a fork lift, but smaller than the biggest building in town, its probably a medium size lift station.)



Sludge pumping from Settling Basins using Progressive Cavity Pumps

Pump runs but little or no fluid comes out.

1. Check that the discharge isolation valve is not closed.
2. Ensure that supply pressure is high enough to overcome application head pressure requirements.
3. Check for pump cavitation; slow pump speed down to match the thickness of the material being pumped.
4. **Check to make sure that all suction connections are air tight, and that the clamp bands are properly tightened.**

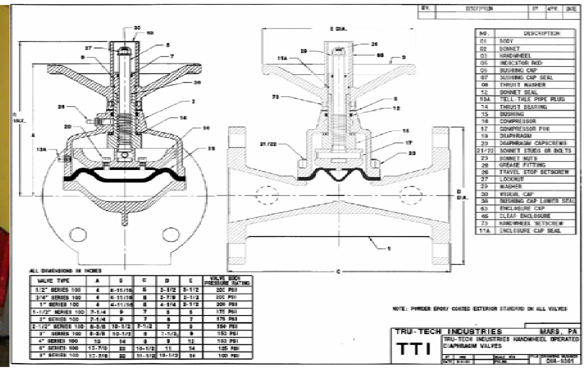
Slurry or Sludge Pump Isolation Valves

Possible Valve Choices:

Plug Valve
1. Good for abrasion
(Metal seated & Resilient).
2. Not so good on suction side
(Leaky stem seals allow air in,
Chevron packings are made to seal
against positive pressure and not vacuum).
3. Build-up in bearing journals increase
the valve torque making them difficult to open.

Pinch Valve
1. Good for abrasion
(Rubber sleeved)
2. Not so good on suction side
(Sleeve can be sucked closed)

Slurry or Sludge Pump Isolation valves



Best choice:
Diaphragm Isolation Valve
1. No packing to leak resilient rubber diaphragm seals the bonnet area
2. No areas for build-up to occur increasing torque
3. Reinforced diaphragm won't suck closed

Tru-Tech Industries
A GA Company

Chemical Feed Isolation and Modulating Control

- Natural Rubber
- Neoprene
- Butyl
- EPDM
- Hypalon
- Viton
- Teflon

Valve Exercising 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.

Here are Common Valve Operation Problems

Valve stem is improperly lubricated or damaged--I always liked 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 the 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-- contact the supply house or warehouse. Most valve salesmen will try to keep your business and do whatever is 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. Don't throw these people under the bus!

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.

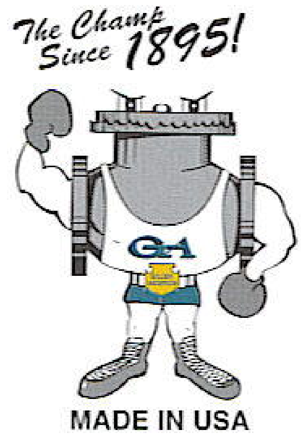
Unlike centrifugal pumps(which produce normally non-damaging high-frequency but low-amplitude pulses), the amplitude is the problem because it's the pressure spike. The peak, instantaneous pressure required to accelerate the liquid in the pipe line can be greater than ten (10) times the steady state 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

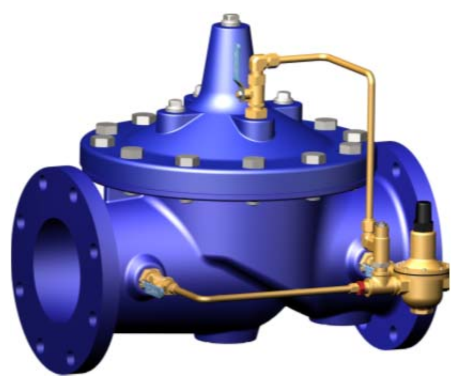
Suggest that you install a pulsation dampener or surge tank. Dampeners provide the most cost efficient and effective choice to prevent the damaging effects of pulsation. A surge suppressor is in design essentially the same as pulsation dampener. The difference primarily lies in sizing and pressurizing.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

References

Several Photographs and Reference were provided by
GA Industries, Inc.
WWW. Gaindustries.com
Telephone (724) 776-1020
Fax (724) 776-1254
9025 Marshall Road
Cranberry Township, PA 16066 USA



CLA-VAL
P.O.Box 1325
Newport Beach, CA 92659-0325
Phone: (949) 722-4800 • 1-800-942-6326
Fax: (949) 548-5441
www.cla-val.com
E-mail: claval@cla-val.com
US Regional Offices
WESTERN REGION:
Phone: (951) 687-9145
1-800-247-9090
Fax: (951) 687-9954
E-mail: lvanderk@cla-val.com
SOUTHERN REGION:
Phone: (281) 759-9590
1-800-336-7171
Fax: (281) 759-8938
E-mail: blindsey@cla-val.com
NORTHERN REGION:
Phone: (847) 697-1413
1-800-238-7070
Fax: (847) 697-5549
E-mail: djurs@cla-val.com
EASTERN REGION:
Phone: (703) 721-1923
1-800-451-3030
Fax: (703) 721-1927
E-mail: bmoore@cla-val.com



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):

$$\omega = \theta / t \quad (2a)$$

where
ω= *angular velocity (rad/s)*
θ = *angular displacement (rad)*
t = *time (s)*

Angular velocity can be expressed as (angular acceleration = constant):

$$\omega = \omega_o + \alpha t \quad (2b)$$

where
ω_o = *angular velocity at time zero (rad/s)*
α = *angular acceleration (rad/s^2)*

Angular displacement can be expressed as (angular acceleration = constant):

$$\theta = \omega_o t + 1/2 \alpha t^2 \quad (2c)$$

Combining 2a and 2c:

$$\omega = (\omega_o^2 + 2 \alpha \theta)^{1/2}$$

Angular acceleration can be expressed as:

$$\alpha = d\omega / dt = d^2\theta / dt^2 \quad (2d)$$

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.)

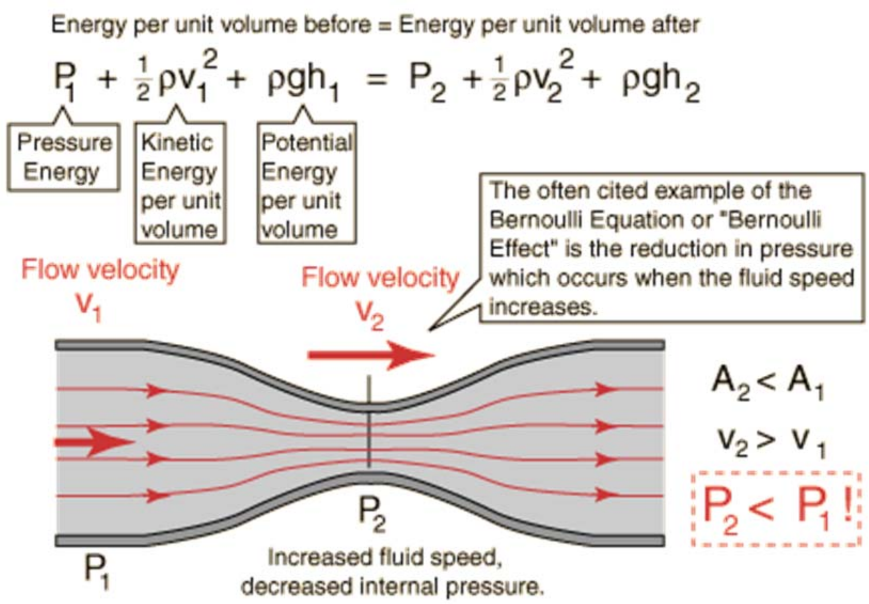
B

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

$\gamma=\rho\cdot g$

$$\frac{\rho\cdot v^2}{2}+p=\text{Constant} \qquad (4)$$

$$\frac{\rho\cdot v^2}{2}=p_d \qquad (5)$$

$$\frac{\rho\cdot v_1^2}{2}+p_1=\frac{\rho\cdot v_2^2}{2}+p_2=\text{Constant} \qquad (6)$$

www.engineeringtoolbox.com

For steady state incompressible flow the Euler equation becomes (1). If we integrate (1) along the streamline it becomes (2). (2) can further be modified to (3) by dividing by gravity.

Head of Flow: Equation (3) is often referred to as the **head** because all elements have the unit of length.

Bernoulli's Equation Continued:

Dynamic Pressure

(2) and (3) are two forms of the Bernoulli Equation for steady state incompressible flow. If we assume that the gravitational body force is negligible, (3) can be written as (4). Both elements in the equation have the unit of pressure and it's common to refer the flow velocity component as the **dynamic pressure** of the fluid flow (5).

Since energy is conserved along the streamline, (4) can be expressed as (6). Using the equation we see that increasing the velocity of the flow will reduce the pressure, decreasing the velocity will increase the pressure. This phenomena can be observed in a **venturi meter** where the pressure is reduced in the constriction area and regained after. It can also be observed in a **pitot tube** where the **stagnation** pressure is measured. The stagnation pressure is where the velocity component is zero.

Bernoulli's Equation Continued:
Pressurized Tank
If the tanks are pressurized so that product of gravity and height (g h) is much less than the pressure difference divided by the density, (e4) can be transformed to (e6).
The velocity out from the tanks depends mostly on the pressure difference.

Example - outlet velocity from a pressurized tank
The outlet velocity of a pressurized tank where

$p_1 = 0.2\ MN/m^2$, $p_2 = 0.1\ MN/m^2$ $A_2/A_1 = 0.01$, $h = 10\ m$

can be calculated as
$V_2 = [(2/(1-(0.01)^2)\ (\ (0.2 - 0.1)x10^6\ /1x10^3 + 9.81\ x\ 10)]^{1/2} = \underline{19.9\ m/s}$

Coefficient of Discharge - Friction Coefficient
Due to friction the real velocity will be somewhat lower than this theoretical example. If we introduce a **friction coefficient** *c* (coefficient of discharge), (e5) can be expressed as (e5b). The coefficient of discharge can be determined experimentally. For a sharp edged opening it may be as low as 0.6. For smooth orifices it may be between 0.95 and 1.

Bingham Plastic Fluids: Bingham Plastic Fluids have a yield value which must be exceeded before it will start to flow like a fluid. From that point the viscosity will decrease with increase of agitation. Toothpaste, mayonnaise and tomato catsup are examples of such products.

Boundary Layer: The layer of fluid in the immediate vicinity of a bounding surface.

Bulk Modulus and Fluid Elasticity: An introduction to and a definition of the Bulk Modulus Elasticity commonly used to characterize the compressibility of fluids.

The Bulk Modulus Elasticity can be expressed as
$E = - dp / (dV / V)$ *(1)*

where
E = bulk modulus elasticity
dp = differential change in pressure on the object
dV = differential change in volume of the object
V = initial volume of the object

The Bulk Modulus Elasticity can be alternatively expressed as
$E = - dp / (d\rho / \rho)$ *(2)*

where
$d\rho$ *= differential change in density of the object*
ρ *= initial density of the object*

An increase in the pressure will decrease the volume (1). A decrease in the volume will increase the density (2).
- The SI unit of the bulk modulus elasticity is N/m^2 (Pa)

- The imperial (BG) unit is lb_f/in^2 (psi)
- 1 lb_f/in^2 (psi) = 6.894 10^3 N/m^2 (Pa)

A large Bulk Modulus indicates a relatively incompressible fluid.

Bulk Modulus for some common fluids can be found in the table below:

Bulk Modulus - *E*	Imperial Units - BG (psi, lb_f/in^2) x 10^5	SI Units (Pa, N/m^2) x 10^9
Carbon Tetrachloride	1.91	1.31
Ethyl Alcohol	1.54	1.06
Gasoline	1.9	1.3
Glycerin	6.56	4.52
Mercury	4.14	2.85
SAE 30 Oil	2.2	1.5
Seawater	3.39	2.35
Water	3.12	2.15

C

Capillarity: (or capillary action) The ability of a narrow tube to draw a liquid upwards against the force of gravity.

The height of liquid in a tube due to capillarity can be expressed as

$$h = 2\,\sigma \cos\theta / (\rho\, g\, r) \quad (1)$$

where
h = height of liquid (ft, m)
σ = surface tension (lb/ft, N/m)
θ = contact angle
ρ = density of liquid (lb/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

$$C = \rho\, v^2 / E \quad (1)$$

where
ρ = density (kg/m^3)
v = flow velocity (m/s)
E = bulk modulus elasticity (N/m^2)

The bulk modulus elasticity has the dimension pressure and is commonly used to characterize the compressibility of a fluid.

The Cauchy Number is the square root of the Mach Number

$M^2 = Ca$ *(3)*

where

C = Mach Number

Cavitation: Under the wrong condition, cavitation will reduce the components life time dramatically. Cavitation may occur when the local static pressure in a fluid reach a level below the vapor pressure of the liquid at the actual temperature. According to the Bernoulli Equation this may happen when the fluid accelerates in a control valve or around a pump impeller. The vaporization itself does not cause the damage - the damage happens when the vapor almost immediately collapses after evaporation when the velocity is decreased and pressure increased. Cavitation means that cavities are forming in the liquid that we are pumping. When these cavities form at the suction of the pump several things happen all at once: We experience a loss in capacity. We can no longer build the same head (pressure). The efficiency drops. The cavities or bubbles will collapse when they pass into the higher regions of pressure causing noise, vibration, and damage to many of the components. The cavities form for five basic reasons and it is common practice to lump all of them into the general classification of cavitation.

This is an error because we will learn that to correct each of these conditions we must understand why they occur and how to fix them. Here they are in no particular order: Vaporization, Air ingestion, Internal recirculation, Flow turbulence and finally the Vane Passing Syndrome.

Avoiding Cavitation

Cavitation can in general be avoided by:

- increasing the distance between the actual local static pressure in the fluid - and the vapor pressure of the fluid at the actual temperature

This can be done by:

- reengineering components initiating high speed velocities and low static pressures
- increasing the total or local static pressure in the system
- reducing the temperature of the fluid

Reengineering of Components Initiating High Speed Velocity and Low Static Pressure

Cavitation and damage can be avoided by using special components designed for the actual rough conditions.

- Conditions such as huge pressure drops can - with limitations - be handled by Multi Stage Control Valves
- Difficult pumping conditions - with fluid temperatures close to the vaporization temperature - can be handled with a special pump - working after another principle than the centrifugal pump.

Cavitation Continued: Increasing the Total or Local Pressure in the System
By increasing the total or local pressure in the system, the distance between the static pressure and the vaporization pressure is increased and vaporization and cavitation may be avoided. The ratio between static pressure and the vaporization pressure, an indication of the possibility of vaporization, is often expressed by the Cavitation Number. Unfortunately it may not always be possible to increase the total static pressure due to system classifications or other limitations. Local static pressure in the component may then be increased by lowering the component in the system. Control valves and pumps should in general be positioned in the lowest part of the system to maximize the static head. This is common for boiler feeding pumps receiving hot condensate (water close to 100 ^{o}C) from a condensate receiver.

Cavitation Continued: Reducing the Temperature of the Fluid
The vaporization pressure is highly dependent on the fluid temperature. Water, our most common fluid, is an example:

Temperature (^{o}C)	Vapor Pressure (kN/m^2)
0	0.6
5	0.9
10	1.2
15	1.7
20	2.3
25	3.2
30	4.3
35	5.6
40	7.7
45	9.6
50	12.5
55	15.7
60	20
65	25
70	32.1
75	38.6
80	47.5
85	57.8
90	70
95	84.5
100	101.33

As we can see - the possibility of evaporation and cavitation increases dramatically with the water temperature.

Cavitation can be avoided by locating the components in the coldest part of the system. For example, it is common to locate the pumps in heating systems at the "cold" return lines. The situation is the same for control valves. Where it is possible they should be located on the cold side of heat exchangers.

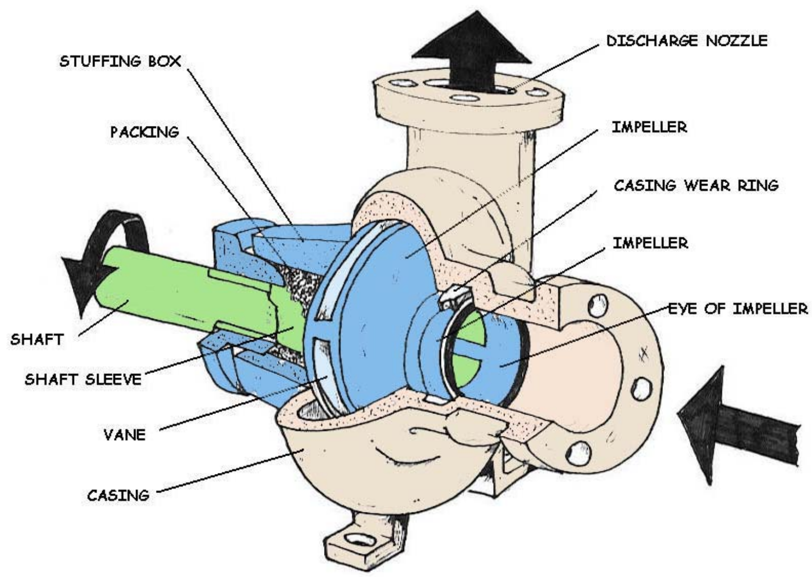
Cavitations Number: A "special edition" of the dimensionless Euler Number.

The Cavitations Number is useful for analyzing fluid flow dynamics problems where cavitations may occur. The Cavitations Number can be expressed as

$Ca = (p_r - p_v) / 1/2 \rho v^2$ *(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

$v = c (R S)^{1/2}$ *(1)*

where
v = mean velocity (m/s, ft/s)
c = the Chezy roughness and conduit coefficient
R = hydraulic radius of the conduit (m, ft)
S = slope of the conduit (m/m, ft/ft)

In general the Chezy coefficient - *c* - is a function of the flow Reynolds Number - Re - and the relative roughness - ε/R - of the channel.
ε is the characteristic height of the roughness elements on the channel boundary.

Coanda Effect: The tendency of a stream of fluid to stay attached to a convex surface, rather than follow a straight line in its original direction.

Colebrook Equation: The friction coefficients used to calculate pressure loss (or major loss) in ducts, tubes and pipes can be calculated with the Colebrook equation.

$$1 / \lambda^{1/2} = -2 \log ((2.51 / (Re\ \lambda^{1/2})) + ((k / d_h) / 3.72)) \quad (1)$$

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.

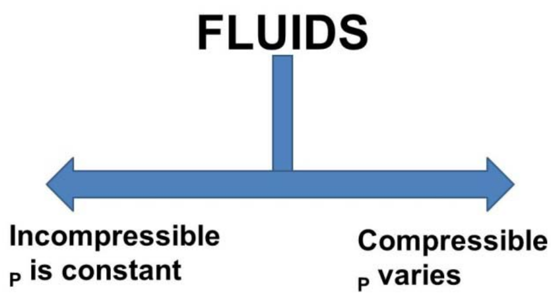
Gases are generally compressible; air being the most common compressible fluid we can find. Compressibility of gases leads to many interesting features such as shocks, which are absent for incompressible fluids. Gas dynamics is the discipline that studies the flow of compressible fluids and forms an 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:

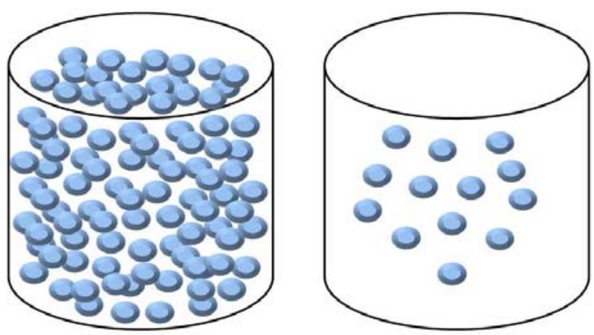
$$\Delta p = \lambda \, (l / d_h) \, (\rho \, v^2 / 2) \quad (1)$$

where
Δp = *pressure loss (Pa, N/m², lbf/ft²)*
λ = *D'Arcy-Weisbach friction coefficient*
l = *length of duct or pipe (m, ft)*
d_h = *hydraulic diameter (m, ft)*
ρ = *density (kg/m³, lb/ft³)*

Note! Be aware that there are two alternative friction coefficients present in the literature. One is 1/4 of the other and (1) must be multiplied with four to achieve the correct result. This is important to verify when selecting friction coefficients from Moody diagrams.

Density: Is a physical property of matter, as each element and compound has a unique density associated with it.

Density defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume. For example: A rock is obviously more dense than a crumpled piece of paper of the same size. A Styrofoam cup is less dense than a ceramic cup. Density may also refer to how closely "packed" or "crowded" the material appears to be - again refer to the Styrofoam vs. ceramic cup. Take a look at the two boxes below.



Each box has the same volume. ***If each ball has the same mass, which box would weigh more? Why?***

The box that has more balls has more mass per unit of volume. This property of matter is called density. The density of a material helps to distinguish it from other materials. Since mass is usually expressed in grams and volume in cubic centimeters, density is expressed in grams/cubic centimeter. We can calculate density using the formula:

Density= Mass/Volume

The density can be expressed as

$$\rho = m / V = 1 / v_g \ (1)$$

where
ρ = *density* (kg/m^3)
m = *mass* (kg)
V = *volume* (m^3)
v_g = *specific volume* (m^3/kg)

The SI units for density are kg/m^3. The imperial (BG) units are lb/ft^3 ($slugs/ft^3$). While people often use pounds per cubic foot as a measure of density in the U.S., pounds are really a measure of force, not mass. Slugs are the correct measure of mass. You can multiply slugs by 32.2 for a rough value in pounds. The higher the density, the tighter the particles are packed inside the substance. Density is a physical property constant at a given temperature and density can help to identify a substance.

Example - Use the Density to Identify the Material:
An unknown liquid substance has a mass of 18.5 g and occupies a volume of 23.4 ml. (milliliter).

The density can be calculated as

$$\rho = [18.5 \ (g) / 1000 \ (g/kg)] / [23.4 \ (ml) / 1000 \ (ml/l) \ 1000 \ (l/m^3)]$$
$$= 18.5 \ 10^{-3} \ (kg) / 23.4 \ 10^{-6} \ (m^3)$$
$$= \underline{790} \ kg/m^3$$

If we look up densities of some common substances, we can find that ethyl alcohol, or ethanol, has a density of <u>790</u> kg/m^3. Our unknown liquid may likely be ethyl alcohol!

Example - Use Density to Calculate the Mass of a Volume
The density of titanium is 4507 kg/m^3 . Calculate the mass of 0.17 m^3 titanium!

$$m = 0.17 \ (m^3) \ 4507 \ (kg/m^3)$$
$$= \underline{766.2} \ kg$$

Dilatant Fluids: Shear Thickening Fluids or Dilatant Fluids increase their viscosity with agitation. Some of these liquids can become almost solid within a pump or pipe line. With agitation, cream becomes butter and Candy compounds, clay slurries and similar heavily filled liquids do the same thing.

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

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

Distribution System Water Quality: Can be adversely affected by improperly constructed or poorly located blowoffs of vacuum/air relief valves. Air relief valves in the distribution system lines must be placed in locations that cannot be flooded. This is to prevent water contamination. The common customer complaint of Milky Water or Entrained Air is sometimes solved by the installation of air relief valves. The venting of air is not a major concern when checking water levels in a storage tank. If the vent line on a ground level storage tank is closed or clogged up, a vacuum will develop in the tank may happen to the tank when the water level begins to lower.

Drag Coefficient: Used to express the drag of an object in moving fluid. Any object moving through a fluid will experience a drag - the net force in direction of flow due to the pressure and shear stress forces on the surface of the object.

The drag force can be expressed as:

$F_d = c_d \, 1/2 \, \rho \, v^2 A$ *(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

$$\tau = \mu \, dc/dy \quad (1)$$

where
τ = shearing stress
μ = dynamic viscosity

Equation (1) is known as the **Newton's Law of Friction**.

In the SI system the dynamic viscosity units are **N s/m²**, **Pa s** or **kg/m s** where
- $1 \text{ Pa s} = 1 \text{ N s/m}^2 = 1 \text{ kg/m s}$

The dynamic viscosity is also often expressed in the metric CGS (centimeter-gram-second) system as **g/cm.s**, **dyne.s/cm²** or **poise (p)** where
- $1 \text{ poise} = \text{dyne s/cm}^2 = \text{g/cm s} = 1/10 \text{ Pa s}$

For practical use the Poise is to large and its usual divided by 100 into the smaller unit called the **centiPoise (cP)** where
- *1 p = 100 cP*

Water at 68.4°F (20.2°C) has an absolute viscosity of one - 1 - centiPoise.

E

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

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

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

Energy and Hydraulic Grade Line: The hydraulic grade and the energy line are graphical forms of the Bernoulli equation. For steady, in viscid, incompressible flow the total energy remains constant along a stream line as expressed through the Bernoulli

Equation:

$p + 1/2\ \rho\ v^2 + \gamma\ h = \text{constant along a streamline (1)}$

where
p = static pressure (relative to the moving fluid)
ρ = density
γ = specific weight
v = flow velocity
g = acceleration of gravity
h = elevation height

Each term of this equation has the dimension *force per unit area* - psi, lb/ft^2 or N/m^2.

The Head
By dividing each term with the specific weight - $\gamma = \rho\ g$ - (1) can be transformed to express the "head":

$p / \gamma + v^2 / 2\ g + h = \text{constant along a streamline} = H\ (2)$

where
H = the total head

Each term of this equation has the dimension length - ft, m.

The Total Head
(2) states that the sum of **pressure head** - p / γ -, **velocity head** - $v^2 / 2\ g$ - and **elevation head** - *h* - is constant along the stream line. This constant can be called **the total head** - *H* -.

The total head in a flow can be measured by the stagnation pressure using a pitot tube.

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.

The Energy Line
The Energy Line is a line that represents the total head available to the fluid and can be expressed as:

$EL = H = p / \gamma + v^2 / 2 g + h$ = constant along a streamline (3)

where
EL = Energy Line

For a fluid flow without any losses due to friction (major losses) or components (minor losses) the energy line would be at a constant level. In the practical world the energy line decreases along the flow due to the losses.

A turbine in the flow will reduce the energy line and a pump or fan will increase the energy line.

The Hydraulic Grade Line
The Hydraulic Grade Line is a line that represent the total head available to the fluid minus the velocity head and can be expressed as:

$HGL = p / \gamma + h$ (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

$ds = c_v \ln(T_2 / T_1) + R \ln(\rho_1 / \rho_2)$ *(1)*
or
$ds = c_p \ln(T_2 / T_1) - R \ln(p_2 / p_1)$ *(2)*

where
ds = entropy change
c_v *= specific heat capacity at a constant volume process*
c_p *= specific heat capacity at a constant pressure process*
T = absolute temperature
R = individual gas constant
ρ *= density of gas*
p = absolute pressure

Equation of Continuity: The Law of Conservation of Mass states that mass can be neither created nor destroyed. Using the Mass Conservation Law on a **steady flow** process - flow where the flow rate doesn't change over time - through a control volume where the stored mass in the control volume doesn't change - implements that inflow equals outflow. This statement is called **the Equation of Continuity.** Common application where **the Equation of Continuity** can be used are pipes, tubes and ducts with flowing fluids and gases, rivers, overall processes as power plants, diaries, logistics in general, roads, computer networks and semiconductor technology and more.

The Equation of Continuity and can be expressed as:

$$m = \rho_{i1} v_{i1} A_{i1} + \rho_{i2} v_{i2} A_{i2} +..+ \rho_{in} v_{in} A_{im}$$
$$= \rho_{o1} v_{o1} A_{o1} + \rho_{o2} v_{o2} A_{o2} +..+ \rho_{om} v_{om} A_{om} \quad (1)$$

where
m = mass flow rate (kg/s)
ρ *= density (kg/m*^{3}*)*
v = speed (m/s)
A = area (m^2*)*
With uniform density equation (1) can be modified to

$$q = v_{i1} A_{i1} + v_{i2} A_{i2} +..+ v_{in} A_{im}$$
$$= v_{o1} A_{o1} + v_{o2} A_{o2} +..+ v_{om} A_{om} \quad (2)$$

where
q = flow rate (m^3*/s)*
$\rho_{i1} = \rho_{i2} = . . = \rho_{in} = \rho_{o1} = \rho_{o2} = . . = \rho_{om}$

Example - Equation of Continuity
10 m^3/h of water flows through a pipe of 100 mm inside diameter. The pipe is reduced to an inside dimension of 80 mm. Using equation (2) the velocity in the 100 mm pipe can be calculated as

$(10\ m^3/h)(1 / 3600\ h/s) = v_{100}\ (3.14 \times 0.1\ (m) \times 0.1\ (m) / 4)$
or
$v_{100} = (10\ m^3/h)(1 / 3600\ h/s) / (3.14 \times 0.1\ (m) \times 0.1\ (m) / 4)$
$= \underline{0.35}\ m/s$
Using equation (2) the velocity in the 80 mm pipe can be calculated
$(10\ m^3/h)(1 / 3600\ h/s) = v_{80}\ (3.14 \times 0.08\ (m) \times 0.08\ (m) / 4)$
or
$v_{100} = (10\ m^3/h)(1 / 3600\ h/s) / (3.14 \times 0.08\ (m) \times 0.08\ (m) / 4)$
$= \underline{0.55}\ m/s$

Equation of Mechanical Energy: The Energy Equation is a statement of the first law of thermodynamics. The energy equation involves energy, heat transfer and work. With certain limitations the mechanical energy equation can be compared to the Bernoulli Equation and transferred to the Mechanical Energy Equation in Terms of Energy per Unit Mass.

The mechanical energy equation for a **pump or a fan** can be written in terms of **energy per unit mass**:

$$p_{in} / \rho + v_{in}^2 / 2 + g\ h_{in} + w_{shaft} = p_{out} / \rho + v_{out}^2 / 2 + g\ h_{out} + w_{loss} \quad (1)$$

where
p = static pressure
ρ = density
v = flow velocity
g = acceleration of gravity
h = elevation height
w_{shaft} = net shaft energy inn per unit mass for a pump, fan or similar
w_{loss} = loss due to friction

The energy equation is often used for incompressible flow problems and is called **the Mechanical Energy Equation** or **the Extended Bernoulli Equation**.

The mechanical energy equation for a **turbine** can be written as:

$$p_{in} / \rho + v_{in}^2 / 2 + g\ h_{in} = p_{out} / \rho + v_{out}^2 / 2 + g\ h_{out} + w_{shaft} + w_{loss} \quad (2)$$

where
w_{shaft} = net shaft energy out per unit mass for a turbine or similar

Equation (1) and (2) dimensions are
energy per unit mass (ft^2/s^2 = ft lb/slug or m^2/s^2 = N m/kg)

Efficiency
According to (1) a larger amount of loss - w_{loss} - result in more shaft work required for the same rise of output energy. The efficiency of a **pump or fan process** can be expressed as:

$$\eta = (w_{shaft} - w_{loss}) / w_{shaft} \quad (3)$$

The efficiency of a **turbine process** can be expressed as:

$\eta = w_{shaft} / (w_{shaft} + w_{loss})$ *(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:

$h_{shaft} = w_{shaft} / g = W_{shaft} / m\, g = W_{shaft} / \gamma\, Q$ *(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 / ρ^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

$$v = \mu / \rho \quad (2)$$

where
v = kinematic viscosity
μ = absolute or dynamic viscosity
ρ = density

In the SI-system the theoretical unit is m^2/s or commonly used **Stoke (St)** where

- *1 St = 10^{-4} m^2/s*

Since the Stoke is an unpractical large unit, it is usual divided by 100 to give the unit called **Centistokes (cSt)** where

1 St = 100 cSt
1 cSt = 10^{-6} m^2/s

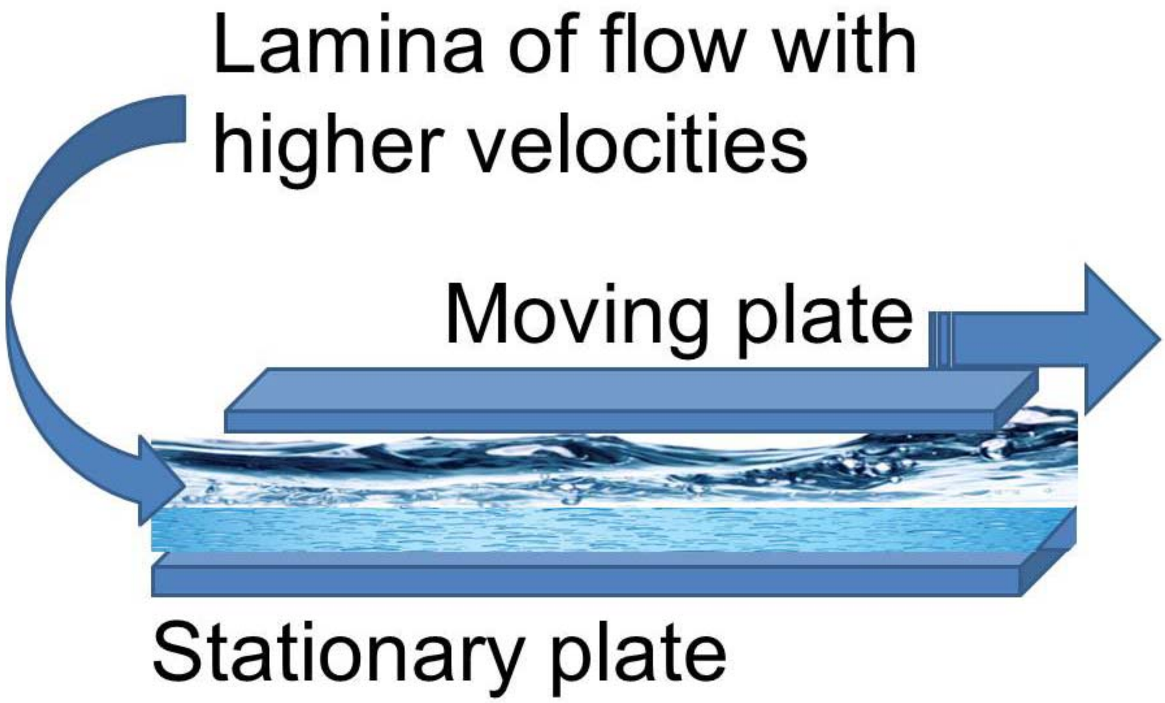
Since the specific gravity of water at 68.4°F (20.2°C) is almost one - 1, the kinematic viscosity of water at 68.4°F is for all practical purposes 1.0 cSt.

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

Knudsen Number: Used by modelers who wish to express a non-dimensionless speed.

L

Laminar Flow: The resistance to flow in a liquid can be characterized in terms of the viscosity of the fluid if the flow is smooth. In the case of a moving plate in a liquid, it is found that there is a layer or lamina which moves with the plate, and a layer which is essentially stationary if it is next to a stationary plate. There is a gradient of velocity as you move from the stationary to the moving plate, and the liquid tends to move in layers with successively higher speed. This is called laminar flow, or sometimes "streamlined" flow. Viscous resistance to flow can be modeled for laminar flow, but if the lamina break up into turbulence, it is very difficult to characterize the fluid flow.



The common application of laminar flow would be in the smooth flow of a viscous liquid through a tube or pipe. In that case, the velocity of flow varies from zero at the walls to a maximum along the centerline of the vessel. The flow profile of laminar flow in a tube can be calculated by dividing the flow into thin cylindrical elements and applying the viscous force to them. Laminar, Transitional or Turbulent Flow? - It is important to know if the fluid flow is laminar, transitional or turbulent when calculating heat transfer or pressure and head loss.

Laplace's Equation: Describes the behavior of gravitational, electric, and fluid potentials.

The scalar form of Laplace's equation is the partial differential equation

$$\nabla^2 \psi = 0, \quad (1)$$

where ∇^2 is the Laplacian.
Note that the operator ∇^2 is commonly written as Δ by mathematicians (Krantz 1999, p. 16). Laplace's equation is a special case of the Helmholtz differential equation

$$\nabla^2 \psi + k^2 \psi = 0 \quad (2)$$

with $k = 0$, or Poisson's equation

$$\nabla^2 \psi = -4 \pi \rho \quad (3)$$

with $\rho = 0$.

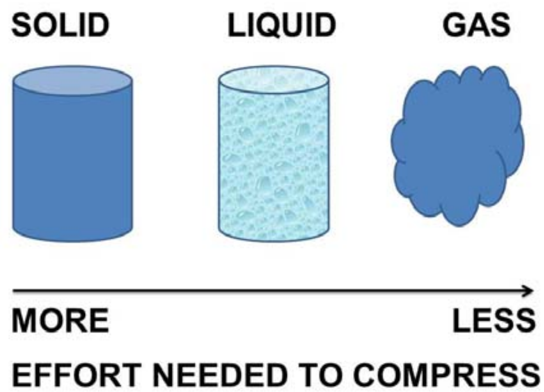
The vector Laplace's equation is given by

$$\nabla^2 \mathbf{F} = \mathbf{0}. \quad (4)$$

A function ψ which satisfies Laplace's equation is said to be harmonic. A solution to Laplace's equation has the property that the average value over a spherical surface is equal to the value at the center of the sphere (Gauss's harmonic function theorem). Solutions have no local maxima or minima. Because Laplace's equation is linear, the superposition of any two solutions is also a solution.

Lift (Force): Lift consists of the sum of all the aerodynamic forces normal to the direction of the external airflow.

Liquids: An in-between state of matter. They can be found in between the solid and gas states. They don't have to be made up of the same compounds. If you have a variety of materials in a liquid, it is called a solution. One characteristic of a liquid is that it will fill up the shape of a container. If you pour some water in a cup, it will fill up the bottom of the cup first and then fill the rest. The water will also take the shape of the cup. It fills the bottom first because of **gravity**. The top part of a liquid will usually have a flat surface. That flat surface is because of gravity too. Putting an ice cube (solid) into a cup will leave you with a cube in the middle of the cup; the shape won't change until the ice becomes a liquid.



Another trait of liquids is that they are difficult to compress. When you compress something, you take a certain amount and force it into a smaller space. Solids are very difficult to compress and gases are very easy. Liquids are in the middle but tend to be difficult. When you compress something, you force the atoms closer together. When pressure goes 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^oK (0^oC) and is **1.01325 bar** or 101325 Pa (absolute). The temperature of 293^oK (20^oC) 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:
$SG = 7850\ kg/m^3 / 1000\ kg/m^3$
= <u>7.85</u>
(the density of water is 1000 kg/m^3)

Specific Weight: Specific Weight is defined as weight per unit volume. Weight is a **force**.

- Mass and Weight - the difference! - What is weight and what is mass? An explanation of the difference between weight and mass.

Specific Weight can be expressed as

$\gamma = \rho\, g$ (2)

where
γ = specific weight (kN/m^3)
g = acceleration of gravity (m/s^2)

The SI-units of specific weight are kN/m^3. The imperial units are lb/ft^3. The local acceleration *g* is under normal conditions 9.807 m/s^2 in SI-units and 32.174 ft/s^2 in imperial units.

Example - Specific Weight Water

Specific weight for water at 60 ^oF is 62.4 lb/ft^3 in imperial units and 9.80 kN/m^3 in SI-units.

Example - Specific Weight Some other Materials

Product	Specific Weight - γ	
	Imperial Units (lb/ft^3)	SI Units (kN/m^3)
Ethyl Alcohol	49.3	7.74
Gasoline	42.5	6.67
Glycerin	78.6	12.4
Mercury	847	133
SAE 20 Oil	57	8.95
Seawater	64	10.1
Water	62.4	9.80

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

Static Pressure: The pressure in a fluid at rest.

Static Pressure and Pressure Head in Fluids: The pressure indicates the normal force per unit area at a given point acting on a given plane. Since there is no shearing stresses present in a fluid at rest - the pressure in a fluid is independent of direction.

For fluids - liquids or gases - at rest the pressure gradient in the vertical direction depends only on the specific weight of the fluid.

How pressure changes with elevation can be expressed as

$dp = - \gamma\, dz$ *(1)*

where
dp = change in pressure
dz = change in height
γ = specific weight

The pressure gradient in vertical direction is negative - the pressure decrease upwards.

Specific Weight: Specific Weight can be expressed as:

$\gamma = \rho\, g$ *(2)*

where
γ = specific weight
g = acceleration of gravity

In general the specific weight - γ - is constant for fluids. For gases the specific weight - γ - varies with the elevation.

Static Pressure in a Fluid: For an incompressible fluid - as a liquid - the pressure difference between two elevations can be expressed as:

$p_2 - p_1 = - \gamma (z_2 - z_1)$ *(3)*

where
p_2 = pressure at level 2
p_1 = pressure at level 1
z_2 = level 2
z_1 = level 1

(3) can be transformed to:

$p_1 - p_2 = \gamma (z_2 - z_1)$ *(4)*
or
$p_1 - p_2 = \gamma\, h$ *(5)*

where
$h = z_2 - z_1$ difference in elevation - the depth down from location z_2.
or
$p_1 = \gamma\, h + p_2$ *(6)*

The Pressure Head

(6) can be transformed to:

$h = (p_2 - p_1) / \gamma$ *(6)*

h express **the pressure head** - the height of a column of fluid of specific weight - γ - required to give a pressure difference of $(p_2 - p_1)$.

Example - Pressure Head
A pressure difference of 5 psi (lbf/in^2) is equivalent to

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 62.4 (lb/ft^3) = <u>11.6</u> ft of water

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 847 (lb/ft^3) = <u>0.85</u> ft of mercury

when specific weight of water is 62.4 (lb/ft^3) and specific weight of mercury is 847 (lb/ft^3).

Streamline - Stream Function: A streamline is the path that an imaginary particle would follow if it was embedded in the flow.

Strouhal Number: A quantity describing oscillating flow mechanisms. **The Strouhal Number** is a dimensionless value useful for analyzing oscillating, unsteady fluid flow dynamics problems.

The Strouhal Number can be expressed as

$St = \omega l / v$ (1)

where
St = Strouhal Number
ω = oscillation frequency
l = characteristic length
v = flow velocity

The Strouhal Number represents a measure of the ratio of inertial forces due to the unsteadiness of the flow or local acceleration to the inertial forces due to changes in velocity from one point to another in the flow field.

The vortices observed behind a stone in a river, or measured behind the obstruction in a vortex flow meter, illustrate these principles.

Stuffing Box: That portion of the pump which houses the packing or mechanical seal.

Submerged: To cover with water or liquid substance.

Supersonic Flow: Flow with speed above the speed of sound, 1,225 km/h at sea level, is said to be supersonic.

Surface Tension: Surface tension is a force within the surface layer of a liquid that causes the layer to behave as an elastic sheet. The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension. The molecules at the surface do not have other like molecules on all sides of them and consequently they cohere more strongly to those directly associated with them on the surface. This forms a surface "film" which makes it more difficult to move an object through the surface than to move it when it is completely submersed. Surface tension is typically measured in dynes/cm, the force in dynes required to break a film of length 1 cm. Equivalently, it can be stated as surface energy in ergs per square centimeter. Water at 20°C has a surface tension of 72.8 dynes/cm compared to 22.3 for ethyl alcohol and 465 for mercury.

Surface tension is typically measured in *dynes/cm* or *N/m*.

Liquid	Surface Tension	
	N/m	dynes/cm
Ethyl Alcohol	0.0223	22.3
Mercury	0.465	465
Water 20°C	0.0728	72.75
Water 100°C	0.0599	58.9

Surface tension is the energy required to stretch a unit change of a surface area. Surface tension will form a drop of liquid to a sphere since the sphere offers the smallest area for a definite volume.

Surface tension can be defined as

$\sigma = F_s / l$ *(1)*

where
σ = surface tension (N/m)
F_s = stretching force (N)
l = unit length (m)

Alternative Units
Alternatively, surface tension is typically measured in dynes/cm, which is

- the force in dynes required to break a film of length 1 cm

or as surface energy J/m^2 or alternatively ergs per square centimeter.

- 1 dynes/cm = 0.001 N/m = 0.0000685 lb_f/ft = 0.571 10^{-5} lb_f/in = 0.0022 poundal/ft = 0.00018 poundal/in = 1.0 mN/m = 0.001 J/m^2 = 1.0 erg/cm^2 = 0.00010197 kg_f/m

Common Imperial units used are lb/ft and lb/in.

Water surface tension at different temperatures can be taken from the table below:

Temperature (°C)	Surface Tension - σ - (N/m)
0	0.0757
10	0.0742
20	0.0728
30	0.0712
40	0.0696
50	0.0679
60	0.0662
70	0.0644
80	0.0626
90	0.0608
100	0.0588

Surface Tension of some common Fluids

- benzene : 0.0289 (N/m)
- diethyl ether : 0.0728 (N/m)
- carbon tetrachloride : 0.027 (N/m)
- chloroform : 0.0271 (N/m)
- ethanol : 0.0221 (N/m)
- ethylene glycol : 0.0477 (N/m)
- glycerol : 0.064 (N/m)
- mercury : 0.425 (N/m)
- methanol : 0.0227 (N/m)
- propanol : 0.0237 (N/m)
- toluene : 0.0284 (N/m)
- water at 20^{o}C : 0.0729 (N/m)

Surge Tanks: Surge tanks can be used to control Water Hammer. A limitation of hydropneumatic tanks is that they do not provide much storage to meet peak demands during power outages and you have very limited time to do repairs on equipment.

T

Telemetering Systems: The following are common pressure sensing devices: Helical Sensor, Bourdon Tube, and Bellows Sensor. The most frequent problem that affects a liquid pressure-sensing device is air accumulation at the sensor. A diaphragm element being used as a level sensor would be used in conjunction with a pressure sensor. Devices must often transmit more than one signal. You can use several types of systems including: Polling, Scanning and Multiplexing. Transmitting equipment requires installation where temperature will not exceed 130 degrees F.

Thixotropic Fluids: Shear Thinning Fluids or **Thixotropic Fluids** reduce their viscosity as agitation or pressure is increased at a constant temperature. Ketchup and mayonnaise are examples of thixotropic materials. They appear thick or viscous but are possible to pump quite easily.

Transonic: Flow with speed at velocities just below and above the speed of sound is said to be transonic.

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

U

U-Tube Manometer: Pressure measuring devices using liquid columns in vertical or inclined tubes are called manometers. One of the most common is the water filled u-tube manometer used to measure pressure difference in pitot or orifices located in the airflow in air handling or ventilation systems.

V

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

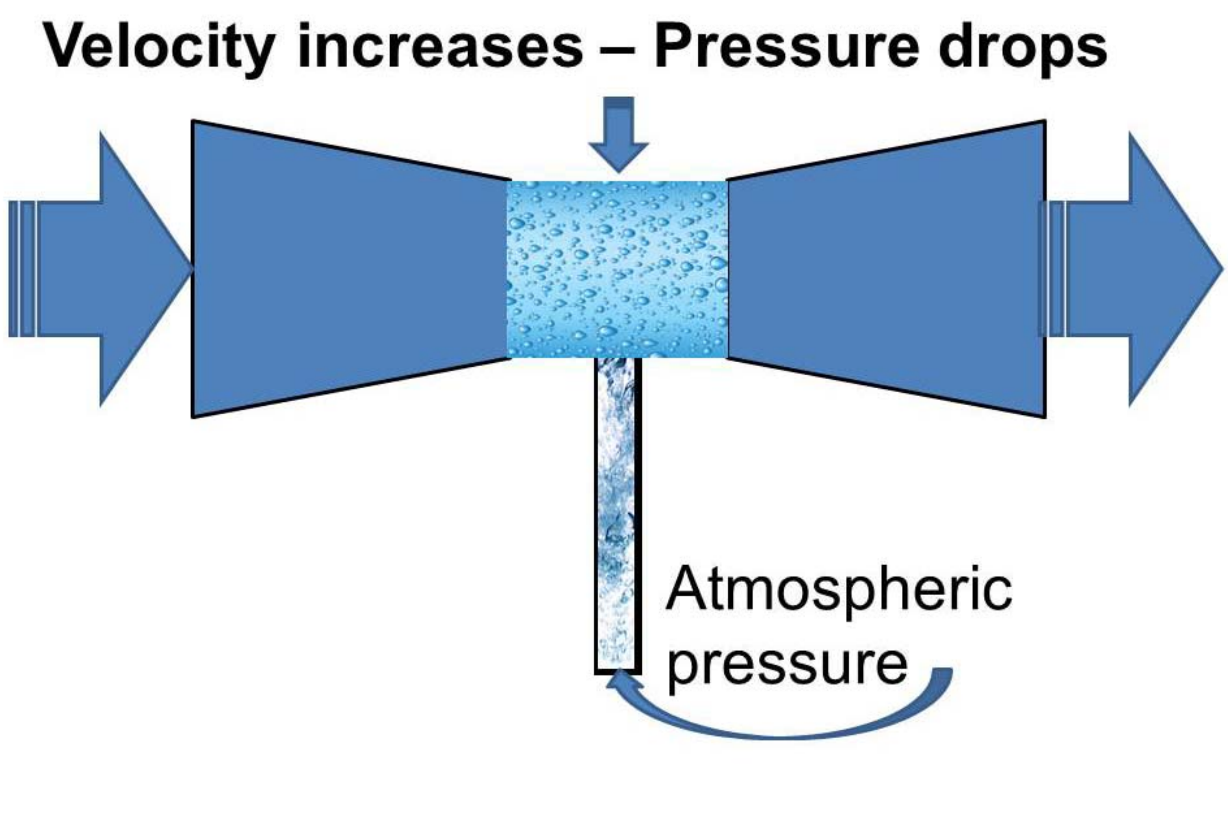
Vane: That portion of an impeller which throws the water toward the volute.

Vapor Pressure: For a particular substance at any given temperature there is a pressure at which the vapor of that substance is in equilibrium with its liquid or solid forms.

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

Venturi: A system for speeding the flow of the fluid, by constricting it in a cone-shaped tube. Venturi are used to measure the speed of a fluid, by measuring the pressure changes from one point to another along the venture. A venturi can also be used to inject a liquid or a gas into another liquid. A pump forces the liquid flow through a tube connected to:

- A venturi to increase the speed of the fluid (restriction of the pipe diameter)
- A short piece of tube connected to the gas source
- A second venturi that decrease the speed of the fluid (the pipe diameter increase again)
- After the first venturi the pressure in the pipe is lower, so the gas is sucked in the pipe. Then the mixture enters the second venturi and slow down. At the end of the system a mixture of gas and liquid appears and the pressure rise again to its normal level in the pipe.
- This technique is used for ozone injection in water.



The newest injector design causes complete mixing of injected materials (air, ozone or chemicals), eliminating the need for other in-line mixers. Venturi injectors have no moving parts and are maintenance free. They operate effectively over a wide range of pressures (from 1 to 250 psi) and require only a minimum pressure difference to initiate the vacuum at the suction part. Venturis are often built in thermoplastics (PVC, PE, PVDF), stainless steel or other metals.

The cavitation effect at the injection chamber provides an instantaneous mixing, creating thousands of very tiny bubbles of gas in the liquid. The small bubbles provide and increased gas exposure to the liquid surface area, increasing the effectiveness of the process (i.e. ozonation).

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

Viscosity: Informally, viscosity is the quantity that describes a fluid's resistance to flow. Fluids resist the relative motion of immersed objects through them as well as to the motion of layers with differing velocities within them. Formally, viscosity (represented by the symbol η "eta") is the ratio of the shearing stress (F/A) to the velocity gradient ($\Delta v_x/\Delta z$ or dv_x/dz) in a fluid.

$$\eta = \left(\frac{F}{A}\right) \div \left(\frac{\Delta v_x}{\Delta z}\right) \quad \text{or} \quad \eta = \left(\frac{F}{A}\right) \div \left(\frac{dv_x}{dz}\right)$$

The more usual form of this relationship, called Newton's equation, states that the resulting shear of a fluid is directly proportional to the force applied and inversely proportional to its viscosity. The similarity to Newton's second law of motion ($F = ma$) should be apparent.

$$\frac{F}{A} = \eta \frac{\Delta v_x}{\Delta z} \quad \text{or} \quad \frac{F}{A} = \eta \frac{dv_x}{dz}$$

$$\Updownarrow \qquad\qquad \Updownarrow$$

$$F = m\frac{\Delta v}{\Delta t} \quad \text{or} \quad F = m\frac{dv}{dt}$$

The SI unit of viscosity is the pascal second [Pa·s], which has no special name. Despite its self-proclaimed title as an international system, the International System of Units has had very little international impact on viscosity. The pascal second is rarely used in scientific and technical publications today. The most common unit of viscosity is the dyne second per square centimeter [dyne·s/cm^2], which is given the name poise [P] after the French physiologist Jean Louis Poiseuille (1799-1869). Ten poise equal one pascal second [Pa·s] making the centipoise [cP] and millipascal second [mPa·s] identical.

1 pascal second = 10 poise = 1,000 millipascal second
1 centipoise = 1 millipascal second

There are actually two quantities that are called viscosity. The quantity defined above is sometimes called dynamic viscosity, absolute viscosity, or simple viscosity to distinguish it from the other quantity, but is usually just called viscosity. The other quantity called kinematic viscosity (represented by the symbol *v* "nu") is the ratio of the viscosity of a fluid to its density.

$$v = \frac{\eta}{\rho}$$

Kinematic viscosity is a measure of the resistive flow of a fluid under the influence of gravity. It is frequently measured using a device called a capillary viscometer -- basically a graduated can with a narrow tube at the bottom. When two fluids of equal volume are placed in identical capillary viscometers and allowed to flow under the influence of gravity, a viscous fluid takes longer than a less viscous fluid to flow through the tube. Capillary viscometers are discussed in more detail later in this section.
The SI unit of kinematic viscosity is the square meter per second [m^2/s], which has no special name. This unit is so large that it is rarely used. A more common unit of kinematic viscosity is the square centimeter per second [cm^2/s], which is given the name stoke [St] after the English scientist George Stoke. This unit is also a bit too large and so the most common unit is probably the square millimeter per second [mm^2/s] or centistoke [cSt].

Viscosity and Reference Temperatures: The viscosity of a fluid is highly temperature dependent and for either dynamic or kinematic viscosity to be meaningful, the **reference temperature** must be quoted. In ISO 8217 the reference temperature for a residual fluid is 100^{o}C. For a distillate fluid the reference temperature is 40^{o}C.

- For a liquid - the kinematic viscosity will **decrease** with higher temperature.
- For a gas - the kinematic viscosity will **increase** with higher temperature.

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

Vorticity: Vorticity is defined as the circulation per unit area at a point in the flow field.

Vortex: A vortex is a whirlpool in the water.

W

Water Freezing: The effects of water freezing in storage tanks can be minimized by alternating water levels in the tank.

Water Storage Facility Inspection: During an inspection of your water storage facility, you should inspect the Cathodic protection system including checking the anode's condition and the connections. The concentration of polyphosphates that is used for corrosion control in storage tanks is typically 5 mg/L or less. External corrosion of steel water storage facilities can be reduced with Zinc or aluminum coatings. All storage facilities should be regularly sampled to determine the quality of water that enters and leaves the facility. One tool or piece of measuring equipment is the Jackson turbidimeter, which is a method to measure cloudiness in water.

Appendixes and Charts

Density of Common Liquids

The density of some common liquids can be found in the table below:

Liquid	Temperature - *t* - (°C)	Density - *ρ* - (kg/m^3)
Acetic Acid	25	1049
Acetone	25	785
Acetonitrile	20	782
Alcohol, ethyl	25	785
Alcohol, methyl	25	787
Alcohol, propyl	25	780
Ammonia (aqua)	25	823
Aniline	25	1019
Automobile oils	15	880 - 940
Beer (varies)	10	1010
Benzene	25	874
Benzyl	15	1230
Brine	15	1230
Bromine	25	3120
Butyric Acid	20	959
Butane	25	599
n-Butyl Acetate	20	880
n-Butyl Alcohol	20	810
n-Butylhloride	20	886
Caproic acid	25	921
Carbolic acid	15	956
Carbon disulfide	25	1261
Carbon tetrachloride	25	1584
Carene	25	857
Castor oil	25	956
Chloride	25	1560
Chlorobenzene	20	1106
Chloroform	20	1489
Chloroform	25	1465
Citric acid	25	1660
Coconut oil	15	924
Cotton seed oil	15	926
Cresol	25	1024
Creosote	15	1067
Crude oil, 48° API	60°F	790

Crude oil, 40^o API	60^{o}F	825
Crude oil, 35.6^o API	60^{o}F	847
Crude oil, 32.6^o API	60^{o}F	862
Crude oil, California	60^{o}F	915
Crude oil, Mexican	60^{o}F	973
Crude oil, Texas	60^{o}F	873
Cumene	25	860
Cyclohexane	20	779
Cyclopentane	20	745
Decane	25	726
Diesel fuel oil 20 to 60	15	820 - 950
Diethyl ether	20	714
o-Dichlorobenzene	20	1306
Dichloromethane	20	1326
Diethylene glycol	15	1120
Dichloromethane	20	1326
Dimethyl Acetamide	20	942
N,N-Dimethylformamide	20	949
Dimethyl Sulfoxide	20	1100
Dodecane	25	755
Ethane	-89	570
Ether	25	73
Ethylamine	16	681
Ethyl Acetate	20	901
Ethyl Alcohol	20	789
Ethyl Ether	20	713
Ethylene Dichloride	20	1253
Ethylene glycol	25	1097
Fluorine refrigerant R-12	25	1311
Formaldehyde	45	812
Formic acid 10%oncentration	20	1025
Formic acid 80%oncentration	20	1221
Freon - 11	21	1490
Freon - 21	21	1370
Fuel oil	60^{o}F	890
Furan	25	1416
Furforol	25	1155
Gasoline, natural	60^{o}F	711
Gasoline, Vehicle	60^{o}F	737
Gas oils	60^{o}F	890
Glucose	60^{o}F	1350 - 1440
Glycerin	25	1259

Glycerol	25	1126
Heptane	25	676
Hexane	25	655
Hexanol	25	811
Hexene	25	671
Hydrazine	25	795
Iodine	25	4927
Ionene	25	932
Isobutyl Alcohol	20	802
Iso-Octane	20	692
Isopropyl Alcohol	20	785
Isopropyl Myristate	20	853
Kerosene	60°F	817
Linolenic Acid	25	897
Linseed oil	25	929
Methane	-164	465
Methanol	20	791
Methyl Isoamyl Ketone	20	888
Methyl Isobutyl Ketone	20	801
Methyl n-Propyl Ketone	20	808
Methyl t-Butyl Ether	20	741
N-Methylpyrrolidone	20	1030
Methyl Ethyl Ketone	20	805
Milk	15	1020 - 1050
Naphtha	15	665
Naphtha, wood	25	960
Napthalene	25	820
Ocimene	25	798
Octane	15	918
Olive oil	20	800 - 920
Oxygen (liquid)	-183	1140
Palmitic Acid	25	851
Pentane	20	626
Pentane	25	625
Petroleum Ether	20	640
Petrol, natural	60°F	711
Petrol, Vehicle	60°F	737
Phenol	25	1072
Phosgene	0	1378
Phytadiene	25	823
Pinene	25	857
Propane	-40	583

Propane, R-290	25	494
Propanol	25	804
Propylenearbonate	20	1201
Propylene	25	514
Propylene glycol	25	965
Pyridine	25	979
Pyrrole	25	966
Rape seed oil	20	920
Resorcinol	25	1269
Rosin oil	15	980
Sea water	25	1025
Silane	25	718
Silicone oil		760
Sodium Hydroxide (caustic soda)	15	1250
Sorbaldehyde	25	895
Soya bean oil	15	924 - 928
Stearic Acid	25	891
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	77^{o}F	1022
Whale oil	15	925
o-Xylene	20	880

1 kg/m^3 = 0.001 g/cm^3 = 0.0005780 oz/in^3 = 0.16036 oz/gal (Imperial) = 0.1335 oz/gal (U.S.) = 0.0624 lb/ft^3 = 0.000036127 lb/in^3 = 1.6856 lb/yd^3 = 0.010022 lb/gal (Imperial) = 0.008345 lb/gal (U.S) = 0.0007525 ton/yd^3

Dynamic or Absolute Viscosity Units Converting Table

The table below can be used to convert between common dynamic or absolute viscosity units.

Multiply by	Convert to				
Convert from	Poiseuille (Pa s)	Poise (dyne s/ cm^2 = g / cm s)	centiPoise	kg / m h	kg_f s / m^2
Poiseuille (Pa s)	1	10	10^3	3.63 10^3	0.102
Poise (dyne s / cm^2 = g / cm s)	0.1	1	100	360	0.0102
centiPoise	0.001	0.01	1	3.6	0.00012
kg / m h	2.78 10^{-4}	0.00278	0.0278	1	2.83 10^{-5}
kg_f s / m^2	9.81	98.1	9.81 10^3	3.53 10^4	1
lb_f s / $inch^2$	6.89 10^3	6.89 10^4	6.89 10^6	2.48 10^7	703
lb_f s / ft^2	47.9	479	4.79 10^4	1.72 10^5	0.0488
lb_f h / ft^2	1.72 10^5	1.72 10^6	1.72 10^8	6.21 10^8	1.76 10^4
lb / ft s	1.49	14.9	1.49 10^3	5.36 10^3	0.152
lb / ft h	4.13 10^{-4}	0.00413	0.413	1.49	4.22 10^{-5}

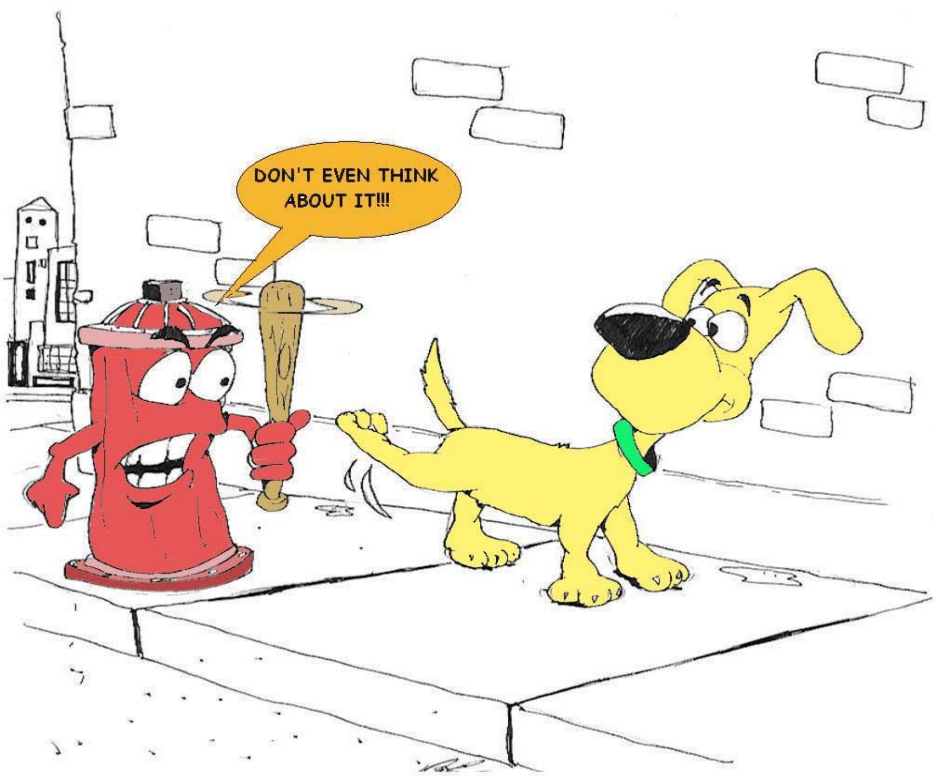
Multiply by	Convert to				
Convert from	lb_f s / $inch^2$	lb_f s / ft^2	lb_f h / ft^2	lb / ft s	lb / ft h
Poiseuille (Pa s)	1.45 10^{-4}	0.0209	5.8 10^{-6}	0.672	2.42 10^3
Poise (dyne s / cm^2 = g / cm s)	1.45 10^{-5}	0.00209	5.8 10^{-7}	0.0672	242
centiPoise	1.45 10^{-7}	2.9 10^{-5}	5.8 10^{-9}	0.000672	2.42
kg / m h	4.03 10^{-8}	5.8 10^{-6}	1.61 10^{-9}	0.000187	0.672
kg_f s / m^2	0.00142	20.5	5.69 10^{-5}	6.59	2.37 10^4
lb_f s / $inch^2$	1	144	0.04	4.63 10^3	1.67 10^7
lb_f s / ft^2	0.00694	1	0.000278	32.2	1.16 10^5
lb_f h / ft^2	25	3.6 10^3	1	1.16 10^5	4.17 10^8
lb / ft s	0.000216	0.0311	8.63 10^{-6}	1	3.6 10^3
lb / ft h	6 10^{-8}	1.16 10^5	2.4 10^{-9}	0.000278	1

Friction Loss Chart

The table below can be used to indicate the friction loss - feet of liquid per 100 feet of pipe - in standard schedule 40 steel pipes.

Pipe Size (inches)	Flow Rate		Kinematic Viscosity - SSU					
	(gpm)	(l/s)	31 (Water)	100 (~Cream)	200 (~Vegetable oil)	400 (~SAE 10 oil)	800 (~Tomato juice)	1500 (~SAE 30 oil)
1/2	3	0.19	10.0	25.7	54.4	108.0	218.0	411.0
3/4	3	0.19	2.5	8.5	17.5	35.5	71.0	131.0
	5	0.32	6.3	14.1	29.3	59.0	117.0	219.0
1	3	0.19	0.8	3.2	6.6	13.4	26.6	50.0
	5	0.32	1.9	5.3	11.0	22.4	44.0	83.0
	10	0.63	6.9	11.2	22.4	45.0	89.0	165.0
	15	0.95	14.6	26.0	34.0	67.0	137.0	
	20	1.26	25.1	46	46.0	90.0	180.0	
1 1/4	5	0.32	0.5	1.8	3.7	7.6	14.8	26.0
	10	0.63	1.8	3.6	7.5	14.9	30.0	55.0
	15	0.95	3.7	6.4	11.3	22.4	45.0	84.0
1 1/2	10	0.63	0.8	1.9	4.2	8.1	16.5	31.0
	15	0.95	1.7	2.8	6.2	12.4	25.0	46.0
	20	1.26	2.9	5.3	8.1	16.2	33.0	61.0
	30	1.9	6.3	11.6	12.2	24.3	50.0	91.0
	40	2.5	10.8	19.6	20.8	32.0	65.0	121.0
2	20	1.26	0.9	1.5	3.0	6.0	11.9	22.4
	30	1.9	1.8	3.2	4.4	9.0	17.8	33.0
	40	2.5	3.1	5.8	5.8	11.8	24.0	44.0
	60	3.8	6.6	11.6	13.4	17.8	36.0	67.0
	80	5.0	1.6	3.0	3.2	4.8	9.7	18.3
2 1/2	30	1.9	0.8	1.4	2.2	4.4	8.8	16.6
	40	2.5	1.3	2.5	3.0	5.8	11.8	22.2
	60	3.8	2.7	5.1	5.5	8.8	17.8	34.0
	80	5.0	4.7	8.3	9.7	11.8	24.0	44.0
	100	6.3	7.1	12.2	14.1	14.8	29.0	55.0
3	60	3.8	0.9	1.8	1.8	3.7	7.3	13.8
	100	6.3	2.4	4.4	5.1	6.2	12.1	23.0
	125	7.9	3.6	6.5	7.8	8.1	15.3	29.0
	150	9.5	5.1	9.2	10.4	11.5	18.4	35.0
	175	11.0	6.9	11.7	13.8	15.8	21.4	40.0
	200	12.6	8.9	15.0	17.8	20.3	25.0	46.0
4	80	5.0	0.4	0.8	0.8	1.7	3.3	6.2
	100	6.3	0.6	1.2	1.3	2.1	4.1	7.8
	125	7.9	0.9	1.8	2.1	2.6	5.2	9.8

	150	9.5	1.3	2.4	2.9	3.1	6.2	11.5
	175	11.0	1.8	3.2	4.0	4.0	7.4	13.7
	200	12.6	2.3	4.2	5.1	5.1	8.3	15.5
	250	15.8	3.5	6.0	7.4	8.0	10.2	19.4
6	125	7.9	0.1	0.3	0.3	0.52	1.0	1.9
	150	9.5	0.2	0.3	0.4	0.6	1.2	2.3
	175	11.0	0.2	0.4	0.5	0.7	1.4	2.6
	200	12.6	0.3	0.6	0.7	0.8	1.6	3.0
	250	15.8	0.5	0.8	1.0	1.0	2.1	3.7
	300	18.9	1.1	8.5	10.0	11.6	12.4	23.0
	400	25.2	1.1	1.9	2.3	2.8	3.2	6.0
8	250	15.8	0.1	0.2	0.3	0.4	0.7	1.2
	300	18.9	0.3	1.2	1.4	1.5	2.5	4.6
	400	25.2	0.3	0.5	0.6	0.7	1.1	2.0
10	300	18.9	0.1	0.3	0.4	0.4	0.8	1.5
	400	25.2	0.1	0.2	0.2	0.2	0.4	0.8



Hazen-Williams Coefficients

Hazen-Williams factor for some common piping materials. Hazen-Williams coefficients are used in the Hazen-Williams equation for friction loss calculation in ducts and pipes. Coefficients for some common materials used in ducts and pipes can be found in the table below:

Material	Hazen-Williams Coefficient - C -
Asbestos Cement	140
Brass	130 - 140
Brick sewer	100
Cast-Iron - new unlined (CIP)	130
Cast-Iron 10 years old	107 - 113
Cast-Iron 20 years old	89 - 100
Cast-Iron 30 years old	75 - 90
Cast-Iron 40 years old	64-83
Cast-Iron, asphalt coated	100
Cast-Iron, cement lined	140
Cast-Iron, bituminous lined	140
Cast-Iron, wrought plain	100
Concrete	100 - 140
Copper or Brass	130 - 140
Ductile Iron Pipe (DIP)	140
Fiber	140
Galvanized iron	120
Glass	130
Lead	130 - 140
Plastic	130 - 150
Polyethylene, PE, PEH	150
PVC, CPVC	150
Smooth Pipes	140
Steel new unlined	140 - 150
Steel	
Steel, welded and seamless	100
Steel, interior riveted, no projecting rivets	100
Steel, projecting girth rivets	100
Steel, vitrified, spiral-riveted	90 - 100
Steel, corrugated	60
Tin	130
Vitrified Clays	110
Wood Stave	110 - 120

Pressure Head

A pressure difference of 5 psi (lbf/in^2) is equivalent to

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 62.4 (lb/ft^3) = 11.6 ft of water

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 847 (lb/ft^3) = 0.85 ft of mercury

When specific weight of water is 62.4 (lb/ft^3) and specific weight of mercury is 847 (lb/ft^3).

Heads at different velocities can be taken from the table below:

Velocity (ft/sec)	Head Water (ft)
0.5	0.004
1.0	0.016
1.5	0035
2.0	0.062
2.5	0.097
3.0	0.140
3.5	0.190
4.0	0.248
4.5	0.314
5.0	0.389
5.5	0.470
6.0	0.560
6.5	0.657
7.0	0.762
7.5	0.875
8.0	0.995
8.5	1.123
9.0	1.259
9.5	1.403
10.0	1.555
11.0	1.881
12.0	2.239
13.0	2.627
14.0	3.047
15.0	3.498
16.0	3.980
17.0	4.493
18.0	5.037
19.0	5.613
20.0	6.219
21.0	6.856
22.0	7.525

1 ft (foot) = 0.3048 m = 12 in = 0.3333 yd

Thermal Properties of Water

Temperature - t - (°C)	Absolute pressure - p - (kN/m^2)	Density - ρ - (kg/m^3)	Specific volume - v - (m^3/kgx10^{-3})	Specific Heat - c_p - (kJ/kgK)	Specific entropy - e - (kJ/kgK)
0	0.6	1000	100	4.217	0
5	0.9	1000	100	4.204	0.075
10	1.2	1000	100	4.193	0.150
15	1.7	999	100	4.186	0.223
20	2.3	998	100	4.182	0.296
25	3.2	997	100	4.181	0.367
30	4.3	996	100	4.179	0.438
35	5.6	994	101	4.178	0.505
40	7.7	991	101	4.179	0.581
45	9.6	990	101	4.181	0.637
50	12.5	988	101	4.182	0.707
55	15.7	986	101	4.183	0.767
60	20.0	980	102	4.185	0.832
65	25.0	979	102	4.188	0.893
70	31.3	978	102	4.190	0.966
75	38.6	975	103	4.194	1.016
80	47.5	971	103	4.197	1.076
85	57.8	969	103	4.203	1.134
90	70.0	962	104	4.205	1.192
95	84.5	962	104	4.213	1.250
100	101.33	962	104	4.216	1.307
105	121	955	105	4.226	1.382
110	143	951	105	4.233	1.418
115	169	947	106	4.240	1.473
120	199	943	106	4.240	1.527
125	228	939	106	4.254	1.565
130	270	935	107	4.270	1.635
135	313	931	107	4.280	1.687
140	361	926	108	4.290	1.739
145	416	922	108	4.300	1.790
150	477	918	109	4.310	1.842
155	543	912	110	4.335	1.892
160	618	907	110	4.350	1.942
165	701	902	111	4.364	1.992
170	792	897	111	4.380	2.041
175	890	893	112	4.389	2.090
180	1000	887	113	4.420	2.138

185	1120	882	113	4.444	2.187
190	1260	876	114	4.460	2.236
195	1400	870	115	4.404	2.282
200	1550	863	116	4.497	2.329
220					
225	2550	834	120	4.648	2.569
240					
250	3990	800	125	4.867	2.797
260					
275	5950	756	132	5.202	3.022
300	8600	714	140	5.769	3.256
325	12130	654	153	6.861	3.501
350	16540	575	174	10.10	3.781
360	18680	526	190	14.60	3.921

Viscosity Converting Chart

The viscosity of a fluid is its resistance to shear or flow, and is a measure of the fluid's adhesive/cohesive or frictional properties. This arises because of the internal molecular friction within the fluid producing the frictional drag effect. There are two related measures of fluid viscosity which are known as **dynamic** and **kinematic** viscosity.

Dynamic viscosity is also termed "**absolute viscosity**" and is the tangential force per unit area required to move one horizontal plane with respect to the other at unit velocity when maintained a unit distance apart by the fluid.

Centipoise (CPS) Millipascal (mPas)	Poise (P)	Centistokes (cSt)	Stokes (S)	Saybolt Seconds Universal (SSU)
1	0.01	1	0.01	31
2	0.02	2	0.02	34
4	0.04	4	0.04	38
7	0.07	7	0.07	47
10	0.1	10	0.1	60
15	0.15	15	0.15	80
20	0.2	20	0.2	100
25	0.24	25	0.24	130
30	0.3	30	0.3	160
40	0.4	40	0.4	210
50	0.5	50	0.5	260
60	0.6	60	0.6	320
70	0.7	70	0.7	370
80	0.8	80	0.8	430
90	0.9	90	0.9	480
100	1	100	1	530
120	1.2	120	1.2	580
140	1.4	140	1.4	690
160	1.6	160	1.6	790
180	1.8	180	1.8	900
200	2	200	2	1000
220	2.2	220	2.2	1100
240	2.4	240	2.4	1200
260	2.6	260	2.6	1280
280	2.8	280	2.8	1380
300	3	300	3	1475
320	3.2	320	3.2	1530

340	3.4	340	3.4	1630
360	3.6	360	3.6	1730
380	3.8	380	3.8	1850
400	4	400	4	1950
420	4.2	420	4.2	2050
440	4.4	440	4.4	2160
460	4.6	460	4.6	2270
480	4.8	480	4.8	2380
500	5	500	5	2480
550	5.5	550	5.5	2660
600	6	600	6	2900
700	7	700	7	3380
800	8	800	8	3880
900	9	900	9	4300
1000	10	1000	10	4600
1100	11	1100	11	5200
1200	12	1200	12	5620
1300	13	1300	13	6100
1400	14	1400	14	6480
1500	15	1500	15	7000
1600	16	1600	16	7500
1700	17	1700	17	8000
1800	18	1800	18	8500
1900	19	1900	19	9000
2000	20	2000	20	9400
2100	21	2100	21	9850
2200	22	2200	22	10300
2300	23	2300	23	10750
2400	24	2400	24	11200

Various Flow Section Channels and their Geometric Relationships: Area, wetted perimeter and hydraulic diameter for some common geometric sections like

- rectangular channels
- trapezoidal channels
- triangular channels
- circular channels.

Rectangular Channel

Flow Area

Flow area of a rectangular channel can be expressed as

$A = b\ h$ (1)

where

A = flow area (m^2, in^2)

b = width of channel (m, in)

h = height of flow (m, in)

Wetted Perimeter

Wetted perimeter of a rectangular channel can be expressed as

$P = b + 2\ h$ (1b)

where

P = wetted perimeter (m, in)

Hydraulic Radius

Hydraulic radius of a rectangular channel can be expressed as

$R_h = b\ h / (b + 2\ y)$ (1c)

where

R_h = hydraulic radius (m, in)

Trapezoidal Channel

Flow Area

Flow area of a trapezoidal channel can be expressed as

$A = (a + z\ h)\ h$ (2)

where

z = see figure above (m, in)

Wetted Perimeter

Wetted perimeter of a trapezoidal channel can be expressed as

$P = a + 2\ h\ (1 + z^2)^{1/2}$ (2b)

Hydraulic Radius

Hydraulic radius of a trapezoidal channel can be expressed as

$R_h = (a + z\ h)\ h / a + 2\ h\ (1 + z^2)^{1/2}$ (2c)

Triangular Channel

Flow Area

Flow area of a triangular channel can be expressed as

$A = z h^2$ (3)

where

z = see figure above (m, in)

Wetted Perimeter

Wetted perimeter of a triangular channel can be expressed as

$P = 2 h (1 + z^2)^{1/2}$ (3b)

Hydraulic Radius

Hydraulic radius of a triangular channel can be expressed as

$R_h = z h / 2 (1 + z^2)^{1/2}$ (3c)

Circular Channel

Flow Area

Flow area of a circular channel can be expressed as

$A = D^2/4 (\alpha - \sin(2 \alpha)/2)$ (4)

where

D = diameter of channel

$\alpha = \cos^{-1}(1 - h/r)$

Wetted Perimeter

Wetted perimeter of a circular channel can be expressed as

$P = \alpha D$ (4b)

Hydraulic Radius

Hydraulic radius of a circular channel can be expressed as

$R_h = D/8 [1 - \sin(2 \alpha) / (2 \alpha)]$ (4c)

Velocity Head: Velocity head can be expressed as

$h = v^2/2g$ (1)

where

v = velocity (ft, m)

g = acceleration of gravity ($32.174\ ft/s^2$, $9.81\ m/s^2$)

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

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°F (0-100°C) - imperial and SI units. Speed of Sound in Water - in imperial units (BG units)

Temperature - *t* - (°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* - (°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

We welcome you to complete the assignment in Microsoft Word. You can find the assignment at www.abctlc.com. Once complete, just simply fax or e-mail the answer key along with the registration page to us and allow two weeks for grading. Once we grade it, we will mail a certificate of completion to you. Call us if you need any help.

If you need your certificate back within 48 hours, you may be asked to pay a rush service fee of $50.00.

You can download the assignment in Microsoft Word from TLC's website under the Assignment Page. www.abctlc.com You will have 90 days to successfully complete this assignment with a score of 70% or better. If you need any assistance, please contact TLC's Student Services.