DISTRIBUTION SYSTEMS

The distribution system is a network of storage tanks, pipes, valves, hydrants, service connections, and meters that are needed to get water from the point of production to the customer. The distribution system begins at the point where water enters the system at usable pressure. It ends at the customer's side of the meter installation. Distribution systems must be designed to store and deliver water to the customer at adequate pressures during peak demand periods.

PIPES

Several different types of pipe are used in distribution systems. They all have advantages and disadvantages related to cost, installation, strength, and corrosion. The most common types of pipe are known by their abbreviations.

ABBREVIATIONS FOR WATER PIPES

- **Cast Iron Pipe (CIP)**
- **Ductile Iron Pipe (DIP)**
- **Steel Pipe (ST)**
- **Asbestos-Cement Pipe (AC)**
- **Concrete Cylinder Pipe (CCP)**
- **Reinforced Concrete Pipe (RCP)**
- **Polyvinyl Chloride Pipe (PVC)**

CAST IRON AND DUCTILE IRON PIPE

Cast iron and ductile iron pipe are known for their strength and load bearing capacity. Most of the iron pipe that has been installed in the past 40 years is ductile iron pipe. Ductile iron is stronger and less rigid than gray cast iron pipe. The main disadvantages of iron pipe are that it is heavy and subject to corrosion from the inside and the outside. It should be coated with a corrosion resistant external coating and, in certain soil conditions, may require some type of cathodic protection to achieve its normal service life.

Cast and ductile iron pipes can be joined by several different means. Flanged joints are used above ground. The most common means of joining them underground are the bell and spigot or the mechanical joint connections. Care must be taken when installing and bedding. CIP and DIP are both brittle and don't flex. The bell holes should only be as wide as the bell portion of the pipe. Otherwise, stresses from improper bedding can cause it to crack.

STEEL PIPE

Steel pipe is lighter than iron pipe and is easier to handle and install. It is more flexible than iron pipe and doesn't require as much care when bedded in the trench. The main disadvantage of steel pipe is that it is very susceptible to corrosion and should be coated both inside and outside. It doesn't have the same bearing strength that cast or ductile iron does and may collapse under vacuum conditions. Steel pipe may be joined the same way that cast iron is joined. It may also be joined using threaded connections.

Steel Pipe (left) and DIP (right)

ASBESTOS-CEMENT PIPE

Asbestos-cement pipe is frequently used as a main line since it is less expensive than cast iron. It is lighter than iron pipe and more easily installed and tapped. AC pipe is joined using sleeved couplings and O-rings. It also resists corrosion and tuberculation. One of the disadvantages of AC pipe is that asbestos is a known carcinogen. This presents more of a hazard to the operator working on the pipe than the customer drinking water from it. The dust created from cutting the pipe during repair and installation should be a cause for concern. All workers in the area should wear proper respirator protection.

The other disadvantage is that the pipe is brittle and tends to crack under stress from trench loads. AC pipe must be as carefully installed and bedded as cast iron and is even more difficult to repair than cast iron. Cracked AC pipe must be cut out and spliced.

AC Pipe and Barrel Coupling

CONCRETE CYLINDER AND REINFORCED CONCRETE CYLINDER PIPE

Concrete cylinder pipe is only available in diameters of 12' and larger. It is cheaper, lighter, and easier to install than comparable sizes of ductile iron pipe. Concrete pipes have cement lining that makes the inner pipe wall less rough than DIP. Concrete cylinder pipes are difficult to tap and repair. They are normally only used for transmission or trunk lines.

Concrete cylinder pipe (CCP) is only used in low-pressure transmission applications. It can't handle pressures that exceed 50 psi. Reinforced concrete cylinder pipe (RCP) is made using pre-stressed steel bands in the pipe wall. It is rated for pressures up to 250 psi. Concrete pipes are joined using bell and spigot or mortise and tenon connections.

POLYVINYL CHLORIDE PIPE

There are a number of different types of plastic pipe available for use in water distribution systems. Polyvinyl chloride or PVC is the most popular pipe for small community water systems. PVC pipe is lightweight, easy to install and repair, available in a wide range of sizes and strengths. PVC is also unaffected by corrosive water and soil and, because it will not conduct electricity, is not subject to galvanic corrosion or electrolysis.

The main disadvantage of PVC pipe is that it has a high rate of thermal expansion. It is also relatively fragile and must be protected by the use of select backfill material.

PVC Pipe with Bell and Spigot Fittings

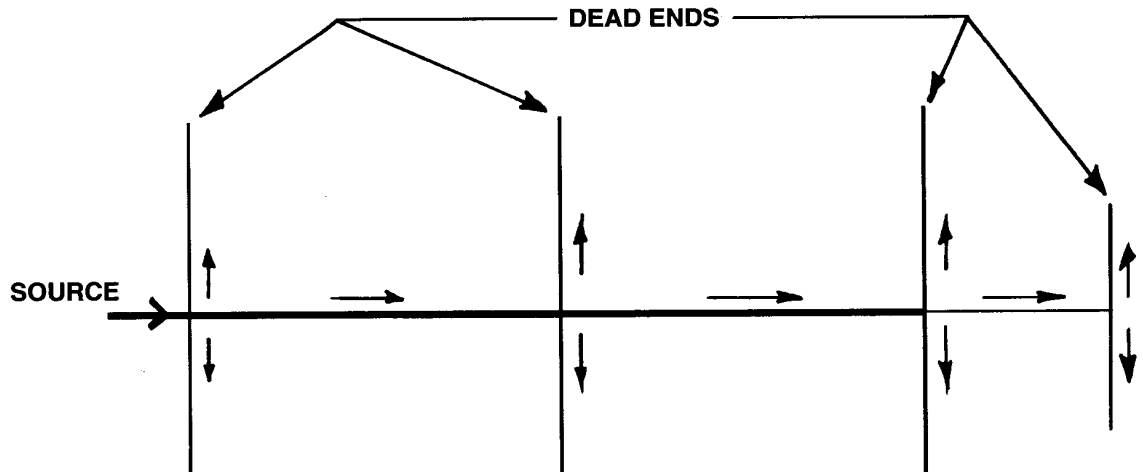
PIPE PRESSURE RATINGS

Some types of pipe are available in more than one pressure rating. PVC pipe is available in several pressure ratings. Schedule 40 and Schedule 80, the latter being rated at a higher pressure, are the most common types of PVC. PVC piping is rated for pressures up to 150 psi. Asbestos-cement piping is rated at 100, 150, or 200 psi. Ductile iron pipe can be rated for pressures up to 500 psi. The difference in the dimensions of these two is in the pipe wall thickness. They will both have the same inside diameter (ID), but different outside diameters (OD), requiring different sizes of clamps or fittings.

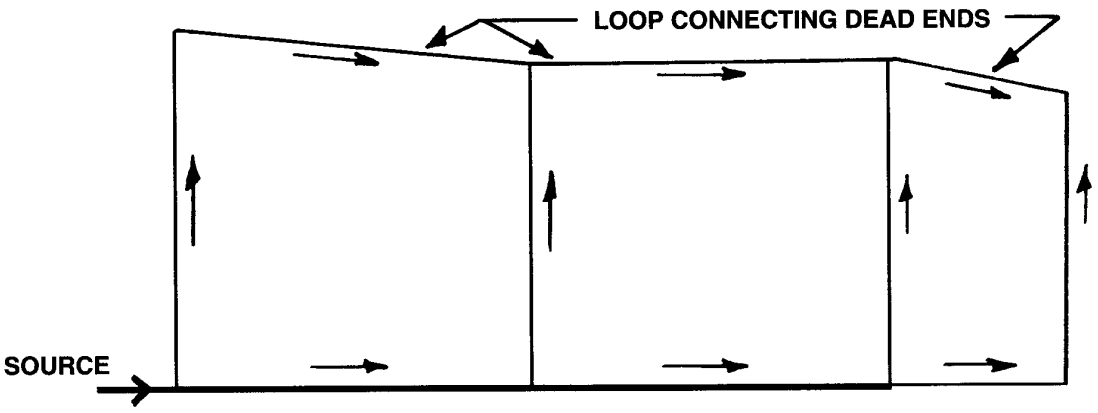
Repair fittings are not purchased for 6" cast iron pipe or 8" PVC pipe, but rather pipes with an outside diameter of 8.72 to 9.25 inches. Tape measures that are designed to read outside diameters of pipes can be purchased from piping distributors. The "inch" markings are actually 3.1416 (pi) inches apart. If an OD tape is not available, measure the outside diameter with a regular tape and divide the reading by 3.1416. (Circumference divided by3.1416 = outside diameter)

PIPING SYSTEMS

Water systems are laid out in one of two ways. They are designed as tree systems, where the main lines branch out from the transmission line like branches on a tree, or looped systems, where branching lines are interconnected at the ends.



Distribution System - Tree



Distribution System - Looped

Tree systems will have lots of dead end lines. Dead ends can create pressure problems at the end of the lines and can seriously limit fire flows. These lines can also be responsible for taste and odor complaints and other water quality issues. Connecting the ends of the tree branches and creating loops will provide flow from more than one direction. This will increase flows and reduce pressure loss due to friction. Stale water problems can be virtually eliminated using looped systems.

DISTRIBUTION SYSTEM VALVES

Valves are used to control flow in a water system. Most of the valves in a distribution system are installed for isolation of sections of piping for maintenance and repair. Control valves like pressure reducing valves, altitude valves, pressure relief valves, pressure sustaining valves, and pump control valves are designed to control pressures and throttle flows to prevent damage to the system. Air relief valves can vent trapped air from the system. Check valves allow water to flow only in one direction.

GENERAL VALVE MAINTENANCE

Valves on the water system should be completely closed and then reopened at least once a year. If not, they may become frozen and inoperative when isolation is necessary. An up-to-date map should be kept of all the valves in the system plus an individual record of each valve.

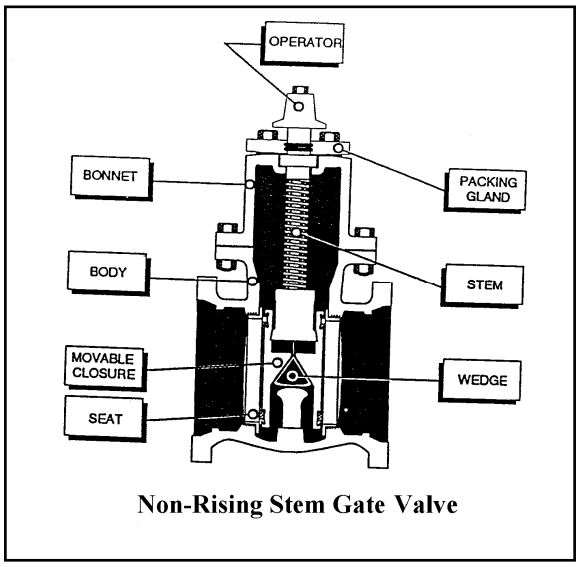
GENERAL VALVE MAINTENANCE DATA

- Location of the valve from a reference point
- Type and size of valve
- Make of the valve
- Number of turns to open/shut
- Dates it was operated
- Date it was repacked or repaired
- Condition of the valve

Always check the valve stem for leaks. There is a stuffing box on the valve body where the shaft enters the valve, just like on a centrifugal pump. The difference is that, unlike a pump, the packing gland should be tightened to prevent leakage. The packing seldom wears out, since the valve stem doesn't move often. If it does wear out, the stuffing box can be repacked like a pump. When a valve must be disassembled, the valve seat, the valve face, and the disc should be checked for damage.

GATE VALVES

Gate valves are used for isolation of equipment and piping. They should never be used to throttle flow. This will cause damage to the valve face. Open gate valves have the less friction loss than any other type of valve. Gate valves can have plug type disks or double disc gates. Double disc gates are used in higher-pressure applications. Gate valves can also have rising or non-rising stems. A rising stem is threaded to the valve body and will rise as the valve is opened. Some types of rising stem valves are called outside yoke and stem (OS&Y) valves. A non-rising stem is threaded to the gate assembly and lifts the gate without rising. Non-rising stems are found on all large buried valves. The number of turns needed to open or close a gate valve that is not gear reduced is equal to 3 times the diameter plus 1-3 turns to seat properly. So a 6" valve will take 3 x 6 = 18 + 1-2 or about 19-20 turns to close. Larger valves will take 2 extra turns.

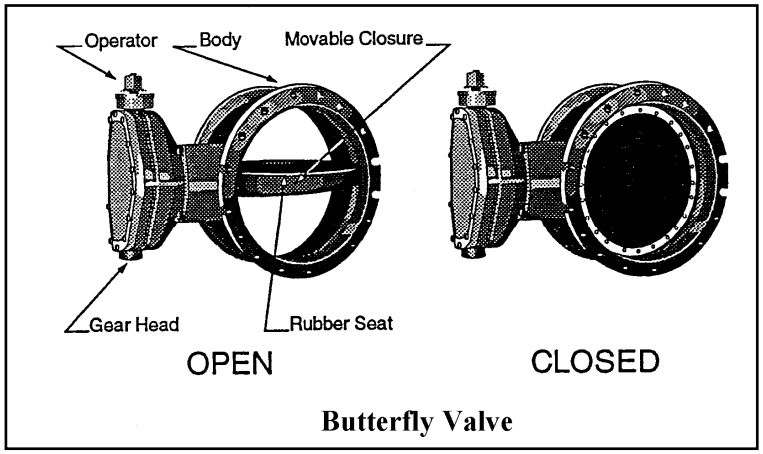


Non-Rising Stem Gate Valve

Large gate valves may have a much smaller bypass valve that is piped in around the large valve. In a distribution system, the water pressure can create tons of force against the valve face. When one side of the valve has been de-pressurized for some reason, the force against the other side can make it impossible to open the valve. The stem will break instead. The bypass valve is much smaller and easier to open (less total force on a smaller surface area). When the pressure has equalized on both sides of the large valve, the stem is only lifting the weight of the gate assembly.

BUTTERFLY VALVES

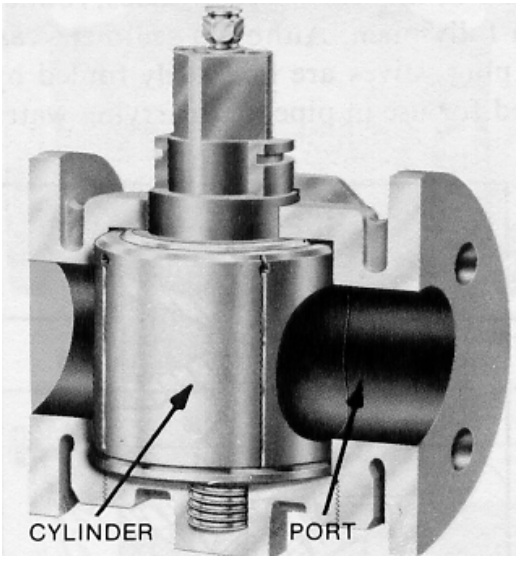
Butterfly valves serve the same purpose as gate valves. These valves usually open and close with ¼ of a turn of the valve disc. Larger valves will have a gearbox on the stem and will require a number of turns to open. Butterfly valves are easier to open than gate valves, usually without the need for a bypass, but have more friction loss when open. They can also be used for throttling flow without damaging the disc. Caution should be used when filling a line through a butterfly valve. When a butterfly valve is 30% open, it can pass 90% of its rated flow. Small butterfly valves will simply have a handle, instead of a threaded stem. The handle is normally aligned with the valve disc. When the handle is in line with the pipe, the valve is open. When it's perpendicular to the pipe it's closed.



Butterfly Valve

BALL OR PLUG VALVES

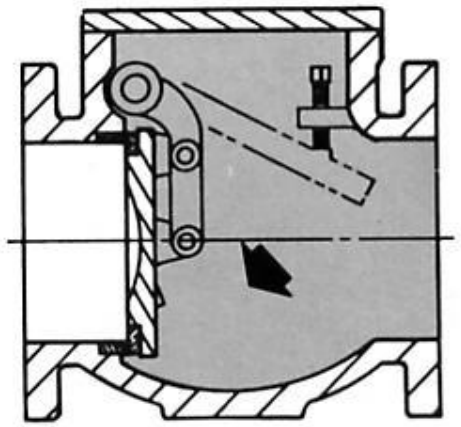
Ball and plug valves are similar to butterfly valves. They have a ball or cone-shaped plug that has a hole in it, instead of a disc. They open and close with ¼ turn. They are the most common types of valve in most systems. They are used as corporation stops on service lines, curb stops on meter setters, and isolation petcocks on control valve pilot piping. They are seldom used in sizes above 2 ½".



Cylindrical Plug Valve

CHECK VALVES

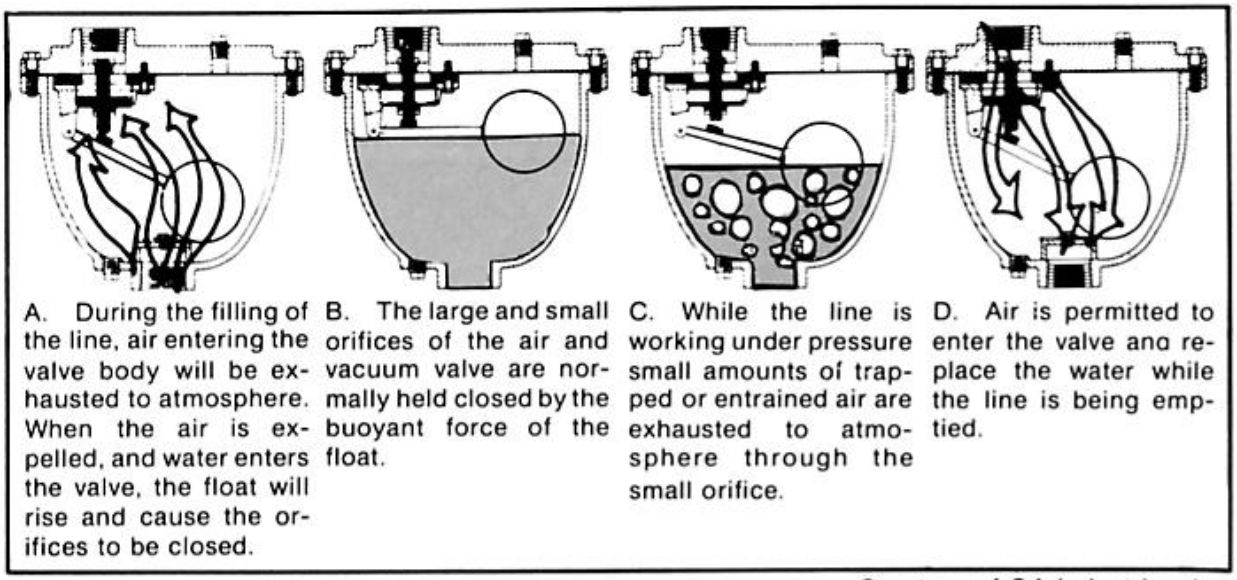
Check valves are used where flow of water should be in one direction only. The swing check valve should be operated in the horizontal position and the lift check valve is operated in a vertical position. These type of valves are most commonly used on the discharge side of the pumps to prevent backflow and as foot valves on the bottom of suction piping to prevent loss of prime to the pumps.



Swing Check Valve

AIR RELEASE VALVES

Air release valves are used to allow air that may be trapped in the line to escape. The trapped air can create pressure and pumping problems, milky-water complaints, and pressure spikes that resemble water hammer. They are very useful in systems that are in hilly country. They should be located at the top of hills where the trapped air will collect. They are also used on booster pumps and wells to removed trapped air. Combination air release valves will also let air in when a vacuum occurs. This is done to protect the piping. They can also be used to vent a line that is being drained.



A. During the filling of the line, air entering the valve body will be exhausted to atmosphere. When the air is expelled, and water enters the valve, the float will rise and cause the orifices to be closed.

B. The large and small orifices of the air and vacuum valve are normally held closed by the buoyant force of the float.

C. While the line is working under pressure small amounts of trapped or entrained air are exhausted to atmosphere through the small orifice.

D. Air is permitted to enter the valve ano replace the water while the line is being emptied.

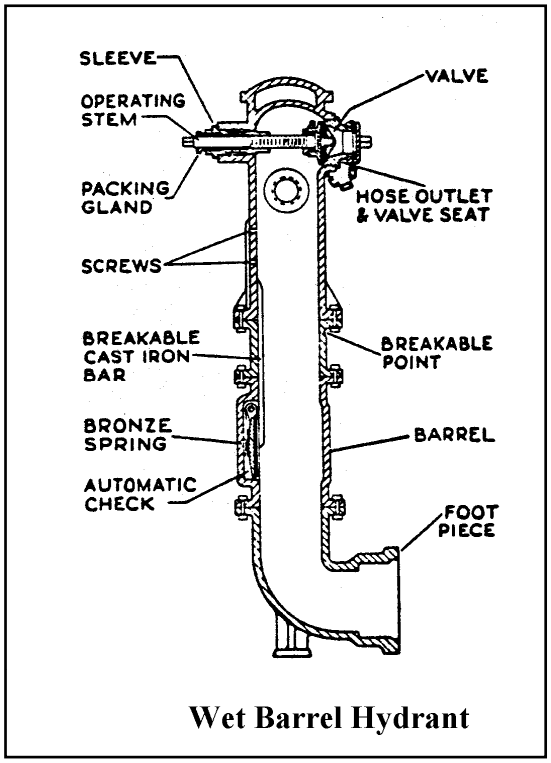
Courtesy of GA Industries, Inc.

FIRE HYDRANTS

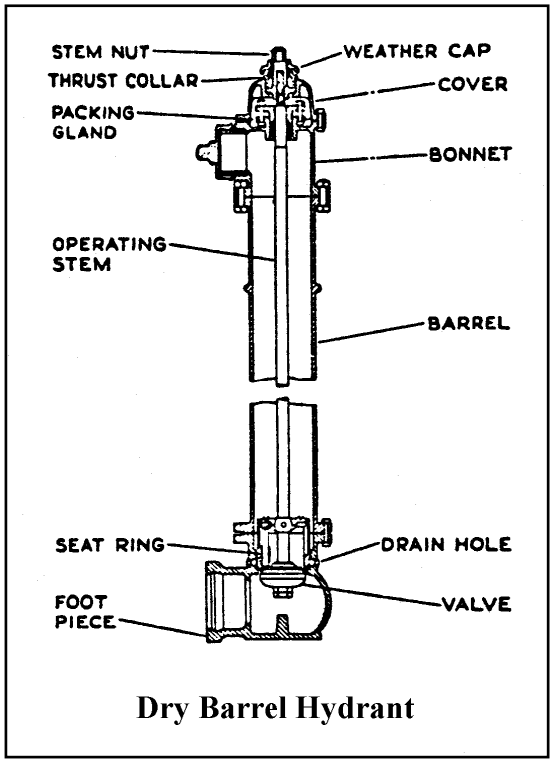
The fire insurance rates for residents on the system will be dependent, in part, on the proper spacing and discharge capabilities of the fire hydrants in the system. Hydrants should not be more than 500-600 feet apart in residential areas. The spacing requirements in industrial and rural districts may vary. They should be located at the end of every dead end line. Hydrants should be operated every 6 months and flow tested annually. Care must be taken to avoid damaging landscaping or creating a safety hazard in traffic when flushing water lines with a hydrant.

There are two types of fire hydrants used in water systems. They are known as wet barrel and dry barrel hydrants. A wet barrel hydrant is always pressurized and the main valve is at the top of the hydrant barrel. A dry barrel hydrant has the valve at the bottom of the barrel and a drain hole that drains the barrel when the hydrant is closed. These hydrants are used in areas where freezing occurs in the winter.

Never operate a dry barrel hydrant with the main valve cracked to throttle flow. The drain hole will be open anytime the main valve is not completely open. The release of water through the drain hole will undercut the sidewalk and hydrant. If a throttled flow is needed, a gate valve should be attached to the hydrant nozzle. With the hydrant valve wide open, the gate valve can be used to throttle the flow. All tanks that are filled from hydrants must be equipped with air gap devices to prevent backflow.

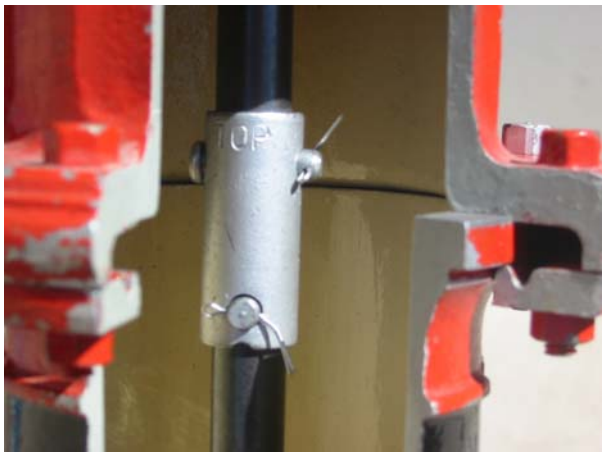


Wet Barrel Hydrant



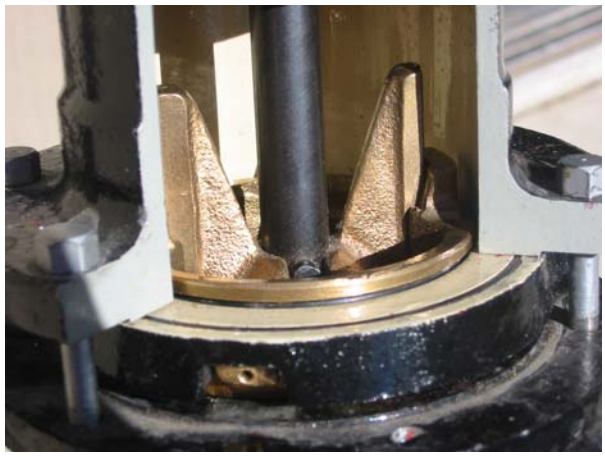
Dry Barrel Hydrant

Fire hydrants should never be placed on lines smaller than 6 inches if they are to be used for fire protection. In addition to provide fire protection, hydrants can also be useful for flushing lines, venting lines as they are filled, and pressure and flow testing. Hydrants on smaller lines (4 inch and down) will not supply enough water to fight a fire but may be used to flush dead end lines. The traffic model of a dry barrel hydrant comes with special breakaway unions on the stem and flanges on the upper barrel that allow it to break cleanly if hit by a vehicle. Hydrants must be installed with the nozzles at least 18 inches above grade. This is the clearance needed to operate a hydrant wrench when removing the nozzle.



Breakaway Flange and Coupling

Main Valve Assembly and Drain Hole



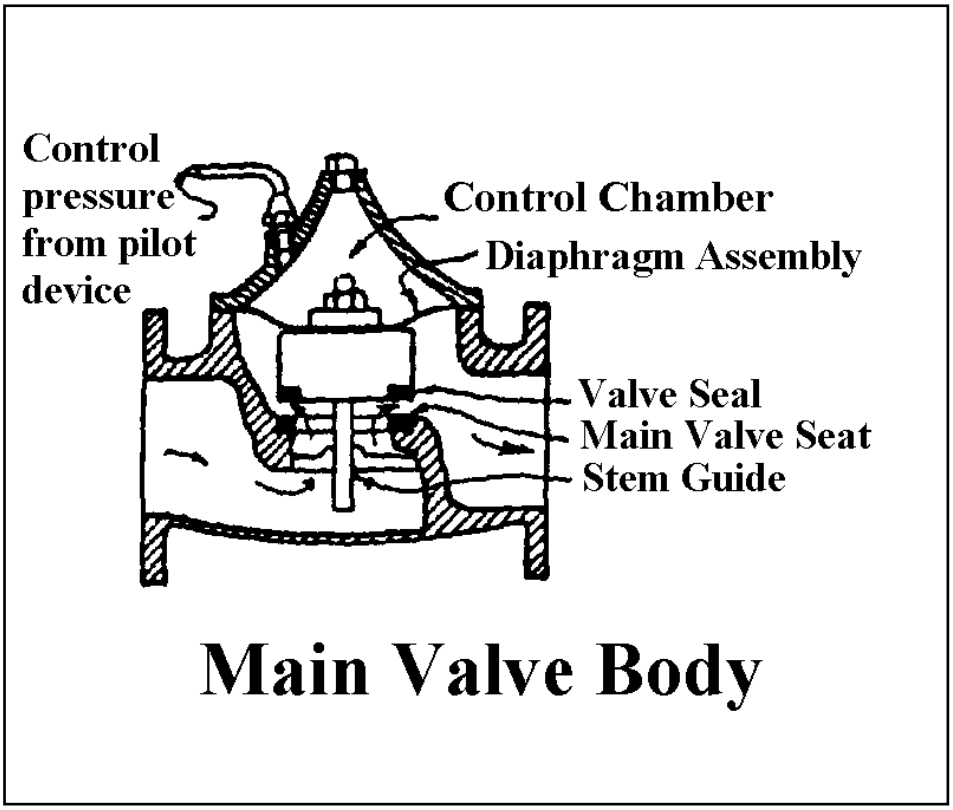
HYDRANT FLOW TESTING

Hydrants should be flow tested annually. Comparing flow test data over time can provide information regarding changing hydraulic conditions in the system. Friction losses in the piping can increase due to tuberculation and deterioration of the inner pipe walls or simply increased system demand in an area. When this occurs, the flow from hydrants in the area will be reduced. Being able to pinpoint where the losses are greatest can help in planning system improvements. Reduced flows from hydrants can also be a problem from a fire protection and fire insurance standpoint.

CONTROL VALVES

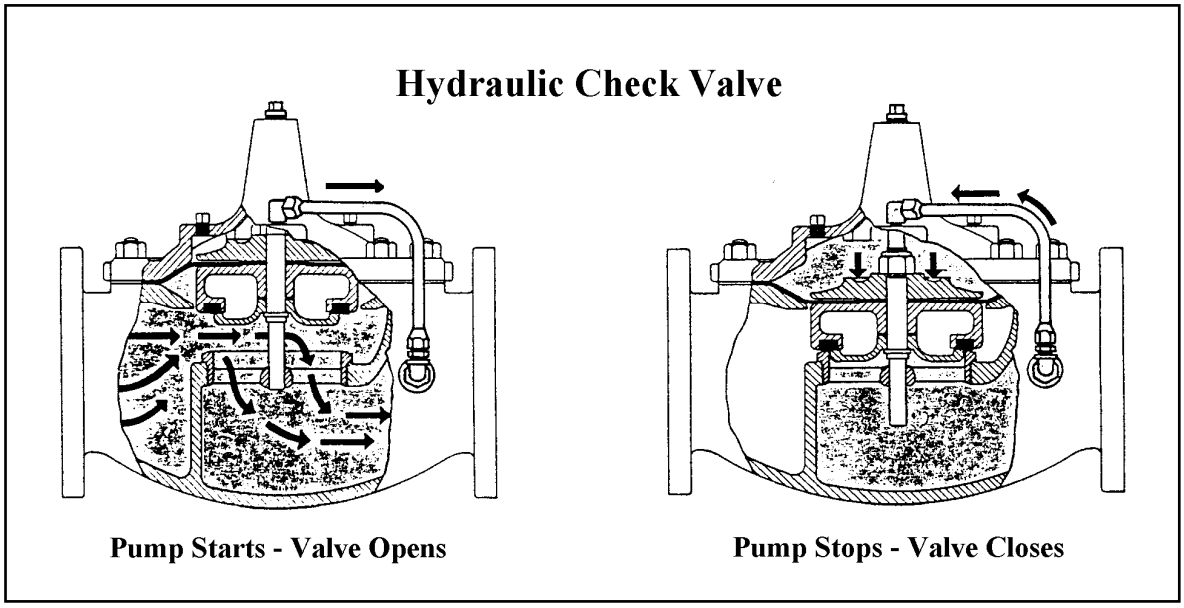
In distribution systems, situations develop that require control of pressures or flows in certain areas of the system. In low areas pressures may exceed the pressure ratings of the piping, requiring pressure reduction and pressure relief. Storage tanks must be isolated when they are full to prevent overflow of tanks at lower elevations. Flows must be limited in some areas so that pressures can be sustained in other areas. Pump flows must be gradually introduced into transmission lines to avoid pressure surges and water hammer that can damage piping. Control valves are used to deal with all of these situations.

Control valves are one of the least understood components of a water system. They are designed to control the flow of water by reacting to changes in the system and automatically opening or closing the valve to compensate. They are globe valves. They share the same basic design as a hose bib valve. The difference is these valves are hydraulically operated, diaphragm actuated, globe valves. The type of pilot or control mechanism that is placed on the valve determines the specific use of a control valve. A control valve can be used as a pump control valve, a pressure reducing valve, a pressure relief valve, a pressure sustaining valve, an altitude valve, or a check valve.



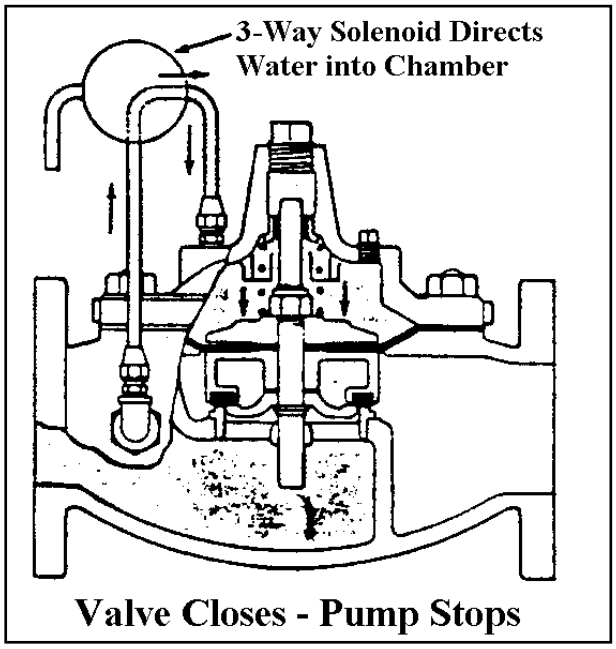
HYDRAULIC CHECK/PUMP CONTROL VALVES

The hydraulic check valve is the simplest form of control valve. It is unique because it is the only application that requires the valve to be turned around backwards so that the flow is over-and-under instead of under-and over the main valve seat. The control piping is simply a line from the downstream side of the valve. When the pump starts, the higher inlet pressure pushes water out of the control chamber. This opens the valve. When the pump stops, the higher outlet pressure closes the valve by putting water in the control chamber.



Pump control valves are found on large high-pressure booster pumps. They act as check valves and provide surge protection for the system. A booster pump that moves several hundred gallons a minute to a storage tank can cause severe pressure surges (water hammer) in the distribution system. The water in the main is coming toward the pump from the tank before the pump starts. The pump will reach its rated flow in about 2 seconds. If that flow hits the flow coming down from the tank at full force it can easily develop enough energy to burst the pipe.

A pump control valve is shut when the pump starts and opens slowly to gradually introduce the flow into the line over 30-90 seconds. When the pump is turned "Off", the control valve closes slowly and the pump stops after the valve is closed. A 3-way solenoid valve is used to operate a single chamber pump control valve.



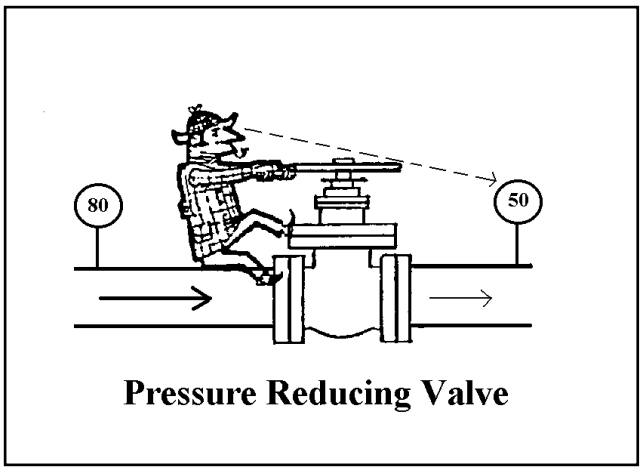
Single Chamber Pump Control Valve w/3-Way Solenoid

When the pump starts the solenoid directs water from the control chamber to drain and the valve opens. Before the pump is stops, the system pressure is applied to control chamber to close the valve. Flow controlling needle valves are installed on the vent and fill lines to adjust the opening and closing speeds of the valve. A drop check valve feature is available on many models. It allows the disc to slide down the shaft and close the valve like a normal check valve. This closes the valve quickly if a power failure shuts the pump down first.

AUTOMATIC CONTROL VALVE APPLICATIONS

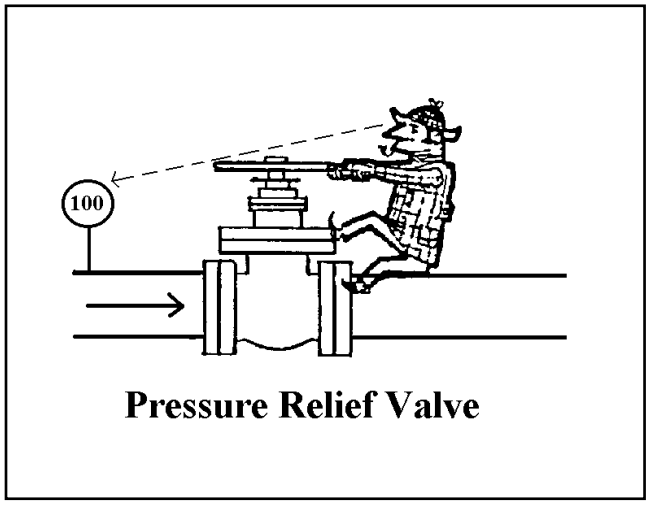
Other common applications for control valves in water systems involve adjusting valve positions based on changing conditions in the system. A pilot control is mounted on the main valve and is used to reduce pressures, relieve pressures, sustain upstream pressures, or prevent overflow of storage tanks. The pilot control will direct water into and out of the control chamber to open and close the main valve. The control pressure or setpoint is maintained as the main valve position modulates. The setpoint can be adjusted to tune the valve to specific conditions for a particular part of the system

In order to understand the principles behind the operation of each type of valve, let's remove the hydraulic pilot control and hire a person to do the job of controlling the valve operation. We can call him "Pilot".

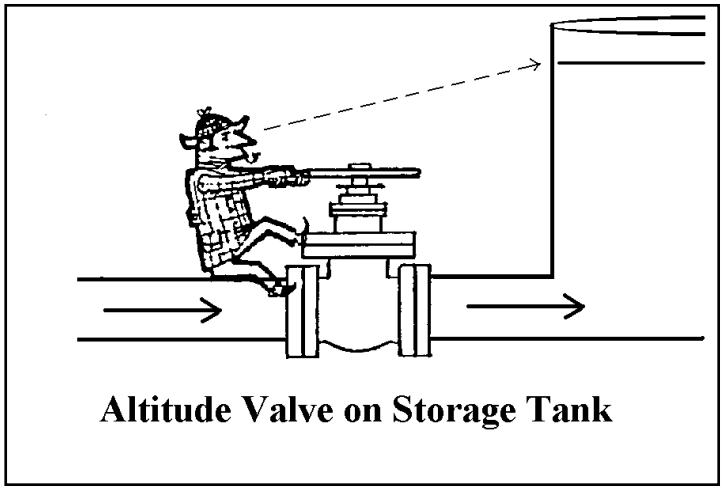


If pressure reduction is needed, Pilot will have to keep an eye on the downstream pressure gauge. His job, in this case, is to keep the downstream pressure at 50 psi. If the pressure is 50 psi, he doesn't have to do anything. The upstream pressure is 80 psi and the main valve stays in some partly closed position to create about 30 psi of pressure drop across the valve. If the downstream pressure drops below 50 psi, he will need to open the valve until it rises back up to setpoint. If the pressure goes up, he'll close the main valve until it drops back down.

Large PRV stations may use two valves in parallel. A large valve to handle high flows during the day and a smaller valve to handle the lower flow at night. The smaller valve must always have a higher setpoint. This will keep the large valve closed during low flow periods.

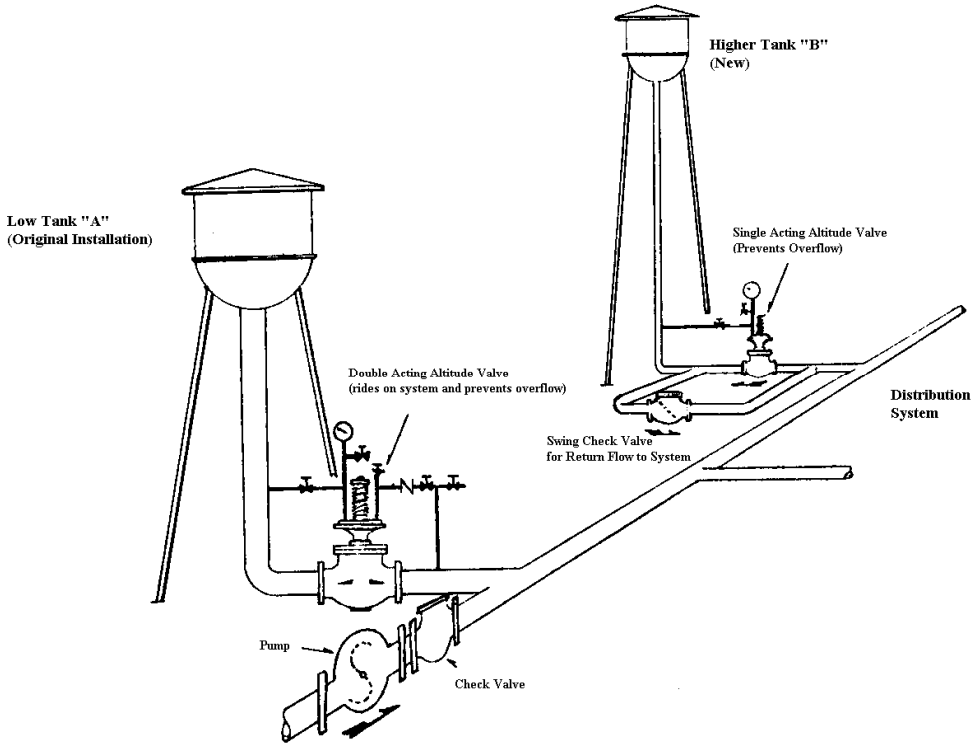


When we need pressure relief, Pilot will need to keep an eye on the upstream pressure gauge. As long as the upstream pressure is below the 100 psi setpoint, he will make sure the valve is closed. When the pressure gets above 100 psi, he'll have to open the valve just enough to drop it back down to 100. When the pressure drops below 100 psi again, he'll close the valve completely.



Altitude Valve on Storage Tank

An altitude valve prevents a storage tank from overflowing. Pilot will need to pay attention to the water level in the tank. As long as the level is below the setpoint level he'll keep the valve open. When the tank is full he'll close the valve.



WATER LINE INSTALLATION AND REPAIR

Many water operators are not directly involved in the installation of water system piping. A knowledge of the proper procedures for correctly and safely installing water lines is important because operators may be responsible for the inspection of a contractor's work or making repairs on existing lines.

HANDLING PIPE

Water piping should always be handled with care. Although it is inspected before it leaves the factory, damage can occur during shipment. Always check all pipe materials, gaskets and fittings before accepting a shipment of pipe. Piping should be unloaded in the area where it is to be installed. It is usually placed along the side of the trench. It should never be moved using a backhoe bucket or blade. Proper rigging and slings are needed to safely move heavy iron or concrete cylinder pipe sections. Store all gaskets and fittings in an area where they will not become damaged or contaminated.

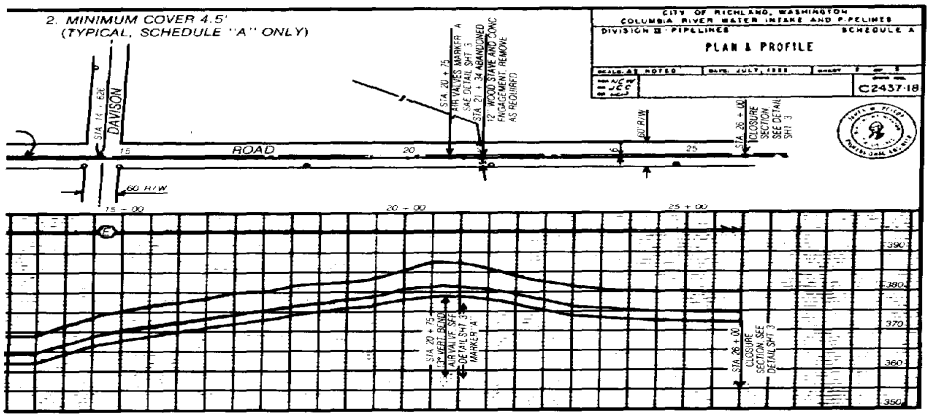
EXCAVATIONS AND UTILITY LOCATION

It is important to remember that the water line is not the only utility located in or near the street. The statewide "Blue Stake" number should be called to get the other utilities spotted before the trenching operations begin. Failure to request line spots for other utilities will make the system responsible for any loss of service or product and the cost of repair if they are hit.

The two most common types of line location devices are metal detectors and radio transmitters. Metal detectors work well for locating brass or cast iron valves and ductile iron or steel pipe. PVC and A-C pipe pose a problem because they aren't metallic. A metallic tape can be laid above the pipe (but no more than 6-12 inches below the surface) to allow line location with a metal detector.

Line locators that use radio frequencies to locate pipes consist of a transmitter and receiver. The transmitter is connected to a valve stem on the line. It sends a signal down the metal pipe, which acts like an antenna, and the receiver picks up the signal and identifies its strength to locate the line. PVC and AC pipes will not transmit the radio signal because they are non-metallic.

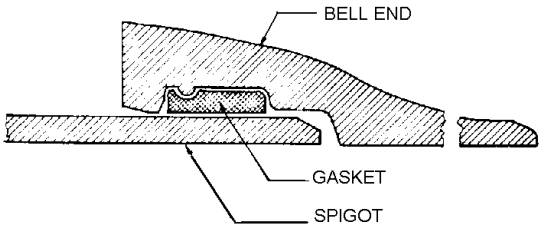
If radio locators are going to be used for PVC and A-C pipe, a copper wire is attached to a brass or cast iron isolation valve and run along the pipe to the next valve. This is done when the pipe is installed so that the radio signal can travel through the copper wire. If the wire is cut during a repair, it must be repaired or the signal will not travel past the break. The installation of metallic tape or copper wire is something that must be specified in the installation bid process.



Excavations for water lines must be dug to grade. The depth of the line may vary with changes in surface contours. The line must be laid deep enough to protect the pipe from trench loading pressure and freezing in the winter. Plan and profile maps are used to determine the correct location and depth of the main. A plan view is a view from above. It is used to determine the location of the line and valves or hydrants attached to the line. A profile view is a side view showing the soil contours and depth of the line.

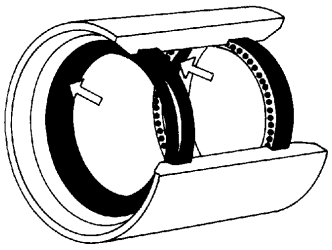
WATER LINE CONNECTIONS

Water line piping can be joined several ways. The most common method of joining pipe sections is the bell and spigot connection. The bell end of the pipe has a rubber compression gasket that the straight, or spigot end, slides into to create a watertight seal.

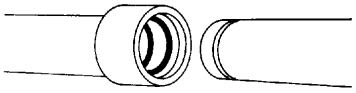


Bell and Spigot Connection

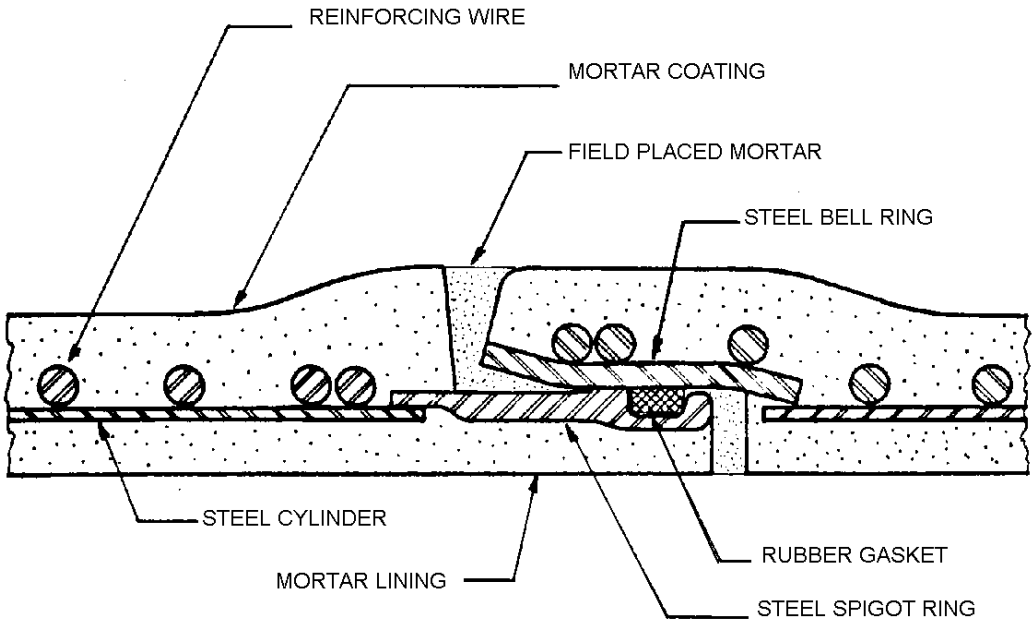
Asbestos-cement pipe is joined using a barrel coupling with gaskets for each pipe end. The ends of the pipe sections must be beveled to prevent the gasket from rolling as it is inserted. Lubrication of the gasket and pipe ends with grease is also necessary to reduce friction.



Barrel Coupling Connection

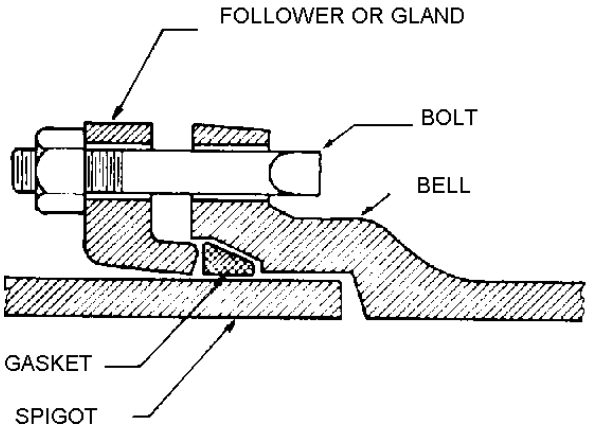


Concrete cylinder pipe is normally joined using a bell and spigot connection or a mortise and tenon connection. The joints are usually sealed with mortar in the field.



Mortise and Tenon Connection

These types of joints required pushing the two pipe sections together. Small diameter PVC pipe can be pushed with a wrecking bar, but larger diameter pipes are usually joined with a hydraulic ram or a backhoe bucket. A block of wood should be placed between the pushing tool and the pipe to protect it from damage.

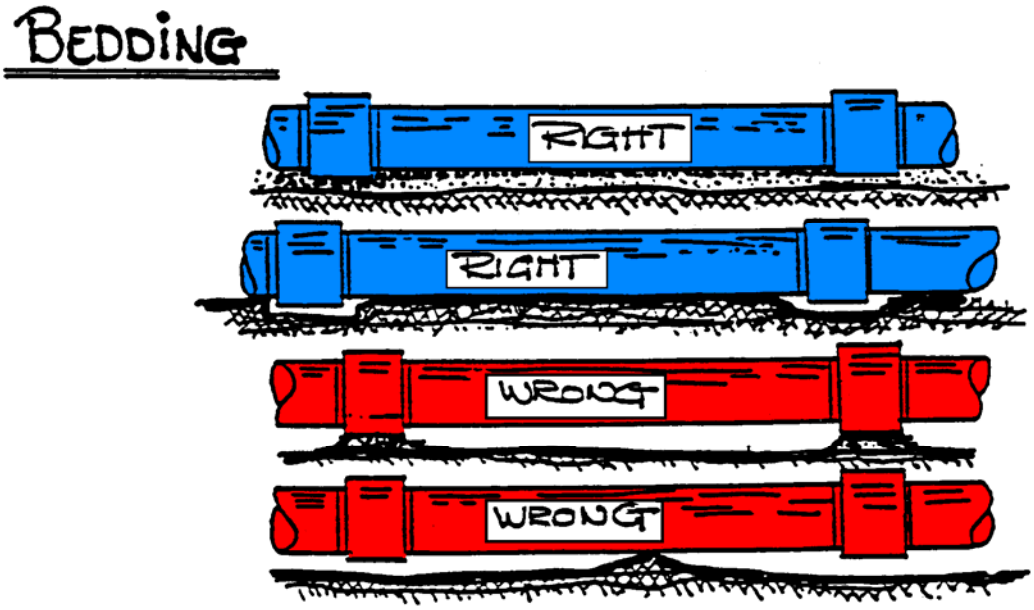


Ductile iron pipe may also be connected using flanges or mechanical joint flanges. Mechanical joint flanges are used to create a flange-type fitting when one pipe end is straight. They are used to connect valves or hydrants to a straight end of pipe.

Mechanical Joint Connection

BEDDING WATER LINES

Bedding material is used to support and protect the pipe from trench loads and pressure points. Bedding material should be free of large or sharp racks. Sand is an excellent bedding material because it compacts around the pipe well and provides excellent support. If bedding materials are not used beneath the new piping, the trench floor must be prepped to support the piping properly. The floor of the trench must be level and free of any protruding rock. Indentations must be dug under the bell ends so that they do not act as the support for the section of pipe. Improper bedding will result in leaks from lateral cracks in the pipe. Cracks must be cut out and spliced with new pipe. Repair clamps will not hold a leak caused by a lateral crack.



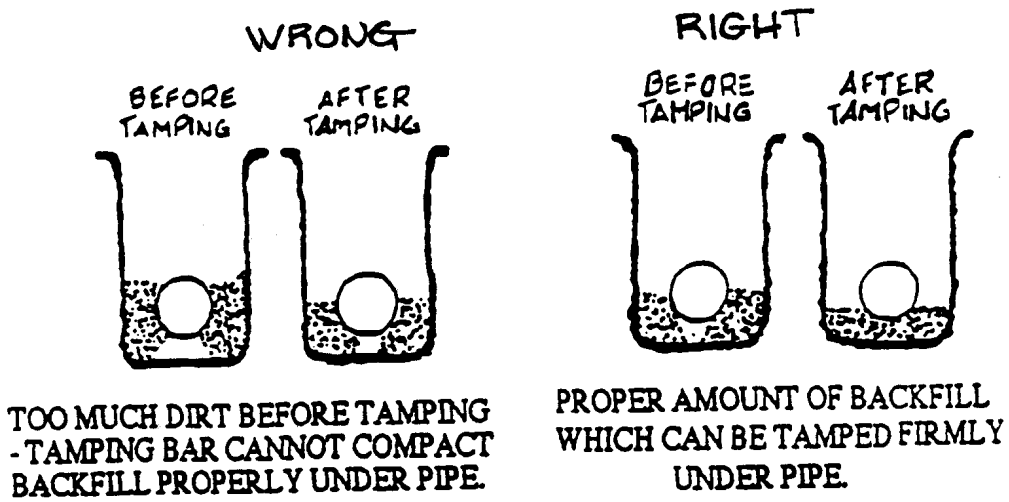
Improper Bedding Caused This Cracked Bell Joint

SEPARATION OF WATER AND SEWER LINES

When installing new water lines certain precautions must be taken when crossing or laying parallel to sewage lines. To prevent cross-connections or contamination of the drinking water, the water line should be separated by at least 10 feet horizontally when the lines are side by side. If the water line crossed a sewage line, the water line must be on top. A vertical distance of at least 18 inches must also separate the lines. If the sewer line crosses over the water line it must have a 20-foot water-tight casing around it extending 10 feet from either side of the water line

BACKFILL CONSIDERATIONS

The type of backfill material used is also a very important factor in the protection of all pipes, especially plastic pipe. If rocks or other abrasive material are present in the backfill, a sharp edge may cut into the line and cause a leak to develop. To prevent this kind of damage from happening a select backfill material, preferably sand, should be used. The backfill should be carefully added and properly tamped to help support trench loads. The backfill material should completely surround the pipe. It should be tamped when the pipe is still half exposed and again when the pipe is covered by about 6 inches of material. After the pipe is covered, backfill should be done in 12-18" lifts or layers that are tamped. If the trench is filled completely before it is tamped, settling will occur. This will result in failure of the paving patch and possible damage to the water line.



Plastic pipe should not be used under railroad crossings, highways, or anywhere that vibration and stress loads are a problem. These situations call for iron or steel pipe that can withstand these external pressures. If a plastic line is used, the PVC pipe should be installed in a steel conduit. Even if the reinforced PVC is used, a conduit is worth its cost. In addition to this, a conduit will make it much easier to replace the damaged water main. Keep PVC water lines as far as possible from highway right of ways. All easements to both highways and private property must include access for construction, repair and inspection.

REPAIRING LEAKS

Once a leak has been located it is a good public relations practice to inform residents in that area that service may be interrupted while the repair is being made. All businesses in the area should also be notified so that equipment that might be damaged by the loss of water service can be shut down. This may take a little extra time but may also save a lot of unnecessary hard feelings between customers and the water system. The following steps should be taken for line repairs:

1. Assemble the proper equipment and notify the customers of the interruption. If the work is going to happen at some time in the future, notification should happen at least 24-48 hours in advance.

2. Isolate the break by shutting all gate valves necessary to stop the flow of water. Tag each valve according to OSHA LOTO guidelines. Identify all closed valves on a map.

3. Mark the line using a line locator or probe. Line spots should also be called in for other utilities before attempting to excavate the leaks. These include the gas service, phone service, cable TV, sewer lines or electrical cable.

4. If the excavation is going to be over 5 feet deep, make sure that the proper shoring equipment is available or that enough of the street has been closed to adequately slope the trench according to OSHA guidelines. The area around the leak should be large enough to work comfortably, usually one foot on either side of the pipe. A sump hole is dug at one end of the trench to allow the water to flow away from the leak and be pumped or dipped out.

5. The type of repair clamp or coupling is selected once the line has been uncovered. A steel wrap-around repair clamp can be used if leak is a hole from a blown service or puncture. Lines that developed cracks along the length of a pipe should be cut out and a new section spliced in with compression couplings. Once the damaged section has been removed it is a good idea to flush the lines out to remove any foreign matter that may have been sucked into the line. Compression couplings are used to reconnect the new section of pipe to the existing line. If pipe with different OD’s are connected a transition coupling should used.

6. Refill the line by carefully cracking a valve low end of the line and opening a hydrant or service to vent air out as it fills. Air relief valves can also be used as vents if they are present on that particular section of pipe. The velocity of the water in the line should be kept below 1 fps and should always be controlled from the fill valve rather than the vent valve. If allowed to fill to quickly, water hammer can occur when the water finally fills the pipe. Check to make sure the repair is not leaking.

7. Backfilling the excavation should be done by hand at first preferably with sand or gravel. This should be tamped carefully to avoid damaging the clamps and couplings. Prior to putting the line back in service, it should be disinfected and have BAC-T samples taken. Reopen all gate valves that were closed.

DISINFECTION OF WATER LINES

Newly laid water lines or lines that have been repaired should be disinfected before they are put into service. This procedure is standard for all water system components including wells and reservoirs. There are four steps that should be taken to insure that the line has been properly disinfected. If a repair is done under low-pressure conditions it will already be full. But if the line has been opened it must be filled prior to flushing.

1. Flush the line. This will remove any dirt or debris that may be in the line. A minimum velocity of 2.5 feet per second is required. Flushing should continue until an amount of water equal to twice the pipe volume has been discharged. A Notice of Intent (NOI) protocol must be followed anytime there is a discharge of flushing water or dechlorinated water from the line.

2. Disinfect the line. Enough chlorine should be added to create a dosage of 50 mg/L with a residual of 5 mg/L after 24 hours. In some instances a higher chlorine dosage can be used and the contact time can then be reduced. If the dosage is 200 mg/L, the contact time is only 2 hours.

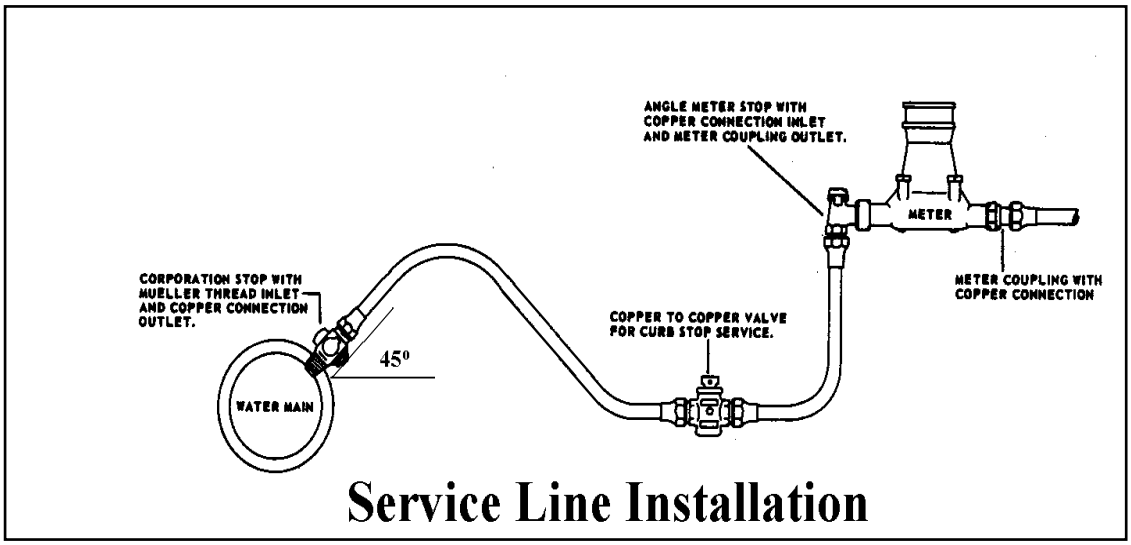
   The chlorine should be added at the same point that the water is introduced back into the line. A solution of HTH or bleach is normally fed through a corporation stop or a tee in the fill hose using a solution pump as the line is slowly filled. Dry HTH should not be put directly into the line or it will be washed to the far end before it dissolves.

3. Flush the line again. The water that is discharged must be dechlorinated. This should be done long enough to remove all of the chlorinated water so that Bac-T samples can be taken.

4. After the line is flushed and the free chlorine residual is below 2.0 mg/l, collect a BAC-T sample from the line. If negative results come back, the line is ready to be put into service.

SERVICE LINES

Services connect the customer to the main in the street. Services are installed using a tapping machine to drill and connect a corporation stop to the main. The tap is normally done while the main is under pressure. This is called a "wet" tap or "hot" tap. Taps can either be made by inserting the corp stop directly into the main or the corp stop can be installed on a saddle that's strapped to the pipe. The corp stop will only operate one time. It is closed until the service line has been installed. It will stay open once the service installation is completed. Taps should be made at a 45^{o} angle from horizontal so that they are less likely to be pulled by a backhoe. The bend in the service line allows the service line to flex when the pipe moves in the trench. Without it, the corp stop could be pulled out of the pipe.



The service line is usually copper, PVC or polyethylene pipe. Galvanized and lead services should be replaced, since the former is prone to corrosion and the latter can cause lead-related health problems if the water is corrosive. The service line should have a bend or goose neck in it at the corp stop. This will allow the service to flex slightly if the trench or piping shifts after backfill.

Sometimes a curb stop is installed in the easement so that the service can be isolated. A meter stop on the yoke can also be used instead of a curb stop. A service line leak may require killing the main or using a crimping tool to isolate for maintenance when a meter stop is used. Service lines and meters must be laid below the frost line for the area or freezing will become a problem in the winter.

WATER METERS

The meter is the primary piece of equipment in a water system that has a direct bearing on income. It is the cash register for the system. Many small systems do not have meters. Billing is based primarily on the size of the service and is a fixed rate. Water meters encourage conservation and distribute the cost of service in proportion to its use. Even though they are critical to maintaining the cash flow for a system, meters tend to be neglected more than any other piece of water equipment. An inaccurate meter cheats the water system and also all the customers whose meters are accurate.

When a meter becomes worn or broken it always under registers and will give water away to the customer. This is not a good point to impress upon a customer who is sure he or she is being charged for too much water. Instead check the meter readings for the last month. It may be that an error has been made in reading the meter. This can be corrected by a credit on the next month's bill and re-reading the meter to make sure the billing is accurate

If this does not correct the situation go out to see the customer and take a 5-gallon bucket and a new meter with you. When you get there have the customer turn off all water using appliances in his or her home and then read the meter. Fill the bucket up twice and then re-read the meter. If the meter reads 10 gallons it is indeed accurate. If the reading is less than 10 gallons the meter is worn and should be replaced. At this point the customer may wish he had not called.

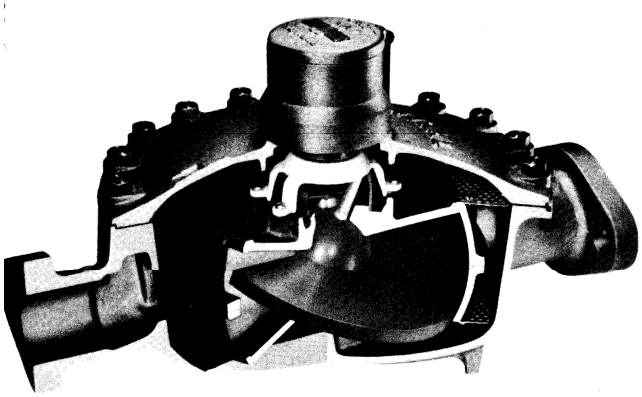
If the meter reading is over 10 gallons then there is a substantial leak in the customer's plumbing. This can be confirmed by re-checking the reading as the customer watches and then explain the situation to them. By the time this is done, enough water should have leaked out to make the meter reading change, which identifies the problem as a leak and not the meter.

Meters should be maintained and tested to insure that they are accurate. A meter that has worn out will under register and rob the system of revenues. Meters should be tested every 5-10 years, or anytime a customer has a complaint regarding the meter. Residential meters should have an accuracy of between 98.5 – 101.5% or 100% +/- 1.5%. Larger meters can have a wider accuracy range, but normally not more than +/- 4%.

POSITIVE DISPLACEMENT METERS

The positive displacement meter is the most common meter used in a water system. It is the meter used for residences and commercial services up to 2 inches. The most common types of positive displacement meter are the nutating disk and oscillating piston meters. Small multi-jet or turbine meters can also be used in these applications.

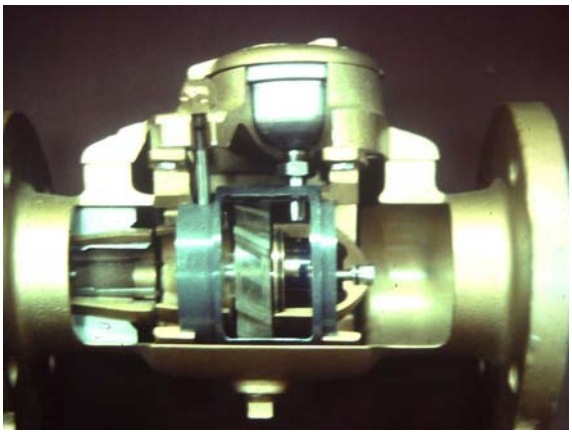
The positive displacement meter contains a measuring chamber with a fitted disc or piston. Each time the chamber fills and empties, a predetermined amount of water is displaced as the disc or piston makes one rotation. The action of the nutating disc or the piston is transferred to the meter head by the use of gears or magnetic drives.



Nutating Disk Meter

TURBINE METERS

This meter is designed so that water flowing through the meter chamber spins a close tolerance turbine or rotor. As the velocity of the water increases the speed of the rotor/propeller/turbine increases. The motion is transferred through a shaft to the meter register. In the past turbine meters were used only for high flows, like fire lines, and were considered to be inaccurate at low flows. Small rotor-type meters are called multi-jet meters. These meters have been improved over recent years and are now available in sizes 5/8 of an inch and up. These are very dependable meters and have relatively low loss of head

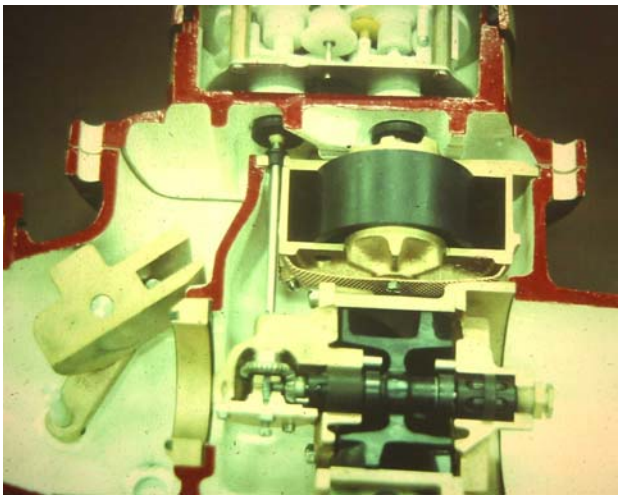


TURBINE METER

FIRE LINE INSTALLATION

COMPOUND METERS

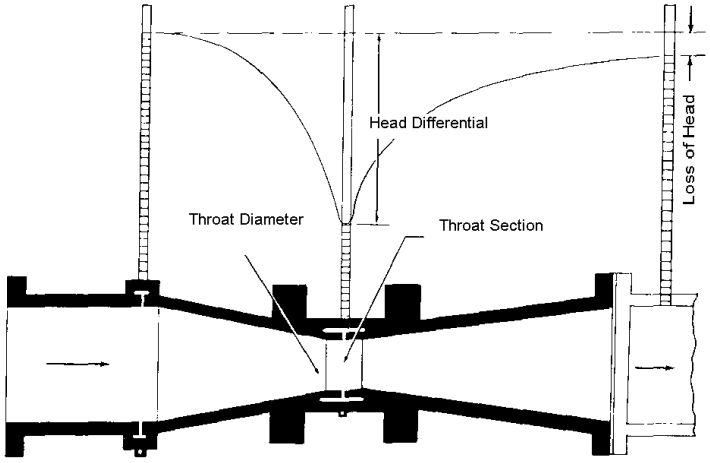
A compound meter has two metering devices in the same housing. One is a positive displacement meter that will measure low flows. The other is a turbine meter to measure high flows. They are used on large service installations where very high and very low flows are anticipated. Compound meters are very expensive and difficult to maintain. Most systems are now able to install the newer turbine meters instead.



Compound Meter

VENTURI METERS

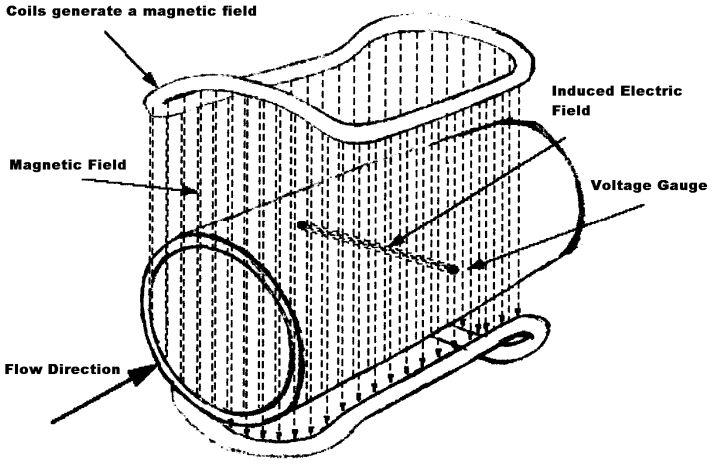
Venturi meters are used to measure high flows such as the intake from rivers or lakes and the discharge from wells. This type of meter resembles an hourglass. The pipe diameter is reduced to a narrow neck and then flared out to the original diameter again. A pressure drop occurs as the water flows through the restriction. The drop in pressure can then be converted into a flow rate. Venturi meters are very dependable and with reasonable care will work for many years without adjustment.



Venturi Meter

MAGNETIC FLOW METERS

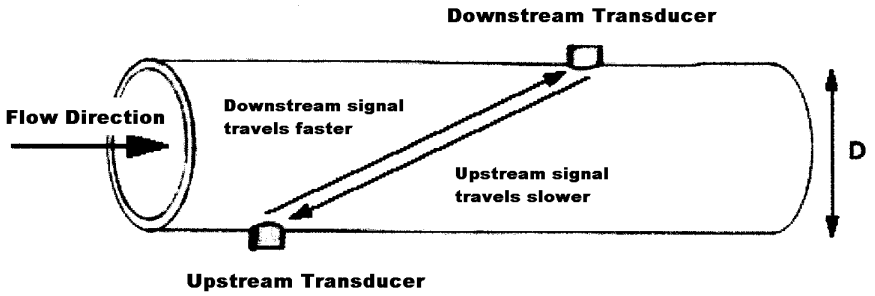
Magnetic flow meters, like venturi meters, have no moving parts. A set of coils generates a magnetic field around the pipe. As water passes through the magnetic field, an electric field is induced in the water. This is the same thing that happens in an electric generator. A voltage gauge is used to read the induced voltage and that value is then converted into a flow reading.



Magnetic Flow Meter

ULTRASONIC FLOW METERS

An ultrasonic flow meter consists of two transducers and a signal transmitter. One of the transducers is located upstream and the other downstream on the pipe. The upstream transducer sends a signal to the downstream transducer and the downstream unit sends a signal to the upstream transducer. When water is flowing in the pipe, the signal that travels downstream will move faster than the signal travels upstream. The difference in this "transit time" is used to determine the flow rate.



Ultrasonic Flow Meter

DISTRIBUTION SYSTEM HYDRAULICS

There are a number of issues related the dynamics of moving water through a distribution system. The pressures in the system are determined by how high water is stacked in the air when conditions are static. But when water begins to move through the system hydraulic factors can affect pressures, flow, and forces exerted against the piping.

FRICTION LOSS

When water flows through a pipe a certain amount of energy must be expended to overcome the friction between the water and the surface of the pipe. The determination of the friction loss in a water line is dependent on four factors:

FRICTION LOSS FACTORS

- Pipe length
- Pipe diameter
- Flow through the pipe
- Coefficient of friction -"C" factor

A certain amount of friction loss results from any flow through any size or type of pipe, and this loss must be overcome, usually by increasing the pumping pressure, in order to maintain a given flow through the pipe. As metal lines get older their inner surfaces get rougher and the "C" Factor increases.

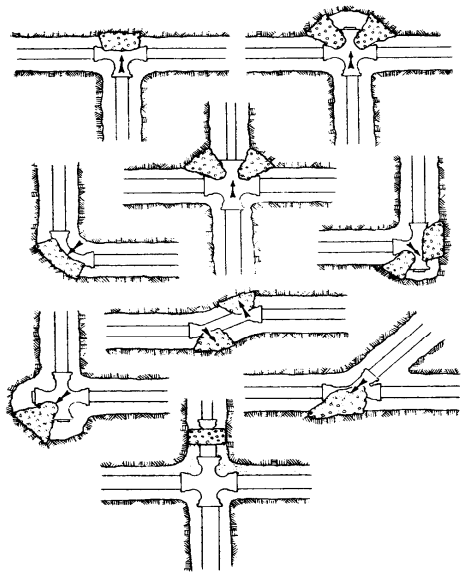
WATER HAMMER

When water, that is moving through a water line, is suddenly stopped a pressure surge will be created in the line. This occurrence is known as a "water hammer." The faster the water movement is stopped the greater pressure surge, or water hammer, will be. Water hammer can create a pressure surge up to 120 psi greater than the system pressure. Severe water hammer can cause ruptured lines and even lift water hydrants out of the ground. Once water hammer has been created it will travel down the line at a speed of about 760 mph.

To minimize the effect of water hammer all valves and hydrants in the system must be opened and closed slowly. Hydraulically operated check valves known as pump control valves also help to protect the pump and reduce water hammer. Thrust blocks should be used on all bends and fittings on water mains.

THRUST AT PIPE BENDS

Wherever a bend, elbow, tee, or dead-end exists in a pipeline having flexible joints, a force is exerted which tends to open the joints nearest the fittings. The magnitude of this force varies with the amount of bend, the diameter of pipe, and the pressure inside the pipe. When determining the resultant thrust for a given pipe it is advisable to use the maximum working pressure anticipated in the pipe plus an allowance for surges or water hammer.

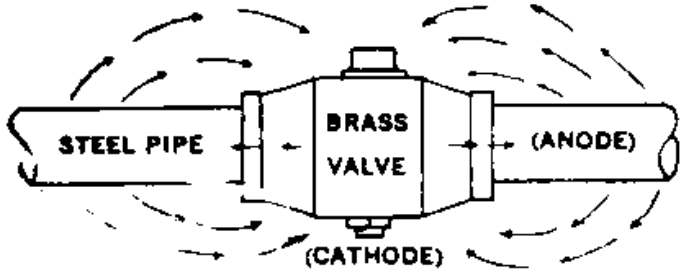


NOTE:
1. The location of thrust blocks depends on the direction of thrust and type of fitting as shown above.
2. Thrust blocks are not required if the ends of pipe are held tightly by mechancial anchorage such as a weld.

Once the resultant thrust has been determined for a particular bend, it becomes necessary to provide a backing block of such size to resist the thrust. The thrust must ultimately be borne by the side of the pipe trench and the surrounding soil. The purpose of the backing block is to spread the thrust over an area sufficiently large that the undisturbed earth can support it. The supporting strength of most solid clay soils should vary between 1,500 and 4,000 pounds per square foot. Sandy soils may not support 1000 pounds per square foot.

GALVANIC CORROSION

Whenever two dissimilar metals come in contact and are submerged in water, an electric current is generated. This type of reaction occurs in most storage batteries. It also occurs in a water system where different kinds of metal components are used, such as meter installations and service connections and couplings.



Galvanic Corrosion

When these conditions exist, the electric current that is generated will pass from one metal surface to the other. Metal from one side of the connection will be plated onto the other side. This will eventually cause a piping failure as the threads of one side are plated on the other.

ELECTROLYSIS

When D.C. electric current enters a metal pipe, it runs down the pipe and, at some point, discharges into the ground. The passage of this current from the pipe into the ground will cause metal in the pipe to be plated into the surrounding soil. This type of corrosion is known as electrolysis.

Any D.C. current from machinery or telemetry equipment that is grounded to water piping will cause electrolysis. However, A.C. current, such as household current, can be grounded to water lines without causing electrolysis, since alternating current will not plate the metal into the soil. The use of plastic pipe will eliminate electrolysis problems since plastic is a non-conductor.

CORROSIVE SOIL

Metal pipe that is laid in highly acid soils may also encounter serious corrosion problems from the outside as well as the inside. If cast iron or ductile iron pipe is to be laid in corrosive soil it should be coated with tar or other protective plastic coating to prevent it from being damaged.

CROSS CONNECTIONS

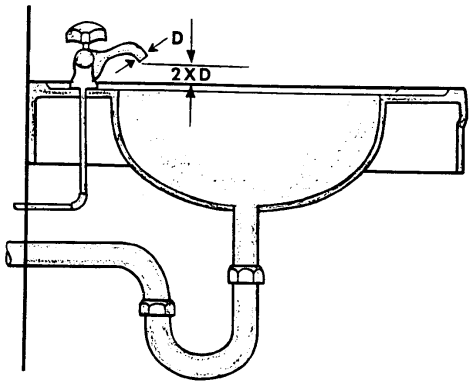
Any time a potable water supply comes in contact with water of questionable, unknown quality, a serious problem is created. This problem is known as a cross connection. Cross connections can be created by many situations. A rural customer, who connects to a water system without disconnecting his old well, can create a cross connection. Water-using machinery (such as chemical feeders, air conditioners, washing machines, etc.) can be a possible source of a cross connection unless proper measures are taken to insure against it.

BACKFLOW AND BACKSIPHONAGE

Under normal working pressures most cross-connections are only caused when the water from the unknown source is at a higher pressure than the system operates. This would be the case where a customer uses a private well or booster pump. There may be times when the system pressure drops suddenly. This can be caused by a large break in the line or flushing lines or by fire trucks pumping out large amounts of water to fight a fire. This drop in pressure may cause a siphon to be created and can draw water out of chemical tanks, air conditioners, hot water heaters or any appliance with a submerged inlet that is not protected from this backsiphonage. Backsiphonage, or backflow, can be prevented by the use of an air gap, a vacuum breaker or a reduced pressure zone backflow preventer. Double check valves may only be used for equipment protection, or when the non-potable water presents a low hazard potential.

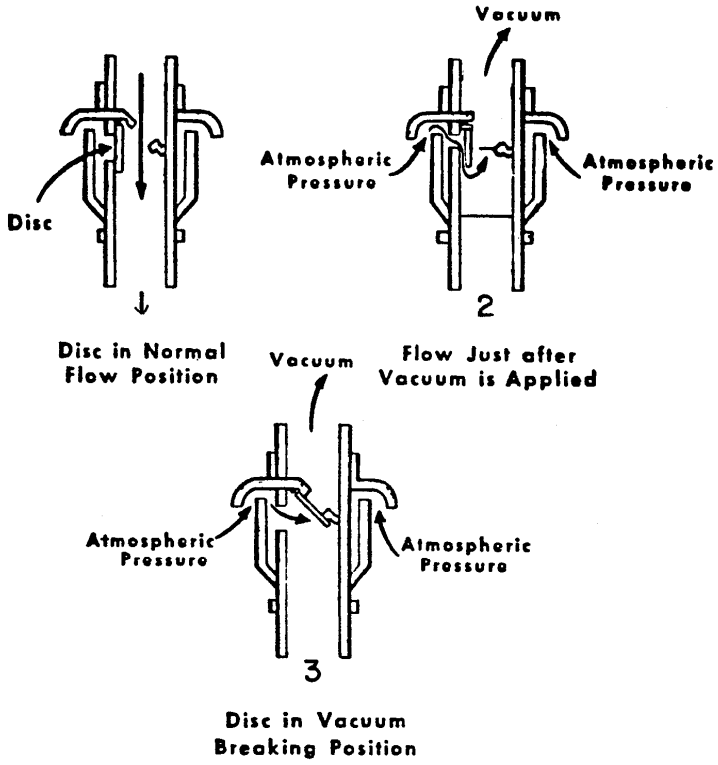
AIR GAP

An air gap is the simplest means of preventing backflow. The outlet of the potable water source is always kept above the water level of the unknown source. Since there is no physical connection between the two sources there can be no backflow into the potable system. The outlet should be kept a distance of at least two times its own diameter above the non-potable source. All storage tank drains must be separated from sewer lines by an air gap. An air gap must be 2 times the diameter of the pipe. A 1-inch pipe will need a 2-inch air gap.



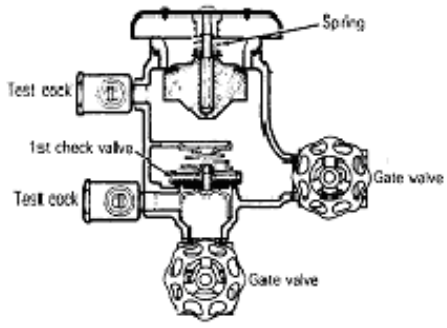
VACUUM BREAKERS

An atmospheric vacuum breaker is used when the outlet of the potable supply is submerged. When water flows in the proper direction the water pressure pushes against a disc that covers a hole in the side of the vacuum breaker. If the pressure in the line drops below atmospheric pressure, creating a vacuum, the air pressure outside pushes the disc back so that air can enter and break the vacuum.



Vacuum Breaker Operation

Pressure vacuum breakers are used when the piping downstream is under pressure. Irrigation systems use pressure vacuum breakers because the sprinklers heads create a pressurized condition downstream of the vacuum breaker. Vacuum breakers and reduced pressure zone backflow preventers should be installed in an accessible location 6–12 inches above the highest point in the system.

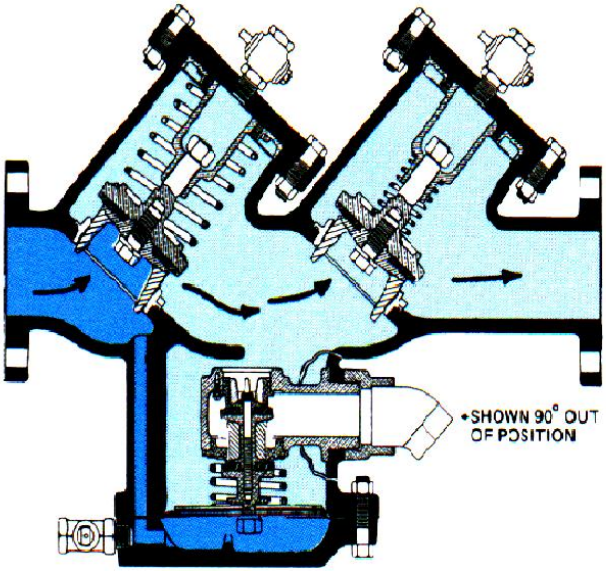


Pressure Vacuum Breaker

REDUCED PRESSURE ZONE BACKFLOW PREVENTER

When pressurized water can come from either direction a vacuum breaker may not provide adequate protection. In this situation, a reduced pressure zone backflow preventer can be used to protect the system from a cross-connection. As the water moves in the normal direction of flow the spring loaded check valves open to the flow. When the direction of flow is reversed the spring snaps valves 1 and 2 shut and the differential pressure opens to discharge the atmosphere. This creates an air gap inside the device.

Annual testing by certified backflow technicians is required for these types of devices. The installation must be 12-18 inches above ground, so that they can drain properly, and should be enclosed in a secured and insulated structure.

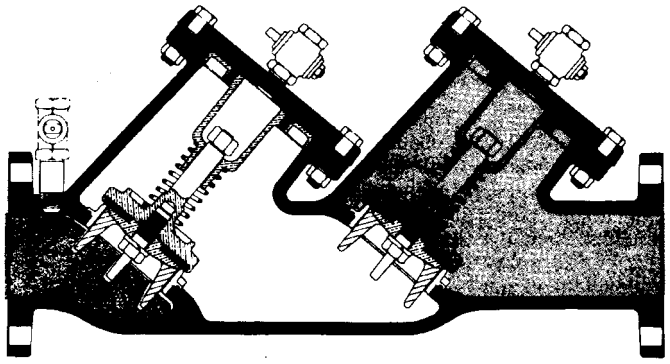


RPBP – Normal Operation

RPBP - Installation

DOUBLE CHECK VALVES

Double check valves can only be used in situations where no health risk is present. They are most commonly found on residential meter installations. They serve as a type of security firewall to prevent intentional contamination of the water supply.



Double Check Valve

BASIC STUDY QUESTIONS

1. What type of gate valve is used for underground applications?

2. Where are check valves used in a distribution system?

3. Which type of pipe is not affected by corrosive water?

4. What is the most common type of residential meter?

5. What type of valve is a corporation stop?

6. What are the two types of fire hydrants?

7. What should be done before you excavate to make a repair?

8. What causes galvanic corrosion?

9. What is a cross connection?

BASIC SAMPLE TEST QUESTIONS

1. In order to get the right size repair clamp, you must know the:

   A. Schedule
   B. Type of pipe
   C. Outside diameter
   D. All of the above

2. What criteria are used to determine the amount of storage required for a water system?

   A. Daily temperatures
   B. Annual rainfall
   C. Daily peak demand
   D. System pressures

3. Which valve should be used to throttle flows?

   A. Gate valve
   B. Check valve
   C. Air release valve
   D. Butterfly valve

4. Always operate a dry barrel hydrant with the valve fully open.

   A. True
   B. False

5. The most common type of valve in a distribution system is:

   A. Gate valve
   B. Plug or ball valve
   C. Check Valve
   D. Control Valve

6. For fire protection, a hydrant should be placed on lines that are at least:

   A. 4 inches in diameter
   B. 6 inches in diameter
   C. 8 inches in diameter

7. Which type of valve is best suited for throttling flows?

   A. Gate Valve
   B. Butterfly Valve
   C. Check Valve
   D. Air relief Valve

8. When a meter gets worn it will always over register and record water that wasn't used.

   A. True
   B. False

ADVANCED STUDY QUESTIONS

1. How is a compound meter different from other meters?

2. What is the procedure for disinfecting water lines?

3. Why should you never throttle the flow using the hydrant valve on a dry-barrel hydrant?

5. What is tuberculation?

6. Where are thrust blocks located?

7. What is an "OD" tape used for?

8. Which type of distribution system creates more stale water issues?

9. What is a "plan view" refer to?

10. Where would an altitude valve be found in a distribution system?

ADVANCED SAMPLE TEST QUESTIONS

1. The best way to protect the water supply from contamination by cross-connection is:

   A. A double check valve
   B. A vacuum breaker
   C. An air gap
   D. A reduced pressure zone device

3. A flow meter on a fire line would probably be a:

   A. Venturi meter
   B. Nutating disk meter
   C. Oscillating piston meter
   D. Compound meter

4. When filling a main, the water velocity should never exceed:

   A. 1 ft/sec
   B. 2.5 ft/sec
   C. 10 ft/sec
   D. 20 ft/sec

5. Which type of repair device should be used when pipe sections must be spliced?

   A. Steel repair clamp
   B. Gate valve
   C. Compression coupling
   D. Radiator hose clamp

6. If two pipe that have a different OD can be joined using a:

   A. Steel repair clamp
   B. Transition coupling
   C. Mechanical joint
   D. Bell and spigot connection

7. When flushing a main, the water velocity should be at least:

   A. 1 ft/sec
   B. 2.5 ft/sec
   C. 10 ft/sec
   D. 20 ft/sec

8. If you must throttle the flow from a hydrant:

   A. Just throttle the hydrant valve
   B. Attach a secondary gate valve to the hydrant nozzle
   C. Use a diffuser
   D. Never throttle hydrant flows

9. Which view is the side view of a map?

   A. Plan view
   B. Profile view
   C. Sector view
   D. GIS view

10. Which meter works by creating an induced electric field?

   A. Compound meter
   E. Turbine meter
   F. Magnetic meter
   G. Ultrasonic meter