After the water treatment facility sterilizes and distributes the water, it is still subject to contamination. Water contamination typically occurs through cross-connections and backflow situations. Plumbers must be able to recognize, prevent and fix backflow emergencies. This lesson is concerned with backflow preventions.

Numerous cases of illness due to cross-connections have been documented. The problem is never solved since plumbing is continually changing. It is installed, repaired, removed, changed and extended. Sometimes, untrained people perform the plumbing. Usually, backflows are caused by cross-connections that are affected by a repair, general maintenance, or due to emergency situations. Plumbers must be trained and certified to perform inspections and repairs.

CONTAMINATION

Unacceptable material can enter our water system in different ways. Sometimes, we are not even aware that our water has been polluted. Two things must happen before backflow and back-siphonage can occur, causing contamination. First, there must be a common link between the questionable water and the potable water. Next, the questionable water must be forced into the potable water supply.

When force is applied, motion is the reaction unless there is a resistance. Weight is a type of force. Weight is caused by the earth's gravitational pull. Force-per-unit of an area is a called pressure. Pounds per square inch (psi) is a pressure measurement. Atmospheric pressure is the weight of the atmosphere located above the earth.

Pounds per square inch absolute (psia) is pressure as an absolute scale. Pounds per square inch gauge (psig) is pressure of the gauge. This is gauge scale pressure. Atmospheric pressure is 14.7 psi at sea level. Absolute pressure is absolute pressure (the atmospheric pressure) plus the gauge pressure. Absolute pressure is the total pressure of the pressure in the pipe and the pressure the atmosphere has on the gauge pressure.

Absolute pressure = gauge pressure + 14.7 psi
Gauge pressure = Absolute pressure - 14.7 psi

Occasionally, the absolute pressure will drop below the atmospheric pressure. This happens if the gauge pressure has a negative value. When this occurs, a vacuum is the result. 0 psia or -14.7 psig is a total vacuum. The vacuum force is the factor causing contamination. If a vacuum is exerted on a pipe containing water, the water is literally sucked up the pipe. This sucking action is referred to as siphonic action. Siphonic action also can be caused by fluid level changes in a piping system.

WATER SUPPLY HAZARDS

Trained plumbers must be aware of the common water supply hazards.

- Cross-connections.
- Gravity backflow.
- Back-siphonage.
- Backpressure backflow.

CROSS-CONNECTIONS

A cross-connection occurs when two separate piping systems flow into each other. One piping system contains potable water while the other contains questionable water, gas, steam or chemicals. The direction of the flow depends on the pressure differential between the piping systems. Cross-connections can occur when untrained individuals design and install plumbing systems. Cross-connections can occur during maintenance or emergencies. Sometimes, cross-connections happen due to negligence. Cross-connections cause contamination to occur when the questionable substance is forced into the potable water system. Cross-connections can be limited to a building or may affect an entire city.

Two types of connections can be installed in a piping system. One is a solid pipe with a valved connection and the other is a submerged inlet. Solid connections are used with an auxiliary piping system and a potable system. The potable water has a direct connection to another pipe or a receptacle. A solid pipe connection is typically connected to a continuous or intermittent waste line and it is assumed that the flow is in one direction only. Condensers join potable water systems with waste water systems. Sewers can easily be subject to backpressure, so some type of backflow preventer is required.

Submerged inlets are located on common plumbing fixtures. However, design standards are trying to phase out submerged inlets whenever possible. Siphon-jet urinals have submerged inlets. Dental cuspidors and flushing rim slop or service sinks also have submerged inlets. Industrial and chemical vat's will often have submerged inlets using water pressure to help diffuse, disperse and agitate the vats substance. A back-siphonage can occur in these systems if a siphonic action is caused by a fluid level change. An extended hose or pipe submerged into the vat can also cause contamination.

GRAVITY BACKFLOW

A common water supply hazard occurs in the ground. Potable water distribution pipes are contaminated when an open or damaged pipe allows trench water to enter the purified water system. Typically, the questionable water is at a higher ground level than the potable water, causing gravity backflow.

BACK-SIPHONAGE BACKFLOW

Backflow is a reversal of the normal flow process when unintended water, liquids, mixtures, or other questionable substances are forced in the reverse direction and into the potable water distributions pipes, fixtures or other potable system. Back-siphonage is a type of backflow. Atmospheric pressure is the deciding factor in a back-siphonage situation. The potable water system somehow acquires a vacuum. The atmospheric pressure then forces the contamination into the clean system.

Back-siphonage occurs through a cross-connection. The water in the potable water system enters the vacuum range and siphonic action allows contaminated water to enter the potable water system. Vacuums occur when very large flows in street mains happen. Firemen use large amounts of water quickly as do associations filling swimming pools. Back-siphonage can be caused by a hose being left in a swimming pool, bucket, puddle, lake or other contaminated solution. Lawn sprinkler vacuums can cause lawn chemicals to disperse into the potable water system when the system pressure is shut off.

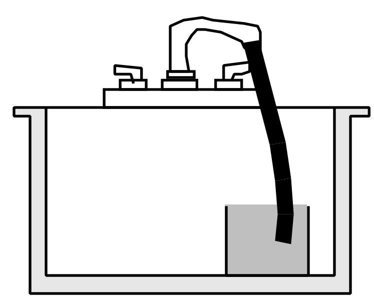

Figure 22-1 Backflow from Siphonage

Back-siphonage can happen when a larger pipe flows into a smaller pipe and back to a larger pipe. Refer to Figure 22-2. The liquid's velocity is increased and causes a negative pressure in the pipe. Aspirators can easily cause a back-siphonage situation to occur.

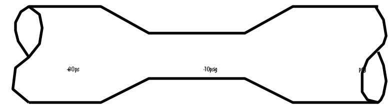

Figure 22-2 Constricted Flow

A city's water supply was contaminated one day by three gallons of chlordane. Chlordane is a highly toxic insecticide used by professional exterminators. The exterminator had a hose running from a residence into a large barrel of chlordane. At the same time, the water department was repairing a water main. A back-siphonage occurred during the water main repair and sucked the chlordane from the barrel, through the hose and into the potable water supply. No one was seriously injured during this emergency, but water was not available for hours while the lines where flushed.

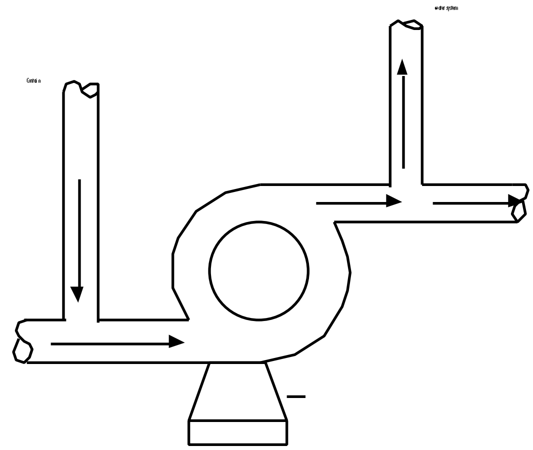

Figure 22-3 Pumps and Pressure

Pumps are another source for back-siphonage contaminations. Refer to Figure 22-3. Reduced pipe pressure occurs on the suction side of a pump. If a booster pump is undersized or does not provide sufficient pressure, a vacuum can occur. The pump intake can also cause pressure fluctuation. Flow can be increased by a reduction in pressure at the pump intake. The result is a negative pressure at the pump intake. The negative pressure can cause vaporization in the water line.

BACKPRESSURE BACKFLOW

Backpressure backflow is not caused by siphonic action like back-siphonage. Backpressure backflow occurs in potable water distribution systems through a cross-connection. The questionable pipe has a higher pressure than the potable water system which allows for contamination. Both the contaminated system and the potable system have pressures greater than the atmospheric pressure. Pressure differentials cause the contaminated material to be forced into the potable water system. Usually, this occurs when the system is shut down for repair. Pressurized devices such as refrigeration systems, boilers, stills and pressurized tanks may produce backflow under abnormal conditions.

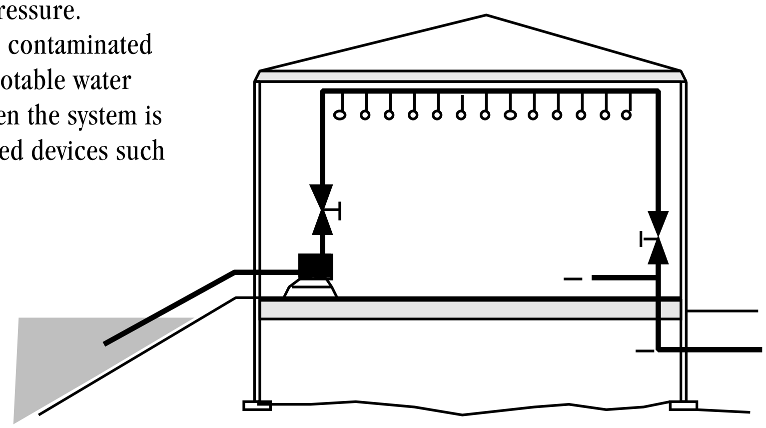

Figure 22-4 Backpressure Backflow

Backpressure backflow is typically found in buildings where two or more piping systems are located. Several piping systems can be installed to ensure one system is always working while the other one requires maintenance or for fire protection purposes. Boilers may require two systems. Figure 22-4 shows an example of a possible backpressure backflow situation.

If the city's water main cannot provide an acceptable water pressure, a booster pump may be used. Other systems may use a centrifugal pump but the backpressure may also be caused by gas or steam pressure from a boiler. For some reason, the pressure in the potable water system drops. These systems should be separated or require a backflow preventer device to prevent contamination.

An aspirator caused a funeral home's potable water system to be contaminated by human blood. The funeral home was using a hydraulic aspirator to drain fluids from human bodies. The aspirator was connected directly to a sink's water faucet with a rubber tube. The building had low water pressure and when used simultaneously with the aspirator, a negative potable water supply pressure resulted. The body fluids were pulled into the faucet and then into the potable water system instead of flowing down the drain. Blood was found pouring from the drinking fountains in the funeral home. A hose bibb could have prevented this horrifying situation.

GRAVITY AND BACKFLOW SITUATIONS

Gravity and backflows typically occur in unusual or emergency circumstances. Pressure differential results in contamination situations. Plumbers should recognize these situations and immediately take action to prevent a health problem. Prior planning before installation will eliminate backflow situations. Shut off questionable valves during maintenance or emergencies. Always separate multiple plumbing systems from each other.

HAZARD DEFINITIONS

Several definitions are used to determine exactly how hazardous the substance actually rates.

Toxic substance — Harmful when combined with potable water. This substance can be liquid, gas or solid.

Nontoxic substance — Nonlethal yet not acceptable for mixing with potable water. This substance can be liquid, gas or solid. When a nontoxic substance contaminates potable water, it poses a moderate hazard, annoyance, smell or other unacceptable situation.

Polluted substance — Not a potential health hazard yet very nasty. Polluted substances may cause foul taste, smell or color.

Contaminated substance — Incredibly bad health hazard. The potable water is unacceptable for human consumption.

BACKFLOW PROTECTION

Backflow protection is critical when installing or repairing plumbing. Older plumbing systems may not have any type of backflow preventers or they may have old, outdated preventers. The type of prevention method installed depends on the degree of hazard posed by the cross-connection. Your choice of protection may be determined by the size of the pipe, its location and the need to have it inspected. Several methods are available to lessen the chance of cross-connection. Refer to Table 22-1.

- Air Gap.
- Atmospheric Vacuum Breaker.
- Reduced Pressure Principle Backflow Preventer.
- Double-Check Valve Assembly.
- Pressure Vacuum Breaker.
- Barometric Loop.

SITUATION	AIR GAP	REDUCED PRESSURE BACKFLOW PREVENTER	PRESSURE TYPE VACUUM BREAKER	ATMOSPHERIC VACUUM BREAKER	DOUBLE-CHECK VALVE ASSEMBLY
Low inlet — toxic substance	x	x	x	x	
Low inlet — nontoxic substance	x	x	x	x	x
Cross-connection via hose	x	x	x	x	
Coils and jacks used with heat exchangers — toxic substance	x	x	x		
Direct connections possible back pressure — toxic substance	x	x			
Direct connections possible back pressure — nontoxic substance	x	x			x
Direct connections possible back pressure — sewage & lethal substances	x				

Table 22-1 Backflow Prevention

Subject to local plumbing codes

Never install cross-connection control devices in pits or submerged locations. These devices should be readily accessible for testing and maintenance. Venting devices should vent to the atmosphere, not to an exhaust hood, fan or location where the air quality is hazardous.

AIR GAP

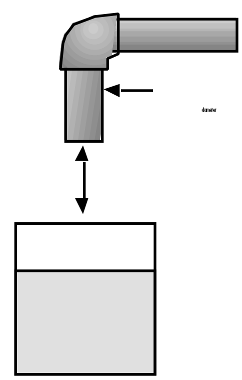

Figure 22-5 Air Gap

The simplest way to prevent a backflow from occurring is to install an air gap. Refer to Figure 22-5. Air gaps should be twice the diameter of the pipe and not less than 1 inch. An air gap is the unobstructed vertical space between the water supply and the flood rim of the receptacle. A physical separation occurs between the potable water system and the possible source of contamination. Use air gaps on direct and inlet connections. Air gaps provide protection when toxic material is apparent.

Air gaps are visible on sinks and bathtubs. They are used in reservoirs, storage tanks and where a break in the piping is not a factor. Once an air gap is installed, a tank or reservoir must be used to hold the water. Then, a new source of pressure must be used to move the water again.

ATMOSPHERIC VACUUM BREAKER

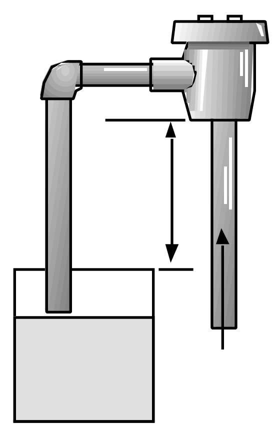

Figure 22-6 Atmospheric Vacuum Breaker Installation

Atmospheric vacuum breakers are the simplest and least expensive type of back-siphonage preventer. It cannot protect against backflow backpressure situations. Atmospheric-type vacuum breakers are similar to pressure-type vacuum breakers. However, the atmospheric-type vacuum breaker is not spring-loaded and the vented chamber remains open.

Atmospheric-type vacuum breakers can be installed only where the contained water is at atmospheric pressure. Atmospheric-type vacuum breakers must be installed 6" above the highest point and after the last control valve is isolated. Refer to Figure 22-6. They are typically manufactured with a polyethylene float that travels on a shaft and seals in the top position against the atmosphere with an elastomeric disc. Water flow lifts the float causing the disc to seal. When the water supply is cut off, the float drops and opens the downstream pipe to atmospheric pressure. Refer to Figure 22-7.

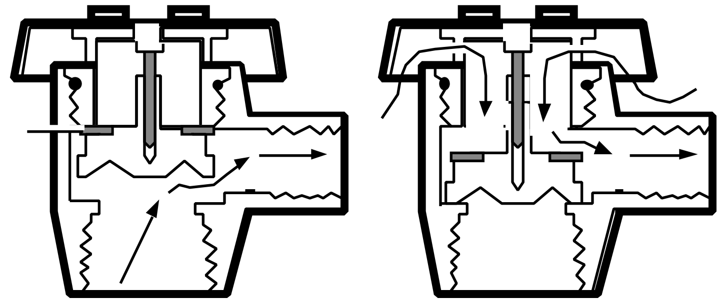

Figure 22-7 Atmospheric Vacuum Breaker

Atmospheric vacuum breakers are installed vertically and are usually available in $\frac{1}{2}$-inch to 3-inch sizes. Shutoffs must not be located downstream. They cannot be tested, but are pretty reliable.

This valve cannot be subject to constant pressure. Atmospheric vacuum breakers are installed on non-potable water systems never experiencing backpressure. Hose-type atmospheric vacuum breakers can be used on sill cocks and service sinks.

HOSE BIBB VACUUM BREAKER

A hose bibb vacuum breaker is a specialized atmospheric vacuum breaker. They are small and fit on the end of a sill cock. Hose bibbs are usually threaded and join directly to sill cocks. Garden hoses, spray outlets, slop or service sink hoses and other types of hoses can be attached to hose bibbs.

Hose bibbs have a spring-loaded check valve that shuts an atmospheric outlet when water pressure is apparent. When the water supply is cut, the valve returns to its closed position. Hose bibb vacuum breakers do not protect against backpressure and should not be used in that manner.

REDUCED-PRESSURE PRINCIPLE BACKFLOW PREVENTER

This part incorporates a check valve in the inlet and outlet with a vented chamber in the middle. Check valves remain in a closed position via a spring-loaded pin. A test port is available to determine the operating condition for the preventer.

When the reduced-pressure principle backflow preventer is operating correctly, the two check valves are open and the vented chamber is not used. When conditions are reversed, the check valves close and the middle chamber drains liquid passed by the check valve to minimize the pressure. The middle chamber opens when the pressure is within 2 psi occurs between the two lines.

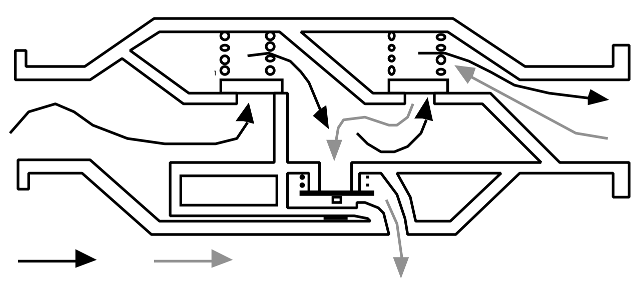

Figure 22-8 Reduced Pressure Principle Backflow Preventer

This unit is available in sizes from $\frac{3}{4}$ to 10 inches. Reduced-pressure principle backflow preventers are very expensive. They typically require annual inspections, are complicated and require maintenance. This type of preventer protects against both back-pressure and back-siphonage backflow while under high, constant pressure. Use this type of device on all direct connections subject to possible contamination from dangerous materials. Reduced-pressure principle backflow preventers are used in car washes, funeral parlors, hospitals, autopsy rooms, laboratories, etc.

This unit is the key to preventing hazardous cross-connections and is used quite often in plumbing and water work installations.

Strainers may be installed on the inlet to prevent fouling of the valves. Valves are installed on the inlet and outlet for testing and servicing.

DOUBLE-CHECK VALVE ASSEMBLY

A double-check valve assembly is a single device with two check valves in a series flow alignment. The valves are spring-loaded and remain in a closed state. The valves require approximately a pound of pressure to open. The spring loading allows small debris to be captured, yet the valve will seal. Test apparatuses are incorporated.

Double-check valve assemblies may not be permitted in your area. These assemblies are used for non-hazard risk installations. This valve can be used where the contaminated material is gas, steam, food, air or any substance that is offensive yet not hazardous. Inlet and outlet valves are required and strainers can be implemented.

Double-check valves protect against backflow, back-siphonage and can be used under continuous pressure. They can be tested independently, in place, to determine if they are functioning or clogged.

DOUBLE-CHECK VALVE WITH ATMOSPHERIC VENT

This is a double-check valve with an atmospheric vent located between the two checks. An atmospheric vent is incorporated to protect against backflow, backpressure and is subject to constant pressure. Refer to Figure 22-9.

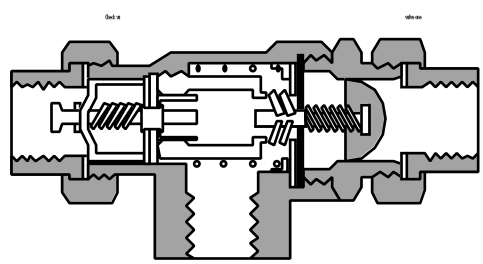

Figure 22-9 Double-check Valve with Atmospheric Vent

DOUBLE-CHECK DETECTOR CHECK

Double-check detector checks are double-check valves used primarily in fire line installation. This assembly helps to protect potable water systems from the contamination caused during typical fire use situations. Fireman use chemicals and booster pumps. Contaminated water is readily present during a fire.

The double-check detector checks have two spring-loaded check valves, a bypass assembly with a water meter and a double-check valve with two tightly closing gate valves. Test cocks are also incorporated. This assembly is specifically designed to deal with the low and high flow demands associated with fires.

RESIDENTIAL DUAL CHECK

A third type of double-check valve is the residential dual-check assembly. It is inexpensive and protects against backpressure and back-siphonage. It is available in ½, ¾ and 1-inch service line sizes. Residential dual checks are installed immediately downstream from the water meter to protect the main potable water supply from individual households. This type of residential dual-check unit provides containment. It isolates the building from contaminating the entire water supply. However, it does not protect the inhabitants from polluting themselves. Most cities use these types of devices to isolate and protect the main water supply.

PRESSURE VACUUM BREAKER

Pressure-type vacuum breakers are spring-loaded check devices installed in the flow path with a chamber vented to the atmosphere. Refer to 22-10. The unit must be installed 12" above the usage point. Refer to 22-11. The valve remains open and the vented chamber is closed during normal operation. When a vacuum occurs, the check closes and the vented chamber opens. If a check valve leakage occurs, only air flows into the potable water line. A pressure-type vacuum breaker requires installation at the highest part of the fixture or system being isolated. Normal water pressure is maintained without leakage during normal conditions.

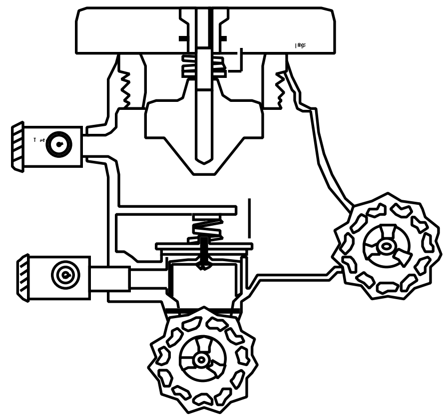

Figure 22-10 Pressure Vacuum Breaker

Pressure vacuum breakers are available in sizes from ½ to 10 inches. They are used in agricultural, irrigation and other situations. The popularity of the pressure vacuum breaker is due to its ability to work under constant pressure and the fact that it can be tested in place.

Pressure-type vacuum breakers are installed on non-potable water systems where backpressure is not likely to occur. However, these breakers can be subject to continuous supply pressure.

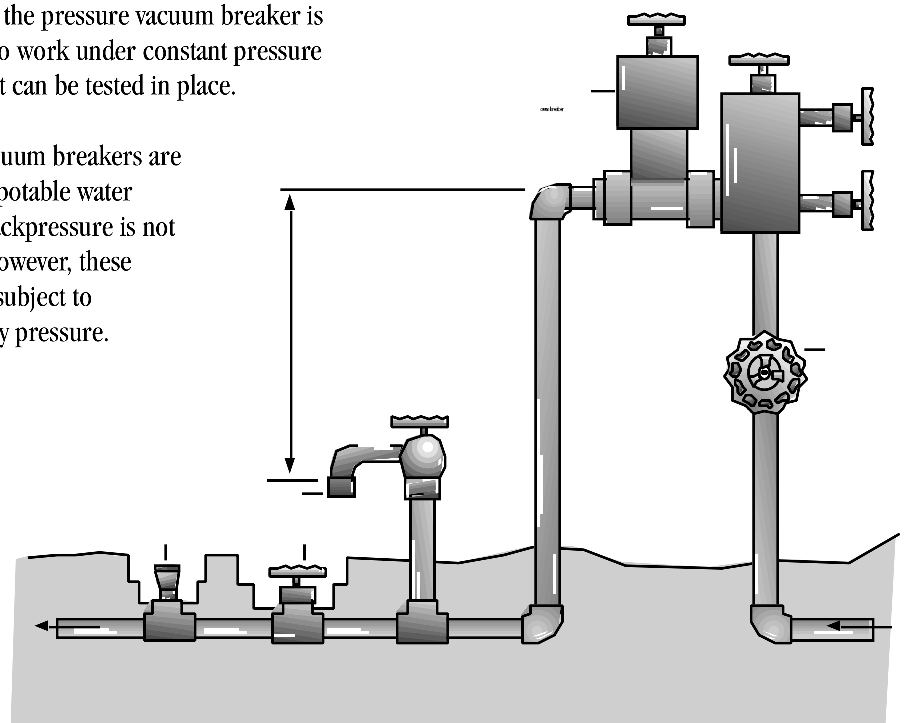

Figure 22-11 Pressure Vacuum Breaker Position

BAROMETRIC LOOP

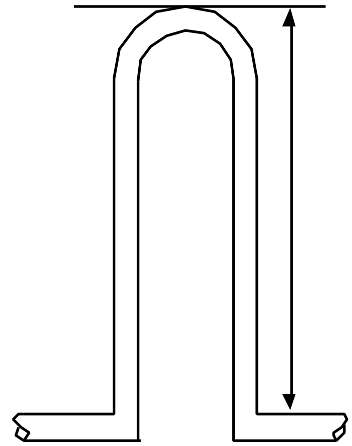

Figure 22-12 Barometric Loop

When a continuous section of pipe is installed 35 feet high and returns back to the originating level, a barometric loop is created. Refer to Figure 22-12. This section of piping prevents back-siphonage from occurring. At sea level, a column of water can only rise 33.9 feet. Barometric loops cannot protect against backpressure. Barometric loops are typically not an option in normal installations.

TESTING BACKFLOW PREVENTERS

Most backflow preventers need periodic maintenance and testing to guarantee they are functioning correctly. Certain types of preventers require an annual inspection. Always obtain permission before you shutoff the water. Hospitals, commercial and industrial plants may require an uninterrupted water supply. While the water is shutoff, the water remaining in the pipes should not be used. Back-siphonage can occur if water in the pipes is drained.

After shutting off the water, examine the device. Determine the flow direction. Number the test cocks and bleed them for debris. Assemble the test cock adapters and any bushings. Turn off the downstream shutoff valve. If you are testing a reduced pressure principle unit, you must wait several minutes before you connect the testing kit. The first check valve is probably fouled due to the water in the relief valve. The valve must be serviced before you continue testing. Double-check valves do not have this problem and you can immediately hook up the test kit if you are testing one of these units. Local codes govern exactly how each test kit is attached and used.

CROSS-CONNECTION PREVENTION

As mentioned earlier, most cities use some type of containment program to isolate the main water supply from possible contamination. When a building is constructed or repaired, the plumber is expected to install the proper backflow prevention devices and determine if cross-connections are or can be a hazard. Cross-connection prevention must be planned. Once installed, the system requires testing and then it must be maintained and periodically tested. Education is the key behind cross-connection prevention. You should understand the concepts behind pressure, how vacuums occur and what can happen.

Initially, you must determine where hazards exist. Residential dual-check backflow devices should be installed on every residence. Internal buildings need to be addressed individually. If the building is new, talk with the building owners and inquire how the building will be used. Are there boilers, processing tanks, dishwashers, etc. Review the blueprints. Cross-connection prevention is easiest if it is planned from the beginning. However, buildings are bought and sold, renovated, and the occupants also change. Change may require new cross-connection prevention devices to be installed after the building is constructed. If this is the case, it is possible to view the existing plumbing system and determine where backflow preventers may be required. Survey the building and make notes or drawings concerning potential hazards. Prioritize the hazard levels found in the building. What type of device will they require?

Research and plan how your cross-connection prevention plan will work. Document your findings. Review your documents with the owners or building manager. Make sure that everything is in order.

After you have planned your cross-connection prevention plan, have it approved by the local water authorities. This is the safest way to ensure you are legally covered in case an emergency does occur. It also double-checks that your procedures are legal in your specific area. New construction always requires approval by the local authorities.

DIRECT CONNECTIONS

The following is a partial list of fixtures and systems which have a direct connection to the potable water supply.

Air conditioning — air washer, chilled water and condenser water
Air line
Aspirator — embalming facilities, laboratories, medical, pesticide and fertilizer sprayers
Autoclave
Auxiliary systems — industrial, surface water, unapproved well supplies
Bidets
Boiler systems
Car washes
Chemical feeders
Chlorinator
Coffee urns
Cooling systems
Dishwashers
Faucets
Fire standpipes
Fountains
Hydraulic equipment
Ice makers
Laboratory equipment
Laundry equipment
Lavatories
Lubrication — pump bearings
Photostat equipment
Pneumatic equipment
Pumps — pneumatic ejector, prime line, water-operated ejectors
Sewer — sanitary, storm
Sinks
Sprinkler systems
Steamers — steam tables
Sterilizers
Swimming pools
Urinals
Water closets

SUBMERGED INLETS

The following is a partial list of fixtures which may contain submerged inlets.

Baptismal font
Bathtub
Bedpan washer — rushing rim
Bidet
Boilers
Brine tank

Cooling tower
Cuspidor
Drinking fountain
Floor drain — flushing rim
Garbage can washer
Ice maker
Laboratory sink — serrated nozzle
Laundry machines
Lawn sprinkler systems
Photo laboratory sinks
Sewer flushing manholes
Slop and service sinks — flushing rim, threaded supply
Steam table
Urinal — siphon jet blowout
Vegetable peelers
Water closets — ball cocks, flush tank, flush valve, siphon jet

CONCLUSION

Installing, recognizing and preventing backflow situations is critical. Multiple people can be subject to contamination without even realizing the problem. Again, the public requires the skilled plumber to guarantee their safety.

Education is the key to prevention. Remain informed about new devices available to prevent backflow and backpressure. Know how and when to use the prevention devices available today. Use backflow prevention devices when necessary. Periodic maintenance is required by these units. Be alert and look for potential water supply hazards.

Do not be afraid to suggest the use of backflow preventers. The general public has no idea what type of dangers are possible. Your specialized education may help save lives.