# Cross-Connection Control

Continuing Education from the
American Society of Plumbing Engineers

CEU 243

January 2017

ASPE.ORG/ReadLearnEarn

Note: In determining your answers to the CE questions, use only the material presented in the corresponding continuing education article. Using information from other materials may result in a wrong answer.

Protecting potable water is an important aspect of plumbing engineering, and cross-connection control is the primary means used in the plumbing profession to accomplish this. The importance of cross-connection control, or backflow protection, was brought to light in the early part of the 20th century when major outbreaks of waterborne diseases such as dysentery occurred. By not ensuring that every opening, outlet, and connection to the potable water supply is protected, backflow from nonpotable sources can contaminate the potable water supply. For this reason, the plumbing engineer must evaluate every opening, outlet, and connection to a nonpotable source for proper protection against backflow. Whatever the source of potable water, protection against cross-connections is imperative.

## TYPES OF BACKFLOW

Backflow occurs through either siphonage or backpressure. Siphonage, also called backsiphonage, is the reversal of water flow when the pressure on the inlet side of the water supply is lower than that on the outlet side. Siphonage can occur due to a water main break, a fire pumper connected to the water main, or poor design in the water distribution system, among other reasons.

The other backflow occurrence is backpressure. Backpressure occurs when a higher pressure is applied on the outlet or connection side of the water distribution side than on the inlet. Examples of backpressure occurrences include an elevated column of water, such as in a multistory building, a pumped connection that pressurizes the water supply, or a pressurized nonpotable system.

Examples of potential cross-connections include plumbing fixtures, faucets, fixture fittings, hose bibbs, appliance connections, hydronic water supply connections, fire sprinkler and standpipe water supply connections, water supply connections to industrial processes, laundries, medical equipment, food service equipment, carbonated beverage dispensers, HVAC equipment, swimming pool water makeup, water treatment backwash, trap primers, irrigation taps, dispensers that dilute their product with water, pressure-relief valve discharge piping, and drain-flushing water supplies.

The potential for backflow can occur at any opening, outlet, or connection to the potable water supply. Opening and outlet are words often used interchangeable to identify a point where potable water is discharged. Examples of openings and outlets include faucets, fixture fittings, hose bibbs, fill valves, and relief valves.

Connections are piping systems that interconnect the potable water supply to a nonpotable water system. Not all piping connections are to a hazardous source. For example, water can be directly connected to a juice dispenser, coffee maker, or carbonated beverage dispenser. All of the identified connections are to liquids that are regularly consumed. However, all of the sources can contaminate the potable water supply.

## HYDROSTATIC FUNDAMENTALS

To derive the pressure relationship in a hydrostatic fluid, consider the volume of the fluid at a given depth. The pressure of a 1-foot column of water can be calculated using Equation 9-1. The pressure at the base of a water column can be determined using Equation 9-2.

Equation 9-1

$$p_1 = \rho / A$$

Equation 9-2

$$p = h \times p_1$$

*where*

$p_1$ = Pressure (gauge), pounds per square inch (psi) (kPa) per foot of water column

$\rho$ = Density of water, lb/ft$^3$

A = Area, in.$^2$ (m$^2$)

p = Pressure at the base of a column of water

h = Static head, ft (m)

The maximum density of water is 62.434 pounds per cubic foot at a temperature of 39.2°F. When the temperature of water is increased or decreased, the density decreases. At 212°F, the density of water is 59.843 pounds per cubic foot. Assuming a density of 62.4 pounds per cubic foot and applying Equation 9-1, the pressure at the base of a 1-foot column of water is 0.433 psi (62.4 divided by 144 square inches per square foot).

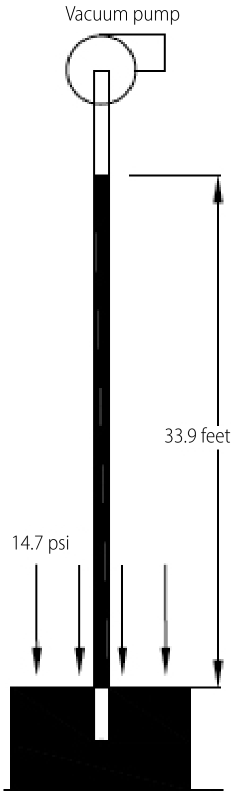



Figure 9-1 Maximum Rise of Water from a Vacuum

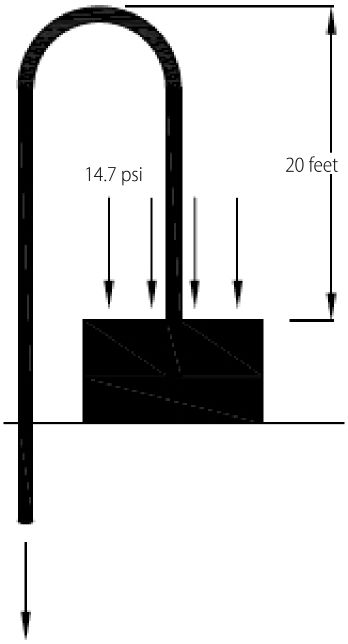



Figure 9-2 Siphon Action Lifting Water from a Tank

If a column of water is 10 feet in height, the pressure at the base of the column is 4.33 psi. The pressure is identified as gauge pressure, assuming atmospheric pressure to be 0 psi. At sea level, atmospheric pressure is 14.7 psi.

A perfect vacuum would be 0 psi absolute, or -14.7 psi gauge. Any vacuum or negative pressure would result in a column of water rising in the piping. With a perfect vacuum, a column of water would rise against atmospheric pressure -14.7 psi, which equates to 33.9 feet. Hence, for a perfect vacuum, water can only rise 33.9 feet in a pipe (see Figure 9-1).

Water will rise in a pipe up to 33.9 feet and return to the source under a vacuum or siphon action (see Figure 9-2). When the upstream pressure is lower than the outlet or connection pressure, flow will be reversed in the piping system. The reversal of water flow can contaminate the potable water supply by introducing nonpotable water or contaminants into the system.

Backflow protection is based on preventing the reversal of flow that may occur when the upstream pressure drops lower than the outlet or connection pressure. A means must be provided to prevent the reversal of flow under all possible conditions.

## CAUSES OF REVERSE FLOW

The most common cause of flow reversal in a water piping system is a fire department pumper truck connected to a hydrant and drawing water from the public main. In many cases, the size of the pump on the fire truck can create a negative pressure throughout the piping systems in adjoining buildings.

Many other situations can also result in flow reversal:

- When a water main breaks, the pressure in the public main drops. Thus, the lower pressure upstream in the piping system leads to flow reversal.
- Flow reversal can occur when a piping system is not properly designed or when fixtures are added to an existing system. If a fixture has a high demand for flow on a lower floor of a building, a reversal of flow may occur from the upper floors of that building. An example would be the flushing of a water closet. The flushometer valve can lower the pressure by 35 psi. Another fixture could be open, resulting in the reversal of water flow.
- A nonpotable system may have a pump that elevates the pressure of that system. If it was connected to a potable system, the pressure in the nonpotable system could become higher than the potable water supply pressure, resulting in the reversal of flow.
- If the water is elevated in a piping system, such as a fire sprinkler system, a change in pressure in the public main can cause a reversal of flow. This type of flow reversal can occur on a regular basis since the pressure in a public main will vary throughout the day.
- At the connection to a boiler, when the water is heated, the pressure increases as the temperature increases, resulting in the reversal of flow.

Whenever a reversal of flow is possible, a means of backflow protection must be provided to keep the potable water system safe.

Other pressure interruptions include broken pipes, broken outlets, air lock, pressure caused by thermal energy sources, malfunctioning pumps, malfunctioning pressure-reducing valves, and uncommon water discharges such as a major firefighting event.

Because it cannot be predicted where a valve may close or where another type of pressure interruption may occur, each water connection point becomes a potential point for reverse flow. Thus, every fixture, every connected piece of equipment, and every connected non-plumbing system becomes a point of reverse flow. Containers of any liquid that receive water from a hose or even a spout of inadequate elevation potentially may flow in a reverse direction. Submerged irrigation systems or yard hydrants with a submerged drain point potentially may flow soil contaminants into the water supply system. Hence, the safety of a water supply distribution system depends on effective control at each connection point. The safety is not ensured if the effectiveness of one point is unknown despite controls at all other points.

A manually closed water supply valve is not considered a cross-connection control, even if the valve is bubble-tight and well supervised. Ordinary check valves also are not considered a cross-connection control.

## HAZARDS IN WATER DISTRIBUTION

Table 9-1 lists some of the common hazards to a potable water system. The potable water supply must be protected against backflow from these and similar hazards.

Risks are more common since they are associated with every plumbing fixture, many types of equipment, and various connections with non-plumbing systems. The nature of the risk ranges from mere objections such as water color or odor to varying exposure levels of nuclear, chemical, or biological material. The exposure levels range from imperceptible to mildly toxic to generally lethal in healthy adults. The current list of drinking water contaminants and their maximum contaminant levels (MCLs) can be found on the U.S. Environmental Protection Agency's website.

### Classification of Hazards

The potential hazards from a cross-connection are identified as low hazard and high hazard. A high hazard is any contamination that can cause sickness, disease, long-term health effects, or death. Examples are sewage, chemicals, body fluids, lubricants, and fertilizers. A low hazard impacts the aesthetics of the potable water, but the pollutant will not immediately cause sickness, disease, or death. Examples are juices, coffee, tea, and humidifier water. Some of the identified pollutants are drinks that are consumed by humans. However, if the drink enters the potable water system, the water does not remain potable.

**Table 9-1 Plumbing System Hazards**

| Direct Connections | Potential Submerged Inlets |
|---|---|
| Air-conditioning, air washer | Baptismal font |
| Air-conditioning, chilled water | Bathtub |
| Air-conditioning, condenser water | Bedpan washer, flushing rim |
| Air line | Bidet |
| Aspirator, laboratory | Brine tank |
| Aspirator, medical | Cooling tower |
| Aspirator, herbicide and fertilizer sprayer | Cuspidor |
| Autoclave and sterilizer | Drinking fountain |
| Auxiliary system, industrial | Floor drain |
| Auxiliary system, surface water | Garbage can washer |
| Auxiliary system, unapproved well supply | Handheld shower |
| Boiler system | Hose bibb |
| Carbonated beverage dispenser | Ice maker |
| Chemical feeder, pot type | Laboratory sink |
| Chlorinator | Laundry machine |
| Coffee maker | Lavatory |
| Cooling system | Lawn sprinkler system |
| Dishwasher | Photo laboratory sink |
| Fire standpipe | Pull-out spray faucet |
| Fire sprinkler system | Sewer flushing manhole |
| Fountain, ornamental | Service sink, flushing rim |
| Heat exchanger | Service sink, threaded supply |
| Hydraulic equipment | Steam table |
| Hydropneumatic drain cleaner | Shower |
| Juice dispenser | Sillcock |
| Laboratory equipment | Urinal |
| Lubrication, pump bearings | Vegetable peeler |
| Process piping system | Water closet |
| Pump, pneumatic ejector | |
| Pump, prime line | |
| Pump, water-operated ejector | |
| Sewer, sanitary | |
| Sewer, storm | |
| Swimming pool or spa equipment | |

## METHODS OF PROVIDING BACKFLOW PROTECTION

The plumbing codes identify the acceptable means of providing protection against cross-connections, including acceptable piping methods and the installation of a backflow preventer. All backflow preventers must be tested and listed by a third-party agency to one of the standards identified in Table 9-2 on the next page.

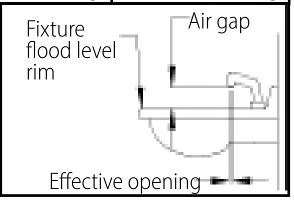
### Air Gap

An air gap is a space between the outlet of the potable water supply and the flood level rim of the fixture or device being supplied with water. The flood level rim is defined as the point where water overflows the fixture or device.

An air gap is considered the highest level of protection against backflow. An air gap provides a physical separation between the opening or outlet and the water in the fixture, vessel, or pipe. An air gap is the most common method of backflow protection. The water supply to most sink faucets, lavatory faucets, shower valves, bathtub fillers, and drinking fountains is protected against backflow by an air gap.

**Table 9-3 Minimum Air Gaps for Water Distribution Systems**

| Effective Fixture Opening Size | Not Affected by Side Walls, in. | Affected by Side Walls, in. |
|---|---|---|
| Not greater than ½ inch in diameter | 1 | 1½ |
| Not greater than ¾ inch in diameter | 1½ | 2¼ |
| Not greater than 1 inch in diameter | 2 | 3 |
| Greater than 1 inch in diameter | 2x diameter of effective opening | 3x diameter of effective opening |




Since the physical separation is by means of air, an air gap is considered to protect against siphonage only. No backpressure can occur with an air gap since any physical connection that creates backpressure would defeat the air gap.

Table 9-3 identifies the minimum air gap spacing requirements between the opening or outlet and the flood level rim. The table identifies the minimum spacing based on whether or not the air gap is affected by a side wall. The side wall will affect the air gap when it is located within three times the effective opening diameter. For example, if the opening was ½ inch in diameter, the side wall would have to be located a minimum of 1½ inches from the opening. Where two walls intersect, the distance increases to four times the opening to not be affected by the side wall.

The distances in Table 9-3 are consistent with the provisions in ASME A112.1.2: *Air Gaps in Plumbing Systems (For Plumbing Fixtures and Water-Connected Receptors)*. When these minimum distances are maintained, any vacuum pressure created by the siphon on the inlet to the water supply would result in air entering the piping. The siphon would not have enough energy to draw the water back into the piping system.

In addition to the physical air gap created by the distance between an outlet or opening and the flood level rim, air gap devices provide an equivalent level of protection. These devices must comply with ASME A112.1.3: *Air Gap Fittings for Use with Plumbing Fixtures, Appliances, and Appurtenances.*

Certain appliances are equipped with internal air gaps to protect the water supply. The types of appliances that may have an internal air gap include residential dishwashers, laundry machines, humidifiers, ice makers, iced tea dispens-

| Table 9-2 Application of Cross-Connection Control Devices | | | | |
|---|---|---|---|---|
| **Means of Backflow Protection** | **Level of Hazard** | **Backflow Protected Against** | **Device Size** | **Regulating Standard** |
| Air gap | High or low hazard | Siphonage or backpressure | | ASME A112.1.2 |
| Air gap fittings for use with plumbing fixtures, appliances, and appurtenances | High or low hazard | Siphonage or backpressure | | ASME A112.1.3 |
| Barometric loop (35 foot rise in piping) | High or low hazard | Siphonage | | |
| Reduced pressure principle backflow prevention assembly | High or low hazard | Backpressure or siphonage | 3/8–16 in. | ASSE 1013, AWWA C511, CSA B64.4, CSA B64.4.1 |
| Reduced pressure detector fire protection backflow prevention assembly | High or low hazard | Backpressure or siphonage (fire sprinkler systems) | 1–16 in. | ASSE 1047 |
| Double check backflow prevention assembly | Low hazard | Backpressure or siphonage | 3/8–16 in. | ASSE 1015, AWWA C510, CSA B64.5, CSA B64.5.1 |
| Double check detector fire protection backflow prevention assembly | Low hazard | Backpressure or siphonage (fire sprinkler systems) | 2–16 in. | ASSE 1048 |
| Pressure vacuum breaker assembly | High or low hazard | Siphonage | ½–2 in. | ASSE 1020, CSA B64.1.2 |
| Spill-resistant vacuum breaker assembly | High or low hazard | Siphonage | ¼–2 in. | ASSE 1056 |
| Anti-siphon fill valves for gravity water closet flush tanks | High hazard | Siphonage | | ASSE 1002, CSA B125.3 |
| Backflow preventer for carbonated beverage machines | High and low hazard | Backpressure or siphonage | ¼–3/8 in. | ASSE 1022 |
| Backflow preventer with intermediate atmospheric vents | Low hazard | Backpressure or siphonage | ¼–¾ in. | ASSE 1012, CSA B64.3 |
| Dual check valve backflow preventer | Low hazard | Backpressure or siphonage | ¼–1 in. | ASSE 1024, CSA B64.6, ASSE 1032 |
| Hose connection backflow preventer | High or low hazard | Low-head backpressure or siphonage | ½–1 in. | ASME A112.21.3, ASSE 1052, CSA B64.2.1.1 |
| Hose connection vacuum breaker | High or low hazard | Low-head backpressure or siphonage | ½–1 in. | ASME A112.21.3, ASSE 1011, CSA B64.2, CSA B64.2.1 |
| Laboratory faucet backflow preventer | High or low hazard | Low-head backpressure or siphonage | | ASSE 1035, CSA B64.7 |
| Pipe-applied atmospheric vacuum breaker | High or low hazard | Siphonage | ¼–4 in. | ASSE 1001, CSA B64.1.1 |
| Vacuum breaker wall hydrant, frost-resistant, automatic draining | High or low hazard | Low-head backpressure or siphonage | ¾–1 in. | ASME A112.21.3, ASSE 1019, CSA B64.2.2 |
| Freeze-resistant sanitary yard hydrant | High or low hazard | Low-head backpressure or siphonage (Type 1 and 2 backpressure) | ¾–1 in. | ASSE 1057 |

ers, juice dispensers, and coffee makers. However, an engineer cannot assume that a given appliance has an internal air gap. Each appliance or device must be individually evaluated for backflow protection.

The plumbing codes recognize that not all air gaps qualify as an air gap for providing protection against backflow. If the air gap can be easily defeated, it cannot be used as a means of backflow protection. The most common means of defeating an air gap is a threaded end on the opening or outlet. A hose can be attached to the threaded end, thus removing the air gap as a means of backflow protection. The same would apply to an opening that has a quick disconnect or a barbed end for hose attachment. Wherever a threaded end, quick disconnect, or barbed connection is present, another means of backflow protection must be provided.

Another device that cannot rely on an air gap to provide backflow protection is a pull-out spray faucet. With this style of faucet, the spout is connected to the faucet body, and the spout end is connected by a hose to the water supply. With a slight tug of the spray end, the spout disengages from the faucet body and can be used as a hose-connected spray. The spray end can be lowered into the sink or vessel, thus defeating the air gap. Faucets with hose-connected outlets (pull-out spray spouts) are protected against backflow by internal backflow components. These faucets are regulated by ASME A112.18.1/CSA B125.1: *Plumbing Supply Fittings*.

## Barometric Loop

A barometric loop is a configuration of piping whereby the water supply pipe rises a minimum of 35 feet above the flood level rim of the fixture, device, or vessel being supplied with water. Under ideal conditions at sea level, the maximum rise of water from a siphon or vacuum is 33.9 feet. Thus, by having a 35 foot rise in piping, nonpotable water cannot be siphoned back into the potable water supply.

A barometric loop is often shown as a pipe rising 35 feet in the air and then descending 35 feet to the outlet or opening. This would be a very ineffective means of providing backflow protection since more than 70 feet of piping is used.

The more common application of a barometric loop is in factory and industrial settings where the water supply piping is installed at an elevated location and the water is supplied to a nonpotable tank, vat, vessel, or fixture by a drop of more than 35 feet (see Figure 9-3).

While a barometric loop is similar to an atmospheric vacuum breaker, the main difference is that pressure can be continuous in the barometric loop. Because a barometric loop uses basic physics to protect against siphonage, any valve or controller can be located in the piping.

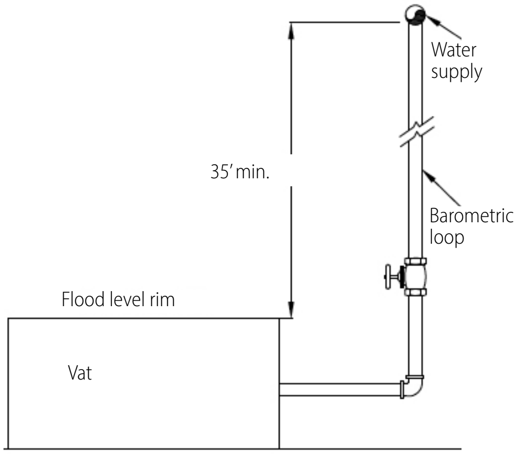



**Figure 9-3 Barometric Loop Providing Backflow Protection**

## Reduced Pressure Principle Backflow Preventer

A reduced pressure principle backflow preventer (see Figure 9-4) provides the highest level of protection of a backflow preventer. A reduced pressure principle backflow preventer has two independent-acting check valves and an intermediate relief valve. The backflow preventer must also have two shutoff valves, one on the inlet to the assembly and one on the outlet.

The two check valves provide redundancy for protecting the water supply against backpressure or siphonage. The first check is spring-biased to at least 3 psi greater than the intermediate area of the valve. The 3 psi is a laboratory test. Most reduced pressure principle backflow preventers have a minimum pressure drop of 5 psi across the first check valve. If there is higher pressure on the outlet of the first check valve than on the inlet, the check valve is required to seal tight, thus preventing backflow. The second check valve is spring-biased to at least 1 psi greater than the outlet pressure. The second check valve must seal drip tight when there is a pressure differential of less than 1 psi between the inlet pressure and the outlet pressure.

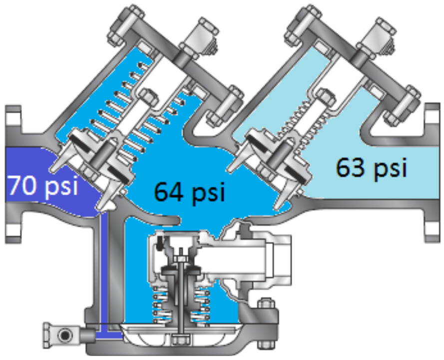



**Figure 9-4 Reduced Pressure Principle Backflow Preventer**

The intermediate chamber of the valve, sometimes referred to as the intermediate zone, has a relief valve that opens to discharge water to prevent any backflow. The relief valve must open when the pressure in the intermediate chamber is 2 psi or less than the pressure on the inlet of the first check valve. If either check valve fails to seal tight, the intermediate chamber is vented to atmosphere. Even when the check valves seal tight, the intermediate chamber is vented to atmosphere when a lowering of the inlet pressure or a siphon of the inlet supply occurs.

The relief valve is required to discharge at a high rate if either check valve fails to close liquid tight. The high rate of water discharge from the relief port must be considered in the design of the water distribution system. A large drain, either a floor drain or a drain to the outdoors, must be provided in the immediate area of a reduced pressure principle backflow preventer. The manufacturer will provide a table identifying the maximum rate of discharge from the relief port.

Reduced pressure principle backflow preventers are considered active valves. They are designed to be installed in systems that are actively flowing water to the nonpotable supply. They are not designed for static systems, such as a fire sprinkler or standpipe system. When no water is flowing in the system on a regular basis, the backflow preventer will constantly discharge water when the inlet pressure to the system fluctuates. For static systems, the plumbing engineer should attempt to design the system so the inlet pressure to the backflow preventer does not experience constant swings in supply pressure.

When installed on a connection to a sprinkler or standpipe system, a detector valve is available, identified as a reduced pressure detector fire protection backflow prevention assembly. These backflow preventers have a smaller-diameter bypass for a water meter with a reduced pressure principle backflow preventer on the bypass. These detector valves are designed to monitor the possible theft of water through the sprinkler system. The detector assemblies are also rated for the higher flow rates that are anticipated with sprinkler and standpipe systems.

A reduced pressure principle backflow preventer is a testable valve. Four test cocks are located on the valve. Before the valve is placed in operation, a test must be performed on the valve to ensure that it is in working condition. The test determines that the first check has the proper bias, the second check is drip tight, and the relief valve opens at the required pressure. After the initial test, an annual test of the backflow preventer is required.

This type of backflow preventer is sometimes referred to as an RP valve or an RP backflow preventer. An older, archaic expression for the valve is RPZ, meaning reduced pressure zone (with zone referring to the intermediate chamber).

## Double Check Valve Assembly

A double check valve assembly (see Figure 9-5) is similar to a reduced pressure principle backflow preventer but does not have a relief valve in the intermediate chamber. This backflow preventer has two independent check valves. Both check valves are spring biased and must be drip tight. The first check valve is not spring biased for as high a pressure drop as a reduced pressure principle backflow preventer. As a result, the pressure drop across a double check valve assembly is less than the pressure drop across a reduced pressure principle backflow preventer. The double check valve assembly must also have two shutoff valves, one on the inlet to the assembly and one on the outlet.

Double check valve assemblies are only intended to be used for low hazard backflow protection. The valves were specifically developed for fire sprinkler and standpipe systems. The double check valve assembly protects against contamination when the sprinkler system is filled with water only. Other applications for a double check valve assembly are lawn sprinkler systems and fill valves for boilers or cooling towers that do not contain chemicals.

When installed on a connection to a sprinkler or standpipe system, a detector valve is available, identified as a double check detector fire protection backflow prevention assembly. These backflow preventers have a smaller-diameter bypass for a water meter with a double check valve assembly on the bypass. These detector valves are designed to monitor the possible theft of water through the sprinkler system. The detector assemblies are also rated for the higher flow rates that are anticipated with sprinkler and standpipe systems.

Double check valve assemblies are testable valves. Test cocks are located on the valve to measure the pressure differential across the check valves. Before the assembly is placed in operation, a test must be performed to ensure that it is in working condition. The test determines that the two checks are drip tight. After the initial test, an annual test is required.

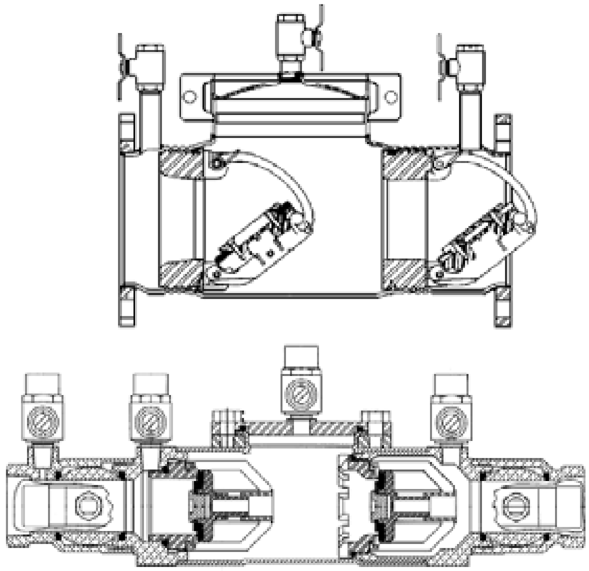


**Figure 9-5 Double Check Valve Assembly**

## Non-Testable Check Valve Backflow Preventers

A variety of backflow preventers that rely on check valves and sometimes relief openings are not testable. These backflow preventers tend to be small in size and do not have test cocks. Since they are not testable, they are considered less reliable by the plumbing codes and the backflow protection industry. Their use is often restricted to nonhazardous applications for backflow protection.

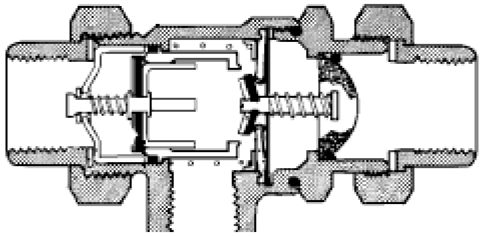


**Figure 9-6 Backflow Preventer with an Intermediate Atmospheric Vent**

## Backflow Preventer with an Intermediate Atmospheric Vent

A backflow preventer with an intermediate atmospheric vent (see Figure 9-6) has two independently acting check valves and a vent that opens to atmosphere. When the first check valve opens, it closes off the opening to the vent. When the first check valve moves to the closed position, the intermediate atmospheric vent opens to vent any nonpotable water that flows past the second check valve. The intermediate atmospheric vent must discharge through an air gap.

These types of backflow preventers are only available in ¼ inch through ¾ inch. The common installation of this backflow preventer is on the fill line to a boiler that does not have conditioning chemicals.

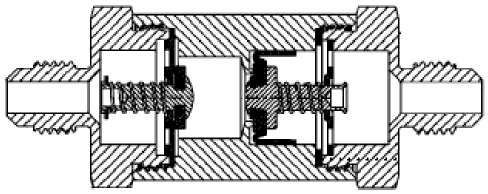


**Figure 9-7 Dual Check Valve**

## Dual Check Valve

A dual check valve (see Figure 9-7) has two independently acting check valves without an atmospheric vent opening, shutoff valves on either end, or test cocks. The many styles of dual check valves depend on the application of use. Larger dual check valves are available in sizes up to 2 inches in diameter. These types of valves are commonly used on the inlet supply to a building or on the water supply to a residential sprinkler system. Smaller-diameter dual check valves are used for backflow protection on the water supply to equipment such as juice dispensers, coffee makers, and humidifiers. The small sizes are also used on laboratory faucets and shampoo sinks.

Not all plumbing codes recognize the use of dual check valves. When dual check valves are permitted by the plumbing codes, they are typically restricted to a narrow application of use for backflow protection.

## Backflow Preventer for Carbonated Beverage Machines

A backflow preventer for carbonated beverage machines has two independent check valves with a vent to atmosphere (see Figure 9-8). The valve is designed for the high pressures associated with carbonated beverage dispensers. When

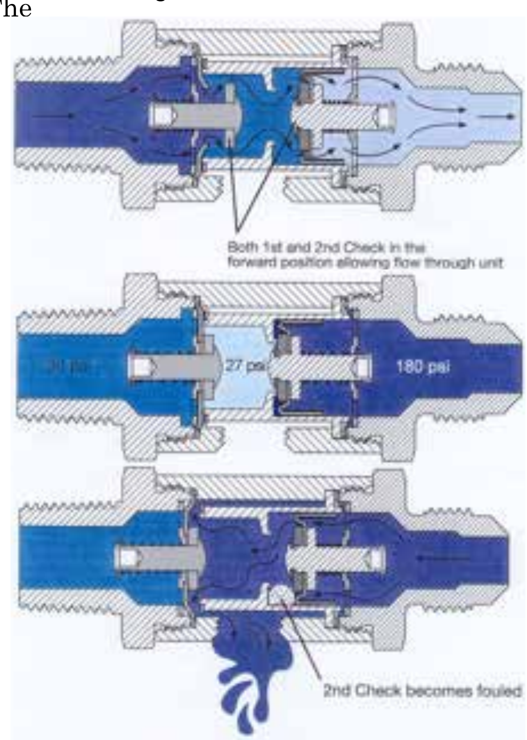



**Figure 9-8 Backflow Preventer for Carbonated Beverage Machines**

carbon dioxide is introduced into the potable water, it converts to carbonic acid (also called carbonated water). The backflow preventer prevents the carbonic acid from entering the potable water system. Carbonic acid can interact with copper tube, resulting in a copper toxicity in the drinking water.

When a backflow preventer for carbonated beverage machines is installed, the engineer must be concerned with the possible escape of carbon dioxide. Adequate ventilation is required to dilute any escape of carbon dioxide, or monitoring must be provided to indicate a hazardous environment.

**Figure 9-9 Pipe-Applied Vacuum Breaker for Flushometer Valve**

## Vacuum Breakers

Vacuum breakers are designed to break a siphon by allowing the introduction of air into the piping system. Vacuum breakers are only designed to prevent siphonage; however, certain vacuum breaker are tested for low-head backpressure, which typically means a column of water elevated to 10 feet or less. For some applications, a lower head height is anticipated. Vacuum breakers must be installed above the flood level rim of the fixture, vat, vessel, or tank that they are protecting against backflow.

### *Atmospheric Vacuum Breaker*

An atmospheric vacuum breaker has a vent opening that is closed when water is normally flowing through the device. Minimal moving parts and no springs are associated with an atmospheric vacuum breaker. Water must flow freely through the vacuum breaker without continuous pressure or a buildup of pressure. For this reason, shutoff valves are not permitted to be placed downstream of an atmospheric vacuum breaker.

The most common type of atmospheric vacuum breaker is a pipe-applied vacuum breaker (see Figure 9-9). Pipe-applied vacuum breakers are installed on most flush valves to water closets and urinals. The flush pipe has an enlarged area with openings to atmosphere. Inside the flush pipe is an elastomeric sleeve that expands, closing off the openings when water passes through the vacuum breaker. After each use, the elastomeric sleeve returns to its normal position, allowing air to enter the openings in the flush pipe.

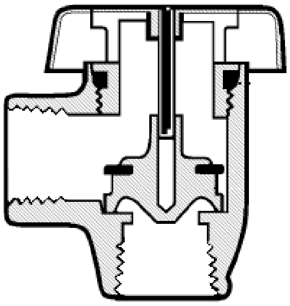


**Figure 9-10 Atmospheric Vacuum Breaker**

The other style of atmospheric vacuum breaker is designed in a 90-degree configuration (see Figure 9-10). Water enters the bottom of the vacuum breaker and exit through the side. At the top of the vacuum breaker is an opening that allows air to enter the piping system. A bonnet covers the air opening to prevent any foreign objects from obstructing the opening. An internal disk moves upward when water enters the vacuum breaker. The disk closes off the air opening, allowing water to flow freely through the valve. When water is not flowing, the disk lowers, allowing air to enter the piping, thus breaking any siphon action. The remaining water in the piping discharges into the fixture or vessel.

### *Pressure Vacuum Breaker*

A pressure vacuum breaker utilizes one or two springs on the disks to ensure that the air inlet opens to allow air to enter to break the siphon action, and the inlet closes when water is not flowing. A pressure vacuum breaker comes with two shutoff valves, one on the supply and the other on the outlet of the valve. Because the disks are spring loaded, shutoff valves can be installed downstream of the pressure vacuum breaker.

Pressure vacuum breakers are testable valves and have two test cocks. Before being placed into service, a pressure vacuum breaker must be tested. An annual test also is required.

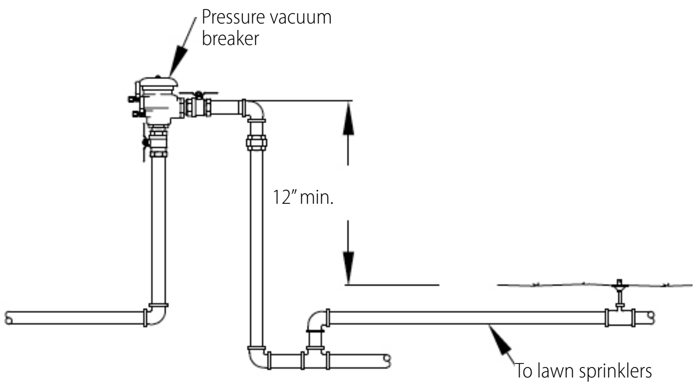



**Figure 9-11 Pressure Vacuum Breaker on the Water Supply to a Lawn Sprinkler System**

Pressure vacuum breakers were originally designed to be installed outdoors (see Figure 9-11), but they can be installed indoors provided measures are taken to prevent damage when the valve discharges water. Pressure vacuum breakers are often referred to as spitting when water first flows through the valve. The spitting is the discharge of water out of the top bonnet, which occurs until the disk seals off the air opening. The amount of water that discharges is less than a gallon; however, some form of drainage, such as a floor drain, should be located near the pressure vacuum breaker.

Most pressure vacuum breakers are required to be installed a minimum of 12 inches above the flood level rim.

### *Spill-Resistant Vacuum Breaker*

Spill-resistant vacuum breakers (see Figure 9-12) are a style of pressure vacuum breaker that does not discharge water when water starts to flow through the valve. Spill-resistant vacuum

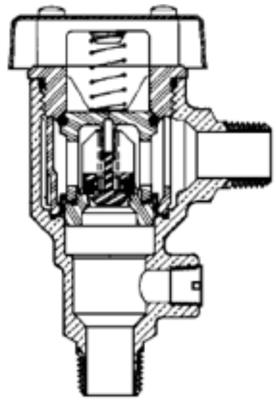


**Figure 9-12 Spill-Resistant Vacuum Breaker**

breakers are specifically designed for installation indoors. A floor drain or other drainage means is not required for the installation of a spill-resistant vacuum breaker.

Spill-resistant vacuum breakers also have test cocks and require testing as a pressure vacuum breaker.

*Hose Connection Vacuum Breaker*

Many styles of vacuum breakers are designed to protect hose connections against backflow (see Figure 9-13). Some vacuum breakers connect to the end of the hose connection while others are internal to the sillcock. Frost-proof sillcocks, intended for outdoor use in cold climates, have internal vacuum breakers that release the water inside the barrel of the sillcock.

Hose connection vacuum breakers are a style of atmospheric vacuum breaker; however, they are all tested for low-head backpressure, which can be present when a hose is connected and elevated during use.

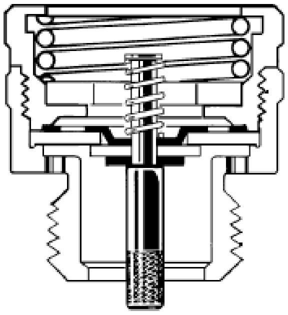


**Figure 9-13 Hose Connection Vacuum Breaker**

## Other Backflow Protection Means

Tank-type water closets have internal anti-siphon ballcocks to protect against backflow. Pressure-assist water closets have internal backflow protection as part of the pressurized tank design.

Other equipment and devices using potable water may have internal backflow protection, which is required in some product standards. However, the plumbing code may or may not accept the internal backflow protection, so any internal backflow preventer must be evaluated to determine if the level of protection complies with the plumbing code. If the internal backflow preventer is not acceptable, another method of backflow prevention must be installed on the water supply to the equipment or device.

## Backflow Protection in Heat Exchangers

A heat exchanger itself appears to not be a concern regarding backflow. For example, in a shell-and-tube heat exchanger used to heat potable water, the potable water is separated from the transfer fluid by a pipe wall. However, the backflow concern is a potential leak in the water piping inside the heat exchanger. If a leak occurs, the nonpotable transfer fluid could enter the hot water piping and contaminate the potable water supply.

When toxic transfer fluid is used in a heat exchanger, the plumbing codes normally require a double-wall heat exchanger (see Figure 9-14). The interstitial space between the two walls has to be vented to make any internal leak visible.

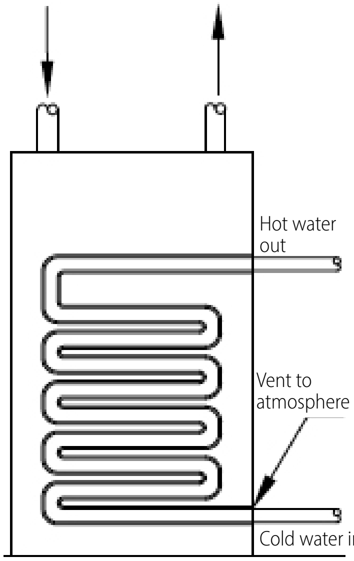



**Figure 9-14 Double-Wall Heat Exchanger**

## INSTALLATION

All backflow preventers must be accessible for inspection, service, repair, maintenance, or replacement via a panel, door, or access opening. Testable backflow preventers must be installed so their test cocks are accessible for installing the test gauges.

The standard orientation for reduced pressure principle backflow preventers and double check valve assemblies is horizontal. A reduced pressure principle backflow preventer and double check valve assembly can only be installed in the vertical orientation when the device is tested and listed for vertical orientation.

For reduced pressure principle backflow preventers and double check valve assemblies that are 3 inches or smaller in diameter, the minimum spacing between the side of the device with the test cocks and the side wall of the building is recommended to be 24 inches. The remaining sides of the device should have a spacing of 12 inches minimum. For 4-inch and larger reduced pressure principle backflow preventers and double check valve assemblies, the minimum spacing on the side with the test cocks should be 48 inches. The remaining sides should have a minimum spacing of 24 inches.

Reduced pressure principle backflow preventers must be installed with an air gap for the relief valve discharge port. The location of a reduced pressure principle backflow preventer must prevent the relief valve discharge port from becoming submerged. Many plumbing codes prohibit a reduced pressure principle backflow preventer from being installed in a pit or underground, which can be interpreted as prohibiting the device from being installed in a basement that could be flooded. Other plumbing codes allow pit or underground installations if adequate drainage is provided to prevent the relief valve discharge port from being submerged.

Double check valve assemblies do not have the same concern about being submerged. Most plumbing codes allow double check valve assemblies to be installed in pits or underground. However, some plumbing codes do not allow these devices to be installed in a pit if the test cocks could be submerged, which could result in contamination of the potable water supply.

When installed outside, reduced pressure principle backflow preventers and double check valve assemblies must be protected from freezing in colder climates. Insulated enclosures and heated, insulated enclosures specifically designed for backflow preventers are available to protect the device from freezing. These outside enclosures also allow the water to discharge to the surrounding ground when a reduced pressure principle backflow preventer is installed. This avoids the need for a drain to be installed.

One of the most overlooked installation design requirements is the size of the floor drain in the immediate area of a reduced pressure principle backflow preventer. Table 9-4 lists the discharge flow rates from the relief valve for one manufacturer's reduced pressure principle backflow preventer with a water supply pressure of 80 psi. Table 9-5 lists the flow rates through a PVC drain pitched ¼ inch per foot flowing half full. The drain for a reduced pressure principle backflow preventer should have a flow rate equal to or greater than the discharge rate from the backflow preventer.

**Table 9-4 Reduced Pressure Principle Backflow Preventer Discharge Rates**

| Backflow Preventer Size, in. | Relief Valve Discharge Rate at 80 psi, gpm |
|---|---|
| 1½ | 80 |
| 2 | 150 |
| 3 | 240 |
| 4 | 620 |
| 6 | 620 |
| 8 | 620 |

**Table 9-5 Flow Rate Through a PVC Drain Pitched ¼ in./ft Flowing Half Full**

| Drain Size, in. | Flow Rate, gpm |
|---|---|
| 1½ | 8.3 |
| 2 | 15.7 |
| 3 | 39.6 |
| 4 | 81.7 |
| 6 | 243.6 |
| 8 | 505.2 |
| 10 | 927 |

All vacuum breakers must be installed in the orientation for which the device is listed (for example, vertical to horizontal orientation). The critical level, typically marked "CL" on the vacuum breaker, must be installed above the flood level rim. Atmospheric vacuum breakers typically require a minimum of 6 inches between the critical level and flood level rim. However, some special atmospheric vacuum breakers, often called deck-mounted vacuum breakers, can be installed 1 inch above the flood level rim. Pressure vacuum breaker are typically required to be installed a minimum of 12 inches above the flood level rim. A lower height may be acceptable if the device has been so tested and listed. The minimum height is specified by the manufacturer and is part of the vacuum breaker's listing.

## MEANS OF PROVIDING PROTECTION

The two philosophical approaches to providing protection against backflow are identified as point-of-use protection and point-of-supply protection. Point-of-use protection is based on providing some means of backflow protection at every opening, outlet, or connection to a nonpotable system. The goal of point-of-use protection is to provide an air gap whenever possible. When an air gap cannot be reasonably provided, an appropriate backflow preventer must be installed.

Point-of-supply protection is based on providing a backflow preventer at the water supply inlet to the building. This level of protection is either by a reduced pressure principle backflow preventer or a double check valve assembly. In some cities the installation of a break tank is also permitted, whereby the water supply fills a tank having an air gap on the water supply from the public utility. The water is pumped from the tank to the building.

Point-of-supply protection is designed to protect the public water supply against backflow, but it does not address backflow protection within the building. Point-of-supply protection is favored by the water utilities as a means of protecting the public supply. Point-of-supply protection may be required by the water utility for certain buildings.

Every plumbing code requires protection by point of use. This method is intended to ensure that the potable water supply is protected in both the building and the public main.

When point-of-supply protection is required by the water purveyor and point-of-use protection is required by the plumbing code, pressure problems within the water piping system can occur. If multiple backflow preventers lower the pressure below the required pressure to operate the plumbing fixtures or connected equipment, a pump system must be installed to elevate the pressure. The other option would be to remove the point-of-supply backflow preventer to increase the pressure as part of an engineered alternative design.

### Acceptable Level of Protection

The plumbing codes stipulate the required level of protection against backflow. An air gap is permitted by every plumbing code to protect any opening or outlet. When an air gap is not possible, the following backflow preventers can be used to protect the outlets, openings, or connections as identified:

- Reduced pressure principle backflow preventer: This backflow preventer can be used to protect any connection. The nonpotable system can contain any chemical or toxic substance.
- Double check valve assembly: This backflow preventer can be used to protect the water supply to a fire sprinkler or standpipe system. If antifreeze or conditioning chemicals are added to the fire sprinkler or standpipe system, a reduced pressure principle backflow preventer is required.
- Backflow preventer with an intermediate atmospheric vent: This backflow preventer can be used to protect the connection to a hot water or steam boiler that does not contain any conditioning chemicals. If conditioning chemicals are added to the boiler, a reduced pressure principle backflow preventer is required.
- Backflow preventer for carbonated beverage machine: This backflow preventer can be used to protect the water supply to a carbonated beverage dispenser.
- Dual check valve: This backflow preventer can be used to protect the water supply to juice dispensers, coffee makers, espresso machines, and humidifiers.
- Barometric loop: A barometric loop can protect a connection to any fixture or open vessel, tank, or vat. The vessel, tank, or vat can contain chemicals or toxic substances.

- Vacuum breaker (atmospheric, pressure, and spill resistant): Vacuum breakers can be used to protect the water supply to any connection that is open to atmosphere. If connected to a tank or vat, the tank or vat can contain chemicals or toxic substances.
- Hose connection vacuum breaker: This device can be used to protect the water supply on any outlet that has a hose connection.
- Heat exchanger: A double-wall heat exchanger can be used to protect the water supply when the heat transfer fluid is toxic, such as ethylene glycol. When a nontoxic heat transfer fluid, such as propylene glycol, is used, a single-wall heat exchanger may be used.

## TESTING BACKFLOW PREVENTERS

Testable backflow preventers must be tested and certified before being placed in service. The testing ensures that the backflow preventer will provide the level of protection required for the device. The types of backflow preventers that are testable include reduced pressure principle backflow preventers, double check valve assemblies, pressure vacuum breakers, and spill-resistant vacuum breakers.

Field testing is conducted in accordance with the protocol that is specified in ASSE 5000: *Cross-Connection Control Certification*. Field testing must be conducted by a certified backflow tester. For a reduced pressure principle backflow preventer, the testing verifies that the first and second check valves are properly operating and that the relief valve is properly functioning. For a double check valve assembly, the testing verifies that the first and second check valves are properly operating. For pressure vacuum breakers and spill-resistant vacuum breakers, the testing verifies that the check valve is properly operating and that the air inlet is properly admitting air.

After the initial testing of the backflow preventer, an annual test is required. In some jurisdictions, test reports must be filed with the jurisdiction to verify that the backflow preventer is operating as anticipated.

# ASPE Read, Learn, Earn Continuing Education

You may submit your answers to the following questions online at **aspe.org/readlearnearn**. If you score 90 percent or higher on the test, you will be notified that you have earned 0.1 CEU, which can be applied toward CPD renewal or numerous regulatory-agency CE programs. (Please note that it is your responsibility to determine the acceptance policy of a particular agency.) CEU information will be kept on file at the ASPE office for three years.

Notice for North Carolina Professional Engineers: State regulations for registered PEs in North Carolina now require you to complete ASPE's online CEU validation form to be eligible for continuing education credits. After successfully completing this quiz, just visit ASPE's CEU Validation Center at aspe.org/CEUValidationCenter.

Expiration date: Continuing education credit will be given for this examination through **January 31, 2018**.

**CE Questions — "Cross-Connection Control" (CEU 243)**

1. Which of the following can cause a reversal of flow in a water piping system?
   - a. water main break
   - b. change in pressure in the public main
   - c. fixtures being added to an existing system
   - d. all of the above

2. What is considered the highest level of protection against backflow?
   - a. barometric loop
   - b. air gap
   - c. vacuum breaker
   - d. reduced pressure principle backflow prevention assembly

3. Which of the following is the reversal of water flow when the pressure on the inlet side of the water supply is lower than that on the outlet side?
   - a. backpressure
   - b. reverse connection
   - c. siphonage
   - d. air gap

4. For a perfect vacuum, water can only rise ________ in a pipe.
   - a. 2.0 feet
   - b. 3.39 feet
   - c. 20 feet
   - d. 33.9 feet

5. Which of the following is required for backflow prevention if antifreeze or conditioning chemicals are added to a fire sprinkler or standpipe system?
   - a. dual check valve
   - b. vacuum breaker
   - c. reduced pressure principle backflow preventer
   - d. double check valve assembly

6. ________ is an example of a potential submerged inlet.
   - a. ice maker
   - b. heat exchanger
   - c. juice dispenser
   - d. storm sewer

7. Which of the following is designed to be installed in systems that are actively flowing water to the nonpotable supply?
   - a. reduced pressure principle backflow preventer
   - b. atmospheric vacuum breaker
   - c. backflow preventer with an intermediate atmospheric vent
   - d. double check valve assembly

8. What is the regulating standard for backflow preventers for carbonated beverage machines?
   - a. ASSE 1002
   - b. ASSE 1022
   - c. ASSE 1012
   - d. ASSE 1057

9. ________ are not permitted to be placed downstream of an atmospheric vacuum breaker.
   - a. water closets
   - b. flush valves
   - c. shutoff valves
   - d. hydrants

10. Tank-type water closets have internal ________ to protect against backflow.
    - a. anti-siphon ballcocks
    - b. frost-proof sillcocks
    - c. pressure vacuum breakers
    - d. atmospheric vacuum breakers

11. Which of the following was specifically developed for fire sprinkler and standpipe systems?
    - a. reduced pressure principle backflow preventer
    - b. atmospheric vacuum breaker
    - c. backflow preventer with an intermediate atmospheric vent
    - d. double check valve assembly

12. ________ is an example of a high hazard.
    - a. humidifier water
    - b. fertilizer
    - c. body fluid
    - d. both b and c