Drinking Water Operator Certification Training

Module #9: Cross-Connection Control and Backflow Prevention

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
Dering Consulting Group
Penn State Harrisburg Environmental Training Center

Topical Outline

Unit 3 – Detecting and Mitigating Backflow Occurrences

I. Indicators of Backflow
 A. Customer Complaints
 B. Pressure Reductions
 C. Loss of Disinfectant Residual
 D. Water Meters Running in Reverse
 E. Total Coliform Detections
 F. Reported Backflow Events

II. Mitigating Backflow Events
 A. Contaminated Area Isolation
 B. Public Notification
 C. System Flushing and Cleaning
 D. Pipeline Replacement
 E. Identify and Correct the Source of Contamination

Unit 4 – Current Cross-Connection Control and Backflow Prevention Practices

I. Regulatory Basis of Cross-Connection Control Programs
 A. PA Safe Drinking Water Act
 B. PA DEP Rules and Regulations

II. Typical Backflow Prevention Program (PA DEP Public Water Supply Manual Part VII)

Unit 1 – Overview of Cross-Connection Control and Backflow Prevention

Learning Objectives

- Define cross-connection and backflow.
- List five examples of common cross-connections.
- Explain why cross-connection control and backflow prevention are necessary.
- Define backsiphonage and backpressure and list potential causes for each.
- Describe the conditions needed for backflow to occur.

Definitions

Backflow

Backflow is a flow condition, induced by a differential pressure, which causes the flow of water, or mixtures of water and other substances, into the distribution pipes of a potable water supply system from a source other than its intended source.[2]

- Backflow can result from backsiphonage or backpressure. Backsiphonage and backpressure are discussed in more detail later in this unit.

Cross-Connection

A **cross-connection** is an arrangement allowing either a direct or indirect connection through which backflow, including backsiphonage, can occur between a system containing a source or potential source of contamination and the drinking water in a public water system. Simply put, a cross-connection links a source of pollution with a potable water supply.

- Cross-connections allow treated water to be removed from any public water system, used for any purpose or routed through any device or pipes outside the public water system, and returned to the public water system.
- Cross-connections do not include connections to devices totally within the control of one or more public water systems and connections between water mains.
- There are two basic types of cross-connections: direct and indirect.
  - A direct cross-connection is subject to backflow by backpressure. A potable water makeup water line that supplies a boiler is one example of a direct cross-connection.

Figure 1.1 Direct Cross-Connection[1]

  - An indirect cross-connection is not subject to backflow by backpressure. Consequently, backflow can only occur due to backsiphonage. An over- the-rim type inlet, used to fill an open vessel, is an example of an indirect cross-connection.

Common Cross-Connections

Cross-connections can be difficult to identify. Many common situations that appear harmless can be actual or potential cross-connections. Because of the dynamic nature of water systems, with constant expansions and modifications occurring, the ability to identify cross-connections is very important. A connection between a drinking water system and a non-potable water system, such as a fire protection system or process water system is an obvious cross-connection, but others are not so obvious. Cross-connections can occur in complex piping arrangements within buildings and equipment or at a simple connection like a wash sink with a hose attached.

List some examples of common cross connections that you can think of and be prepared to discuss them with the class.

____

____

____

____

Importance of Cross-Connection Control and Backflow Prevention

The primary purpose of controlling cross-connections and preventing backflow is to protect public health.

Water Quality and Health/Safety

- Water suppliers go to great effort and expense to produce and deliver high quality drinking water that is safe for consumption. Increasingly stringent water quality regulations continue to improve the quality and safety of drinking water. This requires increased diligence on the part of system operators to assure that their finished water meets or exceeds all water quality standards. In order to provide high quality water to customers' taps, the integrity of the water produced at the source must be maintained throughout the distribution system. Consequently, cross-connections must be controlled and backflow of water and/or other substances into the water system must be prevented.
- The health effects associated with backflow contamination events are as varied as the materials that can backflow into and contaminate water systems. The most common contaminants are biological, although chemical and other physical contamination does occur.
- Health effects commonly include outbreaks of gastrointestinal illnesses of varying severity, although other illnesses and deaths have occurred.
- The degree of risk associated with a cross-connection depends on the substance that may be backflowed. The degree of protection required for a cross-connection must reflect the degree of potential hazard.

Contamination Events

There are many unique ways that backflow contamination of drinking water can occur. The following are just a few examples of backflow contamination events:

- **Garden Hose**

  In 1982 in Bancroft, MD, backflow from a hose-end pesticide sprayer contaminated the water supply when a main was shut down to replace a valve. The event caused a malathion mixture to flow into the water distribution system; two days of flushing were required to remove the contamination.

  In another system, chlordane that had been used at a house for exterminating termites was determined to have flowed back into the distribution system when a hose was immersed into a container of chlordane concentrate and backsiphoned through the house piping to the distribution system. Varying water pressure caused by several water main breaks in the area is believed to have caused the backsiphonage. The water purveyor was unable to remove all traces of chlordane from the water mains and was forced to replace three blocks of water mains, pay claims for injuries, and replace plumbing in 47 homes.

- **Air Conditioning System**

  At Red River College in Winnipeg, Manitoba, a valve in the air conditioning system was left open. A pressure of 140 psi in the air conditioning system compared to 60 psi in the city's distribution system resulted in water treated with a corrosion inhibitor containing chromium entering the potable water system.

- **Defective Valve**

  On a vessel in a Portland, OR, shipyard in 1943, a valve that connected the drinking water to the fire water supply was found to be defective. 1,179 people became ill when contaminated harbor water was pumped through the fire lines, forcing the bacteria-laden water into the drinking water supply.

- **Booster Pumps**

  In 1997, a fire truck pump created backpressure on a fire hydrant before the valve was closed, which forced over 60 gallons of aqueous fire-fighting foam into an estimated 40,000 neighborhood taps in Charlotte-Mecklenburg, NC.

- **Irrigation System**

  A homeowner in Keller, TX, reported finding small worms in his toilet bowl and in water he poured into his coffee maker. He collected samples and provided them to water department personnel who informed him that they were nematodes and likely came from his own irrigation system. The source of the worms was traced back to the irrigation system and backflow through a nine-year old double check valve assembly that had not been tested since installation. This example highlights the importance of backflow prevention and also the need to properly test and maintain backflow prevention devices.

What backflow contamination events are you aware of?

____

____

____

____

Statistics on Backflow and Related Outbreaks

The EPA has compiled data on more than 450 backflow incidents occurring between 1970 and 2001. It is widely believed, however, that only a small percentage of backflow events are detected and reported. Backflow events are generally only reported when customers detect a change in water quality. Some contaminants cannot be detected by taste, odor or sight. Also, system operators are often reluctant to report suspected incidents due to fear of legal liability and loss of customer confidence. Detection and mitigation of backflow events will be discussed further in Unit 3.

- From 1981 to 1998, the Centers for Disease Control (CDC) documented 57 waterborne disease outbreaks related to cross-connections, which resulted in 9,734 illnesses.
    - 20 outbreaks were caused by microbiological contamination.
    - 15 outbreaks were caused by chemical contamination.
    - 22 outbreaks had no contamination event reported.
- A 2001 study by Craun and Claderon reported that more than 30 percent of waterborne disease outbreaks in community water systems during 1971 to 1998 were caused by contamination of water in the distribution system. Of these, more than 50 percent were due to cross-connection and backflow.[3]
- A study by the American Water Works Association (AWWA) reports that in recent history, 78 percent of all waterborne disease outbreaks were caused by cross-connections and backflow, and that cross-connections and backflow caused 95 percent of all waterborne disease outbreaks associated with distribution system contamination in community water systems.[4]

As previously discussed, backflow is the reverse flow of water or other substances into the potable water system from a source other than the intended source. Backflow can occur due to backsiphonage or backpressure.

Backsiphonage

Backsiphonage is the backflow of water (or a mixture of water and other substances) from a plumbing fixture or other customer source, into a public water supply system due to a temporary negative or sub-atmospheric pressure within the public water supply system.

- Backsiphonage occurs when atmospheric pressure exerted on a pollutant forces it toward a potable water system that is under vacuum.
- The water system main does not have to be under a true vacuum (i.e., zero psi absolute pressure or –14.7 psi gage pressure) for backsiphonage to occur. Only a negative difference in pressure and a full pipe or tube is required to produce backsiphonage.

Potential Causes of Backsiphonage

Negative or sub-atmospheric pressures in the water system, which can lead to backsiphonage, are often caused by high demands or high flow rates. System headloss caused by friction losses and minor losses, as well as demand for flow beyond the supply capacity, can result in negative or sub-atmospheric pressure in the system. The following are several common occurrences that can result in negative or sub-atmospheric pressure and can potentially cause backsiphonage:

- **Hydrant Operation**

  Flowing hydrants for fire fighting, hydraulic testing, system flushing and other reasons can result in high flow rates and low systems pressures.

- **Main Break**

  Main breaks can result in the discharge of large volumes of water at very high flow rates, causing low system pressures.

- **High Demands**

  High demands can result in negative or sub-atmospheric pressures when the hydraulic capacity of the system is exceeded, causing low pressure due to friction and minor losses. Also, when water demands exceed supply capacity, low pressure can develop.

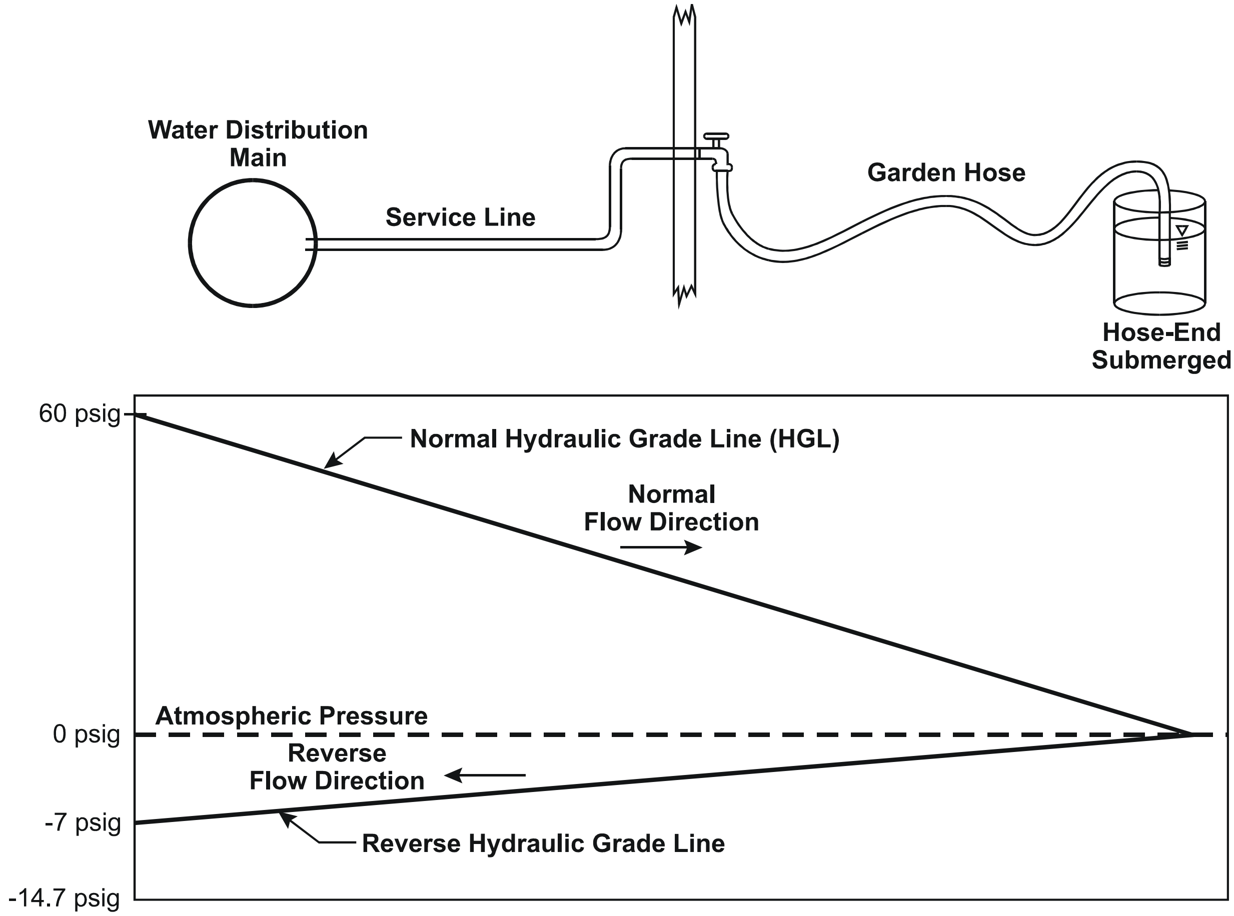


Figure 1.2 Backsiphonage

- **Shutdown of Water Main or Internal Piping**

  When a water main is shut down (such as for repairing a water main break) or customer piping is shut down (such as for repairs or installation of new equipment) the potential exists for backsiphonage if the system is then opened at a point lower in elevation than the shutdown. The water in the piping will drain to the open point or point of water use and may also siphon (backflow) from sources it may contact.

- **Pressure Transients, Surge, and "Water Hammer"**

  Pressure transients, or surges, are commonly referred to as "water hammer." They are generated by a rapid change in flow velocity commonly caused by quickly opening or closing hydrants, valves, or the startup/shutdown of a pump. Transient low pressures can be negative or sub-atmospheric, resulting in a potential for backsiphonage to occur.

Booster Pumps

Operation of booster pumps without a low pressure cutoff switch can result in negative pressures on the suction side of the pumps, causing a potential for backsiphonage.

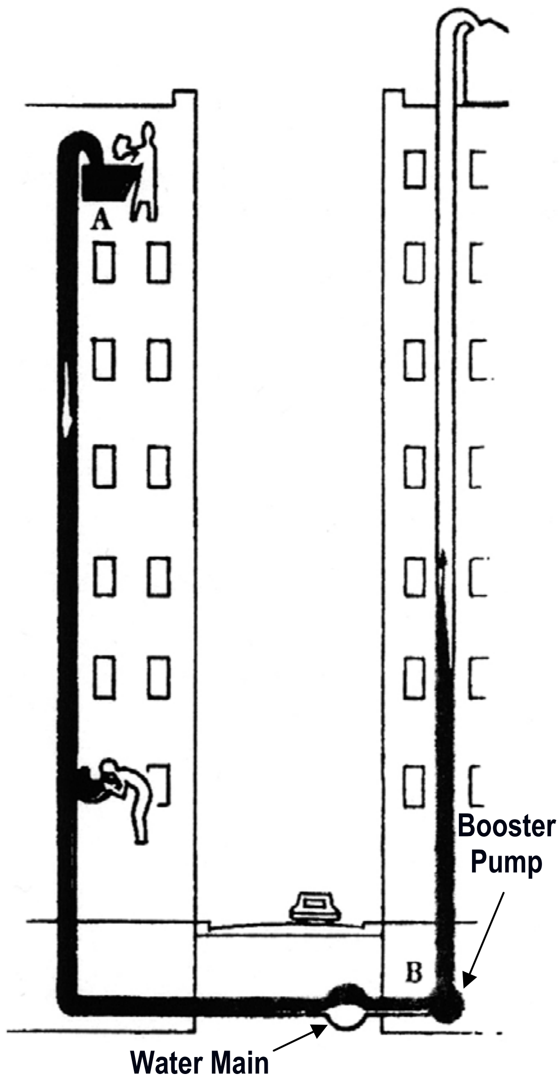


Figure 1.3 Backsiphonage Caused by a Booster Pump [5]

Elevation differences can greatly magnify the effects of low-pressure occurrences, resulting in the potential for backsiphonage. For example, a system may be capable of delivering a flow of 1,500 gpm to a hydrant in a low elevation section of the system, while maintaining an adequate residual pressure at the flowing hydrant; but the reduced hydraulic grade line may translate to negative pressures in pipelines at higher elevations.

Backpressure

Backpressure is the backflow of water, or a mixture of water and other substances, from a plumbing fixture or other customer source, into a public water supply system due to a pressure in the fixture or customer source that exceeds the system pressure.

Backpressure can occur for two reasons:

- An increase in pressure in the customer system.
- A decrease in pressure, to below the customer system pressure, in the public water system.

Potential Causes of Backpressure

- Pumps, boilers, and air/steam pressure in the customer system increase pressure and can cause backflow to the water supply system.
- If pressure decreases in the water supply system, the weight of water in high-rise building piping can provide enough pressure to cause backflow.

Conditions Necessary for Backflow to Occur

Distribution systems are pressurized to provide a driving force for the flow of water from the water supply system to the customer.

- The normal hydraulic gradient slopes from the supplier to the customer. As previously discussed, there are two basic occurrences that can cause the hydraulic gradient to reverse and flow to occur from the customer system to the distribution system. An increase in pressure in the customer system or a decrease in pressure in the distribution system can result in a reversal of the normal hydraulic gradient.
- In order for a backflow contamination event to occur, each of the three following conditions must occur:
    - **Existing Cross-Connection**
      A cross-connection, either permanent or temporary, between the drinking water system and a source or potential source of contamination must exist for backflow to occur.
    - **Backsiphonage or Backpressure Conditions**
      An event or condition must occur to either increase the pressure in the customer system or decrease the pressure in the drinking water system to reverse the hydraulic gradient and provide the potential for backflow.
    - **Unprotected Cross-Connection or Failure of Protection Device**
      The cross-connection must either be unprotected by a backflow prevention device or an existing backflow prevention device must fail to function properly.

Key points for Unit 1 – Overview of Cross-Connection Control and Backflow Prevention

- Backflow is a flow condition caused by a differential pressure and is an undesirable situation.
- A cross-connection is an arrangement that may allow backflow.
- Cross connections can be difficult to identify.
- The primary purpose of controlling cross-connections and preventing backflow is to protect public health.
- Contamination events for drinking water have been documented for a variety of devices including garden hoses, air conditioning systems, valves, booster pumps, and irrigation systems.
- The EPA has reported that more than 450 backflow incidents occurred between 1970 and 2001. This may be only a small percentage of actual occurrences.
- Backflow can occur due to backsiphonage or backpressure.
- Backflow contamination can occur if there are existing cross-connections, backsiphonage or backpressure conditions, and unprotected cross-connection or failure of protection devices.

Exercise for Unit 1 – Overview of Cross-Connection Control and Backflow Prevention.

1. **The two basic types of cross-connections are_____________and_______________.**
2. **Backflow is a flow condition caused by______________________pressure.**
3. **The most common backflow contaminants are__________________although chemical and other physical contamination can also occur.**
4. **List three examples of common backflow contamination events:**
   - **a.______________________**
   - b.____________________
   - c.____________________
5. The normal hydraulic gradient slopes from the_____________________to the _____________.

[1] University of Southern California Foundation for Cross-Connection Control and Hydraulic Research website: http://usc.edu/dept/fcchr/introduction.html.

[2] Public Water Supply Manual - Part VII Cross-Connection Control/Backflow Prevention, Commonwealth of Pennsylvania, Department of Environmental Protection, June 18, 2001. [Document Number 383-3100-111], p. 2.

[3] An Issues Paper by the EPA's Office of Ground Water and Drinking Water, "Potential Contamination Due to Cross-Connections and Backflow and the Associated Health Risks," August 13, 2002, pp. 6-7.

[4] An Issues Paper by the EPA's Office of Ground Water and Drinking Water, "Potential Contamination Due to Cross-Connections and Backflow and the Associated Health Risks," August 13, 2002, pp. 6-7.

[5] *Cross-Connection Control Manual*, United States Environmental Protection Agency Office of Drinking Water, June 1989, Reprinted 1995, [EPA 570/9-89-007].

Unit 2 – Backflow Prevention Methods

Learning Objectives

- List and explain three methods for backflow prevention.
- List seven types of backflow prevention devices and for each type:
    - Identify its schematic.
    - Explain its operation.
    - List its advantages and disadvantages.
    - Describe its application(s).

Cross-Connection Control Program

Implementing an effective cross-connection control program is an important step in reducing the potential for backflow contamination of the water system. The goal of these programs is to eliminate cross-connections where possible and adequately protect other cross-connections to prevent backflow. A cross-connection control program also establishes a legal foundation for enforcement of the backflow prevention rules and regulations. Cross-connection control programs are discussed in more detail in Unit 4 and in the PA DEP Water Supply Manual – Part VII.

Public Awareness

Public awareness and education can successfully prevent many potential cross-connections. Cross-connections are often created unintentionally or unknowingly. Examples of unintentional cross-connections include unprotected connections to irrigation systems and a hose-end submerged in a bucket of pesticide that is being diluted.

The number of cross-connections unknowingly created by customers can be reduced through public education of the dangers associated with cross-connections and backflow. The number of intentionally created cross-connections can also be reduced by ensuring that the public understands the dangers of unprotected cross connections.

PA DEP Public Water Supply Manual, Part II, Chapter 8.1.1 specifies that water systems must maintain a minimum pressure of 20 psi at ground level at all points in the water distribution system under all conditions of flow and that the normal working pressure in the distribution system should be approximately 60 psi.

- Maintaining an adequate system pressure will reduce the risk of backflow.
- Systems with higher operating pressures require even higher levels of pressure to produce backflow by backpressure; therefore, the risk of backflow contamination is reduced.
- By maintaining the minimum system pressure at all times, the potential for backflow contamination by backsiphonage is also reduced.

Common methods for maintaining reliable and adequate system pressure are discussed below. This is only a partial list of water system operating practices that can help to maintain system pressure and reduce the likelihood of backflow occurrences.

Distribution System Capacity and Maintenance

- As discussed in Unit 1, system headloss (due to pipe wall friction, fittings, valves, etc.) during high flow periods can result in low and/or negative system pressures. Maintaining adequate hydraulic capacity throughout the system can reduce the head losses that occur during high flow periods, thereby reducing the potential for backflow.
- Eliminating unintentionally closed valves and other restrictions can reduce the chance of backflow by improving hydraulic capacity in the distribution system. It also avoids unintentionally isolating portions of the system when system valves are closed for maintenance activities. An isolated section of main is especially prone to backsiphonage if a tap is opened at a low elevation point in the main, as discussed in Unit 1.

Redundant Equipment

- When system demands exceed the capacity of the supply to the area, low and/or negative pressures can develop, exposing the system to potential backflow by both backpressure and/or backsiphonage. Equipment redundancy, such as backup pumps or control valves, can allow a system, or portion of the system, to be adequately supplied when other equipment is taken out of service for maintenance, repair, a power outage, or for other reasons.

Pressure Transient (Surge) Control

A complete discussion of pressure transients, also known as surge or water hammer, is beyond the scope of this course. However, a basic understanding of pressure transients and how they can potentially result in backflow occurrences is important.

- Most operators are familiar with the rapidly varying pressures that often occur when flow is quickly started or stopped at pumps, valves, hydrants and other system equipment.

- Aside from the potentially damaging effects that these pressure transients have on system facilities, the pressure transients can also result in brief periods of low and/or negative pressure in the water system, making the system susceptible to backflow by backpressure and backsiphonage. Proper operating procedures for system facilities can reduce the number of occurrences and the magnitude of pressure transients, thereby reducing the potential for contamination by backflow.

    - Pump flow should be started and stopped gradually. Flow rate changes should also be made gradually. This can be accomplished by using the ramping features on variable speed drives, soft-starters, and operating pump discharge valves during startup and shutdown operations. More gradual flow rate changes will reduce the magnitude of the pressure transients that are generated.

    - Hydrants and valves should be opened and closed slowly, especially for the first several turns of opening and the last several turns of closing. Due to the inherent characteristics of most valves and hydrants, the first few turns of opening and the last few turns of closing result in the largest flow rate change per valve turn. Slowly opening and closing valves and hydrants can reduce the magnitude of the pressure transients that are developed.

There are many devices for preventing backflow from backsiphonage and/or backpressure from contaminating a potable water supply. The proper device for each application is selected based on:

- The degree of hazard posed by the cross-connection.
- The probability of backflow (i.e., an area subject to low pressure or with a booster pump on-site.)
- Piping size.
- Connection location.
- The need for periodic testing of the devices.

Backflow prevention devices and assemblies are intended to protect the water system if other backflow prevention approaches, such as maintaining air gaps at fixture outlets, fail or are bypassed.

- Prevention devices are commonly installed at the customer's connection to the water system. This approach is called containment because it keeps potential contaminants on site.
- Prevention devices can also be installed at individual cross-connections within a facility. This approach is called isolation since backflow prevention occurs at the cross-connection and prevents contaminants from entering the customer system.
- Often, these approaches are combined. Devices are installed at individual fixtures to protect the on-site system from contamination (isolation). These fixture outlet devices can be more easily by-passed, though, so backflow prevention assemblies are also installed at the customer connection to the public water supply to contain potential contaminants.

Identification of Hazard Types

The type of backflow prevention device used at the point of cross-connection depends on the type of substance that may flow into the potable supply. Hazard types are commonly divided into Hazardous Facilities and Aesthetically Objectionable Facilities.

Hazardous Facilities

A **hazardous facility** is one where any condition, device, or practice could create a danger to the health and well being of the system users. The highest level of backflow prevention, either an air gap or a reduced pressure zone device, should be required at these facilities.

Examples of hazardous facilities include:

- Sewage treatment plants.
- Petroleum processing facilities.

What are additional examples of hazardous facilities?

Additional examples of hazardous facilities and applicable backflow prevention devices can be found in the PA DEP Water Supply Manual, Part VII and other backflow prevention publications.

Aesthetically Objectionable Facilities

An **aesthetically objectionable facility** is one that may create an impairment of the water quality that is not a hazard to the public health, but does adversely and unreasonably affect the aesthetic qualities of the water.

Examples of aesthetically objectionable facilities include:

- Sprinkler system.
- Facilities using high temperature potable water.

These facilities are often required to have double check valve assemblies.

What are additional examples of aesthetically objectionable facilities?

____

____

____

____

Additional examples of aesthetically objectionable facilities and applicable backflow prevention devices can be found the in PA DEP Water Supply Manual, Part VII, and other backflow prevention publications.

Types of Backflow Prevention Devices

Air Gap

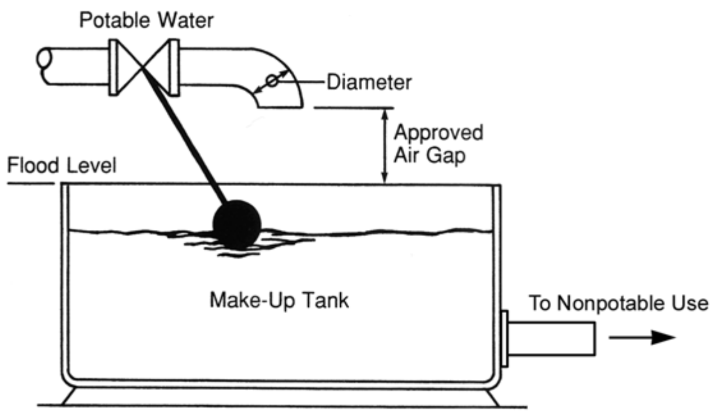


Figure 2.1 Schematic of Air Gap on a Tank [1]

Operation of an Air Gap

An **air gap** provides a physical separation between the end of a potable water supply line, faucet, plumbing fixture or other device, and the flood level rim of an open or non-pressurized receiving vessel.

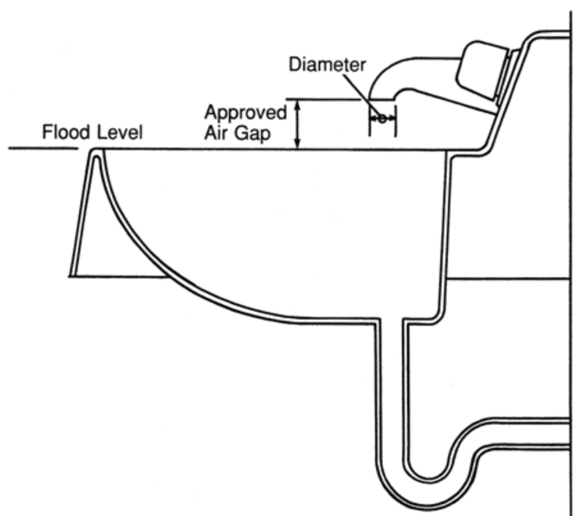


Figure 2.2 Air Gap on a Lavatory [2]

- The air gap is a non-mechanical backflow preventer consisting of an unobstructed vertical distance through free atmosphere between the lowest point of a water supply outlet and the flood level of the fixture being discharged to.

A well-designed and maintained air gap is theoretically the best means available for protection against backflow, and is the only absolute means to eliminate backflow. However, air gaps are impractical in some applications and can be easily bypassed and rendered ineffective.

Advantages and Disadvantages of an Air Gap

Advantages

Air gaps prevent backflow caused by both backsiphonage and backpressure.

Air gap installations provide the maximum degree of protection against backflow and are recommended for health hazard risks.

Disadvantages

Air gaps can be easily bypassed by purposely or inadvertently lowering the supply outlet, such as with the addition of a hose.

Air gaps interrupt the piping flow, causing a loss of pressure. Pressure must often be reestablished using additional pumping or elevated water storage, which can significantly increase the expense of backflow prevention.

The water is exposed to the atmosphere, which can introduce bacteria, dust or other contaminants.

Free chlorine can be removed from water by contact with air at the air gap and churning and splashing as the water enters the receiving device.

Applications of an Air Gap

Air gaps are typically used when filling a tank or reservoir as well as at sinks, tubs and similar applications. The following information is from the PA DEP Water Supply Manual which describes appropriate air gaps for various fixtures.

Typical air gaps are at least 2 x diameter of the effective opening. More detailed information is available at the PA DEP reference at the end of this unit. [3]

Barometric Loop

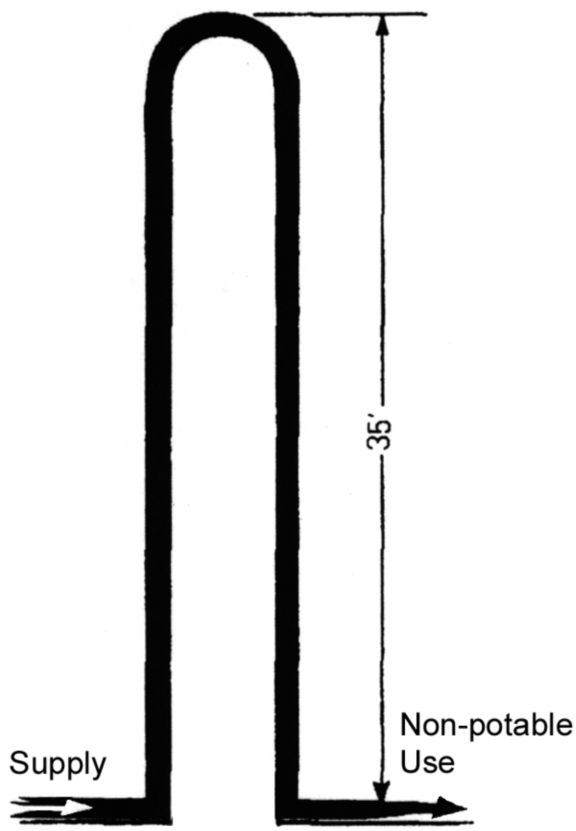


Figure 2.3 Barometric Loop [4]

Operation of a Barometric Loop

A **barometric loop**, as shown in Figure 2.3, consists of a section of supply piping that abruptly rises to a height of 35 feet or more and returns back to the original level, operating on the principle that the largest vacuum pressure that can develop in the potable water is 14.7 psi, or a "full vacuum."

Advantages and Disadvantages of a Barometric Loop

Advantages	**Disadvantages**
Simple operation principles.	Does not protect against backflow resulting from backpressure.
Inexpensive to purchase, install, operate and inspect.	Only protect against backflow resulting from backsiphonage.
Easy to maintain and operate.	Often not practical due to height.

Applications of a Barometric Loop

Barometric loops are not commonly used and may only be used where there is no risk of contamination by backpressure. They are not commonly used because they are 35-feet high, which is impractical to construct in most cases. However, an operator might encounter one and should be aware of the application principle.

An example of the limitations that air pressure can impose on suction pumps can be illustrated by a fire truck. If a fire truck is parked on a bridge over a river and tries to fill its water tank by drawing water out of the river below, it can only do so if the pump is less than 33.87 feet above the water level. This is explained below.

1 cubic foot of water = 62.425 pounds

1 cubic foot / 144 square inches = 0.434 pounds (This means that a column of water 1 inch square x 1 foot high will weigh 0.434 pounds.)

If the standard air pressure is 14.7 pounds per square inch, then
14.7 pounds / 0.434 pounds per foot = 33.87 feet

This means that the fire truck will not be able to draw water using a suction pump unless the pump is less than 33.87 feet above the water level.

In the barometric loop example above, a height of 35 feet is used and that provides a safety margin over the calculated value of 33.87 feet. These numbers are accurate when considering backsiphonage only. If back pressure is involved, backflow may still occur.

Double Check Valve Assembly (DCVA)

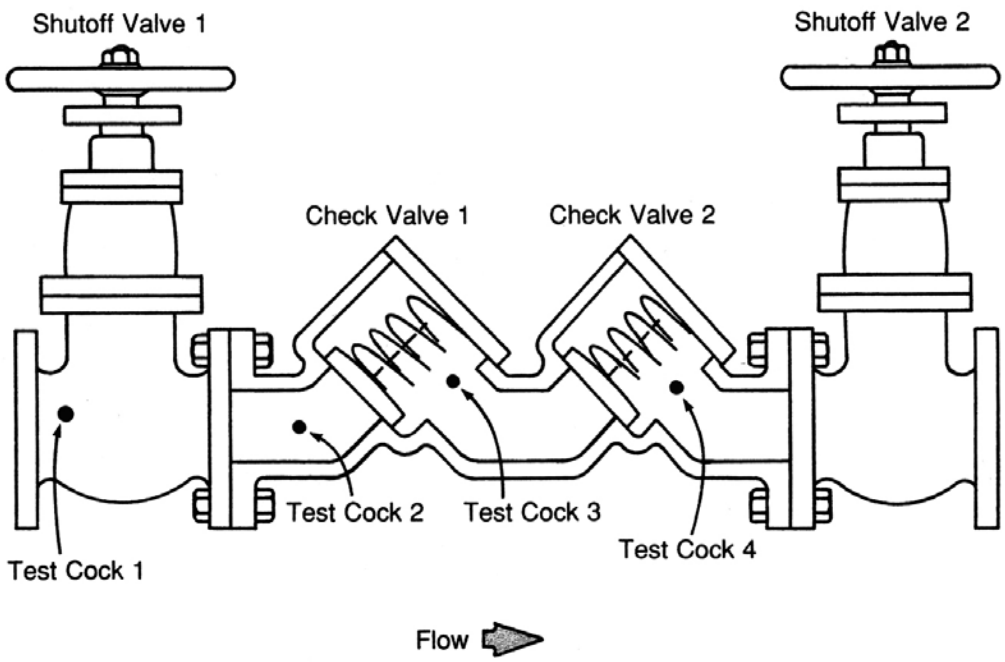


Figure 2.4 Schematic of Double Check Valve Assembly [5]

Operation of a Double Check Valve Assembly

The **Double Check Valve Assembly (DCVA)** consists of two ***independently acting***, soft seated, spring-loaded check valves in series within one body, with two tightly closing shutoff valves and four test cocks.

- During normal operation, the check valves open and permit flow from the potable water system to the customer. If backflow conditions occur due to either backpressure or backsiphonage, the check valves will close tightly and prevent potential pollution of the potable water system.

Advantages and Disadvantages of a Double Check Valve Assembly

Advantages	**Disadvantages**
Prevent backflow due to both backpressure and backsiphonage.	Does not have differential pressure relief valves like RPZDs and are therefore not as reliable.
Can be readily tested.	Can fail without giving an exterior indication that a failure has occurred.
The spring loaded check valves provide the ability to "bite" through small pieces of debris and still seal.	Are mechanical devices that require periodic testing and maintenance.
When the check valves are in the wide-open position, there is relatively little resistance to flow. Typically, the headloss through the device ranges between 3 and 11 psi, depending on the rate of flow and diameter of pipe.	

Applications of a Double Check Valve Assembly

DCVAs are commonly utilized at facilities, such as apartment buildings, with pollutants that are non-health hazards but may be objectionable to the water supply system.   A schematic example of a DCVA application at a non-hazardous industrial facility is shown below.

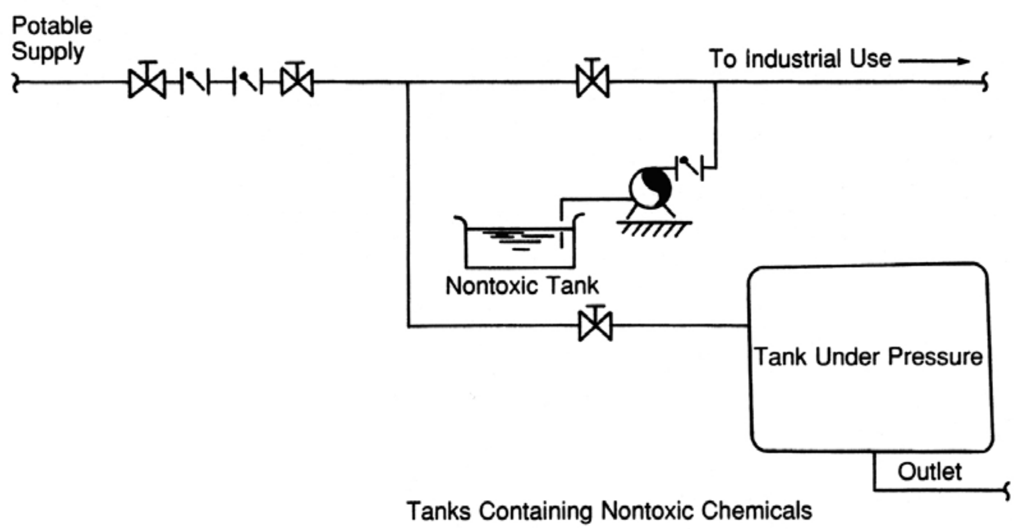


Figure 2.5 Typical Double Check Valve Assembly Application [6]

Reduced Pressure Zone Device (RPZD)

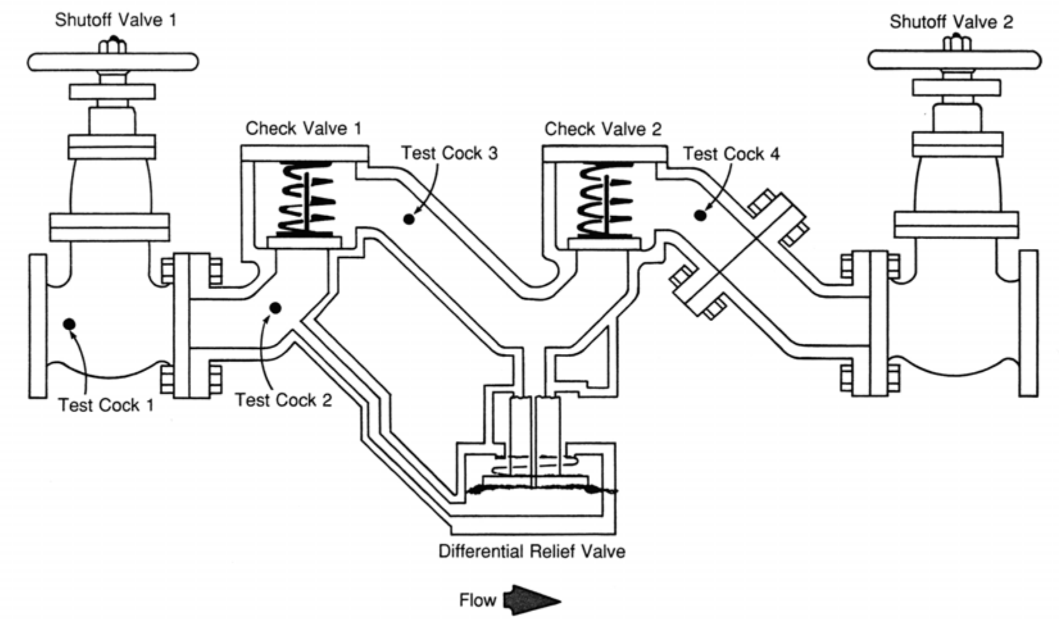


Figure 2.6 Schematic of Reduced Pressure Zone Device [7]

Operation of a Reduced Pressure Zone Device

The Reduced **Pressure Zone Device (RPZD)** consists of two ***independently acting***, soft seated, spring-loaded check valves in series within one body. This is like the DCVA, however, the RPZD also includes a soft-seated, spring-loaded, diaphragm-activated, pressure differential valve, located in the zone between the check valves. The RPZD also includes two tightly closing shutoff valves and four test cocks.

- During operation, the first check valve creates a reduced-pressure zone between the two check valves and the relief valve is held closed by pressure acting on the diaphragm within the relief valve. In a no flow condition, both check valves will close and the supply pressure will hold the relief valve shut. If the supply pressure drops, the relief valve will maintain a minimum pressure in the zone between the check valves of 2 psi lower than the supply pressure. This is accomplished by releasing sufficient water to maintain the required difference in pressure. If the supply pressure drops below 2 psi, the relief valve opens and discharges the material in the reduced-pressure zone to the atmosphere.

- If pressure increases downstream of the assembly, both check valves should close tightly to prevent backflow. If the second check valve does not close tightly, leakage into the reduced-pressure zone will increase the pressure, causing the relief valve to open. If the supply pressure drops to atmospheric pressure or within 2 psi of the reduced-pressure zone, the relief valve will open, creating an internal air gap. The RPZD will indicate leakage through one or both check valves or the relief valve by discharging water from the relief valve port.

Advantages and Disadvantages of a Reduced Pressure Zone Device

Advantages	Disadvantage
Provides protection from backflow resulting from both backpressure and backsiphonage.	RPZDs are mechanical devices that require periodic testing and maintenance.
Can be used at health hazard installations where an air gap cannot be utilized.	RPZDs cause pressure losses of 10 to 30 psi during operation, depending on flow rate and device size.
Indicates malfunction by the discharge water from the relief port.	RPZDs should not be installed below ground level (or where flooding could occur), must be protected from freezing, and must be installed with adequate space to facilitate maintenance and testing.
Can be used under constant pressure.	

Applications of a Reduced Pressure Zone Device

The RPZD effectively protects against backflow caused by backpressure and backsiphonage and may be used to isolate health hazards. The RPZD is typically used where air gaps are impractical. Funeral parlors and hospital autopsy rooms, as shown schematically in Figure 2.7, are two examples of where an RPZD would be used.

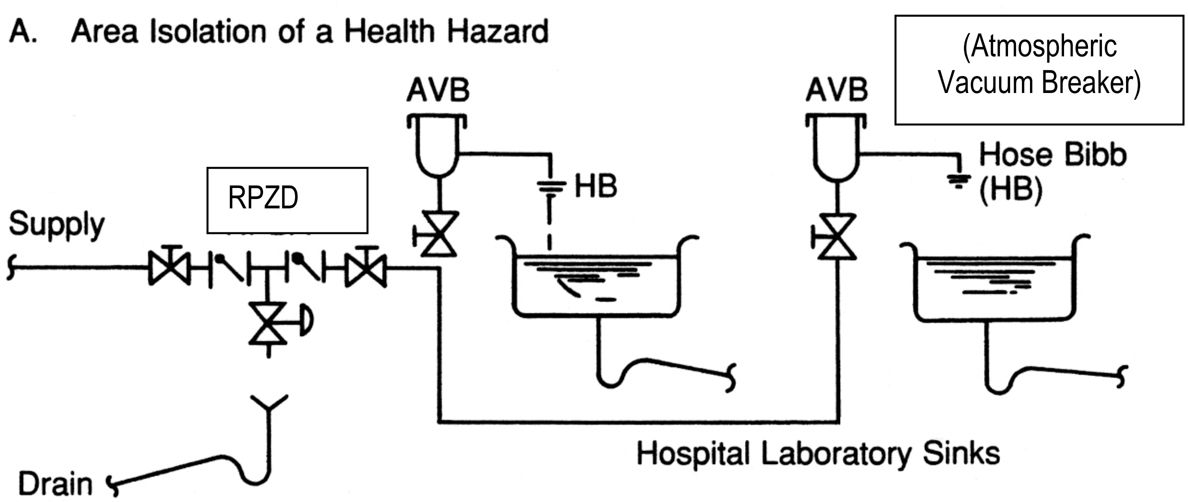


Figure 2.7 Typical Reduced Pressure Zone Device Application [8]

Residential Dual Check Valve (RDCV)

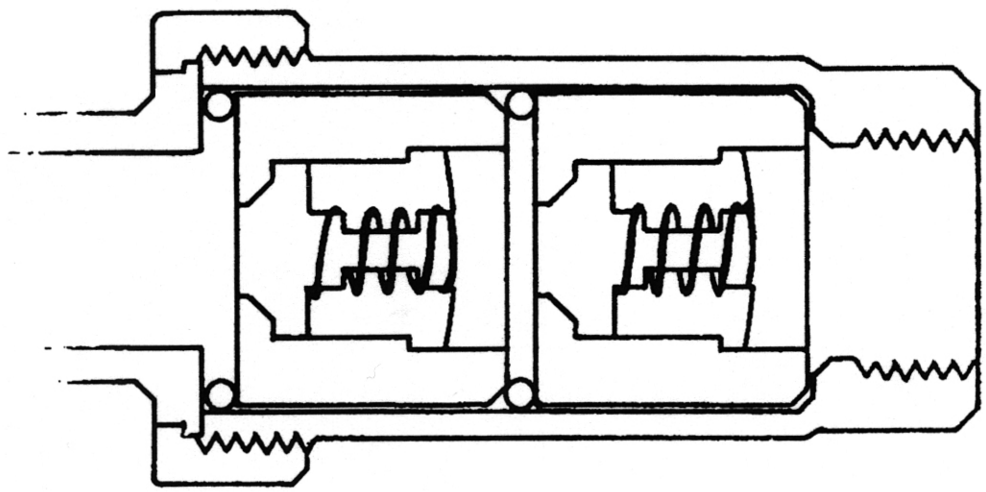


Figure 2.8 Residential Dual Check Valve Schematic [9]

Operation of a Residential Dual Check Valve

The **Residential Dual Check Valve (RDCV)**, consists of two spring-loaded, independently acting check valves in a single valve body. The check valves close to prevent backflow by backpressure and/or backsiphonage.

Advantages and Disadvantages of a Residential Dual Check Valve

<u>Advantages</u>	<u>Disadvantages</u>
Inexpensive and therefore practical to install at individual residences.	Non-testable device. This device is constructed in a manner to make it affordable and allow for installation at individual residences. As such, it is not equipped with test ports and is therefore considered "non-testable."
Effective protection against backflow from backpressure and backsiphonage.	Provides no indication of malfunction.

Applications of a Residential Dual Check Valve

Residential dual check valves are typically installed at individual residences, as shown in Figure 2.9, to protect against household hazards such as cleaning chemicals, pesticides, fertilizers, and other substances used in the home. They are typically available in sizes from 1/2 –inch through 1-inch and are installed in-line, downstream of the service meter. Shutoff valves are not included but may be installed separately.

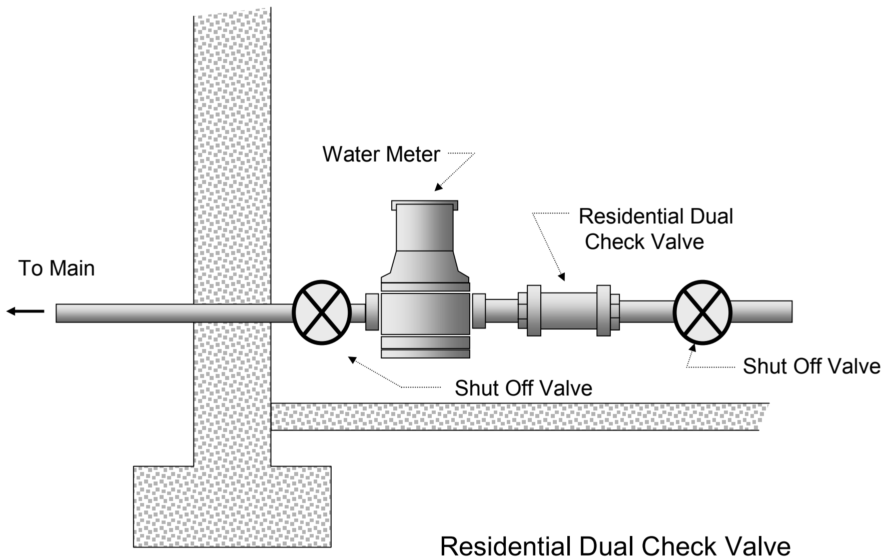
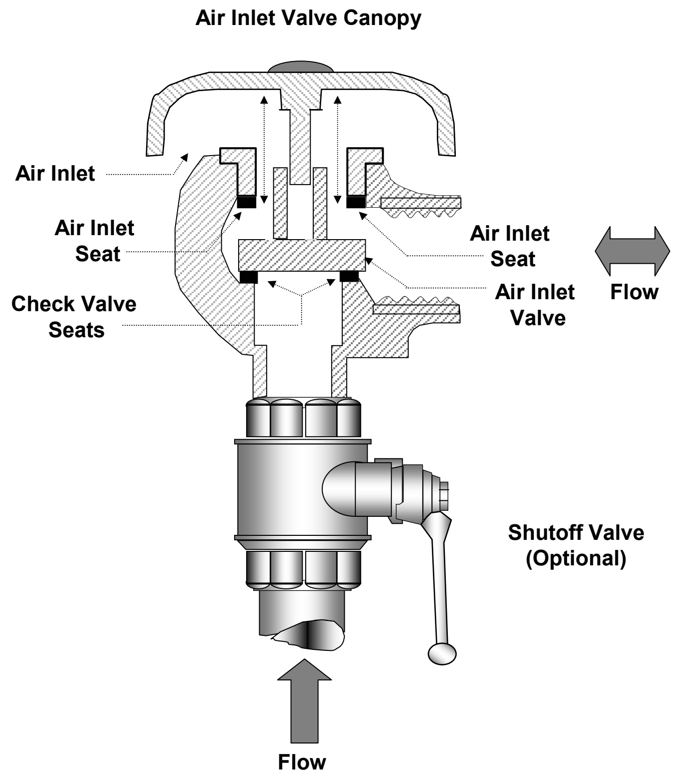


Figure 2.9 Typical Application of Residential Dual Check Valve [10]

Atmospheric Vacuum Breaker (AVB)



Schematic of Atmospheric Vacuum Breaker Assembly

Figure 2.10 Schematic of Atmospheric Vacuum Breaker Assembly [11]

Operation of an Atmospheric Vacuum Breaker

An **Atmospheric Vacuum Breaker (AVB)** consists of a float check valve, a check seat, and an air inlet port.

- During normal flow operation, the flow seals the check against the air inlet seat. When a backsiphonage condition develops, normal flow stops, the float check drops to the check seat and the air inlet is opened. The open air inlet will dissipate vacuum conditions, preventing backsiphonage, should the check fail to seat properly.

Advantages and Disadvantages of an Atmospheric Vacuum Breaker

Advantages	Disadvantages
One of the simplest and least expensive mechanical backflow preventers.	Does not protect against backflow caused by backpressure.
Provides trouble-free and reliable service.	Not for continuous use. AVBs cannot be kept under pressure for more than 12 hours during any 24-hour period because the air inlet disc can become stuck in the closed position, rendering the device ineffective.
Prevents backflow caused by backsiphonage.	Not testable.

Applications of an Atmospheric Vacuum Breaker

AVBs are typically installed at fixture outlets to prevent backsiphonage for non-health hazards. They are also used to isolate a health hazard if additional backflow prevention methods (such as RPZD) are utilized on the premises. AVBs are typically installed with a shutoff valve that is upstream from the AVB. An AVB should be installed at least 6 inches above the fixture outlet and must be installed vertically and not have shutoff valves downstream.

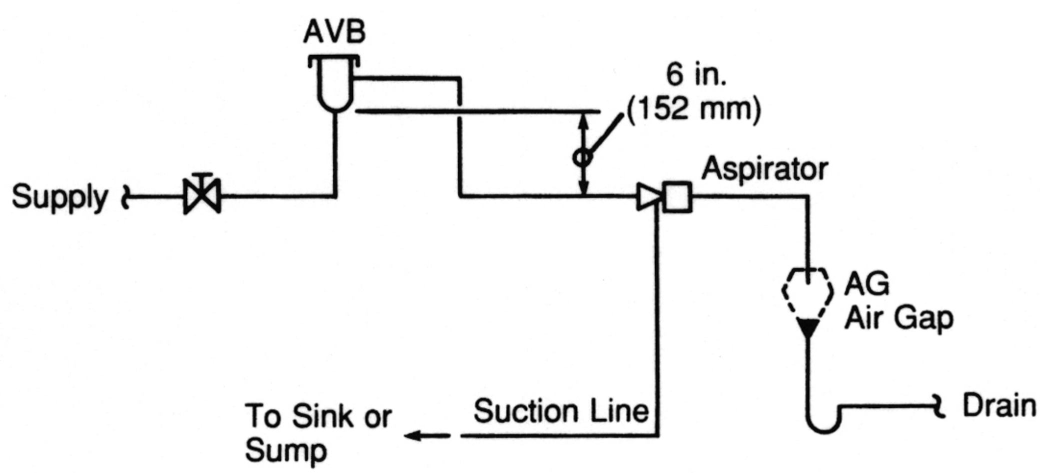


Figure 2.11 Typical Atmospheric Vacuum Breaker Application [12]

Pressure Vacuum Breaker (PVB)

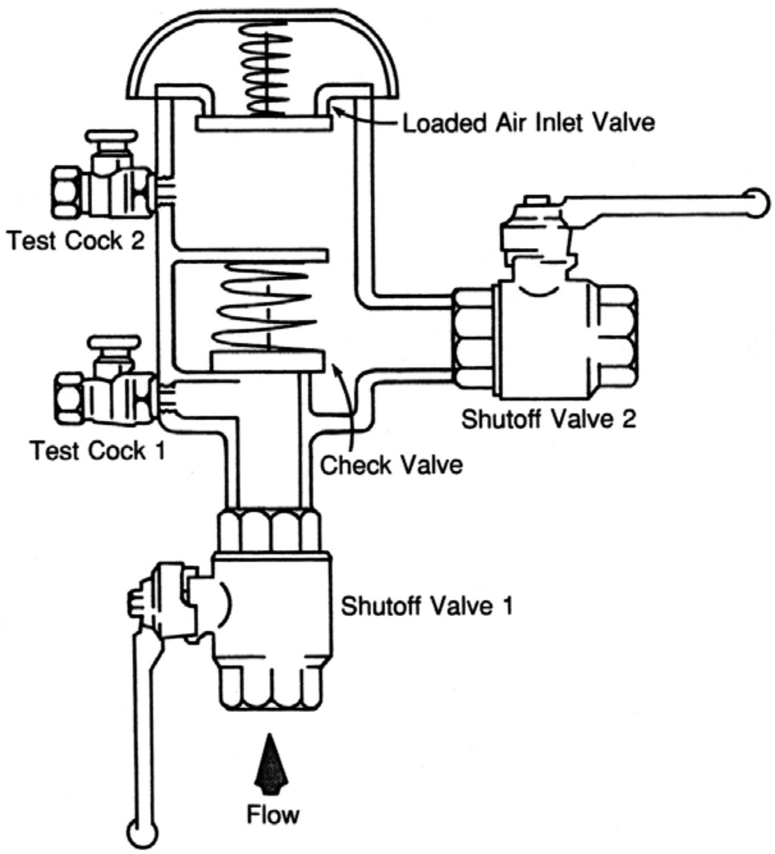


Figure 2.12 Schematic of Pressure Vacuum Breaker Assembly [13]

Operation of a Pressure Vacuum Breaker

A **Pressure Vacuum Breaker (PVB)** consists of an independently operating internally loaded check valve and an independently operating loaded air inlet valve located on the discharge side of the check valve, with test cocks and shutoff valves at either end of the assembly.

- During a normal flow condition, the flow keeps the check valve open and the air inlet valve closed. When a backsiphonage condition develops, the internally loaded check valve closes and prevents backflow. The air inlet valve also opens when flow stops. If the check valve is fouled or does not seat properly, air enters the supply pipe and breaks the vacuum, preventing backsiphonage.

Advantages and Disadvantages of a Pressure Vacuum Breaker

Advantages	Disadvantages
Prevents backflow caused by backsiphonage.	Does not protect against backflow caused by backpressure.
Can be used under constant pressure because of the internally loaded check valve and air inlet valve.	Low inlet supply pressure can make closing the air inlet port difficult.
Is a testable device.	Water hammer often occurs when the inlet valve closes.

Applications of a Pressure Vacuum Breaker

Pressure vacuum breakers are used to protect against backsiphonage in applications under constant pressure. Typical applications include agricultural and industrial uses such as irrigation systems, submerged inlet tanks, and supplies to multiple sinks or hose bibs. They must be installed in a vertical position and at least 6 to 12 inches higher than the existing outlet.

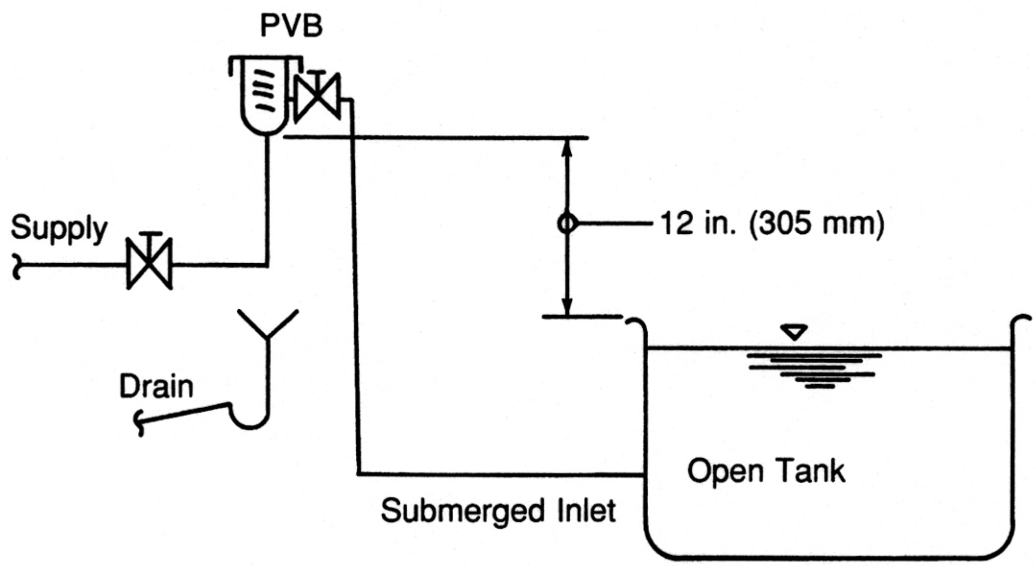


Figure 2.13 Typical Pressure Vacuum Breaker Application [14]

Hose-Bibb Vacuum Breaker (HBVB)

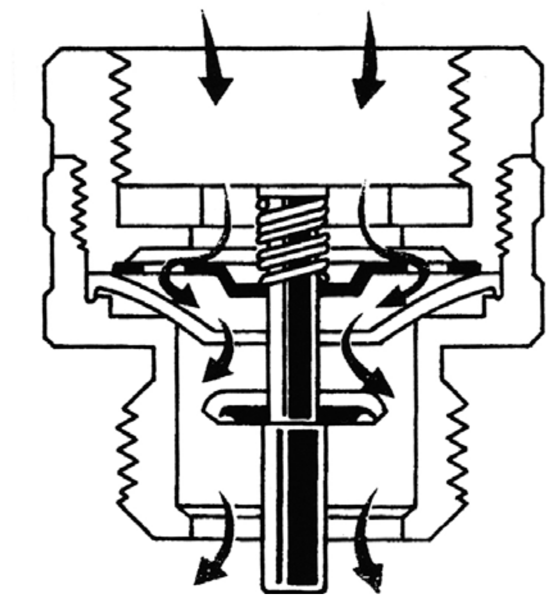
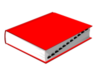


Figure 2.14 Schematic of Hose-Bibb Vacuum Breaker [15]

Operation of a Hose-Bibb Vacuum Breaker



A **Hose-Bibb Vacuum Breaker (HBVB)** consists of a spring-loaded check valve that seals against an atmospheric outlet when the supply pressure is turned on. When the supply is turned off, the device vents to the atmosphere, providing protection against backsiphonage.

Advantages and Disadvantages of a Hose-Bibb Vacuum Breaker

<u>**Advantages**</u>	<u>**Disadvantages**</u>
Relatively inexpensive and small in size.	Does not protect against backflow due to backpressure.
Protects against backsiphonage, which is the most typical cause of backflow in applications involving hose-bibb connections.	Non-testable.

Applications of a Hose-Bibb Vacuum Breaker

An HBVB is typically attached between sill cocks and hose outlets such as garden hoses, slop sink hoses, and spray outlets. They are also available with manual drains and tamper-proof options.

Testing and Maintenance of Backflow Prevention Devices

To ensure that backflow prevention devices are maintained and working properly, they must be tested regularly. Testing is especially important for devices at facilities where a health hazard or aesthetically objectionable contamination potential exists.

Responsibility for Testing and Maintenance

- The responsibility for testing and maintenance of backflow prevention devices should be defined by the local backflow prevention ordinance. Generally, testing and maintenance are the responsibility of the consumer and must be performed by a certified backflow prevention assembly tester.

Schedule for Testing and Maintenance

- Testing frequency should also be defined by local ordinance, but is typically required annually. Ordinances should also require backflow prevention devices to be disassembled, inspected, and cleaned at defined intervals, typically every one to five years.

Key Elements of Testing

- Remember that not all backflow prevention devices are testable. The most common devices used at health hazards and aesthetically objectionable facilities are air gaps, RPZDs, and DCVAs, which are testable. However, unless parallel backflow prevention devices are installed, the water must be shut off during the test; therefore, appropriate arrangements must be made.

- Other devices, such as residential dual check valves and atmospheric vacuum breakers, are not testable.

- Detailed techniques for testing backflow prevention assemblies are beyond the scope of this course. To become certified in cross-connection control and backflow prevention assembly testing, a separate course is required. The information presented here is intended to provide a general knowledge of the techniques used for testing backflow prevention devices.

Air Gap

- Air gaps must be inspected to ensure that the proper air gap is being maintained. Air gaps are easily bypassed and rendered ineffective and therefore should be inspected regularly.

Reduced Pressure Zone Device

- RPZD testing can be accomplished using pressure gages, hoses, and appropriate fittings. Test kits assembled specifically for this purpose are commercially available. A single test kit can be used to test RPZDs, DCVAs, and PVBs.
- Testing consists of the following three steps:
    - Test the differential relief valve to assure that it operates properly to maintain the zone between the two check valves at least 2 psi below the supply pressure.
    - Test Check Valve 2 for tightness against reverse flow under all pressure differentials.
    - Test the tightness of Check Valve 1 and test that the static pressure drop across the check valve is at least 3 psi.
- Note that dampness or water on the floor in the area of the RPZD assembly indicates that the relief valve has opened, possibly signaling a check valve malfunction.

Double Check Valve Assembly (DCVA)

- DCVA testing consists of the following two steps:
    1. Test Check Valve 1 for tightness against reverse flow under all pressure differentials.
    2. Test Check Valve 2 for tightness against reverse flow under all pressure differentials.

Pressure Vacuum Breaker (PVB)

- Testing PVBs consists of the following two steps:
    1. Test the opening pressure differential of the air inlet valve to ensure that it opens when the pressure in the valve body is no less than 1.0 psi above atmospheric pressure. The air inlet valve should be fully open when the water drains from the valve body.
    2. Test the check valve for tightness. The check valve should be drip-tight in the normal direction of flow when the inlet pressure is 1.0 psi and the outlet pressure is atmospheric.

Key points for Unit 2 – Backflow Prevention Methods

- Hazardous facilities such as sewage treatment plants and petroleum processing facilities should use the highest level of backflow prevention.
- An air gap is a non-mechanical vertical separation between the potable water source and the receiving vessel.
- A barometric loop can be effective in stopping backsiphonage, but its large size makes it impractical to use in many situations.
- Double check valves are effective in stopping backflow due to both backpressure and backsiphonage.
- An atmospheric vacuum breaker is one of the simplest and least expensive mechanical backflow preventers.
- When the water supply to a hose protected with a hose-bibb vacuum breaker, the device vents to the atmosphere which provides protection against backsiphonage.
- Backflow prevention devices should be regularly maintained and tested to make sure they are working properly.
- Air gaps can be easily bypassed so it is important to inspect them regularly for proper operation.

Exercise

For each of the following scenarios, explain what type of prevention device would be appropriate.

1. Restricted access military base

2. Customer fire loop

3. Water hauling trucks

4. Single family residence

5. A hospital or medical building

6. Commercial car wash

[1] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14)*. American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p.36.

[2] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14).* American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p.36.

[3] *Public Water Supply Manual - Part VII Cross-Connection Control/Backflow Prevention*, Commonwealth of Pennsylvania, Department of Environmental Protection, June 18, 2001. [Document Number 383-3100-111].

[4] *Cross-Connection Control Manual*, United States Environmental Protection Agency Office of Water Office of Drinking Water, June 1989, Reprinted 1995, [EPA 570/9-89-007], p. 17.

[5] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14).* American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p. 43.

[6] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14).* American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p. 45

[7] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14).* American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p. 39.

[8] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14).* American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p.42.

[9] *Cross-Connection Control Manual*, United States Environmental Protection Agency Office of Water Office of Drinking Water, June 1989, Reprinted 1995, [EPA 570/9-89-007], p. 20.

[10] *Cross-Connection Control Manual*, United States Environmental Protection Agency Office of Water Office of Drinking Water, June 1989, Reprinted 1995, [EPA 570/9-89-007], p. 20.

[11] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14).* American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p. 50.

[12] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14).* American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p. 51.

[13] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14).* American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p. 46.

[14] *Recommended Practice for Backflow Prevention and Cross-Connection Control (AWWA M14).* American Water Works Association Manual of Water Supply Practices, Second Edition, 1990, p. 48.

[15] *Cross-Connection Control Manual*, United States Environmental Protection Agency Office of Water Office of Drinking Water, June 1989, Reprinted 1995, [EPA 570/9-89-007], p.18.

(This page was intentionally left blank.)

Unit 3 – Detecting and Mitigating Backflow Occurrences

Learning Objectives

- List and explain five indicators of backflow.
- Describe four methods for mitigating backflow events.

The following are common methods used to determine the possible occurrence of backflow contamination.

Customer Complaints

- Customer complaints are the primary indicator that backflow may have occurred. Customer water use is essentially a system-wide sampling of aesthetic water quality. Customer complaints generally relate to taste, odor, color and/or physical harm from contact or use of the water.
- Not all customer complaints indicate that a backflow contamination event has occurred.
- Many contaminants cannot be detected by taste, odor, color or physical harm.

Pressure Reductions

- Although a pressure drop alone does not necessarily indicate that backflow has occurred, a pressure drop in conjunction with certain water quality complaints, such as taste and/or odor, can indicate a possible backflow occurrence.
- Monitoring distribution system water pressure can help identify potential locations where a suspected backflow occurrence might have occurred, which can be helpful during mitigation activities.
- Pressure monitoring can also provide information on areas susceptible to low and/or variable pressure. System improvements can be made in these areas to stabilize the pressure and to reduce the chance of future backflow events.
- Some pressure reductions, especially those resulting from a surge or water hammer event, often occur for only brief periods of time and can be difficult to detect with traditional pressure monitoring equipment.

Loss of Disinfectant Residual

- Water systems routinely monitor disinfectant residual concentrations throughout the distribution network. Although disinfectant residual concentrations are somewhat variable, abnormal reductions in disinfectant residual concentrations can indicate the possibility that some foreign material has been introduced into the system and is influencing the disinfectant concentrations.

Water Meters Running in Reverse

- Water meters running in reverse can indicate that backflow is occurring. This can be discovered during investigations of water quality complaints. Some systems may even have the ability to remotely detect meter reversals.

Total Coliform Detections

Total coliform detections indicate the presence of bacteria in the system. The goal of treatment and disinfection is to prevent bacteria in the system.

Heterotrophic plate count (HPC) is another indicator of bacteria in the water system.

- Testing and continued monitoring in the area of the abnormal coliform or HPC counts can help to verify and locate sources of backflow. An abnormal coliform count is any count more than 0 and an abnormal HPC count is more than 500/mL HPC.

- However, systems often monitor only for coliform bacteria in the distribution system. Coliform bacteria may not indicate some forms of microbial contaminants. Also, the relative infrequency of sampling for microbial contaminants severely limits its effectiveness as a tool for detecting backflow contamination events.

Reported Backflow Events

- Backflow events may be reported directly to the water supplier in cases where the customer is aware that backflow has occurred.

The following is a brief description of common mitigation efforts. These methods are not unique to backflow contamination but are used to attempt to mitigate various types of contamination events.

Contaminated Area Isolation

- A typical procedure includes:
  - Close valves to isolate the known area of contamination, including some amount of buffer around the known area of contamination.
  - Sample water outside the isolated area to make sure the contaminant has been isolated. If the contaminant is present outside the isolated area, expand the area until the contaminant has been effectively isolated.
- Although this approach can be very effective, it is more difficult when the contaminant cannot be detected by sight, smell or with rapid and readily available tests. In addition, inoperable system valves can hinder the ability of water system personnel to effectively and quickly isolate a contaminant. Therefore, a valve exercise program, to periodically verify the operability of valves and to identify inoperable valves that should be repaired or replaced, is important to maintain the water supplier's ability to react to a contamination event and effectively isolate the contaminant.

Public Notification

- Adequate public notification can minimize potential harm to customers and reduce the spread of contamination by minimizing system flow rates through reduced water usage.
- Typical types of notification include TV, radio, signs in public places and personal notification.

System Flushing and Cleaning

- Flushing is accomplished using hydrants and blowoffs. If the source of contamination is known, flushing should begin near the source and move outward. This approach minimizes spreading of the contaminant during the flushing efforts. Once the contaminant has been effectively removed from the isolated area, flushing should continue while the isolation valves are being reopened. This will draw water from outside the isolated area to remove any contaminant that was not isolated.
- Some contaminants cannot be removed by flushing. They can accumulate in biofilms and on the corrosion materials on the pipe wall and can be very difficult to remove by flushing. In these cases, pipelines may be mechanically cleaned using techniques called pigging and rodding. These methods involve inserting a device into the pipe and physically scraping the pipe walls. Following mechanical cleaning, pipelines are flushed and disinfected. Jetting and sandblasting are two alternate methods of pipeline cleaning.

Pipeline Replacement

- Some contaminants cannot be removed from the pipeline by flushing or physical cleaning. In these cases, the pipelines must be replaced.
- Examples of contamination that may require pipeline replacement include the pesticide chlordane and radioactive contamination.

Identify and Correct the Source of Contamination

- While each of the previously described mitigation steps are important to minimize the harmful effects of contamination events and remove the contaminant from the system after a backflow event has occurred, it is also important to identify and correct the source of the contamination to avoid future occurrences of a similar event.

Key points for Unit 3 – Detecting and Mitigating Backflow Occurrences

- Indicators of backflow could include customer complaints, pressure reductions, loss of disinfectant residual, meters running in reverse, detection of total coliform, and reported backflow events.
- A contaminated area should be isolated as soon as possible.
- Adequate public notification can help minimize potential harm to customers.
- System flushing should commence near the source of contamination and move outward.
- Cleaning methods must be used when contamination cannot be removed by flushing alone.
- In some cases, the pipeline must be replaced.

Exercise

1. List five indicators of backflow.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

    e. ______________________________

2. Describe four methods for mitigating backflow events.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

Additional Resources Used

"Potential Contamination Due to Cross-Connections and Backflow and the Associated Health Risks", an Issues Paper by EPA's Office of Ground Water and Drinking Water.

Unit 4 – Current Cross-Connection Control and Backflow Prevention Practices

Learning Objectives

- Explain the regulatory basis for cross-connection control programs.
- Describe a typical backflow prevention program as outlined by the PA DEP Water Supply Manual.

PA Safe Drinking Water Act

The Pennsylvania Department of Environmental Protection (DEP) is authorized under the Pennsylvania Safe Drinking Water Act to establish standards for the construction of a water supply to assure compliance with the provisions of the act.

PA DEP Rules and Regulations

Section 109.608 of DEP's rules and regulations states: "A public water system may not be designed or constructed in a manner which creates a cross-connection." In addition, Section 109.709(b) requires that "At the direction of DEP, the public water supplier shall develop and implement a comprehensive control program for the elimination of existing cross-connections or the effective containment of sources of contamination, and prevention of future cross-connections."[1]

Accordingly, water suppliers are required to develop and implement a program to control cross-connections and prevent backflow of contaminants into the public water supply.

PA DEP Public Water Supply Manual Part VII

More detailed information and guidance for developing a program can be found in the *Public Water Supply Manual, Part VII*, the *EPA Cross Connection Control Manual*, *AWWA M14 Recommended Practice for Backflow Prevention and Cross-Connection Control*, *Manual of Cross-Connection Control* by the University of Southern California Foundation for Cross-Connection Control and Hydraulic Research, and other cross-connection control publications.

Although the details of cross-connection control programs may vary significantly from system to system, the basis of these programs is similar. In general, much of the literature on cross-connection control programs is based on the recommendations of the University of Southern California Foundation for Cross-Connection Control and Hydraulic Research. Their model has been widely accepted and is the basis for the recommended cross-connection control practices outlined in the DEP Water Supply Manual.

The program involves establishing standards and procedures for eliminating cross-connections and requiring the installation and maintenance of a specified type of approved backflow prevention assembly at the customer's water service connection when a potential hazard exists or may exist in the customer's system.

The following steps are recommended by DEP for creating and implementing an effective program.

Step 1: Develop the Program

- **Know and understand cross-connection control concepts.**

  In order to establish and effectively implement a cross-connection control program, the water supplier must understand the concepts of cross-connection and backflow and have a working knowledge of the techniques and equipment used to eliminate and protect cross-connections and prevent backflow. This course is intended to provide the basis of such knowledge. Additional information can be obtained from the resources listed at the end of this module and from other backflow prevention literature. Courses designed to certify backflow prevention assembly testers are also recommended.

- **Establish the legal foundation.**

  A local ordinance establishing the water supplier's jurisdiction, responsibilities, and enforcement procedures should be adopted in each municipality served by the water supplier.

  The ordinance should include, but not be limited to:

  - The adoption of a plumbing code.
  - Authority to enter customer premises.
  - Provisions for discontinuance of service.
  - Installer, inspector/tester certification.
  - Inspection frequency.
  - Penalties.
  - Hydrant use restrictions.
  - Exterminator restrictions.
  - Provisions for the required installation of specific cross-connection control devices based on the degree of hazard.

- **Establish a priority system.**

  Water suppliers should identify facilities that pose the greatest hazard in the most vulnerable portions of the system to prioritize implementation efforts. The procedure may involve categorizing all customers as either hazardous facilities, aesthetically objectionable facilities, or non-hazardous facilities and determining the most vulnerable areas of the system based on distribution system water pressure and leakage/main break histories.

- **Estimate customer implementation costs.**

  Installation cost estimates can be based on the assumptions that each hazardous facility will require a RPZD on each service line and each aesthetically objectionable facility will require a DCVA on each service line. Also, assume that each installation will require separate above-ground housing, heat and drainage.

- **Develop a proposed implementation timetable.**

  A reasonable 5-year timetable for implementing the program, as outlined in the DEP manual is as follows.

1st Year	Develop the program plan. Secure management approval. Amend local regulations if needed. Begin a public education program.
2nd Year	Notify high priority customers of the program requirements. These are aesthetically objectionable and hazardous facilities located in the most vulnerable areas of the system. Review backflow prevention plans for high priority customers. Continue the public education program.
3rd Year	Install high priority customers' devices. Notify lower priority customers of the program requirements. Review backflow prevention plans for lower priority customers. Continue the public education program.
4th Year	Install lower priority customers' devices. Review the first backflow prevention assembly test results from high priority customers. Follow up on test results.
5th Year	Review first backflow prevention assembly test results from lower priority customers. Follow up on test results. Consider enforcement actions.

- **Review data and proposed procedures with governmental agencies.**

  Prior to meeting with the governmental agencies, the water supplier should develop draft copies of the forms to be used in implementing the program. A list of these forms, as suggested by DEP, is included in the *DEP Public Water Supply Manual, Part VII*. Examples of many of these forms can be found in the AWWA Manual M14 and other backflow prevention references.

Step 2: Implement the Program

- **Educate the public.**

  The public education program can begin during the program development stage. Focusing on public education and awareness can lead to greater acceptance of the program as well as faster and higher success. Public education also enables local plumbers and plumbing supply firms to prepare to supply and install the equipment required by the program.

- **Notify affected customers.**

  Notify customers of the requirements, meet with customers to discuss the requirements and agree on a timetable for compliance. Solicit assistance from legal counsel or DEP, as necessary, if customers challenge the requirements of the program.

- **Monitor program progress.**

  Monitor customer compliance and program implementation progress. Annually, notify DEP of the cross-connection control program progress. Establishing and maintaining a record keeping system is an important part of monitoring the implementation of the program and maintaining its effectiveness.

- **Initiate testing requirements.**

  Once backflow prevention devices have been installed, the testing requirements should be reviewed with each customer.

Key points for Unit 4 – Current Cross-Connection Control and Backflow Prevention Practices

- PA DEP regulations specifically prohibit cross connections in drinking water systems.
- Water suppliers are required to develop and implement a program to control cross connections and prevent backflow of contaminants into the public water supply.
- A reasonable time for implementing a cross connection program is 5 years.
- Educating the public and notifying customers are important considerations in the implementation of a cross connection control program.

☑ **Exercise**

2. PA DEP rules and regulations state “A public water system may not be designed or constructed in a manner which creates a ______________________________.

3. Water suppliers are required to develop and implement a program to control ___________________ and prevent backflow of __________________ into the public water supply.

4. A reasonable timetable for implementing a backflow prevention program may take up to ________ years.

5. Important steps in implementing the backflow prevention program include ______________ the public and ________________ the affected customers.

[1] Public Water Supply Manual - Part VII Cross-Connection Control/Backflow Prevention, Commonwealth of Pennsylvania, Department of Environmental Protection, June 18, 2001. [Document Number 383-3100-111], p. 1.