

TO PROTECT AND TO SERVE

How Cross-connection Control Prevents Contamination of Potable Water

Steve Ziga, CPD, CET

I was sitting at a restaurant the other day, and when the waiter asked for my drink order, I didn't think twice when I asked for a glass of ice water. It later occurred to me that many citizens of the United States do not realize what a privilege it is to have high-quality water standards.

In 2002, 1.1 billion people lacked access to treated water sources, which represented 17 percent of the global population. In sub-Saharan Africa alone, 42 percent of the population is still without potable water. According to a 1999 study by the American Water Works Association (AWWA) Research Foundation, residential end use of water in the United States is equivalent to more than 1 billion glasses of tap water per day.

These facts hopefully stress the importance of protecting our water supply and the methods we currently implement. To best understand the methods used today for protecting our water supply, we need to go back to the beginning.

THE ROOTS OF BACKFLOW PREVENTION

Federal regulation of drinking water quality began in 1914, when the U.S. Public Health Service set standards to control some disease-causing microbes. These standards were revised and expanded, and eventually, with minor modifications, all 50 states adopted the final 1962 Public Health Service standards either as regulations or as guidelines.

However, by the late 1960s, health concerns spurred the federal government to conduct several studies on the nation's water supplies, which showed that many harmful chemicals were present in treated drinking water. In 1974, the U.S. Congress passed the Safe Drinking Water Act to protect the public health by regulating the nation's public drinking water supply. The Safe Drinking Water Act authorized the U.S. Environmental Protection Agency (EPA) to set national health-based standards for drinking water to protect against both naturally occurring and manmade contaminants that may be found in drinking water. Since 1974, the Safe Drinking Water Act has been amended twice, adding requirements to further protect drinking water and its sources (i.e., rivers, lakes, reservoirs, springs, and ground-water wells). To ensure that drinking water is safe, the Safe Drinking Water Act sets up multiple barriers against pollution. These barriers include source water protection, treatment, distribution system integrity, and public information.

ENSURING SAFE DRINKING WATER

Millions of Americans receive high-quality drinking water every day from their public water systems (an estimated 160,000 systems). Public water systems are responsible for ensuring that contaminants in tap water do not exceed the approved standards. The environmental and drinking water quality regulations that public water systems follow are the responsibility of state departments of health or environment and the EPA.

Public water systems typically are required to supply drinking water that complies with the allowable maximum contaminant levels. This typically requires that the raw water be treated by filtration and/or chlorination. To ensure quality, public water systems must conduct routine monitoring for microbiological contaminants, chemicals, and radiological contaminants. If a violation is found, the public water system is required to issue public notification to their consumers. Public notices typically contain minimum elements, including a description of the violation, actions consumers should take, and when the supplier expects to return to compliance.

Some Sources of Contamination

Contaminants may enter drinking water before, during, or after treatment. Some sources of drinking water contaminants are as follows.

Before treatment they include:

- Bacteria from human or animal sources
- Turbidity in water caused by suspended matter such as clay, silt, and microscopic organisms
- Overflowing storm sewers
- Defective storage tanks
- Leaking hazardous landfills, ponds, and pits
- Saltwater intruding on depleted aquifers near seashores
- Pesticides, fertilizers, and other agricultural runoff
- Runoff from oil-slicked or salt-treated highways
- Underground injection of hazardous wastes
- Naturally occurring fluoride and metals such as arsenic and cadmium
- Industrial chemicals, such as solvents

During and after treatment they include:

Figure 1 Air gap fitting



- By-products of disinfectants
- Lead, copper, asbestos, and other materials from corroding pipes
- Bacteria and dirt entering through leaking pipes
- Improper connections with other systems or cross-connections with non-potable water that allow contaminants to enter drinking water pipes
- Permeation of contaminants through certain pipe materials

Because we accept that our water supplies are safe, we need to ensure that they remain safe once we connect to them. The water purveyor (provider) ensures that necessary means are taken to protect the public water distribution system from any real or potential backflow hazard. The way plumbing engineers can protect the public water system is to ensure that effective backflow prevention measures are provided. This also is known as cross-connection control.

WHAT ARE CROSS-CONNECTIONS?

Cross-connections are the links through which contaminated substances can enter the potable water supply. Contaminated nonpotable water can enter the potable water supply via several methods, the most prevalent being back-siphonage and back-pressure backflow.

Back-siphonage

Back-siphonage backflow is the reversal of normal flow in a system caused by negative pressure (vacuum or partial vacuum) in the supply (upstream) piping. Back-siphonage can be created when the

pressure of the normal water supply drops due to high demand downstream (e.g., fire department use) or repairs or breaks in the distribution (city) main.

Back-pressure

Back-pressure backflow is the reversal of normal flow in a piped system due to an increase in the downstream pressure above that of the supply pressure. Any interconnected fluid system in which the pressure of one exceeds the pressure of another may have flow from one to the other as a result of the pressure differential.

PREVENTING CROSS-CONNECTIONS

The devices typically used to prevent cross-connections in a plumbing system are air gaps, vacuum breakers, double-check valves, and reduced-pressure principal devices. (Other devices are available, but this list is abridged to the types most often specified in commercial plumbing projects.)

Air Gaps

Air gaps (Figure 1) are non-mechanical back-flow preventers that create a gap between the potable water supply and the nonpotable cross-connection. The minimum

required air gap shall be measured vertically from the lowest end of a potable water outlet to the flood level rim of the fixture or receptacle into which the potable water outlet discharges.

Figure 2 Atmospheric vacuum breaker



Figure 3 Pressure vacuum breaker



Atmospheric Vacuum Breakers

The most commonly used atmospheric antisiphon vacuum breakers incorporate an atmospheric vent in combination with a check valve. The atmospheric vacuum breaker (Figure 2) is for low-hazard applications only and should not be used with continuous pressure on the device. Atmospheric vacuum breakers typically are used at local fixtures (i.e., laboratory sinks, mop sinks, hose bibs). Its operation relies on a supply of potable water to seal off the atmospheric vent, admitting water to downstream equipment. If a negative pressure develops in the supply line, the loss of pressure permits the check valve to drop, sealing the orifice, while at the same time the vent opens to admit air to the system to break the vacuum. In general, atmospheric vacuum breakers must be installed vertically, must not have shutoffs downstream, and must be installed 6 inches higher than the final outlet.

Pressure-type Vacuum Breakers

Pressure vacuum breakers (Figure 3) typically are used for agricultural and industrial applications. During normal flow conditions, the check valve remains open, and the float seals on the cap assembly. As the line pressure falls, a spring-loaded

FEATURE: TO PROTECT AND TO SERVE

atmospheric vent valve opens, breaking the vacuum and thereby preventing back-siphonage. In the event of exposure to freezing temperatures, a spring-loaded relief valve in the float protects the pressure vacuum breaker body and internal components from damage. As the temperature increases above freezing, the relief valve automatically reseats. During normal operating conditions, the relief valve will not discharge.

Pressure vacuum breakers typically are required to be installed 6 to 12 inches higher than the flood level rim of the fixture or device served.

Double-check Valve

A double-check valve (Figure 4) is essentially two single check valves (in series) coupled within one body and furnished with test cocks and two shutoff valves. Each check is designed to maintain a minimum of 1 pound per square inch (psi) pressure across the valve during normal operation. If at any time the pressure downstream of the device increases above the supply pressure, both check valves will close to prevent any backflow from occurring. Double-check valves commonly are used to protect low- to medium-hazard installations such as fire service or food service. (Double-check detector check assemblies, not listed here, are similar to the double-check valve assembly with the addition of a metered bypass.)

Reduced-pressure Principal Backflow Preventer

Maximum mechanical protection is achieved against back-siphonage and back-pressure conditions utilizing reduced-pressure principal backflow preventers (Figure 5). These devices are modified double-check valve assemblies with an atmospheric vent capability placed between the two checks. The valve is designed such that the zone between the two checks is always kept 2 psi less than the supply pressure. When the supply pressure drops to the minimum differential pressure required to operate the relief valve, the pressure in the central chamber is atmospheric. If the inlet pressure becomes less than atmospheric pressure, the relief valve remains fully open and discharges any water that may be caused to backflow as a result of back-pressure and leakage of a check valve.

Figure 5 Reduced-pressure principal backflow preventer



WHAT TYPE OF PROTECTION IS REQUIRED?

The local water authority dictates the type and location of the cross-connection control required for the service to the building. The backflow device may be located within the building or outside the building in a vault below grade or above grade, all depending on the area's climate and local custom.

Figure 4 Double-check valve



Once a potable water supply is run within the building, it is the responsibility of the engineer to evaluate fixture and equipment connections to the potable water system and determine the degree of hazard (toxic or nontoxic) and application (back-siphonage or back-pressure). The adopted model plumbing code provides an acceptable application list of backflow preventers for a particular service requirement (Table 1). Food service applications may require additional cross-connection control devices per the state or local health department.

Examples of fixtures and equipment that require backflow protection within a building include:

- Beverage dispensers
- Coffee machines
- Boiler makeup
- Humidifiers
- Cooling towers
- Lawn irrigation systems
- Autoclaves
- Mop sinks

AVOIDING A POTENTIAL DISASTER

In July 1976, a mysterious illness among people attending a convention of the American Legion in Philadelphia occurred. The mystery disease sickened 221 persons, causing 34 deaths. The cause was identified as a previously unknown bacterium, *Legionella pneumophila*.

There are many theories on how the *Legionella* bacteria was transferred through the building—from the bacteria growing within the cooling tower and being transferred via water mist into the air system to the cooling tower makeup being filled from a garden hose run up from a service sink on the floor below.

My personal backflow nightmare story contains no injuries or illness, but it still scares me. Recently my firm was called on to provide a renovation feasibility study for an early 1900s high rise. We were hired to investigate the infrastructure for adapta-

Figure 6 Decommissioned tanks connected to potable water supply



tion, reuse, and overall system integrity. The building hadn't been updated for the last 40 years, and during my walk-through I spotted some old boiler equipment that was decommissioned yet still connected to the domestic water supply. What you see in Figure 6 are old cast iron pressure tanks that had been taken offline and were filled with more than 40 years of sediment and debris. This concerned me because of the age and condition of the equipment and the potential that the gate valves had failed, allowing water to seep in and out of the contaminated tanks and back into the water supply.

Shortly thereafter, I met with my coworkers, and we discussed what we observed. One coworker, who had been on the roof surveying the HVAC equipment, told me that I needed to see some old domestic water-holding tanks on the roof level. We ventured to the roof and found two forged-steel, open-top water-holding tanks that supplied the domestic cold water to the building. I couldn't believe what I was seeing. Turn-of-the-century engineering was still at work! What concerned me the most was that the tanks were open to atmosphere and subject to any number of airborne contaminants. I was equally concerned because the tank also had much debris on the bottom that could be leaching into the water.

I later spoke with the city's building department, and they were aware that some of these tanks still existed and were used in the city. They stated that the tanks were grandfathered in and were not subject to any current code requiring them to be taken out of service. However, the tanks would need to be removed if the building were to undergo infrastructure upgrades.

We issued our report and made our recommendations to disconnect all the potentially hazardous tanks from the potable water system. We soon received a response from the end user that the water was recently tested and came back clean. That's great news for this 100-year-old system, but it doesn't mean that the water wasn't at risk.

This discovery led me to write this article. Whether I drink tap water at home or ice water during lunch, I would like to assume that the water is safe. Fortunately, plumbing engineers can help ensure that it always is. **PSD**

RESOURCES

The following resources can be found online by searching for the title of the publication in your favorite search engine.

"Water, Sanitation, and Hygiene Links to Health." World Health Organization.

"Progress in Providing Safe Drinking Water." U.S. Environmental Protection Agency.

"Understanding the Safe Drinking Water Act." U.S. Environmental Protection Agency.

Cross-Connection Control Manual. U.S. Environmental Protection Agency.

Table 1 List of approved backflow prevention methods and devices per the 2006 International Plumbing Code

Device	Degree of Hazard	Application
Air gap	High or low hazard	Back-siphonage or back-pressure
Air gap fittings for use with plumbing fixtures, appliances, and appurtenances	High or low hazard	Back-siphonage or back-pressure
Anti-siphon fill valves for gravity water closet flush tanks	High hazard	Back-siphonage only
Backflow preventer for carbonated beverage machines	Low hazard	Back-pressure or back-siphonage, sizes 1/4–3/8 inch
Backflow preventer with intermediate atmospheric vents	Low hazard	Back-pressure or back-siphonage, sizes 1/4–3/8 inch
Barometric loop	High or low hazard	Back-siphonage only
Double-check backflow prevention assembly and double-check fire protection backflow prevention assembly	Low hazard	Back-pressure or back-siphonage, sizes 3/8 inch to 16 inches
Double-check detector fire protection backflow prevention assemblies	Low hazard	Back-pressure or back-siphonage (fire sprinkler systems), sizes 2-16 inches
Dual-check valve-type backflow preventer	Low hazard	Back-pressure or back-siphonage, sizes 1/4–1 inch
Hose connection backflow preventer	High or low hazard	Low head back-pressure, rated working pressure, back-pressure, or backsiphonage, sizes 1/2–1 inch
Hose connection vacuum breaker	High or low hazard	Low head back-pressure or back-siphonage, sizes 1/2, 3/4, and 1 inch
Laboratory faucet backflow preventer	High or low hazard	Low head back-pressure and back-siphonage
Pipe-applied atmospheric-type vacuum breaker	High or low hazard	Back-siphonage only, sizes 1/4 inch to 4 inches
Pressure vacuum breaker assembly	High or low hazard	Back-siphonage only, sizes 1/2 inch to 2 inches
Reduced-pressure principle backflow preventer and reduced-pressure principle fire protection backflow preventer	High or low hazard	Back-pressure or back-siphonage, sizes 3/8 inch to 16 inches
Reduced-pressure detector fire protection backflow prevention assemblies	High or low hazard	Back-siphonage or back-pressure (fire sprinkler systems)
Spill-proof vacuum breaker	High or low hazard	Back-siphonage only, sizes 1/4 inch to 2 inches
Vacuum breaker wall hydrants, frost-resistant, automatic draining type	High or low hazard	Low head back-pressure or back-siphonage, sizes 3/4–1 inch



STEVE ZIGA, CPD, CET, is a principal with hpeGROUP, LLC located in Berwyn, Pennsylvania. Steve is a technical editor and writer for *PS&D* and a contributing author for *ASPE's Plumbing Engineering Design Handbook*, and he serves as the technical vice president for ASPE's Philadelphia Chapter. For more information or to comment on this article, e-mail articles@psdmagazine.org.