



# Tech Brief

PUBLISHED BY THE NATIONAL DRINKING WATER CLEARINGHOUSE, A PROGRAM OF THE NATIONAL ENVIRONMENTAL SERVICES CENTER

## Cross Connection and Backflow Prevention

By **Vipin Bhardwaj**, NDWC Engineering Scientist,  
with illustrations by **Bethany Reed**, Graphic Designer

### Summary

When drinking water is transported to a consumer, it is possible for contaminants to be introduced in the distribution system. This situation may occur due to connections between potable water lines and non-potable water sources or by a water flow reversal, resulting in contaminated water. This Tech Brief, discusses cross connections and backflow, and explores ways to prevent these situations.

### What is a cross connection?

A cross connection is a link or structural arrangement where potable water in a distribution system can be exposed to unwanted contaminants. It is the point at which it is possible for a non-potable substance to come in contact with the drinking water system. Cross connections are generally unintentional and can happen anywhere pipes supply water.

### What is a backflow?

**Backflow** is the reverse flow of undesirable materials and contaminants into the water mains. Backflow can happen because of two conditions: backpressure and backsiphonage.

**Backpressure** occurs when pressure in a pipe connected to a main pipe in the distribution system becomes greater than the pressure in the main pipe itself. When this happens, a net force acts on the volume of liquid in the connecting pipe, allowing unwanted material to enter the main pipe.

**Backsiphonage** refers to a situation where the pressure in a service pipe is less than the atmospheric pressure. If water in a supply line is turned off, such as when a pump fails, backsiphonage can cause contamination to be sucked into the system due to a vacuum in the service line.

If a cross connection exists in a system, it does not mean that there will be a backflow every time. But, where cross connections exist, there is always the possibility.

### Backflow Control Methods and Devices

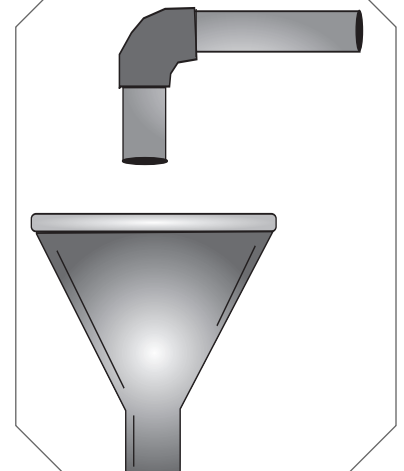
If possible, cross connections must first be eliminated before installing any backflow prevention devices. The device chosen depends on the degree of hazard involved, accessibility to the location of the device, and whether the backflow is due to backpressure or backsiphonage. Basic types of backflow prevention devices are:

- air gaps,
- reduced pressure principle devices,
- double check valves,
- vacuum breakers, and
- barometric loops

### Air Gap

Air gaps are one of the most effective ways to prevent backflow and backsiphonage. An air gap is a vertical separation between a water outlet and the highest level of a potential fluid contamination source. However, because of air gaps, flow of water is interrupted and loss of pressure occurs. Because of this, air gaps are used at the end of a pipe. Air gaps should be twice the size of the supply pipe diameter or at least one inch in length, whichever is greater. (See **figure 1** above.)

**Figure 1 Air Gap**



### Reduced Pressure Principle Backflow Preventer

The reduced pressure zone backflow-preventing (RPBP) device has two spring check valves with a pressure-relief valve located between them that can be vented to the atmosphere.

During normal flow of water through this arrangement, the water flows through the two valves. (See **figure 2**.) The spring action of the first valve opposes the pressure of water as the water flows from left to right and enters the central chamber. Pressure in the central chamber is maintained lower than that in the incoming line by the operation of the relief valve.

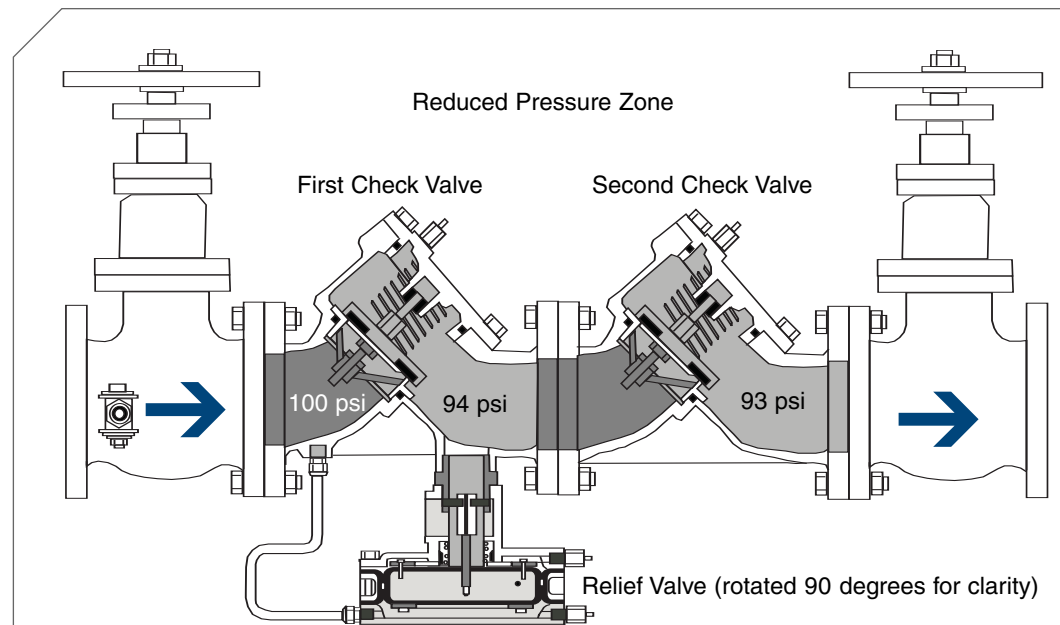
The second check valve to the right is designed to open with a pressure drop of one pound per square inch (psi) in the direction of flow and is independent of the pressure required to open the relief valve. If the pressure downstream from the device increases for some reason (backpressure), the second check valve will close because of the spring action. Reverse flow of water or backflow is thus prevented. In case the pressure in the supply line on the left decreases abruptly or if there is a vacuum in the supply line (backsiphonage), the check valves close because of spring action, and backflow is prevented.

In case the valve leaks and the second check valve on the right does not close fully, water will leak back into the central chamber and increase the pressure in the chamber. The relief valve then opens and discharges water to the atmosphere. Keep in mind, if you see water coming from the relief valve on an RPBP, don't panic. It's actually working as designed. The valve assembly should be checked by a certified tester.

This type of device is usually installed on high hazard locations, such as hospitals, plating plants, and car washes.

### Double Check Valve

The double check valve has two single check valves coupled within one body, and has test cocks (to determine if there's any leakage) and



Source: U.S. Environmental Protection Agency. 2003. *Cross-Connection Control Manual*. Washington DC: EPA.

**Figure 2** Reduced Pressure Principle Backflow Preventer

two closing gate valves (to isolate each section). It is essentially the same reduced pressure zone backflow-preventing (RPBP) device but without the relief valve. (See **figure 3**.)

The absence of the relief valve reduces the effectiveness of the device. Double check valves are used in low- to medium-level hazard installations. The check valves are spring-loaded and require one pound of pressure to open.

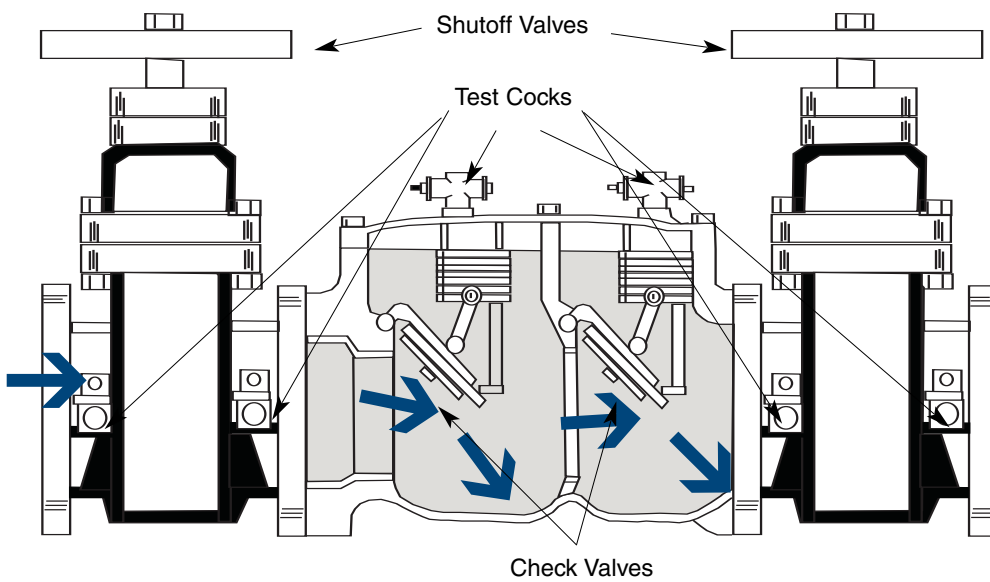
### Vacuum Breakers

Vacuum breakers provide protection against backsiphonage. When the pressure in a service pipe is less than the atmospheric pressure, a vacuum can form in the pipe and cause contamination to be sucked into the system. Vacuum breakers have an element, such as a check valve, that glides on a supporting shaft and seals in the uppermost position from the push of water pressure. (See **figure 4**.)

If the flow in the pipe is stopped, the valve drops down, closes the water supply entry, and opens an air vent. This opens up the downstream piping to atmospheric pressure and prevents backsiphonage. Vacuum breakers do not protect against backpressure.

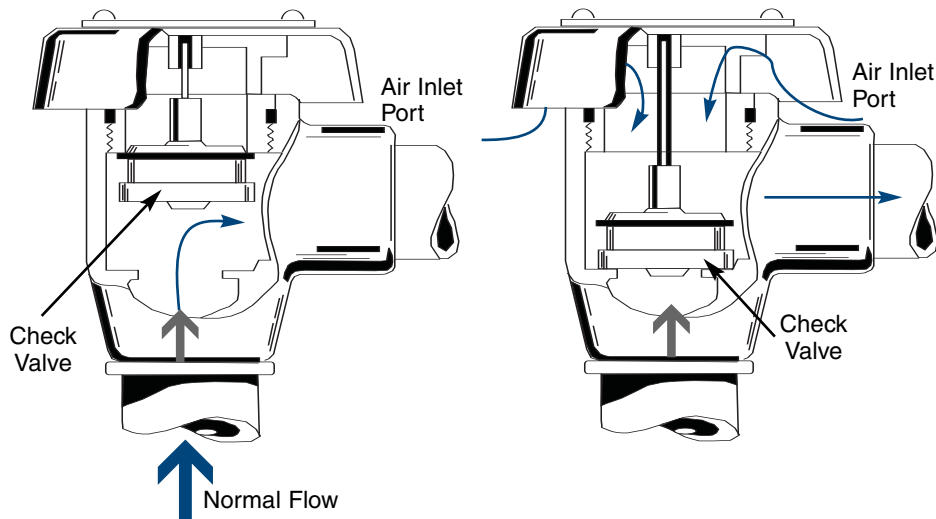
### Barometric Loop

A barometric loop is formed by having a section of the pipe in the shape of an inverted "U" upstream of a cross connection. (See **figure 5**.) Based on a physics principle, the height of a water column open to the atmosphere at the bottom will not be greater than 33.9 feet at sea level pressure.



Source: AWWA, *Water Transmission and Distribution*, Second Edition

**Figure 3** Double Check Valve



Source: AWWA, *Water Transmission and Distribution*, Second Edition

**Figure 4** Vacuum Breakers

If the loop is greater than that height, back-siphonage cannot occur through it. However, the barometric loop is not effective against backpressure.

**Cross Connection Control Programs**

Numerous, well-documented cases about illnesses and other hazards posed by cross connections have been documented. (See the sidebar above.) More information about the health risks cross connections may present and methods to prevent them is needed. Water utility personnel (managers, operators, local officials), plumbers, public health officials, and consumers need to be aware of the risks and understand prevention methods.

As mandated by the Safe Drinking Water Act, water suppliers are responsible for ensuring that the water they supply meets federal primary drinking water regulations and is delivered to consumers without compromising water quality due to its distribution system. Water utilities may want to implement a cross connection program to stave off any problems that could occur. Such a program would include informing consumers, conducting inspections of the distribution system, analyzing and recognizing potential cross connections, and installing backflow prevention devices where needed.

**“Yellow Gushy Stuff” From Faucets**

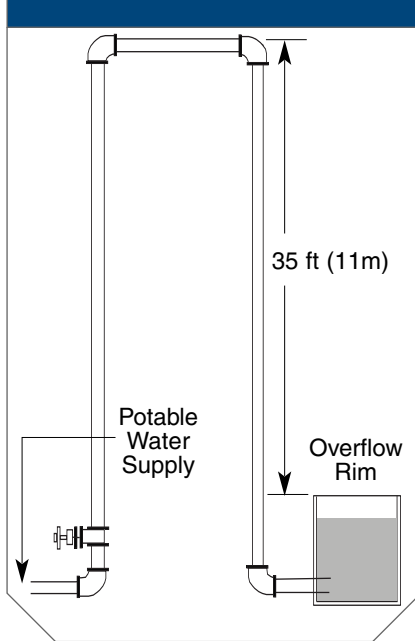
A small town in Maryland provides a dramatic example of what can happen because of a cross connection. One fateful day, yellow gushy stuff poured from some faucets there and the state warned residents from using the water for cooking, drinking, or bathing. The incident drew widespread attention and was a big story in the local media.

An investigation revealed that water pressure in the town mains was reduced temporarily due to a water pump failure in the distribution system. A gate valve between a herbicide chemical holding tank and the town water supply mains had been left open. A lethal cross connection was created that allowed the herbicide to flow into the water supply. When the normal water supply pressure returned, water containing the herbicide was pumped into many faucets.

Door to door public notification, extensive flushing, sampling, and other measures were taken to get the situation under control. Fortunately, no one was seriously injured in this incident.

Source: U.S. Environmental Protection Agency. 2003. *Cross-Connection Control Manual*. Washington DC: EPA.

**Figure 5 Barometric Loop**



Source: AWWA, *Water Transmission and Distribution*, Second Edition

### What about terrorism and water security?

Concern that U.S. water supplies could be vulnerable to terrorist attacks has increased in the post-9/11 era. Because they are a place where lethal substances could be introduced into the water distribution system, cross connections should be identified and corrected.

### The Public Health Security and Bioterrorism Preparedness and

Response Act of 2002 (Section 1433) requires systems that serve more than 3,300 people to assess their vulnerability to a terrorist attack. (See the article "Security and Emergency Planning: Community-Wide Efforts Require Preparation" in the Winter 2003 *On Tap*.)

The act states that the vulnerability assessment shall include but not be limited to "a review of pipes and constructed conveyances, water collection, pretreatment, storage and distribution facilities, electronic, computer or other automated systems."

### Where can I find more information?

American Water Works Association. 1996. *Water Transmission and Distribution, Principles and Practices of Water Supply Operations*. 2nd Edition. Denver: AWWA.

U.S. Environmental Protection Agency. 2003. *Cross-Connection Control Manual*. Washington DC: EPA. (Available as a product from NDWC, item #DWBLDM03)

Montana Water Center. 2002. *Sanitary Survey Fundamentals Preparation Course CD*. Bozeman, MT: Montana Water Center. (Available as a product from NDWC, item #DWCDTR19)

NDWC Engineering Scientist **Vipin Bhardwaj** has a bachelor's degree in chemical engineering, and master's degrees in environmental engineering and agriculture from West Virginia University.



## Have YOU read all of our Tech Briefs?

*Tech Briefs*, drinking water treatment and supply fact sheets, have been a regular feature in the National Drinking Water Clearinghouse (NDWC) publication *On Tap* for more than seven years.

A free package of *Tech Briefs* is available as a product. A three-ring binder holds all the current *Tech Briefs* in print. New selections can easily be added to the package as they become available. To order, call the NDWC at (800) 624-8301 or (304) 293-4191 and ask for item #DWPKE71.

(Additional copies of fact sheets are free; however, postal charges may be added.) You can also order copies of one or all of the free *Tech Briefs* listed below.

Tech Brief: **Organics Removal**, item #DWBLPE59

Tech Brief: **Package Plants**, item #DWBLPE63

Tech Brief: **Water Treatment Plant Residuals Management**, item #DWBLPE65

Tech Brief: **Lime Softening**, item #DWBLPE67

Tech Brief: **Iron and Manganese Removal**, item #DWBLPE70

Water **Conservation Measures Fact Sheet**, item #DWBLPE74

Tech Brief: **Membrane Filtration**, item #DWBLPE81

Tech Brief: **Treatment Technologies for Small Drinking Water Systems**, item #DWPSPE82

Tech Brief: **Ozone**, item #DWBLPE84

Tech Brief: **Radionuclides**, item #DWBLPE84

Tech Brief: **Slow Sand Filtration**, item #DWBLPE99

Tech Brief: **Ultraviolet Disinfection**, item #DWBLPE101

Tech Brief: **Leak Detection and Water Loss Control**, item #DWBLPE102

Tech Brief: **Diatomaceous Earth Filtration for Drinking Water**, item #DWBLPE108

Tech Brief: **Reservoirs, Towers, and Tanks**, item #DWFSOM15

Tech Brief: **System Control and Data Acquisition (SCADA)**, item #DWFSOM20

Tech Brief: **Valves**, item #DWFSOM21

Tech Brief: **Water Quality in Distribution Systems**, item #DWFSOM25

Tech Brief: **Water Treatment Plant Residuals Management**, item #DWBLPE65



You also may order online at [ndwc\\_orders@mail.nesc.wvu.edu](mailto:ndwc_orders@mail.nesc.wvu.edu) or download fact sheets from our Web site at [www.ndwc.wvu.edu](http://www.ndwc.wvu.edu).