15. Design of plumbing systems for industrial and temporary applications

15.1 Backflow prevention in industrial, commercial and institutional water systems

Any water piping installation where there is a possibility that a harmful substance may gain access to a drinking-water supply must have a backflow protection device installed. Various types of backflow protection are described in this chapter. This topic is addressed in considerable detail in the Cross-connection control manual (EPA 2003). Following are some examples of installations that require backflow protection devices:

- irrigation and watering systems where harmful chemicals can be siphoned back into the drinking-water supply system;
- boilers and cooling towers where harmful water treatment chemicals can seep into the drinking-water supply system;
- faucets that are installed below the overflow rim of bathtubs, sinks and lavatories or other plumbing fixtures;
- water connections, water closets, urinals;
- faucets and make-up lines to open tanks;
- automatic drink-vending machines where there is a need to prevent carbon dioxide gas from getting into the drinking-water supply system;
- hospitals, mortuaries and industrial facilities;
- swimming pools and spa make-up water;
- connections to private drinking-water supply systems;
- locations where drinking-water supply hoses can be placed in contaminated water or sewage.

Dangers associated with hose connections are more insidious because precautions against contamination depend on the user rather than the installer and consequently are much more difficult to control.

15.2 Backflow and backsiphonage

Backflow is an unwanted flow of potentially contaminated water, used water, industrial fluids or other substances from any domestic, industrial or institutional piping system into a drinking-water system. The flow under these conditions is in the reverse direction from that intended. Backflow is caused by a reverse pressure gradient that, if not interrupted, will cause a flow of water back into the
drinking-water system. This is sometimes referred to as a vacuum, which in these circumstances means a pressure below that of the atmosphere. So in a water distribution system a true vacuum is not necessarily the cause of backflow of fluids; a small difference of pressure is all that is necessary to cause the reversal of flow in any pipeline.

Backsiphonage is an undesirable or reverse direction of flow caused by atmospheric pressure differentials exerted against a pollutant liquid, forcing it towards a drinking-water supply system that is under a lower pressure. When fluid is siphoned out of a container through a piece of tubing, the fluid will flow up and over the rim of the container and then down into a lower elevation. In a dangerous cross-connection, unwanted fluid may be sucked over into the drinking-water line. It is not necessary for a true vacuum to exist in the system main for this siphonage to occur; all that is required is a negative difference in pressure and a section of tubing or pipe that is completely full of fluid.

15.3 Water system backflow protection devices

Protective devices are installed in order to minimize risks associated with the operation of drinking-water supply and domestic sewerage systems. A vital role of these devices is to prevent backflow or backsiphonage into the mains drinking-water supply. This section describes the nature and operation of the most common protective devices. The diagrams of the devices are from the 2000 Uniform Plumbing Code illustrated training manual published by the International Association of Plumbing and Mechanical Officials (IAPMO 2000).

Air gap. This is a physical separation between drinking-water (the mains drinking-water supply system) and other fluids.

Atmospheric or non-pressure-type vacuum breaker. This device is always installed downstream from the shut-off valve. The air vent valve closes when water flows in the normal direction. As soon as the water ceases to flow the air

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**FIGURE 15.1 ATMOSPHERIC VACUUM BREAKER**

Disc

Disc in normal flow position

Disc in vacuum breaking position

Vacuum

Flow just after vacuum is applied

Atmospheric pressure

Atmospheric pressure

Atmospheric pressure

Source: IAPMO 2000 (p. 6).
vent valve opens, thus interrupting any possible backsiphonage effect (Figures 15.1 and 15.2). No hose should be attached to the device and run to a point of higher elevation because the weight of the water in the hose will keep the relief valve closed and the device will not provide the intended protection.

CASE STUDY 3. CHLORDANE BACKFLOW OR BACKSIPHONAGE

Approximately 11 litres of chlordane, a highly toxic insecticide, was sucked back (backsiphoned) into the water system of a residential area of a city. Residents complained that the water “looked milky, felt greasy, foamed and smelled”. The problem developed while water department personnel were repairing a water main. Meanwhile, a professional exterminator was treating a nearby home with chlordane for termite elimination. The workman for the exterminator company left one end of a garden hose that was connected to an outside hose bib tap in a barrel of diluted pesticide. During the water interruption, the chlordane solution was backsiphoned from the barrel through the house and into the water main. Fortunately, due to the obvious bad taste, odour and colour of the contaminated water, no one consumed a sufficient quantity to endanger health.

Source: Adapted from EPA 2003 (p. 8).

Double check valve assembly. This consists of two internally loaded, specially designed operating check valves. This assembly is fitted with a tightly closing shut-off valve upstream and downstream of the check valves (Figure 15.3).

Pressure-type vacuum breaker. This device is designed to open with the aid of a spring when the line pressure drops so that air will break a potential vacuum. It includes a single check valve that closes at the cessation of normal flow (Figure 15.4).
The water system of a small town had been contaminated with caustic sodium hydroxide. Residents were covered with tiny blisters after showering in their homes. One person complained of blisters on her head after she washed her hair and others complained of burned throats or mouths after drinking the water. Several persons received medical treatment at the emergency room of the local hospital. A possible source of the contamination was from a nearby chemical company that distributes chemicals such as sodium hydroxide. The sodium hydroxide is brought to the plant in liquid form in bulk tanker trucks and is transferred to a holding tank and then pumped into 208-litre drums. While washing the truck’s tank, the driver was adding the water from the bottom of the tank truck instead of the top, when the water main broke and sodium hydroxide backsiphoned into the water main (Figure 15.5).

Source: Adapted from EPA 2003 (p. 3).
FIGURE 15.5 BACKSIPHONAGE ILLUSTRATION

Chemical bulk storage and holding tanks

Hose with bottom fill

“Burned in the shower”

Water service

Water main break and repair

Source: EPA 2003 (p. 3).
Reduced pressure principle device. This is an assembly of two internally loaded, independently operating check valves, with a relief valve between the valves. It is specifically designed to maintain a zone of reduced pressure between the two check valves at all times, and has a tightly closing upstream and a tightly closing downstream shut-off valve (Figure 15.6).

FIGURE 15.6 REDUCED PRESSURE PRINCIPLE BACKFLOW PREVENTER

![Diagram of a reduced pressure principle backflow preventer]

Source: IAPMO 2000 (p. 12).

CASE STUDY 5. SHIYARD CROSS-CONNECTION

The drinking-water system at a coastal shipyard became contaminated from incorrectly connected water lines between ships at the pier and the shipyard. The cause of the problem was a direct cross-connection between the on-board saltwater fire protection system and the freshwater line connected to one of the ships at the dock. As a result, the on-board saltwater fire protection system, being at a greater pressure than the potable supply, forced the salt water, through backpressure, into the shipyard potable supply (Figure 15.7).

Source: Adapted from EPA 2003 (p. 7).

Devices to protect sewerage systems. This category of devices aims to limit unwanted contamination of domestic sewage outflow and to protect the environment. Where possible, reclamation of useful waste materials for recycling should be attempted. A large number of specialized protective devices of this nature are now commercially available. Many of these promise to be more efficient in the long run than the traditional devices illustrated here. The illustrations for the grease trap, grease interceptor and grease and sand interceptor are diagrammatic only. The size and design of these devices or apparatus is dependent on the nature of the material to be treated, its temperature, the anticipated flow rates involved and numerous other factors.
**FIGURE 15.7 SHIPYARD BACKFLOW CONTAMINATION**

Source: EPA 2003 (p. 7).

**Grease trap.** This device is installed inside the facility, usually near the grease-producing fixtures (Figure 15.8).

**FIGURE 15.8 GREASE TRAP**

Source: IAPMO 2000 (p. 16).
**Grease interceptor.** This type of device is usually installed outside the building (Figure 15.9).

![Grease Interceptor Diagram](image-url)

Source: IAPMO 2000 (p. 18).

**Sand and oil interceptor.** This device is used to prevent sand and oil from parking areas getting into sewers or storm sewers (Figure 15.10).

![Precast Concrete Sand and Oil Interceptor Diagram](image-url)

Source: IAPMO 2000 (p. 21).
15.4 Guidance for protective devices

Backflow prevention devices are classified as testable or non-testable for the purposes of regulation. These devices can also be classified according to the level of hazard involved.

15.4.1 Testable devices

Requirements for reduced pressure zone devices – high hazard:

- must have free ventilation to the atmosphere for the relief valve outlet at all times;
- must not be located in an area that may be subject to ponding;
- must have the relief drain outlet located not less than 300 millimetres (12 inches) above the surrounding surface;
- must be located so as not to be subject to freezing;
- must be tested and certified every year.

Requirements for pressure-type vacuum breakers – medium hazard:

- must be located not less than 300 millimetres (12 inches) above the highest outlet;
- must be ventilated to the atmosphere at all times;
- must not be located in an area that may be subject to ponding or freezing;
- must be tested and certified every year.

Requirements for double check valves – medium hazard:

- must be located so as not to be subject to freezing;
- must be tested and certified every year.

Testable devices should be tested annually to ensure they are operating properly. The drinking-water supply authority or company should be able to register and monitor all such devices using an inspection and maintenance report system.

15.4.2 Non-testable devices

Non-testable devices include atmospheric vacuum breakers, hose connection vacuum breakers, vented double check valves, dual check valves, dual check valves with atmospheric vent and single check valves. Non-testable devices do not require annual reports. However, they should be regularly checked by the owner-occupant to ensure that they are operating correctly.

Requirements for atmospheric vacuum breakers:

- must be located not less than 150 millimetres (6 inches) above the highest outlet;
- must have no isolating valves located downstream of the vacuum breaker;
- must not remain continuously pressurized for more than 12 hours in normal operation;
• must be ventilated to the atmosphere at all times;
• must not be located in an area that may be subject to ponding;
• must be located in line, and be at least the same size as the supply and discharge piping.

Requirements for hose connection vacuum breakers:
• must be located downstream of the isolation valve;
• must not remain continuously pressurized with the water for more than 12 hours in normal operation;
• must be ventilated to the atmosphere at all times.

Requirements for vented double check valves:
• must not be located in an area that is subject to ponding or freezing;
• must have the vent port located not less than 300 millimetres (12 inches) above the surrounding surface so that the device is freely drained.

Requirement for dual check valves:
• must be located in an area not subject to freezing.

Requirements for dual check valve with atmospheric vent:
• must not be located in an area that is subject to ponding;
• must have the vent port located not less than 300 millimetres (12 inches) above the surrounding surface so that the device is freely drained.

Requirements for single check valve:
• must have an isolating valve installed upstream and adjacent to the device;
• must be fitted in an accessible location;
• must only be used in fire services.

Note: Single check valves are not deemed to be backflow prevention devices.

15.5 Guidance for sanitary waste systems

All human and domestic waste must be discharged to a public sewer, or a private sewage disposal system containing a septic tank and proper seepage pits or disposal field. Untreated human or domestic waste must not be discharged direct to the ground or into waterways. All sanitary waste systems, whether discharged to a public sewage treatment facility or to a septic tank and disposal system, should contain domestic sewage only. All other waste should be pretreated or processed. The following guidelines should be observed:

• Industrial waste should be pretreated to remove harmful chemicals and heavy metals from the waste stream. The governmental authority should specify the pretreatment requirements.
• Restaurants should have kitchen waste discharged through a grease trap or grease interceptor to remove grease from the sanitary sewer.
• Swimming pools, cooling towers and water displays should discharge into the sanitary sewer instead of the storm sewer.
• Rainwater surface flows that become contaminated by contact with oil, grease or harmful chemicals should be pretreated if possible prior to being allowed to discharge into the storm sewer or waterway.
• Industrial or laboratory waste discharge that may change the pH of the sewer system must be pretreated to neutralize the industrial waste stream so it does no harm to the waste treatment operation.
• Nothing should be admitted into the public sewer that could damage, choke or clog the pipes, produce a flammable or explosive mixture, constitute a danger to the public or the authority’s workers or interfere with the sewer treatment process.

The sewer authority should consider the following factors when deciding whether to accept an industrial waste:

• What is the relation between the quantity of the effluent to be discharged and the quantity of sewage with which it will be mixed? If the effluent is diluted sufficiently it may be less harmful.
• How complex is the process of treatment and what space and facilities are available at the factory site?
• Are there other industries in the neighbourhood producing similar waste? There may be arguments in favour of combining the outflows and treating them together.

Some sewer authorities base their charges for receiving and disposing of industrial waste on the quantity received and on the degree of treatment necessary. This encourages larger factories to install their own treatment plants. However, smaller companies may be unable to do this because of lack of space or of capital. In areas where a particular industry is important to the community, it may be better for the authority to accept waste and charge accordingly. When dealing with commercial waste, the authority will also have to be guided by the nature, quantity and strength of the effluent before deciding whether to receive it untreated into the public sewers. Premises such as slaughterhouses, breweries and dairies may at particular times discharge quantities of highly oxidized waste that can upset the biological process at the disposal works unless special precautions are taken. Under certain circumstances it may be necessary to require that the waste is diverted to a holding tank and released at a steady rate over a specified period of time rather than in sudden rushes or large batches.

15.6 Storm water drainage systems

Only clear, clean uncontaminated storm water drainage should be allowed into a storm water drainage system or discharged into local waterways. Storm waters containing deleterious substances should not be discharged into watercourses or
surface water drainage. They must either be taken to the public storm sewer, or must be treated on site to remove the offensive pollutants. These requirements may, however, be incompatible in industrial and similar premises. For example, rainwater falling on roads and paved areas should be separated from sewage to prevent overloading of the sewerage system. It should be discharged to a ditch or watercourse. However, if chemicals, oil or other spillage on the road is washed into the watercourse, serious damage to fish and other wildlife may result. Therefore, precautions should be taken to divert the initial flow into the sanitary sewer and the overflow then can be discharged to the storm water drainage system.

15.7 Temporary plumbing installations and connections

A plumbing hazard that is particularly difficult to control is a temporary installation for a particular purpose. Backflow and backsiphonage devices should be installed as described in sections 14.5 and 15.3. Because these temporary installations are not part of a plumbing system or connected to conventional fixtures, they are not subject to the requirement of plans submission, but they should be subject to other controls. Such temporary installations can be more dangerous than permanent systems, especially when they are not subject to the plumbing code of practice construction and use requirements.

15.7.1 Temporary connections on building sites

One common purpose for a temporary connection is for provision of water during building construction. Hoses from standpipes on building sites commonly deliver water into tanks of muddy water. A drop in mains pressure could siphon the contents back into the public system. Hoses may also connect standpipes to concrete mixers and provide water for various building processes. Temporary latrines may be constructed with defective sanitary fixtures that are illegally connected to the main.

15.7.2 Other temporary connections

Hoses or other temporary piping may constitute a danger in other circumstances, such as at a petrol garage (gas station), farmyard, fairground, commercial garden or pesticide applicator (especially when coupled to an insecticide sprayer), or when cleansing a market or the interior of market vehicles. The plumbing approval would cover the permanent system, possibly including a legitimate external tap to which a hose may be connected, but normally the use of the hose is not covered in the code of practice. One safeguard is an agreement between the water authority and the owner that should specify the purpose of the hose or temporary piping and assess the payment for the water used. Rules for sanitary usage may also be incorporated into the permit or agreement.
All the water piping downstream of backflow protection devices is normally classified as an industrialized water system. To protect workers from taking this water for domestic use, each outlet in such industrialized water systems should be clearly marked “Industrial water – do not drink”.

Most widely used model plumbing codes of practice specify the use and type of backflow prevention devices for specific applications. While every potential cross-connection scenario cannot be covered by the plumbing code of practice, the defined governing principles protecting the drinking water system are usually specified.

When writing a plumbing code of practice the authority should carefully assess the applications of backflow protection devices to be expected in their area together with any special hazards associated with them. The plumbing code of practice can be framed comprehensively but without being overloaded with inappropriate material. It is often better to restrict the code to basic principles and reserve the right of the authority to impose conditions in special circumstances, rather than attempting to cover every possible situation in detail.