# Block B: Water Services and Distribution Systems

# Block B: Water Services and Distribution Systems

## Plumbing Apprenticeship Program Level 3

Industry Training Authority BC

BCCAMPUS
VICTORIA, B.C.

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# Introduction

Potable water – water that is safe for human consumption – is the basis for life. Safe and readily available water is important for public health, whether it is used for drinking, domestic use, or food production. A safe and reliable supply system ensures water is delivered to consumers in a potable state.

To help describe the different parts of a water supply system, the content in Block B is broken into 4 Competencies.

- Competency B1 will describe the water supply system from the raw water source all the way to the curb stop. This part of the system will be referred to as the **municipal water supply system.**
- Competency B2 will cover the water supply system downstream of the curb stop. The curb stop is generally where the plumber gets involved in the design, including sizing of the water service pipe, as well as the design, sizing, installation and maintenance of the **building water supply system.**
- Competency B3 will describe the installation of irrigation systems
- Competency B4 will describe alternative green water supply systems

# Competency B1: Install Water Services

It is important that plumbers have a basic understanding of the water supply system from the source to the tap. Although plumbers may not be involved in the design of municipal water supply systems, they can be involved in the installation and maintenance. Competency B-1 will cover the municipal water supply system.

Learning Objectives

After completing the learning tasks in this Competency, you will be able to:

- use common terminology associated with water supply systems,
- describe and identify parts of a municipal water supply system, and
- describe the installation of pipes and components used in a municipal water supply system

## Resources

You will be required to reference the most current British Columbia Plumbing Code.

# Learning Task 1

Describe Water Services

Building Codes require that every dwelling unit shall be supplied with potable water. The water supply system that supplies the potable water can be provided by public or private water supplies, and the source can be from above ground water such as lakes and rivers, or it can come from underground aquifers that are accessed through wells. Once a water supply has been established, a distribution system that will ensure a safe and adequate delivery of potable water must be designed and installed.

For the purposes of the content in this section, the term “water services” will be interpreted as the water supply system upstream of the curb stop. This part of the water supply system is often referred to as the municipal water supply system if the water source is public.

Many of the terms used to describe water supply systems are defined below.

## Terminology

As with all trade-specific content, an understanding of the related terms is important before covering the content in detail. The terms defined below are used to describe water supply systems and the associated components and equipment. The list of terms is specific to British Columbia, but most will have a similar meaning in other regions of Canada.

An example of a complete system, from source to tap, is shown in Figure 1 and can be used to identify different parts of the water supply system. ()

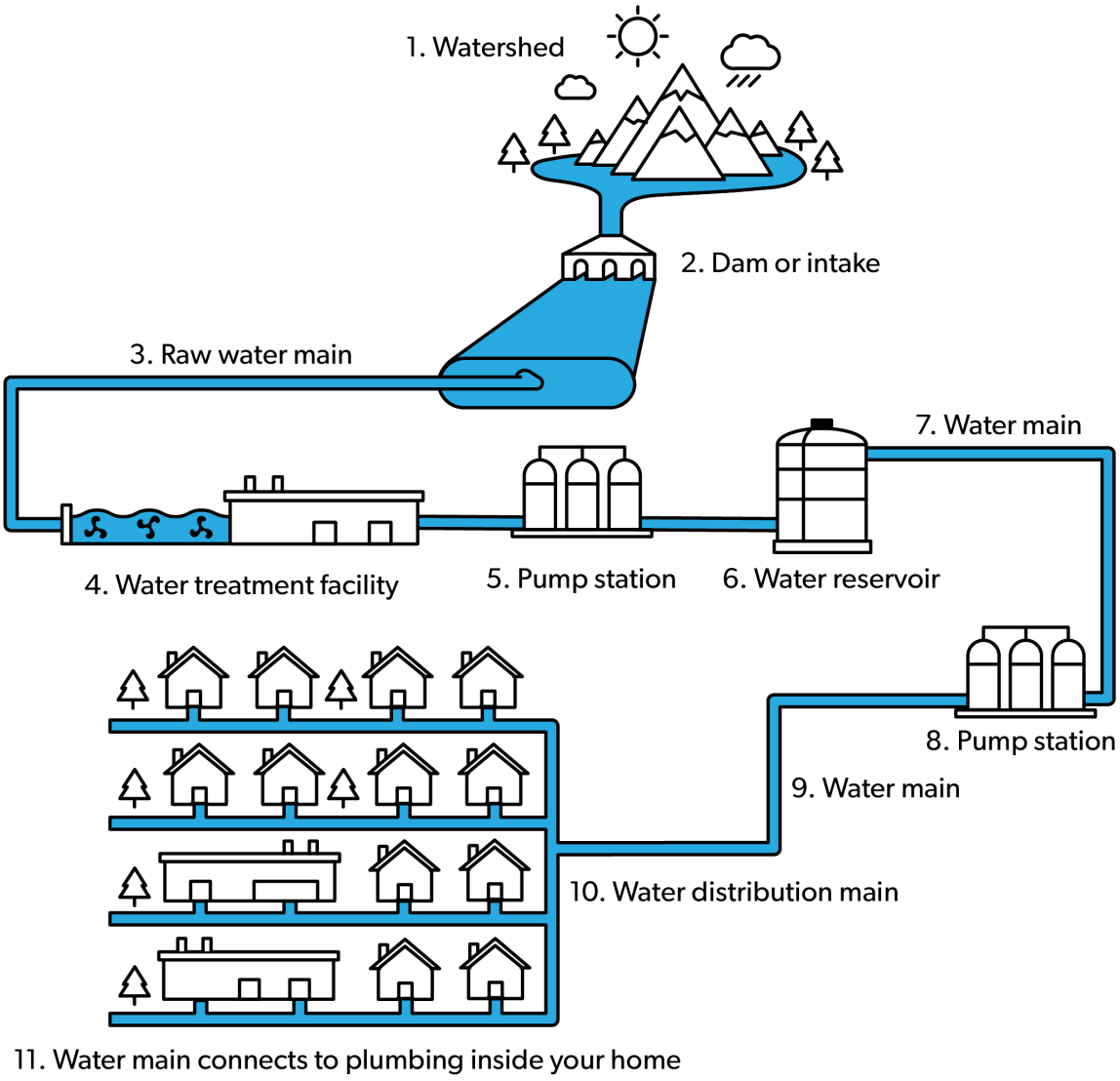



*Figure 1 Water system from source to tap [Image description] (#id1)*

## Building Water Distribution System

The BC Plumbing Code (BCPC) defines the term “water distribution system” as an assembly of pipes, fittings, valves and appurtenances that conveys water from the water service pipe or private water supply system to water supply outlets, fixtures, appliances and devices. Although the BC Plumbing Code implies that a water distribution system is the piping and components downstream of the curb stop, the term “distribution system” also gets used to describe parts of the municipal water supply system that is upstream of the curb stop. For the purposes of this competency, the term “building water distribution system” will be used to define the water distribution system inside the building.

## Building Water Supply System

This term is used to differentiate the water distribution system downstream of the curb stop from the

system upstream of the curb stop. The term comprises the water service pipe and the building water distribution system. Plumbers are involved in the design and installation of this part of the system.

### Contaminated Water

Contaminated water is water that contains matter that is capable of seriously affecting the health of people drinking the water. Contaminants may be organic or inorganic in origin.

### Corporation Stop

A valve installed on a municipal water main to permit joining of the water service pipe.

### Cross Connection

A cross connection is an existing connection or a potential connection between any part of a potable water system and any other environment containing any other substances in a manner which, under any circumstances, would allow such substance to enter the potable water system.

Another way to define a cross connection is any actual or potential connection between the waterworks and any source of pollution, contamination or other material or substance that could change the quality of water in a drinking water supply.

### Curb Stop

The curb stop is the valve installed on a water service to turn the flow of potable water to a building on or off.

### Domestic Purposes

This term means the use of water for human consumption, food preparation or sanitation.

### Municipal Water Distribution System

This term is used to define the part of the water supply system upstream of the curb stop, and includes piping commonly referred to as the water main. Plumbers are not generally involved in the design of this part of the system but may install and maintain the piping and components that make up the system.

### Polluted Water

Polluted water is water that contains objectionable matter that will not injure the health of humans drinking the water. Pollutants may be organic or inorganic in origin.

### Potable Water

The BC Drinking Water Act defines potable water as water provided by a domestic water system that meets the prescribed standard(s), and is safe to drink and fit for domestic purposes without further treatment. Essentially, potable water is water that is safe for human consumption.

### Pressure System

A pressure system is a water supply design that uses equipment and components that include pumps, pressure tanks, and controls. Types of pressure systems include shallow well, deep well, and boosted systems.

### Private Water Supply System

The BC Plumbing Code defines this term as an assembly of pipes, fittings, valves, equipment and appurtenances that supplies water from a private source to a water distribution system. The term “rural water supply” is sometimes used interchangeably with private water supply system. Both terms refer to systems that generally incorporate pressure systems.

### Raw Water

Raw water is water in its natural state, like rainwater, groundwater, and water from bodies like lakes and rivers. Water is considered to be raw until it is treated by a potable water treatment process.

### Riser

The BC Plumbing Code defines riser as a water distribution pipe that extends through at least one full storey of a building. A riser is part of a building water distribution system

### Used Water

Any water supplied by a water purveyor from a public potable water system to a consumer’s water system after it has passed through the service connection and is no longer under the control of the water purveyor.

### Water Distribution System

The BC Plumbing Code defines this term as an assembly of pipes, fittings, valves and appurtenances that conveys water from the water service pipe or private water supply system to water supply outlets, fixtures, appliances and devices. Although the BC Plumbing Code implies that a water distribution system is the piping and components downstream of the curb stop, the term “distribution system” also gets used to describe parts of the municipal water supply system that is upstream of the curb stop. For the purposes of this competency the term “municipal water distribution system” will be used to describe part of the system that is upstream of the curb stop.

### Water Mains

Water mains are part of the municipal water distribution system. These large pipes are used to deliver potable water from the purveyor's source to the water service pipe. Usually these are underground pipes operating at higher pressures than required by the end user. This term also gets used as a catch-all term to describe the entire water supply system upstream of the curb stop.

### Water Purveyor

A purveyor is the owner or operator of a potable waterworks system. A water purveyor is also referred to as a water provider or water supplier. A water purveyor can be a private for-profit entity, or public not-for-profit entity. Purveyors can be a water wholesaler, selling potable water to municipalities for resale to their customers, or a retailer, directly selling to the end-user.

### Water Service Pipe

The BC Plumbing Code defines this term as a pipe that conveys water from a public water main or private water source to the inside of the building.

### Water Supply System

This term is used to describe the entire system of pipes, fittings, valves, and appurtenances that supply potable water from the source to the tap. For the purposes of this content the water supply system can be divided into the system upstream of the curb stop, referred to as the municipal water supply system, and the system downstream of the curb stop, referred to as the building water supply system.

### Water System

The BC Plumbing Code defines this term as a private water supply system, a water service pipe, a water distribution system or parts thereof.

## The Water Supply System

In British Columbia, over 90% of residents get their water from municipal water supply systems, while the remainder get their water from private wells, with a small percentage getting their water delivered by tanker trucks into holding tanks.

Most of the raw water that feeds into municipal water supply systems comes from rivers and lakes, referred to as surface water sources. Municipal water supply systems can also get raw water from underground aquifers, referred to as ground water sources. In municipal water supply systems, the raw water is treated before it is pumped to homes and businesses. The quality of the raw source water determines the type of treatment method required.

After treatment, municipal water supply systems distribute water to homes and businesses in large

pipes called water mains that are usually buried under roads and sidewalks. Water mains are maintained by the purveyor, and paid for by water rates and property taxes.

Water service pipes and building water distribution systems are smaller pipes that transport the water from water mains to individual homes, apartments and businesses.

Figure 2 shows the water supply system, from source to tap, separated into different sections. Each section will be covered in the content below. ()

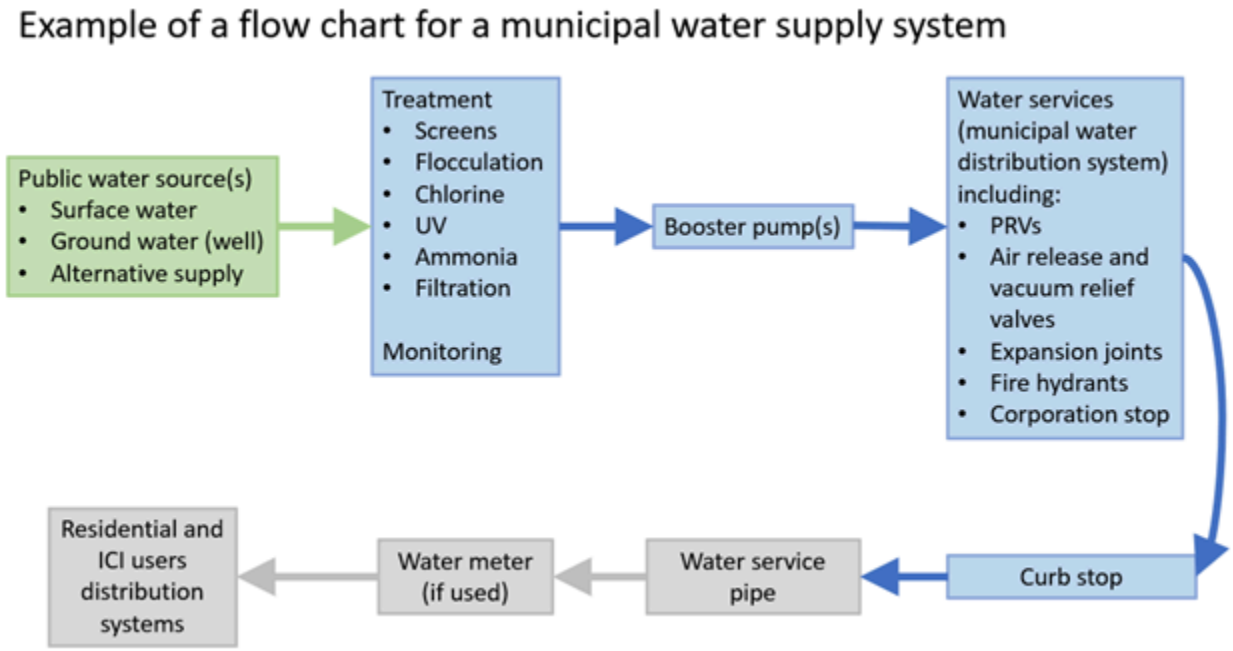



*Figure 2 Source to tap flow chart [Image description] (#id2)*

## The Water Cycle

Without water, there would be no life on Earth. Earth and its atmosphere comprise a closed system where no new water is introduced; rather, the water that exists on earth today is the same water that existed billions of years ago. The journey water takes to your tap begins with a source that is supplied by the water cycle. The water cycle, or hydrologic cycle, is the path water takes as it moves through the environment. It is a natural recycling system that cleans water and allows it to be endlessly reused.

The water cycle is a complex system that includes many different processes. Liquid water ***evaporates*** from oceans, lakes, and streams into water vapor, ***condenses*** to form clouds, and ***precipitates*** back to earth in the form of rain and snow. Water in different phases moves through the atmosphere. Liquid water flows across land as ***surface runoff***, and into the ground by infiltration and percolation. ***Groundwater*** moves into plants (plant uptake) and evaporates from plants into the atmosphere through a process called ***transpiration***. Solid ice and snow can turn directly into gas (sublimation). The opposite can also take place when water vapor becomes solid (deposition).

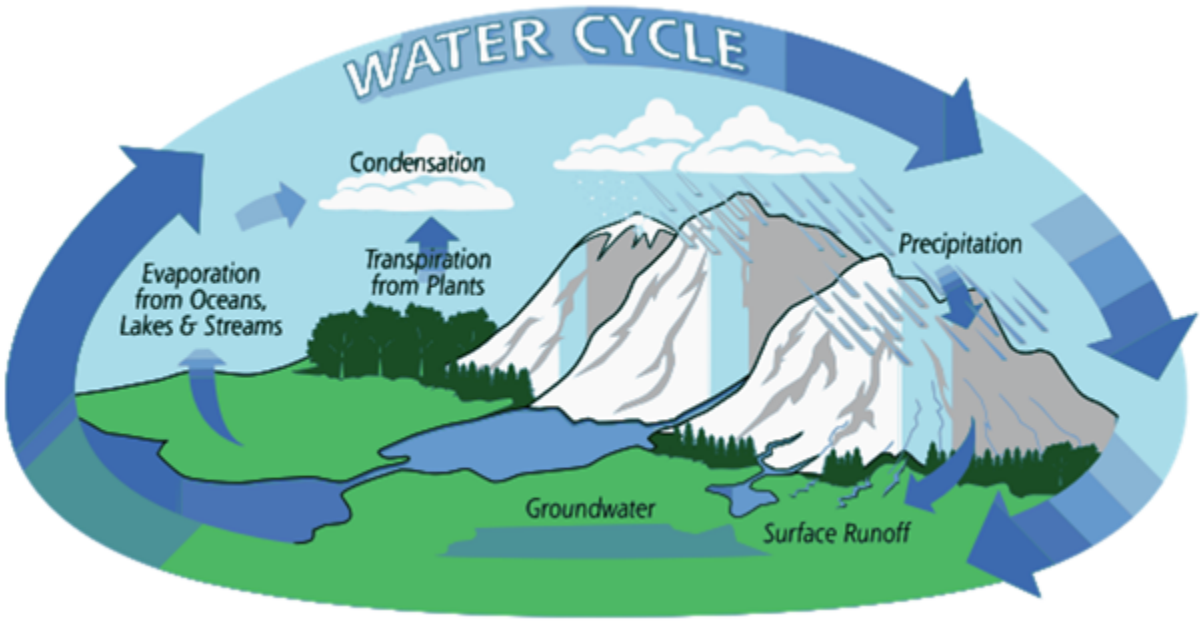



*Figure 3 The water cycle.*

Although water that has been evaporated starts out as pure water, pollution and contamination can quickly occur. Water stored in clouds absorbs carbon dioxide from the atmosphere and precipitation may collect other impurities from the atmosphere as it falls to earth. Absorbed carbon dioxide lowers the pH of water below neutral. The more carbon dioxide absorbed, the lower the pH level will be. Other atmospheric impurities, such as nitrogen oxides and sulphur, also lower the pH level of precipitation. If the pH level is less than 7, the water is considered to be acidic. The pH level of natural precipitation is commonly close to 5.6, but lower levels have been reported, particularly downwind from large cities or industrial developments. At pH levels over 7, water is considered to be alkaline. The pH level of precipitation is rarely above 7, but higher levels have been observed, primarily downwind from industrial areas generating alkaline pollutants.

When precipitation falls to earth, its increased carbon dioxide content boosts its capability to dissolve mineral matter on which it falls. Water is called a universal solvent because more things can be dissolved by water than by any other liquid. The amount of mineral or chemical matter that water can dissolve depends on the pH level and temperature of the water, solubility of the substance it contacts and how long the water is in contact with the substance. These factors partially determine how potable or suitable for human consumption, the water is.

Each water source has its associated advantages and disadvantages. Primary considerations for a water source are:

- the quantity of water available,
- the continuity of supply from the source and
- the quality of water the source is able to provide.

## Water Supply System Types

In British Columbia, a “water supply system” is defined as all the equipment, works and facilities used for treatment, diversion, storage, pumping, transmission and distribution for a system which serves more than a single-family residence.

The majority of Canada’s population is classified as urban, and the distribution of water to this group of users is a major task. Most of Canada’s larger cities are located on or near a major river system or lake, which can be used as a source for a public water supply system. If a public water supply system is not available, a private water supply, or alternative water supply, may be used as a drinking water source.

To help identify and describe common piping and components of a water supply system this Competency will use the figure below to break the system into sections. We will begin at the upstream end of the water supply system by defining the different types of systems.

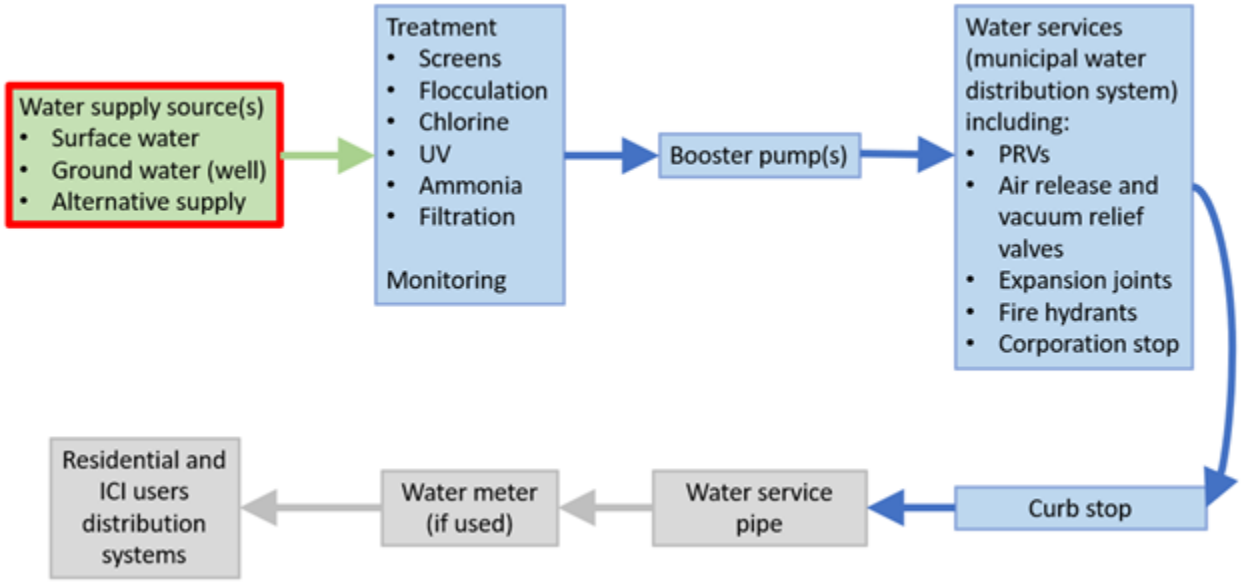



*Figure 4 Source to tap flow chart with “Public water source(s)” emphasized*

### Public water supply systems

Public systems are generally owned and operated by municipalities or specifically created utilities. The purveyor of public supply systems commonly uses reservoirs to ensure an adequate supply of water throughout the year and, if necessary, treatment and testing systems are in place to ensure the water quality meets provincial and national standards.

Modern public systems can be defined as being either small or large. In British Columbia a “small system” means a water supply system that serves up to 500 individuals during any 24-hour period. This means a “large system” would serve more than 500 individuals during any 24-hour period.

Publicly-owned municipal water supply systems must provide water for fire protection, and are sized based on pressure and flow at the period of peak demand.

#### Private water supply systems

A private water supply system is defined by the BC Plumbing Code as an assembly of pipes, fittings, valves, equipment and appurtenances that supplies water from a private source to a water distribution system. Since the term “water distribution system” essentially means the water piping inside the building, the term “private water supply system” is interpreted as meaning a water supply to be used only on the same property as the source.

There are many situations where a public water supply system may not be available, so in this case a property owner has the option to drill a private well and use groundwater, or use surface water such as lakes and streams, to supply domestic water for personal use. These residential systems are intended to be used only for supplying potable water to the single-family home (dwelling unit) on the property; sharing water with a neighbour, for instance, may not be permitted. If you have a good neighbour system and own the water source, you might be considered to be a water purveyor (provider) and specific responsibilities under the Drinking Water Protection Act may apply to you.

Residential systems are also referred to as rural systems or pressure systems. There are several types of these systems including shallow well, deep well, and boosted systems. These systems include components such as pressure tanks, pumps, and controls and are covered in more detail in the plumber Level 4 content.

Unlike a municipal water supply system, a private water supply system does not typically provide water for fire protection.

#### Private water utility

In British Columbia, there are private water utilities (purveyors) that source their water from private property. A private water utility under the Water Utility Act is a person/business who owns or operates equipment or facilities for the delivery of domestic water service to five (5) or more persons or to a corporation for compensation. Private water utilities are usually created by developers to serve rural land development where community water service is required for subdivision approval, and where there is no other water purveyor in the area that can provide service.

There are dozens of regulated private water utilities throughout British Columbia that provide water to customers who are not connected to a public system. The private water system purveyors must meet the same water quality standards as the public systems and, therefore many incorporate water treatment as part of their process.

#### Alternative green water supply systems

This content is covered in another Competency of the plumber Level 3 content.

## Protecting the Water Supply

Health Canada states “the best way to make sure drinking water supplies are kept clean, safe and reliable is to take a preventive risk management approach. This means understanding each water supply from its beginning in nature to where it reaches the consumer.”

### The multi-barrier approach to safe drinking water

As drinking water travels on its journey to the end user, it can become contaminated in many ways. The multi-barrier approach to managing drinking water supplies is a preventive risk management approach that identifies all known and potential hazards and makes sure barriers are in place to reduce or eliminate the risk of contamination.

The BC Plumbing Code addresses protecting a potable water system from contamination in Article 2.6.2.1. Connection of Systems:

1. Except as provided in Sentence (2), connections to potable water systems shall be designed and installed so that non-potable water or substances that may render the water non-potable cannot enter the system.
2. A water treatment device or apparatus shall not be installed unless it can be demonstrated that the device or apparatus will not introduce substances into the system that may endanger health.

### Cross connection devices

Cross connection control devices, such as back-siphonage preventers and backflow preventers, are found throughout public ad private domestic water systems. These devices help prevent “used water” from backflowing into the potable water supply system. “Used water” is any water supplied by a water purveyor from a public potable water system to a consumer’s water system after it has passed through the service connection and is no longer under the control of the water purveyor.

The source water is protected by the water supply system operator (purveyor), but the plumber may be required to determine the protection required for the treatment equipment and building water distribution system. Because of the liability associated with selecting the correct level of protection for cross connection control, plumbers are more likely to install and service cross connection devices than to actually select them.

The BC Plumbing Code lists most of the back-siphonage and backflow preventers used by plumbers in Article 2.2.10.10.

Cross connection control devices are covered in detail in Block C section of the plumber Level 3 content.

## Water Treatment and Monitoring

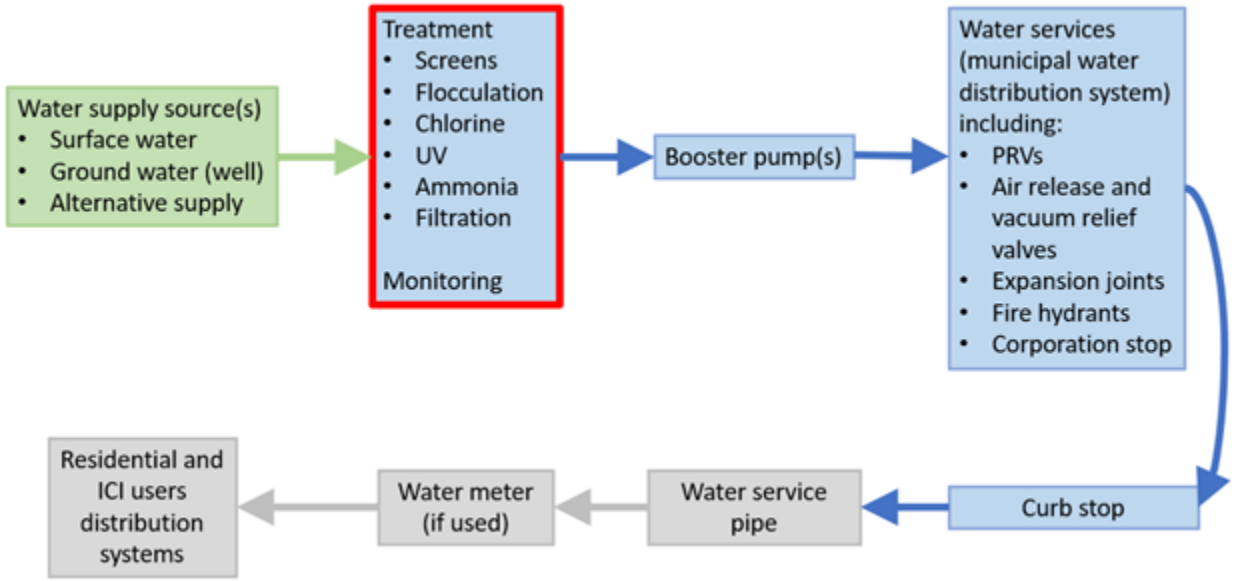



*Figure 5 Source to tap flow chart with "Treatment" emphasized*

Moving downstream, the next section of the municipal water supply system to be covered is Treatment and Monitoring.

Water purveyors rely on the water cycle to provide high quality raw water as a starting point for their potable water supply systems. Depending on the initial water quality, some form of water treatment may be required. The potable water delivered to the end user must meet the applicable water quality standards set out by the authority having jurisdiction (AHJ).

Almost all domestic water goes through some form of treatment before being delivered to the end user. In British Columbia, water suppliers are responsible for delivering safe drinking water that meets the requirements of the Drinking Water Protection Act and Drinking Water Protection Regulation, as well as the conditions set on their operating permits. These requirements include treating the water, if necessary, and ensuring water quality through monitoring. Water suppliers must notify the public when there is a potential or actual problem.

Most public water supply systems will include several stages of screens and filtration (to remove suspended particles, debris and algae) and disinfection (to remove bacteria and viruses). Disinfection methods include chlorination and treatment with ultra violet (UV) light. Water obtained from any source must not be considered potable (safe for human consumption) until the water has been properly tested for its mineral, chemical and biological characteristics and the results of the test compared to the Guidelines. Water is then piped into the transmission and distribution network and sent to homes, schools, and businesses for people to use.

The water purveyor carefully manages the supply and delivery of safe and sustainable drinking water. Delivering safe drinking water from source to tap includes protecting the source, disinfecting the water and monitoring water quality, operating and maintaining transmission and distribution systems, and

investing in infrastructure renewal. Purveyors have strategic plans in place to ensure safe and sustainable drinking water well into the future.

Potable water from a public system is closely monitoring for water quality but if the water source is a private system that only supplies water to one connection then the responsibility for testing the water is up to the homeowner. The water treatment equipment used for single-family dwellings is covered in the Level 4 content of the plumber program. Plumbers will typically design the residential water treatment system and then complete the installation of the system, integrating it in with the building water distribution system.

## Pumps

Moving downstream to the next section of the public water supply system will bring us to Booster pumps. Booster pumps are used throughout water supply systems but the content in this section is only an introduction to pumps in general. Booster pumps used on building water distribution systems will be covered in Competency B-2.

Note that pumps for private water supply systems are covered in greater detail in the plumber Level 4 content.

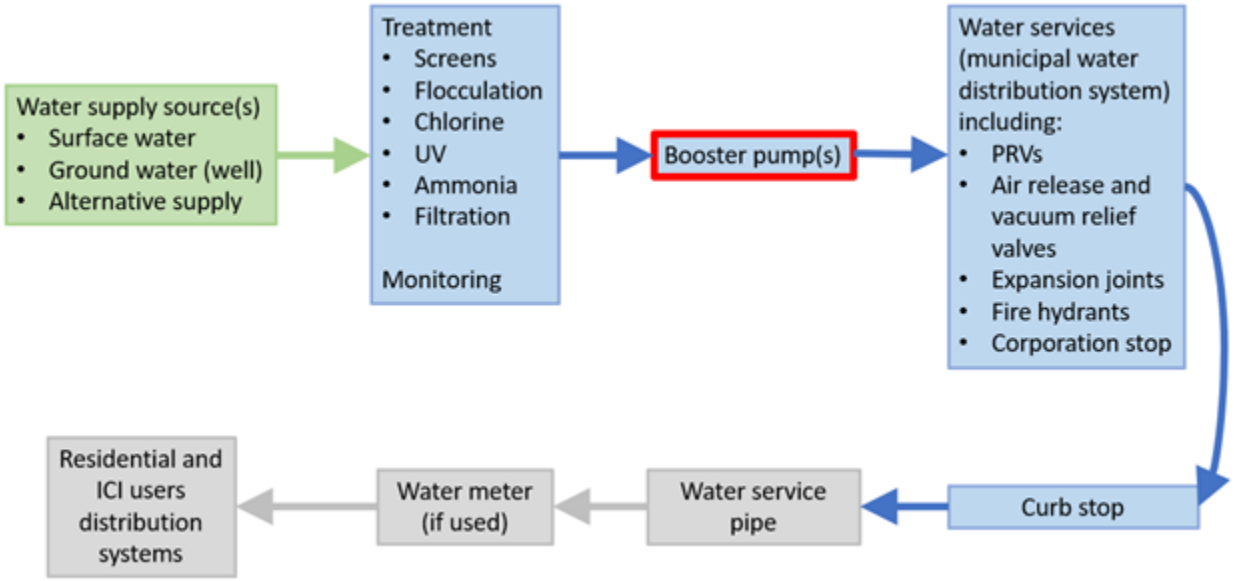



*Figure 6 Source to tap flow chart with "Booster pump(s)" emphasized*

Ideally, a water supply system would rely only on head pressure to move the water from the source to the tap. This is almost never possible. A municipal water supply system will use pumps to move water in many different locations, including:

- Raw surface water from source to treatment plant
- Municipal wells to the treatment plant
- Water treatment plant processes

- Potable water to water towers
- Distribution system booster pumps

Modern pumps come in many designs and are used for an extraordinary range of applications. The focus of this section will be to describe the basic operation of different pumps and to introduce common pumps used by plumbers. Pump manufacturers and suppliers can be great resources for plumbers who are new to working with pumps. In all cases, the applicable documentation must be reviewed before selecting and installing any pump to ensure the selected unit will meet or exceed the system parameters.

Classifying or categorizing pumps is complex so, for the purposes of this content, pumps will be categorized as two different types based on the operating principle. The categories are **positive displacement** and **centrifugal**, but there are many different design classifications within these categories. ()

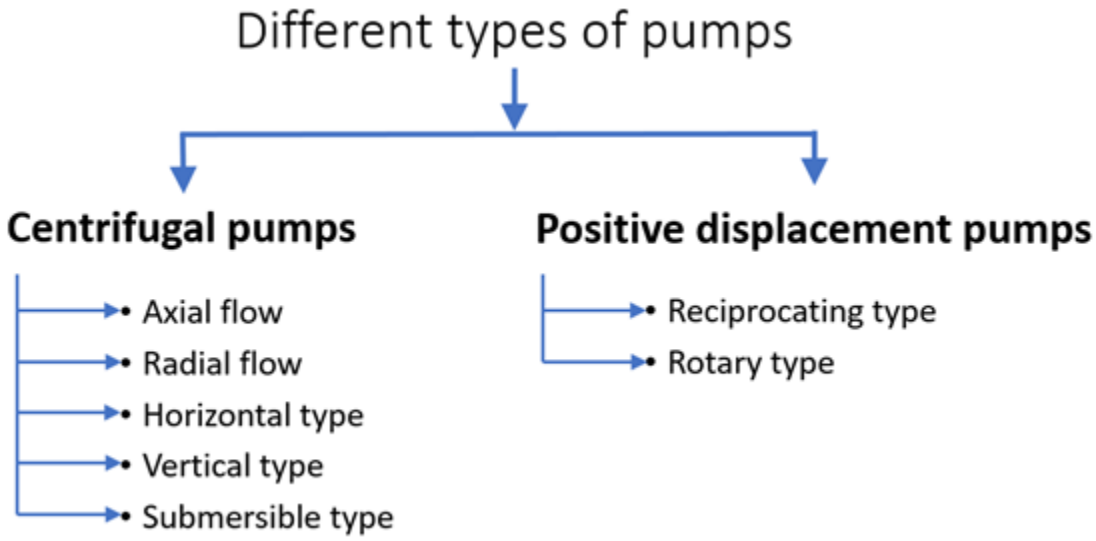



*Figure 7 Simplified list of pump categories and types [Image description] (#id7)*

## Centrifugal Pump Design and Theory of Operation

A centrifugal pump is a mechanical device designed to move a fluid by means of the transfer of rotational energy from one or more driven rotors, called impellers. Fluid enters the rapidly rotating impeller along its axis and is cast out by centrifugal force along its circumference through the impeller's vane tips. The action of the impeller increases the fluid's velocity and pressure and also directs it towards the pump outlet. The pump casing is specially designed to constrict the fluid from the pump inlet, direct it into the impeller and then slow and control the fluid before discharge.

The impeller is the key component of a centrifugal pump. It consists of a series of curved vanes. Fluid enters the impeller at its axis (the eye) and exits along the circumference between the vanes. The impeller, on the opposite side to the eye, is connected through a drive shaft to a motor and rotated at high speed. The rotational motion of the impeller accelerates the fluid out through the impeller vanes into the pump casing.

Figure 8 shows the names associated with a centrifugal pump, as well as the flow path through the impeller and casing.

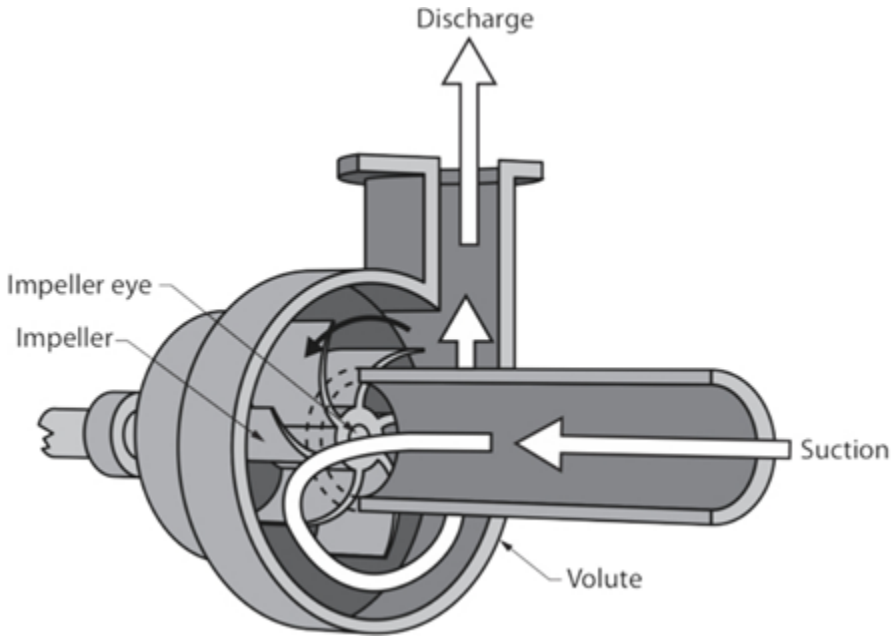



*Figure 8 Simplified centrifugal pump cutaway showing parts and their names*

## Positive Displacement Pump Design and Theory of Operation

A positive displacement pump moves a fluid by repeatedly enclosing a fixed volume and moving it mechanically through the system. The pumping action is cyclic and can be driven by pistons, screws, gears, rollers, diaphragms or vanes. Although there are a wide variety of pump designs, the majority can be placed into two categories: reciprocating and rotary.

#### Reciprocating pumps

A reciprocating positive displacement pump works by the repeated back-and-forth movement (strokes) of either a piston, plunger or diaphragm. These cycles are called reciprocation. A simple hand pump that uses the reciprocating piston principle is shown below.

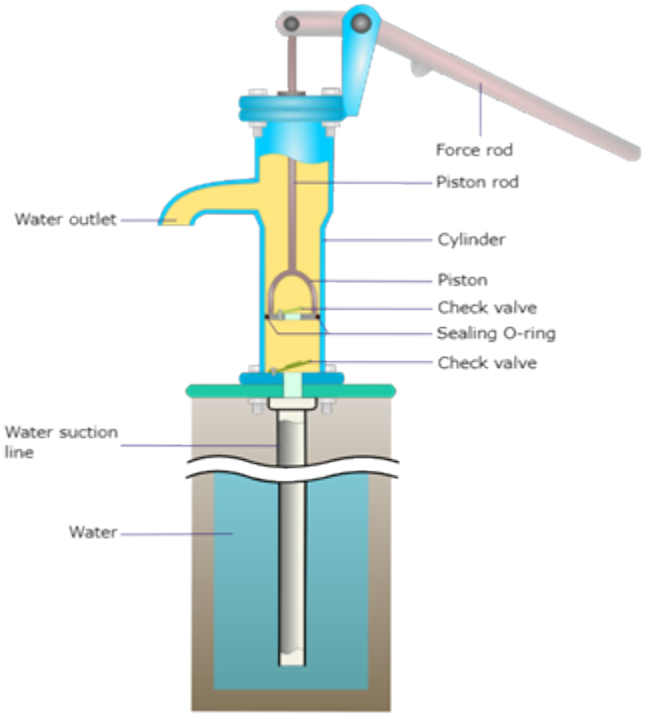



*Figure 9 One design of a reciprocating pump*

**Rotary pumps**

Rotary positive displacement pumps use the actions of rotating cogs or gears to transfer fluids, rather than the back-and-forth motion of reciprocating pumps. The rotating element develops a liquid seal with the pump casing and creates suction at the pump inlet. Fluid drawn into the pump is enclosed within the teeth of its rotating cogs or gears and transferred to the discharge. The simplest example of a rotary positive displacement pump is the gear pump. Examples of external gear, internal gear and a peristaltic rotary positive displacement pumps are shown below.

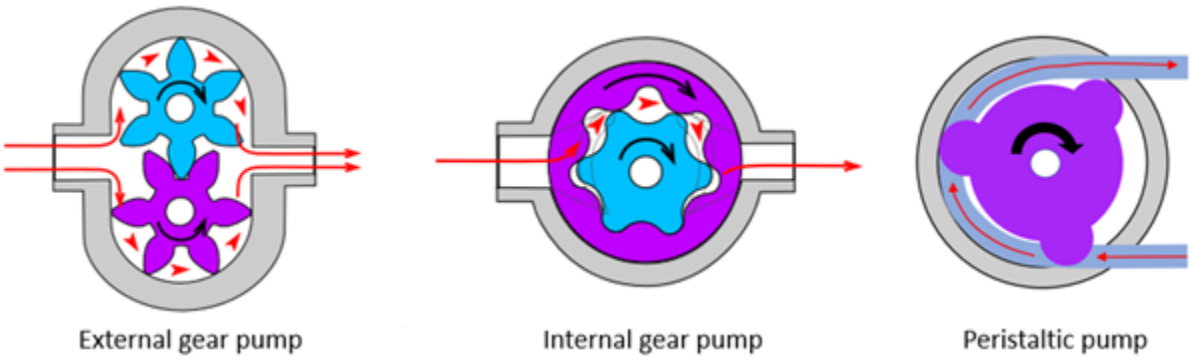



*Figure 10 Examples of rotary pumps*

When selecting a pump for a specific application, the plumber chooses the type and design based on factors such as the outlet pressure required, the volume required to be delivered, the fluid being pumped, etc. Below is a description of some of the pumps commonly used by plumbers.

#### Booster pumps

These pumps are usually electrically driven, multi-stage, centrifugal pumps incorporating a non-return valve and are used when the water supply pressure is not high enough to operate fixtures and equipment downstream. Water purveyors use booster pumps to boost the water main pressure at different intervals based on pressure loss in the piping or elevation change within the system. Buildings such as high-rises may use booster pumps to ensure an adequate pressure at the upper storeys. Since booster pumps may elevate the water pressure above the maximum working pressure of some downstream components, it is common to use pressure reducing valves (PRV) in the downstream system. PRVs are described later in this section.

#### Centrifugal pump

As previously mentioned, the term centrifugal pump can be considered a category of pump, but the term can also be used to refer to the simplest design of this type of pump.

#### Condensate pump

Plumbers would see condensate pumps on modern, high-efficient, condensing gas-fired appliances. They are a centrifugal pump that is specifically designed to handle low pH fluid and pump it to an applicable location such as the building sewer.

#### Diaphragm pump

This positive displacement pump uses a flexible membrane instead of a piston or plunger to move fluid. By expanding the diaphragm, the volume of the pumping chamber is increased and fluid is drawn into the pump. Compressing the diaphragm decreases the volume and expels some fluid. Diaphragm pumps have the advantage of being hermetically sealed systems making them ideal for pumping hazardous fluids.

#### Hot water recirculation pump

A hot water recirculating pump is a centrifugal pump that is used to circulate domestic hot water so that any faucet or valve will have hot water within a few seconds of being opened. These systems circulate hot water from the most remote fixture back to the hot water source. They are commonly used on residential and Industrial-Commercial-Institutional (ICI) hot water systems. The major difference between this design and the hydronic circulator design is that the wetted-components must be made of materials that will not contaminate the potable water supply. Bronze and stainless steel materials, as well as plastics, are typically used in hot water recirculating pumps. More content on hot water recirculation will follow in Competency B-2.

#### Hydronic circulator

This design of this centrifugal pump is intended to only create a pressure differential within the closed-loop hydronic (hot water) heating system. The pressure differential creates flow within the system when the circulator is operating. Smaller systems incorporate wet-rotor designed circulators, while bigger systems, and older systems, still use 3-piece circulator designs.

**Hydrostatic test pump**

These positive displacement pumps are designed for pressure testing systems such as water lines and sewer force mains. They are typically either power-driven (gas engine, air pressure, electric motor) diaphragm design or hand-operated piston style water pressure test pumps.

**Jet pump**

Jet pumps are most commonly used to lift water from wells. There are two different designs that are used based on the depth of the well. The design operates on the principle of a high-pressure fluid jet and the venturi effect, which exerts suction. Essentially, a jet pump is really two pumps in one; a centrifugal pump and a jet assembly commonly called an ejector. The ejector can be attached to the pump body, or it can be located down in the well. The location of the ejector will determine the pumping depth of the jet pump as shown in the figure below.

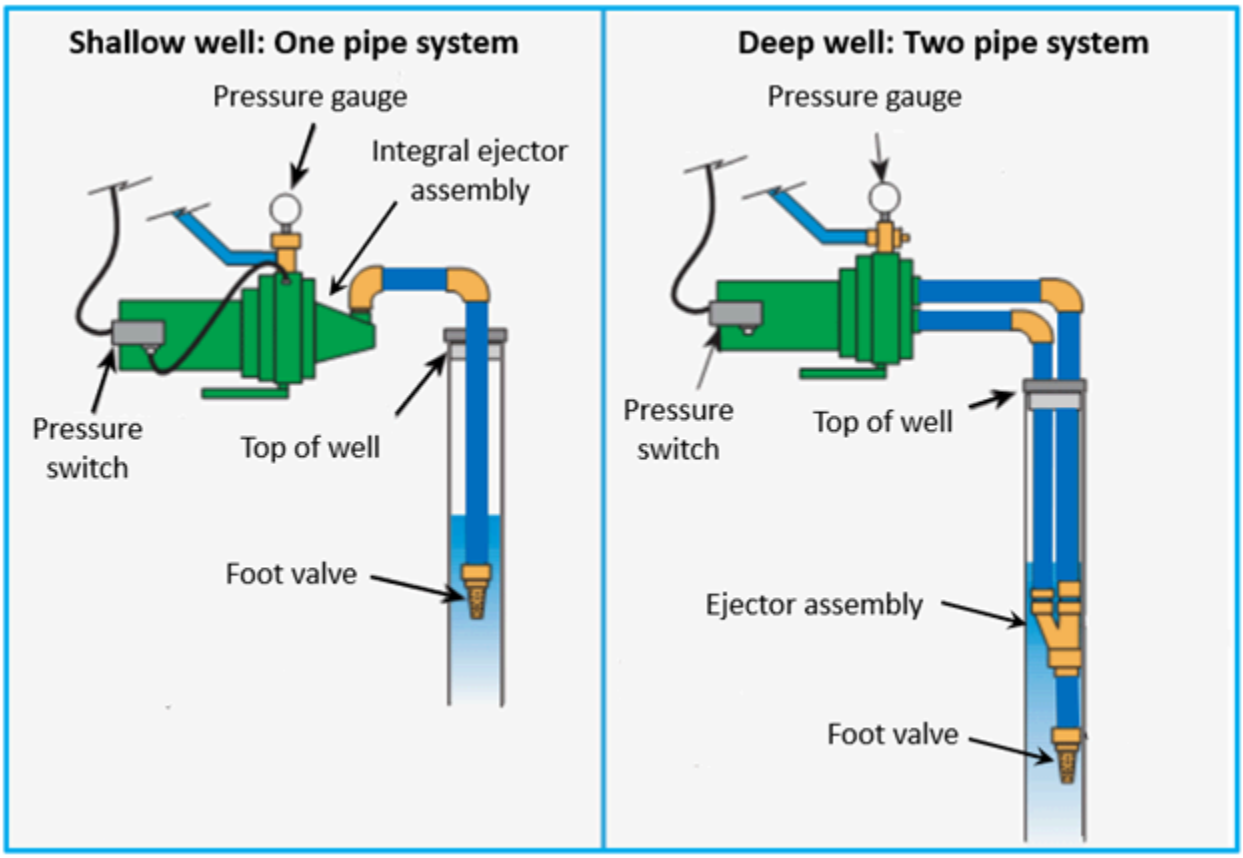



*Figure 11 Jet pump designs*

**Peristaltic pump [Level 3]**

These pumps are also commonly known as a roller pump. It is a type of positive displacement pump used for pumping a variety of fluids. The fluid is contained in a flexible tube fitted inside a circular pump casing. Most peristaltic pumps work through rotary motion, and are commonly used to pump chemicals, such as in laundry and hospital applications.

#### Submersible pump

This pump design falls under the centrifugal classification and is a device which has a hermetically sealed motor close-coupled to the pump body. The whole assembly is submerged in the fluid to be pumped. The main advantage of this type of pump is that it does not require priming as the suction is submerged in the fluid. Submersible pumps push fluid to the surface, rather than pull liquid up like a jet pump, which create a vacuum and relies on atmospheric pressure. Plumbers would use submersible pumps as sump pumps, sewage pumps, stormwater pumps, deep well pumps, etc.

The BCPC Figure A-2.4.6.3. Arrangement of Piping at Sump, shows a sump using a submersible pump.

#### Transfer pumps

These are typically positive displacement gear pumps that are able to pump at high pressures and excel at pumping high viscosity liquids efficiently. An example of a use for this type of pump would be for a plumber to add glycol to a heating system.

#### Well pumps

The Ground Water Protection Act lists many classes of wells (geotechnical, monitoring, closed-loop geoexchange, etc.) but this section will focus on pumps for water supply wells.

Pumps are needed when a well is used to provide domestic water and the water level in the well is lower than the house or building. There are basically four types of wells (dug, bored, driven, and drilled) which can be divided into two groups, shallow or deep. These terms are referring to the depth of the water source or well. A shallow well is one where the water is within 25 feet of the ground surface. A deep well is where the static water level is more than 25 feet down.

A typical well water system lifts water from an underground well and delivers it to a storage tank where it is pressurized and stored until it is needed. Most well pumps fall into one of two categories, either jet pumps or submersible pumps. Choosing a jet pump or submersible pump will likely depend on the depth of your well. There are many factors involved in selecting the correct well pump and the list below can be used as a general guideline.

- If less than 25′, use a shallow well jet pump
- If 25′ – 110′, use a deep well jet pump
- If 25′ – 400′, use a 4-inch submersible pump

Selecting the correct pump is so important that the Groundwater Protection Regulation (GWPR) lists the rules and requirements for installing well pumps in British Columbia. This means that installing a pump in a well is a restricted activity in B.C., and in most cases may only be performed by a registered well pump installer. Registered well pump installers are certified to work in the province and will install a pump in compliance with the regulations.

In British Columbia, registered well drillers and well pump installers must be members of the BC

Ground Water Association (BCGWA). Well pumps are covered in detail in the plumber Level 4 content.

## The Municipal Distribution System

Using the flow chart below, the section downstream of Booster pump(s) will be covered next. This section includes many of the pipes, fittings, valves, and appurtenances that a plumber would need to know about if working on the installation or maintenance of a municipal water supply system.

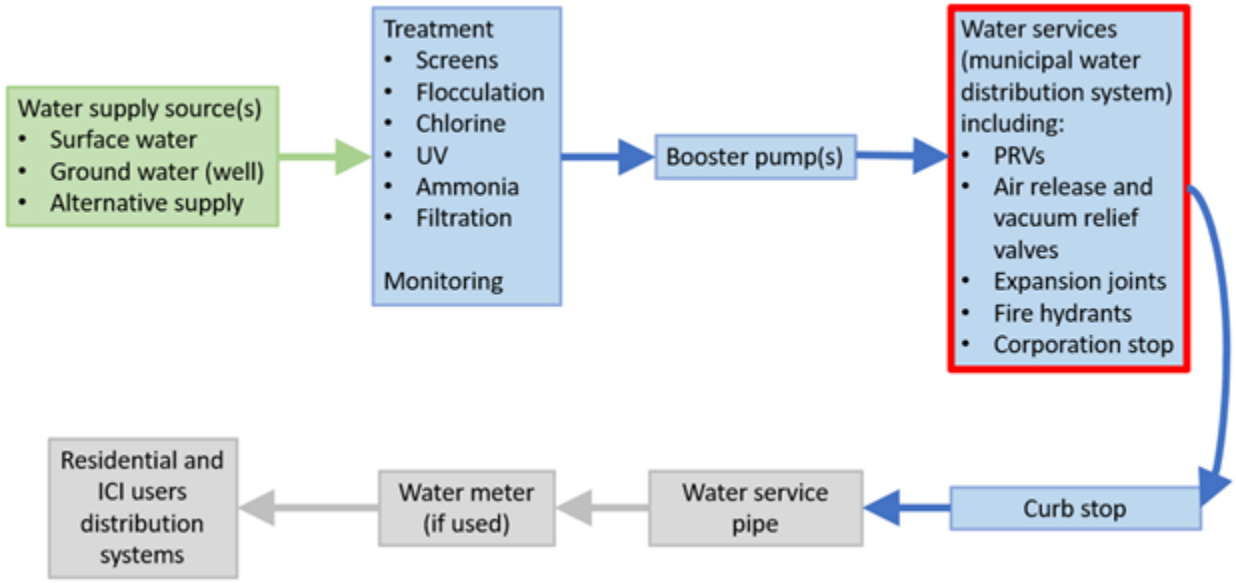



*Figure 12 Source to tap flow chart with "Water services" emphasized*

### Municipal Distribution System Designs

After water has been treated, pumps move the water to the transmission and distribution network. Modern distribution systems are laid out in a pattern that connect all pipes into one of three piping networks, or a combination of them.

#### The arterial loop system

This system design is found in areas of the municipality needing large quantities of water or where heavy demand is placed on the system. This system uses two equally sized transmission lines that supply water to equally sized distribution pipes as shown in Figure 13.

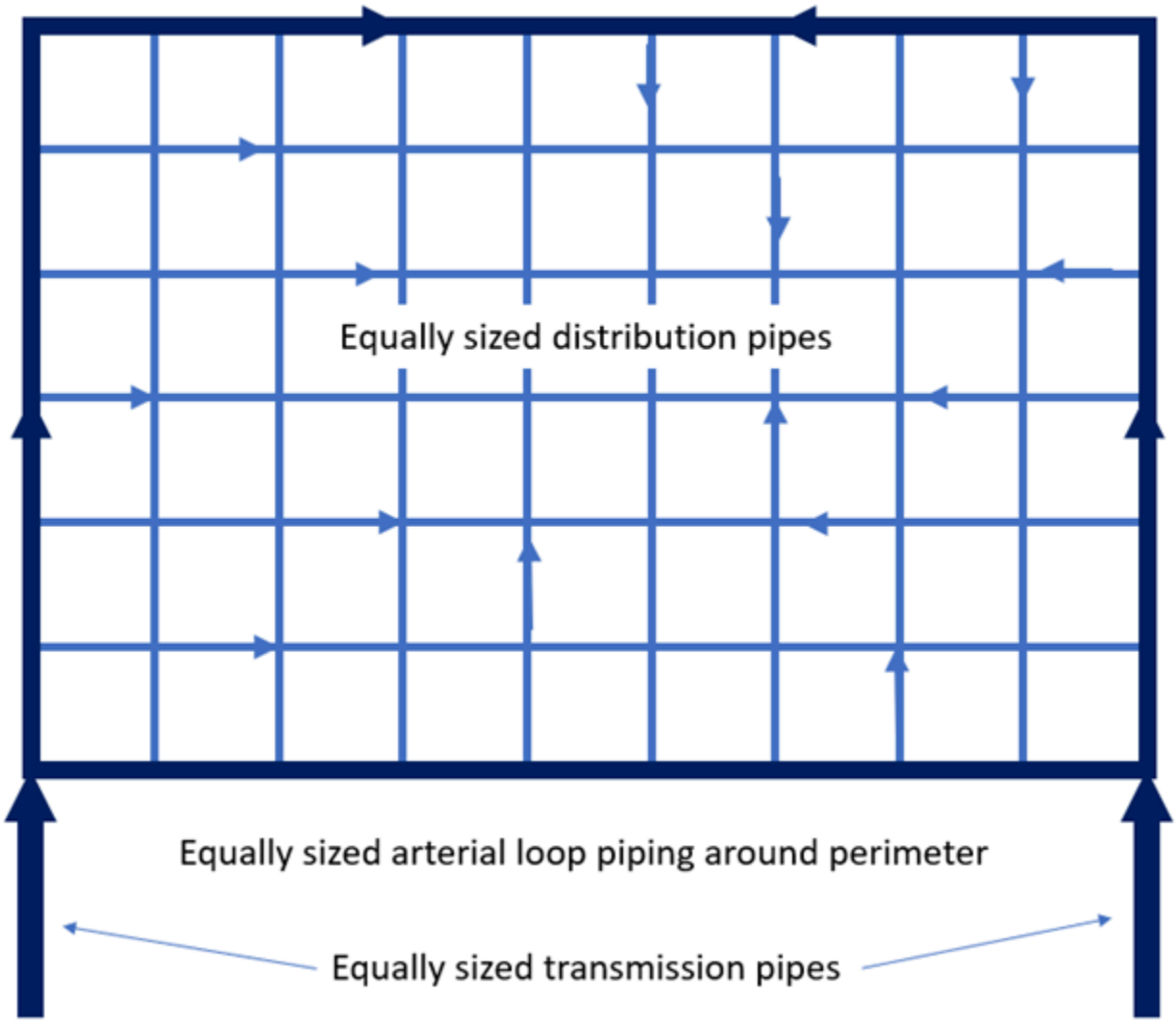



*Figure 13 Arterial loop municipal distribution system*

**Grid distribution**

The second piping arrangement commonly used is the grid distribution system. The grid system is fed by large piping to the middle of the configuration and the main reduces in size as branch pipes are connected to it, similar to Figure 14. The grid system arrangement is similar to the arterial loop configuration, but is fed from one pipe instead of two. The grid system is often installed in conjunction with arterial loop arrangements and is common in cities and built-up areas.

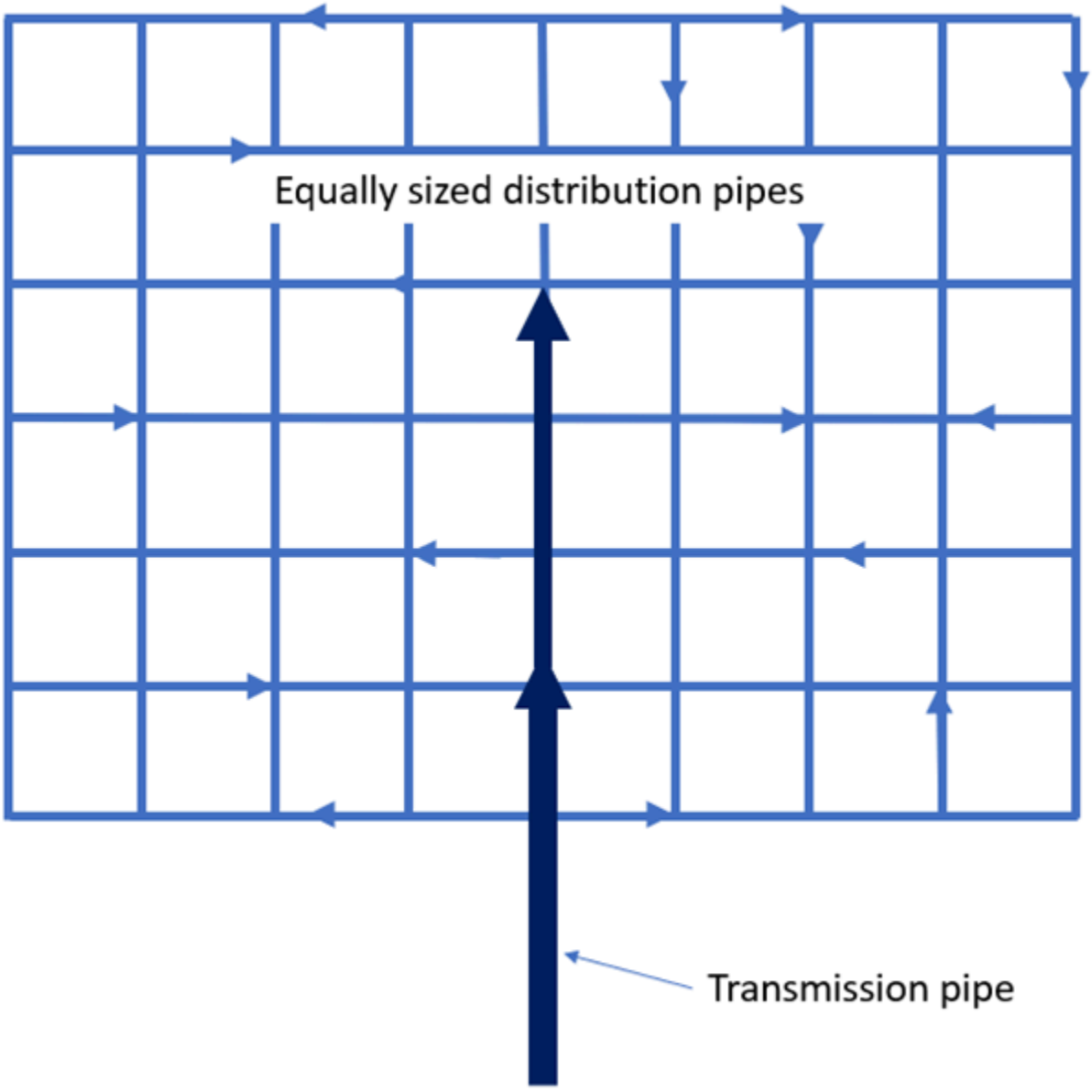



*Figure 14 Grid municipal distribution system*

**Dead end configuration**

A third method is the dead-end configuration (sometimes called the tree system). It is still found in older cities, but not recommended as the primary method of water distribution for new installations. In this system, distribution pipes are fed from a large transmission pipe and smaller branches connect to the distribution piping. Figure 15 shows a simplified dead-end configuration. This arrangement requires fewer isolation valves, but makes it difficult to supply good quality water to all parts of the system. Dead ends of the network must be drained periodically and line breaks or line shutdowns isolate the remaining distribution system. Also, this configuration is prone to taste and odour problems.

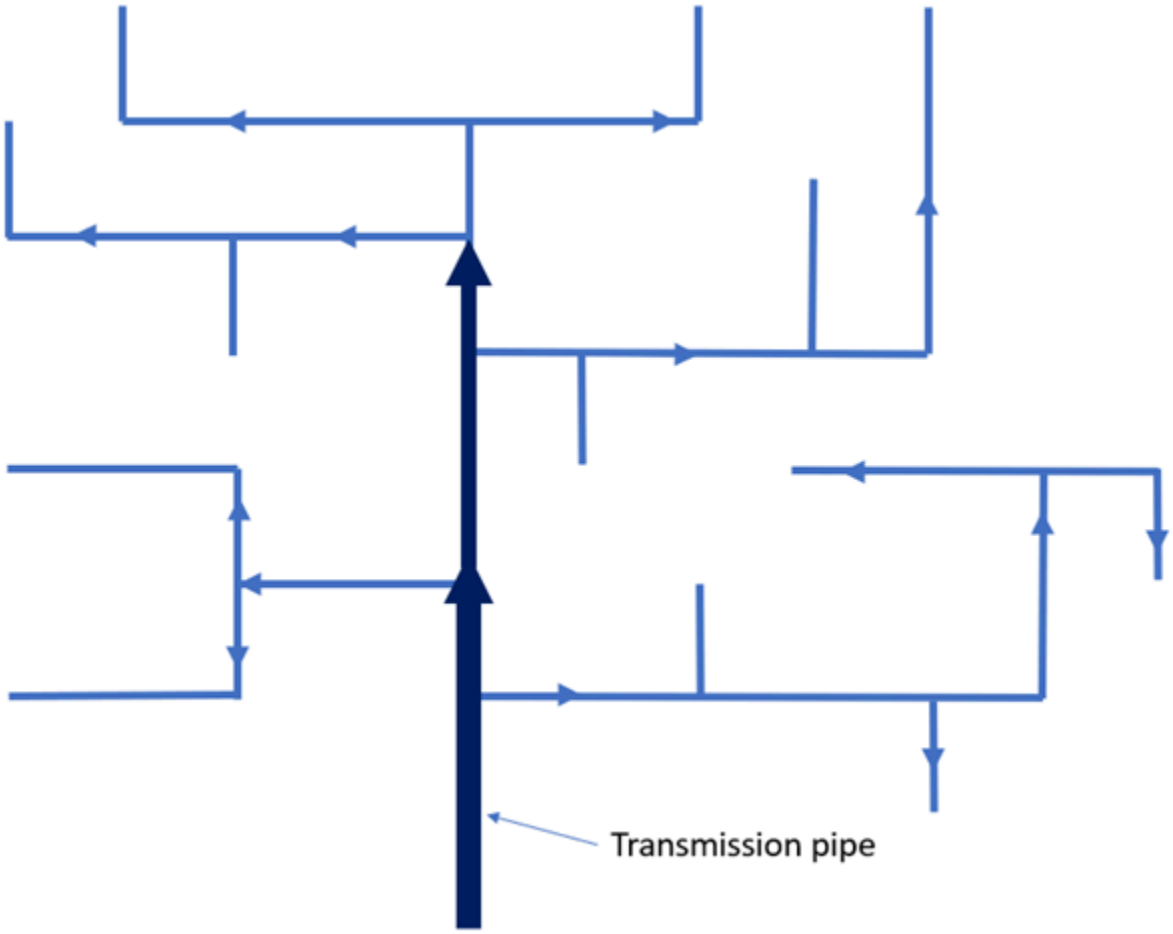



*Figure 15 Dead-end municipal distribution system*

## Drawings and Specifications

Competencies in the plumber Level 1, Level 2, and Level 3 content have introduced drawings and specifications, so this section will focus on drawings and specifications specific to water supply systems.

### Drawings

Recall from previous plumber program content that a drawing (or print) provides dimensions and details of materials of construction, and specifications give details on installation procedures and the standards required for materials. Some installations may have the specifications and all other pertinent information on the drawings in the form of notes. These drawings are known as working drawings.

Architectural, structural, mechanical, and civil drawings might all be used by the plumber to help with the design and installation of the water supply system. On larger projects, the water supply system may be shown on several drawings, with many other mechanical systems combined on the same drawings. This can be a challenge when tracing and interpreting the piping arrangement. It is common for the designer to create either a schematic drawing, or an isometric drawing, of the water piping arrangement

as a separate detail or mechanical drawing. In all cases, it is important that the plumber understand how the system is supposed to work in case there are errors on any of the drawings.

One type of schematic drawing sometimes used on larger jobs, such as municipal water supply systems, is called a Piping and Instrumentation Drawing, or P&ID. This type of drawing is a graphic representation of a process system that includes the piping, vessels, control valves, instrumentation, and other process components and equipment in the system. The P&ID is the primary schematic drawing used for laying out a process control system's installation. As such, the P&ID is crucial in all stages of process system development and operation.

A P&ID will show all major equipment and process streams, but pipe lengths, fittings, or anything not critical to the process represented in the drawing is not shown. Flow direction, line numbers, and pipe sizes are given for the process piping in the drawing, while another set of P&IDs might list piping specifications. An example of a simple P&ID is shown in the figure below.

Figure 16 shows a process maintaining a pH of 7 for a water treatment system. The field-located pH sensor (pHE symbol) reads the pH of the water, which is transmitted through the field-located pH transmitter (pHT symbol) to the indicating control in the remote-located control panel (pHIC symbol). The control operates the pneumatic control valve (CV-101 or 102) as required to maintain the setpoint.

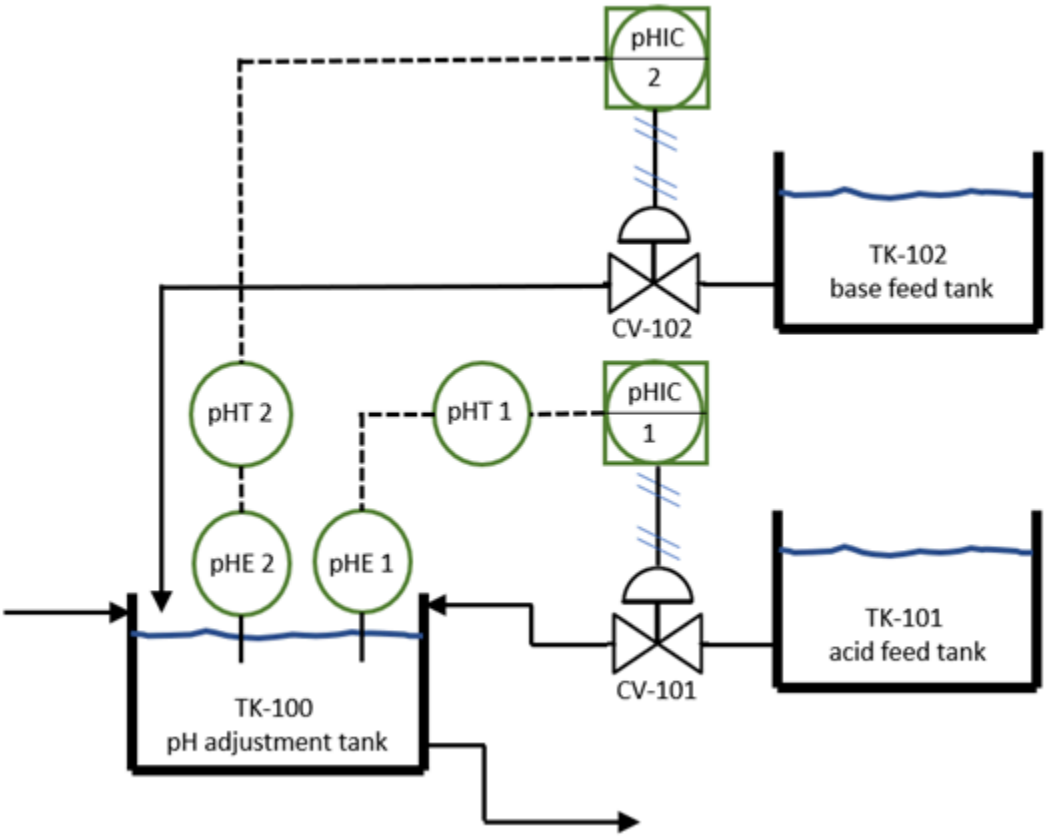



*Figure 16 Simple P&ID of a pH adjustment system for water treatment*

For smaller ICI water distribution system projects, and for most residential water distribution systems, the designer will use either multiple orthographic drawings or an isometric drawing to help determine locations and see potential problems. These types of drawings also work well to transfer information to

the tradesperson doing the installation. For example, an isometric sketch can be created during a discussion between a journeyperson plumber and an apprentice to help clarify pipe location, routing, floor and wall penetrations, flow direction, terminations, etc. To aid the installer during the installation of the water piping, notes can be added to any drawing to act as specifications.

An example of a simple residential waterline sketch is shown in the figure below.

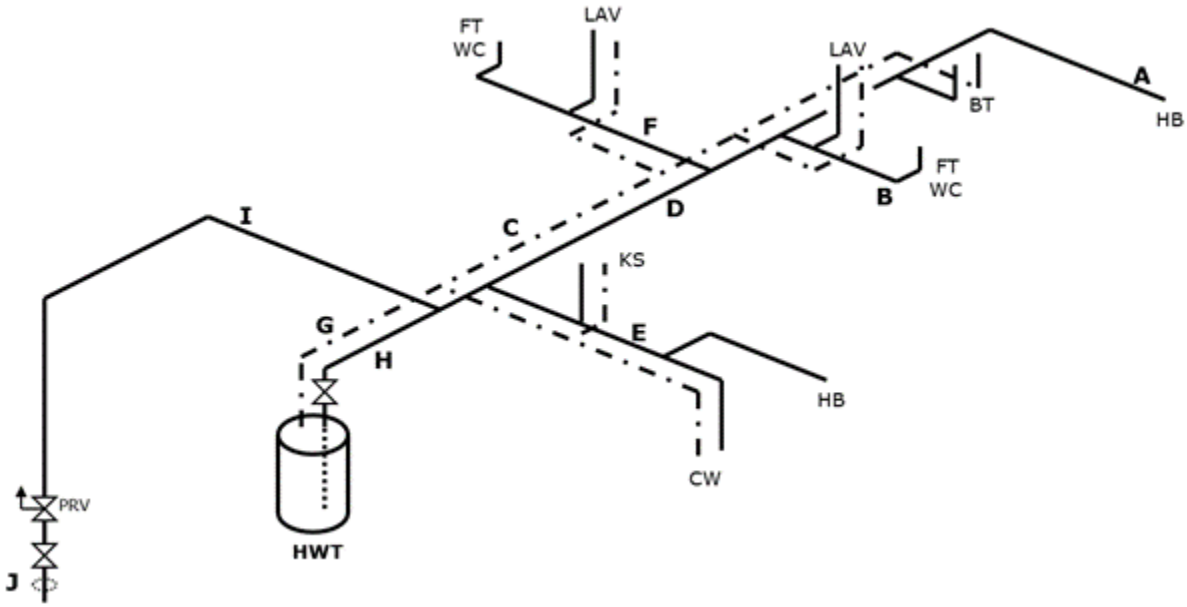



*Figure 17 Example of a sketch of a residential building water supply system*

#### Specifications

Specifications give details on installation procedures and the standards required for materials. The specifications for a hospital could be hundreds of pages, while a separate specifications document for a residential project may not exist. On large, complex, ICI projects the specifications are a living document and are updated as required so the plumber must ensure that the installation is following the latest version. On a basic residential project, the plumber makes decisions on installation standards and material specifications based on meeting the minimum standard of the BC Plumbing Code.

The list that follows is an example of the standards and material specifications that could apply to a municipal water distribution system.

Water Distribution System Standards and Material Specifications

## 1.0 Standards

- 1.1 Excavation
- 1.2 Disposal of excavated material
- 1.3 Pipe material
- 1.4 Excavated material

- 1.5 Trench preparation
- 1.6 Corrosion protection
- 1.7 Dewatering
- 1.8 Tracer wire
- 1.9 Joint deflection
- 1.10 Backfilling
- 1.11 Connection to existing watermains
- 1.12 Fire hydrants and valves
- 1.13 Water valves and valve boxes
- 1.14 Flushing, testing, and disinfection

**2.0 Material Specifications**

- 2.1 Watermain pipe
- 2.2 Pipe fittings
- 2.3 Valves
- 2.4 Corrosion protection
- 2.5 Water service pipe
- 2.6 Water meters

**3.0 Diagram References**

- 3.1 Meter pits
- 3.2 Fire hydrant specifications
- 3.3 Service connections
- 3.4 Trench widths

#### Elevations

Pipe elevations are shown on several drawings. Plumbers need to know pipe invert elevations for gravity systems such as sanitary and storm sewers but, for the water service pipe, the elevation shown may be the top-of-pipe elevation. Top-of-pipe elevation is shown on the contract drawings where watermains cross a sewer or other obstruction, or to indicate the minimum coverage for freeze protection.

## Components and Equipment

Water supply systems incorporate many different types of pipes, fittings, valves, equipment and appurtenances. The BC Plumbing Code prescribes the use of specific materials in some circumstances but the system designer has a lot of flexibility in selecting most of the other components and equipment

that makes up the system. The major components and equipment used to construct a water supply system upstream of the water service pipe are described in the following content.

### Pressure reducing valves

Water pressure reducing valves (PRVs) are used in residential and ICI applications to reduce incoming water pressure for protection of plumbing system components and to reduce water consumption. Water supply utilities use pumps to increase pressure in water mains to sufficient levels to supply water for firefighting, to overcome loss of pressure in the upper floors of high-rise buildings and to supply water towers and supply tanks. Pressure in water supply mains can exceed 1380 kPa (200 psi).

Since excessive pressure in a water supply system can cause a number of issues, the BC Plumbing Code Article 2.6.3.3 states that “where the static pressure at any fixture may exceed 550 kPa, a pressure-reducing valve shall be installed to limit the maximum static pressure at the fixture to 550 kPa.” Pressure-reducing valves can also greatly reduce the effects of water hammer. They are available within specified pressure ranges and are adjustable within the specified ranges.

There are two types of pressure reducing valves used on water supply systems, direct-acting and pilot-operated.

#### Direct-acting PRV

Direct-acting, spring-loaded PRVs are used for low flow rates. These valves consist of globe-type bodies with a spring-loaded, heat-resistant diaphragm connected to the outlet of the valve that acts upon a spring. This spring holds a pre-set tension on the valve seat installed with a pressure equalizing mechanism for precise water-pressure control. They are the most commonly used PRVs and are found in a range of applications, including residential, OEM, and commercial, where diameters smaller than 3 inches are acceptable.

The parts of a direct-acting PRV are shown in the figure below.

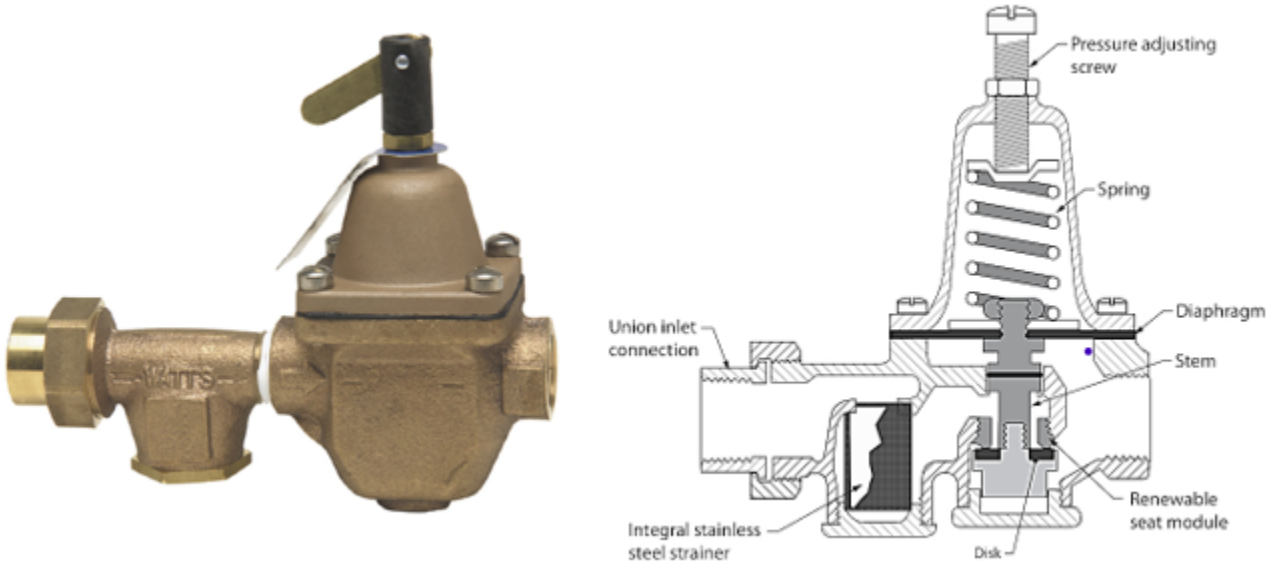



*Figure 18 comparison of an actual direct-acting PRV with strainer and a cutaway showing the parts*

### Pilot-operated PRV

Pilot-operated, diaphragm-actuated PRVs are used for higher flow rates. Pilot-operated valves have a sensing control pilot and main valve in one unit. These valves are typically used for commercial applications such as schools, hotels and hospitals, as well as in industrial and municipal applications and installations that require more consistent pressure control over wide flow ranges. Those applications typically demand valves with larger diameters, ranging from 1–¼ inch to 16 inches.

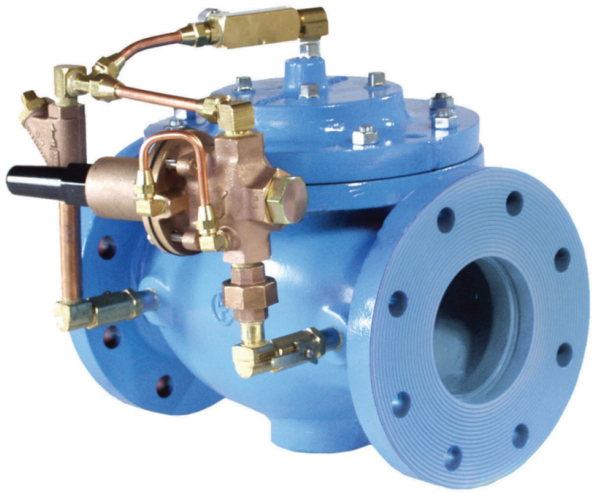


*Figure 19 Pilot-operated water pressure regulator*

### Pressure-reducing valve installation considerations

When installing pressure-reducing valves, it is very important to follow the manufacturer's installation instructions. Proper installation techniques will result in trouble-free operation and ease of maintenance. The content below lists several additional components that the plumber could install with the PRV.

- Installing shut-off valves (ball or gate) and bypasses (globe) will permit removal or repair of a PRV without disruption of water supply to the building or to the fixture or appliance that the PRV is serving.
- A strainer is often installed on the high-pressure side to prevent dirt and debris from becoming lodged between the valve seat and disc, preventing it from shutting off. If a PRV fails to shut off, the pressure may rise to a dangerous level. The strainer can be a separate component or it can be integral to the PRV body.
- A pressure-relief valve is typically installed on the downstream side of the PRV when it is used to supply domestic water in a high-pressure application. Failure of the PRV or improper throttling of the bypass valve during repairs to the PRV could cause a dangerous high-pressure condition downstream. If this occurred, the pressure-relief valve would activate and relieve the excess pressure.
- A pressure gauge could be used in conjunction with a PRV to set and monitor the outlet pressure. An optional pressure gauge is often installed upstream of the PRV to indicate the inlet pressure.

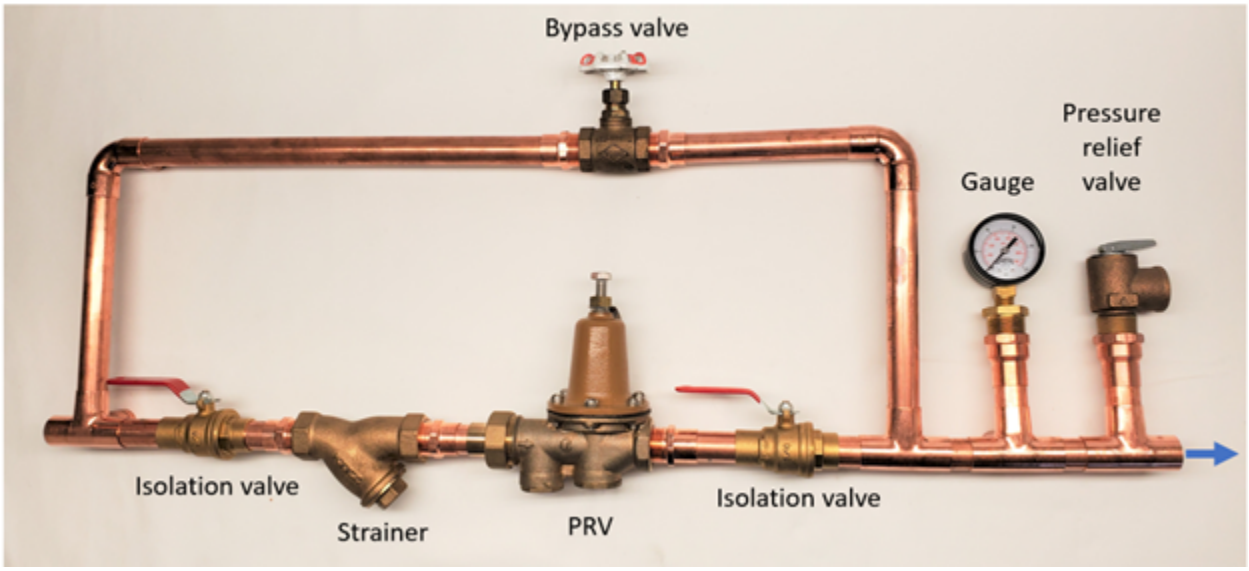



*Figure 20 Pressure-reducing valve station showing additional components*

Series installation of pressure-reducing valves

When a second PRV is installed immediately downstream of the first PRV it is referred to as series, or two-stage, regulation. This design is used for greater pressure reduction than that provided by a single valve. Series use of pressure-reducing valves may be necessary where pressure reduction is required to a fixture such as a commercial dishwasher or drinking fountain.

Pressure-reducing valves are also used in series in a downfeed riser in a tall building. Downfeed building distribution systems are discussed in detail in Competency B-2.

Parallel installation of pressure-reducing valves

Two (or more) pressure-reducing valves are often installed side by side to replace one large, expensive valve. This installation also eliminates the need for a valve bypass, as one valve can be removed from the line for repair or maintenance while the other continues to meet the demands of the supply system at a reduced rate.

When two or more small pressure-reducing valves are used to replace a large valve in a parallel installation, one might be set at a slightly higher opening pressure so as to prevent both valves from operating during low-demand periods. This cuts down on valve seat etching caused by the passage of water between the valve seat and disc. It also reduces maintenance costs by causing only one valve to be in constant operation.

Where two PRVs are used, a smaller valve might be installed parallel to the large valve. The smaller valve can handle very low-demand periods, such as a single fixture being used, while the larger PRV handles the peak demand flow. This setup is also less noisy, as the PRV valve is more closely sized for the flow during minimal flow conditions.

### Air release and vacuum relief valves

The design of a water supply system must allow for removal of air when filling the system and for

vacuum relief when draining the system. Air trapped in a piping will naturally rise and collect at high points within the system. This trapped air can cause pump failures, faulty instrumentation readings, corrosion, flow issues, and water hammer or pressure surges. Unnecessary air in the pipeline also makes the pump work harder, resulting in additional energy consumption. Air in the piping comes from three primary sources:

- The piping itself – Before start-up, a piping system isn't technically empty, it's filled with air. As water fills the piping, the air must be allowed to evacuate.
- Pumping – Water contains 2% air by volume. As the water is pumped through the system, air separates and accumulates at system high points.
- Mechanical equipment – Air can be drawn into the system through equipment like pumps, packing, valves, and pipe joints.

A vacuum relief valve is used to prevent a vacuum condition from occurring in the piping. The valve will admit large volumes of air to prevent a vacuum when draining the system for planned maintenance, or in the event of an emergency such as an accidental line break.

There are several options for air and vacuum relief valves, depending on the system designer's preference:

- Manually-operated valves
- Air release valve only
- Vacuum relief valve only
- Separate air release and vacuum relief valves
- Combination air release and vacuum relief valves

The figures below show a combination air release and vacuum relief valve in operation.

During the filling of the line, air enters the valve body and is released to the atmosphere. When the air is expelled and the water enters the valve, the float will rise and cause the orifices to be closed. The large and small orifices of the air and vacuum valve are normally held closed by the buoyant force of the float.

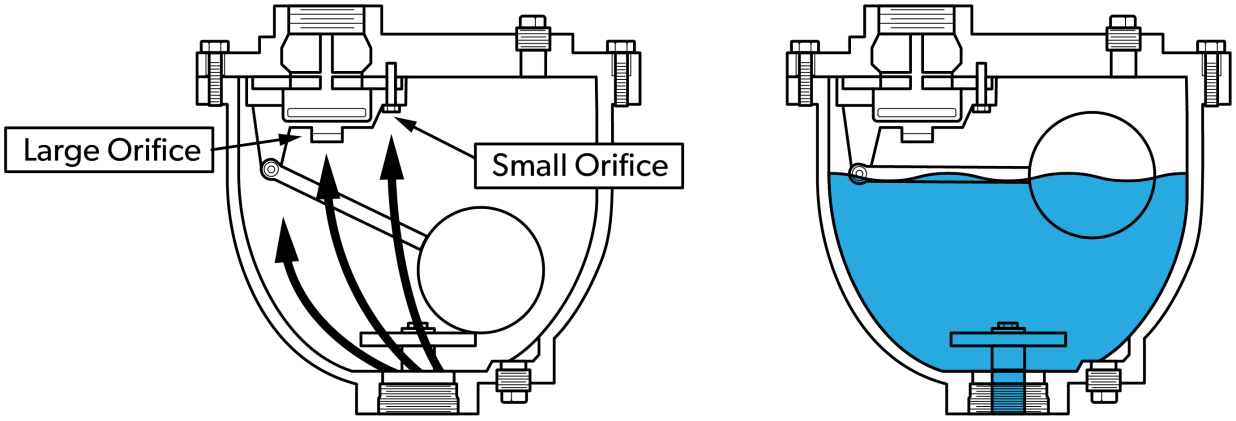



*Figure 21 Combination valve operation showing air being expelled on the left, and the valve closed by water on the right*

While the line is working under pressure, small amounts of trapped or entrained air are exhausted to the atmosphere through the small orifice in the combination air release and vacuum relief valve, as shown in the figure below.

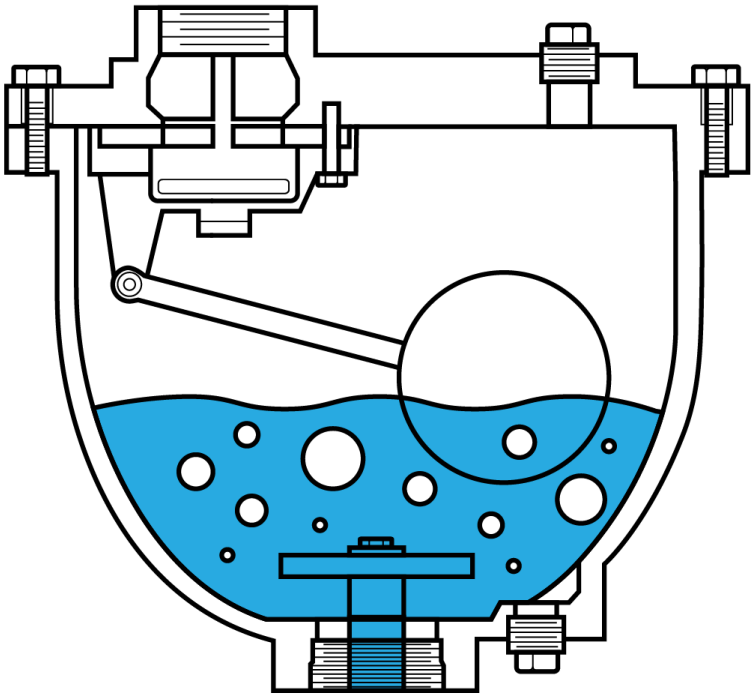


*Figure 22 Combination valve operation showing entrained air being exhausted*

Air is permitted to enter the combination air release and vacuum relief valve and replace the water while the line is being drained.

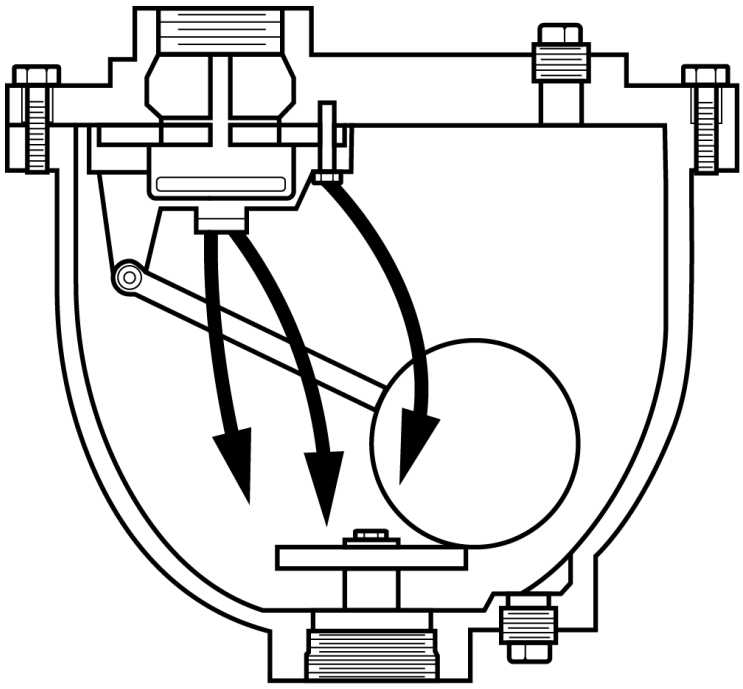


*Figure 23 Combination valve operation showing air entry when piping is drained*

**Expansion control**

The need for thermal expansion control in piping systems arises from the tendency of the pipe to expand or contract due to changes in temperature of the pipe material. Sentence 2.3.3.9.(1) in the BC Plumbing Code addresses the need for expansion control by stating “The design and installation of every piping system shall include means to accommodate its expansion and contraction caused by temperature changes, movement of the soil, building shrinkage or structural settlement.” The BC Plumbing Code Notes to Part 2, A-2.3.3.9, has a figure similar to the one shown below that compares different materials and their linear expansion rate.

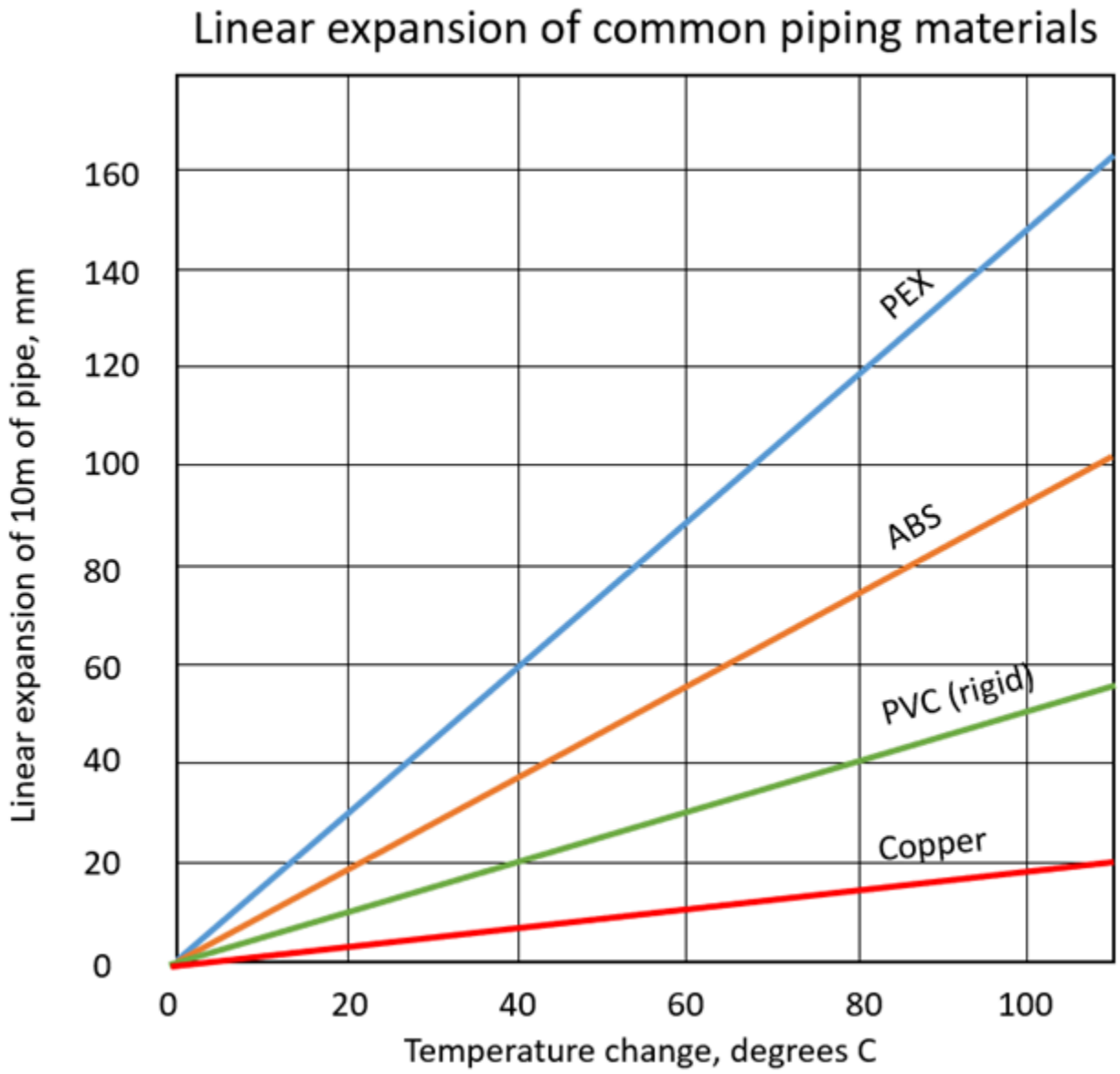



*Figure 24 Different piping materials and their linear expansion rate*

Expansion control for underground water piping

Underground water piping is dealt with differently than above ground water piping since the temperature differential is significantly less for buried piping. The temperature of the ground remains fairly constant and, since the water is relatively close to the ground temperature, there is usually no need for expansion control for underground water supply piping. Rubber reinforced expansion joints are available if the water supply system designer decides expansion control is required for underground piping. Some types of underground pipe connections will also allow for expansion and contraction because of the nature of the push-on or mechanical joint. Pipe and fittings and the connection methods are covered in Learning Task 3 of this Competency.

There is one location in the underground water supply system where an expansion loop (also referred to as a settlement loop or gooseneck) is used. Figure 25 shows how an S-shaped bend is placed in the

water service connection of small diameter, flexible pipe at the upstream end to provide a minor amount of movement for the water service connection. This helps to prevent breakage of the corporation main stop or the service connection as backfill settles, from expansion, or ground movement from frost or traffic. Service lines over 2 inches (50 mm) do not require a settlement loop.

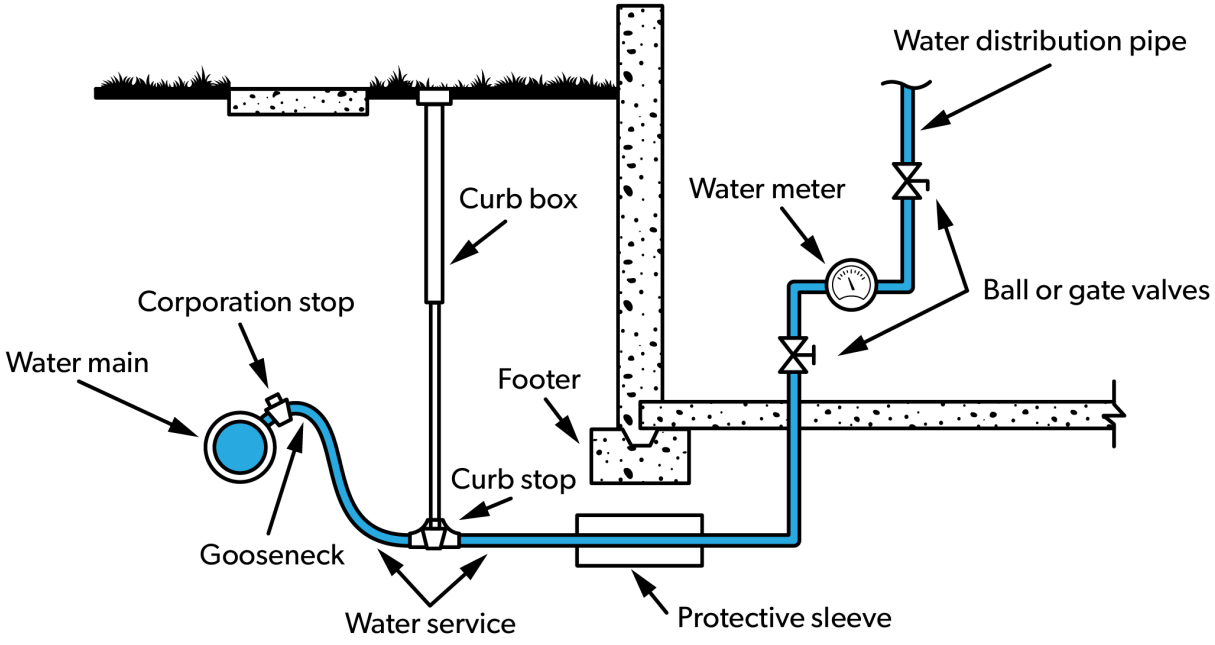



*Figure 25 Residential water supply system showing a gooseneck, or expansion loop, on the service pipe*

Expansion control for above-ground water piping

Above-ground water supply piping may need to be installed with methods to control or accommodate expansion and contraction since the temperature differential can be significant when considering the difference between the ambient air temperature and the potential temperature of hot water in the piping. Since the BC Plumbing Code doesn't give direction on how to accommodate expansion and contraction of above-ground water distribution piping, designers and installers must come up with solutions based on each situation.

Expansion and contraction in piping systems may be accommodated in a number of ways including (but not limited to) piping design and layout, material selection, and the inclusion of expansion joints, offsets, and expansion loops in the piping arrangement. Specially designed hangers and supports may be needed to allow the pipe to expand and contract without causing unnecessary force on fittings and joints. The installer must be careful not to unintentionally restrict pipe movement by creating restraint or anchor points in a piping arrangement.

Most pipe and fitting manufacturers have documentation on how to allow for expansion and contraction of their products. Some manufacturers, like IPEX, have expansion calculators for their Aquarise® potable water products. For example, if a 60-foot run of 2 inch Aquarise® was installed inside a building and used for the hot water distribution system, option 1 shown below is calculated using the IPEX online calculator.

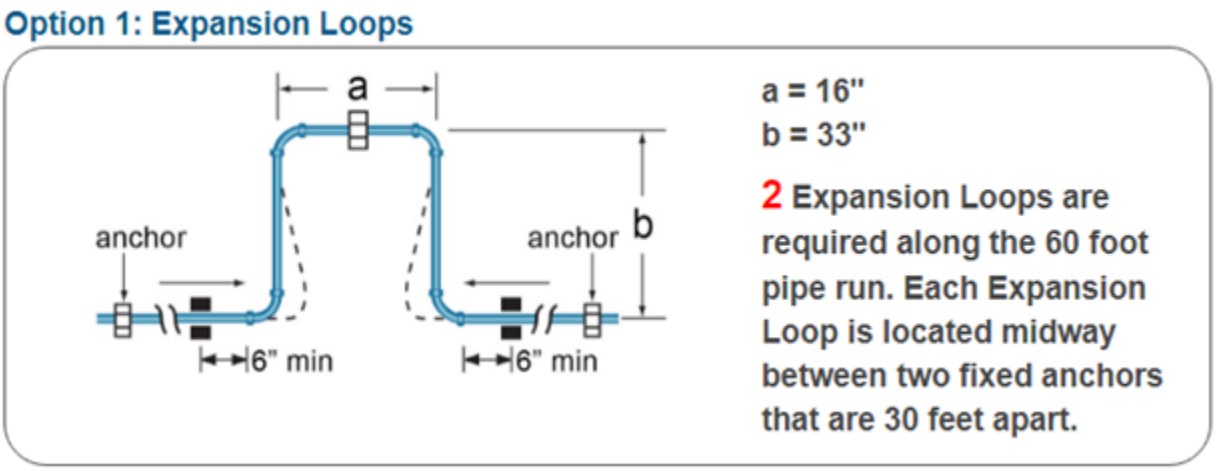



*Figure 26 One example of an expansion loop design for above-ground water piping*

**Fire hydrants**

Municipal water supply systems are designed for maximum peak-demand flow and for fire-fighting demands that could be placed on the system. In most cases, fire hydrants are connected to the municipal water supply system. If fire hydrants are required on private property, a separate water supply is usually supplied. This separate supply is to ensure an adequate supply of water under fire-fighting conditions, which may not be possible if the connection was on the water service pipe, or downstream of a water meter. If the municipal water supply system cannot provide the minimum volume of water required for fire-fighting on private property, a separate private water supply may have to be provided for the fire hydrant system.

There are many fire protection systems installed inside of buildings that are connected to the potable water supply. These systems are designed and installed by trained persons in the Sprinkler Fitter trade.

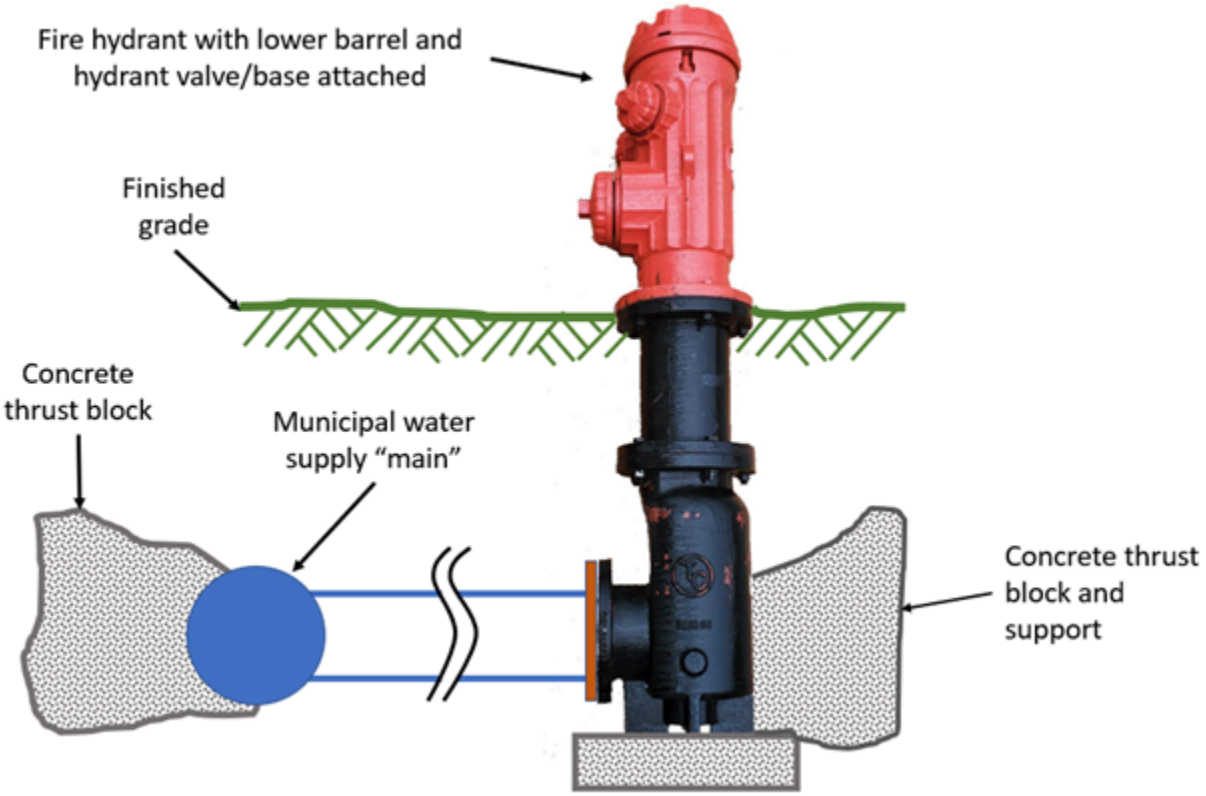



*Figure 27 Fire hydrant connection to a municipal water supply system*

**Corporation stop**

The corporation stop, or corporation valve, is the valve installed on a municipal water main to permit joining of the water service pipe. The valve may be threaded into a tapped coupling (tee fitting), threaded into a service saddle, or direct-tapped into the water main. The valve may have flared, iron pipe thread, flanged or compression outlet connections. The inlet thread of 2 inch (50mm) or smaller corporation main stops has traditionally been made to specifications developed by the AWWA and is commonly called a Mueller thread. These threads are NOT pipe threads. However, many purveyors now use National pipe thread connections up to 2 inches in size. Most corporation stops over 2 inches are threaded or flanged.

Small corporation main stops can not be opened or closed from ground surface, as they are covered over with backfill. If they must be closed for any reason, they must be excavated to expose them. Larger services typically use gate or globe valves as service shutoff valves connected to the distribution main with a tapping tee or split tee.

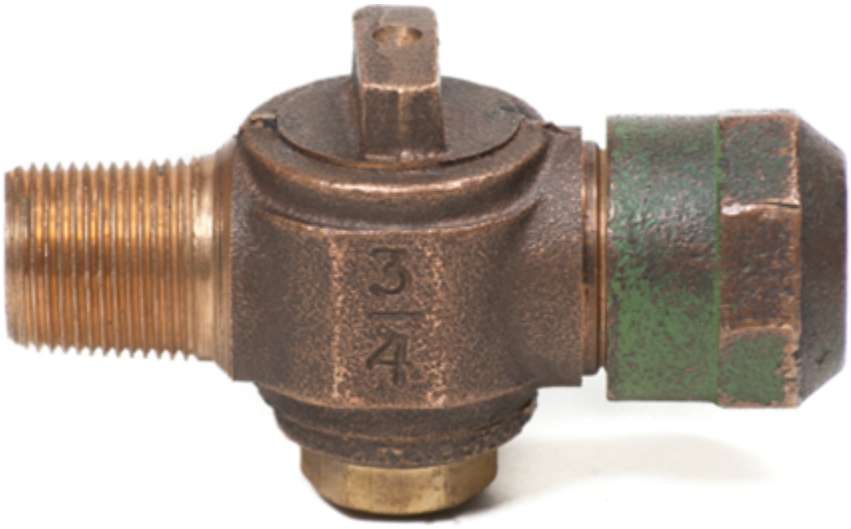



*Figure 28 A small diameter, quarter-turn, residential-style corporation stop*

The corporation stop connection to the water main can be done while the system is de-pressurized, or it can be done by hot-tapping (also called live-tapping) while the pipe is under pressure. Hot-tapping is covered in Learning Task 3 of this Competency.

Ideally, a corporation stop is installed above the horizontal centreline of the water main to prevent sediment from entering the service pipe.

## Curb Stop

Moving downstream from the Water services section on the municipal water supply system flow chart, we come to the curb stop. For the purposes of this content, the curb stop is where the municipal water supply system ends and where the plumber will begin interacting with the water supply system. It is common for the plumber to connect to an existing curb stop and to continue with the design and/or installation of the water service pipe and the building water distribution system.

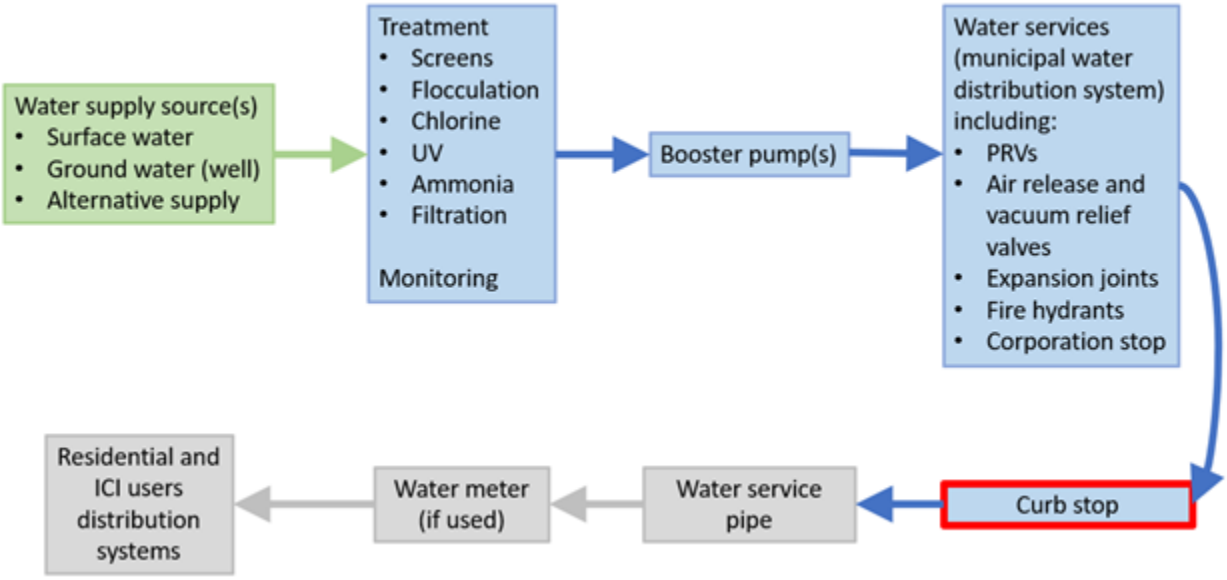



*Figure 29 Source to tap flow chart with "Curb stop" emphasized*

On municipal water supply systems, the curb stop is located at the curb line, or just outside the customer's property line. This valve is used to allow the service to be shut off for repair or non-payment of utility fees. The curb stop is installed below ground, the depth depending on local frost depth conditions. In areas where the frost depth is minimal, the curb stop is located in the water meter box and is readily accessible in case of an emergency. Where the frost depth is deeper, the curb stop is buried well below the finished grade and the valve stem is either extended to the surface with a curb box, or is only accessible with a curb stop key (valve stem extension rod).

If the curb stop is installed with a water meter, in a meter box, it is common for the purveyor to use an angle curb stop to allow for easier assembly and disassembly. There are several combinations for piping and tubing sizes and types for the purveyor and plumber to choose from, requiring curb stops to have inlet and outlet connections that match most combinations.

The purveyor may install a curb stop chair (shoe) under the curb stop to support the stop and the extension. This support frame prevents deflection of the service pipe as the buried curb stop valve is operated. Since the curb stop is owned by the water purveyor, the plumber must communicate with the purveyor before operating the valve.

The figure below shows a curb stop well below grade with a curb box installed to allow for operating the valve.

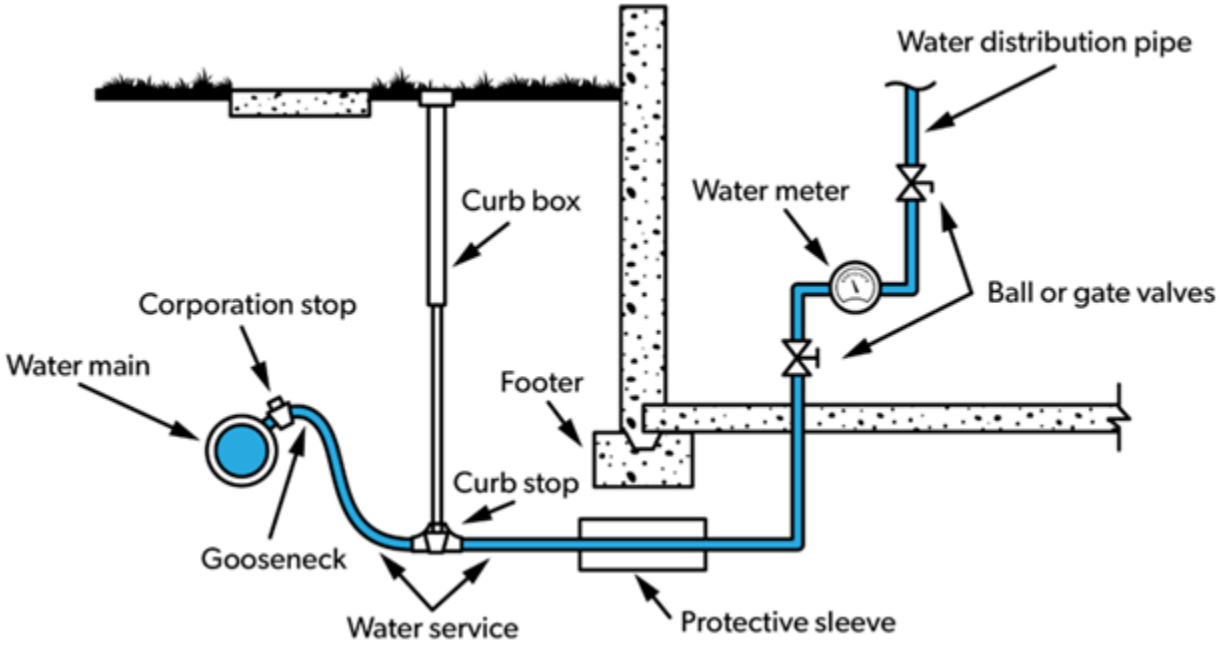



*Figure 30 Residential water supply system showing a curb box*

There is a wide variety of curb stop designs and styles depending on the upstream and downstream connections. Common materials of construction for small diameter (residential size) valves are bronze and red brass, with older versions being plug valves, and newer versions being ball valves.




*Figure 31 Quarter-turn ball valve design curb stop with compression type connections.*

Now complete Self-Test 1 and check your answers.

# Self-Test 1

Self-Test 1

1. How is ***potable water*** defined?
    a. Water in its natural state, like rainwater, groundwater
    b. Water that has the minimum allowable level of contaminants
    c. Water that will not injure the health of humans drinking the water
    d. Water that meets the prescribed standard(s), and is safe to drink and fit for domestic purposes without further treatment
2. How is a ***water service pipe*** defined?
    a. A pipe that conveys water from the water meter to inside the building
    b. A pipe that carries water from the water meter to the most remote fixture
    c. A pipe that carries water from the curb stop to the most remote fixture in the building
    d. A pipe that conveys water from a public water main or private water source to the inside of the building
3. Transpiration is water that evaporates from plants into the atmosphere.
    a. True
    b. False
4. Water is a natural solvent.
    a. True
    b. False
5. What is the name used to describe the water from a public water system after it has passed through the consumer's service connection?
    a. Used water
    b. Potable water
    c. Domestic water
    d. Customer water
6. As water flows through a centrifugal pump, it slows down and the pressure:
    a. Pulsates
    b. Increases
    c. Decreases

d. Remains the same

7. The friction loss of fittings and valves is usually expressed in:

    a. Head loss in feet
    b. Pressure loss per inch
    c. Head loss per square inch
    d. Equivalent lengths of straight pipe

8. What information is required when using a performance curve to select a pump?

    a. Pump head and static pressure
    b. Pump head and pump capacity
    c. Vertical lift and total pressure loss
    d. Pump horsepower and pump capacity

9. Which municipal water distribution system is prone to taste and odour problems?

    a. Arterial loop system
    b. Grid distribution
    c. Dead end configuration
    d. Trunk and branch system

10. According to the BC Plumbing Code what is the maximum static pressure allowed at a fixture before a pressure-reducing valve is installed?

    a. 350 kPa
    b. 500 kPa
    c. 550 kPa
    d. 700 kPa

11. What is the most commonly used PRV for residential, and small diameter commercial, water systems?

    a. Direct-acting
    b. Indirect-acting
    c. Pilot direct-acting
    d. Pilot indirect-acting

12. What is the purpose of series installation of pressure-reducing valves?

    a. Less chance of backflow
    b. Two-stage pressure reduction
    c. More flow through smaller PRVs
    d. Cost savings compared to one large PRV

13. Where is a corporation valve installed?
    a. Upstream of a fire hydrant to allow for servicing
    b. On every water service pipe where it enters the building
    c. On a corporation trunk line to allow for water main isolation
    d. On a municipal water main to permit joining of the water service pipe
14. What is the purpose of a curb stop?
    a. Allow for water meter servicing (not every municipality uses meters)
    b. Prevent backflow of used water into the municipal water main
    c. Allow the service to be shut off for repair or non-payment of utility fees
    d. Allow for the connection of the water service pipe to the municipal water main
15. When may a private water supply system be interconnected with a public water supply system?
    a. If is only used for irrigation
    b. No interconnection is permitted
    c. If a reduced pressure assembly is installed
    d. If a double check valve assembly is installed

Check your answers using the Self-Test Answer Keys in Appendix 1.

**Image Descriptions**

**()Figure 1 Water system from source to tap**

1. Watershed
2. Dam or intake
3. Raw water main
4. Water treatment facility
5. Pump station
6. Water reservoir
7. Water main
8. Pump station
9. Water main
10. Water distribution main
11. Water main connects to plumbing inside your home.

[Return to place in text] (#f1)

**()Figure 2 Source to tap flow chart**

Example of a flow chart for a municipal water supply system

- Public water source(s)
    - Surface water
    - Ground water (well)
    - Alternate supply
- Treatment
    - Screens
    - Flocculation
    - Chlorine
    - UV
    - Ammonia
    - Filtration

  Monitoring
- Booster pump(s)
- Water services (municipal water distribution system) including:
    - PRVs
    - Air release and vacuum relief valves
    - Fire Hydrants
    - Corporation stop
- Curb stop
- Water service pipe
- Water meter (if used)
- Residential and ICI user distribution systems

[Return to place in text] (#f2)

**()Figure 7 Simplified list of pump categories and types**

Different types of pumps

- Centrifugal pumps
    - Axial flow
    - Radial flow
    - Horizontal type
    - Vertical type

    - Submersible type
- Positive displacement pumps
    - Reciprocating type
    - Rotary type

[Return to place in text] (#f7)

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- Figure 25 Residential water supply system showing a gooseneck, or expansion loop, on the service pipe by Camosun College is licensed under a CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).
- Figure 26 One example of an expansion loop design for above-ground water piping by Camosun College is licensed under a CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).
- Figure 27 Fire hydrant connection to a municipal water supply system John Gordon is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 28 A small diameter, quarter-turn, residential-style corporation stop by Camosun College is licensed under a CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).
- Figure 30 Residential water supply system showing a curb box by Camosun College is licensed under a CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).
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# Learning Task 2

## Describe Sizing for Municipal Water System Piping

Sizing of public water supply systems upstream of the water service pipe is typically done by engineers, or designed in accordance with good engineering practice, using a detailed engineering design method. However, the water service pipe and building water distribution system are typically sized by the plumber. The BC Plumbing Code allows for alternative methods, which apply to both public and private water supplies, to be used in determining the size of each section of the water system.

BC Plumbing Code Sentence 2.6.3.1 (2) states “Potable water systems shall be designed, fabricated and installed in accordance with good engineering practice, such as that described in the ASHRAE Handbooks and ASPE Data Books.” Sizing of the water service pipe and the building water distribution system is covered below in Competency B-2 of the Level 3 content.

The municipal water supply system designer will typically use accepted engineering methods to size the municipal water supply systems. These systems contain transmission pipes and distribution piping (water mains). Several factors will go into the designer’s choice of pipe size and material, such as the peak-demand flow rate required, and the maximum intended velocity of the water in the system. For smaller communities – those with up to approximately 50,000 people – sizing of the water distribution system is often based on supply requirements for fire fighting. Pipe sizes are selected that will supply the quantity of water needed at a velocity that will not cause too much pressure loss. Municipal water supply system pipe water velocity is kept to a maximum of approximately five feet per second. To ensure this velocity is not exceeded, and to allow the network to accommodate a reasonable amount of future expansion, the water mains are commonly upsized one pipe size above calculated size.

Water pressure in transmission and distribution pipes is usually 80 to 120 psi (approximately 550 to 825 kPa), although water purveyors can choose to operate at higher pressures. As discussed in previous content, if higher system pressures are encountered as services are connected to building distribution pipes, pressure-reducing valves are installed.

Fluctuations will occur in municipal water supply systems based on elevation and during peak demand periods of the day. For example, water pressure at lower elevations in the municipality will be greater than at higher elevations in the municipality. Water pressure at peak demand periods (times of the day when the most water is being used) can be significantly lower than the pressure during low-demand periods. It is commonly accepted that the minimum pressure for water services should not be less than 35 psi during normal use, but may drop to 20 psi during periods of high demand.

As previously mentioned, municipal water supply systems are usually sized by engineers, using current fluid dynamics engineering practices. Typically, software is used to determine municipal transmission and distribution system pipe sizes. The designer would enter relevant data into software that would use several accepted formulas and equations to determine the pipe sizes. One of these formulas is the Hazen-Williams formula.

## Hazen-Williams Formula

The Hazen–Williams formula is an empirical relationship which relates the flow of water in a pipe with the physical properties of the pipe and the pressure drop caused by friction. It is used in the design of water pipe systems such as fire sprinkler systems, water supply systems, and irrigation systems, but its use is limited to the flow of water in pipes larger than 2.0 inch and smaller than 6.0 feet in diameter, and for water flowing at ordinary temperatures of 40 to 75 degrees Fahrenheit (4 to 25 degrees Celsius) through pressurized pipes.

The Hazen-Williams formula is commonly used by municipal water supply system designers to calculate pipe friction loss. The calculation is done during the engineering stage to ensure the design pipe size does not exceed the allowable friction loss. The Hazen-Williams formula shown below can be used to calculate friction loss.

$$P = \frac{4.52Q^{1.85}}{C^{1.85}d^{4.87}}$$

**Where:**

- P = friction loss, psi per linear foot
- Q = flow, gpm
- d = average pipe ID, inches
- C = constant 150

Note: The constant “C” is different for the types of pipe materials being used. The smoother the inside wall of a pipe is, the higher the C factor.

The Hazen-Williams formula is often the method used to create pipe pressure loss tables. These tables are used by engineers and plumbers to make pipe sizing decisions once other factors are known.

An example of a table showing pressure loss of water due to friction is shown below.

### Pressure Loss due to Friction Loss in Copper Tube (psi per Linear Foot of Tube)

**Pressure loss in copper tube chart – ½ inch**

| Flow GPM | K | L | M |
|---|---|---|---|
| 1 | 0.010 | 0.008 | 0.007 |
| 2 | 0.035 | 0.030 | 0.024 |
| 3 | 0.074 | 0.062 | 0.051 |
| 4 | 0.125 | 0.106 | 0.086 |
| 5 | 0.189 | 0.161 | 0.130 |

**Pressure loss in copper tube chart – ¾ inch**

| Flow GPM | K | L | M |
|---|---|---|---|
| 1 | 0.002 | 0.001 | 0.001 |
| 2 | 0.006 | 0.005 | 0.004 |
| 3 | 0.014 | 0.011 | 0.009 |
| 4 | 0.023 | 0.018 | 0.015 |
| 5 | 0.035 | 0.027 | 0.023 |
| 10 | 0.126 | 0.098 | 0.084 |

**Pressure loss in copper tube chart – 1 inch**

| Flow GPM | K | L | M |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 0.003 | 0.002 | 0.001 |
| 3 | 0.003 | 0.003 | 0.001 |
| 4 | 0.006 | 0.005 | 0.004 |
| 5 | 0.009 | 0.007 | 0.006 |
| 10 | 0.031 | 0.027 | 0.023 |
| 15 | 0.065 | 0.057 | 0.049 |
| 20 |  | 0.096 | 0.084 |

**Pressure loss in copper tube chart – 1¼ inch**

| Flow GPM | K | L | M |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 0.001 | 0 | 0 |
| 3 | 0.001 | 0.001 | 0.001 |
| 4 | 0.002 | 0.002 | 0.002 |
| 5 | 0.003 | 0.002 | 0.002 |
| 10 | 0.010 | 0.009 | 0.009 |
| 15 | 0.022 | 0.020 | 0.018 |
| 20 | 0.037 | 0.035 | 0.031 |
| 25 | 0.057 | 0.052 | 0.047 |

| | | | |
|---|---|---|---|
| 30 | 0.079 | 0.073 | 0.066 |

Now complete Self-Test 2 and check your answers.

## Self-Test 2

Self-Test 2

1. What is the Hazen-Williams formula used to calculate?
    a. Flow velocity in a water main
    b. Head pressure created by a pump
    c. Fixture unit load of industrial fixtures
    d. Pressure drop caused by friction in pipe
2. Referencing the “Pressure loss in copper tube chart”, what is the pressure loss due to friction for 150 feet of 1 inch type L copper tube flowing 10 gallons a minute?
    a. 0.027 psi
    b. 0.027 feet of head
    c. 4.05 psi ANSWER
    d. 4.05 feet of head
3. ASHRAE Handbooks and ASPE Data Books can be used as resources when water pipe sizing. What does the abbreviation ASHRAE stand for?
    a. American Society of Hydronic, Refrigeration and Air-Conditioning Experts
    b. American Society of Heating, Refrigeration and Air Conditioning Engineers
    c. American Standards for Heating, Refrigeration and Air-Conditioning Engineers
    d. Association of Standards for Heating, Refrigeration and Air-Conditioning Engineers

Check your answers using the Self-Test Answer Keys in Appendix 1.

# Learning Task 3

## Describe the Installation of Piping for Municipal Water Systems

This section will look at the installation of the piping upstream of the curb stop. Although plumbers may not be directly involved with the installation of the municipal water supply piping, the materials and techniques used are the same for the installation of both residential and ICI water service pipes, which plumbers would install.

## Pipe and Fitting Materials

As discussed earlier in this Competency, municipal water systems are designed by engineers, or by qualified designers, using current engineering practices. Since the municipal system is outside the scope of the BC Plumbing Code, the designers have more freedom to choose materials and fittings for the water supply system upstream of the water service pipe. The municipal water distribution system will include pipes of a variety of sizes and materials and designers must have flexibility to choose these components based on recognized standards and past experience. However, the majority of municipal water distribution systems will use pipes and fittings that meet the requirements of the BC Plumbing Code Tables A-2.2.5., 2.2.6. and 2.2.7. These Tables are a summary of pipe and fitting applications so are used by plumbers when making choices for the design of the building water distribution system and the water service pipe.

The Tables reference the types of piping and fittings in one column and have separate columns for above-ground potable water system and underground potable water systems. The above-ground column is separated into two more columns, one for cold water and one for hot water. The underground column is also separated into two more columns, one for under the building, and the other for outside the building.

The list below shows a selection of piping and fittings from the BC Plumbing Code (BCPC) Tables A-2.2.5., 2.2.6. and 2.2.7 that could be used for underground municipal distribution systems and the water service pipe to buildings.

- Polyethylene water pipe and tubing, Series 160 sizes with compression fittings. BCPC Article 2.2.5.4 applies. Note: Permitted only for water service pipe.
- Polyvinyl chloride (PVC) pressure fittings. BCPC Article 2.2.5.7 applies.
- Polyvinyl chloride (PVC) water pipe. BCPC Article 2.2.5.7 applies. Note: Not permitted in hot water systems.
    - Dimension ratios (DR) or standard dimension ratios (SDR) 14, 17, 18, 21, 25 and 26.
    - Schedule 40 in sizes from ½ inch to 2½ inches inclusively
    - Schedule 80 in sizes from ½ inch to 6 inches inclusively

- PVC fittings, Schedule 80. BCPC Sentence 2.2.5.7.(2) applies.
- Crosslinked polyethylene (PEX) pressure tubing. BCPC Article 2.2.5.6 applies.
    - A-2.2.5.6.(1) Crosslinked Polyethylene Pipe and Fittings. There are some special installation requirements for the use of crosslinked polyethylene pipe and its associated fittings. Reference should, therefore, be made to the installation information in CAN/CSA-B137.5, “Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications.”
- Chlorinated polyvinyl chloride (CPVC) water pipe. BCPC Article 2.2.5.8 applies. Note: Not to exceed design temperature and design pressure stated in Sentence 2.2.5.8.(2).
- Polyethylene/Aluminum/Polyethylene (PE/AL/PE) pressure pipe. BCPC Article 2.2.5.12 applies.
- Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX/AL/PEX) pressure pipe. BCPC Article 2.2.5.13 applies.
- Polypropylene (PP-R) pressure pipe. BCPC Article 2.2.5.14 applies.
- Cast-iron water pipe (Ductile iron). BCPC Article 2.2.6.5 applies.
- Cast-iron screwed fittings. BCPC Articles 2.2.6.6 and 2.2.6.7 apply.
- Stainless steel pipe. BCPC Article 2.2.6.11 applies.
- Stainless steel tube. BCPC Article 2.2.6.15 applies.
- Welded and seamless steel galvanized pipe. BCPC Article 2.2.6.8 applies. Note: Permitted only in buildings of industrial occupancy as described in Book I (General) of this Code, or for the repair of existing galvanized steel piping systems.
- Copper and brass pipe. BCPC Article 2.2.7.1 applies.
- Brass or bronze threaded water fittings. BCPC Article 2.2.7.3 applies.
- Copper tube Types K and L soft temper. BCPC Article 2.2.7.4 applies.
- Solder-joint water fittings. BCPC Article 2.2.7.6 applies.

The BC Plumbing Code Tables A-2.2.5., 2.2.6. and 2.2.7 include a column that references the applicable standard for each type of pipe and fitting. The BCPC Article that is referenced also directs the plumber to the applicable standard. One standard that is not mentioned in the Code, but is followed by manufacturers of piping used on potable water systems, is the ANSI/NSF Standard 61: Drinking Water System Components – Health Effects. NSF International is an independent, not-for-profit, non-governmental organization that is dedicated to improving global health through the development of standards and certifications that protect food, water, products and the environment.

## Common Pipe Materials for Underground Systems

The water supply system includes piping and fittings in several different sections of the system. The water purveyor makes decisions on piping and fittings for transmission lines, in-plant systems, the distribution system (mains), and service lines. Common piping materials used by the municipal water supply system designer are ductile iron, PVC, HDPE, concrete pressure pipe, PEX, copper tubing, and

polyethylene tubing. Some of the considerations made by municipal water supply system designs for selecting pipe material and fittings are listed here:

- Meets ANSI/AWWA/CSA standards
- Meets NSF 61 standard
- Strength: internal pressure as well as external loads (backfill, traffic)
- Pressure rating
- Durability: water tight for service life
- Corrosion resistance: soil conditions, water pH, and chemistry
- Inner surface smoothness: C value, roughness causes head loss
- Ease of tapping and repair
- Installation labour cost

The plumber must decide on the piping and fittings for the water service pipe. Common piping materials used by plumbers for large diameter water service pipes (approximately 4 inch and greater) are ductile iron and PVC. Small diameter water service piping, such as copper, PEX, and polyethylene, are covered in Competency B-2 below.

Four of the most common materials used for municipal water distribution systems are covered below.

#### Ductile-iron

Ductile iron pipe is a type of cast iron pipe used for potable water distribution. Ductile cast iron is produced by a technique known as centrifugal casting. The molten ductile iron is poured into a rapidly spinning water-cooled mold. Centrifugal force causes the molten iron to spread evenly around the circumference of the mold.

This type of pipe, when used for potable water pipe, must be cement mortar lined on the interior wall to reduce the process of tuberculation (electrochemical corrosion) inside the pipe network. The cement mortar lining provides an area of high pH near the pipe wall and provides a barrier between the water and the pipe, reducing its susceptibility to corrosion. Over time, tuberculation can result in restricted flow because it decreases the inside diameter, thus the cross-sectional areas of the pipe. The cement lining forms a physical barrier between the pipe wall and the minerals found in the water. This barrier does not allow the minerals to adhere to the pipe wall. The exterior of the pipe is coated with bituminous coating. The primary purpose of the coating is to minimize atmospheric oxidation for aesthetic reasons but not act as a form of corrosion control.

Joining of ductile-iron piping and fittings is typically done with push-on or mechanical joints, but can utilize flanged connections for valves and fittings. Common sizes are 3 to 64 inch (75 to 1625 mm)

#### Polyvinyl chloride (PVC)

PVC is the most widely used material for underground municipal water distribution systems. PVC pressure pipe is known as a low-cost solution with strength, versatility, durability, and an easy

installation process to back its popularity. PVC is made of polyvinyl chloride, a widely used thermoplastic material that can be molded into different shapes. Note that all underground PVC pipe installations need to include tracer wire laid alongside, and at the bottom, of a new water main pipe.

There are no governing bodies that require specific color coding and, therefore, the PVC pipe industry has self-standardized color coding of PVC pipe. The typical industry color coding standard of PVC pipe is:

- Blue for pressurized potable water
- Green for sewer, both gravity and force main
- Purple for reclaimed (non-potable) water
- White for general use – (plumbing, Drain/Waste/Vent, or water well)
- Gray for general use – (typically plumbing and electrical)

Joining of PVC pressure piping and fittings is typically done with push-on or mechanical joints, with solvent cement joints generally used for smaller diameters (less than 4 inch). Common sizes used in the municipal water distribution system range from 2 inch to 60 inch (50 mm to 1525 mm)

#### High density polyethylene (HDPE)

High-density polyethylene, known as HDPE, is a denser version of polyethylene pipe and is a polyethylene thermoplastic made from petroleum. HDPE pipe can be joined by butt welding, electrofusion welding, socket welding, or extrusion welding. These types of connections are heated during the joining process, creating a completely homogenous joint so the weld becomes as strong, or stronger, than the existing pipe on either side of the weld. There is no need to use rubber seals or jointing chemicals, as is used for joining PVC pipe. Common sizes are 1¼ inch to 48 inch (32mm to 1200mm).

#### Concrete pressure pipe

Concrete pressure pipe (CPP) can be manufactured to meet any combination of working pressure, surge pressure, earth loads, and live loads. The cement mortar provides an alkaline environment that passivates the steel in most natural soils and water environments. The pipe has self-centering steel joint rings and rubber gaskets to ensure water tightness and joint flexibility for potential ground movements, and once installed needs no maintenance. Fittings can be designed and built to almost any shape or geometry. Water purveyors have traditionally used CPP for the transmission piping system that connects the reservoirs to downstream treatment facilities. Common sizes for this type of piping is 14 inch to 140 inch (350 mm to 3600 mm).

CPP is not to be confused with asbestos-cement pressure pipe (also referred to as transite pipe and white pipe), which was extensively used by plumbers prior to it being discontinued in North America in the late 1970s due to health concerns associated with the manufacturing process and the possible release of asbestos fibres from deteriorated pipes.

## Pipe and Fitting Pressure Ratings

Water supply system piping materials must withstand higher than normal pressures caused by pump start-up, water hammer, etc. This increased pressure can be significantly above the design working pressure of the system. Water supply system designers will choose materials with pressure ratings that will withstand any anticipated pressure increase based on engineering documents and past experience. To accommodate the wide range of pressure in a water supply system, manufacturers make pipe and fittings with a variety of wall thicknesses for different pressure ratings. For example, small diameter PVC pipe is rated by schedule, but larger PVC pipe is typically rated using “dimension ratio” (DR) and “standard dimension ratio” (SDR). Ductile-iron is rated using a Pressure Class designation.

Plumbers were introduced to pipe and tubing standards in the level one content so the following is just a review.

#### Standard dimension ratio (SDR) explained

The terms “dimension ratio” and “standard dimension ratio” are widely used in the PVC pipe industry. Both terms refer to the same ratio, which is a dimensionless term that is obtained by dividing the average outside diameter of the pipe by the minimum pipe wall thickness. Originally SDR referred only to a particular series of numbers (51, 41, 32.5, 26, 21, etc.) while DR was used for any non-SDR numbers. It is now common to use the two terms interchangeably.

- **SDR = outside diameter (OD) ÷ minimum wall thickness**

Theoretically, different sizes of piping made of the same material, with the same SDR, should have the same pressure ratings. For example, 1 inch and 6 inch PVC pressure pipe with an SDR 26 rating are both suitable for 1.1 MPa (160 psi). The figure below shows a cross-sectional drawing of two different sizes of plastic pipe: NPS 1 and NPS 2. Each pipe is made of the same kind of plastic. Notice the increased wall thickness of the larger diameter pipe. When the outside diameter is divided by the wall thickness, the ratio or SDR is the same. Each pipe has an SDR of 11, which means that both sizes of pipe can be used at pressures up to 160 psi.

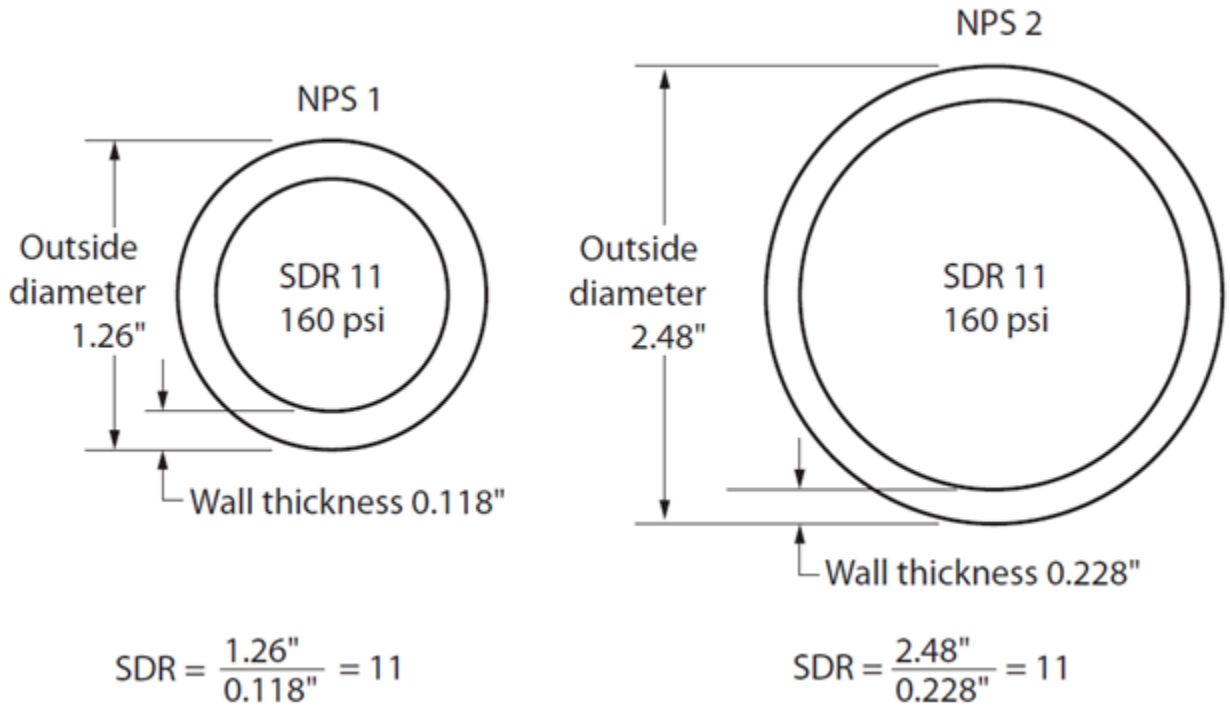



*Figure 1 Comparison of SDR relationship*

An example for a water supply system design specification could be DR18 for 100mm to 300mm PVC pipe, but DR25 for 350mm to 600mm PVC pipe.

#### Pressure class explained

Pressure classes are defined as the hydrostatic water working pressure of the pipe in psi. The pressure classes include a surge allowance of 100 psi with a safety factor of 2. The standard pressure classes are determined by the ANSI/AWWA C151/A21.51 standard for “Ductile-Iron Pipe, Centrifugally Cast”. The BC Plumbing Code Article 2.2.6.5., Cast-Iron Water Pipes, refers to several standards for ductile-iron pipe, fittings, and gaskets.

For example, a water supply system designer  could decide that ductile-iron pipe must be supplied in minimum Pressure Class 350 for 4″ through 12″ (100 mm through 300mm); Pressure Class 250 for 14″ through 20″ (350mm through 500mm); Pressure Class 200 for 24″ (600mm), and Pressure Class 150 for 30″ (750mm) and larger.

## Fitting Designs for Underground Systems

This section will discuss fittings specific to ductile iron and PVC piping used for underground water supply systems that have not been covered by previous content. Look back at the content “Describe Fittings Used in the Pipe Trades” from the plumber Level One textbook for a review of commonly used fittings in the pipe trades.

Ductile-iron and PVC piping for underground municipal water supply systems are traditionally installed in a trench and, for large city applications, could cover hundreds of square kilometers. The

installation would require fittings for changes of direction and elevation, as well as the installation of valves, fire hydrants, pressure-reducing stations, and service connections.

To accommodate small changes in direction and elevation, this type of system would use fittings that have much smaller angles than fittings used by plumbers in other mechanical systems, such as drainage systems or building water distribution systems. Manufacturers of ductile-iron and PVC fittings make elbows with change-of-direction angles such as 5 degrees and 11¼ degrees to ensure the joint deflection does not exceed specifications.

Joint deflection can be used to make small changes of direction when a trench needs to divert the pipe from a straight line. Fittings for both ductile-iron and PVC are well suited to applications where joint deflection is required but the installer must not exceed the deflection limitation specified by the manufacturer. Most manufactures limit joint deflection to a maximum of 5 degrees. More content on joint deflection is included in the section “Installation techniques for ductile-iron and PVC piping and fittings” below.

While ductile-iron fittings are cast in static moulds, PVC fittings are manufactured using high-pressure injection molding techniques, or they are fabricated using PVC parts to create a new fitting. Molded fittings are made by injecting hot plastic into a pre-made mold. This technique is generally used for the most common fitting types and sizes as it lends itself to mass production. To create fabricated fittings, manufacturers may cut, weld, and bend PVC to construct a fitting that cannot be easily molded. This process is less automated than injection molding, so fabricated fittings tend to be more expensive than molded fittings. Some manufacturers choose to fabricate large diameter, or unique fittings, because it is more cost effective than creating a special mold for something that will rarely be used. Molded fittings are typically for diameters up to approximately 12 inch, and fabricated fittings are for diameters up to approximately 60-inch PVC fittings.

Plumbers need to be aware that PVC pipe and fittings can be used with ductile-iron systems. This means that PVC pipe and fittings are manufactured in iron pipe size (IPS) outside diameter, as well as cast iron outside diameter (CIOD) sizes. Manufacturers make adapters to ensure the pipe and fittings are compatible.

The list below shows common fitting designs for municipal water supply systems using ductile-iron and PVC pressure piping.

- Bends (standard or custom angles)
- Couplings
- Tees
- Reducers
- Adapters
- Plugs
- Tapped couplings

Another type of fitting that is used on underground municipal water supply systems is the service saddle. A service saddle is a threaded outlet that is attached to a larger diameter pipe, usually the water

main, using straps, U-bolts, or brackets of various designs. Different materials, such as ductile-iron, brass, and stainless steel, are used based on the water purveyors' specifications.

Whenever possible, water purveyors use tapped couplings, or tapped tees, to connect the water service pipe to the main. Under specific conditions water purveyors may allow for the water service pipe connection to be made by direct-tapping into the pipe wall. Most purveyors will specify the use of a service saddle to complete the water service pipe connection if a tapped coupling or tapped tee is not available.




*Figure 2 Example of a stainless steel service saddle*

Repair couplings are another fitting that are used on underground municipal water supply systems and larger diameter water service pipes. Most PVC manufacturers make a fitting that is designed to simplify and speed up the repair operation. The double bell design repair coupling is used as it can be slid all the way onto one spigot, and then slid back onto the other spigot. To complete a repair, a section of damaged pipe would be removed and a new piece of pipe, along with two repair couplings, would be used to re-assemble the system.

Alternatively, third party mechanical couplings can be used to complete a pipe repair. These types of couplings can also be used to join plain end piping, as well as to make a non-restrained connection between two pipes of the same nominal size but with same or different ODs.



*Figure 3 Mechanical coupling*

Repair clamps are also available and are used to effectively repair holes or breaks in water mains. The figure below shows a stainless steel repair clamp.

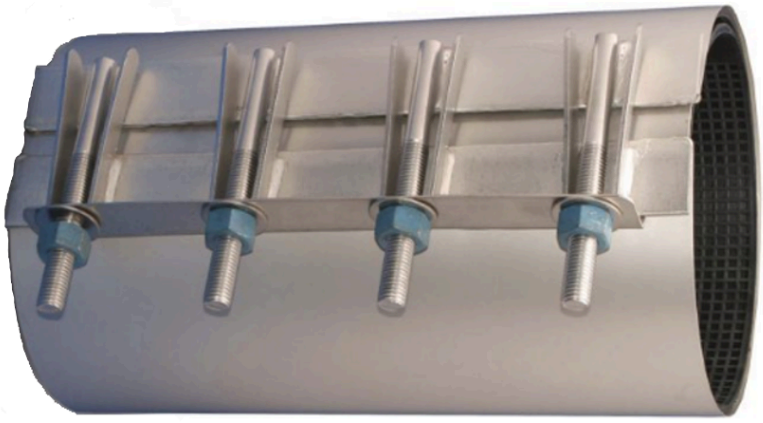


*Figure 4 Repair clamp*

## Resisting Thrust in Underground Systems

Typically, numerous fittings are needed to create the desired piping configuration. The fittings and pipe must remain in their installed position or leaks and blowouts will occur. Water that is in motion and under pressure can exert tremendous forces inside a piping system. Thrust is one of these forces that

pushes against valves, fittings, and hydrants, causing fittings to leak or to come apart entirely. Water pressure and sudden changes in water velocity cause thrust.

It is impossible to eliminate thrust, but it is possible to control the effects of thrust. As the pipe changes direction or elevation, and as fittings are placed to accommodate distribution branches, the fittings and pipe must be protected from disconnection by some form of joint restraint. Since several types of pipe and fittings are used, there are several types of joint restraint methods used by municipal water supply system designers and plumbers.

Some of the common methods to resist thrust are listed here:

- Thrust blocks using correctly sized and placed concrete blocks for horizontal forces
- Thrust anchors using correctly sized and placed concrete blocks for vertical forces
- Traditional push-on joints using external clamps and rods
- Mechanical joints using integral external joint restraint
- Proprietary push-on joints using specially designed locking gaskets (internal restraint)

Restrained push-on and restrained mechanical joints are used for resisting thrust forces as an alternative to thrust blocking. Some special self-restrained joining systems are used for trenchless (horizontal directional drilling) applications that will not be covered by this content, but are popular for municipal water supply system designers when challenged with upgrading old systems, or installing new systems, in built-up areas of their municipalities.

External and internal restrained joints are covered in the content below under the heading “Special purpose joint designs”. The information that follows will cover only the installation of thrust blocks and thrust anchors.

## Describe Thrust Blocks and Thrust Anchors

Thrust blocks and thrust anchors are one method used to aid in keeping underground pipe in its installed position. Three areas that require restraint are described below.

- At valves – All valves must be anchored. This includes valves installed in a chamber or in line with the pipe, whether it is operated frequently or only once a year.
- At changes in direction (vertical or horizontal) – Fittings such as elbows, tees, or dead ends must be restrained since they involve a significant directional change for the fluid.
- At reductions in size – The thrust component at reductions in size will depend on the amount of the reduction, and must be adequately restrained.

The thrust blocks and thrust anchors are poured concrete reinforcements placed at branches, fittings and changes of direction or elevation. Thrust blocks are used where primarily horizontal forces are created, and thrust anchors are used primarily where vertical forces need to be restrained.

**Thrust blocks**

Thrust blocks prevent separation of joints and pipe by transferring the horizontal thrust force in the piping system at a fitting to the undisturbed soil behind the thrust block. This means the area behind the thrust block must engage enough soil area to resist the resultant thrust force at a change in direction. Figure 38 shows a plan view of several typical thrust block locations in a municipal water supply system.

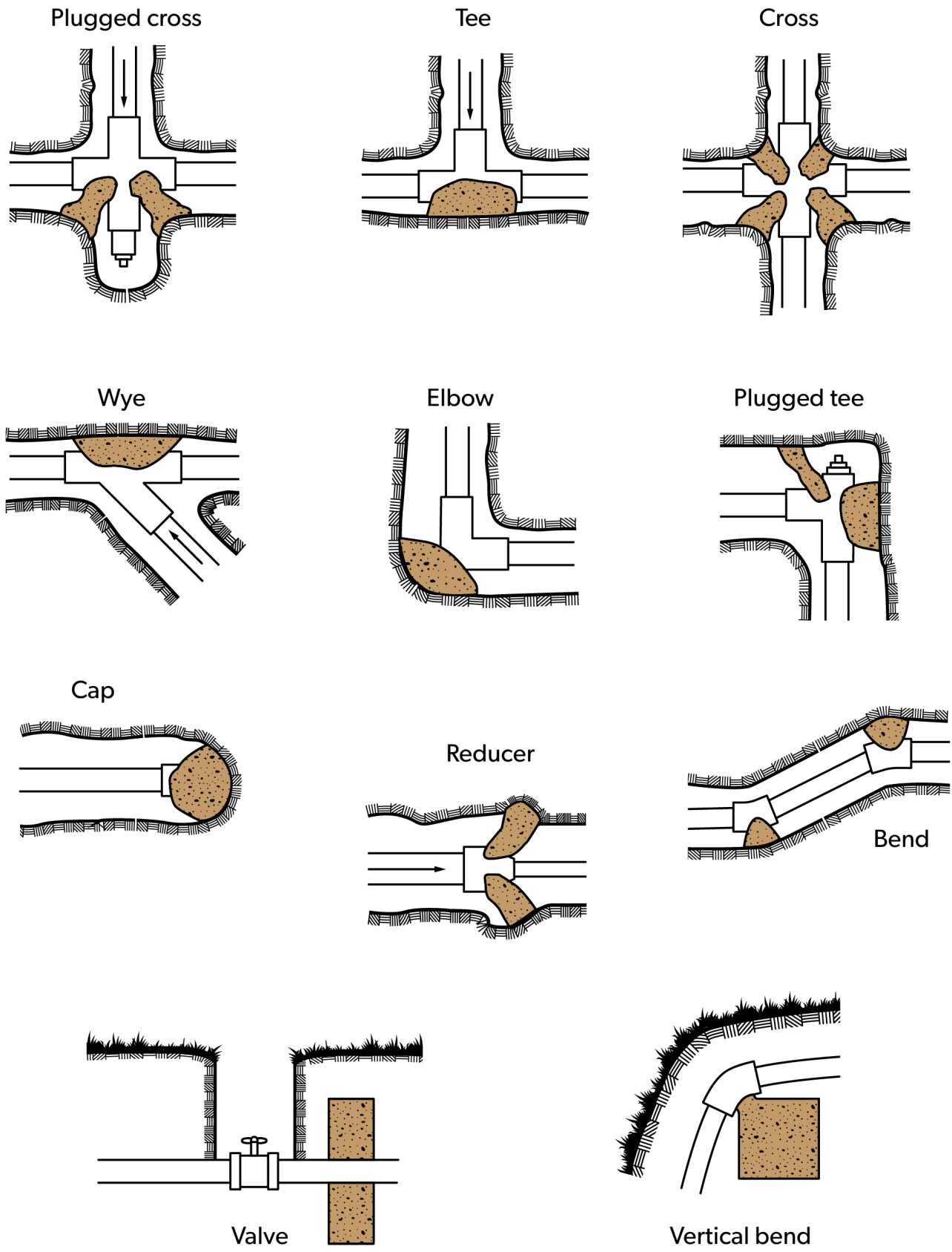



*Figure 5 Plan view of typical thrust block locations in a municipal water supply system*

#### Thrust anchors

Thrust anchors (also referred to as gravity thrust blocks) are used to resist thrust at vertical down bends. A thrust anchor uses the weight of the concrete block to balance the vertical thrust force. Shackle rod, or strapping, is installed around the fitting and embedded in the concrete to help hold the assembly in place. The figure below shows elevation views of two typical thrust anchor installations.

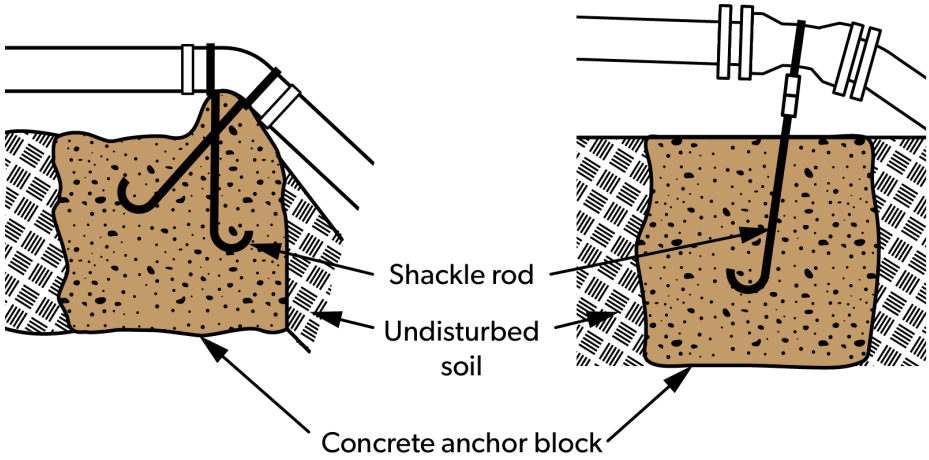



*Figure 6 Typical thrust anchor installations*

A properly designed thrust block or thrust anchor involves much more than dumping a load of concrete in a trench. The design involves consideration of undisturbed soil, soil bearing strength, test pressure, pipe size, fitting configuration, and trench depth to determine the bearing area of the thrust block or thrust anchor.

#### Resisting thrust in very poor soils

Where the pipeline passes through soils having little or no bearing strength, thrust forces may be restrained by the encasement of the fitting in concrete and the extension of this pour to form a monolith having sufficient inertia to resist the thrusts. It may also be possible to loop tie rods around the fitting and anchor the tie rods into an upstream concrete pour across the trench in more stable soils. Mechanical thrust restraints may also be used in these cases.

## Installing Thrust Blocks

When the water supply system design calls for the use of thrust blocks, concrete must be poured into a form built in the field by the installer. Concrete is poured between the fitting and undisturbed native soil at the side of the trench using forms, such as plywood sheets, to shape the block. When constructing thrust blocks, care needs to be taken to prevent the concrete from covering the joints at fittings, the weep holes in hydrants, and operating mechanisms of valves. The use of polyethylene film to cover the fitting will help if future disassembly, or revision, is desired.

While the design engineer usually specifies the concrete mix for thrust blocks, compressive strength at 28 days should be at least 2,000 psi and minimum curing time should be five days. When installing thrust blocks, the dimensions should be strictly adhered to as they have been designed for the specific

water pressure and external soil conditions. Alternatively, pre-cast thrust blocks can be used if approved by the design engineer.

## Sizing Thrust Blocks

The recommended bearing area to be established by the concrete pour may be given by the design engineer, or may be determined in the field by the installer. The area (ft.²) can be calculated by determining the total thrust generated at the fitting.

Here is an example problem to help work through the thrust block sizing method.

STEP # 1. Gather all the required information.

- Fitting details where thrust block is required (for example ***6 inch 90 degree elbow***)
- Working pressure of the system (for example ***100 psi***)
- Bearing load of soil. (for example, estimated soil type as ***sand and gravel cemented with clay***. The bearing load for this type of soil is ***4000 lbs per square foot*** (from the Table below).

These soil bearing capacities are approximate and conservative. For the most accurate design it is recommended that soil bearing tests be carried out by a competent soils engineer.

**Table 1 Bearing Strength of Undisturbed Soils**

| | |
|---|---|
| **Organic Material (such as Peat, etc.)** | 0 lb/ft² |
| **Soft Clay** | 1000 lb/ft² |
| **Sand** | 2000 lb/ft² |
| **Sand and Gravel** | 3000 lb/ft² |
| **Sand and Gravel Cemented with Clay** | 4000 lb/ft² |
| **Hard Pan** | 5000 lb/ft² |

STEP # 2. Determine the thrust force at each fitting from the table below.

For example: The 6-inch 90-degree elbow that we are using will produce 54 lbs of thrust for every 1 psi of working pressure.

The total thrust force for this application will be 54 pounds of thrust per 1 psi x 100 psi of pressure = 5400 pounds of thrust.

**Table 2 Thrust in POUNDS, per PSI of water pressure**

| Pipe size | Dead-end or Tee | 90 degree elbow | 45 degree elbow | 22½ degree elbow | Side thrust per degree of deflection in pipe line joint |
|---|---|---|---|---|---|
| **3** | 12 | 17 | 9 | 5 | 0.24 |
| **4** | 19 | 26 | 14 | 8 | 0.35 |
| **6** | 38 | 54 | 29 | 15 | 0.72 |
| **8** | 66 | 93 | 50 | 26 | 1.22 |
| **10** | 107 | 151 | 82 | 42 | 1.97 |
| **12** | 153 | 216 | 117 | 60 | 2.78 |
| **14** | 207 | 293 | 159 | 81 | 3.77 |
| **16** | 268 | 397 | 205 | 105 | 4.86 |
| **18** | 344 | 485 | 264 | 134 | 6.65 |
| **20** | 426 | 600 | 326 | 165 | 7.90 |
| **24** | 615 | 867 | 472 | 239 | 11.50 |
| **30** | 963 | 1258 | 740 | 357 | 18.80 |
| **36** | 1390 | 1960 | 1166 | 540 | 26.60 |

STEP # 3. Determine the total bearing area required.

For this example, divide the total thrust force by the bearing strength of the soil.

Total thrust 5400 lbs ÷ Bearing load of soil 4000 lbs per square foot = 1.35 square feet of bearing required.

The concrete thrust block that is installed must bear up against the undisturbed soil for an area of at least **1.35 square feet**.

## Joining Methods for Ductile-Iron and PVC Piping and Fittings

There are a variety of ductile iron and PVC pipe joints on the market. Joining pipe together is just as important as the pipe itself. The different types of joint designs will allow the designer maximum flexibility when selecting piping and fittings for various applications, such as:

- joints that can restrain the pipe.
- joints with primary use for above-ground applications only.
- specialty joints that allow for deflection and expansion/contractions within the same

coupling.

- joints that allow a span of greater distance than the pipe length.
- joints that use trenchless technology to install piping under roadways, rivers, etc.

For municipal water supply systems and large diameter building water service pipes (typically 4 inch and greater) requiring no specialty joints, both ductile-iron and PVC use similar methods to join piping and fittings. This section will cover the 2 most common methods used to join ductile-iron and PVC piping and fittings: push-on and mechanical joints.

The most common choice for pipe ends is the bell and spigot design. The bell end (hub end) receives the spigot (plain end) as shown in the cutaway figure below.

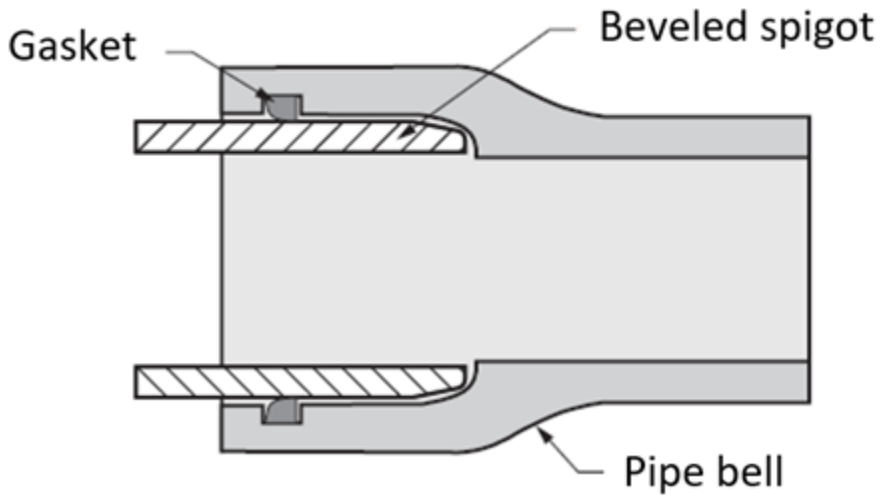



*Figure 7 Bell and spigot push-on connection*

## Push-on Joints

The push-on joint has been used since the 1950s and is the most common joint used for underground water supply systems. This joint consists of a single elastomeric gasket placed in a groove inside the bell end of the pipe. Elastomeric refers to a flexible synthetic rubber-like compound (neoprene) designed for specific uses. Some elastomeric compounds, for example, must be able to resist different chemicals, temperatures and pressures. This allows manufacturers to supply elastomeric gaskets for many different applications. For example, the standard gasket supplied may be a Styrene Butadiene (SBR) gasket, but other gasket materials such as EPDM, Nitrile, Neoprene and VITON® are also available. Nitrile gaskets are an example of a gasket option that is used for applications where fittings must be buried in soil with hydrocarbon contamination.

After lubricating the joint in accordance with the manufacturer’s instructions, the spigot end of the pipe is pushed past the gasket, compressing it and forming a seal that is tight versus high internal pressures. Assembly of the push-on joint is simple and fast, and it can be assembled under wet-trench conditions or even under water.

The basic push-on joint is a non-restraint joint, but special purpose designs are available for push-on joints that are considered restrained joints.

Different push-on joint designs are used by various manufacturers. This means the bell socket is different for each type of gasket and, consequently, the gaskets are not interchangeable. Care must be exercised to make certain that the correct gasket is being used for the joint design being installed and that the gasket faces the proper direction.

## Mechanical Joints

The term mechanical joint fitting refers to a variety of fittings that use specially designed clamps and elastomeric gaskets to connect the piping and fittings.

Mechanical joint connections are primarily used in fittings and valves. These joints use the gland's compression against the bell to wedge the gasket, forming a watertight seal. The mechanical joint has four parts: a flange cast with the bell, a gasket that fits in the bell recess, a gland (follower ring) to compress the gasket, and tee-head bolts with nuts for tightening the joint. The basic mechanical joint is not a restrained joint and so offers no practical resistance against joint separation due to thrust forces. Common sizes for this design are from 4 inch through 24 inch, with special orders available up to 48 inch.

The figure below shows a ductile-iron mechanical joint fitting. Note that the mechanical joint fitting still uses a bell to accommodate a gasket, unlike the flanged fitting.



*Figure 8 Mechanical joint fitting*

## Flanged Joints

Flanged joints for municipal water supply systems are similar to flanged joints for other fluid applications. Flanged joints are seldom used for underground municipal water supply systems or building water service piping except for valves and fittings for large meter settings, valve vaults, and similar installations. This joint is most commonly used for above-ground piping in pump rooms, water

treatment plants, and is occasionally used with valves adjacent to fire hydrants. Because of its rigidity, the flanged joint is not recommended where heavy settlement or vibration is likely to occur.

The figure below shows a ductile-iron flanged reducer. Note the absence of a bell to accommodate a gasket. Instead, a full-face flange gasket is used for this design.

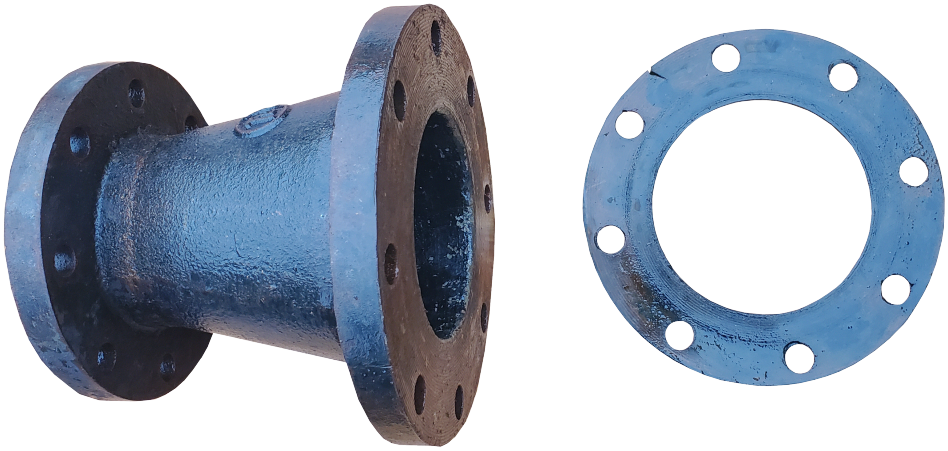


*Figure 9 Ductile-iron flanged fitting*

Although common on ductile-iron systems, PVC pipe may be connected to flanged joints by using a flange adapter. As is the case with ductile-iron, flanged joints on PVC systems are not recommended for buried underground installations.

## Special-Purpose Joint Designs

There are many variations of the joining types based on the piping material and fitting requirements. Joints designed to restrain the pipe and fitting connection, either internally or externally, are available as an alternative to thrust blocks and thrust anchors. Several designs use a clamp on the wall of the pipe and tie back to a mating collar on the fitting or the pipe bell. The use of these devices may provide the entire thrust restraint necessary at the fitting, in sizes up to 60 inches (1500 mm). The use of several thrust restraints to tie together two or three lengths of pipe on either side of the fitting may be required.

The content below covers some of the popular special-purpose designs for ductile-iron and PVC piping and fittings.

### Push-on joint restraint design

There are several variations of this design but most manufacturers use a restraint ring on the spigot and a split ring behind the bell. Manufacturers have external joint restraint designs that work for ductile-iron and PVC piping and fittings.

#### External restraint for push-on joints

These devices clamp to the wall of the pipe and tie back to a mating collar on the fitting or pipe bell. Since rods are used to connect the clamp and the collar, this method is also referred to as rodding.

The figure below shows an external joint restraint assembly that is used only with ductile-iron push-on fittings with restraining ears. This design uses different restraint rings on the spigot depending on the type of piping being installed.

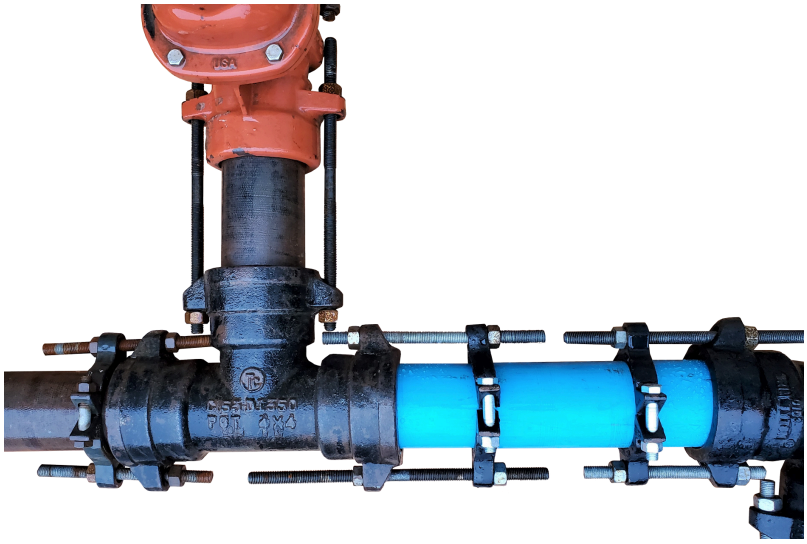


*Figure 10 An external joint restraint for ductile-iron fittings with restraining ears.*

Internal restraint for push-on joints

Although open-cut trench construction is the standard method of installing PVC pipe, in many cases trenchless construction may be more viable. The pushing or pulling of pipe in trenchless installation causes loads on a pipe that are not typical for open-cut trench construction. As a result, the PVC pipe industry has developed several different types of restrained joint systems for trenchless projects.

While these restraint systems are necessary for trenchless installations, they are also used in open-cut trench situations where restraint is required. Plumbers should always check with the design engineers before choosing to use one of these joining methods to replace more traditional restraint systems.

*Pin-and groove joints for push-on joints*

The figure below shows a pin-and-groove gasketed joint. In this joining system, when the pipe is assembled, a groove on the outside of the pipe spigot aligns with holes spaced around the pipe bell. Pins are hammered through an external ring, through the holes in the bell, and bottomed out in the spigot groove. Pin-and-groove (also known as ring-and-pin) joints have no metallic components.

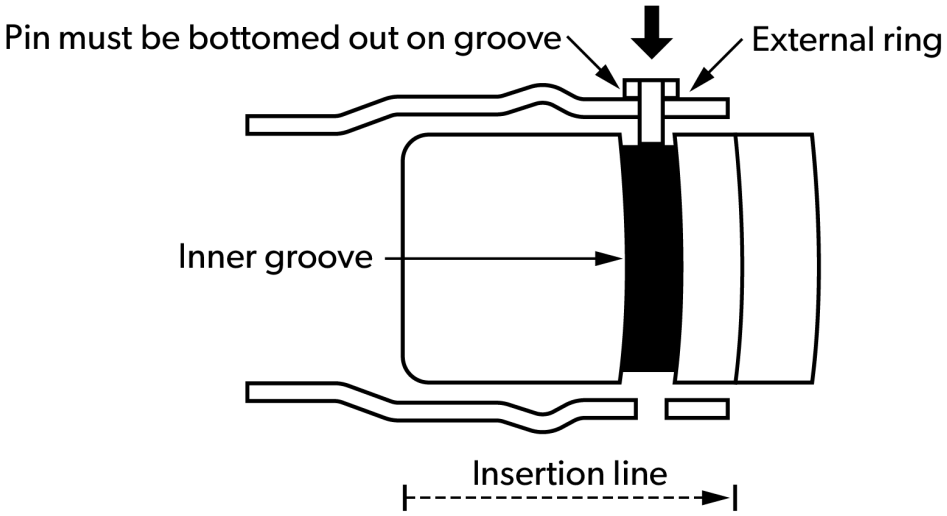



*Figure 11 An example of pin-and-groove joint restraint for PVC connections*

*Locking gaskets for push-on joints*

Another internal restraint system for push-on joints is the use of proprietary locking gaskets. The restraint is engaged after the joint has been properly assembled including deflection. Pulling back on the joint will engage, or lock, the teeth in place. Restraint gaskets are an excellent option and are primarily used in smaller diameters (24-inch and down). This type of restraining system is primarily used for buried applications using ductile-iron push-on joints.

*Spline-lock gasketed joint*

The figure below shows a spline-lock gasketed joint. This joint uses a nylon locking spline that is inserted into mating grooves in the pipe spigot and the bell/coupling. Spline-lock joints form a non-metallic, mechanically restrained joining system that can be disassembled and reused if necessary.

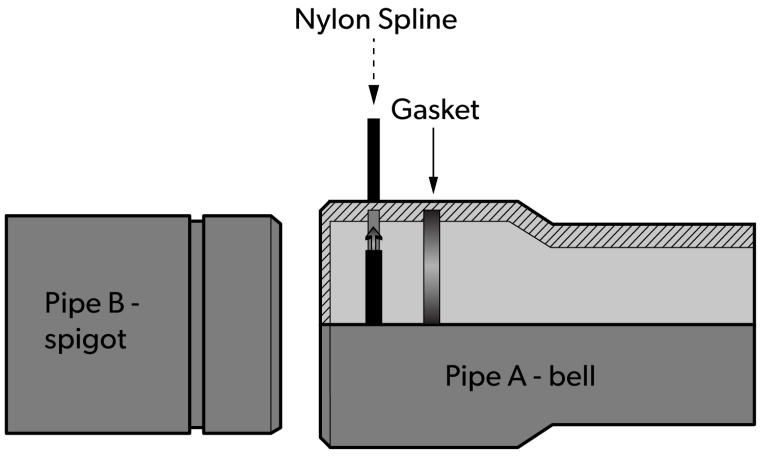



*Figure 12 An example of spline-lock internal joint restraint for PVC connections*

### Mechanical joint restraint design

Mechanical joints look similar to a flanged connection but unlike flanges, these joints use a gasket installed in a bell of the fitting. Manufacturers have several restraint joint designs for use with the mechanical joint system.

#### External ring restraint for mechanical joints

These joints have an external ring either welded onto the ductile iron pipe, or are a proprietary design that doesn't require welding, for use on both ductile-iron and PVC piping. The design typically uses an additional gland set behind the ring to achieve the restraining capabilities.

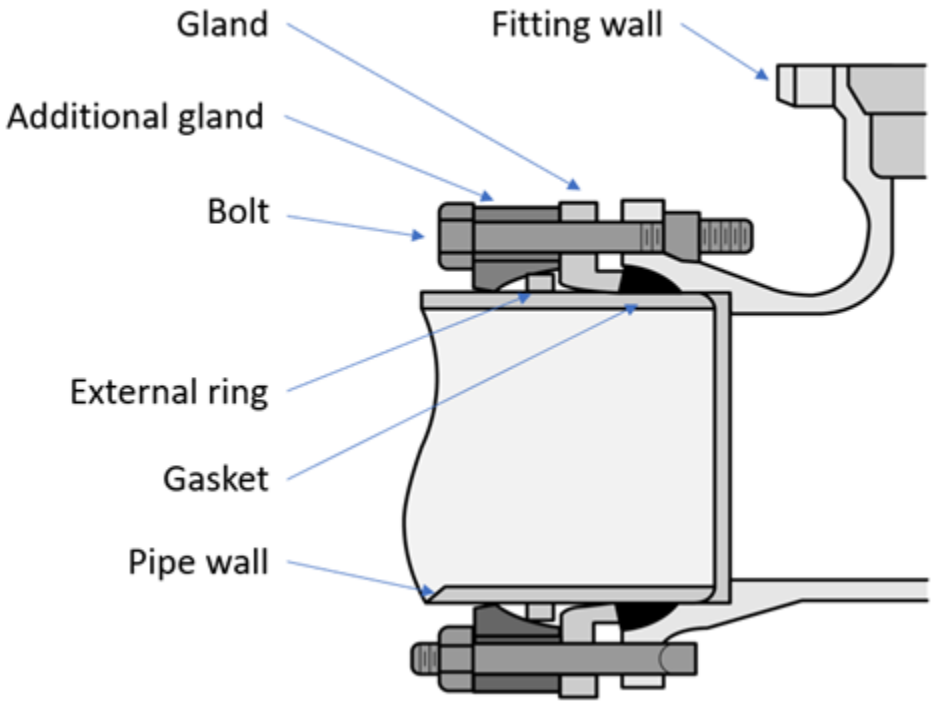



*Figure 13 A cutaway of one version of the external ring restraint system*

#### Wedge action retainer for mechanical joints

The wedge action retainer is a mechanical joint restraining gland, incorporating a number of individually activated wedges located around the circumference of the pipe. This design allows for more deflection than traditional mechanical joints, and may be applicable for use in unstable soil conditions where small amounts of movement may occur.

### Seismic-resistant joints

Some manufacturers of PVC pressure water pipe have joining systems that are designed to survive significant seismic events and permanent ground deformation. This unique design uses proprietary pipe connection that has lengthened bell ends that, when properly restrained, allow the pipe to extend in a chain-like fashion.

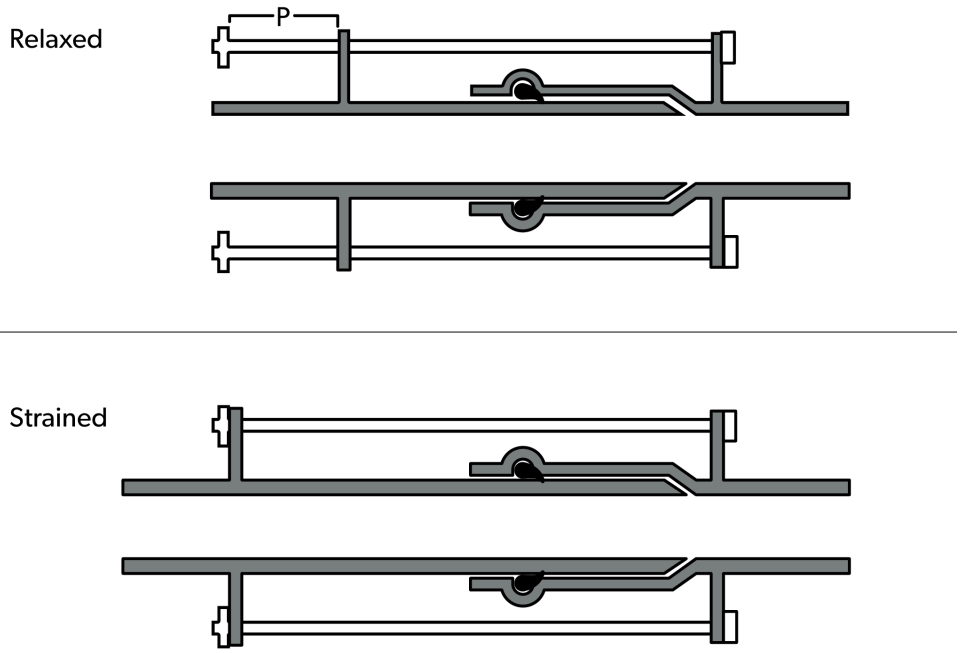



*Figure 14 How a seismic-resistant joint allows for movement in the piping*

## Installation Techniques for Ductile-Iron and PVC Piping and Fittings

Several steps must be done to complete the assembly and installation of underground piping. It is best practice to follow manufacturers instructions when completing the steps listed below.

- Pipe handling and storage
- Trench preparation.
- Cutting, bevelling, and chamfering the pipe
- Assembly techniques
- Deflection of the piping
- Tapping and service connections
- Bedding and backfill

### Pipe Handling and Storage

Pipes can be distorted by improper storage such as improper handling and stacking, exposure to sunlight, and excessive heat or cold. Pipe and fittings stored outside for an extended period should be stored and supported as per the manufacturer’s instructions.

The following list gives guidelines for general pipe storage conditions:

- Exposure to excessive heat should be avoided to reduce the risk of pipe distortion.

- If plastic pipes or fittings are to be stored outdoors for extended periods of time, they should be protected as directed by the manufacturer. Plastic pipes may be affected by exposure to sunlight, especially if exposed for extended time periods and outside of protective cover.
- When purchasing pipe, check for damage such as deep scratches, cracked ends, out of round, etc.
- When receiving pipe, check for damage to the pipe, or shortages as compared to the bill of lading.
- When storing pipe, keep dirt and debris from getting into piping by leaving the protective caps and coverings on until the piping is installed.
- When stacking pipe at the job site, set the pipe on evenly spaced, level runners to prevent sagging. Place wedges or blocking to stop the pipe from rolling off the runners.
- Pipe delivered on pallets is often banded. Be sure that cutting the band does not cause the pipe stack to collapse uncontrolled. If the pipe is not on a supporting cradle, block the stack before cutting the banding.
- When stacking pipe that has hub ends, alternate the hub and spigot ends with the ends protruding so that the pipe barrels will lie flat.
- When unloading alongside a trench, stack the pipe on the opposite side of the trench from the excavated soil pile. Installing large and heavy pipe will be easier from the clean side of the trench

## Trench Preparation

The drawings and bid documents will specify the correct line and grade to be established by the trenching operation. The trench depth will be deep enough to allow for the designer's support system, the size of the piping, depth of coverage, and protection from the effects of freezing.

The BC Plumbing Code Article 2.3.5.1 indicates the minimum depth for underground piping is determined by the requirement for 300 mm (12 inches) of backfill material over the top of the pipe. Each jurisdiction in the province will have different minimum depths for the water service pipe to protect against freezing. BC Plumbing Code Article 2.3.5.3 simply states "Where piping may be exposed to freezing conditions, it shall be protected from the effects of freezing". Plumbers should always check with the Authority Having Jurisdiction (AHJ) to ensure the pipe is buried to the correct depth.

The trench must be wide enough to permit proper installation of the pipe and to allow room to assemble joints and tamp backfill around the pipe. The width is governed by size of pipe, type of soil, and type of excavating equipment. A wider trench may be required if the installer intends to offset the pipe using joint deflection.

Refer to the "British Columbia Occupational Health and Safety Regulation Part 20: Construction, Excavation and Demolition" for trench shoring and requirements and safe sloping procedures.

De-watering of the trench may also need to take place. For safe and proper construction, the

groundwater level in the trench should be kept below the pipe invert. This can be accomplished by the use of pumps placed in the trench.

#### Crossings

Where a watermain crosses a sanitary or storm sewer, the watermain should be laid to provide a minimum vertical distance of 0.45 metres between the outside of the watermain and the outside of the sewer. While the watermain may be either above or below the sewer, it is preferred that the water main be above the sewer. Locate one full length of water pipe at the crossing, so both joints will be as far from the sewer as possible. Special structural support for the water and sewer pipes may be required. If conflicts occur, provide additional protective measures.

### Cutting, Bevelling, and Chamfering the Pipe

Most piping projects require pipe to be field-cut and bevelled (or chamfered) to allow for the installation of valves and fittings, etc. Although pipe is typically shipped with a bevel or chamfer on the end of the spigot, field cutting is regularly done by the installer, and therefore the bevel (or chamfer) must be created on the new spigot. For the purposes of this content, the terms bevel and chamfer are used interchangeably.

Depending on the type of joint, there are times when the installer must recreate a factory bevel after field cutting so the pipe's spigot will correctly engage the sealing gasket. There are other times when the installer only needs to remove a sharp edge from the cut end of the pipe so the gasket will not be damaged. The decision on how much of a bevel to create depends on the connection to be made. A light bevel is adequate when the connection will be a mechanical joint, while a factory-replicated bevel is required for a push-on installation.

Although cutting and bevelling (chamfering) ductile-iron pipe and PVC pipe are similar, they use different tools and different techniques as described below.

#### Cutting and bevelling ductile-iron pipe

Field cutting of ductile-iron pipe is usually done with a gas-powered saw with abrasive wheel, or with an angle grinder. Using these power tools, it can take up to a minute per inch to cut the pipe. For example, it could take 16 minutes to cut a 16-inch diameter pipe. Care must be taken to ensure the pipe is cut square so the joint integrity is not compromised. An angle grinder, or hand file, can be used to bevel the spigot to the manufacturer's specifications for push-on joints.

#### Cutting and bevelling PVC pipe

Field-cutting and bevelling of PVC can be done with power tools or with hand tools. As with ductile-iron pipe, a square cut is important. For smaller diameter pipes a mitre-box can be used with a hand saw to complete the cut. With large diameter pipes, it is common to use an abrasive disc or steel saw blade in a power tool. Take care not to cause burns.

An angle grinder, power sander, rasp, or hand file are commonly used to bevel the spigot of PVC pipe to the manufacturer's specifications for push-on joints. There are also specialty power tools that are

designed to cut the bevel on plastic piping. For PVC pipe inserted into a PVC pipe bell or into a PVC fitting, match the pipe's factory bevel. For PVC pipe inserted into a ductile-iron fitting, where the bells of iron fittings are much shallower than the bells of PVC fittings, the spigot should have only a slight bevel. Create the slight bevel at the end of the pipe by removing the sharp edge of the cut all the way around the outside edge.

The figure below shows an example of the dimensions for a factory bevel (chamfer) for installation into a PVC push-on fitting.

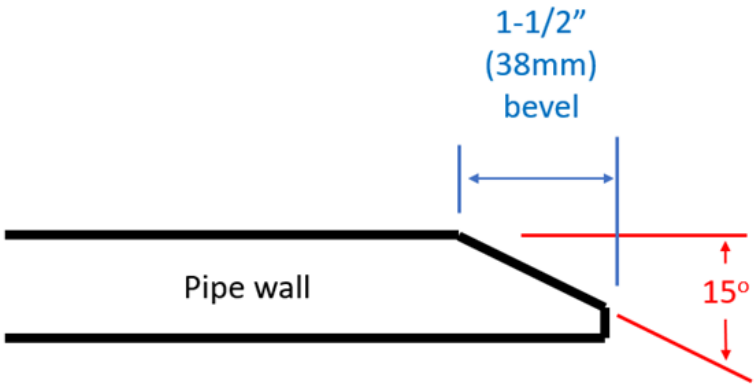



*Figure 15 Bevel dimensions for pipe spigot*

## Assembly Techniques [Level 2]

Once the assembly process has begun, it is recommended to keep the three basic operations (digging, pipe laying and backfilling) as close together as practical. The shortest length of time a trench is open is the safest for all workers and reduces the possibility of problems associated with water, frozen ground, impact damage, flotation, and traffic.

### Laying the pipe

It is good practice to lay ductile-iron and PVC pressure pipe with bells forward so that the assembly operation will consist of pushing the spigot into the bell. This will minimize the possibility of contaminating the surfaces with foreign material. Although rare, on occasion it may be necessary to lay pipe backward (bell into previously laid spigot end). This practice is normally not recommended due to the chance of dirt or debris compromising the joint. This method also requires extra care when backfilling and tamping as larger bell holes are generally required in the trench bottom to accommodate the assembly process.

### Supporting underground pipe

The design of support of underground municipal water lines is normally done by engineers, or designed in accordance with good engineering practice. The specifications for a water supply system upstream of the water service pipe would include details on support for the different pipe and components that will be used. It is common for engineers, or other designated designers, to specify the support for the water service pipe for large ICI projects as well. If the drawings or specifications do not include information

on underground water system piping support, then the plumber would make decisions based on the BC Plumbing Code Article 2.3.4.6., Support for Underground Horizontal Piping.

In the BC Plumbing Code Notes to Part 2, A-2.3.4.6.(1) shows permitted installations in Figure A-2.3.4.6.(1)(a). The methods of support shown in Figure A-2.3.4.6.(1)(b) are NOT permitted because the base does not provide firm and continuous support for the pipe.

#### Preparing the bell and spigot

For most pipes, gaskets are factory-installed. If the gasket is not pre-installed make sure that you are installing the correct gasket design for the type of pipe being used. Make sure that the gasket is clean and that the bell groove is free of any debris or dirt before positioning it into the groove in the bell. If the gasket is already installed it is usually not necessary to remove the gasket for cleaning. It is important to note that gaskets are not interchangeable between manufacturers, or between bell types.

Clean the inside of the bell (including the face of the gasket), and the outside of the spigot with a rag, brush, or paper towel to remove any dirt or foreign material before assembling. Apply a thin coating of lubricant (equivalent to a brushed coating) using a glove, a rag, or a paint brush. Most manufacturers recommend applying lubricant to the bevelled area of the spigot, as well as all around the entry lip of the bell and the face of the gasket. Use only manufacturer’s recommended pipe lubricant as the use of substitute lubricants may affect water quality or damage the gaskets.

#### Final assembly

There are differences between push-on joints and mechanical joints, so always follow the manufacturer’s installation requirements for the type of joint being installed.

Keeping the spigot out of the dirt, position it so that the bevel is resting against the gasket in the bell. Push the spigot into the bell until the assembly line on the spigot is even with the edge of the bell. The assembly effort can be delivered by hand for small diameter piping with the aid of a twist as the spigot enters the bell, or by using a bar and block. Other assembly methods include lever pullers, come-alongs, hydraulic jacks, and specialty pipe pullers for large diameter pipes. Excavating equipment, such as backhoes, is often used to assemble large diameter piping systems. Extra care must be taken when using these types of equipment to ensure worker safety and prevent component damage.

Since ductile-iron fittings can be used with PVC pressure pipe, some special assembly methods are used. The bells of both mechanical joint and push-on ductile-iron fittings are much shallower than the bells of PVC pressure fittings. For this reason, the assembly line on the pipe spigot of the PVC pressure pipe is of no value as an indicator of proper assembly to ductile-iron fittings. In order to fully engage the gasket in the ductile-iron push-on bell, the factory bevel of the PVC pipe spigot should be reduced to only a slight bevel.

The figure below shows a bar being used to assist in the installation of the spigot into the bell of a push-on joint.

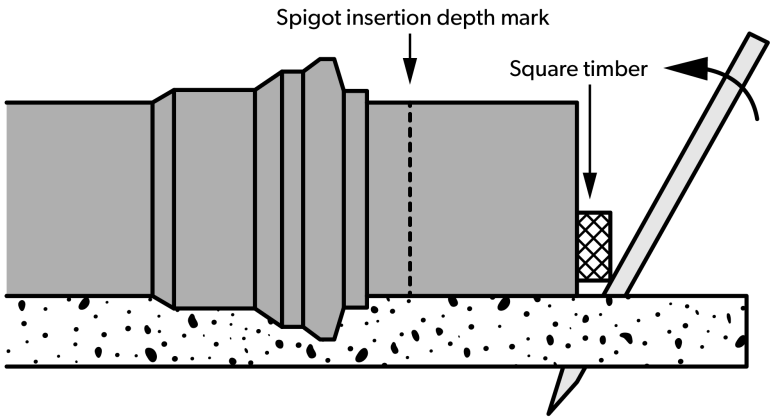



*Figure162 Push-on fitting assembly technique*

Where mechanical means, such as a backhoe, is used, the assembly effort should not be applied directly to the edge of the pipe. A two by four or a plank should be placed between the backhoe bucket and the edge of the pipe. Since the backhoe operator cannot clearly see when the assembly is complete, the installer must be in a position near the joint to signal when the assembly is complete.

## Deflection of the Piping

If the piping assembly requires horizontal or vertical deflection, the necessary deflection can sometimes be done within the push-on or mechanical joint. Depending on pipe size, type of pipe, pipe joint design, coverage depth, and other parameters, manufacturers may allow for up to five degrees of deflection. A five-degree deflection equates to approximately 20 inches of offset for a 20-foot length of pipe.

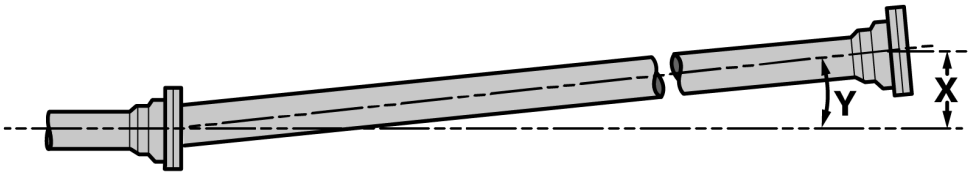



*Figure 17 Plan view of a push-on joint being deflected.*

When deflection is necessary, pipe should be assembled in a straight line, both horizontally and vertically, before deflection is made. To allow for deflection in push-on joints, the manufacturer recommends the installer assembles the joint but does not insert the spigot fully into the bell. It is recommended to push the spigot into the bell only to a point about 1/2 inch (13mm) short of the factory reference line (the first reference line if there are two). This assembly permits more movement of the end of the pipe at the bottom of the bell. For mechanical joints, assemble the joint in a straight line and then hand-tighten the bolts. Make the desired amount of deflection in the pipe and then complete the tightening of the bolts.

## Tapping and Service Connections

The service connection, the connection of the water service pipe to the municipal water distribution system (water main), is required for almost every building served by the system. Although water

purveyors prefer tapped couplings (tapped tees) there are other methods for making service connections to underground ductile-iron and PVC piping.

### Direct tapping

Both ductile-iron and PVC piping can be direct tapped, where the corporation stop is threaded directly into the wall of the water main. This method is best performed using a power tool designed for the specific purpose of drilling and tapping pipe. Manufacturers make pipe tapping machines for ductile-iron and PVC pipe sizes from 4 inch to 48 inch. Some machines are even able to drill and tap under pressure, called hot-tapping.

#### Direct tapping PVC pressure pipe

For PVC pressure pipe, direct tapping is only recommended for specific sizes with specific DR ratings. For example, DR18 and DR14 pipe in sizes 6 inch (150 mm) through 12 inch (300 mm), conforming to AWWA C900 and CSA B137.3, can be direct tapped. The maximum size water service line connection for direct tapped PVC piping is 1 inch.

Corporation stops should be installed at least 2 feet (600mm) from the ends of PVC water main piping. Multiple taps should be separated by at least 18 inches (450mm) measured along the pipe length, and they should be staggered radially.

#### Direct tapping ductile-iron pipe

For ductile-iron pipe, the maximum recommended tap size for pressure class ductile-iron pipe is decided by class and pipe size. All classes of ductile-iron pipe 24 inches and larger in diameter can be direct tapped for 2-inch corporation stops. The cut-off at 2-inch diameter taps was chosen because most, if not all, tapping machines used to direct tap pressurized mains are limited to a maximum tap size of 2 inches.

The figure below shows a ductile-iron pipe that has been direct tapped.



*Figure 18 A ductile-iron pipe that has been direct tapped*

#### Service saddles

As mentioned previously in this Learning Task, a service saddle is a threaded outlet that is attached to a larger diameter pipe, usually the water main, using straps, U-bolts, or brackets of various designs. Different materials, such as ductile-iron, brass, and stainless steel, are used based on the water purveyors' specifications. Service saddles are available for any size or class of pipe. A service saddle is used to make connections up to a maximum size of 2 inch (50mm). Above this size a tapping sleeve, or tapped coupling, is required.

#### Tapping sleeves

Tapping sleeves are used to allow the branch line, or water service pipe, to be joined to the main using a connection at a metal sleeve that wraps around the pipe. One advantage to this system is the maximum branch line size, or water service pipe size, can be the same as the main size.

These fittings are suitable for making large taps in ductile-iron and PVC pressure pipe, but do require the use of a power operated tapping machine. Tapping sleeve installation may be sufficiently specialized to warrant the services of an expert contractor who can provide the necessary equipment.

#### Hot tapping (live tapping)

Water line hot tapping is a safe way to tie into an existing pressurized system. It is done by drilling into the pipe while it is under pressure, which completes a water line connection without having to interrupt the area around it. Once a saddle fitting has been added at the connection location, and the corporation stop has been installed, a special machine is required to complete the hot tap. The machine essentially drills a hole through the pipe wall using a special fitting installed into the stop valve. Most hot tapping machines work on the ductile-iron, PVC pressure pipe, and HDPE pipe used for municipal water mains.

The figure below shows stages of completing a hot tap. The left figure shows the hot tapping machine installed and ready to start the process. The centre figure shows the hot tapping machine drilling through the pipe wall through the open valve. The right figure shows the cutting tool retracted, with the pipe wall coupon removed with the cutting tool, and the valve closed. The machine is now ready to be removed so the water service pipe can be connected.

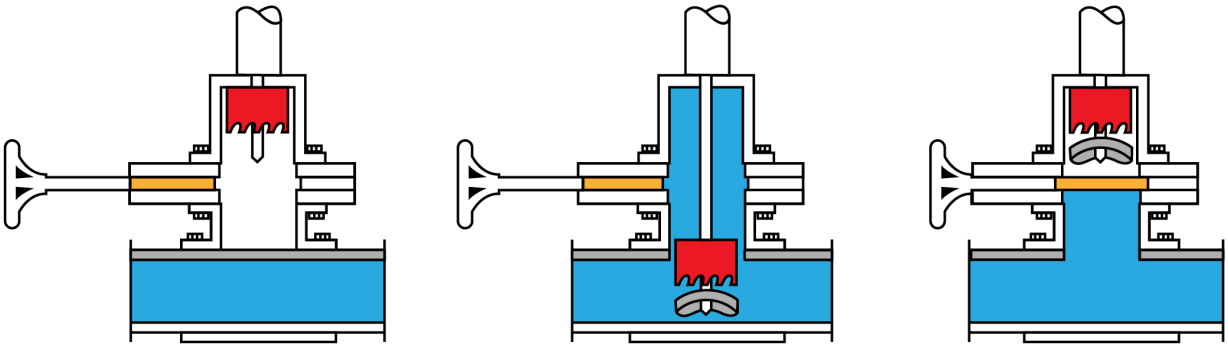


*Figure 19 The hot-tapping process*

## Bedding and Backfill

Municipal water supply system designers will include bedding and backfill specifications as part of the design package. The objective of bedding is to provide a continuous support for the pipe at the required line and grade. During installation, the projecting bells of the pipe should be properly relieved in the trench bottom so that the entire pipe is evenly supported by the bedding. Where the trench bottom is unstable (organic material) the trench bottom should be over-excavated and brought back to grade with approved material.

Design engineers will typically specify at least two different backfills, an initial backfill and a final backfill.

- Initial Backfill – The material placed over the pipe itself to a height of 6 to 12 inch (150mm – 300mm) above the top of the pipe is the initial backfill. The maximum size of stone in the initial backfill, where not specified, should be 1-1/2 inch (38mm). Where it is not otherwise specified, the initial backfill may consist of the native material in the trench provided it is free from large stones, not frozen, and free of debris or other organic materials. The purpose of the initial backfill is to protect the pipe from the final backfill.
- Final Backfill – The material placed over the initial backfill to the top of the trench is the final backfill. If not otherwise specified the final backfill material may contain stones up to 4 inch (100mm) in diameter and may consist of native material.

When plumbers install water service pipes, the BC Plumbing Code Article 2.3.5.1. covers a simplified version of backfilling of a pipe trench. It states that where piping is installed underground, the backfill shall be:

a. carefully placed and tamped to a height of 300 mm over the top of the pipe, and
b. free of stones, boulders, cinders and frozen earth.

BC Plumbing Code Notes to Part 2, A-2.3.5.1.(1) Backfilling of Pipe Trench states that “stronger pipes may be required in deep fill or under driveways, parking lots, etc., and compaction for the full depth of the trench may be necessary”. The Note also includes a figure similar to the one below, which shows details of the bedding and backfilling of pipe trenches.

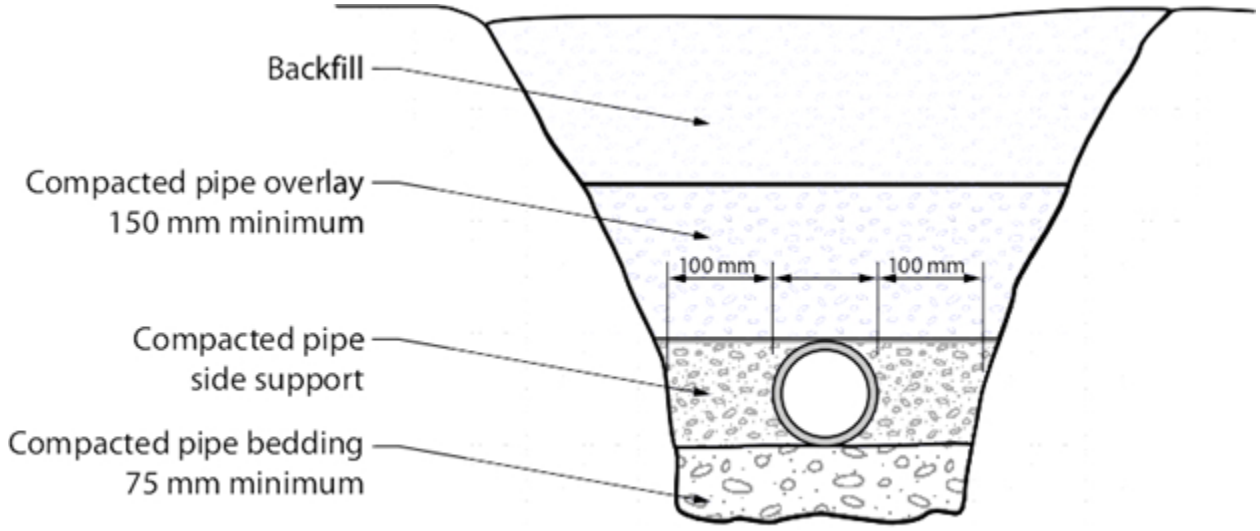



*Figure 20 Backfilling a trench [Book: Piping Trades Apprenticeship Program L1 D-1: Install Pipe Publisher: Open School BC]*

## Freeze Protection

The BC Plumbing Code Article 2.3.5.4., Protection Against Freezing, simply states “Where piping may be exposed to freezing conditions, it shall be protected from the effects of freezing.” The Notes to Part 2, A-2.3.5.4. indicate that the TIAC “Mechanical Insulation Best Practices Guide” is a comprehensive source of information on the selection, installation and proper use of thermal insulation materials. (Note that Section 4 of this Guide is not included in the scope of this Note as it contains information on proprietary products, which are not within the mandate of the Code.)

It is understood that exposure of piping systems to freezing conditions will cause water to freeze. The expansion of the water as it freezes can rupture the pipe. When the water thaws, the resulting damage can be extensive. In the context of the underground water service pipes that are installed by plumbers, installing the piping below the frost line, or insulating and heat tracing, are proven methods to prevent the water in pipes from freezing. These methods, along with frost boxes, will also work for the piping that gets exposed in the water meter box, if the water meter is installed close to grade at the property line.

The plumber Level One textbook, Line D, has a significant amount of content covering freeze protection.

## Corrosion Control

The BC Plumbing Code Notes to Part 2, A-2.6.3.1. has some good content on water quality and corrosion control.

> "Water destined for use as potable water can originate from a variety of sources that are generally classified as surface waters or well waters, such as lakes, rivers, streams and aquifers. In some localities, there may be seasonal variations in the water supply, and surface and well waters may be blended at times.
>
> Water composition is the primary consideration in determining the cause of corrosion in potable water systems. If the water has corrosive characteristics, water treatment may be necessary to control its corrosiveness: this may be as straightforward as adjusting the pH of the water at the treatment plant, or it may involve more extensive corrosion-control treatment methods. Water purveyors normally consult treatment specialists to develop methods suitable for specific conditions. The treatment of water from private wells may also require expert consultation.
>
> The past performance of plumbing materials and products in different localities often provides insight into what can be expected with new installations. In areas where water-related corrosion is known to occur, adjustment of water chemistry may be sufficient or it may be necessary to select alternative piping and fitting materials or more robust products.
>
> It is important to note that not all corrosion can be attributed to water conditions: the improper design and installation of potable water systems may result in erosion corrosion, galvanic corrosion, fatigue cracking, and so forth."

Water purveyors will make decisions on material selection based on the water quality and soil conditions in their jurisdiction. Common piping materials are ductile-iron, PVC, and HDPE, but fittings can be made from brass, stainless steel, and copper, among others. Water chemistry and velocity can cause erosion-corrosion as well as galvanic corrosion on the pipe inner wall, while dissimilar metals and soil conditions can case corrosion of the pipe outer walls.

In some jurisdictions, the ductile iron can be wrapped in a polyethylene sleeve. The sleeve of polyethylene completely wraps the pipe and the bell of any joints. The sleeve inhibits galvanic corrosion by physically separating the pipe from the surrounding soils.

PVC pipe is unaffected by electrolytic or galvanic corrosion, or any known corrosive soil or water condition. Tuberculation on the inner pipe wall is also not a concern, or the need for lining, wrapping, coating, or cathodic protection for the outer wall.

## Testing and Disinfection

Testing and disinfection of potable water supply piping will be covered in the plumber level 4 content.

Now complete Self-Test 3 and check your answers.

# Self-Test 3

Self-Test 3

1. How can ductile-iron pipe and fittings be joined?
    a. Push-on joints only
    b. Mechanical joints only
    c. Push-on and mechanical joints
    d. Push-on, mechanical joints and flanged joints
2. A push-on type joint uses a gasket that is installed in the spigot pipe end.
    a. True
    b. False
3. What methods are used to resist damage to underground piping from thrust forces?
    a. Internal joint restraint only
    b. External joint restraint only
    c. Thrust blocks and thrust anchors only
    d. Thrust blocks, thrust anchors, and joint restraint
4. When must PVC pipe be bevelled to match factory specifications?
    a. For push-on joints only
    b. For mechanical joints only
    c. For push-on and mechanical joints
    d. For push-on, mechanical, and flanged joints
5. Using the tables in LT3, calculate the required thrust block area for the following specifications:
    - 10″ – 90° Elbow
    - 120 Psi Working Pressure
    - Bedded in Sand

    Answer = _____$ft^2$
6. Using the tables in LT3, calculate the required thrust block area for the following specifications:
    - 12″ – Tee
    - 90 Psi Working Pressure
    - Bedded in Sand and Gravel cemented with Clay

Answer = _____ $ft^2$

7. Using the tables in LT3, calculate the required thrust block area for the following specifications:
    - 36″ – 45° Elbow
    - 110 Psi Working Pressure
    - Bedded in Sand and Gravel

    Answer = _____ $ft^2$
8. Using the tables in LT3, calculate the required thrust block area for the following specifications:
    - 24″ – 90° Elbow
    - 160 Psi Working Pressure
    - Bedded in Sand and Gravel

    Answer = _____ $ft^2$
9. Using the tables in LT3, calculate the required thrust block area for the following specifications:
    - 14″ – Tee
    - 100 Psi Working Pressure
    - Bedded in Soft Clay

    Answer = _____ $ft^2$

Check your answers using the Self-Test Answer Keys in Appendix 1.

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# Competency B2: Install Potable Water Distribution Systems

The building water service pipe and the building water distribution system make up the building water supply system. This competency will cover the design, sizing and installation of the building water supply system.

Learning Objectives

After completing the learning tasks in this Competency, you will be able to:

- Interpret the National Plumbing Code (NPC) Section 6, potable water systems;
- Describe the building potable water supply system;
- Size pipe for potable water service and distribution systems; and
- Describe the installation of piping for potable water service and distribution systems.

## Resources

You will be required to reference the most current British Columbia Plumbing Code.

# Learning Task 1

## Describe the Building Water Supply System

The plumber is responsible for the installation of the piping that delivers water to a building, distributes water to various plumbing fixtures, and installing specialized systems related to the building water supply.

The term building water supply system was used in Competency B1 to differentiate the water distribution system downstream of the curb stop from the system upstream of the curb stop. The term comprises the water service pipe and the building distribution system. Plumbers are involved in the design and installation of this part of the system.

The building water distribution piping may supply a simple residential system, or it may supply a complex industrial, commercial, or institutional (ICI) system. The content in this Competency will cover the installation of the pipes, fittings, valves and appurtenances that make up both residential and ICI distribution systems, as well as describe several specialized systems and specialized components that are commonly included as part of a building water distribution system.

## Terminology

Many of the terms that apply to a water supply system were defined in Competency B1.

Figure 1 can be used to identify components that are used specifically in the building water supply system and are defined in this terminology section.

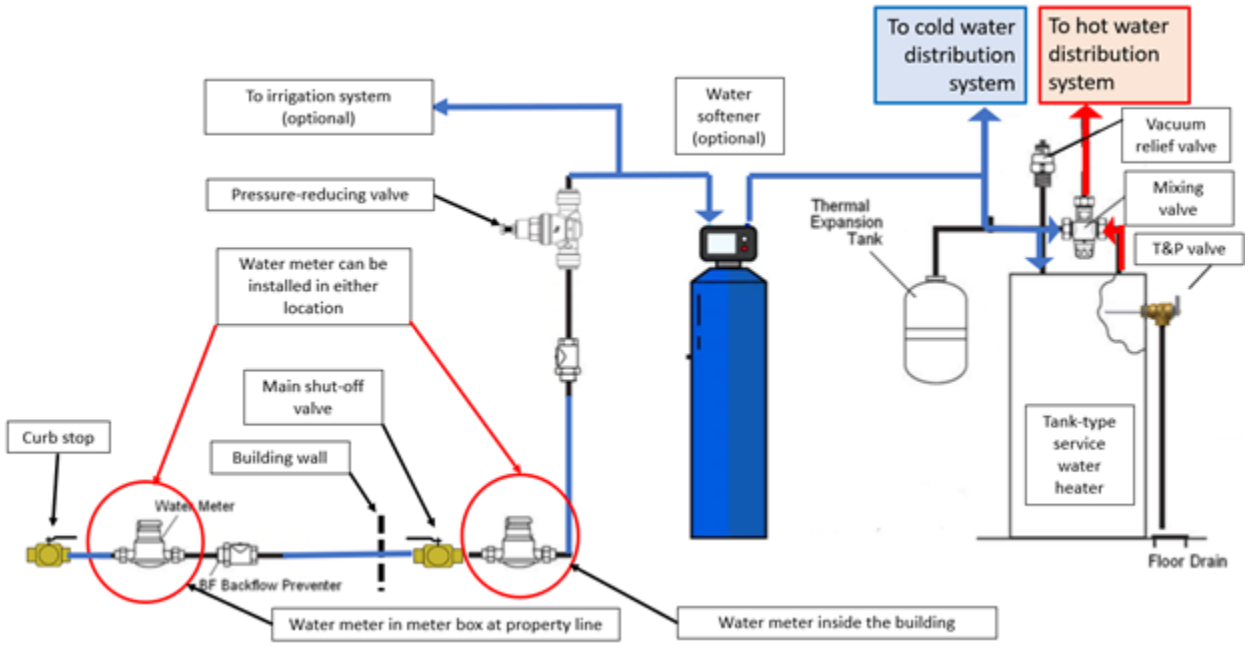



*Figure 1 Simplified residential water supply system*

## Backflow Preventer

The BC Plumbing Code defines a backflow preventer as a device or a method that prevents backflow. Check valves are commonly used in backflow preventer assemblies and are considered nonreturn valves.

## Building Water Distribution System

The BC Plumbing Code defines the term “water distribution system” as an assembly of pipes, fittings, valves and appurtenances that conveys water from the water service pipe or private water supply system to water supply outlets, fixtures, appliances and devices. Although the BC Plumbing Code implies that a water distribution system is the piping and components downstream of the curb stop, the term “distribution system” also gets used to describe parts of the municipal water supply system that is upstream of the curb stop. For the purposes of this competency, the term “building water distribution system” will be used to define the water distribution system inside the building. It includes the service hot water heater and hot and cold water piping.

## Domestic Purposes

This term means the use of water for human consumption, food preparation or sanitation.

## Hose Bibb

A hose bibb is a valve installed on the end of a water distribution pipe that terminates outside of the building envelope. Hose bibbs typically have a mounting flange and external threads to attach a garden hose. A sediment faucet also has external garden hose threads, but does not have a mounting flange for

attachment to the building exterior finish. Sediment faucets are typically used for interior applications, such as water heater drains and boiler drains, but can be used as hose bibbs.

### Governing Fixture

The fixture or device connected to a building water distribution system that requires more pressure than the others to operate correctly.

### Service Water Heater

The BC Plumbing Code defines this term as a device for heating water for plumbing services.

### Water Service Pipe

The BC Plumbing Code defines this term as a pipe that conveys water from a public water main or private water source to the inside of the building.

### Water Meter

A water meter is a device used to measure the volume of water that passes through a water service.

## The Water Service Pipe

The building water service pipe is the most upstream part of the building water supply system. The BC Plumbing Code (BCPC) defines the water service as a pipe that conveys water from a public water main or private water source to the inside of the building. The water service pipe that is part of a private water source will be covered in the plumber Level 4 content. The water service pipe connection to a public water main was covered in the Competency B1 content, as well as the type of piping and fittings used for large (4 inch and larger) ICI water service systems. The content in this section will cover the piping and components that are used for small diameter (sizes less than 4 inches) water service piping and fittings for residential and ICI buildings. Learning Task 3 of this Competency, “Describe the installation of the building water supply system,” will cover the piping and fitting materials for small diameter building water service systems.

### Water Meters

In most urban areas, water is supplied and distributed by a municipal water supply system, which will include a water meter on the water service pipe. A water meter is a device that is installed to accurately measure and record the volume of water passing through the pipe. The end user (consumer) usually must pay for the water they use. To determine the cost of the water that is used, a water meter can be installed in the building water service line so a consumer is billed on the exact flow recorded through the meter. However, some purveyors do not use a water meter; instead, the consumer pays a flat rate. In a flat rate system, the consumer pays a pre-set monthly or yearly charge regardless of the amount of

water used. Studies have shown that purveyors that use a metered service use approximately 40 percent less water per person compared to services that are not metered.

### Water meter locations

Figure 1 shows optional locations for the water meter installation for a simple building water supply system. One optional location is on the building water service pipe immediately downstream of the curb stop. This location would be acceptable only if the Authority Having Jurisdiction (AHJ) determined the depth of the installation would protect against freezing. In British Columbia, many jurisdictions on the south coast allow water meters on residential systems to be installed outside, at the property line. For this type of installation, the water meter would be installed in a meter box, making it accessible from finished grade.

Figure 2 shows a 2-inch water meter, with bypass and V-shaped integral strainer, installed in a meter box at the property line. This installation also incorporates a remote reader option.



*Figure 2 Typical small-diameter outside meter installation*

Installations where the frost depth determines the water service pipe must be buried at a depth that makes it impracticable to use a meter box will usually require that the water meter gets installed inside a heated building. Some jurisdictions will allow a water meter to be installed in a meter pit, which keeps the water service pipe below the frost depth, but brings the water meter up to an accessible depth. These types of installations will require some form of insulation, or alternate freeze protection, to protect the water meter and the associated piping and appurtenances.

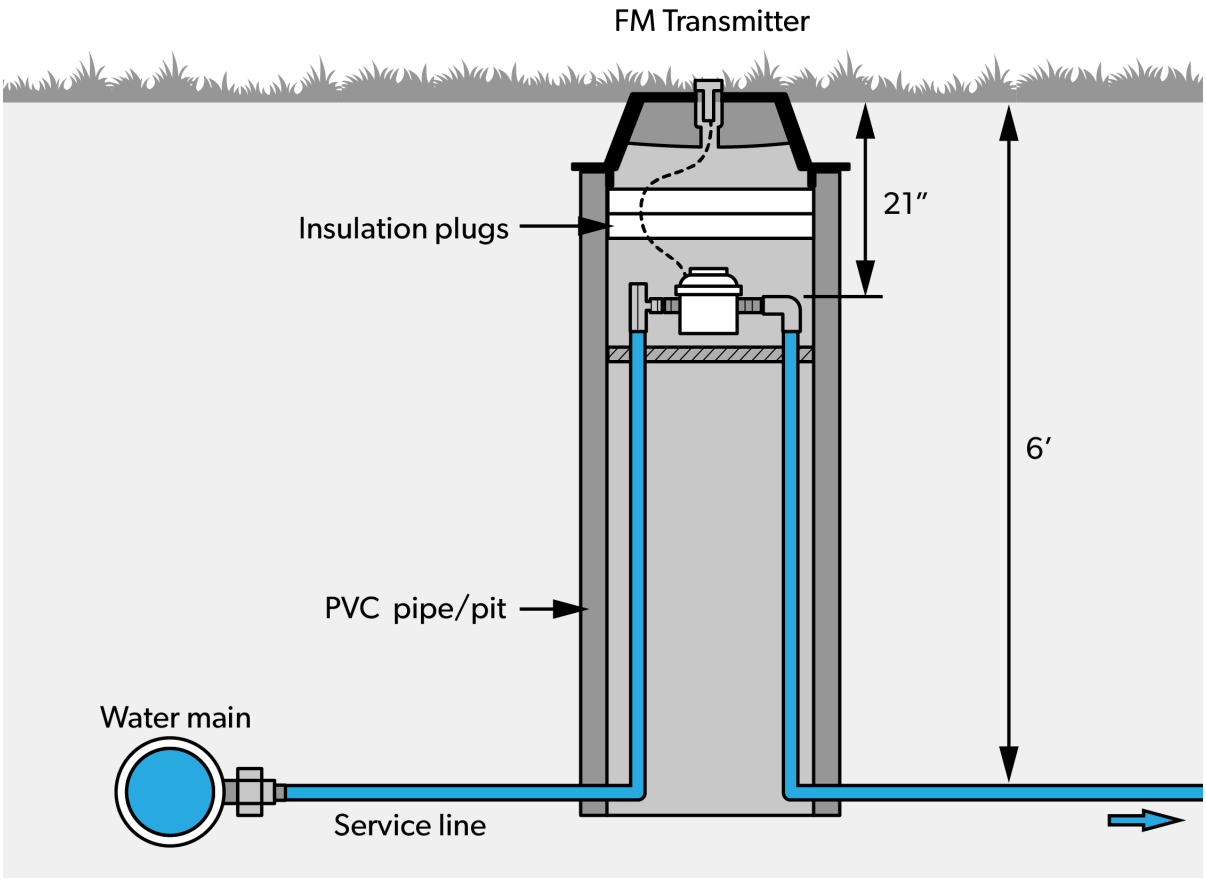



*Figure 3 A water meter installed in a meter pit*

If the curb stop is installed with a water meter in a meter box or meter pit, it is common for the purveyor to use an angle curb stop to allow for easier assembly and disassembly. There are several combinations for piping and tubing sizes and types for the purveyor and plumber to choose from, requiring curb stops to have inlet and outlet connections that match most combinations. Other components may also be required by the purveyor. The use of a backflow preventer is common on municipal water service connections. The backflow preventer can be located in the meter box or meter pit for outside installations, or it can be located adjacent to the water meter for inside installations. Backflow preventers are covered in detail as part of the Cross Connection content in the Block C section of the Level 3 content

The figure below shows an example of an inside installation with a backflow preventer installed downstream of the water meter.

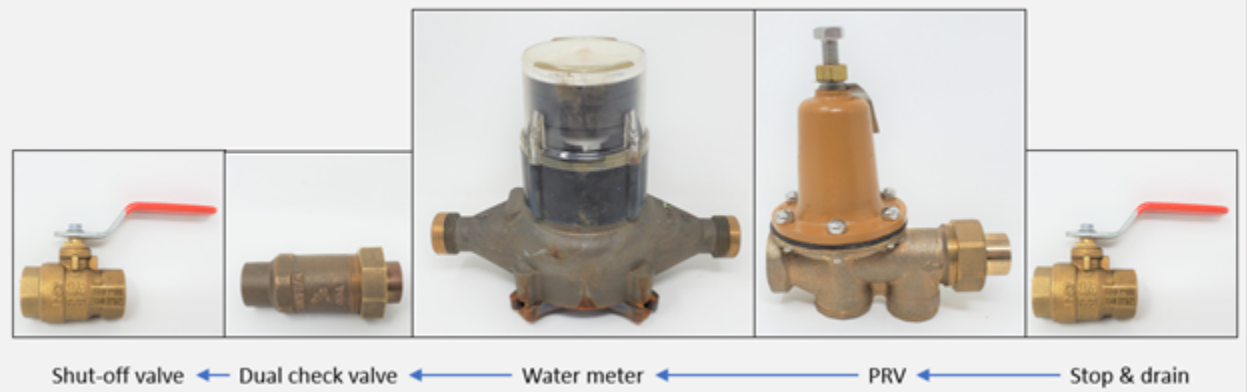



*Figure 4 Possible components used for an inside small-diameter water meter installation*

Water meters are installed in many locations other than on a water service line. In certain ICI applications, the amount of water passing through specific equipment is often recorded. For example, meters may be installed in the water softener supply to large-capacity industrial water softeners in order to determine when regeneration is necessary. Meters may be used to relay signals to control the operation of equipment. In certain ICI processes, chemicals must be added to the water. Generally, this involves adding a predetermined amount of chemical to a predetermined volume of water. A meter can be used to activate a chemical pump or injector each time the predetermined volume of water passes through the meter.

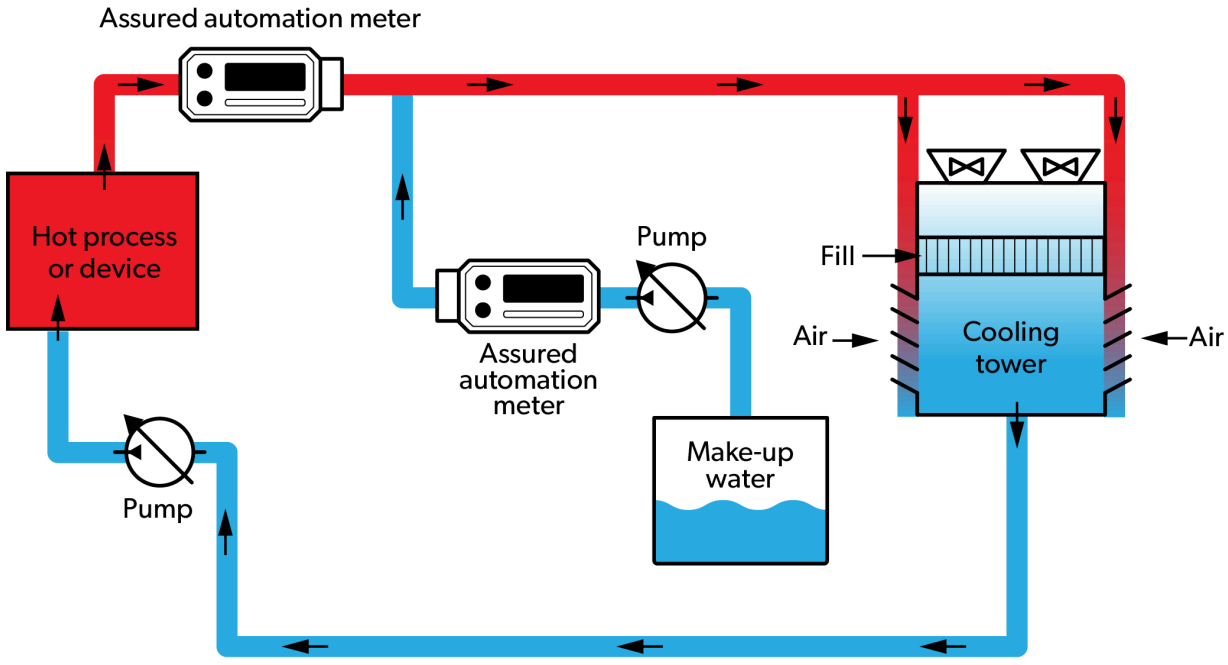



*Figure 5 A drawing with two water meters installed on an industrial system – FROM SHAREPOINT*

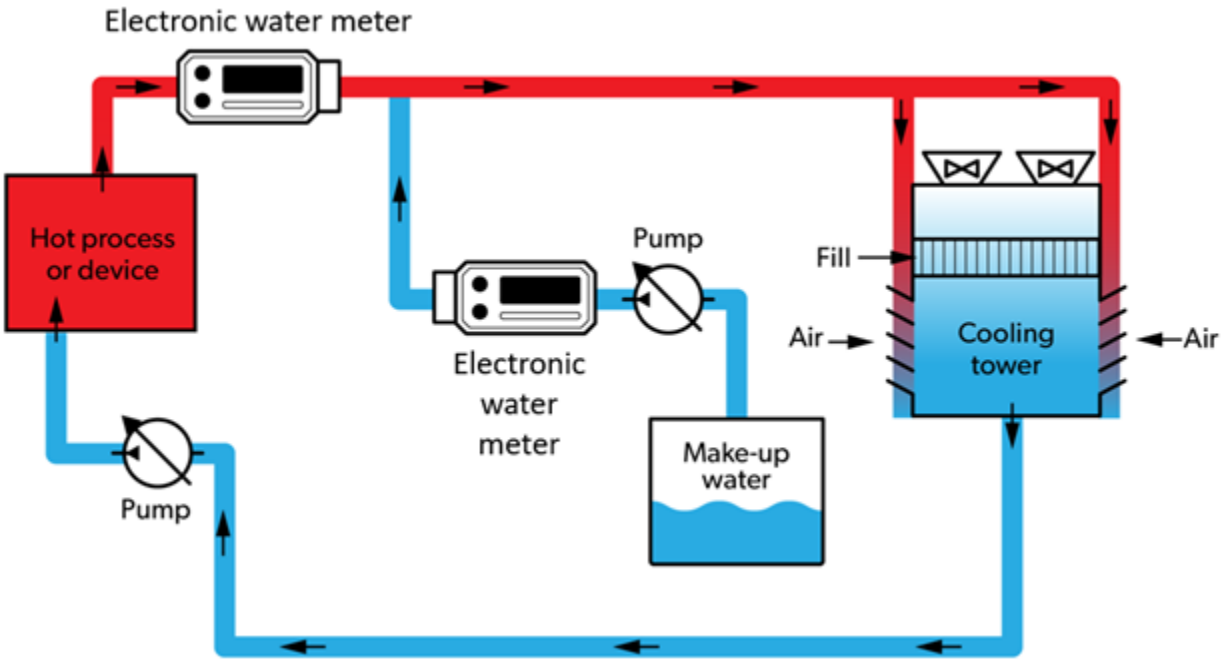



*Figure 5 A drawing with two water meters installed on an industrial system – FROM WORD*

One benefit to having a water meter installed is that it can be used to determine if a leak is occurring, or if there is unauthorized use of water taking place. The small dial on the meter can be used to see if flow is occurring.

The figure below shows the water meter face with a small red dial that rotates whenever flow is occurring.




*Figure 6 Small-diameter water meter face*

**Water meter types**

Meters are available in a variety of sizes and designs. The type of meter chosen for a particular installation generally depends on the size of the service or supply pipe and on the expected flow rate through the meter.

Meters are classified into two basic types: positive displacement and velocity. Each of these meter types has variations, leading to the perception that there are several different kinds. Meters that feature both positive displacement and velocity are known as compound meters. The unit of measurement can be in gallons, or it can be in cubic feet or cubic meters.

Positive displacement meters

In this type of meter, a known volume of liquid in a tiny compartment moves with the flow of water. Positive displacement flow meters operate by repeatedly filling and emptying these compartments. The flow rate is calculated based on the number of times these compartments are filled and emptied. The movement of a disc or piston drives an arrangement of gears that registers and records the volume of liquid exiting the meter. There are two types of positive displacement meters: nutating disc and piston.

***Nutating disc meters***, also called rotating disc meters, have a round disc that is located inside a cylindrical chamber. The disc is mounted on a spindle. The disk nutates, or wobbles, as it passes a known volume of liquid through the cylindrical chamber. The rotating motion of the disk is then transmitted to the register that records the volume of water that went through the meter.

***Piston meters*** have a piston that oscillates back and forth as water flows through the meter. A known volume of water is measured for each rotation, and the motion is transmitted to a register through an arrangement of magnetic drive and gear assembly.

Small diameter water meters with the base or bottom of the meter constructed of cast iron or plastic are installed where freezing might occur. The design contains a weak point that will fracture when freezing water expands, thereby keeping the more expensive parts of the meter from being damaged. This meter is typically available in $\frac{5}{8}''$, $\frac{3}{4}''$ and $1''$ sizes and is used extensively for residential applications.

The figures below show a nutating-disc design on the left and a piston design on the right.

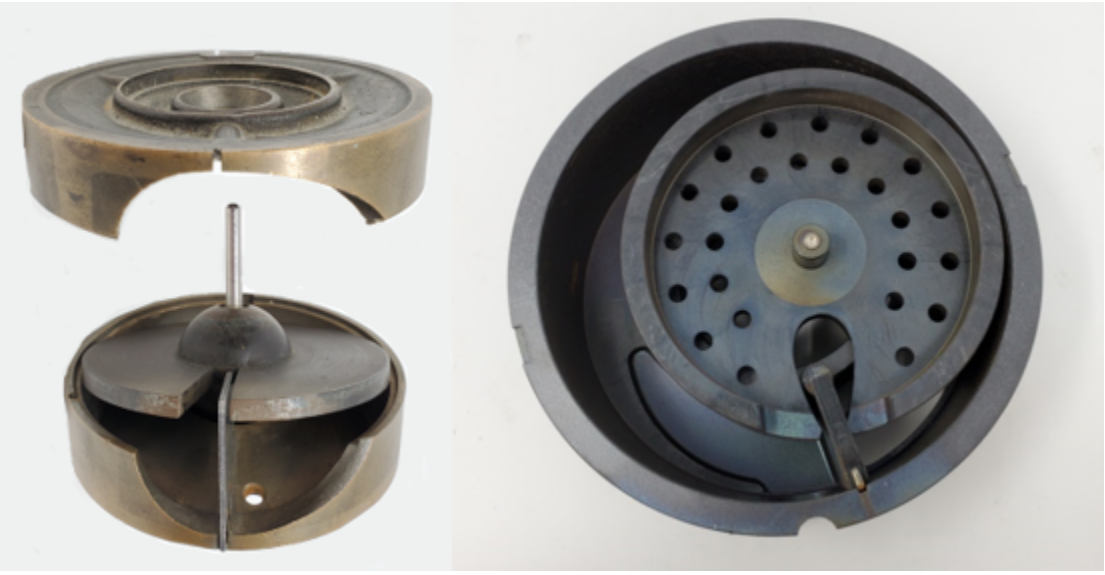


*Figure 7 Internal parts of a nutating disc on the left and a piston water meter on the right*

Positive displacement meters are sensitive to low flow rates and have high accuracy over a wide range of flow rates. These meters are used in homes, small businesses, hotels, and apartment complexes. They are typically available in sizes from $\frac{5}{8}$ inch to 2 inches.

### Velocity meters

Velocity meters operate on the principle that water passing through a known cross-sectional area with a measured velocity can be equated into a volume of flow. Velocity meters are good for high flow applications. Velocity meters come in different types, including magnetic, multi-jet, orifice, propeller, turbine, ultrasonic, venturi. These meters are available in sizes of two inches and larger with the exception of multi-jet meters, which are between $\frac{5}{8}$ inch and 2 inches.

***Magnetic meters*** have an insulated section through which water flows. The flow of water induces an electrical current that is proportional to the velocity and hence the flow rate.

***Multi-jet meters*** have tangential openings in a chamber to direct the water flow across a rotor with many vanes. Flow is measured proportional to the speed of the rotor.

***Orifice meters*** work on the same principle as venturi meters, except that, instead of the decreasing cross-sectional area, there is a circular disk with a concentric hole. Flow rate is calculated similarly to the venturi meter by measuring the difference in pressures.

***Propeller meters*** have a fan-shaped rotor that spins with the flow of water. A recorder is attached to the rotor to register the readings.

***Turbine meters*** have a rotating element that turns with the flow of water. Volume of water is measured by the number of revolutions by the rotor.

***Ultrasonic meters*** send sound waves diagonally across the flow of water in the pipe. Changes in the velocity of water are converted electronically to change in flow rate.

***Venturi meters*** have a section that has a smaller diameter than the pipe on the upstream side. Based on a principle of hydraulics, as water flows through the pipe, its velocity is increased as it flows through a reduced cross-sectional area. Difference in pressure before water enters the smaller diameter section and at the smaller diameter "throat" is measured. The change in pressure is proportional to the square of velocity. Flow rate can be determined by measuring the difference in pressure. Venturi meters are suitable for large pipelines and do not require much maintenance.

#### Compound meters

In some cases, it is necessary to have a combination meter—both a positive displacement meter and velocity meter installed together—to be able to measure high and low flows. Low flows are measured through positive displacement while high flows are measured by velocity. A valve arrangement directs flows into each part of the meter.

### Water meter installation

As discussed previously, it is common to have a meter installed inside a heated building or, alternatively, the meter can be installed in a meter box outside. Although not always possible because of the requirement of freeze protection, it is better to have the meter located at the curb or property line because of easy access for reading or maintenance. It is sometimes difficult to gain access to the residence or building when no one is there. If not installed inside a heated building, large meters are usually installed in underground concrete or block vaults, preferably out of traffic areas. If the meter is installed in a vault (large meter pit), the vault should have a drain, or a sump pump if a drain is not possible. There should never be standing water in the vault.

The water service pipe may not have any outlets placed upstream of the meter location, other than meter bypass arrangements or fire protection system connections. This is to ensure all water used for consumption is accounted for. Also, there is less possibility of unauthorized use of water, a situation termed "theft of services." To prevent disruption of service when replacing or repairing large meters, there should be a bypass that can also be metered. The minimum size of water service that is permitted to have a bypass arrangement around the meter is typically 1½ inch (approximately 40mm). The bypass must include a shut off valve that will be sealed by the water purveyor by applying strong wire around the pipe and through the valve handle.

Having the bypass metered would be similar to a manifold set-up where you have two or more meters in parallel, making service of one meter easy without service disruption or lost revenue. Large meter installations should have good structural support to prevent stress on the water line. Also, there should be at least ten times the pipe diameter of straight pipe before the meter and five times the pipe diameter of straight pipe after the meter. Some large meters recommend or require a strainer to be installed ahead of the meter.

Remember: if anyone has to enter the meter vault or large pit, this is considered a confined space entry and the proper safety procedures must be followed.

Small meter installation is easier with a meter yoke (also known as a meter setter). Meter yokes have

different configurations and can have any combination of built-in check valves, regulators, and lockable shutoff valves. Utilities should have their own set specifications with illustrations depicting proper meter installations.

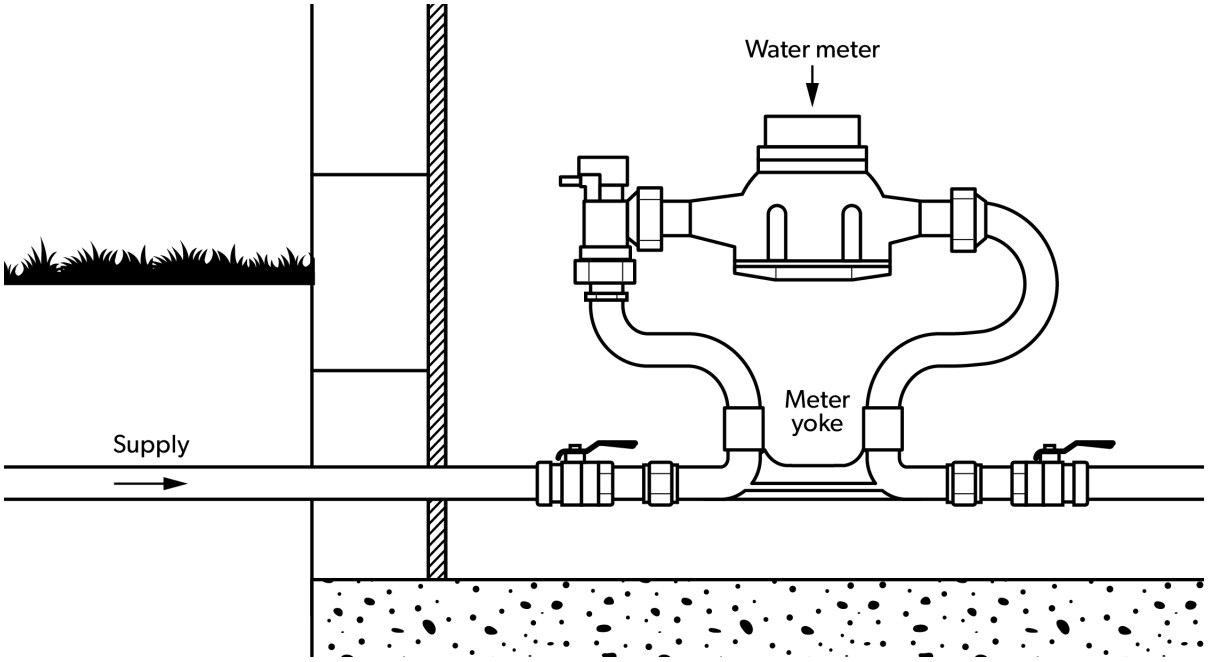



*Figure 8 A small-diameter residential meter installed inside the building using a meter yoke*

On all indoor settings, it is very important that electrical continuity be maintained through the waterline. Most utilities require electrical bonding around meters to prevent accidental electrocution of service personnel changing meters. If the meter setting itself does not provide a continuous electrical circuit when the meter is removed, a permanently bonded electrical grounding strap should be provided. Electrical grounding is a requirement specified by the Canadian Electrical Code and all service and installation personnel should be advised of this safety requirement. Most commercially available prepared meter settings provide a continuous metallic circuit, even when the meter is removed from the line.

## The Building Water Distribution System

The building water distribution system can be broken into two categories: the cold water distribution system and the hot water distribution system. The design of these systems varies depending on the type of building, size of piping required, and the designer’s preference for piping materials and layouts.

For example, industrial, commercial, and institutional buildings will require more complex water distribution piping arrangements than a single family dwelling. The designer will need to think about pipe sizes while making decisions about materials and layouts. Although any pipe that is listed on the BC Plumbing Code Tables A-2.2.5., 2.2.6. and 2.2.7. under the potable water system above-ground column can be used, smaller diameter piping is typically installed using PEX and copper, while larger diameter piping is typically PVC, CPVC, stainless steel, or polypropylene.

## Water Distribution System Layouts

The designs of cold and hot water distribution systems can be quite complex, so some unique terminology is used to help identify different pipes in the system. Some terms are defined in the BC Plumbing Code, but others are colloquialisms of the trade.

### Terminology

#### Main

This term is not defined in the BC Plumbing Code but shows up in the Notes to Part 2 at A-2.6.3.2.(4) and is commonly used by plumbers in the field to describe a larger diameter pipe that supplies several “branches.” The term “trunk” is used by other codes in North America to help identify the “main” pipe in a water distribution system.

#### Branch

This term is not used in the BC Plumbing Code, but is commonly used by plumbers in the field to describe a pipe that connects to a “main” at the upstream end, and more than one fixture supply pipe on the downstream end.

#### Fixture supply pipe

This term describes a pipe installed between a fixture and another building water distribution pipe. Although not a defined term in the BC plumbing Code, Table 2.6.3.2.-A uses the term “supply pipe” with the term “fixture,” implying a fixture supply pipe.

#### Riser

The BC Plumbing Code defines “riser” as a water distribution pipe that extends through at least one full storey. A riser is part of a building water distribution system.

### Branch system layout

The branch system layout uses a “main” and “branches”. The main (sometimes called a trunk) is the largest diameter at the upstream end and gets smaller as each branch is connected. This layout is very common for residential and ICI installations using rigid piping materials like copper, PVC, CPVC, stainless steel, and polypropylene. The branch system layout can be used on both cold and hot water distribution systems.

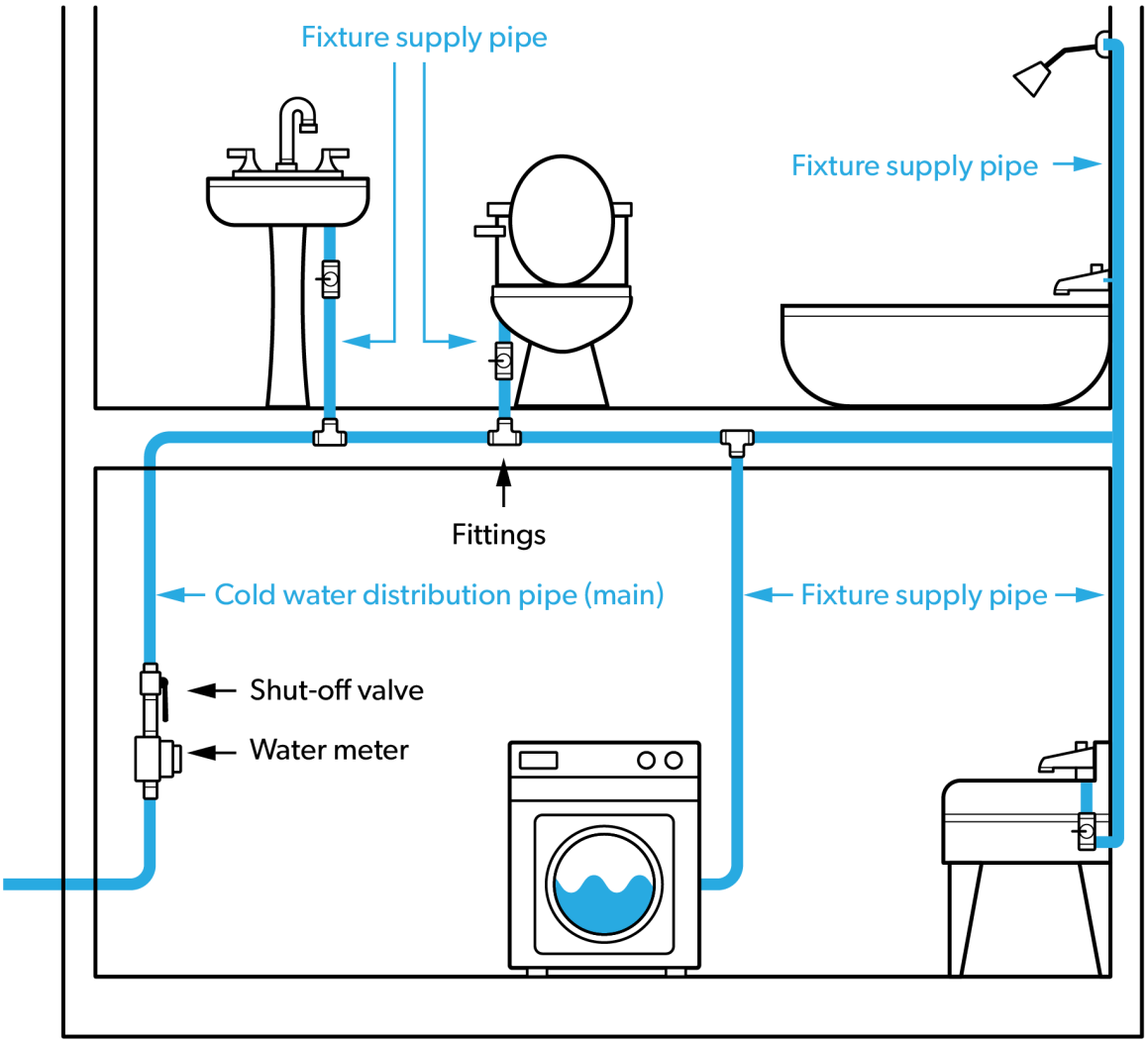



*Figure 9 A simple branch system layout for a cold water residential installation*

**Home-run manifold system layout**

The home-run manifold layout is commonly used for residential installations, and can be used on both cold and hot water distribution systems. In this layout, all fixtures are supplied with smaller diameter pipe that is run from the manifold to each fixture. The hot water manifold should be located in close proximity to the hot water source to ensure fast and efficient delivery.

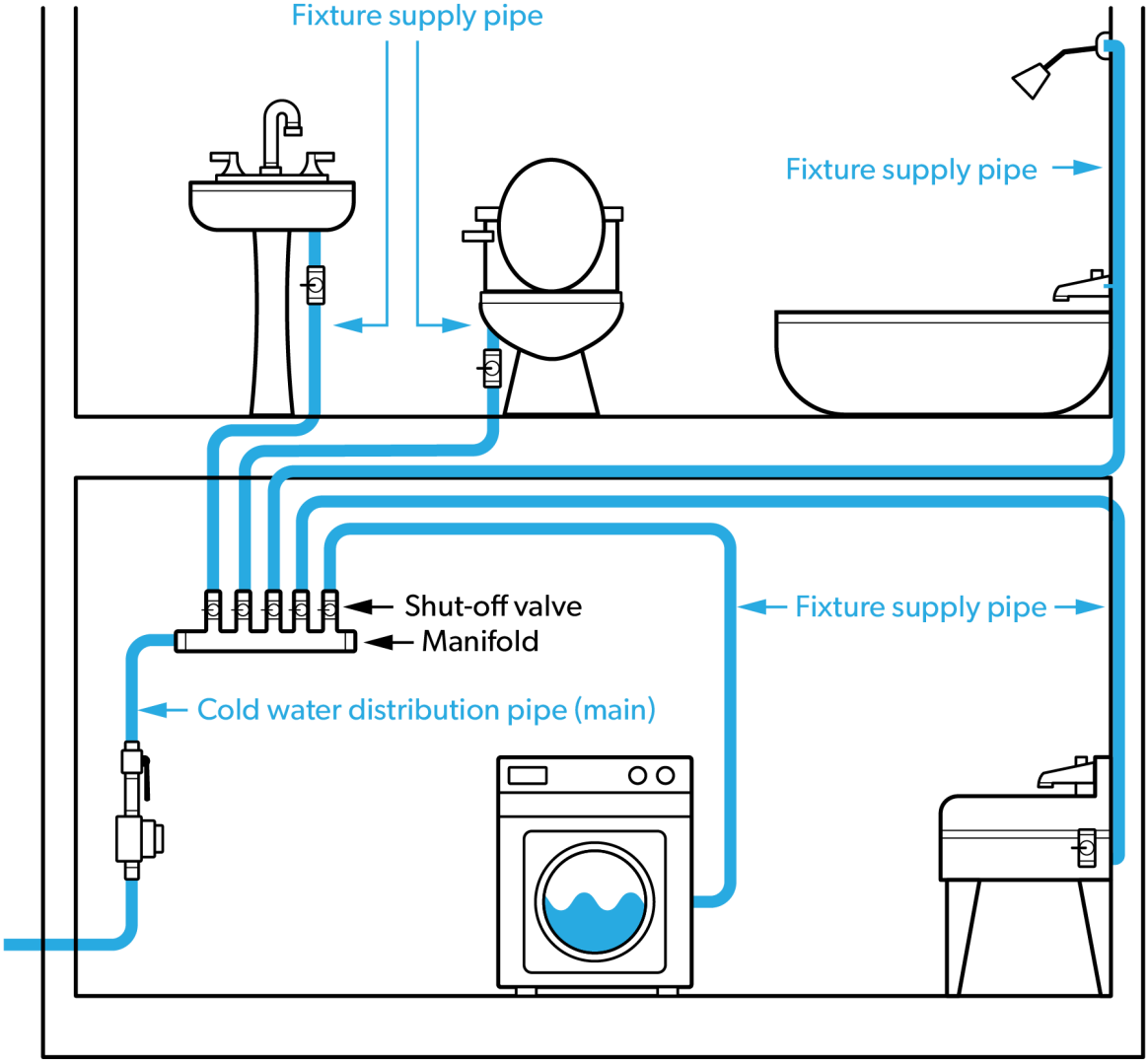



*Figure 10 A simple home-run manifold system layout for a cold water residential installation*

**Combination system layout**

This layout combines properties of the branch system layout with properties of the home-run manifold system layout. Sometimes called the sub-manifold layout, or remote-manifold layout, this design is commonly used in apartment buildings, condominium buildings, and similar buildings that incorporate groups of fixtures. The combination system layout can be used on both cold and hot water distribution systems.

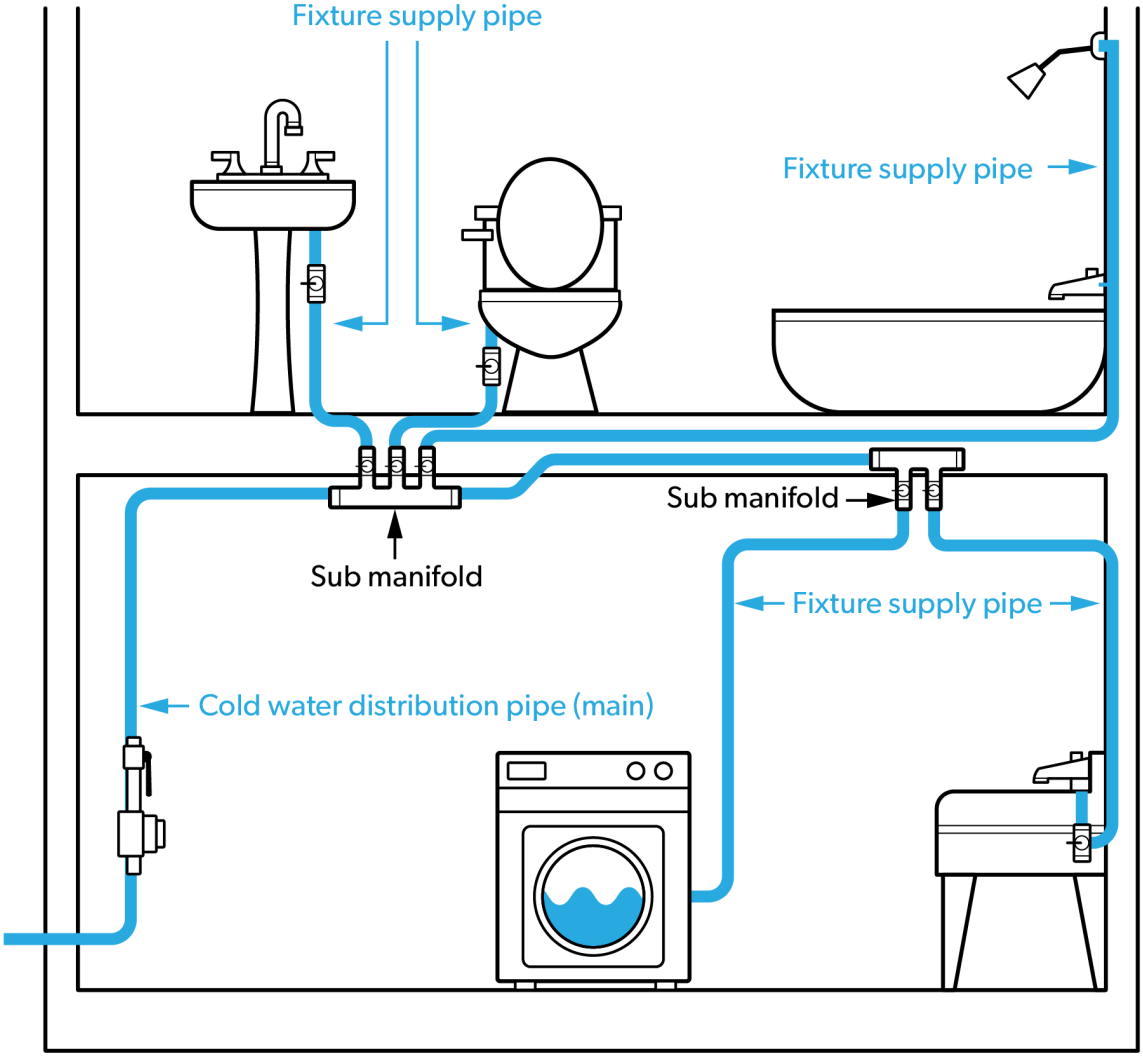



*Figure 11 A simple combination system layout for a cold water residential installation*

**Water distribution systems for tall buildings**

Tall buildings, where the height of the building prevents the municipal water from reaching the top floors, require different piping designs and additional components to ensure every fixture has enough water pressure to operate properly. For example, a water service pressure of 80 psi should theoretically be sufficient for an 18 storey building, but there must be sufficient surplus pressure to overcome resistance in riser pipes, as well as approximately 15 psi (105 kPa) to operate most fixtures.

Upfeed booster systems and downfeed booster systems use a pump, or pumps, to boost the pressure of the building's service pressure. An upfeed booster system uses the additional pressure in the risers to overcome the height, the resistance in the piping, and ensure adequate pressure for the governing fixture on the top storey. This design will usually increase the pressure at lower storeys over the maximum allowable by the BC Plumbing Code. To reduce the pressure at the lower floors, pressure-reducing valves are used on the branches at each storey.

Downfeed booster systems use a pump, or pumps, to boost the pressure of the building's service pressure and then use this additional pressure to deliver potable water to the roof, or the top storey of the building. Some systems use a storage tank, or tanks, on the roof to create head pressure in the downfeed piping supplying each storey. This design could also increase the pressure at lower storeys over the maximum allowable by the BC Plumbing Code. To reduce the pressure at the lower floors, pressure-reducing valves are used on the branches at each storey.

The figure below shows a simplified downfeed booster system on the left and a simplified upfeed booster system on the right.

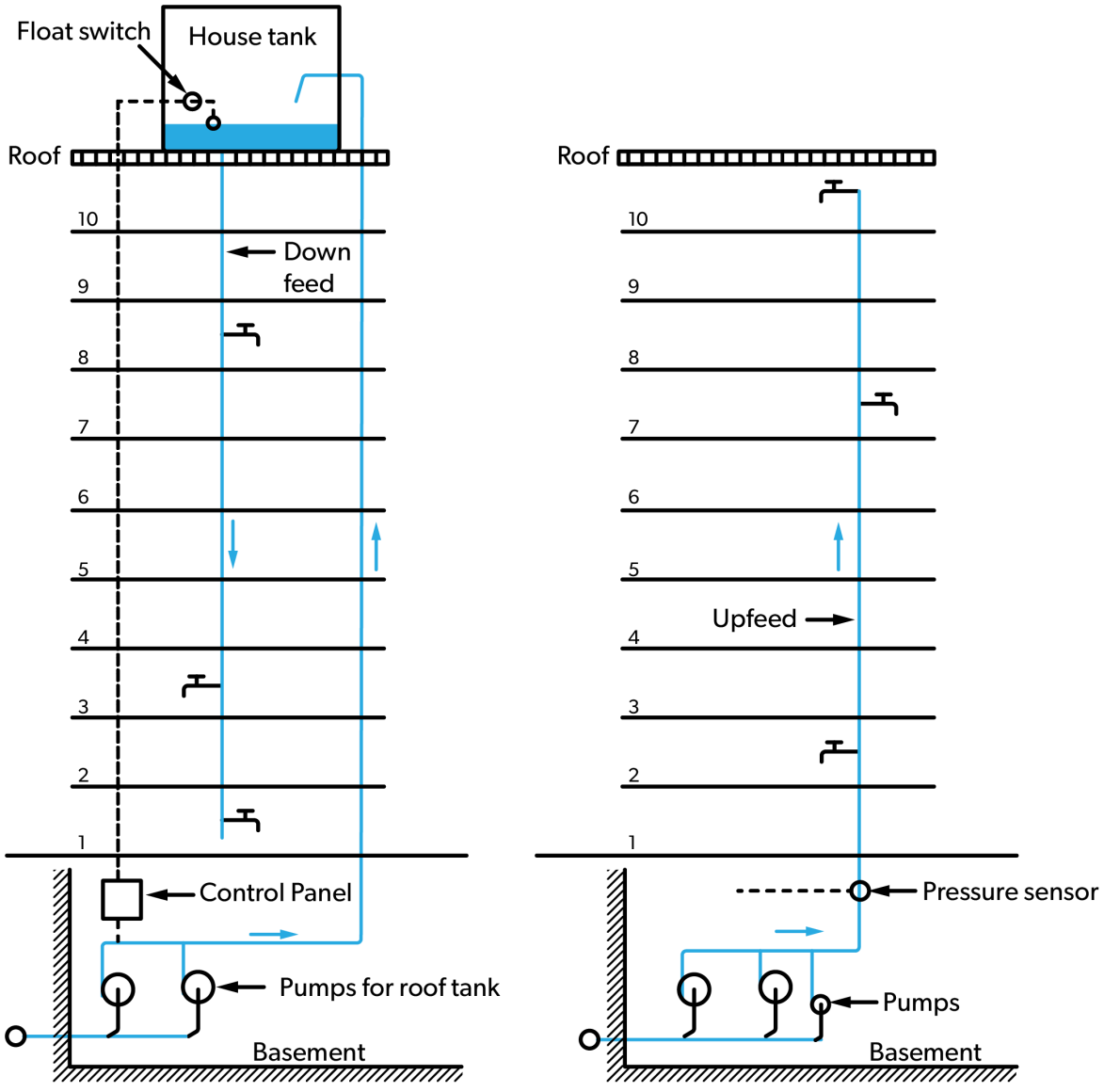



*Figure 12 Simplified downfeed and upfeed examples*

There are variations of both the downfeed and upfeed systems. One variation of the upfeed system, shown in the figure below, would use , where separate pumps are used for different storeys. This design would eliminate the need for pressure-reducing valves but adds complexity to the system.

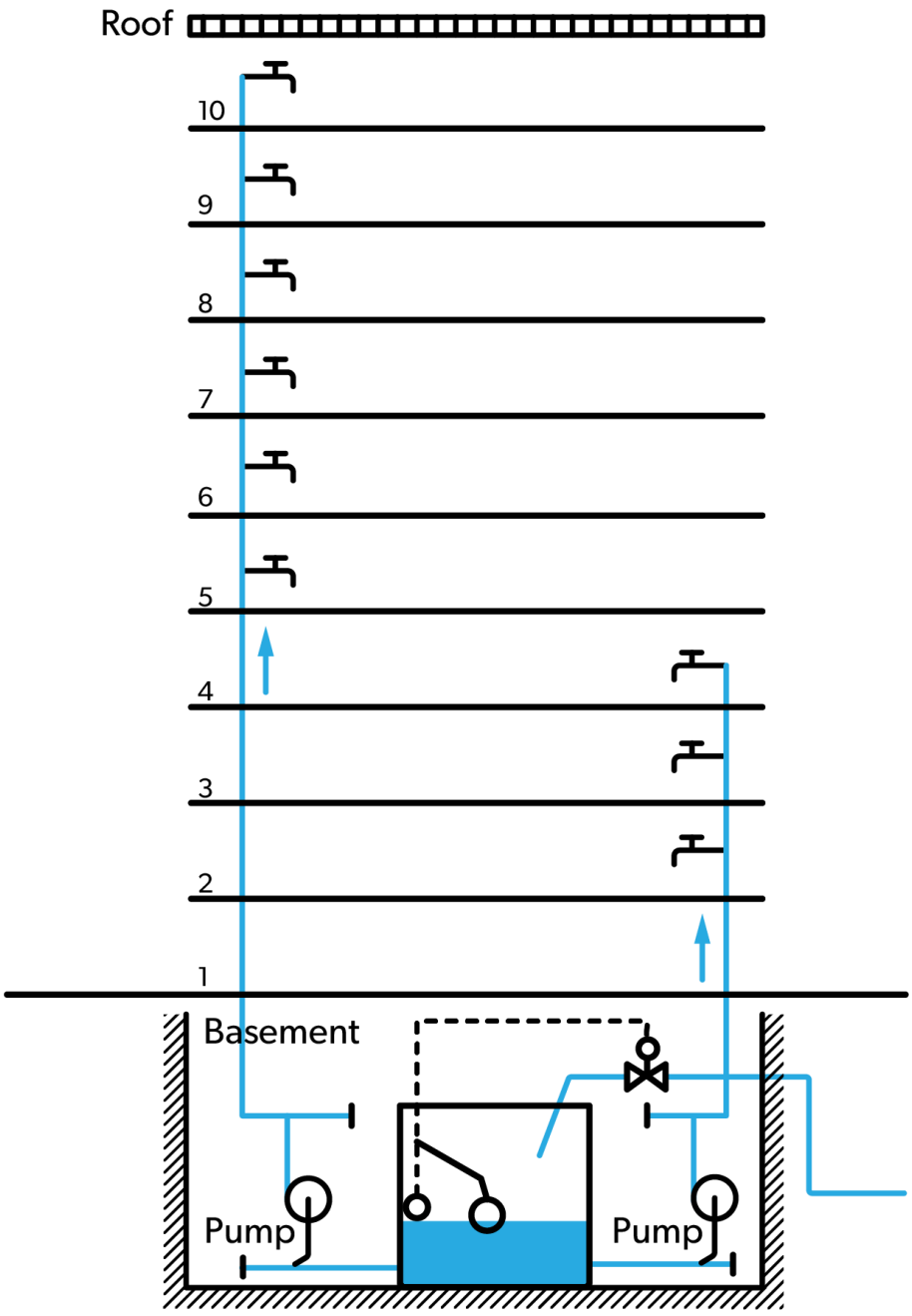



*Figure 13 One variation of the upfeed booster system design using 2 separate pumps*

There are also combination booster designs where the lower part of the building is supplied by the water service pressure, and the storeys above are supplied by a downfeed system.

The variety of water distribution system designs means there are many different components and equipment that could be installed by plumbers as part of cold and hot water distribution systems. Many of these components and equipment are covered below.

## Cold Water Building Distribution System

The cold water distribution system begins where the water service pipe ends. In systems where the water meter is outside, the water service ends once the pipe has entered the building. Since the BC Plumbing Code Sentence 2.6.1.3.(1) requires a shut-off valve located as close as possible to where the water service pipe enters the building, the shut-off valve usually indicates the start of the cold water distribution system. If the water meter is installed inside the building, the cold water distribution system would start immediately downstream of the meter location.

#### Components and equipment

The cold water distribution system incorporates many different types of pipes, fittings, valves, equipment and appurtenances. The BC Plumbing Code prescribes the use of specific materials in some circumstances, but the plumber has a lot of flexibility in selecting most of the other components and equipment that makes up the system. The cold water distribution system can include several unique systems and devices, such as:

- Main shut-off valve
- Fire sprinkler system
- Pressure reducing valve
- Backflow preventer
- Irrigation system
- Exterior hose bibbs
- Water treatment

Some of these components and system connection points are shown on Figure 1, and all of them are covered in the content below.

##### Main shut-off valve

The BC Plumbing Code Sentence 2.6.1.3.(1) requires that water service pipes shall be provided with an accessible shut-off valve located as close as possible to where the water service pipe enters the building. This valve is referred to as the main shut-off and is positioned so it will stop the flow of water to all of the building water distribution system in the event of an emergency. The BC Plumbing Code Sentence 2.6.1.2.(1) also states that a water distribution system shall be installed so that the system can be drained or blown out with air. These two Sentences in the BC Plumbing Code combine to mean that a stop-and-drain (also called a stop-and-waste) shut-off valve is usually installed on the residential water service pipe.

A 1 inch (25 mm) water service is permitted to have a stop-and-drain valve as the shut off valve for the building. When the water service pipe size increases to 1-1/4 inch (approximately 32mm), the shut off valve for the building must be a shut off valve only. A separate drain valve is placed downstream of the meter to allow the meter set and building distribution system to be drained. Any faucets or equipment that are placed on the building distribution system to allow the system to function properly must be accessible for servicing or repair of the components. Accessibility must be considered in system design

to minimize disruption of the living space. As the building distribution system is installed, it may be necessary to place portions of the pipe under beams, air ducts or other obstructions. Any low points in the building distribution system that do not drain by gravity should include drain valves as part of the low point piping.

*Residential combined (multipurpose) fire sprinkler systems*

These systems integrate with the cold water distribution system, with the sprinklers fed off of the same water source as the other fixtures in the home. Because they use the same pipes and fewer fittings and connections, the installation costs and complexity tend to be less with combined systems. Combined systems may not be an option for homeowners who are looking to retrofit sprinklers into their house, as these systems require carefully planned hydraulic calculations that account for water pressure, the size of the system, and even the diameter of piping needed to meet specific flow requirements.

Two types of combined fire sprinkler systems are defined in the BC Plumbing Code.

- Residential full flow-through fire sprinkler/standpipe system means an assembly of pipes and fittings installed in a one- or two-family dwelling that conveys water from the water service pipe to the sprinkler/standpipe system's outlets and is fully integrated into the potable water system to ensure a regular flow of water through all parts of both systems.
- Residential partial flow-through fire sprinkler/standpipe system means an assembly of pipes and fittings installed in a one- or two-family dwelling that conveys water from the water service pipe to the sprinkler/standpipe system's outlets and in which flow, during inactive periods of the sprinkler/standpipe system, occurs only through the main header to the water closet located at the farthest point of the two systems.

For combined, multipurpose systems, a water meter is used. This means the designer must include the water meter in the hydraulic calculations when sizing the system.

*Residential standalone fire sprinkler systems*

This design uses a network of piping that is separate from the piping used in the water distribution system. Both the standalone sprinkler and building water supply systems can draw from the same water supply, or a standalone system can draw from its own supply, such as a dedicated water tank. If the standalone system uses the same water supply as the building, it is generally connected upstream of the water meter. The National Fire Protection Association (NFPA) Standard 13D is referenced in the BC Building Code as the standard for installation of sprinkler systems in one- and two-family dwellings and manufactured homes. The NFPA 13D standard recommends that a water meter not be installed on the sprinkler line because the meter could produce friction or blockage or reduce water pressure.

In jurisdictions that require meters on standalone systems, the meter is placed before the tee between the domestic and sprinkler lines. In these cases, the meter must be included in the hydraulic calculations for the sprinkler system.

If the residential standalone system design incorporates fewer than nine sprinklers, the BC Building Code Sentence 3.2.5.12.(4) allows the water supply for these sprinklers to be supplied from the domestic water system for the building provided the required flow for the sprinklers can be met by the

domestic system. This means the plumber would not have to allow for the fixture unit load when calculating the water service pipe size.

There are two classes of fire sprinkler systems used for residential applications:

- Class 1 Fire sprinkler/standpipe system means an assembly of pipe and fittings that conveys water from the water service pipe to the fire system outlets that has direct connections only from public water mains and has no pumps, tanks, or reservoirs and all sprinkler drains discharging to atmosphere, dry wells or other safe outlets.
- Class 2 Fire sprinkler/standpipe system means an assembly of pipe and fittings that conveys water from the water service pipe to the fire system outlets that is the same as a Class 1 Fire sprinkler/standpipe system and that also includes a booster pump in the connection from the street mains.

The figure below shows the preferred connection method for a standalone residential fire sprinkler system using the building water service pipe as the supply.

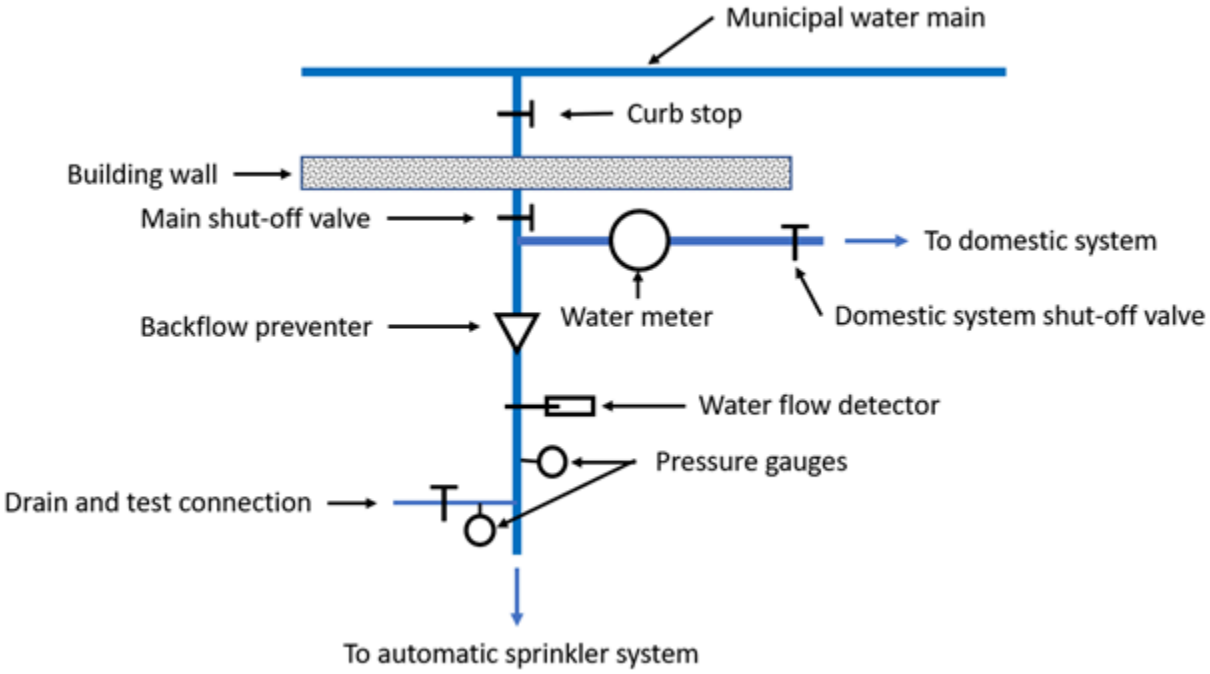



*Figure 14 Plan view of the recommended connection method for a standalone residential fire sprinkler system*

Pressure-reducing valves

As mentioned in Competency B1, pressure-reducing valves are used for many plumbing system applications in both residential and ICI applications. PRVs installed in buildings are used reduce high municipal main pressure to an acceptable operating range for use in the water distribution system. The BCPC Article 2.6.3.3 states that where the static pressure at any fixture may exceed 550 kPa, a pressure-reducing valve shall be installed to limit the maximum static pressure at the fixture to 550 kPa.

### Backflow preventer

A backflow preventer is typically found on a water supply service to a building, as well as in many locations inside buildings on the water distribution system.

As mentioned in Competency B1, cross connection control and backflow prevention devices are covered in detail in Block C section of the Level 3 content.

### Hose bibbs

All buildings need water supplied to the outdoors for many reasons. These exterior, or outdoor, hose bibbs are commonly referred to as wall hydrants and have been traditionally supplied by only cold water. Since any exterior water supply must be protected, the BCPC Article 2.6.1.4. allows two methods of installation to prevent freezing during the colder months.

The frost-proof hydrant is designed so that the water supply to the faucet is shut off inside the building, where it is heated. Sloping the barrel to the outside during installation will ensure the water drains from the barrel and will prevent freezing of the water in the hydrant. It is important that the garden hose or any attachments placed on the hydrant for connection of a hose or other accessory are removed to ensure that the barrel of the frost-proof hydrant drains completely in cold weather. Frost-proof hydrants are available in a variety of lengths to accommodate most building construction methods.

Another method of installation to prevent a hose bibb from freezing is to install a stop-and-drain (also called a stop-and-waste) valve on the supply piping leading to the exterior. The drain or waste outlet on the valve will need to be opened once the valve has been closed for the season. The hose bibb should be opened to allow any water trapped in the supply piping to drain or allow air into the piping to permit water to drain through the hose bibb. It is important that the stop-and-drain valve be installed in the right direction; otherwise, the piping to the exterior cannot be drained.

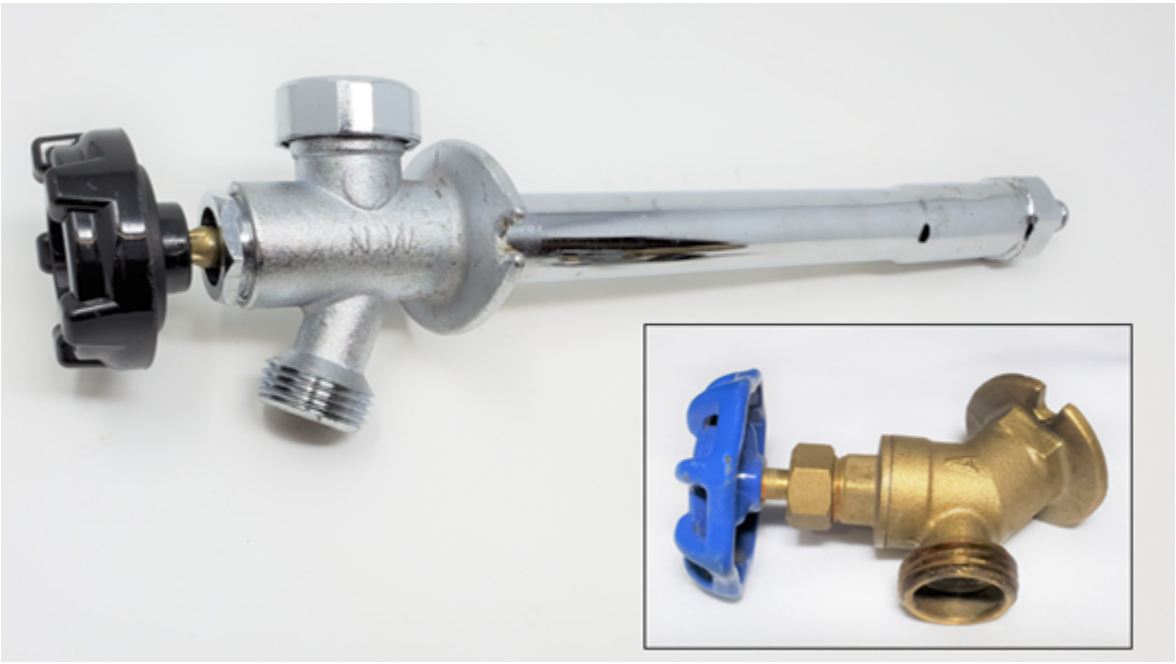


*Figure 15 A frost-proof hydrant on the left and a standard hose bibb on the lower right*

Hose bibbs are also available as hot and cold units if homeowners or businesses require tempered water outdoors.

#### Irrigation connection

Connections to the building water supply system for irrigation systems is common for residential and ICI buildings. For ICI buildings, the irrigation system designer will need to provide the water supply system designer with load requirements so the water service pipe can be sized correctly. When residential irrigation systems are added to an existing building, it is common for the designer to calculate the irrigation system's maximum available flow for each zone based on the existing water service pipe size and the water meter size. For irrigation systems installed with new residential construction, the irrigation system designer needs to provide the plumber with the calculated demand flow. Section 2.6 of the BC Plumbing Code requires that the fixture units for irrigation system be added to the water service sizing.

Residential irrigation systems are described in more detail in the Plumber level 3 Competency B3.

#### Water treatment equipment

As discussed in Competency B1, almost all domestic water goes through some form of treatment before being delivered to the end user. Water purveyors must treat the raw source water to ensure it meets the requirements of the Drinking Water Protection Act and Drinking Water Protection Regulation, as well as the conditions set on their operating permits. There are times when the potable water delivered to the end-user meets the minimum requirements, but still requires further treatment. Conditions such as hard water and aesthetically-displeasing water may require the use of water treatment equipment that is installed in the building by the owner.

Residential and small commercial water treatment systems, such as whole-system water softeners and point-of-use water purification equipment, are generally selected and installed by plumbers. Larger and/or more complex water treatment systems are more likely to be designed by specialists, such as engineers. Private water supply systems regularly require the use of water treatment equipment to ensure it meets the requirements for domestic use. For example, if you are the owner of a well that only supplies water to one connection (e.g. a private household), you are responsible for testing your water to determine if it is safe for you and your family to drink. Water samples should be sent to a qualified laboratory for testing. Be aware that test results will only tell you about the water quality on the day you test it, as well water quality can change over time. Weather, seasons, drought, floods or other events may cause contamination. It is recommended well-users test for water quality after significant weather events and, once a year, see if water quality has become a problem.

The water treatment equipment used for single-family dwellings is covered in the Level 4 content of the plumber program.

### Hot Water Building Water Distribution System

A hot water supply is required by the BC Building Code for every dwelling unit, and for every building where a water closet and lavatory are mandatory. The hot water distribution system starts at the service water heater.

### A brief history of water heating

From the Roman bathhouses to modern day fixtures and appliances, hot water seems essential to every person. However, what most us now take for granted—clean, hot running water at the turn of a faucet—was not available in much of North America only a couple of generations ago. It still isn't available in many parts of the underdeveloped world.

Water heated on open fireplaces gave way to wood and coal-fired stoves for heating and cooking. Pipes carrying hot water from elevated tanks to fixtures in the building replaced the need for carrying buckets of hot water. The evolution of the hot water distribution system continued with the invention of electric and gas-fired storage-type service water heaters. The modern tankless service water heater continues the evolution of the domestic water heating appliance.

### Components and equipment

Just like the cold water distribution system, the hot water distribution system also incorporates many different types of pipes, fittings, valves, equipment and appurtenances. The hot water distribution system can include several unique systems and devices, such as:

- Service water heaters, and associated appurtenances
- Mixing valves (Tempering valves)
- Thermal expansion protection devices
- Hot water recirculation systems

These components and system connection points are covered in the content below.

#### Service water heater types

The BC Plumbing Code defines a "service water heater" as meaning a device for heating water for plumbing services. The service water heater is the domestic water heating source and can be one of several different appliances. The different appliance types can be categorized by the method of heat development, either direct heating or indirect heating, as well as by the location in the system, either point-of-distribution or point-of-use.

- Direct heating – heat from the combustion of fuels, collection of solar energy, or direct conversion of electrical energy into heat applied directly in water heating equipment.
- Indirect heating – heat energy developed from remote heat sources such as boilers, solar, cogeneration, refrigeration, waste heat, etc. and then transferred to the water.
- Point-of-distribution – water heaters that serve the entire domestic hot water distribution system. The term "central water heater" is also used to describe this type of water heater.
- Point-of-use – water heaters designed to deliver hot water almost instantaneously, and are installed at the location of the fixture or appliance requiring the hot water.

The most common designs for service water heaters are listed here:

- Indirect service water heaters
- Tankless (on-demand, instantaneous) water heaters
- Storage-type (tank-type) water heaters (electric, gas, heat pump, etc.)
- Point-of-use water heaters (electric, steam, etc.)

The water heaters listed here are described in the content below.

*Indirect service water heaters*

The BC Plumbing Code defines an “Indirect service water heater” as a service water heater that derives its heat from a heating medium such as warm air, steam or hot water.

There are several variations of indirect heating of the domestic water. In most indirect water heaters, hot water from a heat source flows through one side of a heat exchanger while potable water flows through the other side. Systems that incorporate domestic water heating into a space heating system are referred to as combined systems. The figure below shows a hydronic heating boiler as the heat source for space heating as well as providing heat for domestic hot water through a heat exchanger.

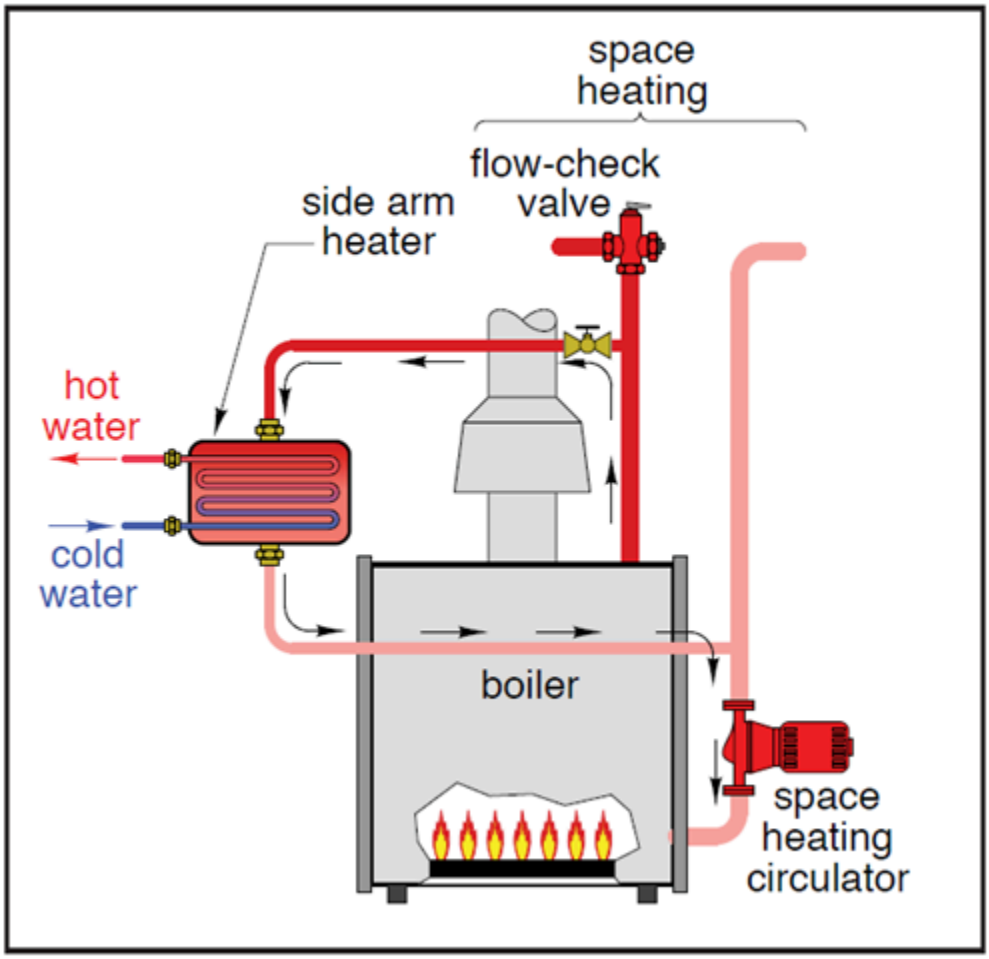



*Figure 16 One example of indirect domestic water heating*

*Tankless (on-demand, instantaneous) water heaters*

A tankless water heater is a direct heating appliance that heats water almost instantaneously without the use of a storage tank. When a hot water faucet is turned on, and a minimum flow is detected by the controls, either a natural gas burner or an electric element heats the water as it flows through a heat exchanger in the unit. Both the electric model and the gas-fired model have large energy inputs so, given this relatively high rate of heat generation, the heat exchanger warms quickly. Tankless water heaters are available in a wide range of capacities for both residential and commercial applications.

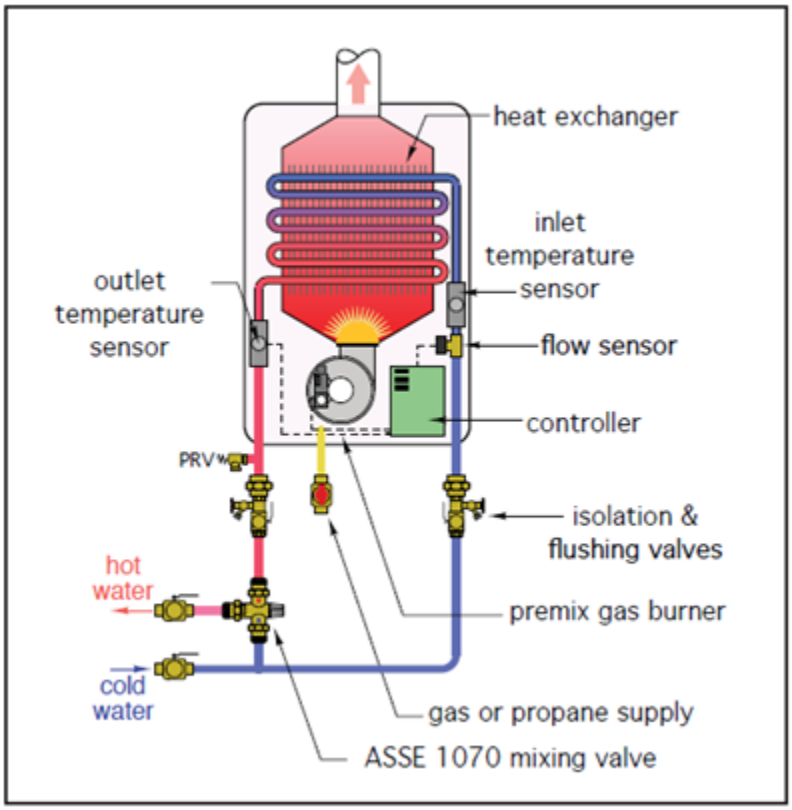



*Figure 17 A simplified illustration of the internal components in a gas-fired tankless water heater*

*Storage-type (tank-type) water heaters*

Storage-type water heaters, also referred to as tank-type water heaters or simply hot water tanks, are the dominant design of domestic water heater installed in residential and commercial buildings. This section will go into more detail on the storage-type water heater since the water distribution system sizing drawings used in this Block incorporate this design.

*Electric tank-type water heaters*

One of the most common devices used in residential and light commercial buildings is a tank-type electric water heater. Most tank-type electric water heaters have a welded steel pressure vessel surrounded by an insulated jacket. The space between the pressure vessel and jacket is filled with fiberglass or foam insulation. The higher the R-value of this insulation, the lower the standby heat loss from the tank.

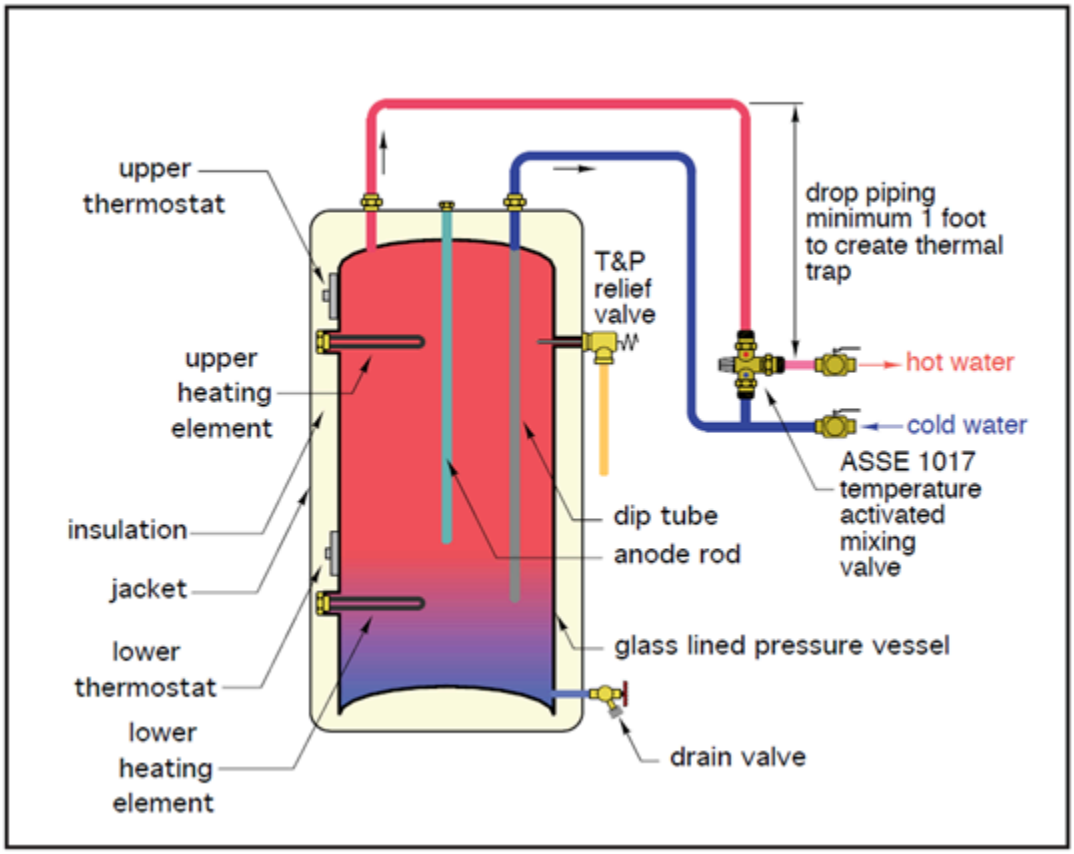



*Figure 18 The typical components used with a tank-type electric water heater*

Storage-type service water heaters are shipped with several components already installed. The content below describes most of these components.

*Heating elements*

Almost all tank-type electric water heaters sold today are designed to use immersion-type heating elements. The number of elements that are installed by the manufacturer depend on the tank size and the recovery rate required by the system design. It is important when replacing an element to ensure the new element matches the old element, as there are different lengths, different mounting designs, different voltages, and different wattages.

For example, a 40 US gallon residential tank would typically use two 240-volt, single-phase, 4-bolt, 3000-Watt elements while a large volume electric commercial tank might require five 208-volt, 3-phase, threaded, 4000-Watt elements.

*Anode rod*

The inner surfaces of the steel pressure vessel are coated with a heat-fused vitreous material often referred to as “glass lining”. Its purpose is to isolate the steel tank surfaces from the corrosive effects of water. Although this glass lining covers the majority of the inner tank surfaces, there are small areas that may not be coated. To protect these exposed steel areas against corrosion, most tank-type water heaters are supplied with one or more anode rods, which are screwed into ports at the top of the tank. Anode rods are made of either aluminum or magnesium. These metals are less noble on the galvanic

scale compared to steel. As such, they serve as the preferred corrosion surface (rather than the exposed steel within the tank). Over time, anode rods are consumed, or sacrificed, by this corrosion process and need to be replaced to extend the life of the water heater. Hence the term “sacrificial anode” commonly used in the plumbing trade.

The lifespan of steel tanks will vary based on many factors, but the warranty on the tank is based on the number of anodes. A tank with a single anode is typically warrantied for six years, while a tank with two anodes could have a warranty up to twelve years. There are non-metallic electric water heaters available that are impervious to rust and corrosion, removing the need for an anode rod. These tanks typically have a lifetime warranty.



*Figure 19 A new and an old anode rod*

*Dip tube*

Tank-type water heaters also contain a dip tube. Its purpose is to deliver cold water near the bottom of the tank, thus preserving temperature stratification within the tank (e.g., hottest water at the top and coldest water at the bottom).

An electric tank-type water heater that is sized to cover all the water heating needs of an average single family home will usually range in size from 30 to 119 gallons. It will have two electric heating elements, one in the lower portion of the tank and the other near the top of the tank.

In residential applications, these elements are powered by a 240 VAC circuit and have heating outputs ranging from 3.8 to 6.0 kW (approximately 13,000 to 20,500 Btu/hr). Under normal operating conditions, the lower element provides the heating. It is turned on and off by a line voltage thermostat built into the tank. During periods of high demand, the water temperature near the top of the tank may drop several degrees. When this occurs, the lower heating element is turned off and the upper element is turned on. This concentrates heat input where water is leaving the tank. The objective is to sustain acceptable water temperature to the fixtures during high demand. When demand lessens and the upper tank thermostat is satisfied, the lower element resumes heating under the control of the lower tank thermostat.

The figure below shows the cycling of the two elements in a tank-type electric water heater.

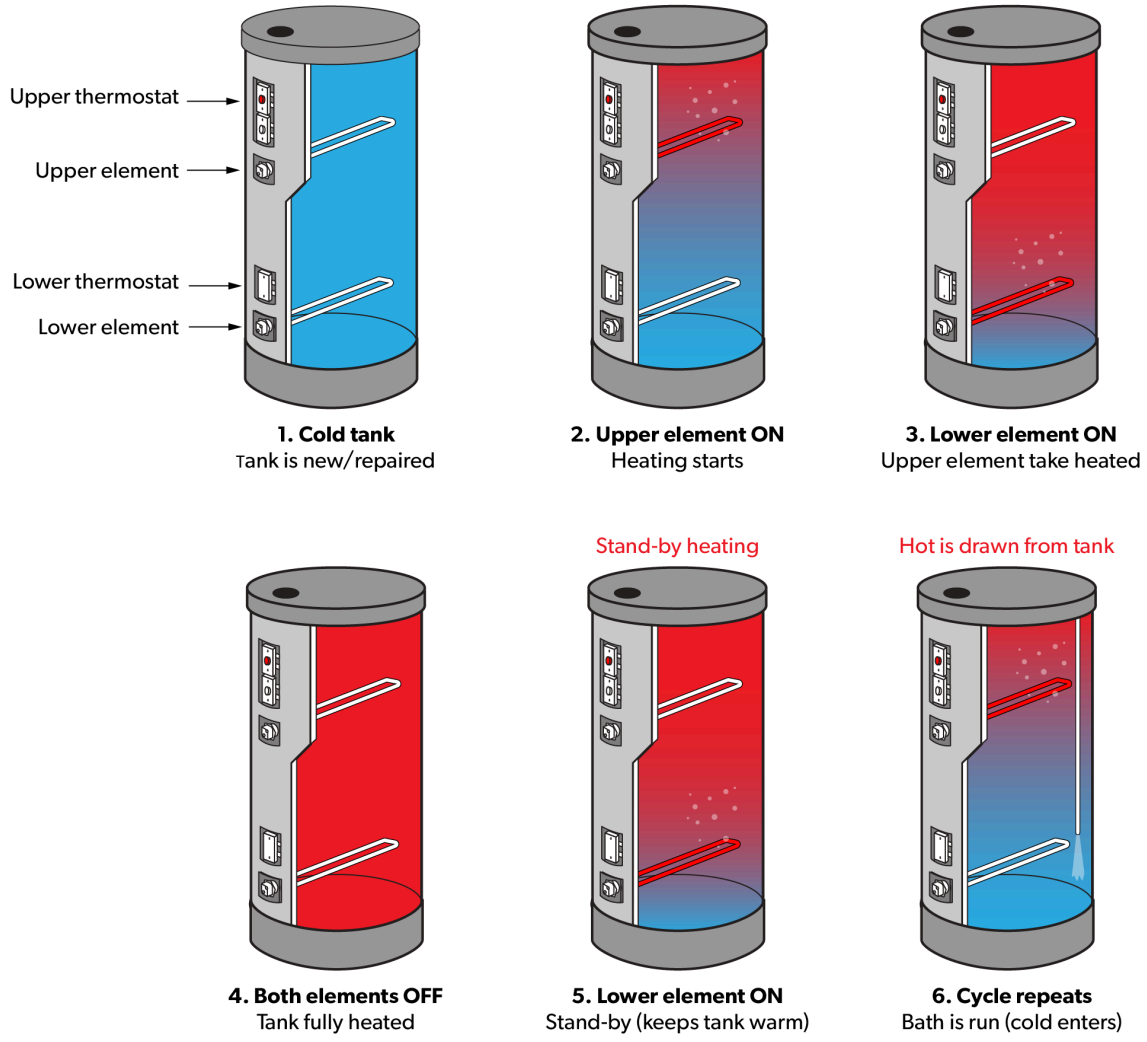



*Figure 20 Electric water heater element cycling*

*Relief valve*

Water that is enclosed in a container expands when heated. If the heat is not controlled, excessive temperature and pressure can build up to the bursting point. To eliminate this hazard, a temperature and pressure relief valve is installed on all hot water tanks and direct the outlet to within 12 inches of the floor. The pressure portion of the temperature and pressure valve relieves excess pressure, while the temperature-relief valve prevents overheating the unit. This valve is normally a thermal expansion type.

Before activating any service hot water tank, make absolutely sure it is full of water. A simple method of purging air from the hot water tank is to open a hot water faucet and allow the air to escape while the tank is filling. A constant flow of water from the hot water faucet indicates that all the air has been expelled from the hot water tank.

The BC Plumbing Code Article 2.6.1.7. includes several Clauses that cover the requirements for relief valves on service water heaters.

Gas-fired tank-type water heaters

Another very common tank-type water heater is a gas-fired model fueled by either natural gas or propane. This model of service water heater incorporates many of the same components as the electric model. These tanks will be covered in more detail in the Gasfitter portion of the program.

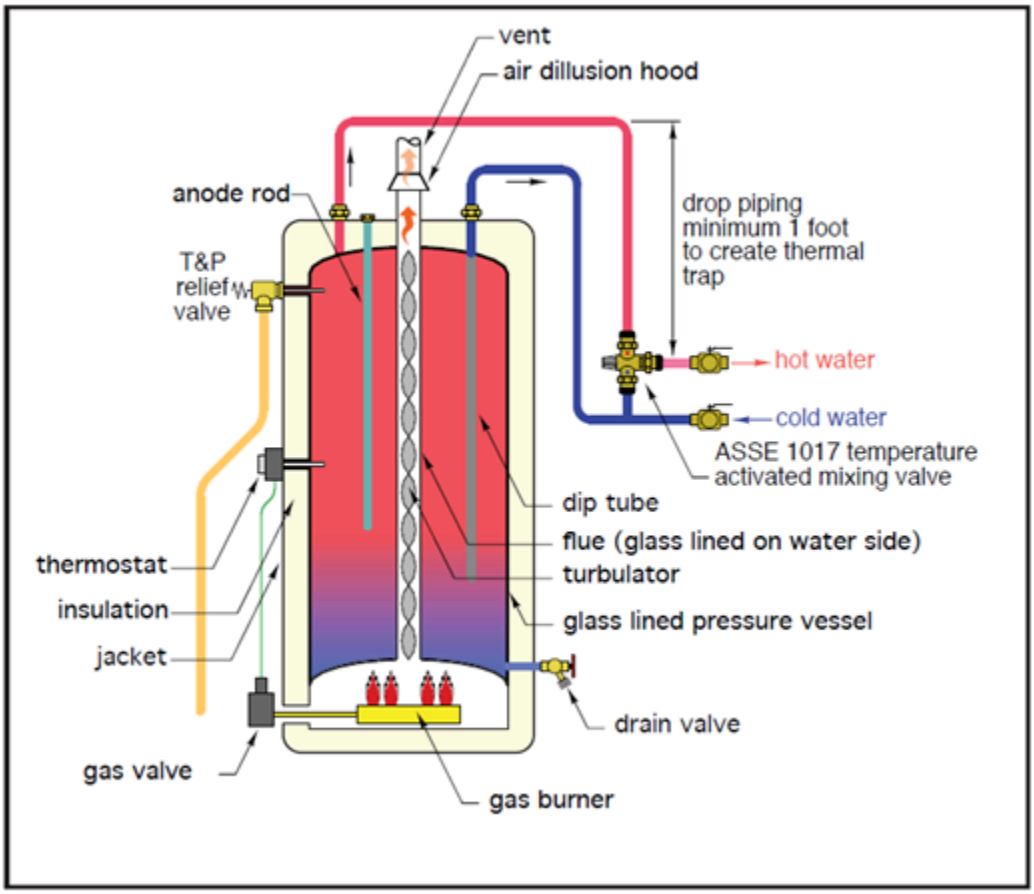



*Figure 21 The typical components used with a tank-type gas-fired water heater*

Service water heater start-up, commissioning, service, and maintenance

Service water heater start-up, commissioning, service, and maintenance will be covered in the plumber level 4 content.

Point-of-use water heaters

These types of water heaters are commonly referred to as “booster heaters”. In North America, they are generally installed as a booster for commercial dishwashing to ensure the minimum final rinse temperature of 180 degrees F (82 degrees C) is reached. Some models are compact enough to be installed under sinks and remote locations for use as booster heaters for users to have instant hot water. These types of water heaters are typically electric and have a small reservoir of heated water ready for use at all times.

The figure below shows an electric point-of-use water heater installed at a kitchen sink.

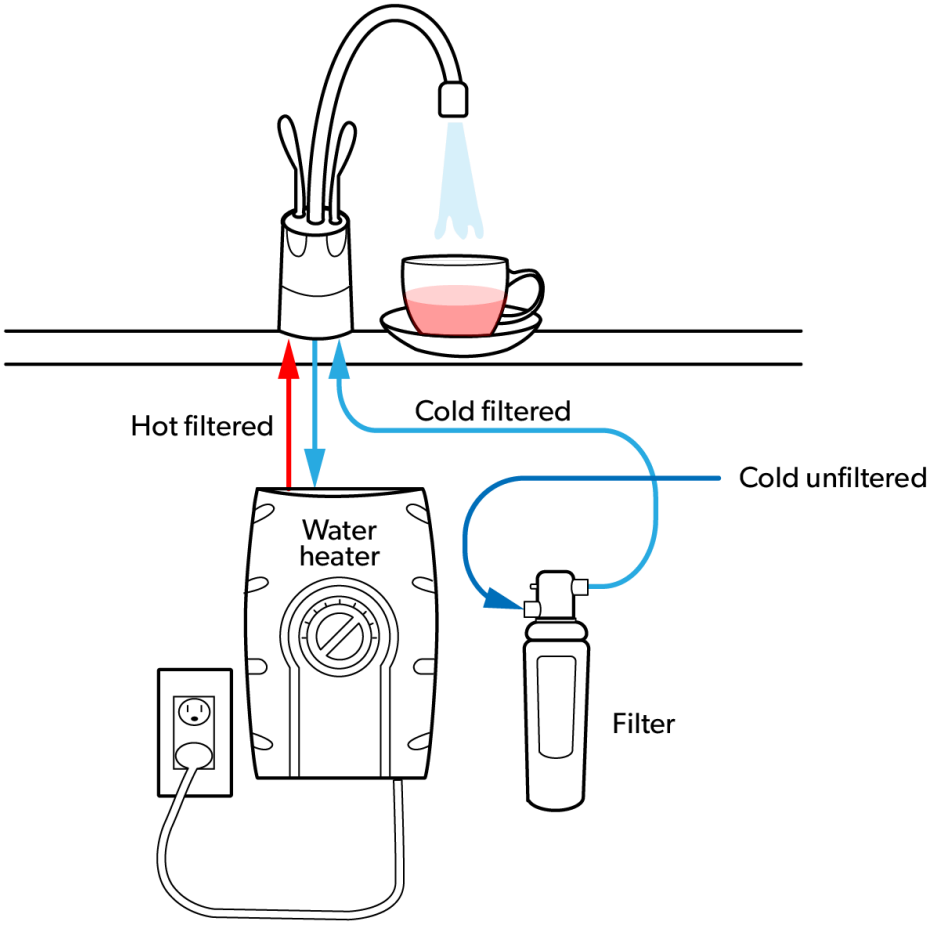



*Figure 22 Point-of-use water heater with filter*

Advantages and disadvantages of different water heater designs

Storage-type water heaters are still the most popular type of domestic and commercial water heaters being installed. One disadvantage to a storage-type water heater is the size of the tank. Higher demand for hot water generally means a larger tank. Electric hot water tanks have the advantage of being the lowest cost heater design, and can be installed in more locations than a gas-fired hot water tank because they don't require a vent. Electric hot water tanks tend to be quieter when operating as there is no gas burner noise. Electric hot water tanks are also very efficient, although this may not mean the annual operating cost is lower than other designs as the cost of electricity may be higher in some regions than the cost of fuel gas. One disadvantage of electric hot water tanks is that they may not recover as fast as gas-fired hot water tanks. Recovery rate is covered in the "Sizing service water heaters" content later in the Competency.

Tankless designs are very popular for new construction and are considered to be one of the most economical designs of domestic water heating, as there is no water being stored so there is no standby heat loss. They are smaller than storage-type water heaters and are wall-mounted, requiring very little floor space. [JG1] Their size can make them particularly attractive in homes where square footage is at a premium. The on-demand design means that, if sized correctly, these heaters can provide a continuous supply of hot water. One disadvantage of tankless water heaters is the large energy input

required for on-demand water heating. The electric version creates a significant amperage draw when in use, so this must be accommodated in the electrical service size. Gas-fired versions have burners several times larger than a storage-type water heater, so retrofitting may mean a gas piping revision. The gas-fired version also needs a vent to outdoors, which may restrict the locations it can be installed in the building. The large energy input of both designs causes some precipitation of the mineral in the water and frequent maintenance may be required. It is important that these heaters have a supply of high-quality potable water to ensure a long life. Tankless water heaters have been known to create a "cold-water sandwich effect", which is the undesired introduction of cold water into the hot water supply line on occasions of frequent on/off operations. Most manufacturers have now resolved this issue.

Indirect water heaters are typically used when there is a heat source installed for another purpose. These designs often combine space heating with domestic water heating, so can be referred to as combination systems. The advantage of this design is the initial cost savings. For example, using a hydronic heating boiler as the heat source means the tank is only for hot water storage and does not require its own heat source. This involves less maintenance and potentially a lower annual operating cost. The disadvantage of this design is that a storage tank is still required, so space must be found for it. This design also needs to be controlled correctly so that the customer can maintain indoor temperature as well as meet the domestic water heating load. Some consideration must be taken if a combination system is installed in a region where there is no need for space heating during the summer months. This would require the boiler to operate solely to supply hot water, which would lower the efficiency of the system.

There may be an advantage to having a pre-heat system installed for the service water heater. If the inlet water temperature is raised by a pre-heat system, then the service water heater operates less, which theoretically lowers the annual operating cost. Care must be taken by the designer to ensure the pre-heat system does not jeopardize the potable water quality or create a complex system that could interrupt the domestic hot water supply if it failed. One pre-heat system that has been used extensively in British Columbia is the solar domestic hot water pre-heat system.

### Solar domestic hot water pre-heat system

Solar energy can be used to heat water when the right conditions are met. A building with suitable amounts of south-facing roof or walls can have solar collectors installed and transfer the water heated in the panels to a storage system in the building. In the system shown below, heated water from the solar storage tank is routed through a heat exchanger of an electric water heater, where its temperature is increased to the desired setpoint (when necessary). A thermostatic mixing valve on the outlet of this water heater prevents high temperature water from reaching the building's fixtures. High water temperatures are possible in almost any type of solar water heating system during prolonged sunny weather, especially if hot water demand is low.

Tank-type water heaters are typically used as "finishing" heaters to boost the temperature from the solar water heating system to the desired outlet temperature. Tankless water heaters are not typically used because the controls in some tankless heaters will not allow the unit to come on if the thermal load is less than the minimum heat transfer rate for the appliance. The controls constantly monitor the flow rate and inlet water temperature, and then use this information along with the unit's setpoint temperature to determine the thermal load on the heater and compare it to the heater's minimum heat

transfer rate. For example, if the water temperature from the solar water heating system is too close to the setpoint, the unit may not come on.

Plumbers can design and install solar pre-heat systems, but the BC Plumbing Code Article 2.6.1.8. states that systems for solar heating of potable water shall be installed in conformance with CAN/CSA-F383, Installation of Packaged Solar Domestic Hot Water Systems.

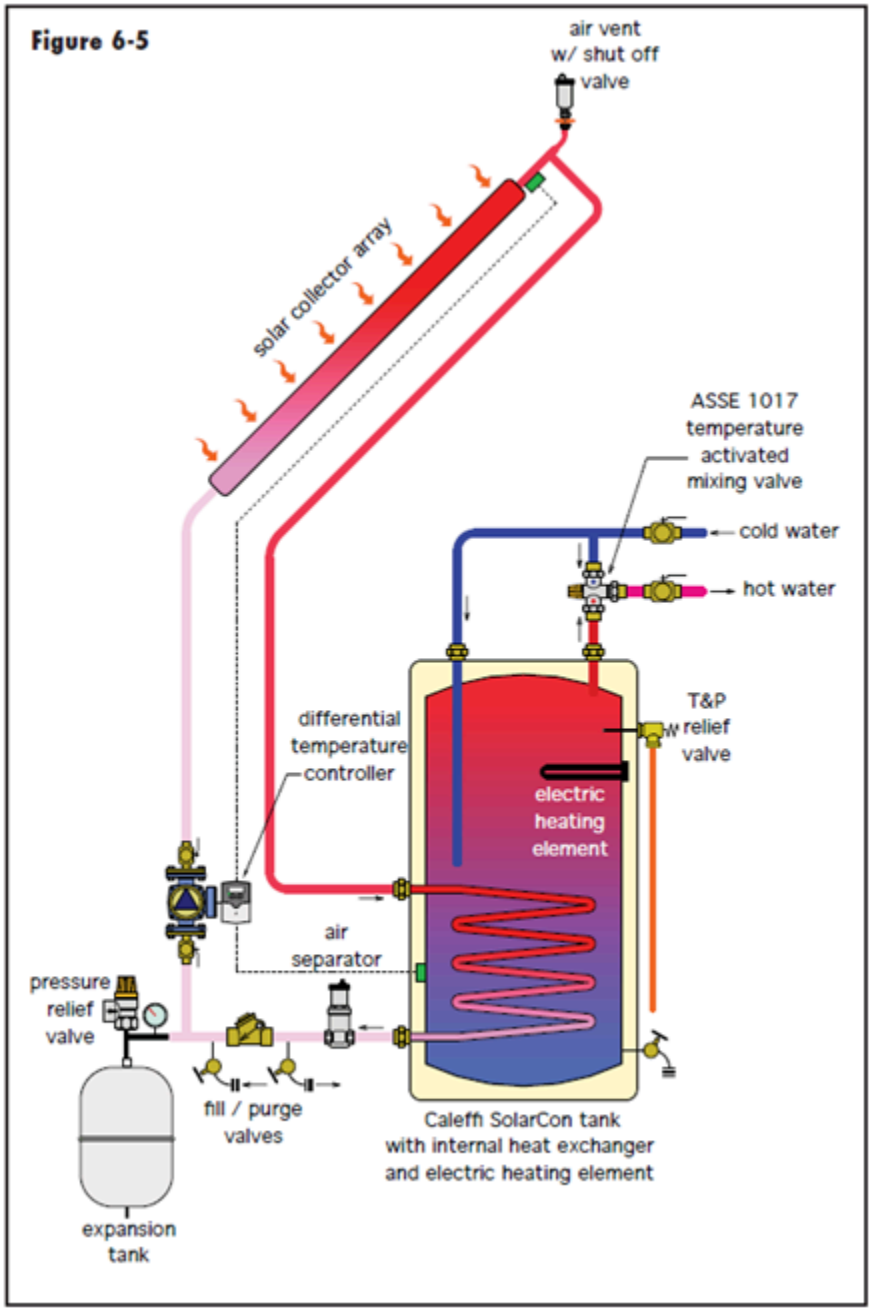



*Figure 23 Typical solar water heating system using a storage tank with an internal heat exchanger*

Service water heater efficiency

The BC Building Code Article 9.36.4.2. addresses equipment efficiency standards for service water

heaters, listing the performance requirements on Table 9.36.4.2. For example, while electric water heater efficiency typically approaches 100%, a gas-fired tankless service water heater must be a minimum of 80% efficient.

Service water heater temperature setpoint

There is a lot of debate over the best hot water heater temperature setpoint. Safe storage and distribution of domestic hot water is imperative in any application. Storing water at temperatures high enough to eliminate bacteria, but delivering hot water at temperatures safe for use by all users, has been a challenge for plumbers. To help guide plumbers, the BC Plumbing Code has added the following information at Notes to Part 2 A-2.6.1.12.(1):

> **Service Water Heaters.** Storing hot water at temperatures below 60°C in the hot water tank or in the delivery system may lead to the growth of legionella bacteria. Contemporary electric water heater tanks experience temperature stratification and thus tend to have legionella bacteria in the lower parts of the tank. Article 2.6.1.12. specifies a thermostat setting of 60°C (140°F), which addresses the concern over the growth of legionella bacteria in electric hot water storage tanks and is enforceable without introducing unnecessary complications. The growth of legionella bacteria is not a concern for other types of water heaters with different designs that use different fuels. Electrically heated water heaters are shipped with the thermostat set at 60°C (140°F). Article 2.6.1.12. is included in this Code to formalize this de facto temperature setting as a requirement. The thermostats have graduated temperature markings to allow such a setting, which is not the case with gas- or oil-heated water heaters.

The figure below shows the relationship between the status of Legionella bacteria and the temperature of the water in which they exist.

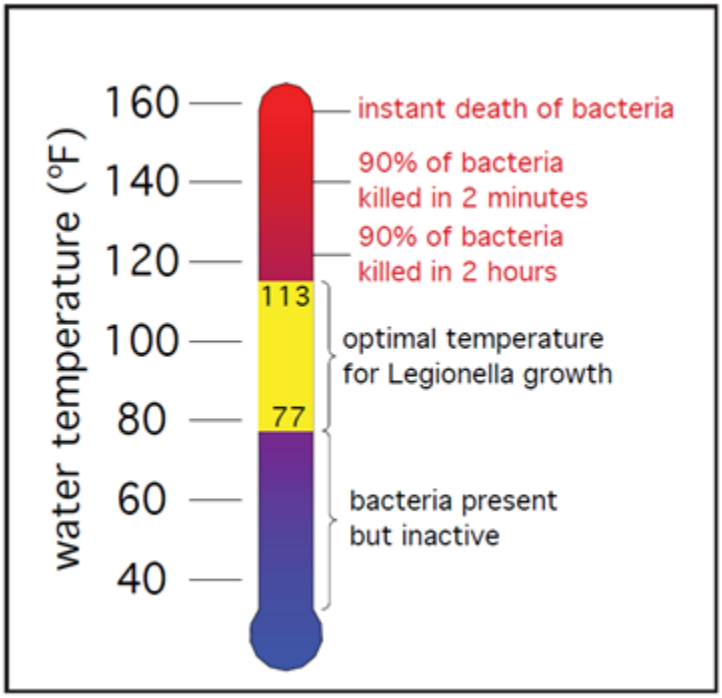



*Figure 24 Legionella growth chart*

The information on service water heater settings addresses the temperature requirements for hot water storage but does not address the recommended hot water delivery temperature. The ideal temperature

setting for a service water heater requires the plumber to consider many factors. The BCPC guides plumbers with Article 2.2.10.7 by prescribing a maximum water outlet temperature for showers and bathtubs as 49°C (120°F). This maximum temperature setting is to minimize the possibility of a scald or thermal shock to the user, and would require the use of a mixing valve in many applications, especially if using an electric storage-type water heater. Since modern shower and bathtub valves are typically one-handle, pressure balanced/thermostatic type, and have an integrated maximum temperature stop, these valves can be set up by the plumber to meet the 49°C maximum setpoint. The BC Plumbing Code provides additional information on hot water temperature setpoints at Notes to Part 2 A-2.2.10.7:

> **Hot Water Temperature.** Hot water delivered at 60°C (140°F) will severely burn human skin in 1 to 5 seconds. At 49°C (120°F), the time for a full thickness scald burn to occur is 10 minutes. Children, the elderly and persons with disabilities are particularly at risk of scald burns. Compliance with Article 2.2.10.7. will reduce the risk of scalding in showers and bathtubs, and reduce the risk of thermal shock from wall-mounted shower heads.
>
> These requirements apply to all occupancies, not just residential occupancies.
>
> The water outlet temperature at other fixtures, such as lavatories, sinks, laundry trays or bidets, is not addressed by Article 2.2.10.7., but a scald risk may exist at such fixtures nonetheless.

### Service water heater sizing

Determining the correct water heater size is a critical step in the design of a hot water distribution system. Fortunately, water heaters are produced in a wide variety of designs and sizes to help designers select the best model for their specific application.

Selecting a service water heater for a residential building is much simpler than determining the service water heating system for ICI buildings. Since both tank-type and tankless water heaters are common for residential and ICI applications, the sizing methods will be covered separately as follows:

- Residential tank-type water heater sizing
- Residential tankless water heater sizing
- ICI tank-type water heater sizing
- ICI tankless water heater sizing

#### *Residential tank-type water heater sizing*

There are essentially two methods used to size residential service water heaters. The designer can go through the sizing process using a worksheet and decide based on the results, or the designer can use online sizing tools that most manufacturers provide. For both methods, the designer will need to collect accurate information about the domestic hot water system and the customer’s needs.

**Worksheet method for storage-type tank size selection.**

**Table 1 Worksheet for estimating peak hour demand/first hour rating for storage-type water heaters**

| **Use** | **Average gallons of hot water per usage** | **×** | **Times used during 1 hour** | **=** | **Gallons used in 1 hour** |
|---|---|---|---|---|---|
| Shower | 20 | × | | = | |
| Shaving | 2 | × | | = | |
| Automatic dishwasher | 7 | × | | = | |
| Hand dishwashing or food prep | 3 | × | | = | |
| Clothes washer – Top-load model | 25 | × | | = | |
| Clothes washer -Front-load model | 15 | × | | = | |

**Total peak hour demand =**

The worksheet shown above uses “peak hour demand.” This is an estimate of the customer’s maximum usage of hot water during a one-hour period of the day. For some residential applications, this is in the morning when everyone is getting ready for work or school; for other applications, this may be in the evening, when dishes are getting done and people are showering, etc. Some manufacturers’ water heater sizing calculations use a two-hour peak usage period while others use one hour or even 30 minutes.

Once the designer has estimated the total peak hour demand, the tank-type water heater can be selected based on the first hour rating. The first hour rating is the number of gallons of hot water the heater can supply per hour (starting with a tank full of hot water). It depends on the tank capacity, source of heat (burner or element), and the size of the burner or element. The rating can be found on manufacturers’ websites in the specific literature for each tank. The designer would look for water heater models with a first hour rating that at least matches the application’s requirements.

An example of product specifications for a 40 gallon electric hot water tank are shown on the chart below. The first hour rating is the last row on the chart.

**Table 2 Example of product specs for a hot water tank**

| | |
|---|---|
| **Nominal Capacity** | 40 |
| **Rated Storage Volume** | 36 |

| | |
|---|---|
| **UEF** | 0.92 |
| **Recovery Gallons** | 25 |
| **Power Source** | Electric |
| **Limited Tank Warranty** | 9 Years |
| **Limited Parts Warranty** | 9 Years |
| **Anode** | Alum |
| **Water Connection Location** | Top |
| **Water Connection Size** | ¾″ |
| **First Hour Rating** | 50 |

Note: when a large capacity bathtub (such as a whirlpool tub) is part of the home equipment, it is important that the water heater first hour rating be capable of filling the tub. This may mean the tank-type water heater size is increased just to meet this special demand.

*Online sizing tool method for storage-type tank size selection*

For the selection of residential tank-type water heaters using a manufacturers online sizing tool, the designer typically needs to answer a series of questions, such as:

- What is the length of the longest shower someone takes?
- How many showers would your household like to take back-to-back?
- How many showers would your household like to take at the same time?
- What size is the largest bathtub?
- Do any of the showers have body sprays or multiple/high flow heads?
- How would you like to heat your water?
- How much space do you have?

Once the questions have been answered, the sizing tool will give the designer several options to choose from.

*Residential tankless water heater sizing*

Tankless or on-demand type water heaters are rated by the maximum temperature rise possible at a given flow rate. To determine temperature rise, subtract the coldest incoming water temperature from the desired outlet temperature. An example for British Columbia would be 140°F (desired outlet temperature) minus 40°F (cold water temperature in the service pipe in winter) equals 100°F temperature rise.

Flow rate can be calculated by adding up the individual flow rates for all the hot water devices that are expected to operate at any one time during the peak usage period. For example, if the two fixtures that

will use hot water simultaneously are a hot water faucet with a flow rate of 0.75 US gallons (2.84 liters) per minute and a shower head with a flow rate of 2.5 US gallons (9.46 liters) per minute, then the desired flow rate required for the on-demand water heater would be 3.25 US gallons per minute (12.3 liters per minute). It is possible to estimate flow rate by holding a bucket under the faucet or shower head and measuring the flow for one minute.

Once the temperature rise and flow rate have been determined, the designer can use a manufacturer's sizing chart to select a model that will meet the needs of the customer. An example of a sizing chart is shown below. If a model can not be determined because of excessive flow rate, the designer may need to suggest the homeowner install low-flow fixtures.

**Table 3 An example of a sizing table for tankless water heaters. – Tankless heater sizing chart. Note: GPM is US gallons**

| Temp rise (°F) | Model 150 GPM | Model 180 GPM | Model 210 GPM | Model 240 GPM | Model 270 GPM |
|---|---|---|---|---|---|
| **30** | 6.8 | 8.4 | 10.1 | 11.1 | 11.9 |
| **40** | 5.9 | 7.3 | 8.7 | 9.7 | 10.6 |
| **50** | 4.7 | 5.8 | 7.0 | 7.8 | 8.6 |
| **60** | 3.9 | 4.9 | 5.8 | 6.5 | 7.1 |
| **70** | 3.4 | 4.2 | 5.0 | 5.5 | 5.9 |
| **80** | 2.9 | 3.6 | 4.4 | 4.8 | 5.1 |
| **90** | 2.6 | 3.2 | 3.9 | 4.3 | 4.6 |
| **100** | 2.4 | 2.9 | 3.5 | 3.9 | 4.2 |
| **110** | 2.1 | 2.6 | 3.2 | 3.5 | 3.7 |
| **120** | 2.0 | 2.4 | 2.9 | 3.2 | 3.4 |

Manufacturers' online sizing tools are also available for selecting tankless water heaters.

*ICI tank-type water heater sizing*

Industrial, commercial, and institutional (ICI) hot water demands vary significantly based on the building's designated usage. The designer needs to determine the building usage before sizing the service water heater. The list below shows the most common designations for ICI buildings:

- Apartment
- Hotel/motel
- Dormitory
- School
- Restaurant/food service

- Office building
- Hospital/nursing home
- Prison
- Industrial plant

Once the building designation has been decided, the recovery capacity and usable storage capacity for the tank-type heater needs to be calculated. A graph from the manufacturer that plots recovery capacity versus usable storage capacity can be used to estimate the water heater parameters for the application. For example, using the figure below, if 100 people were in an office building at peak demand time, the solid arrows show that a water heater could be selected that has 100 US gallons of usable storage capacity (1 US gallon per person x 100 people) as long as it could recover 15 US gallons per hour (0.15 USGPH per person × 100 people). Alternatively, the dashed arrows show that a smaller 50 US gallon water heater could be used as long as it could recover 25 US gallons per hour.

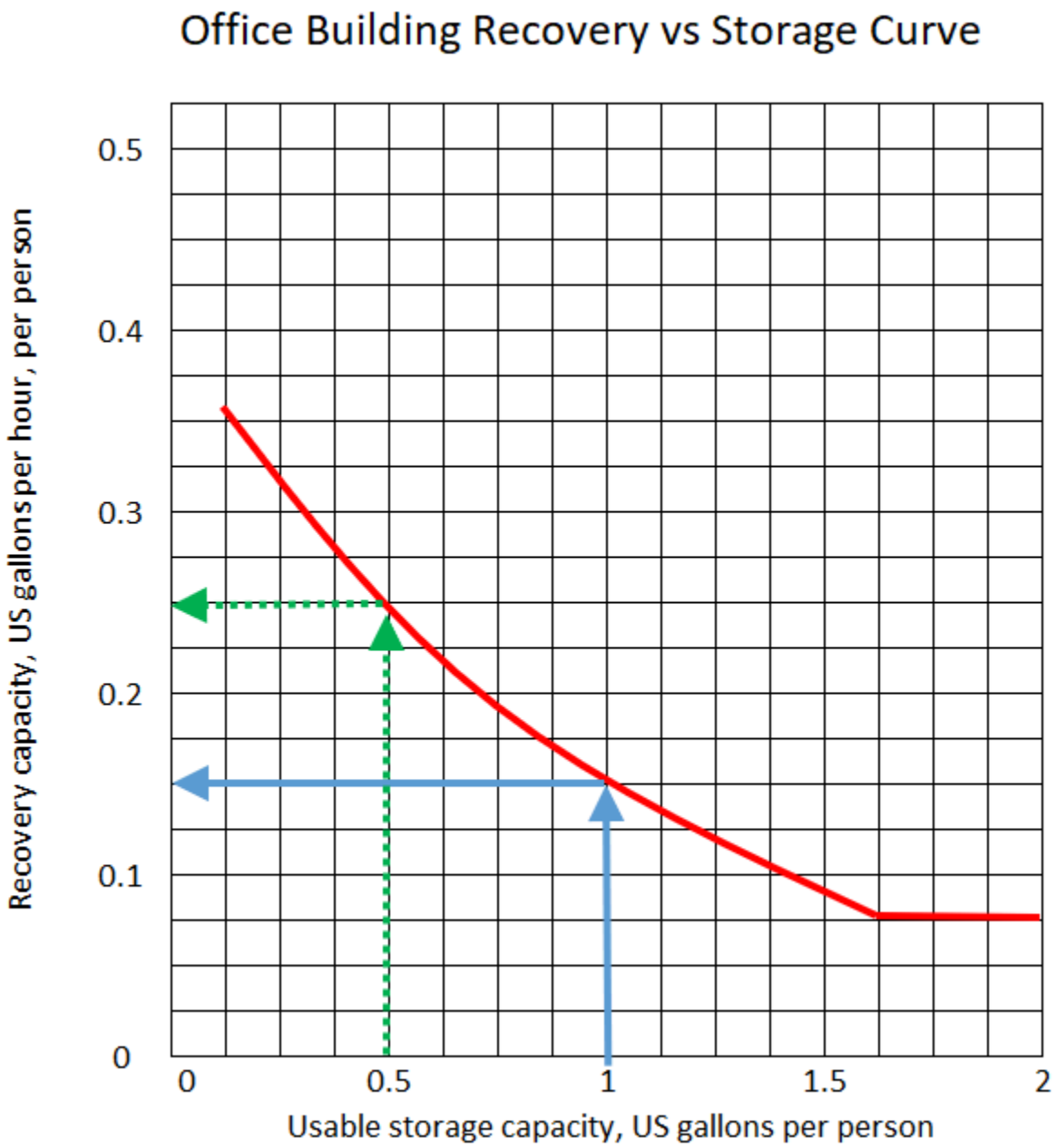



*Figure 25 Pump curve example for an office building*

Manufacturers' online sizing tools are also available for ICI applications. Similar to the residential version, the designer goes through a series of questions, inputting accurate data to get several options for water heater choices. One of the questions that gets asked is about the number of water heaters the designer plans to use. For larger ICI applications, more than one tank-type water heater may be required to meet the peak demand needs. It is important when installing multiple tank-type water heaters that the piping is done correctly. The content below goes through the two most common piping arrangements for multiple tank-type water heater installations.

*Series connection*

In this system, a number of storage tanks are connected so that all water flows through each tank in

series. The first tank and heater combination does most of the heating during low-demand periods, and the remaining units serve only as storage. As the demand for hot water increases and the first unit is unable to supply sufficient water at the correct temperature, the next heater in the series activates. As the demand increases, more units begin to operate. The main advantage of this system is its efficiency: only one small heater operates most of the time, with the other heaters in reserve for heavy demand periods. Also, if one unit in a multiple tank system is faulty, the other units can maintain a reasonable supply of hot water. If a failure occurred in a single-tank system, no hot water would be available.

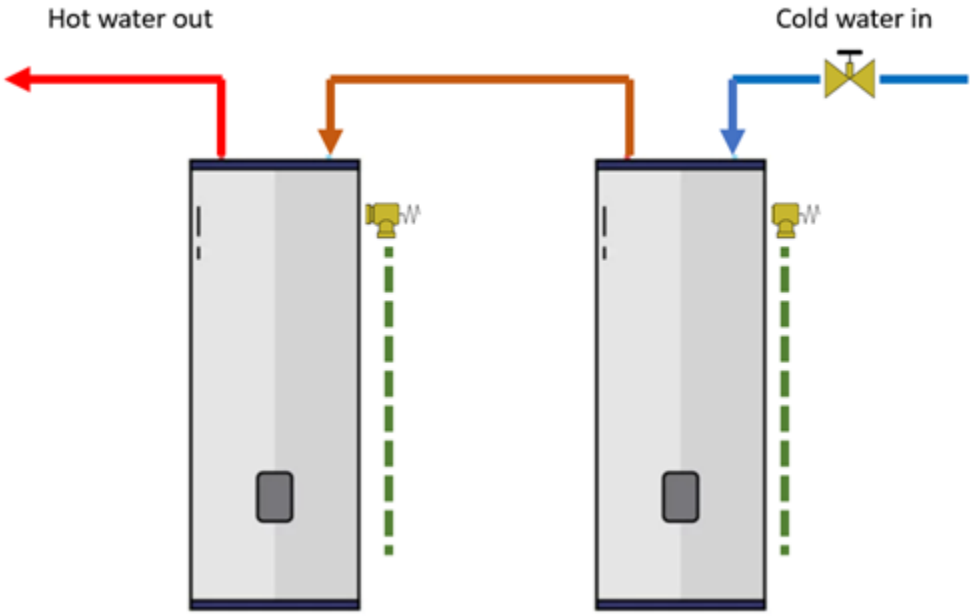



*Figure 26 2 tank-type heaters piped in series*

*Parallel connection*

The parallel connection of multiple hot water heaters has most of the advantages of the series connection, with the difference being that the flow of water through the system is distributed proportionally to each tank, meaning each heater does an equal share of the work. However, the piping for this system must be carefully installed to ensure that no one tank is restricted or overtaxed, as such a condition would allow short-circuiting of the cold water into the hot system.

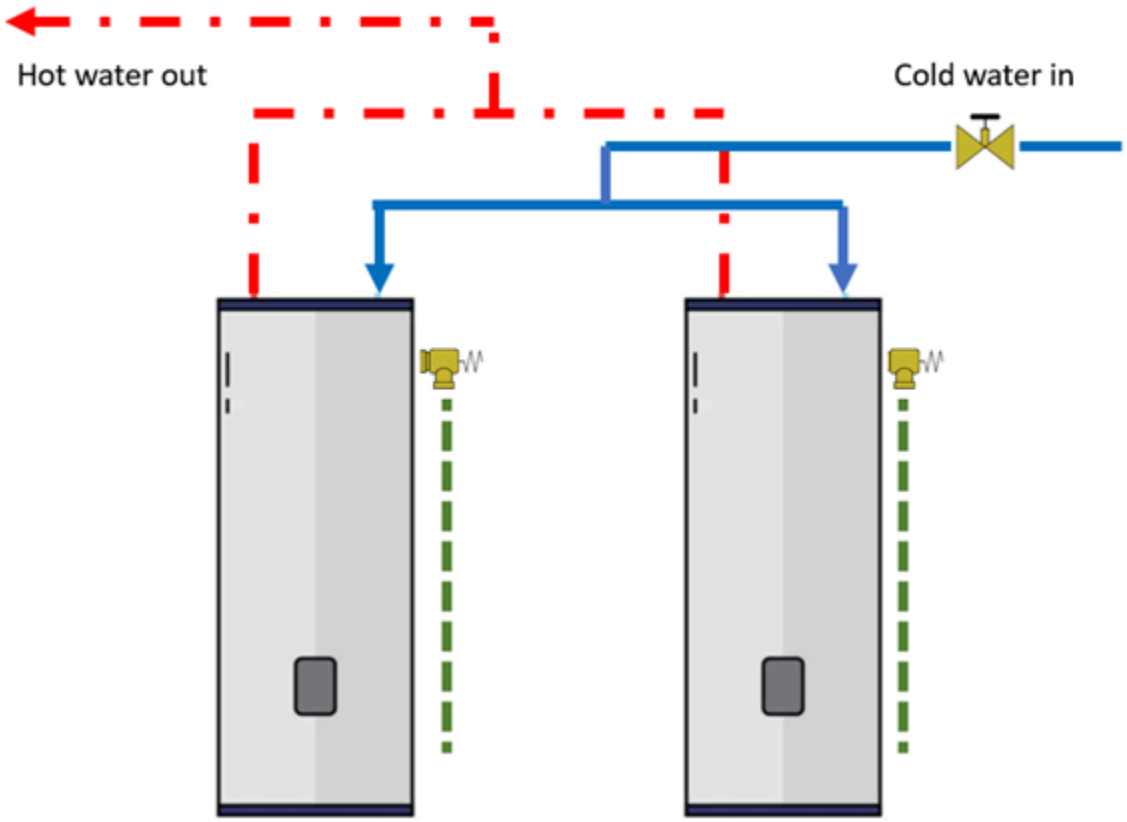



*Figure 27 2 tank-type heaters piped in parallel*

*ICI tankless water heater sizing*

The domestic water heating system designer may choose tankless heaters instead of tank-type heaters, or an indirect heating system may be selected. For large ICI applications, most manufacturers have designed their tankless heaters to be interconnected. This system is referred to as a “cascading system”. For example, when a unit gets up to 80% capacity, the next unit will turn on to help meet requirements of the domestic hot water demand. The flow-on-demand ratio will continue until all the units are generating hot water as needed. This cascading system design will balance out the workload of each unit.

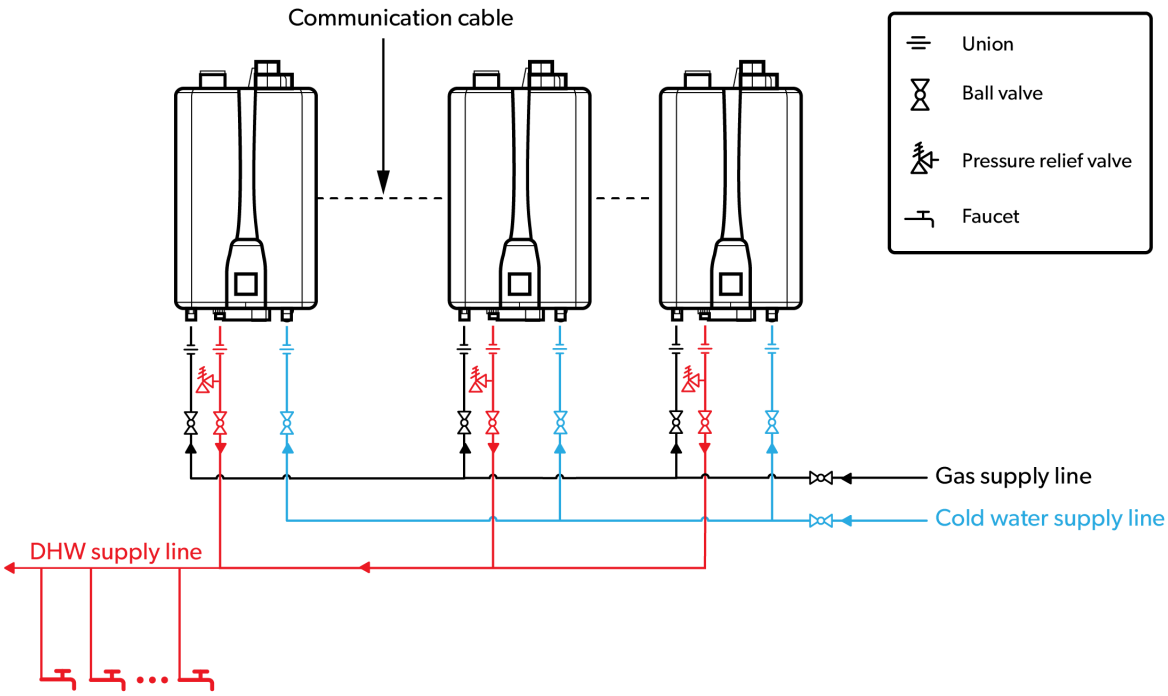



*Figure 28 On-demand water heaters using cascading controls for an ICI application*

Mixing valves (Tempering valves)

When the water temperature needs to be controlled on fixtures or appliances other than showers and bathtubs meeting the requirements of BC Plumbing Code Article 2.2.10.7, mixing valves (also called tempering valves) can be installed. Mixing valves can be selected to serve one fixture (point-of-use), multiple fixtures, or to temper the entire hot water supply (point-of-distribution).

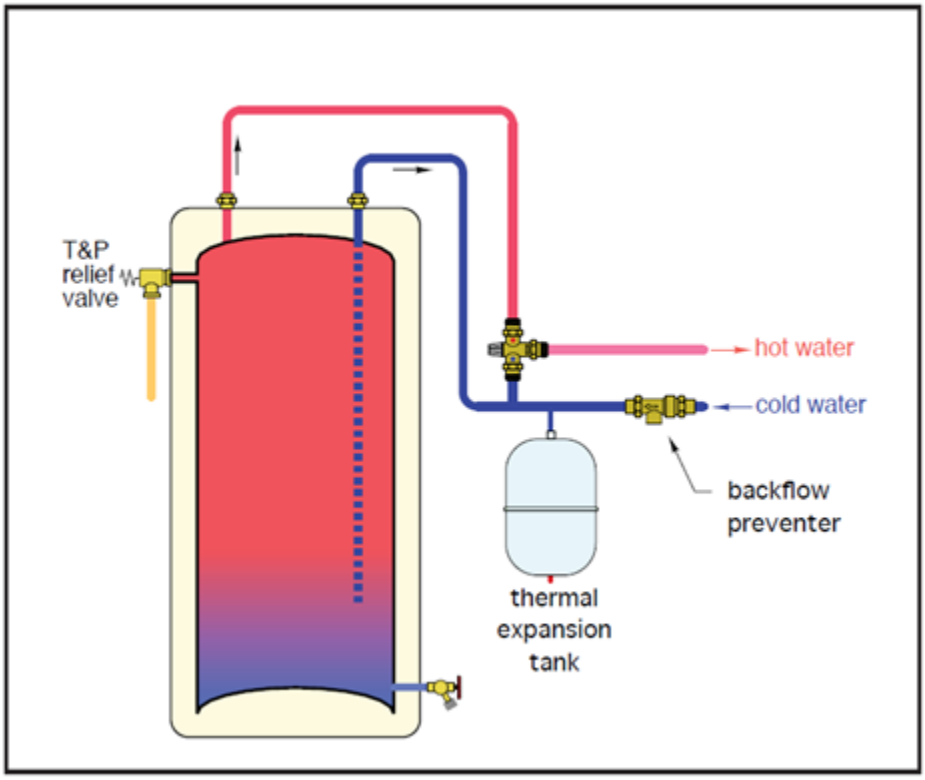



*Figure 29 A mixing valve installed to temper the entire hot water distribution system*

There are two types of mixing valve design: pressure-balanced and temperature-activated (thermostatic).

Pressure balanced shower valves react to changes in water pressure to balance the temperature by reducing the flow of hot water leaving the valve, thereby maintaining a stable temperature. Unfortunately, the pressure of the water from the shower head can vary greatly as the temperature is stabilized. This is especially noticeable in low-flow shower heads or a shower setup with more than one shower head. The reduction in pressure, while not necessarily as shocking as a change in temperature, can still disrupt the shower experience. These models of mixing valves were referred to as anti-scald valves.



*Figure 30 Pressure-balanced tub and shower valve*

Temperature-activated valves continuously adjust the proportions of hot water and cold water entering the valve so that the mixed water stream leaving the valve remains at a set (and safe) temperature. The thermostatic element contains a specially formulated wax that expands and contracts with temperature changes. This element is fully immersed in the mixed flow stream leaving the valve, and continually reacts to changing inlet temperatures and flow rates.



*Figure 31 An example of a temperature activated mixing valve*

Mixing valves are used throughout building water distribution systems. The BCPC Article 2.2.10.7., Water Temperature Control, addresses several applications:

1. Except as provided in Sentence (2), valves supplying fixed-location shower heads shall be individual pressure-balanced or thermostatic-mixing valves conforming to ASME A112.18.1/ CSA B125.1, “Plumbing Supply Fittings.”
2. Individual pressure-balanced or thermostatic-mixing valves shall not be required for shower

heads having a single tempered water supply that is controlled by an automatic compensating valve conforming to CSA B125.3, “Plumbing Fittings.”

3. Mixing valves that supply shower heads shall be of the pressure-balanced, thermostatic, or combination pressure-balanced/thermostatic type capable of maintaining a water outlet temperature that does not exceed 49°C, and limiting thermal shock.
4. The temperature of water discharging into a bathtub shall not exceed 49°C.

Temperature-sensitive aerators, showerheads, etc., are all aftermarket products that offer an excellent safety function for those systems that are not otherwise protected. However, these devices are not alternatives to the Code-required pressure balance or thermostatic mixing valves.

### Thermal expansion protection

When water is heated, its volume increases. This expansion often occurs when there is no simultaneous demand at the fixtures within the building. If a ‘nonreturn device (such as a backflow preventer, pressure reducing valve or check valve) is present in the cold water piping, the pressure in the building’s water distribution system can rise rapidly as the water is heated.

Although temperature and pressure (T&P) relief valves are installed on storage-type service water heaters to open if excessively high pressure occurs, it is not desirable for such valves to be constantly activated. Allowing water heaters to operate at excessively high pressures can create bursts of water and piping noise when a hot water fixture is first opened. It can also lead to leaks in fittings or valves, such as the T&P relief valve. The life expectancy of glass-lined water heaters can also be reduced by high pressure that causes flexing of the tank walls.

The BC Plumbing Code addresses the need for thermal expansion protection in the Notes to Part 2, A-2.6.1.11.(1). This Note states that to accommodate the increase in pressure caused by thermal expansion within a closed water distribution system, one of the following should be installed:

1. a suitably sized diaphragm expansion tank designed for use within a potable water system,
2. an auxiliary thermal expansion relief valve (T.E.R. valve) conforming to CSA B125.3, “Plumbing Fittings,” set at a pressure of 550 kPa or less and designed for repeated use, or
3. other means acceptable to the authority having jurisdiction.

Although there are options to relieve excess pressure from thermal expansion, such as ball valves and ball cocks with built-in T.E.R valves, installing a suitably sized potable water expansion tank is the preferred method of accommodating thermal expansion in the water distribution system. The thermal expansion tank should always be placed in the cold water piping supplying the water heater, and always downstream of any non-return valve or device. This placement ensures that the tank will always have direct access to the pressure in the service water heater.

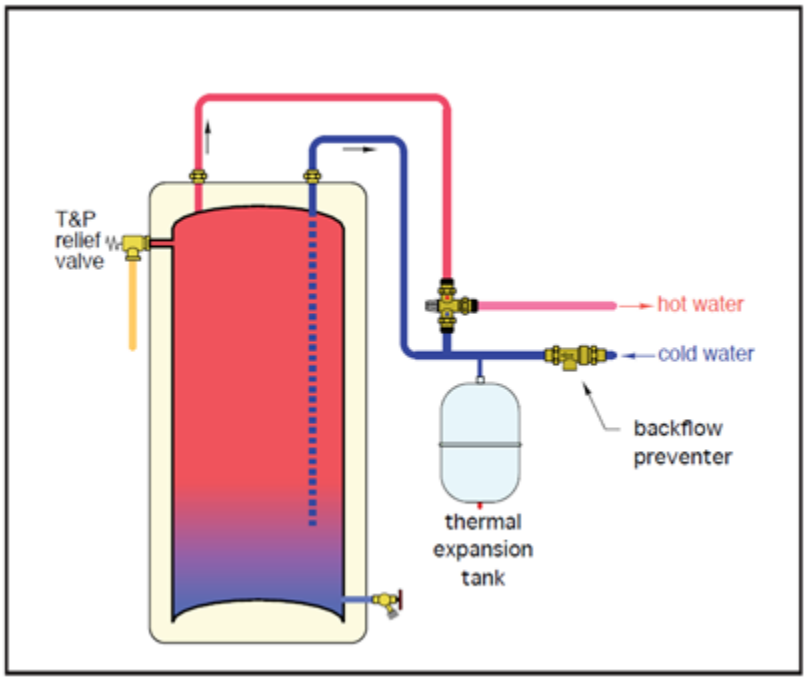



*Figure 32 The correct location of a potable water expansion tank*

Thermal expansion tanks for domestic water heating systems are similar to expansion tanks used in closed hydronic systems. They have a steel shell and flexible butyl diaphragm. The diaphragm separates a sealed chamber of air in the lower portion of the tank from the water contained in the upper portion of the tank. Thermal expansion tanks for domestic water systems also include a non-corrosive polypropylene liner that separates the steel shell from potable water in the upper portion of the tank.

As water expands, the increased volume is forced into the tank, compressing the air under the flexible diaphragm, as illustrated in the figure below. In a system with a properly sized tank, the increase in air pressure is such that the T&P relief valve does not open during each normal heating cycle.

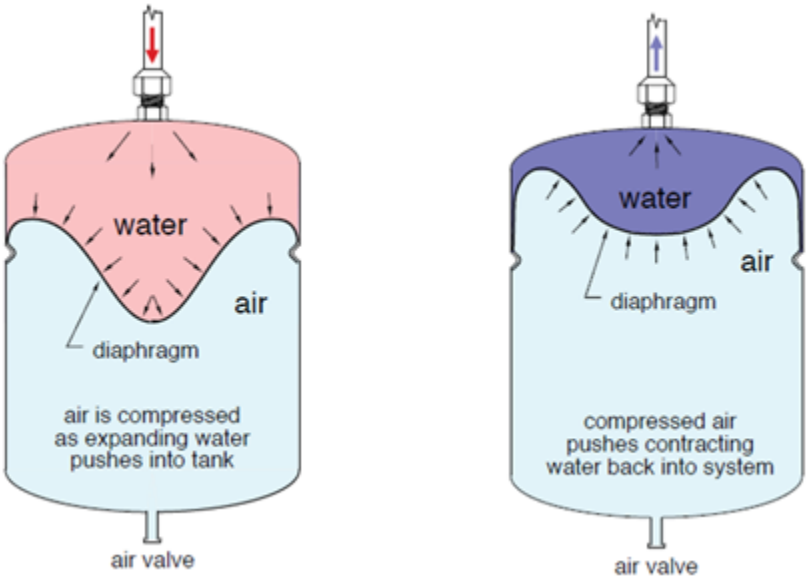



*Figure 33 Potable water expansion tank cycling*

During installation, the air side of the thermal expansion tank must always be pressurized to match the line water pressure at the water heater. This ensures that the diaphragm in the tank is fully expanded against the tank's shell before the water in the system expands. If the tank is underpressurized, a portion of its water side volume will fill with water before the water starts to expand. This needlessly wastes tank volume and reduces the tank's ability to moderate pressure fluctuations. The air pressure within the tank is adjusted by adding or removing air through the Schrader valve on the tank.

The minimum size of a potable water thermal expansion tank for a domestic potable water heating system can be determined using the equation below.

$$V_{min} = V_s \times \left[\frac{P_{max} + 14.7}{P_{max} - P_L}\right] \times \left[\frac{D_c}{D_H} - 1\right]$$

Where:

- $V_{min}$ = minimum total volume (not acceptance volume) of thermal expansion tank (US gallons)
- $V_s$ = total volume of heated water in system (US gallons)
- $P_{max}$ = maximum allowed pressure in water heater, usually the T&P rating (psi)
- $P_L$ = pressure in cold water line supplying water heater (psi)
- $D_C$ = density of cold water based on the figure below ($lb/ft^3$)
- $D_H$ = density of water at setpoint temperature based on the figure below ($lb/ft^3$)

The graph below shows the relationship between water density and the water temperature for use in the potable water expansion tank sizing equation.

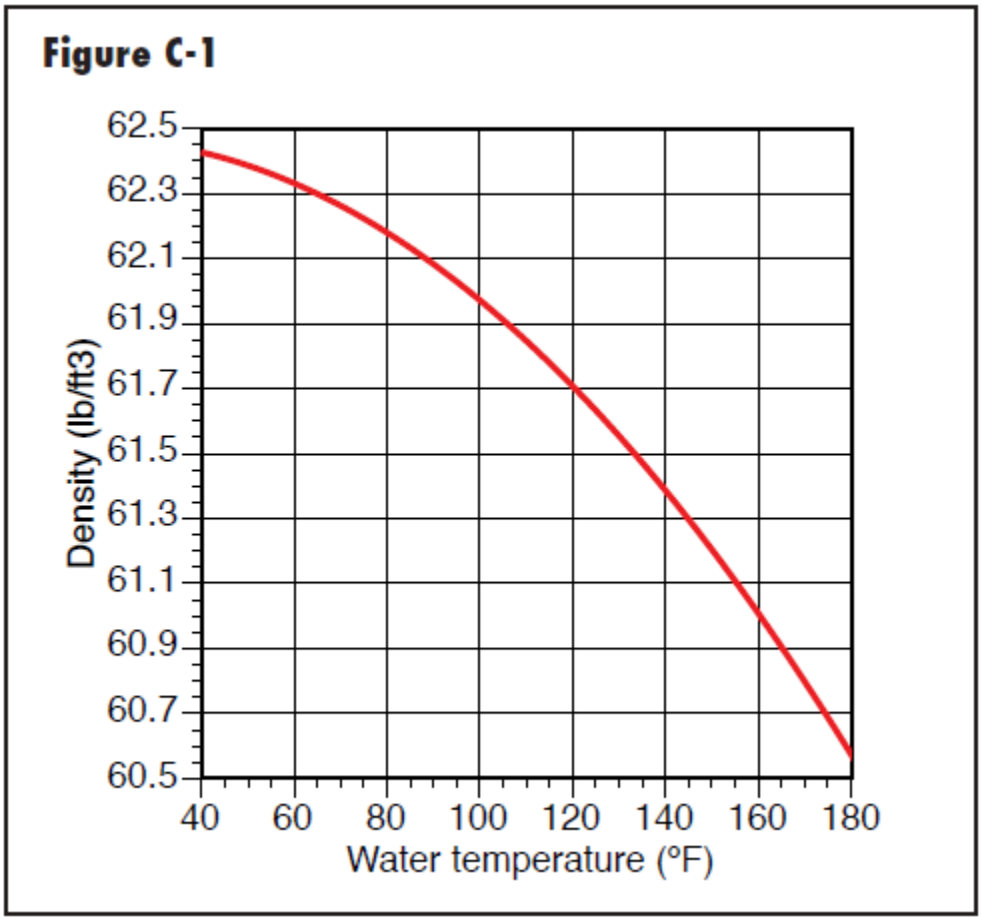



*Figure 35 Water density and the water temperature graph*

*Example of sizing a potable water expansion tank*

A plumber has decided to install an expansion tank on a system that contains 5 US gallons of water in the piping, and is using a 40 US gallon storage-type water service heater. The water enters the system at 40°F, but will be heated to 140°F. The T&P relief valve setpoint is 210°F. The water pressure has been reduced to 60 psi and the T&P relief valve setpoint is 150 psi. Determine the minimum size of thermal expansion tank required for the system.

**Solution:**

Enter all the information into the equation:

$$V_{min} = 45\text{US gallons} \times \left[\frac{150\text{ psi} + 14.7}{150\text{ psi} - 60\text{ psi}}\right] \times \left[\frac{62.43\text{ lb/ft}^3}{61.38\text{ lb/ft}^3} - 1\right]$$

Solve the equation:

$$V_{min} = 1.4\text{ US gallons}$$

Most manufacturers have online sizing tools available to ensure the plumber selects a potable water expansion tank that will meet or exceed the potable water distribution system needs.

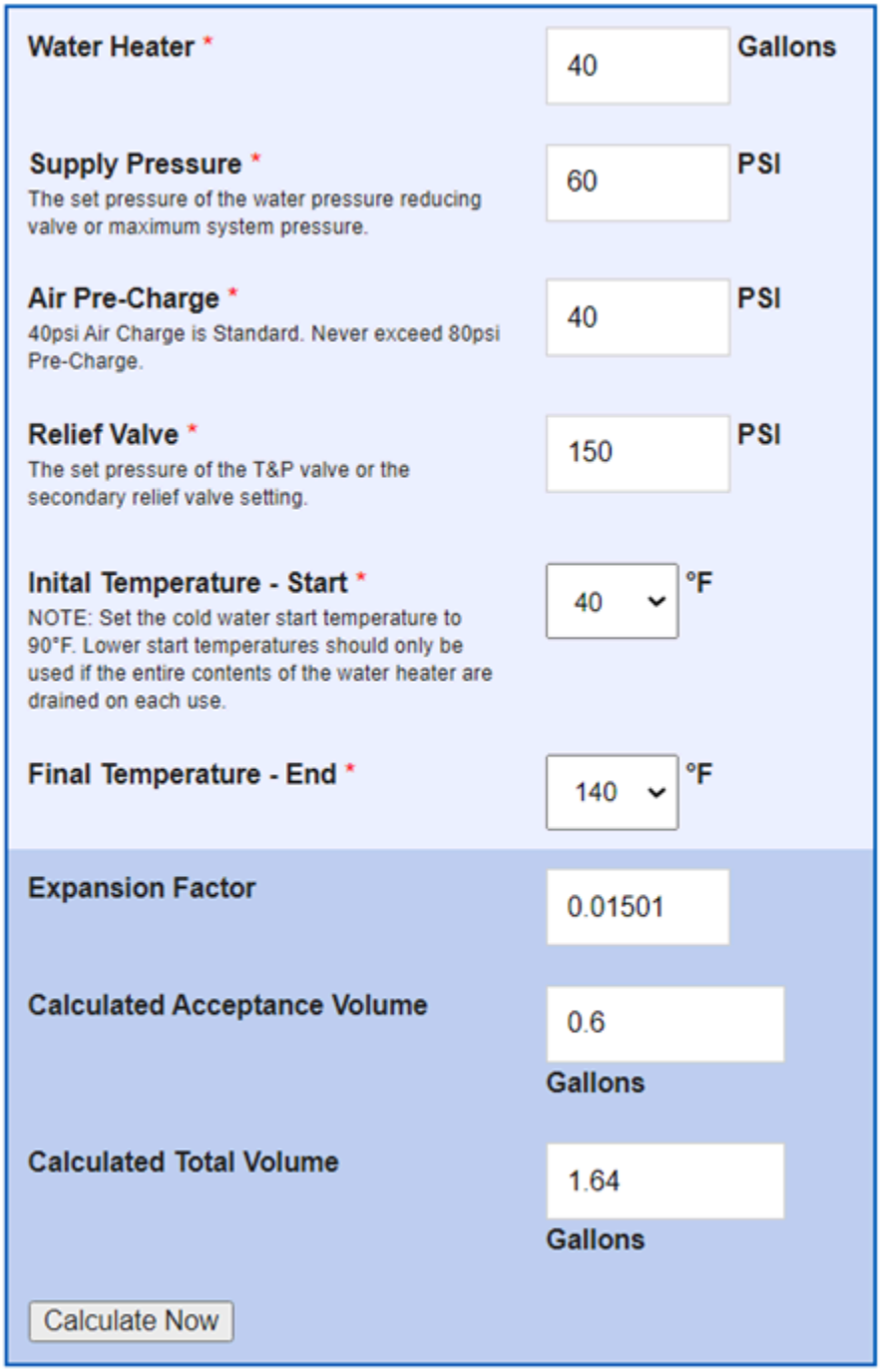



*Figure 36 Example of an online tool worksheet for the previous example*

Pressure tanks

Pressure tanks are virtually the same as potable water expansion tanks. The most significant difference between the two tanks is their functionality. An expansion tank handles potable water expansion and provides protection for water valves and heaters. A pressure tank lengthens the lifespan of a well pump. Pressure tanks, used on domestic water well systems, [JG1] are covered in the plumber level 4 content.

**Hot water recirculation**

The BC Plumbing Code Sentence 2.6.1.1.(2) requires that when there is a hot water distribution system of a developed length of more than 30m or supplying more than four storeys, the water temperature shall be maintained by recirculation or a self-regulating heat tracing system.

Although a self-regulating heat tracing system is an option, most installations will include a domestic hot water recirculation system (DHWR). Hot water recirculation systems work by circulating the water in the hot water distribution system back to the service water heater. This is done to ensure hot water is almost instantly available at every fixture that requires it, minimizing the waste of water while the user waits for hot water from the service water heater. For example, if a faucet was opened on a fixture that was 100 feet (30m) away from a service water heater, it could take 25 seconds or more to get hot water. This is based on the faucet not having a restricting aerator, the hot water travelling in copper pipe at the maximum velocity of 4 feet/sec, and the entire hot water distribution pipe has cooled to ambient temperature. Although this seems like an extreme case, low-flow aerators and other restrictions can create much longer wait times. A long wait for hot water at a remote fixture is a common occurrence in residential and ICI buildings. While the user waits for hot water, the fixture is flowing water to the building DWV system, essentially wasting water.

The ASHRAE Handbooks and ASPE Data Books mentioned in the BC Plumbing Code Sentence 2.6.3.1.(2) are good resources for the design and sizing of the cold and hot water distribution systems as well as the DHWR system. Most DHWR systems use a dedicated return line to allow the flow of water back to the service water heater. This additional pipe connects at one end to the downstream end of the hot water distribution system and the other end returns to the service water heater. The water can flow back to the water service heater by gravity if the system is designed correctly, but most systems use a pump to circulate the water. On complex systems, there may be several recirculation systems using multiple circulators. There are some retrofit systems for residential applications that do not have a dedicated return line but, instead, use the cold water distribution system to return water back to the service water heater.

Recirculation systems can be added to any system, including tankless water heaters. Some tankless heaters now have a recirculation system built in to them.

A simplified residential hot water recirculation system using a circulator pump is shown below. The dedicated return line is connected on one end as close as practical to the fixture furthest away from the service water heater, and the other end would connect at the domestic cold water inlet to the service water heater. Note the check valve installed in the dedicated return line to ensure the domestic cold water cannot “short-circuit” to the hot water distribution system.

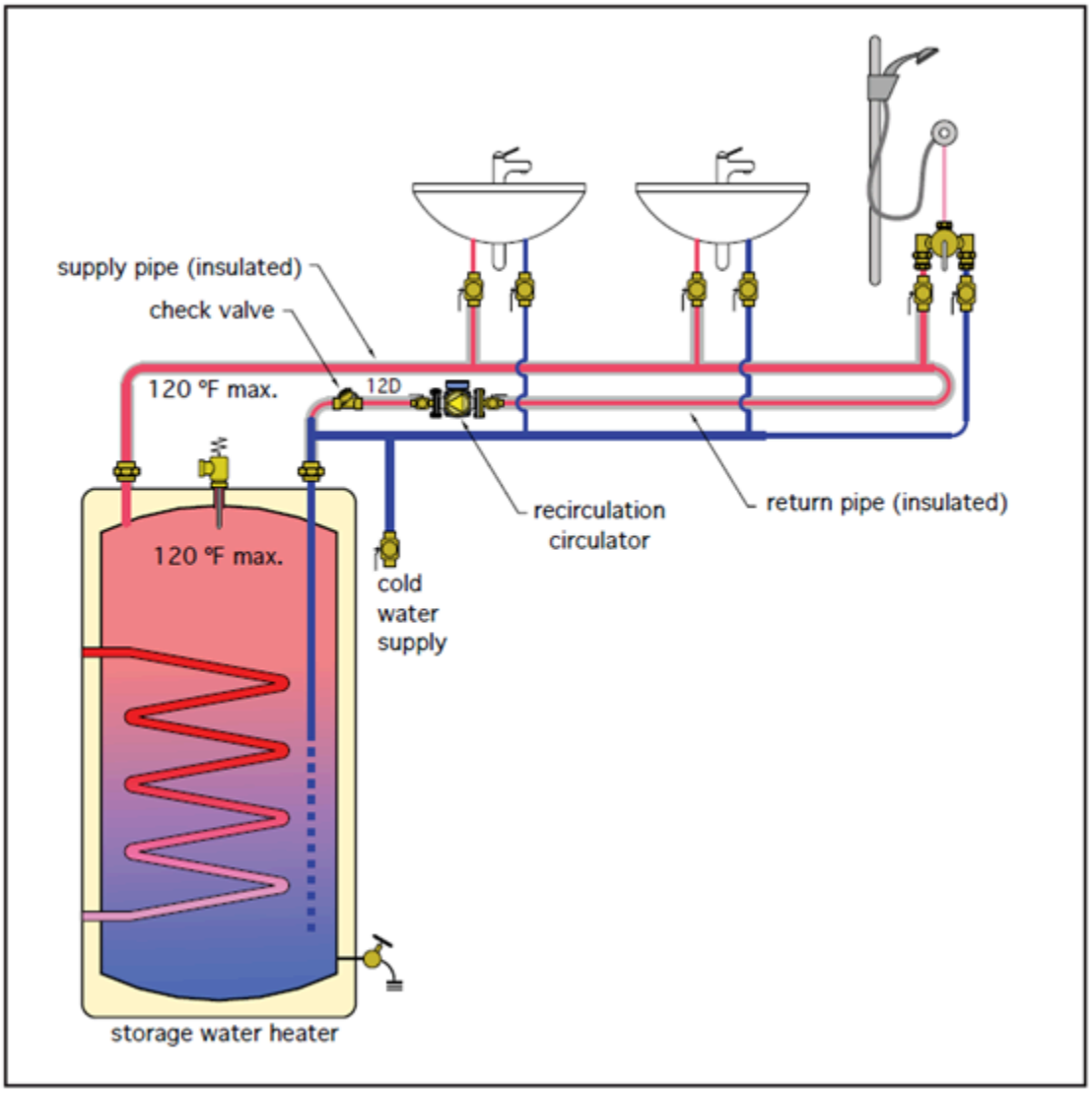



*Figure 37 Simplified water recirculation system for a residential distribution system*

Controlling hot water recirculation system

Hot water recirculation systems can run continuously, but most installations will activate the circulator pump using one of these methods:

- an aquastat to turn the pump on and off based on the water temperature
- a timer to circulate water during low use periods
- a motion-sensor to activate the circulator only when fixture usage is about to happen
- manually-activated to circulate water during low use periods.

Some manufacturers have integrated a timer and an aquastat in with the circulator pump. This method of installation will ensure maximum energy savings when both controlling limits – fluid temperature observed by the aquastat and the timer setting – are satisfied.

Hot water circulator pump selection

Since a domestic hot water recirculation system using a dedicated return line is essentially a closed-loop heating system, many of the same selection principles can be used when selecting a circulator pump for a hydronic heating system. Ideally, the circulator pump needs to keep the recirculated water at the design temperature using the smallest model available. If the circulator pump is undersized, the water will cool before being delivered to the fixture; if oversized, the velocity of the water could erode the pipe material.

Circulator pump selection is a complex undertaking, as the designer must account for the type of piping material, minimum and maximum water velocity based on water temperature, temperature difference between hot water and the surrounding air, head[JG1] losses of the piping and fittings, minimum and maximum flow rates to ensure hot water at the furthest fixture, etc. Ultimately, pumps are sized with two critical pieces of information: how much fluid you want to move (flow) in gallons per minute , and how much pressure you need to overcome, typically measured in feet of head.

Just as in hydronic design, there are many ways to design a system. Some designs are simple enough to use just one circulator, while other designs may need multiple circulators, or one circulator with balancing valves. Circulator pump manufacturers are good resources DHWR system design information. Most circulator manufacturers provide a DHWR pump sizing method, or online sizing tool, to help designers select the correct pump. The sizing method will use different graphs, charts, and formulas to help select the best circulator pump for the application.

The following example will go through a basic DHWR circulator pump selection process for a residential application. This example will use copper tubing as the piping material. The domestic hot water temperature will be 140°F and there will be no point-of-distribution mixing valve used at the water heater. If a point-of-distribution mixing valve is used, the designer will need to account for the extra head loss as well as the lower hot water temperature.

**Step 1: Decide if the copper hot water distribution piping will be insulated.**

The tables below show the advantage of insulating the water lines. For example, an uninsulated 3/4 inch copper tube at 70°F ΔT (ΔT is temperature differential between the hot water and the surrounding air) is 30 Btu/hr/ft of heat loss. An insulated ¾ inch copper tube at 70°F ΔT is approximately 10 Btu/hr/ft of heat loss. Lower heat loss will mean a smaller circulator pump can be selected.

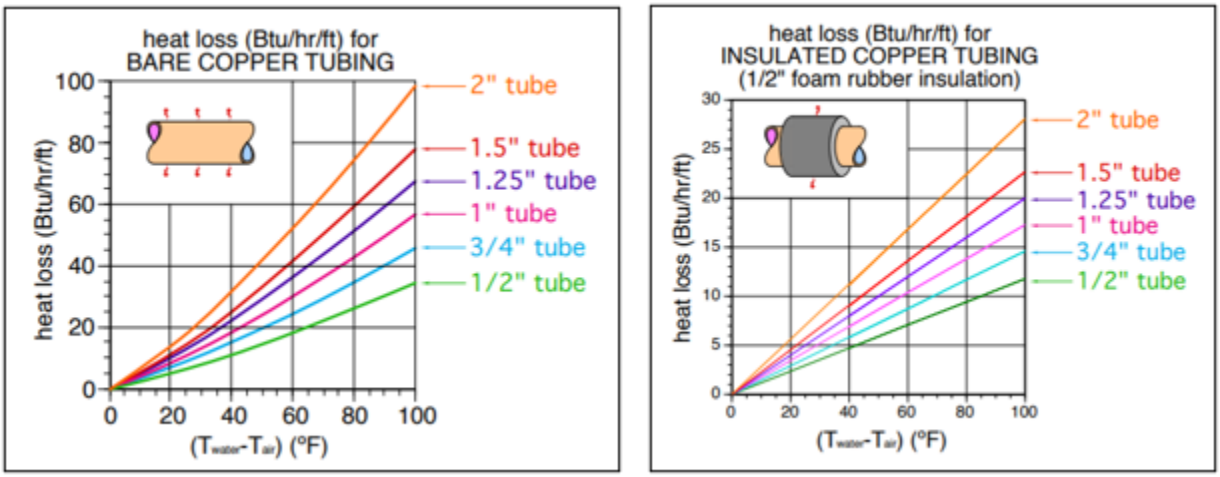



*Figure 38 Compare bare copper tube to insulated copper tube heat loss*

Note that the BC Building Code Sentence 9.36.4.4.(2) requires that all piping forming part of a ***continuously operating*** recirculating service water heating system shall be covered with piping insulation that is at least 12 mm thick.

For this example, insulated copper tube will be used.

**Step 2: Estimate of length of pipe from service water heater to furthest fixture.**

The dedicated return portion of the recirculation piping need not be considered, as that heat loss occurs after the last fixture and will not impact the supply water temperature.

For this example, a length of 50 feet from the service water heater to the furthest fixture will be used.

**Step 3: Calculate the heat loss of the 50 feet of tubing based on an estimated pipe size.**

This is done once the pipe sizing has been completed. Since pipe sizing will be done in the next Learning Task, this example will use ¾ inch copper tubing as the pipe size for all of the hot water distribution system, although it is likely that some downstream sections would be ½ inch copper tube.

Therefore, 50 feet of ¾ inch copper tube with a heat loss of 10 Btu/hr/ft will equal a total of 500 Btus of heat loss per hour.

**Step 4: Calculate the recirculation flow rate required to maintain hot water temperature at the most remote fixture.**

This is done using the universal hydronic formula shown below.

$$f_r = \frac{Q}{500 \times \text{delta-T}}$$

Where:

- $f_r$ = the required recirculation flow rate (USgpm)

- Q = total heat loss of the DHW supply piping (Btu/hr)
- delta-T = the design temperature drop (degrees F)

The formula requires an allowable temperature drop (delta-T). The temperature drop from the heating source to the most remote fixture that is commonly used is 10°F, the same as for residential hydronic heating systems. The constant 500 used in the formula is derived from the weight of a US gallon of water at 60°F multiplied by 60 minutes (8.33 x 60 = 500), and is used only when water is the fluid in the system.

Complete the calculation: **Flow rate = 500 Btu/hr ÷ (500 x 10OF)**

After completing the calculation, the required recirculation flow rate for this example is 0.1 USGPM.

**Step 5: Estimate the head loss of the recirculation loop.**

The pressure driving the water along the pipes is the head. [JG1] This pressure is opposed by the friction losses in the pipes, which can be thought of as the pressure-difference-per-foot needed to push the water along at the required flow rate. This can be done using a formula such as the Darcy-Weisbach equation or the Hazen-Williams equation, or can be estimated using a graph or chart. Many pipe manufacturers have online capacity and friction loss calculators. The calculation will need to consider the type of material, the velocity of the water, and the required flow.

The figure below shows a portion of a larger graph that could be used for selecting pipe sizes that do not exceed the maximum permitted velocity, as well as estimating friction loss. Graphs are usually specific to one material but can include several wall thickness choices.

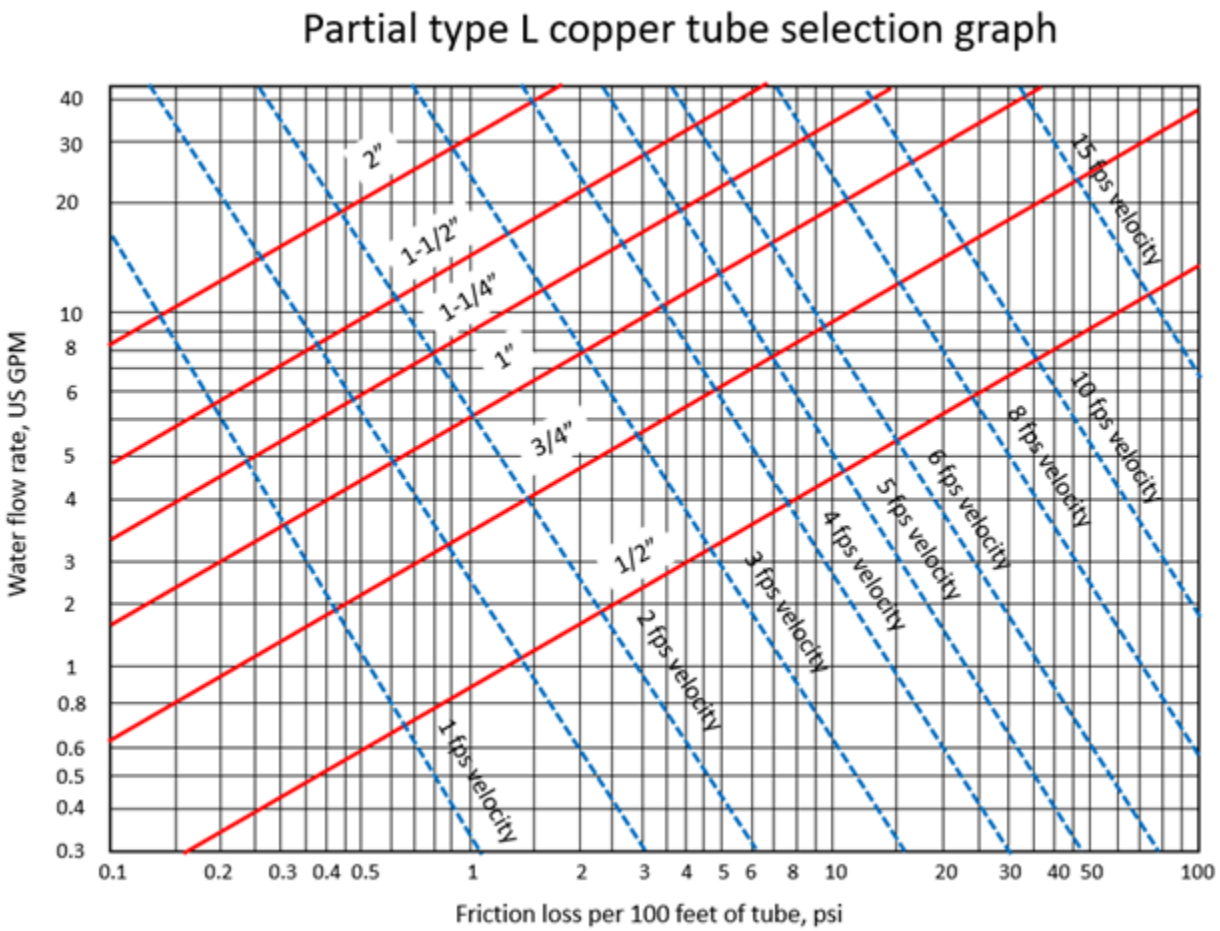



*Figure 39 Graph used for selecting type L copper tube*

Tables are also commonly developed as an alternative to using graphs. The graph above includes information on several pipe sizes of the same material, but the table below was developed using the Hazen-Williams formula just for type L copper tubing friction loss. Other tables would need to be developed for different types of copper, or different materials.

**Table 4 Type L copper tubing friction loss table (feet of head/100 feet)**

| **Flow rate GMP** | **½″** | **¾″** | **1″** | **1¼″** | **1½″** | **2″** |
|---|---|---|---|---|---|---|
| **0.1** | 0.028 | 0.005 | 0.001 | 0.001 | 0 | 0 |
| **0.2** | 0.094 | 0.017 | 0.005 | 0.002 | 0.001 | 0 |
| **0.3** | 0.191 | 0.035 | 0.010 | 0.004 | 0.002 | 0 |
| **0.4** | 0.315 | 0.059 | 0.017 | 0.006 | 0.003 | 0 |
| **0.5** | 0.466 | 0.087 | 0.025 | 0.010 | 0.004 | 0.001 |
| **1** | 1.568 | 0.291 | 0.083 | 0.032 | 0.014 | 0.004 |
| **2** | 5.273 | 0.979 | 0.281 | 0.108 | 0.048 | 0.013 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **3** | 10.720 | 1.991 | 0.571 | 0.219 | 0.099 | 0.027 |
| **4** | 17.735 | 3.295 | 0.944 | 0.362 | 0.163 | 0.044 |
| **5** | 26.207 | 4.868 | 1.396 | 0.525 | 0.241 | 0.065 |
| **10** | 88.149 | 16.375 | 4.694 | 1.799 | 0.811 | 0.220 |

Using the Type L copper tubing friction loss table above, the head loss due to friction per 100 feet of ¾ inch type L copper tube at the flow of 0.1 US GPM (from Step 4) would be 0.005 feet. Since this DHWR example has 100 feet of pipe, the head loss from the table can be used as-is. If the DHWR piping circuit was shorter or longer a calculation would be made to determine the proportional head loss.

The static head (or height of the system) does not need to be accommodated in the total head loss calculation, but friction loss of fittings does need to be addressed. Fitting friction loss can be calculated using the actual resistance of fittings and valves, expressed in equivalent length of straight pipe, using the manufacturer's literature. Alternatively, many designers use a rule-of-thumb method for fitting friction loss based on the type of material. The designer would typically add between 10% and 50% to the estimated friction loss for the piping.

In this example, a 50% fitting friction allowance will be added to the piping friction loss: **0.005 feet + 50% = 0.0075** feet of head of total equivalent friction loss.

**Step 6: Selecting the circulator pump.**

This pump selection example has a pumping requirement of 0.1 USGPM at 0.0075 feet. This is a very small pumping requirement that can be handled by a small circulator designed specifically for recirculation systems. The circulator can be selected using a pump performance curve. Most pump manufacturers provide a pump curve for every pump they make. Simply stated, a pump curve is a normally curved line drawn over a grid of vertical and horizontal lines to form a graph. The curved line represents the performance of a specific pump, while the gridlines provide units by which performance can be measured.

The figure below shows an example of a performance curve for a small pump that could be used as a circulator on the DHWR system for this example. The graph has two curves, showing the same model but with two different connection methods.

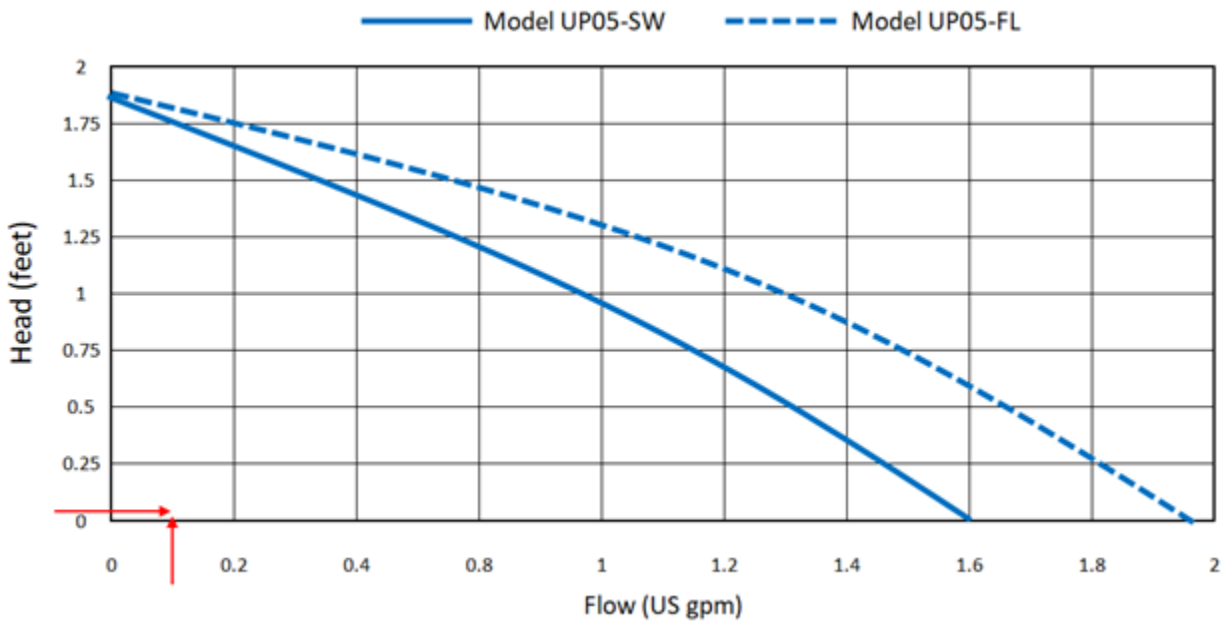



*Figure 40 Example of a circulator pump performance curve*

Using the flow rate of 0.1 USGPM and a total equivalent friction loss of 0.0075 feet of head, the calculated “duty point” of the circulator for this system can be determined. The duty point is where the flow rate and the head loss for the example intersect on the pump curve, shown by the arrows in the lower left of the graph. Since the duty point is under the pump curve, this pump could work for the example , but may be oversized.

*Confirm water velocity*

With so little friction loss to overcome, this pump is capable of easily meeting the flow rate required. Extending the arrow from the Head (feet) axis over to the pump curve for the UP05-SW model shows that the pump would be able to flow the maximum of approximately 1.6 GPM. With this amount of flow the maximum velocity for the piping material may be exceeded.

The velocity can be determined using the formula below:

$$V = \frac{Q}{A}$$

Where:

- V = Water velocity inside the pipe (feet per second)
- Q = Flow rate of water inside the pipe (cubic feet per second)
- A = Area of pipe inside diameter (square feet)

This formula works great when flow rate is measured in the cubic form of a standard length unit. But when flow rate is measured in gallons per minute an alternate version of the formula can be used.

Using the formula below, the velocity created by the pump must be confirmed to be under the maximum recommendation of 3 feet per second for the smallest pipe in the system.

$$V = \frac{(0.408)Q}{D^2}$$

Where:

- V = Water velocity inside the pipe (feet per second)
- Q = Flow rate of water inside the pipe (US GPM)
- D = Pipe inside diameter (inches)

For this example, the velocity in the 3/4 inch copper has been calculated to be 1.16 feet per second. This velocity is below the recommended 3 feet per second, so the circulator could be selected.

*Conclusion*

The circulator pump model has been determined for this example. The circulator pump body material must be approved for potable water applications. Brass, bronze, stainless steel, and some plastics can be used, but cast iron pump bodies are only used on non-potable systems like hydronic heating systems. Although the pump selected for this example was a single speed model, multi-speed and variable speed options are also available.

*Pump sizing challenges*

Sizing any pump is challenging. Pump selection is a function of pipework layout, affected by lengths of straight pipe and fittings. During the design phase of a project, the actual pipe route is unknown. When the system is actually installed the original estimated total equivalent friction loss may be inaccurate. This uncertainty can lead to an under-sized or over-sized circulator pump.

When a pump is undersized the system doesn’t get the required flow and doesn’t perform as designed. This can show up as long delays in waiting for hot water at faucets. Over-sizing, however, may not cause problems for several years. High velocity can cause noise but more importantly, copper pipes will develop pinhole leaks, most often at elbows and fittings. The pinhole leaks and wear on the inside diameter of copper piping is from turbulence and erosion-corrosion caused by the high velocity and can be complex and costly to repair.

One solution is to install variable speed pumps. Although not usually installed for domestic hot water recirculation due to their higher price tag, they would be able to run at just the right speed to provide the head and flow needed.

*DHWR systems in ICI buildings*

The figure below shows an example of a more complex DHWR design, employing one circulator pump but using balancing valves. It is imperative that these system designs are balanced to ensure that the water is recirculated equally from every riser. Several pump manufacturers offer online sizing tools to help design the DHWR recirculation system for ICI buildings.

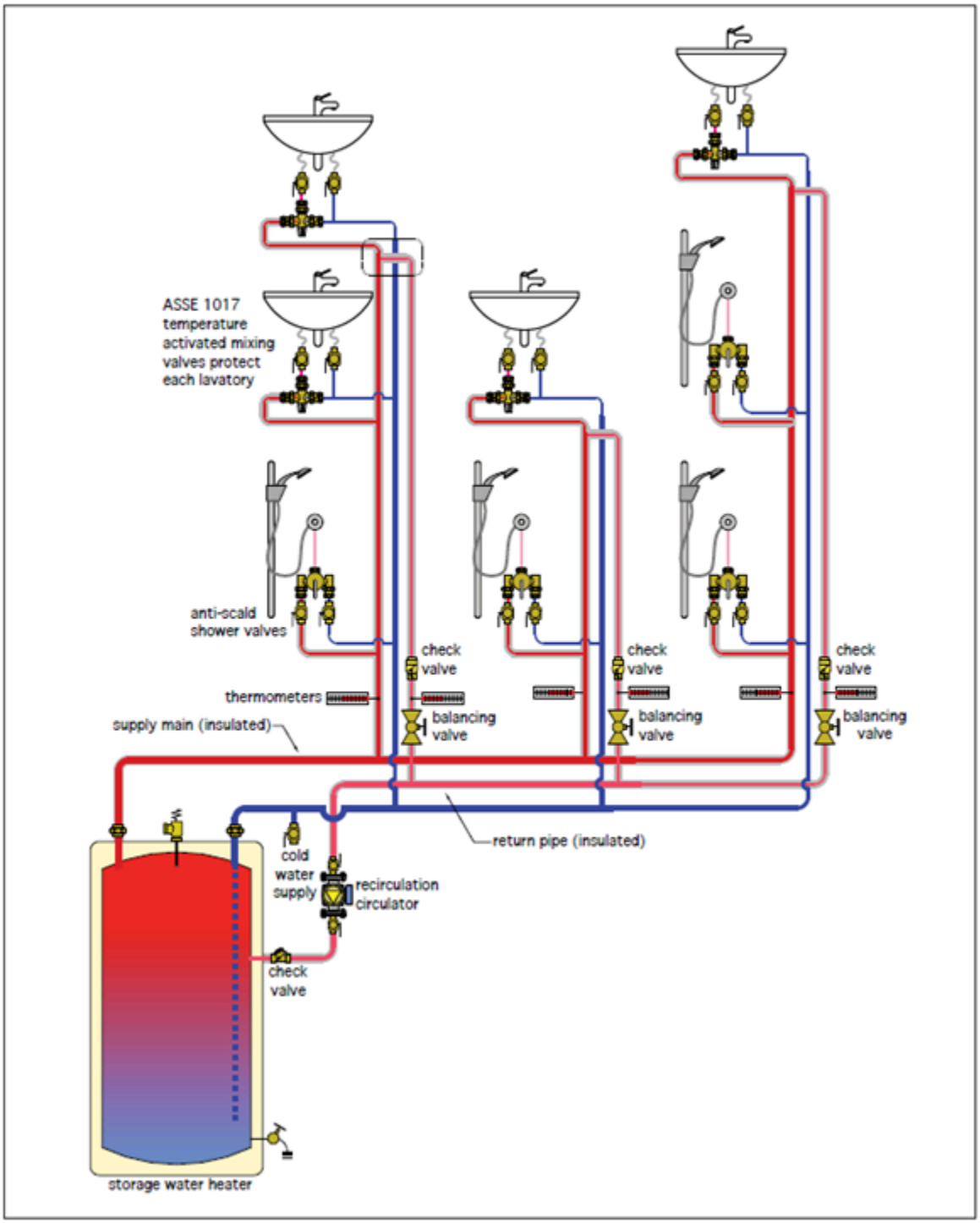



*Figure 41 DHWR system using balancing valves*

Now complete Self-Test 1 and check your answers.

## Self-Test 1

Self-Test 1

1. To protect a water meter from frost damage, where is the weak point located?
    a. Top
    b. Inlet
    c. Outlet
    d. Bottom
2. Which shut off valve is located on the water service, immediately inside the building?
    a. Curb cock
    b. Service valve
    c. Main stop and drain
    d. Corporation cock
3. Which water meter type is commonly used to measure and record small water flows?
    a. Turbine Meter
    b. Compound Meter
    c. Rotating disk meter
    d. Micro Compound Meter
4. When in use, what will happen to an anode rod that is located in a hot water storage heater?
    a. Increase in size when in use
    b. Stays the same size in use
    c. Decreases in size when in use
    d. Change electrical charge several times
5. What is the purpose of a service loop on a water service line?
    a. To increase the depth of the water service
    b. To decrease the depth of the water service
    c. To provide adequate room to mount the water meter
    d. To allow for settlement or movement of the water main
6. When does the Code require that a check valve be installed on a water service pipe?
    a. When the water service is subject to backflow

b. Check valves are never required on a water service
c. Any time the water service is more than 3 ft below grade
d. When the water service pipe is rated for cold-water only

7. “A water pipe that passes through one or more storeys” is definition of:

a. Main
b. Riser
c. Trunk
d. Branch

8. Shower valves must be pressure balanced, thermostatic-mixing, or controlled by a master thermostatic-mixing valve.

a. True
b. False

9. What is a direct fired hot water heater?

a. The heating source is located at the hot water storage tank
b. A heat exchanger is inserted in the hot water storage tank
c. A remote heating source heats the hot water storage tank
d. A converter is inserted in the hot water storage tank

10. Where should the downstream end of the domestic hot water recirculation line be connected?

a. At the nearest cold faucet to the storage tank
b. At the branch line leading to the closest hot water fixture
c. Near the hot water outlet at the top of the storage tank
d. To the cold water inlet to the storage tank, or to the bottom inlet of the tank

11. To ensure equal flow in all circuits of a re-circulation system, what devices are installed?

a. Check valves
b. Balancing valves
c. Booster pumps
d. Flow inducing valves

12. Circulation pumps on potable water systems must be what type?

a. Bronze body
b. Cast iron body
c. Aluminum body
d. Galvanized body

13. What is the recommended minimum required water temperature for domestic hot water storage?

a. 50 °C
b. 60 °C
c. 70 °C
d. 80 °C

14. According to the NPC, systems for solar heating of potable water shall be installed in conformance with which standard?

a. CSA F378
b. CSA F379
c. CSA F383
d. CSA F390

Check your answers using the Self-Test Answer Keys in Appendix 1.

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# Learning Task 2

Describe Sizing for the Building Water Supply System

The proper sizing and installation of potable water distribution systems in residential and small commercial applications is critical to proper operation of the plumbing fixtures and equipment installed within the building. The potable water system must be capable of meeting the ***peak water supply demands*** of the connected fixtures and appliances. Each fixture or appliance requires a ***minimum supply pressure*** and ***flow rate***; if the system fails to maintain these conditions, the fixture or appliance may not adequately perform its intended function. An undersized cold water pipe to a washroom group of fixtures could lead to an excessive ***pressure drop*** upon operation of a water closet, which could lead to an adjacent shower valve suddenly being starved of cold water, which could lead to scalding. Similarly, an excessive pressure drop due to flow to other fixtures could lead to a flush valve fixture failing to function properly.

## Terminology

### Peak Water Supply Demands

Each fixture, device, or appliance is given a fixture unit value, referred to as a water supply fixture unit to differentiate from DWV fixture units. The peak demand flow is the total of all the fixture unit values if all fixtures were used at once, including any additional load for a fire sprinkler system, irrigation system or any other demands on water service.

### Minimum Supply Pressure

Every building water distribution system will have one fixture that requires more pressure than the others to operate correctly. This fixture is referred to as the “governing fixture.” The BCPC Sentence 2.6.3.1. (1) states that the “water distribution systems shall be designed to provide peak demand flow when the flow pressures at the supply openings conform to the plumbing supply fitting manufacturer’s specifications.” This means that the plumber must determine the minimum pressure required for the governing fixture by using the manufacturer’s specifications.

In past BC Plumbing Codes, the minimum pressure for common fixtures was listed on Table 2.6.3.2.-A along with the fixture unit load. In previous codes, fixtures such as clothes washers, dishwashers and direct flush valves required a minimum flow pressure of 15 psi (approximately 105 kPa) at the fixture to operate properly. Therefore, when the manufacturer’s specifications cannot be used – because the make and model of the fixture are unknown, for example – the plumber should still use 15 psi (approximately 105 kPa) when calculating water pipe sizing.

## Pressure Drop

Pressure drop in a water supply system is difference between pressure at the upstream end of a pipe and the pressure delivered to a fixture of device. Pressure loss will occur in water pipe due several factors, including:

- The type of pipe material
- The age of the pipe
- The size of the pipe
- The number and type of fittings
- The velocity of the water
- The temperature of the water

Pressure drop is pressure loss due to friction, or friction loss, and is anticipated by designers and can be accommodated in the pipe sizing process. Although friction loss was previously discussed during the selection of circulator pumps for DHWR systems, it will be covered again as the size of water supply piping is dependent on the friction created by the piping material. For example, water flowing through a relatively large, smooth pipe at low velocity has laminar, or a smooth, streamlined flow. At the other extreme, when the pipe is small in diameter with a rough interior, and the velocity of the water is high, the flow is turbulent. Laminar flow produces little friction, while turbulent flow can produce considerable friction.

Friction loss in water piping is also referred to as head loss due to the fact that the friction loss is equated to the loss of pressure measured in feet [JG1] per 100 feet of piping material being used. It is important to note that flow rates substantially increase the head loss within the piping system. Head loss or friction loss increases as pipe ages and internal wall conditions of the piping material change.

## Flow Rate

Flow rate is the volume of water delivered to a fixture of device. Flow rate is dependent on water velocity and the size of the pipe. The following formula shows the relationship between flow rate, pipe size and water velocity.

$Q = A \times V$

Where:

- Q = Quantity (flow rate in cubic feet per sec)
- A = Area of the pipe in square feet (this is the size of the pipe)
- V = Velocity of the water in feet per sec.

A steady rate of flow means that equal quantities of water flow past every point in the system during a given period of time. This means that in a water distribution system design using larger pipes upstream, and smaller pipes as the fixture unit load decreases, the velocity of the water in the pipes will be

different. To have the same amount of water flow through a small pipe as through a larger pipe in the same length of time, the velocity will have to increase. The designer needs to ensure the velocity of the water in the piping system does not exceed the manufacturer's limits. The maximum velocity will be different for different materials, as well as for different water temperatures.

#### Water conservation

The BC Plumbing Code lists the maximum flow rates for lavatory supply fittings, kitchen supply fittings, and shower heads in Table 2.2.10.6. Water usage per flush cycle for water closets is listed in Table 2.6.1.6 of the BCPC. Many municipalities have chosen to introduce their own water conservation bylaws and require more restrictive water use measures. Different building construction methods such as LEED, Passive House Design, BC Step Code also require more restrictive water use.

## Water Velocity

Since the BC Plumbing Code Sentence 2.6.3.5. (1) simply states that the maximum permitted water velocities shall be those recommended by the pipe and fitting manufacturer, the table below has been compiled to show the water velocity limits for common water distribution system materials.

#### Recommended water velocity limits for common water distribution system materials

**Table 1a Recommended water velocity limits for PEX (Aquapex®)**

| **Temperature** | **Maximum velocity (meters per second/feet per second)** |
|---|---|
| COLD (unheated) | 3.0 mps/10 fps |
| HOT up to and including 140°F (60°C) | 2.4 mps/8 fps |
| HOT above 140°F (60°C) | 1.5 mps/5 fps |
| DHW Recirculation system (recommended) | 0.6 mps/2 fps |

**Table 1b Recommended water velocity limits for Copper**

| **Temperature** | **Maximum velocity (meters per second/feet per second)** |
|---|---|
| COLD (unheated) | 2.4 mps/8 fps |
| HOT up to and including 140°F (60°C) | 1.5 mps/5 fps |
| HOT above 140°F (60°C) | 0.9 – 1.2 mps/3 – 4 fps |
| DHW Recirculation system (recommended) | 0.6 mps/2 fps |

**Table 1c Recommended water velocity limits for CPVC (Aquarise®)**

| Temperature | Maximum velocity (meters per second/feet per second) |
|---|---|
| COLD (unheated) | 2.4 mps/8 fps |
| HOT up to and including 140°F (60°C) | 2.4 mps/8 fps |
| HOT above 140°F (60°C) | 2.4 mps/8 fps |

**Table 1d Recommended water velocity limits for PP (Aquatherm®) ½ to 8 inch sizes**

| Temperature | Maximum velocity (meters per second/feet per second) |
|---|---|
| COLD (unheated) | 2.4 mps/8 fps |
| HOT up to and including 140°F (60°C) | 2.4 mps/8 fps |
| HOT above 140°F (60°C) | 2.4 mps/8 fps |

**Table 1e Recommended water velocity limits for stainless steel and Ductile iron (all temperatures)**

| Material | Maximum velocity (meters per second/feet per second) |
|---|---|
| Stainless steel | 2.0 mps/6.5 fps |
| Ductile iron | 4.3 mps/14 fps |

## Building Water Supply System Design Considerations

The BCPC Subsection 2.6.3. Size and Capacity of Pipes introduces the designer to some important information regarding pipe sizing for potable water service pipes and water distribution systems.

Of particular importance is Sentence 2.6.3.1.(2), which states that “potable water systems shall be designed, fabricated and installed in accordance with good engineering practice, such as that described in the ASHRAE Handbooks and ASPE Data Books.” This Sentence refers to Note A-2.6.3.1.(2) in the Notes to Part 2. The Note lists several documents that are considered good engineering practice in the field of potable water systems, but adds an alternative method. The alternative to a detailed engineering design method is to use Table A-2.6.3.1.(2)-A (Small Commercial Building Method) and Table A-2.6.3.1.(2)-F (Average Pressure Loss Method).

The BCPC allows for another method of pipe sizing described in Sentence 2.6.3.4.(5), which states: “Where both hot and cold water is supplied to fixtures in residential buildings containing one or two dwelling units or row houses with separate water service pipes, the water system may be sized in accordance with Table 2.6.3.4.”

Interpreting this information, it can be concluded the BCPC allows for four methods of sizing the building water supply system:

- Simplified method for buildings containing one or two dwelling units or row houses with separate water services
- Small commercial building method
- Average pressure loss method
- Detailed engineering design method

Each of these methods has a similar process to go through to come up with the minimum pipe size for each section of a water supply system. Depending on the building type, the plumber could use any of the methods, but is unlikely to use the detailed engineering design. The detailed engineering design method allows designers like engineers to use design standards that aren't readily available to a plumber. To help plumbers use the sizing methods in the BCPC, the Notes to Part 2 section goes through a sizing example for each method.

- Note A-2.6.3.1.(2) goes through the Method for Small Commercial Buildings', as well as the Average Pressure Loss Method.
- Note A-2.6.3.4.(5) covers sizing using the simplified method

Information to help understand water supply system pipe sizing diagrams and drawings is required. The topics on the list below will be explained in more detail in this section.

- Common abbreviations and terminology used on water pipe sizing diagrams
- BC Plumbing Code Table 2.6.3.2.-A
    - Water supply fixture unit definition
    - Fixture or Device column
    - Minimum Size of Supply Pipe, inches
    - Private Use Hydraulic Load, fixture units and Public Use Hydraulic Load, fixture units
    - Cold, Hot, Total columns
- Direct flush valve WSFU values
- Table 2.6.3.2.-D
- Developed length
- Pressure loss/gain due to elevation
- Pressure loss due to friction
- Minimum pressure required
- Maximum design velocity for piping material

## Common Abbreviations and Terminology Used on Diagrams

**WSP** – for the Water Service Pipe. This pipe conveys water from a public or private water system into the building.

**WDP** – for the Water Distribution Pipe. This pipe conveys water from the WSP to the fixtures or devices. These pipes can be further described by the abbreviation **HWDP** for hot water piping, and **CWDP** for cold water piping.

**SP –** for Supply Pipe. This pipe is part of the water distribution system that supplies a single fixture. This is the WDP that usually protrudes through the floor or wall, and to which a shut-off valve or tail piece adapter is attached.

**Tailpiece or Connector** – This component is a flexible connector that conveys water from the Supply Pipe to the fixture

**Common fixture abbreviations:**

- BT = Bathtub
- CW – Clothes Washer
- DW = Dish Washer
- FU = Fixture Unit
- HB = hose bibb
- HWH = Hot Water Heater
- KS = Kitchen Sink
- Lav = Lavatory
- LT = Laundry Tray
- FTWC = Flush Tank Water Closet

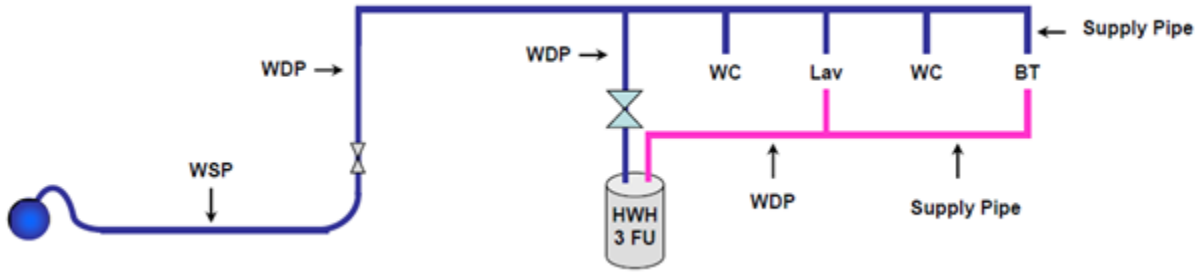



*Figure 1 An example of a simple piping layout using some common abbreviations*

## BC Plumbing Code Table 2.6.3.2.-A

Plumbers and building water supply system designers need to determine the quantity of potable water that will be used by each fixture or device that is installed in the building. The BCPC Table 2.6.3.2.-A,

Sizing of Water Distribution Systems, is an extensive list of fixtures and devices that require domestic water. To use the table, the plumber needs to interpret the column headings correctly to ensure the correct WSFU value is selected. The table headings and table values are described here.

#### Water supply fixture unit (WSFU)

The Code defines a fixture unit (as applying to water distribution systems) as the unit of measure based on the rate of supply, time of operation and frequency of use of a fixture or outlet that expresses the hydraulic load that is imposed by that fixture or outlet on the supply system. Since the term fixture unit is also used in the DWV system, the abbreviation WSFU is commonly used to indicate water supply fixture units.

The purpose of having fixture units is to ensure that every designer using the BC Plumbing Code for water supply system pipe sizing is using the same values for fixtures or devices. This will reduce the probability of inappropriate assumptions regarding hydraulic loads, which reduces the probability of undersized water supply system piping.

Table 2.6.3.2.-A is used to determine the WSFU load for most fixtures and devices. However, a note located below the table, refers the designer to Table 2.6.3.2.-D. for fixtures not indicated in Table 2.6.3.2.-A. Using these two tables, it is possible to come up with a WSFU load for almost every fixture or device.

#### Fixture or device

A fixture is defined in the BCPC as a receptacle, appliance, apparatus or other device that discharges sewage or clear-water waste and includes a floor drain, while a device is defined as a piece of equipment or a mechanism designed to serve a special purpose or perform a special function

Most fixtures and devices that use potable water are listed on BCPC Table 2.6.3.2.-A. Some fixtures have different designs that change their WSFU value, so will have multiple rows on the table. An example of a fixture with multiple rows is a sink:

- Sink, bar
- Sink, clinic service faucet
- Sink, clinic service wit h direct flush valve
- Sink, kitchen commercial, per faucet
- Sink, kitchen domestic, 8.3 LPM
- Sink, kitchen domestic, greater than 8.3 LPM
- Sink, laboratory
- Sink, laundry (1 or 2 compartments)
- Sink, service or mop basin
- Sink, washup

The plumber or designer needs to accurately determine the design of fixtures to ensure the correct WSFU value is selected from the table.

Note that the “Bathroom Group” (BG) fixture load options on Table 2.6.3.2.-A may be acceptable, but adds complexity to design. When using the BG WSFU loads, it is important to know that the value on the table is based on a ½-inch size bathtub supply pipe. If a bathtub with a larger load is installed, the BG load may not work. Also, the three standard fixtures that make up a BG are a water closet, lavatory and bathtub. If an additional fixture is installed so there are more than the three standard fixtures, the additional fixture load must be added to the bathroom group.

Note that the hydraulic load of urinals and water closets with direct flush valves shall be the number of fixture units listed in Tables 2.6.3.2.-B and 2.6.3.2.-C. of the BCPC. There is an example of these tables and interpreting the decreasing values later in this content.

#### Minimum size of supply pipe, inches

A supply pipe is the water distribution pipe that delivers water to only one fixture or device. Table 2.6.3.2.-A lists the size of the supply pipe for individual fixtures or devices, even allowing $\frac{3}{8}$ inch size for some. The table uses inside diameter (ID) sizes which means the $\frac{3}{8}$ inch pipe listed is actually $\frac{1}{2}$ inch outside diameter (OD). This size pipe is not a common pipe size for plumbers. The smallest diameter commonly used for water distribution systems is $\frac{5}{8}$ inch OD, which plumbers refer to as $\frac{1}{2}$ inch copper pipe.

#### Private use hydraulic load, fixture units and public use hydraulic load, fixture units

The table uses the terms “private use” and “public use” fixtures to differentiate between the type of use in different buildings. This means the plumber must decide which column to use when determining WSFU values.

- Private use means fixtures in residences and apartments, in private bathrooms of hotels, and in similar installations in other buildings for one family or an individual.
- Public use means fixtures in general washrooms of schools, gymnasiums, hotels, bars, public comfort stations and other installations where fixtures are installed so that their use is unrestricted.

#### Cold, hot, total columns

Fixtures can be supplied by cold water only, such as water closets and urinals, or can be supplied by hot water only, such as dishwashers, but many fixtures are supplied by both cold and hot water. The table has separate columns for cold and hot WSFU values, but these columns are only used when completing a detailed engineering design method. Plumbers will therefore only use the column indicating the total WSFU value for each fixture.

The plumber must not combine the WSFU load from the cold with the WSFU load from the hot as this

would “double count” the WSFU load. The combined load at the fixture or device is determined by the maximum load at the spout, or the opening the water flows through at the fixture or device.

An example of the WSFU load for a public use lavatory, with greater than 8.3 LPM of flow, is shown in the figure below.

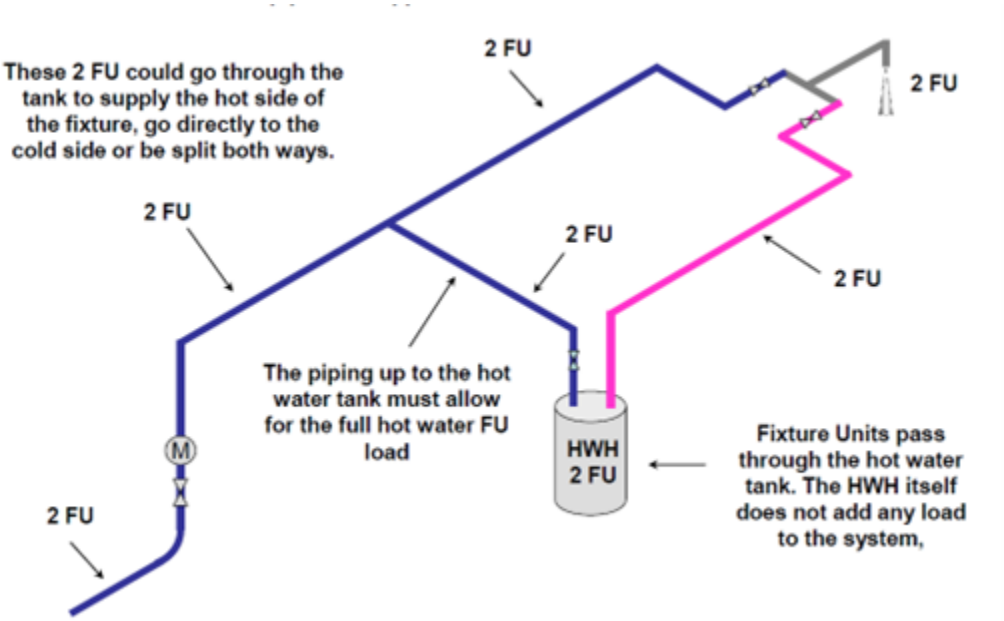



*Figure 2 TOTAL fixture load at the fixture spout*

For this example, if only the cold water was turned on the spout would allow 2 WSFU of flow, and if only the hot water was turned on the spout would allow 2 WSFU of flow. If both the cold and hot water were turned on the spout would still only allow 2 WSFU of flow, some from the cold and some from the hot.

An example of a simple building water distribution system is shown below. The sketch shows the piping layout and the location of the fixtures, while labels indicate the type of fixture. A separate legend gives more information on the fixtures and devices to help with the use of Table 2.6.3.2.-A when determining WSFU loads for fixtures and combined pipes.

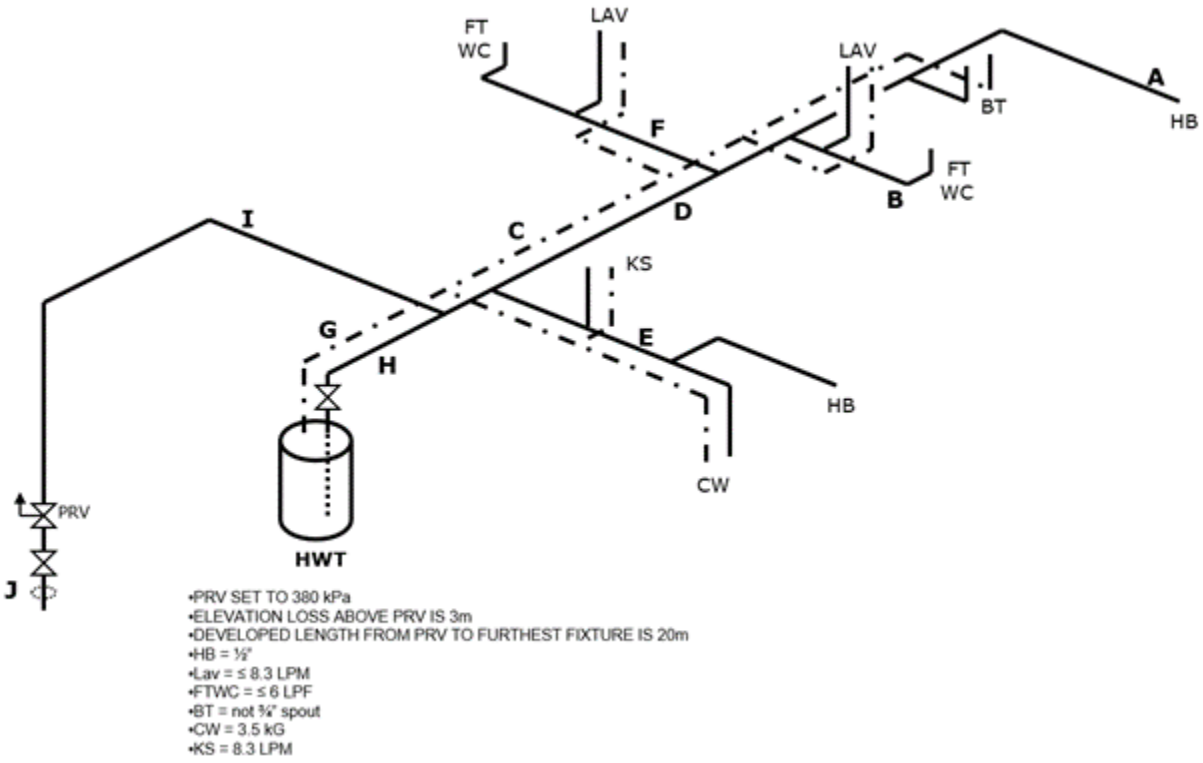



*Figure 3 Simple building water distribution system sketch*

The table below, based on the example sketch above, shows the decisions a plumber would need to make when selecting fixtures and deciding on WSFU values.

**Table 2**

| **Abbreviation on sketch** | **Fixture or device description** | **Minimum size of supply pipe, inches** | **Private Use Hydraulic Load, fixture units** ~~**Public Use Hydraulic Load, fixture units**~~ | | |
|---|---|---|---|---|---|
| | | | **Cold** | **Hot** | **Total** |
| BT | Bathtub with or without shower head ~~Bathtub with ¼ inch spout~~ | ½ inch ID | | | 1.4 |
| CW | Clothes Washer 3.5 kg ~~Clothes washer 6.8 kg~~ ~~Clothes washer, commercial~~ | ½ inch ID | | | 1.4 |
| FTWC | Water closet, 6 LPF or less with flush tank ~~Water closet, greater than 6 LPF with flush tank~~ ~~Water closet, with direct flush valve~~ | $\frac{3}{8}$ inch ID | | | 2.2 |
| HB | Hose Bibb ½ inch ~~Hose Bibb ¾ inch~~ ~~Hose bibb, combination hot and cold~~ | ½ inch ID | | | 2.5 |

| | | | | | |
|---|---|---|---|---|---|
| HWT | Hot Water Tank | | WSFUs pass through the tank, but do not add any load to the system. | | |
| KS | ~~Sink, kitchen commercial, per faucet~~<br>Sink, kitchen domestic, 8.3 LPM<br>~~Sink, kitchen domestic, greater than 8.3 LPM~~ | $\frac{3}{8}$ inch ID | | | 1.4 |
| LAV | Lavatory, 8.3 LPM or less<br>~~Lavatory, greater than 8.3 LPM~~ | $\frac{3}{8}$ inch ID | | | 0.7 |

| Abbreviation on sketch | Fixture or device description | Minimum size of supply pipe, inches | Private Use Hydraulic Load, fixture units | | | ~~Public Use Hydraulic Load, fixture units~~ | | |
|---|---|---|---|---|---|---|---|---|
| | | | Cold | Hot | Total | Cold | Hot | Total |
| BT | Bathtub with or without shower head<br>~~Bathtub with ¾ inch spout~~ | 1/2 inch ID | | | 1.4 | | | |
| CW | Clothes Washer 3.5 kg<br>~~Clothes washer 6.8 kg~~<br>~~Clothes washer, commercial~~ | 1/2 inch ID | | | 1.4 | | | |
| FTWC | Water closet, 6 LPF or less with flush tank<br>~~Water closet, greater than 6 LPF with flush tank~~<br>~~Water closet, with direct flush valve~~ | 3/8 inch ID | | | 2.2 | | | |
| HB | Hose Bibb 1/2 inch<br>~~Hose Bibb 3/4 inch~~<br>~~Hose bibb, combination hot and cold~~ | 1/2 inch ID | | | 2.5 | | | |
| HWT | Hot Water Tank | | WSFUs pass through the tank, but do not add any load to the system. | | | | | |
| KS | ~~Sink, kitchen commercial, per faucet~~<br>Sink, kitchen domestic, 8.3 LPM<br>~~Sink, kitchen domestic, greater than 8.3 LPM~~ | 3/8 inch ID | | | 1.4 | | | |
| LAV | Lavatory, 8.3 LPM or less<br>~~Lavatory, greater than 8.3 LPM~~ | 3/8 inch ID | | | 0.7 | | | |

**Direct flush valve WSFU values**

Water closets can be designed to use a flush tank or a direct flush valve, and urinals are designed to use a direct flush valve in almost every case. Direct flush valves require a significant flow of water to create the flushing and cleaning action they perform in the few seconds they are open. For example, this means that the minimum supply line size of a direct flush valve WC is larger than the supply line for a tank-type WC, as shown on BCPC Table 2.6.3.2.-A.

The BCPC Code has two separate tables to help plumbers design a water distribution system that includes direct flush valves. Table 2.6.3.2.-B is titled “Sizing of Water Distribution Systems for Urinals with Direct Flush Valves” and Table 2.6.3.2.-C is titled “Sizing of Water Distribution Systems for Water Closets with Direct Flush Valves”.

The figure below is a piping system sketch showing an interpretation of decreasing values from Table

2.6.3.2.-B for urinals with direct flush valves and Table 2.6.3.2.-C for water closets with direct flush valves.

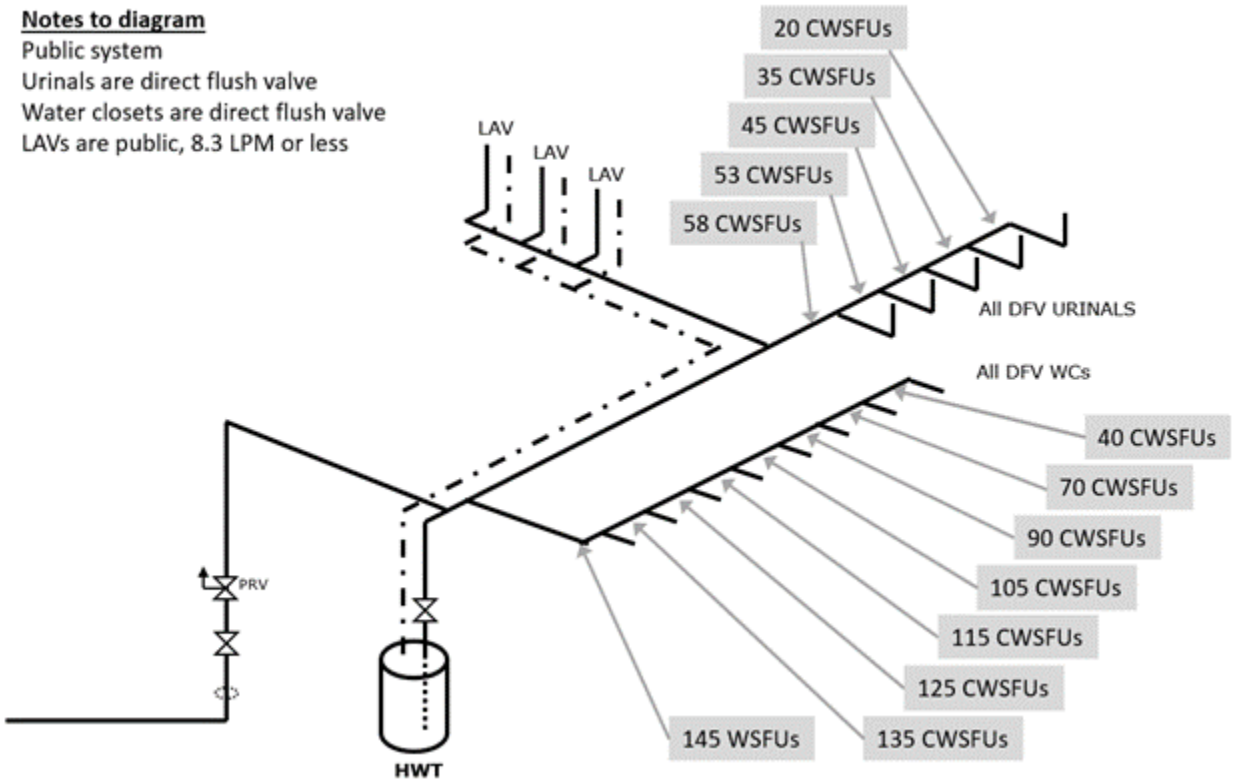



*Figure 4 Decreasing fixture unit values for direct flush valves*

### Table 2.6.3.2.-D

This table is used when the fixture or device is not listed on Table 2.6.3.2.A. Manufacturer's literature will need to be used to determine the size of the supply pipe before a hydraulic load can be selected.

### Developed Length

The BCPC defines developed length as "the length along the centre line of the pipe and fittings." When using some water pipe sizing tables in the BCPC, the plumber will need to choose a column of maximum allowable length based on the developed length of the water supply piping. If the water supply system does not use a pressure-reducing valve inside the building, the developed length upstream end is considered to be at the property line. If the water supply system uses a pressure-reducing valve inside the building, then the developed length upstream end starts at the outlet of the PRV. This is because the PRV essentially creates a new pressure zone.

### Pressure Loss/Gain due to Elevation

Pressure is highest as it enters the building through the water service pipe. As water flows downstream, there are several losses from components that must be subtracted from the incoming pressure, such as

the water meter, a pressure reducing valve, or a backflow prevention device. The incoming water must also flow to the highest fixture in the building. Pressure loss will occur as the water gains elevation, but pressure increase will occur if the water travels to a fixture below the water service pipe. Pressure gain and loss is based on the weight of water. Pressure will decrease 0.433 psi per foot of elevation gain (10 kPa per meter) or increase 0.433 psi per foot of elevation loss. The figure below shows how pressure at fixtures will be reduced based on elevation gain.

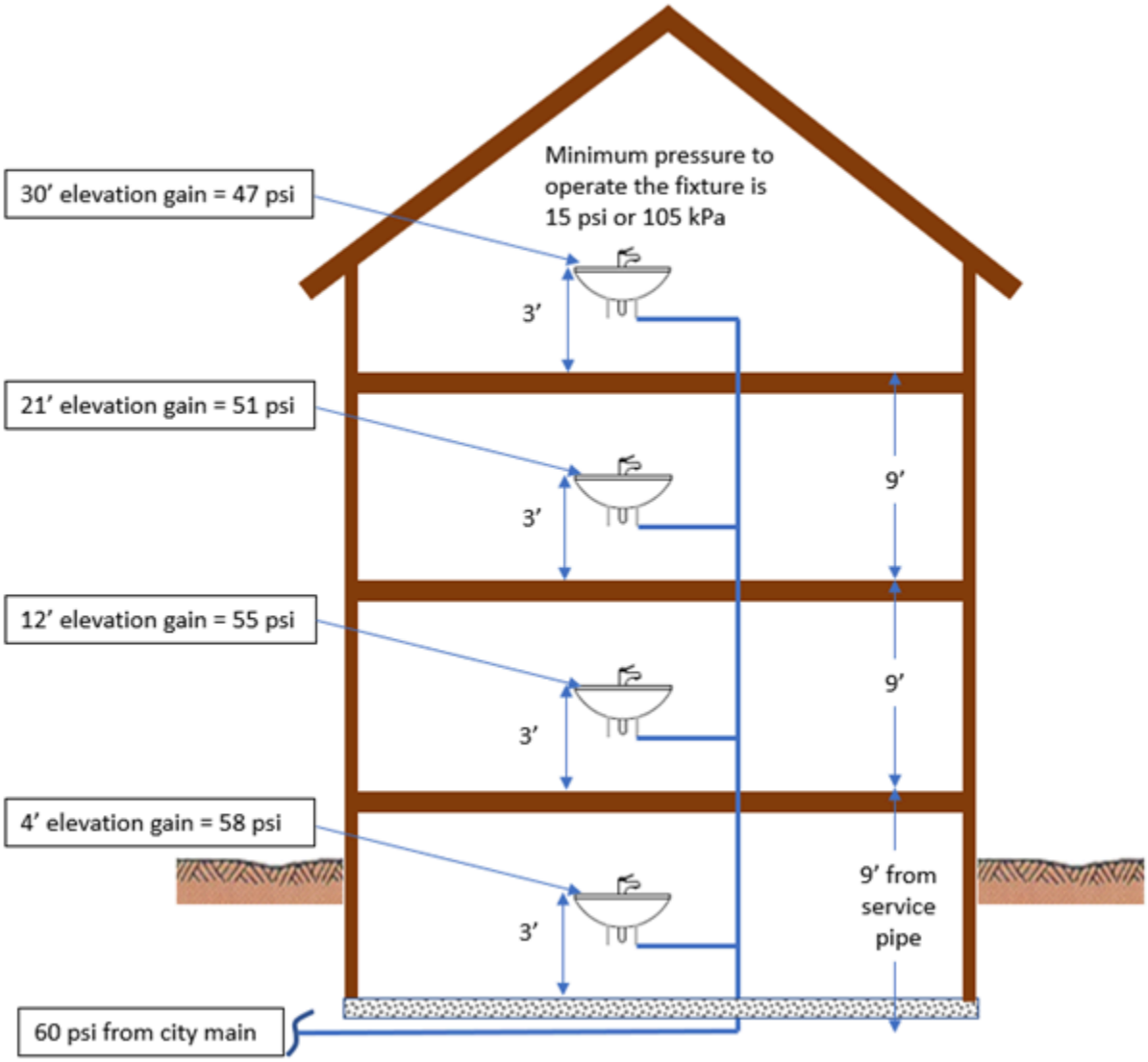



*Figure 5 An example of pressure loss due to elevation*

Note that the incoming pressure of 60 psi was reduced to 47 psi because of the pressure loss due to a change of elevation of 30 feet.

## Pressure Loss due to Friction

Friction loss in piping was previously discussed in the section on hot water circulator pump selection, and is also described in the Terminology section above. Friction causes pressure loss in pipe and fittings and can be thought of as the pressure-difference-per-foot needed to push the water along at the

required flow rate. The designer will need to ensure that the pressure loss due to friction does not exceed the maximum allowable for the pipe size and type used in the water distribution system.

### Minimum Pressure Required

The minimum pressure required is determined by the governing fixture or device as described in the Terminology section above. Unless a specific minimum pressure is known, the plumber should use 15 psi (approximately 105 kPa) when calculating water pipe sizing.

### Maximum Design Velocity for Piping Material

Maximum design velocity for piping material is described in the Terminology section above. The plumber will need to consider the water velocity when sizing piping in the building water distribution system. Some pipe sizing tables in the BCPC will require the plumber to choose a section of the table based on water velocity. The maximum water velocity will depend on the type of piping material and the temperature of the water flowing through the piping. Some commonly used velocities for residential water distribution piping are listed here:

- PEX pipe with cold unheated water = 3.0 m/s (10 f/s)
- PEX pipe with hot water up to and including 60°C (140°F) = 2.4 m/s (8 f/s)
- PEX pipe above 60°C (140°F) = 1.5 m/s (5 f/s)
- Copper pipe with cold unheated water = 2.4 m/s (8 f/s)
- Copper pipe with hot water up to and including 60°C (140°F) = 1.5 m/s (5 f/s)
- Copper pipe above 60°C (140°F) = 1.2 m/s (4 f/s)

### Sizing Residential and Small Commercial Water Supply Systems

Recall that there are four methods for sizing the building water supply system. Since the detailed engineering design is done using ASHRAE Handbooks and ASPE Data Books, a plumber will use one of the other three methods listed here:

- Simplified method
- Small commercial building method
- Average pressure loss method

When using any of the methods, it is advisable to have a worksheet to help pull together all the important information. Some options for worksheets are shown below, based on the sizing method chosen.

Note that the BCPC Sentence 2.6.3.4.(1) states that water service pipes shall be sized according to the peak demand flow but shall not be less than ¾ inch (19mm) in size.

### Simplified method

The BC Plumbing Code includes an example of this method using Figure A-2.6.3.4.(5)-B and Tables 2.6.3.2.-A, -B, -C and -D. A “Fixture Units Summary” is included and is a good example of a worksheet that should be used to collect all the WSFU values for fixtures or devices. Other worksheets, for the water service pipe, the hot water piping sizes, and the cold water piping sizes, are also included. The worksheets for this method include several water velocities for different materials. The example below is of how a worksheet could be used for the simplified system example in the BCPC if the building water supply system was constructed using PEX material.

**Table 3 BC Plumbing Code Simplified Method Example PEX tubing version**

| Pipe or tube identifier | Cold or hot piping | WSFU load | Notes | Maximum water velocity based on material | Pipe or tube size |
|---|---|---|---|---|---|
| 1 | Hot | 3.5 | | 2.4 m/s (8 ft/s) | ½″ |
| 2 | Hot | 6.3 | | 2.4 m/s (8 ft/s) | ½″ |
| 3 | Hot | 8.4 | | 2.4 m/s (8 ft/s) | ¾″ |
| 4 | Hot | 2.1 | | 2.4 m/s (8 ft/s) | ½″ |
| 5 | Hot | 6.3 | | 2.4 m/s (8 ft/s) | ½″ |
| 6 | Hot | 14.7 | | 2.4 m/s (8 ft/s) | ¾″ |
| A | Cold | 1.4 | | 3 m/s (10 ft/s) | ½″ |
| B | Cold | 5.7 | | 3 m/s (10 ft/s) | ½″ |
| C | Cold | 5.7 | | 3 m/s (10 ft/s) | ½″ |
| D | Cold | 11.4 | | 3 m/s (10 ft/s) | ¾″ |
| E | Cold | 14.7 | | 3 m/s (10 ft/s) | ¾″ |
| F | Cold | 19.1 | | 3 m/s (10 ft/s) | 1″ |
| G | Cold | 19.1 | | 3 m/s (10 ft/s) | 1″ |
| H | Cold | 21.3 | | 3 m/s (10 ft/s) | 1″ |
| I | Cold | 23.8 | | 3 m/s (10 ft/s) | 1″ |
| J | Cold | 2.8 | | 3 m/s (10 ft/s) | ½″ |
| K | Cold | 3.6 | | 3 m/s (10 ft/s) | ½″ |
| Water service pipe | Cold | 23.8 | PEX from curb stop to building | 3 m/s (10 ft/s) | 1″ |

The simplified method example in the BCPC Notes has an HWT that is supplied by cold water after

several cold water branches have already drawn water for fixtures. The location of the HWT in the water distribution system can make the WSFU load counting complex. The WSFU load added for the HWT depends on the location of the hot water tank. Unfortunately, the BCPC is not clear on how to add the WSFU loads for the different HWT locations.

The figure below shows three locations for the HWT to be connected to the CWDP: most upstream, most downstream, and somewhere in between. Each example shows the correct addition of the WSFU loads.

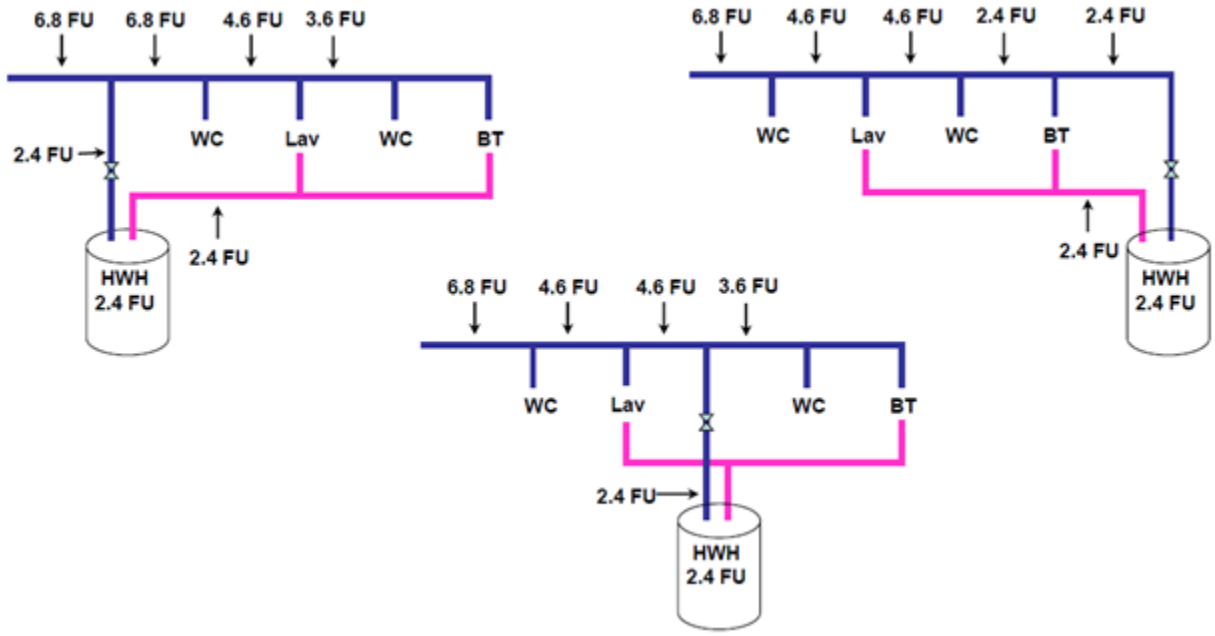



*Figure 6 Service water heater possible connection locations to the distribution system*

If the HWT is the most upstream, WSFU addition is straight forward. If the HWT is the most downstream or somewhere in the middle, it is best to think of it as the most upstream and then add in only the fixtures supplied with cold-only that are downstream of the connection, and continue adding in the cold-only fixture loads moving upstream from the HWT. The figure below shows this method so that the HWT load is not doubled-counted.

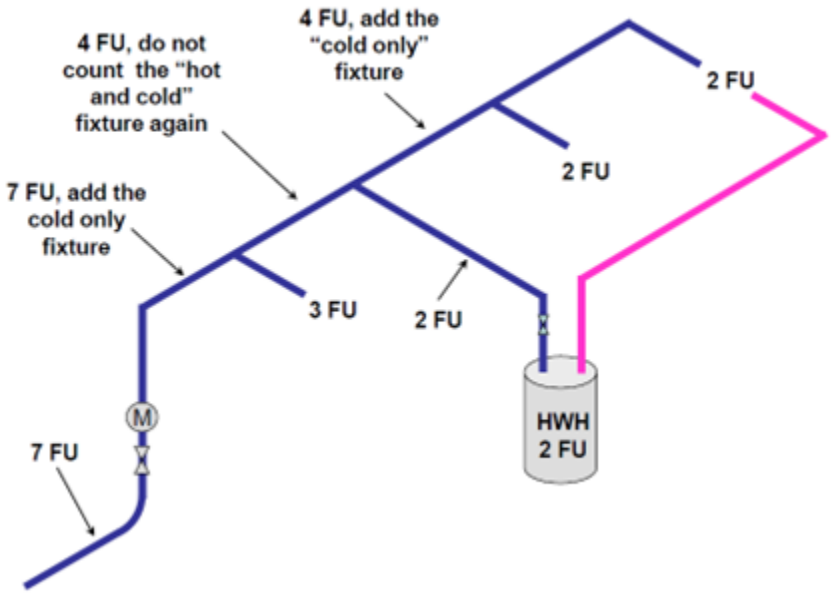



*Figure 7 Correct method to count WSFU load with the HWH connected in the middle*

#### Small commercial building method

The BC Plumbing Code Figure A-2.6.3.1.(2)-A is an example of the water supply system for a commercial and residential development and is used with the small commercial building pipe sizing method.

Table A-2.6.3.1.(2)-A, Pipe Sizes for Water Systems Based on Number of Fixture Units Served Using the Small Commercial Method, is used for this method.

To use the table, the plumber will need to separate the water service pipe and the cold and hot distribution systems into separate sections when determining the developed length and the minimum static pressure.

The water service pipe:

- The minimum static pressure is the pressure available at the property line, including all pressure losses for the water service. The water supply pipe does not generally have many losses as the components that create the losses are installed after the water service pipe enters the building. Losses or gains due to changes in elevation, and friction loss, may need to be considered.
- The developed length is measured from the property line to the point of entry.

The cold and hot distribution systems:

- The minimum static pressure is the pressure available once the water service pipe enters the building. Losses for water meters, pressure-reducing valves, backflow preventers, water treatment systems, and any other devices need to be considered.

- The developed length is measured from the water service entry point to the building to the most remote water outlet.

The small commercial building method includes a Fixture Units Summary and is a good example of a worksheet that should be used to collect all the WSFU values for fixtures or devices. The example in the BCPC also has good examples of tables for sizing each section of the system, divided into the water service pipe, the hot water distribution system and the cold water distribution system.

The worksheet below shows an example of determining the minimum static pressure available for the water service pipe when using the small commercial building method.

**Table 4**

| **Water service pipe minimum static pressure available** | **PSI** | **kPa** |
|---|---|---|
| Minimum available pressure at the property line (PL) during peak demand[1] | 82 | 565 |
| Pressure loss from PL to entry point of the building[2] | subtract 4 | subtract 25 |
| Pressure gain from PL to entry point of the building[3] | add 0 | add 0 |
| Adjusted pressure at water service entry to the building | equals 78 | equals 540 |
| Select the pressure range for sizing from Table A-2.6.3.1.(2)-A | 30-45<br>46-60<br>over 60 | 200-310<br>311-413<br>over 413 |

| **Water service pipe minimum static pressure available** | | **PSI** | **kPa** |
|---|---|---|---|
| Minimum available pressure at the property line (PL) during peak demand (1) | | 82 | 565 |
| Pressure loss from PL to entry point of the building (2) | subtract | 4 | 25 |
| Pressure gain from PL to entry point of the building (2) | add | 0 | 0 |
| Adjusted pressure at water service entry to the building | equals | 78 | 540 |
| Select the pressure range for sizing from Table A-2.6.3.1.(2)-A | | 30-45 | 200-310 |
| | | 46-60 | 311-413 |
| | | over 60 | over 413 |

Notes

(1) Where there is a wide fluctuation of pressure in the main throughout the day, the minimum static pressure available

(2) 1 foot of head = 0.433 psi loss or gain and 1 meter of head = 10 kPa loss or gain

The worksheet below shows an example of determining the minimum static pressure available for the cold and hot water distribution systems when using the small commercial building method.

1. Where there is a wide fluctuation of pressure in the main throughout the day, the minimum static pressure available.
2. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain
3. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

**Table 5**

| Cold and hot distribution systems minimum static pressure available | PSI | kPa |
|---|---|---|
| Adjusted pressure at water service entry to the building from previous worksheet | 78 | 540 |
| Pressure loss due to water meter installed inside the building (use manufacturer's specifications) | subtract 3 | subtract 20 |
| Pressure loss due to pressure-reducing valve (use manufacturer's specifications) | subtract 0 | subtract 0 |
| Pressure loss due to backflow preventer (use manufacturer's specifications) | subtract 0 | subtract 0 |
| Pressure loss due to other components (water treatment systems, etc.) | subtract 0 | subtract 0 |
| Pressure loss due to elevation change[4] | subtract 5 | subtract 35 |
| Pressure gain due to elevation change[5] | add 0 | add 0 |
| Cold and hot distribution systems minimum static pressure available | equals 70 | equals 485 |
| Select the pressure range for sizing from Table 1-2.6.3.1.(2)-A | 30-45<br>46-60<br>over 60 | 200-310<br>311-413<br>over 413 |

| Cold and hot distribution systems minimum static pressure available | | PSI | kPa |
|---|---|---|---|
| Adjusted pressure at water service entry to the building from previous worksheet | | 78 | 540 |
| Pressure loss due to water meter installed inside the building (use manufacturer's specifications) | subtract | 3 | 20 |
| Pressure loss due to pressure-reducing valve (use manufacturer's specifications) | subtract | 0 | 0 |
| Pressure loss due to backflow preventer (use manufacturer's specifications) | subtract | 0 | 0 |
| Pressure loss due to other components (water treatment systems, etc.) | subtract | 0 | 0 |
| Pressure loss due to elevation change (2) | subtract | 5 | 35 |
| Pressure gain due to elevation change (2) | add | 0 | 0 |
| Cold and hot distribution systems minimum static pressure available | equals | 70 | 485 |
| Select the pressure range for sizing from Table A-2.6.3.1.(2)-A | | 30-45 | 200-310 |
| | | 46-60 | 311-413 |
| | | over 60 | over 413 |

Notes
(1) Where there is a wide fluctuation of pressure in the main throughout the day, the minimum static pressure available
(2) 1 foot of head = 0.433 psi loss or gain and 1 meter of head = 10 kPa loss or gain

4. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

5. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

The example in the Notes to Part 2 of the BCPC goes through the sizing of each section of the water distribution system. When using Table A-2.6.3.1.(2)-A make sure to follow the steps described in the example. One technique that needs further explanation is how to determine a pipe size when a flow velocity shaded area does not continue in a maximum allowable length column. An example question can be used to clarify the use of the table.

Example question

When using Table A-2.6.3.1.(2)-A, what size is a copper hot water pipe serving 12 fixture units and using the maximum allowable length of 30m?

Solution

In the 30m column for maximum allowable length the only dark shaded number of fixture units allowed to be served for the velocity of 1.5 m/s is 3. To find the pipe size for 12 fixture units continue to slide right, and down, in the adjacent columns until a number equal to, or greater than, the 12 fixture unit load is found for 1.5 m/s flow velocity. For this example, the pipe size would be 1 inch, found under the 76m column as shown in the figure below.

**Table A-2.6.3.1.(2)-A**
**Pipe Sizes for Water Systems Based on Number of Fixture Units Served Using the Small Commercial Method**

| Water Service Pipe, inches | Water Distribution System, inches | Maximum Allowable Length, m | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12 | 18 | 24 | 30 | 46 | 61 | 76 | 91 | 122 | 152 | 183 | 213 | 244 | 274 | 305 |
| | | Number of Fixture Units Served | | | | | | | | | | | | | | |
| | | | | | | Flow Velocity, m/s | | | | 3.0 | 2.4 | 1.5 | | | | |
| | | Pressure Range 200 to 310 kPa | | | | | | | | | | | | | | |
| 3/4 | 1/2 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3/4 | 5/8 | 12 | 10 | 9 | 7 | 5 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 0 |
| 3/4 | 3/4 | 18 | 16 | 14 | 12 | 9 | 6 | 5 | 5 | 4 | 4 | 3 | 2 | 2 | 2 | 1 |
| 1 | 1 | 36 | 31 | 27 | 25 | 20 | 17 | 15 | 13 | 12 | 10 | 8 | 6 | 6 | 6 | 6 |
| 1-1/2 | 1-1/4 | 83 | 68 | 57 | 48 | 38 | 32 | 28 | 25 | 21 | 18 | 15 | 12 | 12 | 11 | 11 |
| 1-1/2 | 1-1/2 | 151 | 124 | 105 | 91 | 70 | 57 | 49 | 45 | 36 | 31 | 26 | 23 | 21 | 20 | 20 |

*Figure 8 How to use the table for the example question*

**Average pressure loss method**

The BC Plumbing Code Figure A-2.6.3.1.(2)-A is an example of the water supply system for a commercial and residential development and is used with the average pressure loss pipe sizing method.

Table A-2.6.3.1.(2)-F, Pipe Sizes for Water Systems Based on Number of Fixture Units Served Using the Average Pressure Loss Method, is used for this method.

The average pressure loss method includes a Fixture Units Summary and is a good example of a worksheet that should be used to collect all the WSFU values for fixtures or devices. The example in the Code also has good examples of tables for sizing each section of the system, divided into the water service pipe, the hot water distribution system and the cold water distribution system.

Determining the minimum static pressure is very similar to the small commercial building method, except this method requires the plumber to calculate the pressure available for friction loss before using Table A-2.6.3.1.(2)-F.

To use the table, the plumber can go through a similar process as used for the “Small commercial building” method. The static pressure available for the water service pipe can be determined using a worksheet like the one shown below.

**Table 6**

| **Water service pipe minimum static pressure available** | **PSI** | **kPa** |
|---|---|---|
| Minimum available pressure at the property line (PL) during peak demand[6] | 82 | 565 |
| Pressure loss from PL to entry point of the building[7] | subtract 4 | subtract 25 |
| Pressure gain from PL to entry point of the building[8] | add 0 | add 0 |
| Adjusted pressure at water service entry to the building | equals 78 | equals 540 |

| **Water service pipe minimum static pressure available** | | **PSI** | **kPa** |
|---|---|---|---|
| Minimum available pressure at the property line (PL) during peak demand (1) | | 82 | 565 |
| Pressure loss from PL to entry point of the building (2) | subtract | 4 | 25 |
| Pressure gain from PL to entry point of the building (2) | add | 0 | 0 |
| Adjusted pressure at water service entry to the building | equals | 78 | 540 |

Notes

(1) Where there is a wide fluctuation of pressure in the main throughout the day, the minimum static pressure available

(2) 1 foot of head = 0.433 psi loss or gain and 1 meter of head = 10 kPa loss or gain

Once the adjusted pressure is known at the entry to the building the water distribution system pressure losses can be calculated. There is one additional pressure loss that must be considered when using this method: the governing fixture pressure requirement.

The worksheet below is similar to the one used for the small commercial building method, but with the cold and hot distribution systems minimum static pressure available reduced by the minimum pressure necessary at the fixture for operation (governing fixture).

**Table 7**

| **Cold and hot distribution systems minimum static pressure available** | **PSI** | **kPa** |
|---|---|---|
| Adjusted pressure at water service entry to the building from above | 78 | 540 |
| Pressure loss due to water meter installed inside the building (use manufacturer’s specifications) | subtract 3 | subtract 20 |

6. Where there is a wide fluctuation of pressure in the main throughout the day, the minimum static pressure available.

7. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

8. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

| | | |
|---|---|---|
| Pressure loss due to pressure-reducing valve (use manufacturer's specifications) | subtract 0 | subtract 0 |
| Pressure loss due to backflow preventer (use manufacturer's specifications) | subtract 0 | subtract 0 |
| Pressure loss due to other components (water treatment systems, etc.) | subtract 0 | subtract 0 |
| Pressure loss due to elevation change[9] | subtract 5 | subtract 35 |
| Pressure gain due to elevation change[10] | add 0 | add 0 |
| Cold and hot distribution systems minimum static pressure available | equals 70 | equals 485 |
| Minimum pressure necessary at the fixture for operation (governing fixture) | subtract 15 | subtract 105 |
| Final adjusted pressure loss to find pressure available for pressure loss | 55 | 380 |

| Cold and hot distribution systems minimum static pressure available | | PSI | kPa |
|---|---|---|---|
| Adjusted pressure at water service entry to the building from above | | 78 | 540 |
| Pressure loss due to water meter installed inside the building (use manufacturer's specifications) | subtract | 3 | 20 |
| Pressure loss due to pressure-reducing valve (use manufacturer's specifications) | subtract | 0 | 0 |
| Pressure loss due to backflow preventer (use manufacturer's specifications) | subtract | 0 | 0 |
| Pressure loss due to other components (water treatment systems, etc.) | subtract | 0 | 0 |
| Pressure loss due to elevation change (2) | subtract | 5 | 35 |
| Pressure gain due to elevation change (2) | add | 0 | 0 |
| Cold and hot distribution systems minimum static pressure available | equals | 70 | 485 |
| Minimum pressure necessary at the fixture for operation (governing fixture) | subtract | 15 | 105 |
| Final adjusted pressure loss to find pressure available for pressure loss | | 55 | 380 |

Notes
(1) Where there is a wide fluctuation of pressure in the main throughout the day, the minimum static pressure available
(2) 1 foot of head = 0.433 psi loss or gain and 1 meter of head = 10 kPa loss or gain

The minimum static pressure for the cold and hot water distribution systems can be calculated using a worksheet similar to the one used above, or using Figure A-2.6.3.1.(2)-B in the BCPC Notes to Part 2. Once the minimum static pressure and the developed length has been determined, the plumber uses the formula shown below, from Figure A-2.6.3.1.(2)-B Step 1(e), to calculate the pressure available for pressure loss.

**Step 1(e)**

9. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

10. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

| | | | | |
|---|---|---|---|---|
| 380 kPa | ÷ | 114m | = | 3.3 kPa per metre |
| Total pressure available for friction loss | | developed length × 1.5 for fittings and/or additional losses if insert fittings are used | | Average pressure loss must be minimum 2.6 kPa per metre |

**Step 1(e)**

| | | | | |
|---|---|---|---|---|
| 380 kPa | ÷ | 114m | = | 3.3 kPa per metre |
| Total pressure available for friction loss | | Developed length x 1.5 for fittings and/or additional losses if insert fittings are used | | Average pressure loss must be minimum 2.6 kPa per metre |

To use this method, and Table A-2.6.3.1.(2)-F, the pressure available for friction loss must be 2.6 kPa per metre (0.115 psi per foot) or more. If it is less than that, the system must be designed according to a detailed engineering design method. The pressure available for pressure loss is a simple way of making sure that, no matter what piping material is used, the friction loss will not create excessive pressure drop.

### Industrial, Large Commercial, and Institutional Water Supply System Sizing

These systems are sized using a detailed engineering design as they generally require much higher volumes of water than residential and small commercial systems. Some of the water is used for domestic applications, such as water for human consumption, food preparation, or sanitation, but most of the water is for non-potable processes. Industrial, large commercial, and institutional applications can include pulp mills, hospitals, car washes, high-rise condominiums, hotels, swimming pools, etc.

Industrial, large commercial, and institutional systems can use a public or private source for their water supply. Many large applications will use public water for domestic use and any processes that require potable water, but may have a private supply, such as a site-constructed reservoir, for processes that could use non-potable water. The non-potable processes can include irrigation, chemical systems, specialized fixtures and equipment, etc. To prevent contamination of the public potable system, the BCPC Article 2.6.2.5 states that “No private water supply system shall be interconnected with a public water supply system.” If the application uses the public system for both the domestic uses and the non-potable processes, the piping arrangements will require an evaluation of possible cross-connections. The use of backflow preventers (cross connection devices) is very common on industrial, large commercial, and institutional water supply and distribution systems.

Now complete Self-Test 2 and check your answers.

# Self-Test 2

Self-Test 2

1. What is the minimum size (NPS) water service to a commercial building?
    a. ½ inch
    b. ¾ inch
    c. 1 inch
    d. 1¼ inch
2. According to the NPC, what is the hydraulic load of a ¾ inch hose bibb for public use?
    a. 2.5 fixture units
    b. 3 fixture units
    c. 6 fixture units
    d. 7 fixture unit
3. According to the Code, what is the hydraulic load of a bathtub with a ¾ inch spout for private use?
    a. 0.7 fixture units
    b. 1.4 fixture units
    c. 4 fixture units
    d. 10 fixture units
4. According to the Code, what is the total hydraulic load on a branch that serves 5 direct flush valve urinals?
    a. 58 fixture units
    b. 53 fixture units
    c. 45 fixture units
    d. 35 fixture units
5. What is the maximum water velocity permitted for cold water copper distribution systems, as recommended by copper tube manufacturers?
    a. 3.0 m/sec
    b. 2.4 m/sec
    c. 1.5 m/sec
    d. 1.2 m/sec

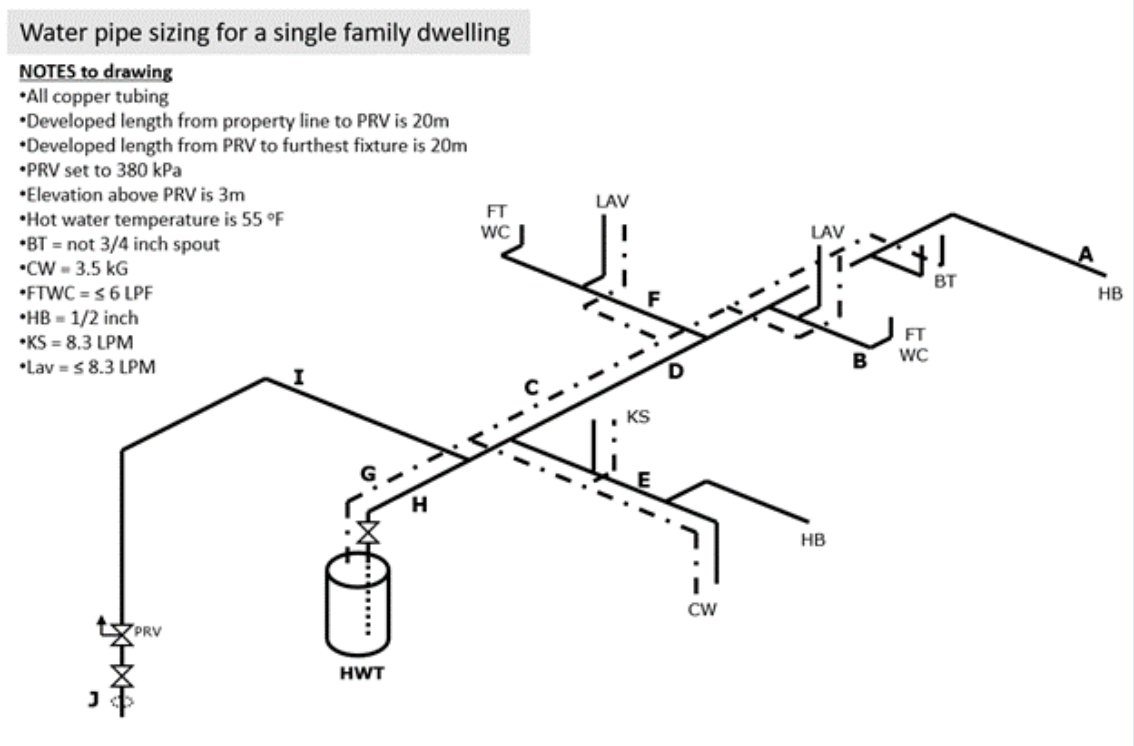
6. When sizing a water supply system using the NPC, the final size of the water service pipe shall be what size?

    a. 75% of the combined fixture unit value
    b. The sum of the total hot and the total cold
    c. Sized for peak demand flow and not less than ¾″
    d. The sum of the cold water fixture unit values in the system plus 50%

7. What water supply system sizing method would a plumber use to size the piping in a single family dwelling?

    a. Simplified method
    b. Simplified method or Average pressure loss method
    c. Simplified method, Average pressure loss method, or Small commercial building method
    d. Simplified method, Average pressure loss method, Small commercial building method, or a Detailed engineering design

8. Size the lettered building water supply system pipes on the drawing below.

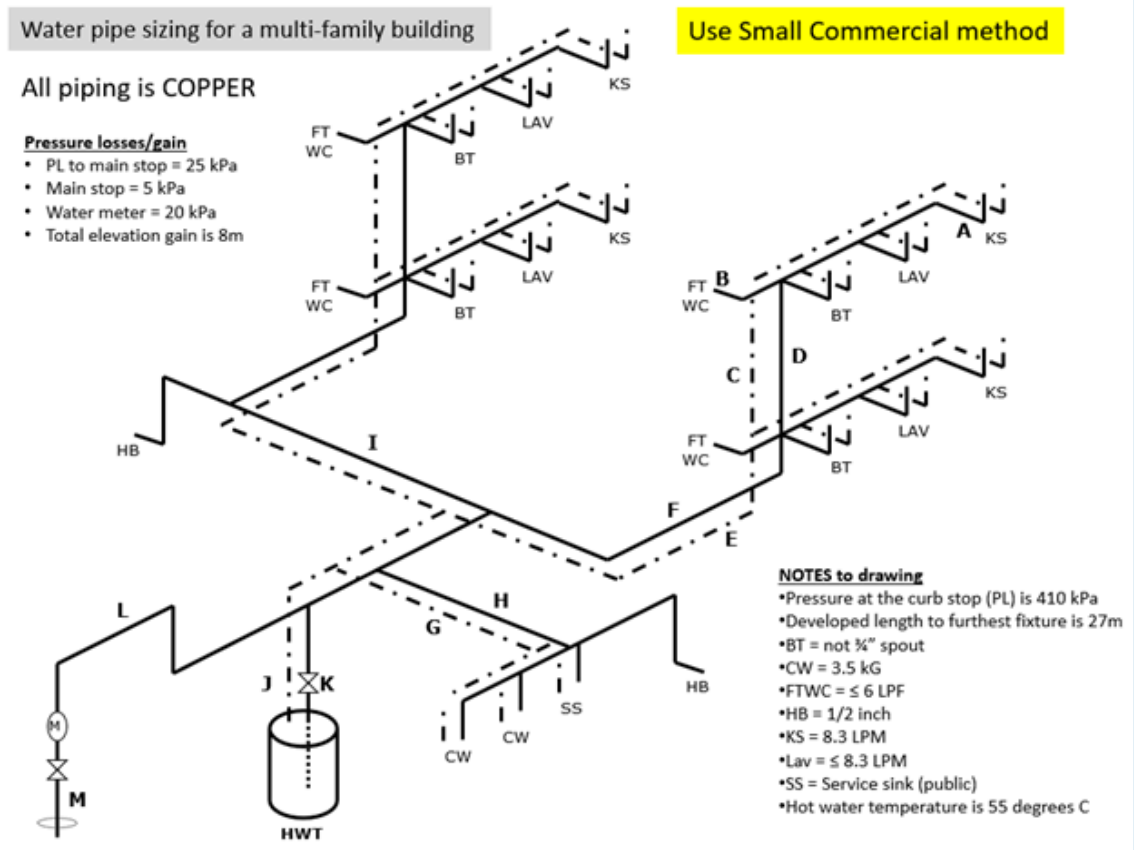



**Competency B2 Learning Task 2 Quiz: Simplified method Copper tubing version**

| Pipe or tube identifier | Cold or hot piping | WSFU load | Notes | Maximum water velocity based on material | Pipe or tube size |
|---|---|---|---|---|---|
| A | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| B | | | | | |
| C | | | | | |
| D | | | | | |
| E | | | | | |
| F | | | | | |
| G | | | | | |
| H | | | | | |
| I | | | | | |
| J | | | | | |

9. Size the lettered building water supply system pipes on the drawing below.

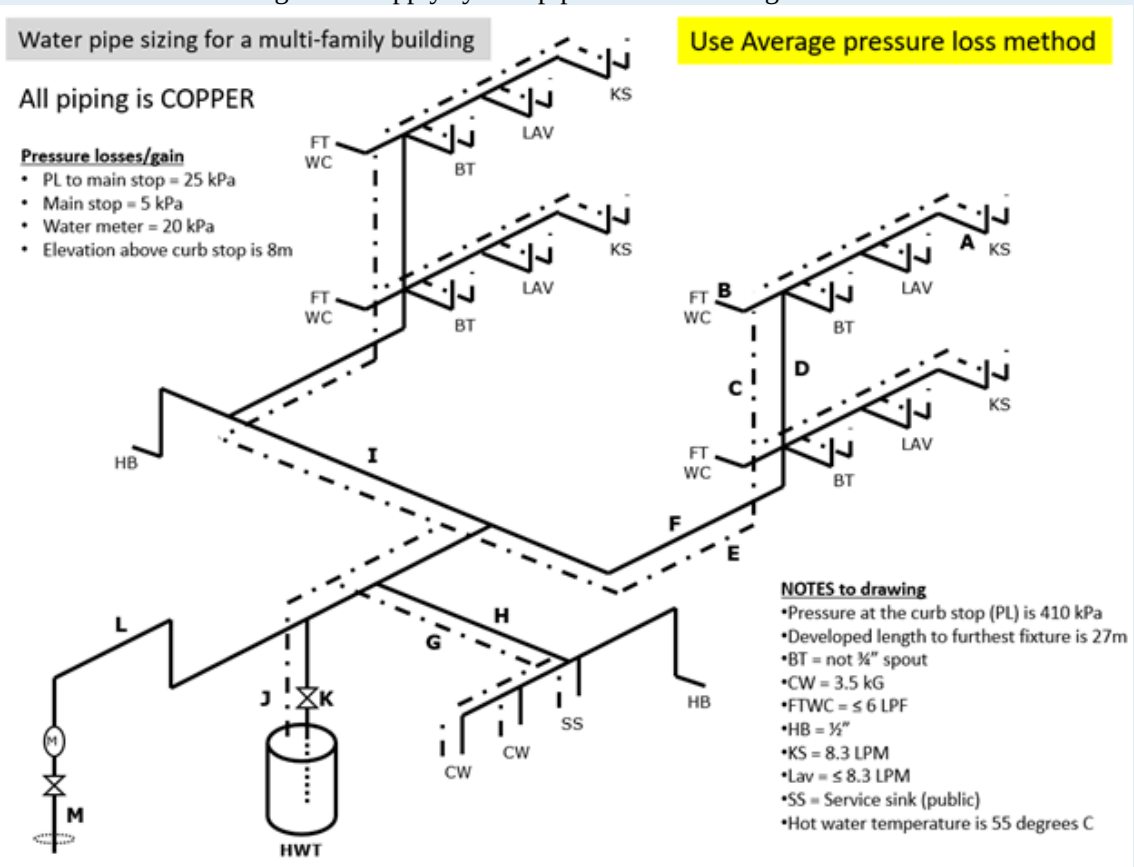



**Competency B2 Learning Task 2 Quiz: Small commercial building method Copper tubing version**

| Pipe or tube identifier | Cold or hot piping | WSFU load | Notes | Maximum water velocity based on material | Pressure range | Pipe or tube size |
|---|---|---|---|---|---|---|
| A | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |
| F | | | | | | |
| G | | | | | | |
| H | | | | | | |
| I | | | | | | |
| J | | | | | | |
| K | | | | | | |
| L | | | | | | |
| M | | | | | | |

10. Size the lettered building water supply system pipes on the drawing below.



**Competency B2 Learning Task 2 Quiz: Average pressure loss method Copper tubing version**

| Pipe or tube identifier | Cold or hot piping | WSFU load | Notes | Maximum water velocity based on material | Pipe or tube size |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
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| | | | | | |

Check your answers using the Self-Test Answer Keys in Appendix 1.

**Media Attributions**

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# Learning Task 3

Describe the Installation of the Building Water Supply System

Connected and installing the different materials used for potable water systems has been discussed in previous levels of the plumber program. This section will cover BCPC references not previously reviewed. Ultimately, it is the plumber's responsibility to ensure the potable water supply system is installed to meet the minimum of the Code.

## Restrictions on Re-Use

BCPC Sentence 2.2.1.2. (1) states that "materials and equipment that have been used for a purpose other than the distribution of potable water shall not be subsequently used in a potable water system."

## Working Pressure of a Water Service Pipe

BCPC Sentence 2.2.1.6.(1) states the "the working pressure rating of a water service pipe shall not be less than the maximum water main pressure at their point of connection as established by the water supply authority."

## Pipe and Fitting Applications

The "Summary of Pipe and Fitting Applications" Table A-2.2.5., 2.2.6. and 2.2.7. will direct the plumber to the acceptable pipe and fitting materials for a building water supply system.

Common pipe materials used for the building water service pipe are listed here, based on the calculated pipe size:

- ¾ inch = PEX is used for most installations, copper is rarely used, and PE is used occasionally for longer runs (e.g. over a 100')
- 1 inch = PEX is used for most installations, with PE used occasionally
- 1¼ inch = PEX and PE
- 1½ inch to 3 inches = PVC solvent cement (typically sch 40 piping and sch 80 fittings)
- 4 inch and larger = PVC push-on (e.g. IPEX Blue Brute®) is used for most projects. Ductile-iron can be used when the water service is close to the surface or inside a building. PVC and ductile-iron were covered in detail in Competency B1.

Common pipe materials (based on current costs and availability) which are used for the building water distribution piping are listed here:

- Copper
- CPVC (e.g. IPEX Aquarise®)
- Polypropylene (e.g. Aquatherm Green Pipe)
- PVC
- Stainless steel

### Galvanized Steel Pipe

BCPC Sentence 2.2.6.8. (3) states that galvanized steel pipe and fittings shall not be used in a water distribution system except in buildings of industrial occupancy, or for the repair of existing galvanized steel piping systems.

BCPC Notes to Part 2, A-2.2.6.8.(3).) states that the use of galvanized steel pipe and fittings in a water distribution system may have proven acceptable on the basis of past performance in some localities and its acceptance under this Code may be warranted.

## Copper Joints Used Underground

BCPC Sentence 2.3.3.12.(1) states that joints in copper tubes installed underground shall be made with either flared or compression fittings, or be brazed using a brazing alloy within the American Welding Society's AWS-BCuP range.

BCPC Sentence 2.3.3.12.(2) states that compression fittings shall not be used underground under a building.

## Support of Piping

BCPC Subsection 2.3.4. covers capability of support, support for vertical piping, support of horizontal piping, support of underground piping, etc.

BCPC Table 2.3.4.5. covers the maximum horizontal spacing of supports for different piping materials.

BCPC Sentence 2.3.4.3.(1) states that where a hanger or support for copper tube or brass or copper pipe is of a material other than brass or copper, it shall be suitably separated and electrically insulated from the pipe or tube.

BCPC Sentence 2.3.4.3.(2) states that where a hanger or support for stainless steel pipe or tube is of a material other than stainless steel, it shall be suitably separated and electrically insulated from the pipe or tube.

## Protection Against Freezing

Exposure of piping systems to freezing conditions will cause water and similar low freezing point fluids to freeze. The expansion of the fluid (water) as it freezes can rupture the pipe. When the water thaws, the resulting water damage can be extensive. The plumber level one content covered freeze protection of piping systems in detail.

There are several methods to prevent damage during freezing conditions, including:

- installing the piping within a heated structure
- applying pipe insulation, boxing in the piping, or tenting
- applying spray foam
- installing piping on the heated side of building insulation
- draining or blowing out the system during cold weather
- adding anti-freeze solution
- using hot boxes
- installing heat trace systems
- for buried piping, installing the piping below the frost line or insulating and heat tracing
- using constant circulation

BCPC Sentence 2.3.5.4.(1) states that where piping may be exposed to freezing conditions, it shall be protected from the effects of freezing.

BCPC Notes to Part 2, A-2.3.5.4. indicates that the TIAC Mechanical Insulation Best Practices Guide is a comprehensive source of information on the selection, installation and proper use of thermal insulation materials. (Note that Section 4 of this Guide is not included in the scope of this Note as it contains information on proprietary products, which are not within the mandate of the Code.)

BC Building Code Sentence 9.36.4.4.(1) states that the first 2 m of outlet piping downstream and of inlet piping upstream leading from a storage tank or heating vessel shall be covered with piping insulation that is at least 12 mm thick.

### Plumbing System Components in Exterior Walls

The BC Building code addresses plumbing components placed within an exterior wall. If a water distribution pipe is installed in an exterior wall it must be insulated behind to the effective thermal resistance required for the above or below grade wall assembly. This means the plumber will have to increase the RSI value of insulation behind the piping being installed to ensure the continuity of insulation meets the minimum requirements in BC Building Code Sentence 2.36.2.5.(6)

## Testing of Potable Water Systems

BCPC Subsection 2.3.7, Testing of potable water systems, is covered in the plumber level 4 content.

## BC Plumbing Code Section 2.6. Potable Water Systems

### Design

BCPC Sentence 2.6.1.1.(1) states fixtures supplied with separate hot and cold water controls shall have the hot water control on the left and the cold on the right.

### Shut-off Valves

BCPC Article 2.6.1.3. covers shut-off valves.

BCPC Notes to Part 2, A-2.6.1.3.(5). states that where multiple risers convey the water supply to dwelling units, each dwelling unit's water distribution system shall be provided with a shut-off valve located immediately where the water piping enters the suite so as to isolate the fixtures as well as the water distribution piping serving the dwelling unit's fixtures. Fixture stopcocks or shut-off valves located immediately adjacent to a fixture may not be adequate to protect the water distribution piping. Where a dwelling unit is served by a single shut-off valve on the water supply, additional shut-off valves may be required to achieve compliance with Sentences 2.6.1.3.(4) and (7).

### Thermal Expansion

BCPC Sentence 2.6.1.11.(1) states that protection against thermal expansion shall be required when a check valve is required by Article 2.6.1.5., a backflow preventer by Article 2.6.2.6., or a pressure-reducing valve by Article 2.6.3.3. (See Notes to Part 2, A-2.6.1.11.(1).)

BCPC Note to Part 2, A-2.6.1.11.(1) indicates that to accommodate the increase in pressure caused by thermal expansion within a closed water distribution system, one of the following should be installed:

1. a suitably sized diaphragm expansion tank designed for use within a potable water system,
2. an auxiliary thermal expansion relief valve (T.E.R. valve) conforming to CSA B125.3, "Plumbing Fittings," set at a pressure of 550 kPa or less and designed for repeated use, or
3. other means acceptable to the authority having jurisdiction.

## Securement of Service Water Heaters

Tank-type water heaters are secured against tipping over for several reasons. In the event of major seismic activity, the tank-type water heater provides a source of drinking water. Securement of the water heater will also prevent the water pipes and, if connected, the gas pipe from disconnecting and

causing serious damage. In many localities, a pair of seismic straps that wrap around the tank and attach to the walls is recommended for securing residential water heaters.

The BC Building Code Note to Part 9, A-9.31.6.2.(3), indicates that Guidelines for Earthquake Bracing of Residential Water Heaters is available from the California Office of the State Architect and provides more detail and alternate methods of bracing hot water tanks to resist earthquakes.




*Figure 1 Hot water storage heater with seismic restraint using manufactured strapping*

## Sleeves and Fire-Stopping

Sleeves and fire-stopping were covered in detail in the plumber level one and 2 content. The figure below shows the location of several sleeves that may be used when installing a water supply system, including a water service pipe entering the building through a sleeve.

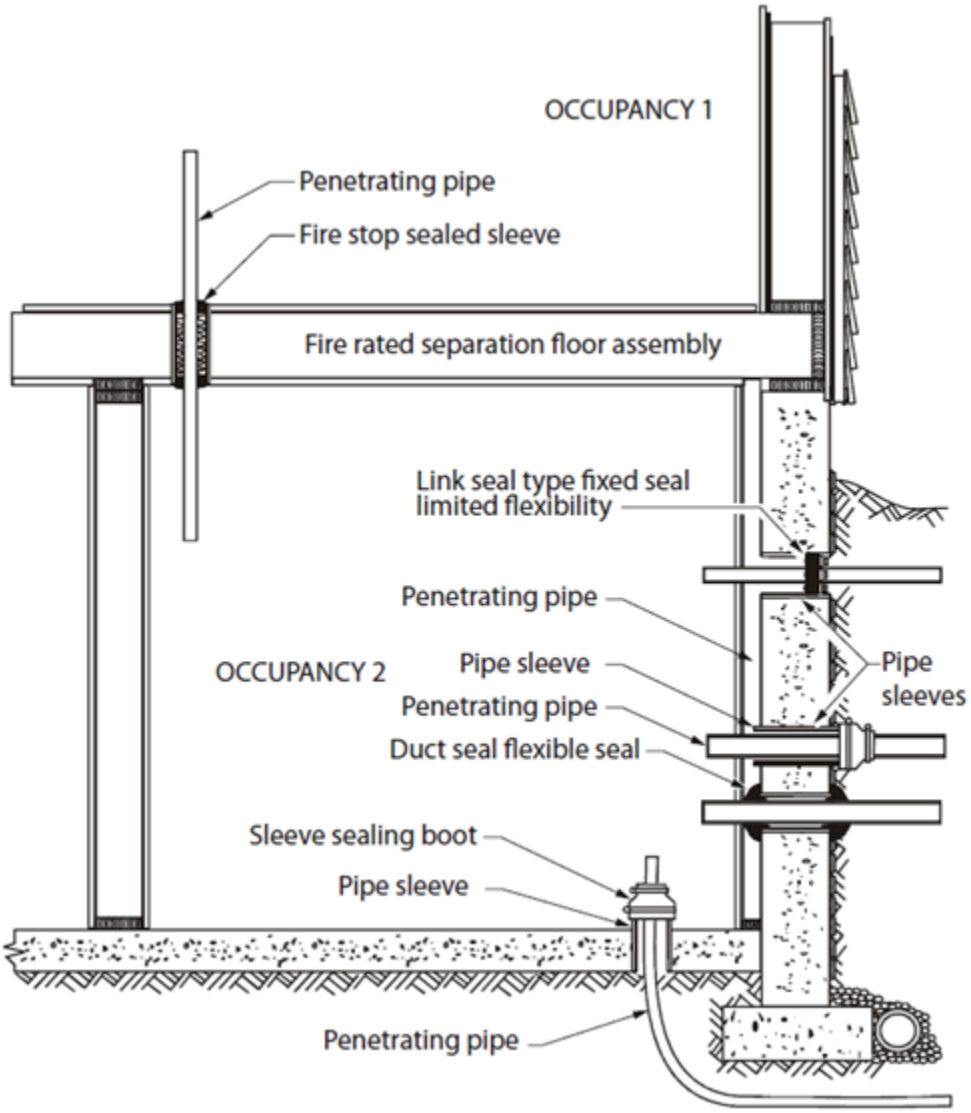



*Figure 2 Typical building sleeve and penetration locations*

The openings created where pipes pass through walls and floors can cause problems by allowing water, smoke, fire, drafts, vapours and sound to enter or pass freely within the structure. Pipe sleeves installed around the pipe may need to be sealed at one or both ends. Pipe sleeves and the pipe seals installed in fire separations must be fire rated. The fire rating must be equal to the rating of the fire separation.

## Water Hammer

The BC Plumbing Code states that provision shall be made to protect the water distribution system from the adverse effects of water hammer in Article 2.6.1.9. The Notes to Part 2, A-2.6.1.9.(1) in the BCPC includes more information on water hammer prevention.

> Water hammer is a buildup of pressure in a length of horizontal or vertical pipe that occurs when a valve or faucet is closed suddenly. The longer the pipe and the greater the water velocity, the greater the pressure exerted on the pipe, which can be many times the normal static water pressure and be sufficient to damage the

> piping system. Since air chambers made from a piece of vertical pipe do not provide acceptable protection, pre-manufactured water hammer arresters are required to address this potential problem. Water hammer arresters need not be installed at every valve or faucet, nor in every piping system.

Since the BCPC is silent on the appropriate location to install a water hammer arrestor in a water distribution system or on a water supply pipe, it is best to consult manufacturer's installation details on where they should be installed in relation to the fixture(s) being served.

Water hammer arrestors come in two basic designs. One design, used mostly in residential applications, has a pre-charged air chamber with a sealed-in diaphragm, and is rechargeable using a shraeder valve connection. The other common design incorporates a pre-charged, permanent sealed air chamber to absorb the shock. The sealed chamber prevents the loss of air to the water and insures long and trouble-free life since only a piston is the only moving part. This design is manufacturer in larger sizes for use on residential and ICI applications.

The preferred location for a water hammer arrestor serving multiple fixtures is at the end of the branch line between the last two fixtures served. Different designs of water hammer arrestors are made for individual fixtures such as:

- Dishwashers
- Clothes washers
- Fixtures with fast closing positive shutoff valves



*Figure 3 Different water hammer arrestor designs*

Now complete Self-Test 3 and check your answers.

## Self-Test 3

Self-Test 3

1. Which type of water service pipe is not rated for hot water?
    a. Polyethylene series 160
    b. Polypropylene
    c. Polyethylene (Cross-linked)
    d. Chlorinated Polyvinyl Chloride
2. Which condition would most likely cause water hammer?
    a. Piping sized too small

b. Piping sized too large
c. Slowly closing a valve
d. Quickly closing a valve

3. Can a shut-off valve be installed on the pipe between any tank and the relief valve, or on the discharge lines from the relief valve?

a. No
b. Yes

4. A water distribution system shall be installed so the system can be drained or blown out with air.

a. True
b. False

5. Every fixture supplied with separate hot and cold water controls shall:

a. Have a mixing valve installed
b. Have an anti-scald device installed
c. Have an aerator installed that has no provision for backflow
d. Have the hot water control on the left and the cold on the right

6. In all applications, which fixture(s) must have a shut-off valve provided on the water supply pipe?

a. Water closets
b. Water closets and lavatories
c. Kitchen sinks and lavatories
d. Water closets, kitchen sinks, and lavatories

Check your answers using the Self-Test Answer Keys in Appendix 1.

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# Competency B3: Residential Irrigation Systems

Landscaping is an important aspect of any residential site and maintaining the health and appearance of lawns and shrubs can be challenging. Overwatering and forgetting to water are the common results of manually caring for their needs. An automatically operating irrigation system not only ensures that lawns and shrubs get as close to the exact amount of water they need, but it can save water in doing so. Water conservation should be a priority not only for ecological reasons but at the very least, it should be recognized that wasted water wastes money. This learning guide will take you through the considerations that should be addressed in the process of designing and installing a residential automatic irrigation system.

Learning Objectives

When you have finished processing the information in this learning guide, you should be able to:

- Describe and lay out residential irrigation systems
- Select and install irrigation components, and
- Test, service and commission an irrigation system

# Learning Task 1

Types of Irrigation Systems

## Types of Irrigation Systems

An irrigation system is simply one that supplies water to plants of different varieties. They can be broadly classed as being agricultural (crops such as hay, alfalfa, etc.), commercial (large-scale building sites, golf courses) or residential (single family dwellings, duplexes and small townhouses). This guide will focus on a single-family house in its descriptions, but it should be noted that the design considerations covered can be applied to installations of any size.

There are two different styles of irrigation systems, which are traditional sprinkler-based systems and drip irrigation systems. They are often used together to ensure that the watering needs of all plants are met.

Traditional sprinkler-based systems are well suited for large areas of grass and plants that have similar watering needs. They water uniformly by broadcasting water in well-defined patterns which are often 1.5m (5′) or more in diameter.



*Figure 1 Traditional Sprinkler System*

Drip irrigation complements traditional systems by targeting smaller, more specific areas such as planters on patios, hanging baskets and such. They use very little water and, in doing so, are effective in discouraging weed growth.



*Figure 2 Drip irrigation*

Because drip systems are quite simple and easy to install, with little piping or trades knowledge required, we will leave their considerations alone and will instead concentrate on traditional sprinkler-based systems. Within that context, we will describe the steps involved in the installation of an irrigation system in a logical sequence that will span from the investigation and planning process through installation, testing and commissioning. The steps in this procedure should be taken in this order to reduce the chances of overlooking important factors in the process.

The steps are:

1. Obtaining site information
2. Determining the irrigation requirement
3. Determining water and power supply
4. Selecting and locating sprinklers
5. Layout of zone valves and main lines
6. Sizing pipe and valves and calculating total system pressure loss
7. Locating controllers and sizing wire
8. Installing the system
9. Flushing, testing and commissioning
10. Routine maintenance and troubleshooting

## Step 1: Site Information

Before embarking on any installation, contact the local Authority Having Jurisdiction (AHJ) for information regarding any permits and other requirements such as backflow prevention. It is also imperative that you recognize the need to “call before you dig”. In British Columbia, a service known as “BC 1 Call” is available that will gather and relay to interested parties the information that is archived with utility providers. It will show the approximate location and depth of known underground services such as hydro, water, telephone, gas and sewer. This information usually takes a couple of business days to reach the inquirer so be sure to make the request well in advance of the intended work.

This is the logical point where a sketch of the site should be created. For newer buildings there may

already be one that could be utilized; if not, it should be drawn as accurately as possible, and to scale. This will assist in the selection and placement of the types of sprinklers to be used as well as the number and location of zones and zone valves. The use of graph paper is the best choice for the sketch. Each square of graph paper should represent one square foot of property if possible. Alternatively, choose a scale such as 1 inch = 10 feet, or 1 inch = 20 feet. Try to use a scale that will represent the proposed site with as much detail as possible. Remember to:

- Measure and show the perimeter of the property including landmarks and benchmarks
- Outline the house, garage and any other structures
- Identify trees and other obstacles to water streams from sprinklers
- Show walkways, driveways, slabs, patios and any other areas that are not intended to be watered
- Show all areas to be watered, including groundcover, grass, landscaping shrubs and flower beds
- Indicate slopes
- Identify the irrigation system's water supply location and size of pipe

Again, make the sketch as accurate as possible and make a few copies. The system layouts will be drawn directly onto this paper so ensure there are enough clean spare copies.

## Step 2: The Irrigation Requirements

A few factors need to be considered to determine how much water is needed for the plant material, which in turn determines how often and how long the system needs to operate (see Step 9). The local climate is one of the main factors that influences how much water is needed to maintain good plant growth. Another factor is the plant water requirement which includes the water lost by evaporation into the atmosphere from the soil and soil surface, and by transpiration, which is the amount of water used by the plant. The combination of these is known as evapotranspiration (ET). The table below is a "ballpark" estimate that takes into consideration the average amount of water, in inches or mm per day, that satisfies the evapotranspiration (ET) needs of most plants in conjunction with the local climate.

**Climate Inches (millimeters) Daily**

| | |
|---|---|
| Cool Humid | .10 to .15 in (3 to 4 mm) |
| Cool Dry | .15 to .20 in (4 to 5 mm) |
| Warm Humid | .15 to .20 in (4 to 5 mm) |
| Warm Dry | .20 to .25 in (5 to 6 mm) |
| Hot Humid | .25 to .30 in (6 to 8 mm) |
| Dot Dry | .30 to .45 in (8 to 11 mm) "worst case" |

*Cool = under 70° F (21˚ C) as an average midsummer high*

*Warm = between 70° and 90° F (21˚ and 32˚ C) as midsummer highs*

*Hot = over 90° F (32˚C)*

*Humid = over 50% average midsummer relative humidity*

*Dry = under 50%*

Where larger agricultural watering needs are concerned there are other more accurate calculations that should be performed but for most residential scenarios the table above is adequate.

Soil absorbs and holds water in much the same way as does a sponge. A given texture of soil will hold a certain amount of moisture and will influence the precipitation rate and type of sprinkler to be used, whereas the ability of the soil to hold moisture and the amount of moisture it can hold will influence the irrigation schedule. Soil is comprised of particles of sand, silt and clay, and the percentage of each determines the soil's texture. Because the percentage of any one of these three particles can differ, there is virtually an unlimited number of soil types possible.

An accurate way to determine the amount of sand, silt and clay in soil is to conduct a jar test as laid out below.

- Remove 1 to 2 cups of soil from the zone to be irrigated. Take it from a point 6 to 8 inches (150 mm to 200 mm) below the ground's surface. Place it into a clear glass jar, like a mason jar.
- Fill the jar halfway with water. Replace the lid, shake and let sit for 2 hours so the particles can settle. The heavier sand particles will settle to the bottom, then silt, then clay on top.
- Measure the height of all 3 layers of the soil then the height of each layer. Divide the height of each layer by the total liquid height to compute the percentage of each soil in the jar (see the graphic below).

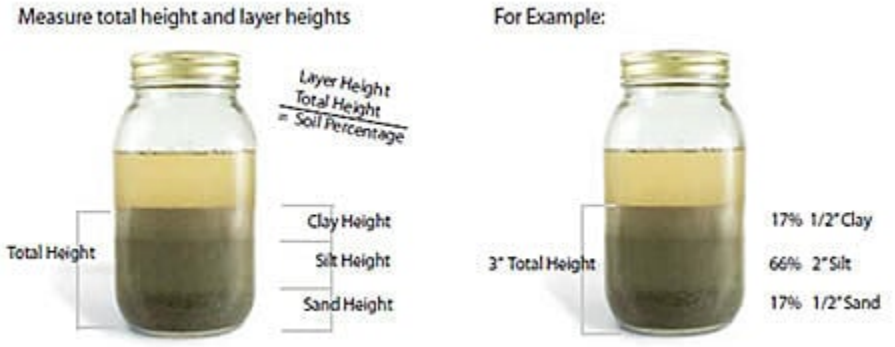



*Figure 3 Jar test*

Apply these figures to the "Soil Classification" chart shown below.

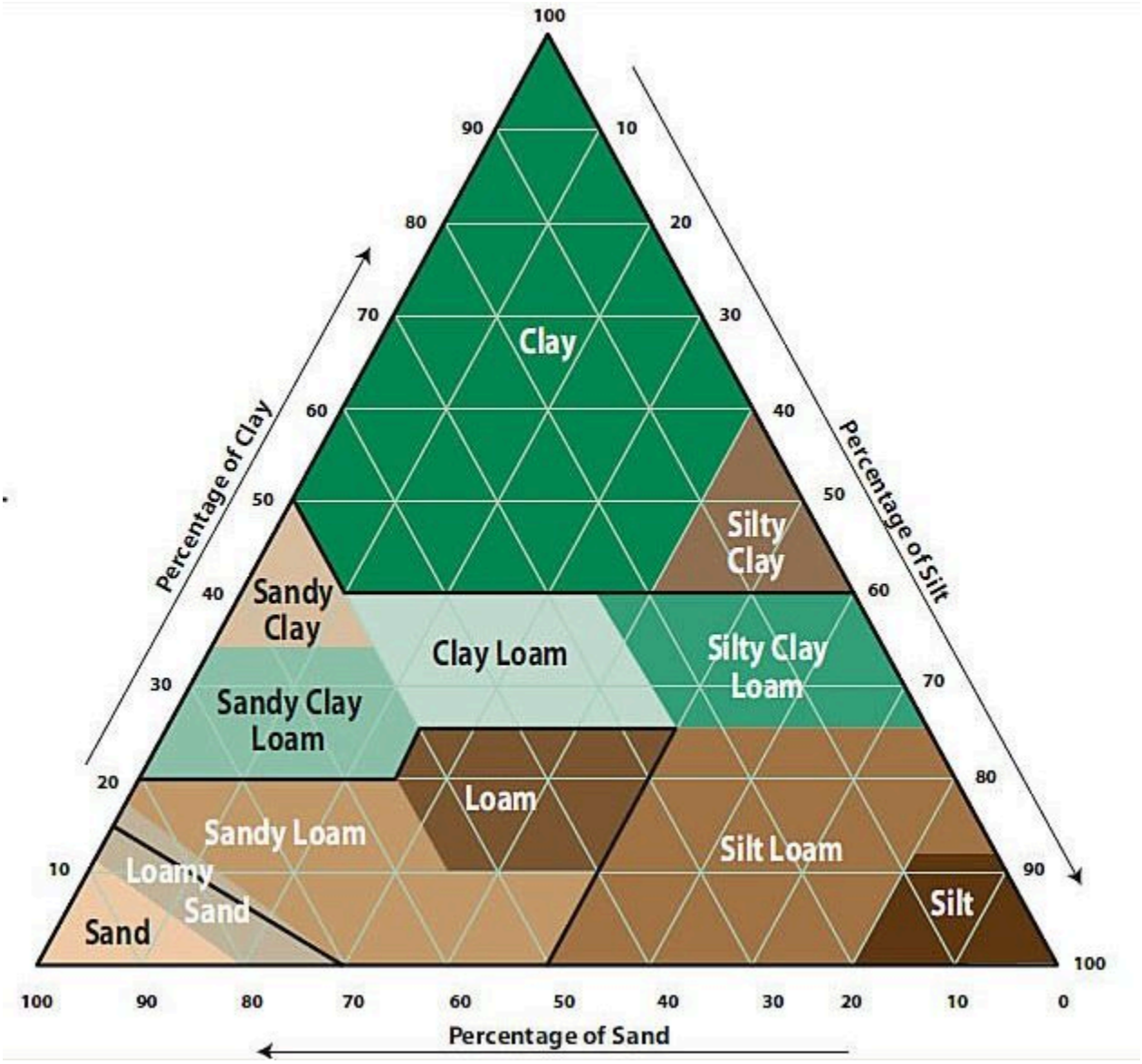



*Figure 4 Soil classification chart (https://www.rainbird.com/sites/default/files/inline-images/soiltypes-pyramid.jpg)*

To use the chart, start with the clay content. Estimate where its percentage amount lies on the left of the chart and draw a horizontal line across to the right. Next, estimate where the percentage of sand is at the bottom of the chart and draw a line diagonally upward to the left. Finally, estimate where the silt percentage is on the right side of the triangle and draw a diagonal line downward and to the left. The approximate point where the three lines intersect will be the texture of the soil. The sample shown in the jar test above would be classed as mainly silt loam.

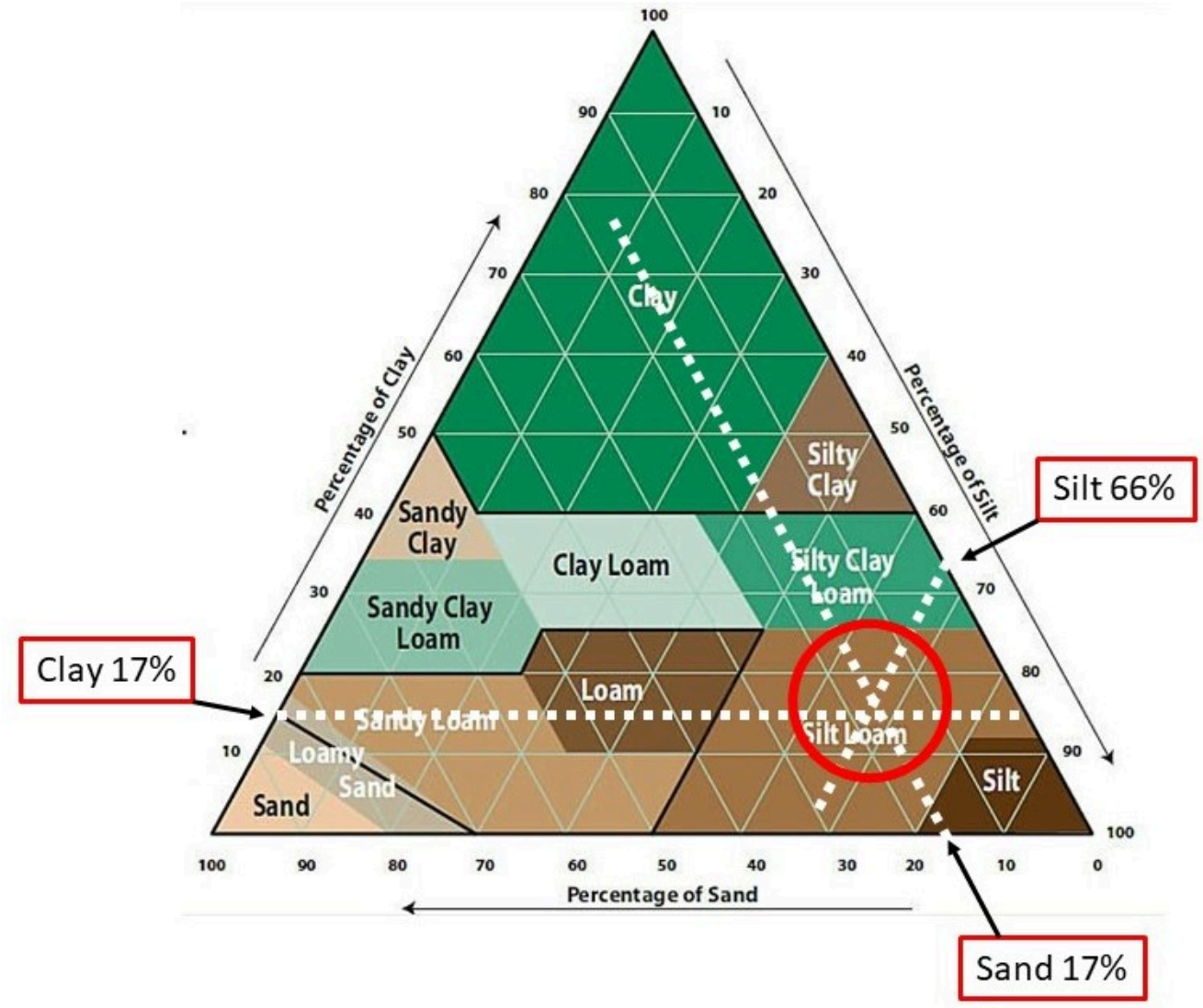



*Figure 5 Using the soil classification chart*

One of the most significant differences between soil types is the way in which they absorb and hold water. Capillary action is the primary force in spreading water horizontally through the soil. Both gravity and capillary action influence vertical movement of water. Sandy or coarse soils allow water to sift through them rather quickly and have a hard time retaining moisture, requiring more frequent watering.

The opposite is true for finer soils. Soils that are heavy in clay content will have a much slower percolation rate than the other two types. Its soil absorption pattern is shallow and wide. What this means is that water will take longer to be absorbed into the ground but will be retained longer as well, so less frequent watering is required.

Loamy soils are preferred for water absorption and retention. Their soil absorption pattern would be more rounded and less deep than that of a sandy soil but deeper than clay soil.

A representation of the soil moisture profiles is shown below. Underground drip emitters are used for this illustration, but the concept applies to the soil types regardless of the application method.

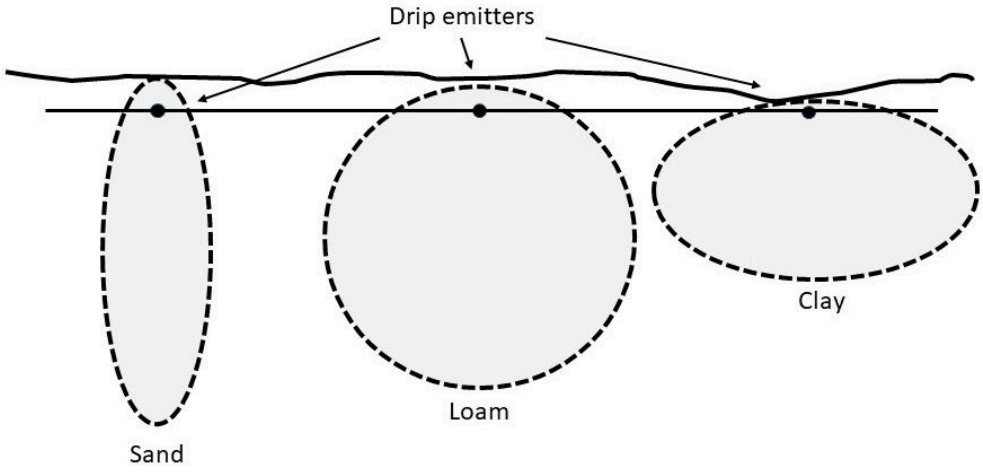



*Figure 6 Soil absorption patterns from drip emitters*

Sloping ground further complicates the issue of soil absorption and contributes to erosion if not recognized and allowed for. The table below shows the estimated maximum precipitation rates, in inches/hr for various soil textures and ground slopes. To convert the figures within the table to mm/hr, multiply the table value by 25 (25mm = 1 inch). Remember that these are estimates only.

**Maximum precipitation rates for slopes (as suggested by US Dept of Agriculture)**

| Soil Texture | 0 to 5% slope – cover | 0 to 5% slope – bare | 5 to 8% slope – cover | 5 to 8% slope – bare | 8 to 12% slope – cover | 8 to 12% slope – bare | 12%+ slope – cover | 12%+ slope – bare |
|---|---|---|---|---|---|---|---|---|
| **Coarse sandy soils** | 2.00 | 2.00 | 2.00 | 1.50 | 1.50 | 1.00 | 1.00 | 0.50 |
| **Coarse sandy soils over compact subsoils** | 1.75 | 1.50 | 1.25 | 1.00 | 1.00 | 0.75 | 0.75 | 0.40 |
| **Light sandy loams uniform** | 1.75 | 1.00 | 1.25 | 0.80 | 1.00 | 0.60 | 0.75 | 0.40 |
| **Light sandy soils over compact subsoils** | 1.25 | 0.75 | 1.00 | 0.50 | 0.75 | 0.40 | 0.50 | 0.30 |
| **Uniform silt loams** | 1.00 | 0.50 | 0.80 | 0.40 | 0.60 | 0.30 | 0.40 | 0.20 |
| **Silt loams over compact subsoils** | 0.80 | 0.30 | 0.50 | 0.25 | 0.40 | 0.15 | 0.30 | 0.10 |
| **Heavy clay or clay loam** | 0.20 | 0.15 | 0.15 | 0.10 | 0.12 | 0.08 | 0.10 | 0.06 |

Instead of being represented by numbers, as in the previous table, the table below describes the various soil characteristics and compares the intake rate, water retention rate and tendency for water to either be absorbed by (drain) or run off (erode) the soils.

| Soil type | Soil texture | Soil components | Intake rate | Water retention | Drainage/erosion |
|---|---|---|---|---|---|
| Sandy soil | Coarse texture | Sand | Very high | Very low | Low erosion<br>High drainage |
| | | Loamy sand | High | Low | |
| Loamy soil | Moderately coarse | Sandy loam | Moderately high | Moderately low | Low erosion<br>High drainage |
| | | Fine loam | Moderately high | Moderately low | |
| | Medium texture | Very fine loam | Medium | Moderately high | Moderate drainage |
| | | Loam | Medium | Moderately high | Moderate drainage |
| | | Silty loam | Medium | Moderately high | Moderate drainage |
| | | Silt | Medium | Moderately high | Moderate drainage |
| | Moderately fine | Clay loam | Moderately low | High | Low drainage |
| | | Sandy clay loam | Moderately low | High | Low drainage |
| | | Silty clay loam | Moderately low | High | Low drainage |
| Clay soil | Fine texture | Sandy clay | Low | High | Low drainage |
| | | Silty clay | Low | High | Severe erosion |
| | | Clay | | | |

*Figure 7 Soil characteristics*

Of note is the information in the last three columns. The soil's intake rate, or how fast it absorbs water, dictates how quickly water can be applied by the irrigation system. This will impact the length of a watering cycle. Coarse, sandy soil absorbs water very quickly and will not have much of a chance to puddle. Silts and clays have a very low intake rate so extended run times will no doubt cause puddling and runoff. The fine textured soils, once wet, retain moisture longer than do the coarse-grained soils. The main problem we wish to avoid is applying water faster than the soil can receive it. Puddling and runoff are signs of overwatering which tend to waste water and cause soil erosion. These conditions must be avoided.

Identifying soil types and setting zone run times and cycles correctly will help to prevent these issues.

## Step 3: Determine the Water and Power Supplies

### Water Supply

The available water flow and pressure must be determined before any design work can be started. To do this, use one of the two following methods.

#### Method #1: Using a flow/pressure gauge

A combination flow/pressure gauge can be obtained through irrigation equipment companies such as Toro® and Rainbird®. They attach to a common ¾″ male hose thread and will measure pressures to 160 psi (1100 kPa) at flow rates of up to 13 GPM (0.91 L/S). The following is a description of the use of such a gauge as supplied by Toro©.

Firstly, measure the static pressure. To do this, make sure no water is being used inside or outside the home. Attach the flow gauge to the outside hosebibb nearest to where the main line enters the house. Make sure the flow gauge is closed by completely turning the handle clockwise. Open the outside faucet slowly to avoid damaging the flow gauge. When the outside faucet is fully opened, read the system static pressure, and record it. Next, measure the dynamic (flow) pressure and gallons-per-minute rates. With the flow/pressure gauge still attached, open the flow gauge slowly by turning the handle counter clockwise. As the flow gauge opens, pressure will drop from the static reading and the flow rate in GPM (l/s) will rise. Open the flow gauge until the pressure reading drops to 50 PSI (350 kPa) and record the GPM (l/s) reading. Continue to close the gauge to 45 (315 kPa) and then 40 PSI (280 kPa) and record the flow rate readings at those pressures. If the pressure does not drop to 40 PSI (280 kPa) after opening the flow gauge all the way, take the flow and pressure reading at the full-open position.

*Note that most sprinklers need a minimum of 35 PSI (245 kPa) to operate properly.

#### Method #2: Using a bucket and standard pressure gauge

If a flow/pressure gauge is not available, use the following procedure:

Find the outside hosebibb that is closest to your water supply line (call this Faucet 1). Find a different outside hosebibb on your house and attach a pressure gauge to it (call this Faucet 2). With Faucet 1 closed, open Faucet 2 all the way and record the static water pressure. Next, open Faucet 1 all the way and check the pressure reading on the gauge at Faucet 2. If it is less than 40 PSI, turn down the water flow from Faucet 1 until the reading reaches 40 PSI. Place a 5-gallon bucket under Faucet 1 and time how long it takes to fill it (use the chart below to convert to GPM). This test tells you what the home's water capacity is, measured in GPM, at 40 PSI. Repeat this procedure at 45 PSI and 50 PSI and record these three results. This is how much water is available with a working pressure of 40 PSI or the higher readings that you recorded.

| **Time to fill 5-gallon bucket** | **Gallons per minute** |
|---|---|
| 15 seconds | 20 GPM |
| 20 seconds | 15 GPM |
| 25 seconds | 12 GPM |
| 30 seconds | 10 GPM |
| 40 seconds | 7.5 GPM |

*Note: If you use a different size bucket, time how long it takes to fill it. Convert this to GPM using the following formula:

$$(60 \div \text{Seconds}) \times \text{Gallons} = \text{GPM}$$

For example: A 2-gallon bucket that fills in 15 seconds means the available flow is:

$$(60 \div 15) \times 2 = 8 \text{ GPM}$$

Record the flow rate in GPM and the corresponding pressure. These will be important factors which will be used when determining the number and placement of zones needed in Step 5.

## Power Supply

The automatic operation of irrigation systems is sequenced by a controller, also known as a timer, that plugs into a 120VAC (120 volt alternating current) electrical outlet. An outlet should be chosen that is within the power cord's length to the desired location of the controller. The controller is normally mounted on a wall indoors (e.g. inside a garage) or outdoors, provided it is approved for outdoor use and is protected from the elements as well as from spray from the operating sprinklers. Also, a consideration for the choice of controller location should be to allow the irrigation technician to easily view the zones in operation when setting up the controller while not being hit by the sprinklers' discharge. Most homes have at least two 120 VAC exterior electrical "GFCI" (ground fault circuit interrupter) outlets which may be of use for this purpose. If the location doesn't provide the timer enough protection from the elements, a lockable waterproof cabinet is available. Locking the cabinet also helps to prevent vandalism and unwanted adjustments of settings.




*Figure 8 Timer/controller with weatherproof cabinet*

The controller should also be in as close a proximity as possible to the zone valve locations, in order to minimize the length of control wire needed between the two points.

Now complete Self Test 1 and check your answers. Answers are at the end of this learning guide.

## Self-Test 1

Self-Test 1

1. Which one of the following could be seen as a downside to installing an automatic sprinkler system rather than watering manually?
    a. Giving plants an exact amount of water
    b. Water conservation
    c. Cost of installation
    d. Cost of operation
2. What style of irrigation system is installed to water small, specific areas such as planters and hanging baskets?
    a. Drip
    b. Deluge
    c. Stream rotor
    d. Fixed spray
3. What is the service known as in British Columbia that will send information on any buried utilities to interested parties at no cost?
    a. IDigIt
    b. BC 1 Call
    c. DigAnywhere
    d. CallMeAMole
4. Which one of the following would likely *not* need to be plotted on a site plan for a proposed irrigation system?
    a. Walkways, driveways, and patios
    b. Water supply connection
    c. Gutter downspouts
    d. Trees
5. What is the term given to the water that is used by the plant and lost into both the air and the soil?
    a. Evapotranspiration
    b. Transpiration
    c. Evaporation
    d. Percolation

6. According to the figures in the list on page 4, a daily water need of 0.23 inches (5.5 mm) would be classed as .

    a. Cool dry
    b. Warm dry
    c. Hot humid
    d. Warm humid

7. Which one of the following can easily be used to determine the soil's texture?

    a. Jar test
    b. Loam test
    c. Percolation test
    d. Evapotranspiration test

8. What is the category of soil texture if it has these approximate contents: 30% clay, 40% sand and 30% silt? (Use the triangular chart on page 6)

    a. Sandy clay loam
    b. Silty clay loam
    c. Sandy loam
    d. Clay loam

9. Which one of the following soil types is considered best for water absorption and retention?

    a. Silt
    b. Sand
    c. Loam
    d. Rock

10. Which one of the following is the most likely result of applying water too fast to sloping ground?

    a. Puddling
    b. Sponginess
    c. Runoff and erosion
    d. Healthy stable plants

11. If a 3-gallon pail takes 18 seconds to fill, what would this be in gallons per minute?

    a. 1.11
    b. 3.33
    c. 10
    d. 54

12. Which one of the following would *not* be a consideration in the choice of location for mounting a residential timer/controller?

a. Exposure to weather
b. Proximity to 120 VAC
c. Ability to view zones operating
d. Proximity to the house water supply

Check your answers using the Self-Test Answer Keys in Appendix 1.

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# Learning Task 2

Install a Residential Sprinkler System

## Step 4: Selecting and Locating Sprinklers

This is the point where the sprinklers are selected and plotted onto the sketch. Many would-be designers consider this to be the first step in the whole design process, but most of the criteria needed for sprinkler selection is gathered through the preliminary steps leading to this point.

The size and shape of the areas to be irrigated often determine what type of sprinkler will be used. The goal is to select the type of sprinklers that will cover the area properly using the least number of sprinklers. There are 2 basic types of sprinklers: fixed spray and rotating.

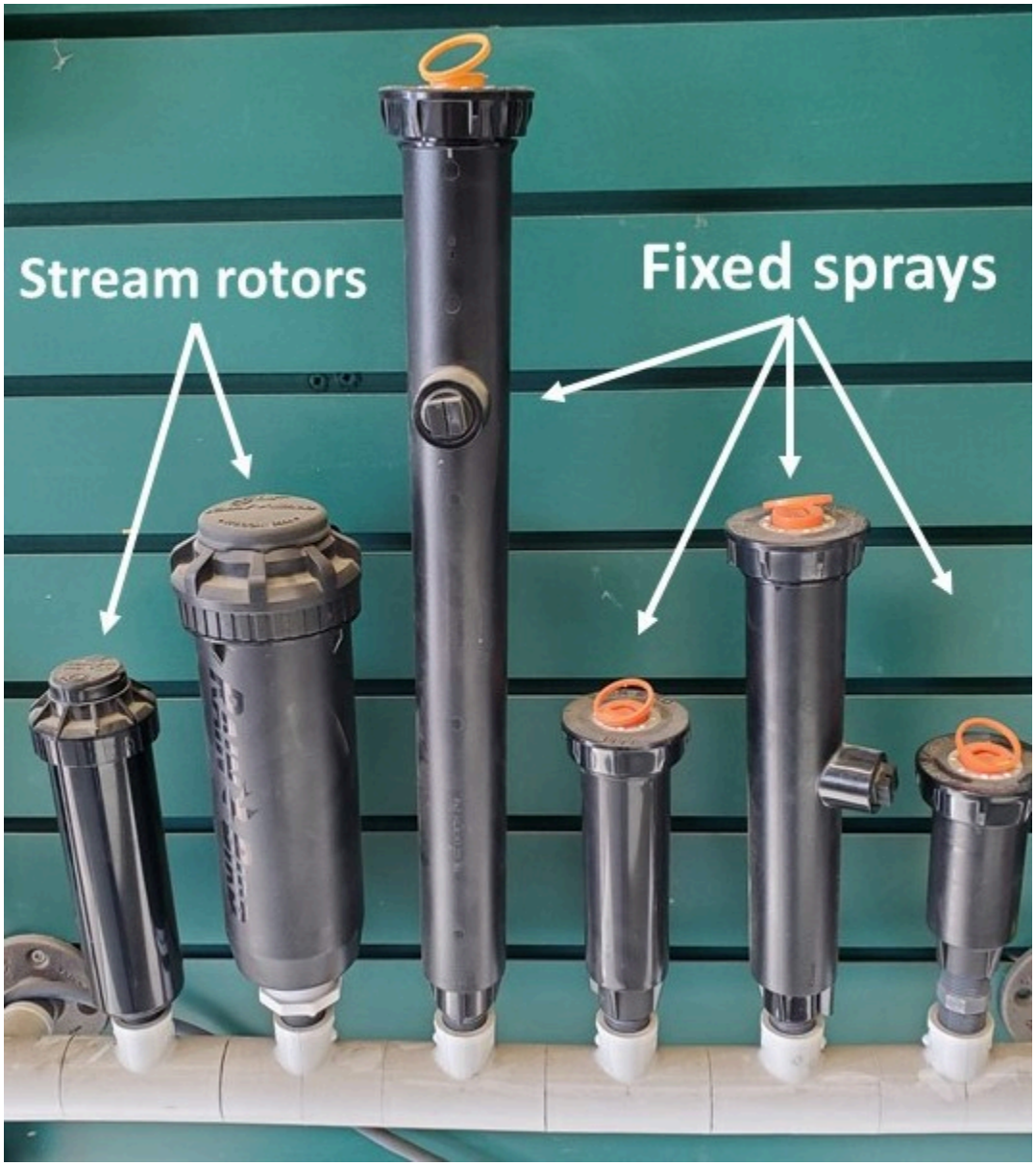



*Figure 1 Stream rotors and fixed spray heads*

## Fixed Spray Sprinklers

Spray sprinklers are required for smaller landscaped areas, for those areas with enclosed borders requiring tightly controlled spray, for areas with dense tree growth that would significantly hinder a rotating sprinkler's coverage and for areas that have mixed sections of plantings that require many sprinklers because of differing amounts of water required. Spray sprinklers generally emit single or double sheets or fans of water in a fixed pattern. These patterns are usually a particular part of a circle or arc.

The most common fixed patterns are full circle, three-quarter circle (270°), two-thirds circle (240°), half circle (180°), one-third circle (120°), quarter circle (90°) and one-eighth circle (45°). In addition to the arcs, some specialty spray patterns like center strips, side strips and end strips are available that tend to spray in a rectangular pattern. Also available from some manufacturers is a variable arc nozzle

which is a hybrid spray nozzle intended to handle the occasional odd-shaped, in-between area. This type of nozzle allows the designer and installer to adjust the arc of coverage from a few degrees to 360°.

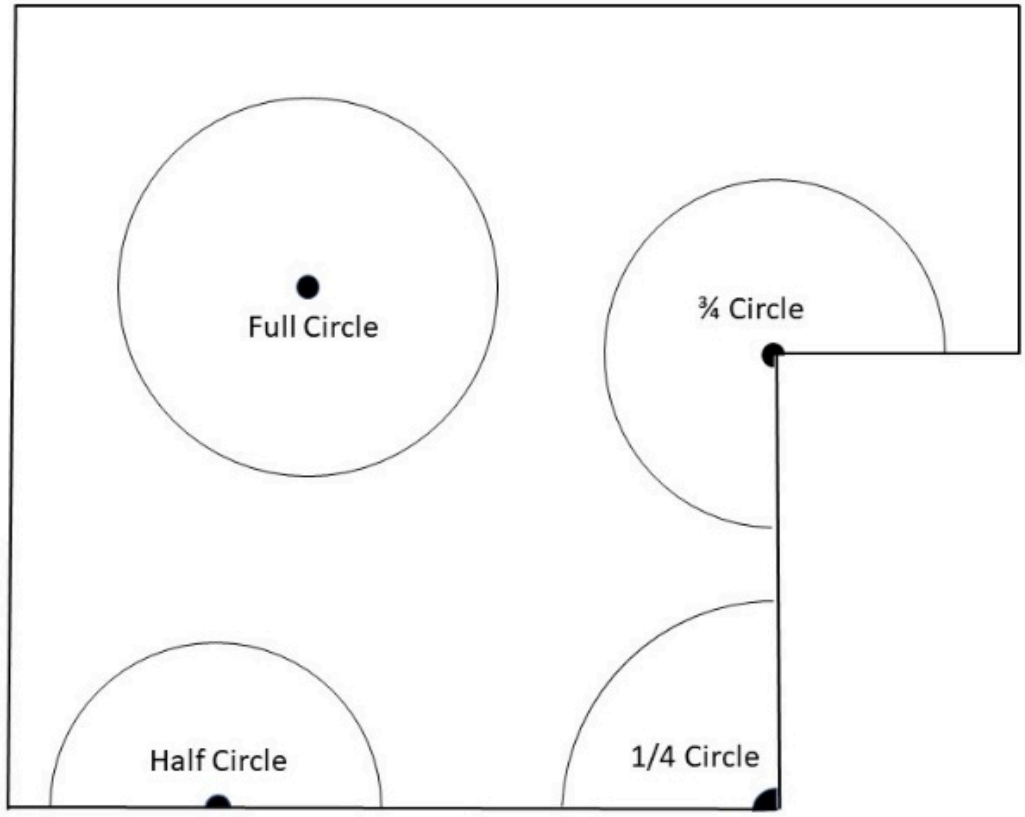



*Figure 2 Examples of Fixed Spray Patterns*

Bubblers are fixed spray heads that produce short throw or zero radius water distribution. The most common type of bubbler delivers anywhere from 1/2 to 3 gpm (0.03 to 0.19 l/s), depending on the pressure available and how it is adjusted. The water either runs down the riser supporting the sprinkler, much like spillage from a container, or sprays out a few inches (centimeters) in an umbrella pattern. The advantage of a bubbler is that it can irrigate a specific area without overthrow onto other plants. Bubblers can be used in very narrow or small planting areas and can be adjusted to low flow so large numbers of bubblers can be mounted on one line.

Spray sprinklers can be either mounted on risers in shrub beds where concealment isn't an issue or can be of a pop-up variety to avoid mowing or foot traffic interference in small lawn areas.

### Rotating Sprinklers (Stream Rotors)

Like the spray sprinklers, rotating sprinklers are available in riser-mount configuration for irrigating larger shrub and ground cover areas, and in pop-up versions for watering turfgrasses. Rotating

sprinklers use various means for converting a portion of the flow and pressure passing through them into “drive” energy to turn the sprinkler.



*Figure 3 Rainbird® 3500 stream rotor with nozzle assortment*



*Figure 4 Rainbird® 3500 pop-up stream rotor in operation*

In general, rotating sprinklers have a single nozzle or pair of nozzles that revolve to distribute water over the area of coverage. Part circle units have a reversing or shutoff mechanism to avoid watering outside their arc pattern. Instead of fixed arcs of coverage, most part circle rotating sprinklers are adjustable from about 20 to 240° and many can be switched to the 360° (full circle) setting. Full-circle-only units are also available.

Available in a wide range of sizes, most rotating sprinklers on the market today operate somewhere in the 25 to 100 psi (175 to 700 kPa) range. The distance of throw is much greater than for spray sprinklers. Rotating sprinklers can throw from about 20 ft (6 m) minimum for the small units to well over 100 ft (30 m) of radius for larger commercial units. It should be noted that the flow demands for large radius sprinklers are much higher. Discharge rates of up to 100 gpm (6.3 L/s) are not uncommon for large rotating sprinklers used for watering golf courses, whereas flow rates of between 1 and 10 GPM are common for residential rotors.

Impact sprinklers are a variety of rotating sprinkler that are more commercial/agricultural in nature. They have a paddle that “slaps” the water stream to provide watering close to the sprinkler location as well as to cause the nozzle to move horizontally with each “slap”. Many traditional residential hose-operated sprinklers are of this variety.

Despite their large water flow, rotating sprinklers usually apply water much more slowly than spray sprinklers because the water is spread out over greater areas. The precipitation rates for these large sprinklers run more in the ¼ to 2 in/hr (6 to 51 mm/hr) range. This makes rotating sprinklers appropriate for slopes, tight soils and other areas where slower application rates are required in order to prevent runoff and erosion.

Pop-up versions of rotors and spray heads are buried deep enough so that the highest point of the sprinkler is just below the ground (not the grass) level when the system is at rest. This keeps them out

of the way of mower blades and foot traffic while allowing enough height for the head to clear the surrounding grass when in operation. Pop-up valve bodies are available in lengths between 2″ and 18″ depending on manufacturer.

Economics usually drives the choice between stream rotors and fixed spray heads. The large radius sprinklers are usually more economical, and energy and water efficient for large-area irrigation, where their streams are uninterrupted and allow for full coverage. Fewer sprinklers, fewer fittings, and less trenching are definite advantages of rotating sprinklers compared to spray sprinklers, however smaller or irregularly shaped areas are usually better served with spray sprinklers.

## Plotting Sprinklers

Now it is time to select and plot the sprinklers onto the drawing. Do this one area at a time. When selecting the proper sprinklers for a project, several factors should be considered. Some of these factors are:

- type of sprinklers requested by the owner
- size and shape of the areas to be watered
- types of plant material to be irrigated
- water pressure and flow available
- local environmental conditions such as wind, temperature, slope and precipitation
- soil type and the rate at which it can accept water
- compatibility of the sprinklers which can be grouped together

Tackle one area at a time. This helps to lessen the feelings of being overwhelmed by the size of any project and ensures that nothing is missed. Some points to consider when plotting sprinkler locations are:

- Start with quarter circle heads at corners, then half circle types along the borders of straight edges, full circles for large open areas and lastly specialty types for odd-shaped areas.
- Place sprinklers with the greatest radius in larger areas to reduce the numbers of sprinklers.
- Use “head-to-head” coverage; in other words, make sure the spray from one head will reach all the heads adjacent to it. This ensures uniform water application, which saves water and creates the best possible results. Nozzle specs are based on head-to-head coverage.
- Use a compass to draw the arcs to scale. This will help ensure head-to-head coverage.
- Note the GPM flow rate on the sketch beside each sprinkler. Refer to this number when assigning sprinklers to zones in Step 5.
- Avoid spraying onto buildings, fences, walls, sidewalks, driveways and streets.
- Use rotor sprinklers to cover large areas and fixed spray sprinklers for small areas.
- Do not mix fixed spray and rotors within the same zone. Rotor + rotor = OK; spray head + spray head = OK; rotor + spray head = NOT OK

- It is best to use one product manufacturer for the sprinklers, valves and controllers, to ensure they are compatible with each other.

At this stage, use the manufacturers' nominal radius distances for the initial sprinkler spacing layout. Head-to-head coverage should be the design goal, as shown in the image below.

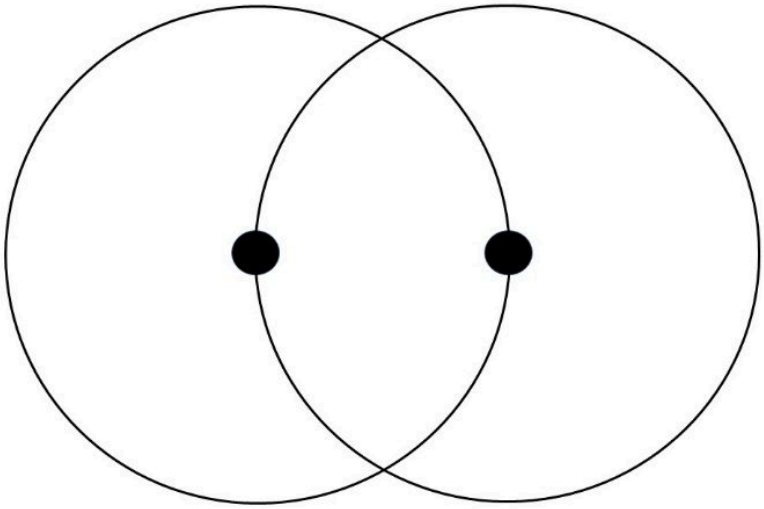


*Figure 5 Head-to-head coverage*

This is termed "50% spacing", meaning that the distance between heads is 50% or half of the diameter of the spray pattern.

## Spacing Patterns

There are two main types of sprinkler spacings: square and triangular. The square pattern, with its equal sides running between four sprinkler locations, is used for irrigating areas that are square themselves, or have borders at 90° angles to each other, and that confine the design to that pattern. Although the square pattern is the weaker for proper coverage if not used carefully, enclosed areas often rule out the use of a triangular pattern. The weakness in square spacing coverage is caused by the diagonal distance between sprinklers across the pattern from each other. When the sprinklers are spaced head-to-head along the sides of the square pattern, the distance between sprinklers in opposite corners of the pattern is over 70% spacing. This 70% diagonal stretch across the square pattern can leave a "weak" spot at the center. Wind may move the weak spot slightly away from the center and summer heat may make the weak spot quite large if it is a common climatic condition for the site. If windy conditions are common, it may be prudent to reduce the spacing between heads to 45 or even 40%. This will increase the number of heads required.

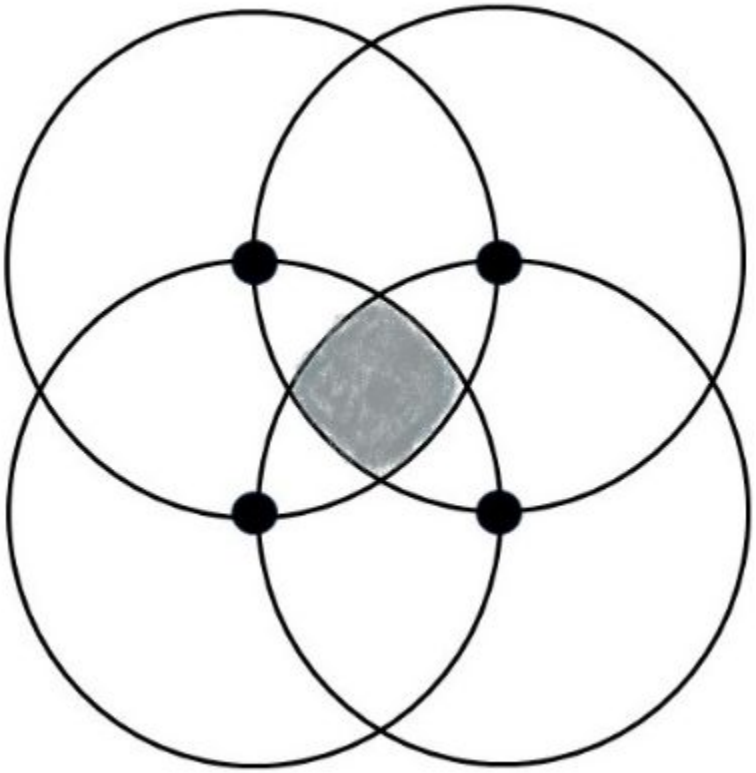


*Figure 6 Weak spot caused by square spacing*

A better choice of spacing is triangular. This pattern is generally used where the area to be irrigated has irregular boundaries or borders that are open to over spray, or do not require part-circle sprinklers. The equilateral triangle pattern, where the sprinklers are spaced at equal distances from each other, has a distinct advantage over square spacing. Because the rows of sprinklers are offset from adjacent rows to establish the triangular pattern, the weak spot that could be a problem in square spacing is absent. In most cases, the sprinklers can be spaced further apart, possibly to 60% of their diameter depending on wind conditions. This additional distance between sprinklers often means fewer sprinklers will be required on the project. This translates to less equipment cost for the project, less installation time and lower maintenance costs over the life of the system.

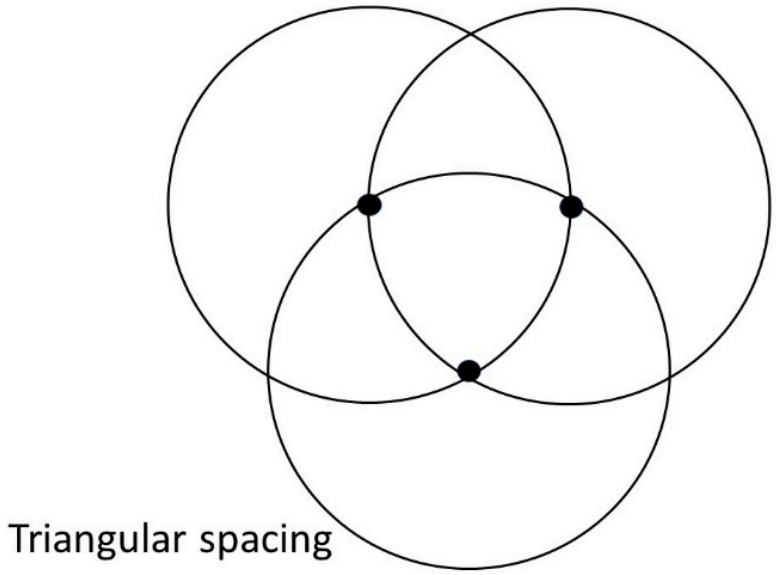



*Figure 7 Triangular spacing*

The determination of run times for the zone valves will be dependant upon precipitation rates from the heads and those will be dependant upon whether the spacings are square or triangular.

Once sprinklers are initially plotted, a site plan might look like the one below.

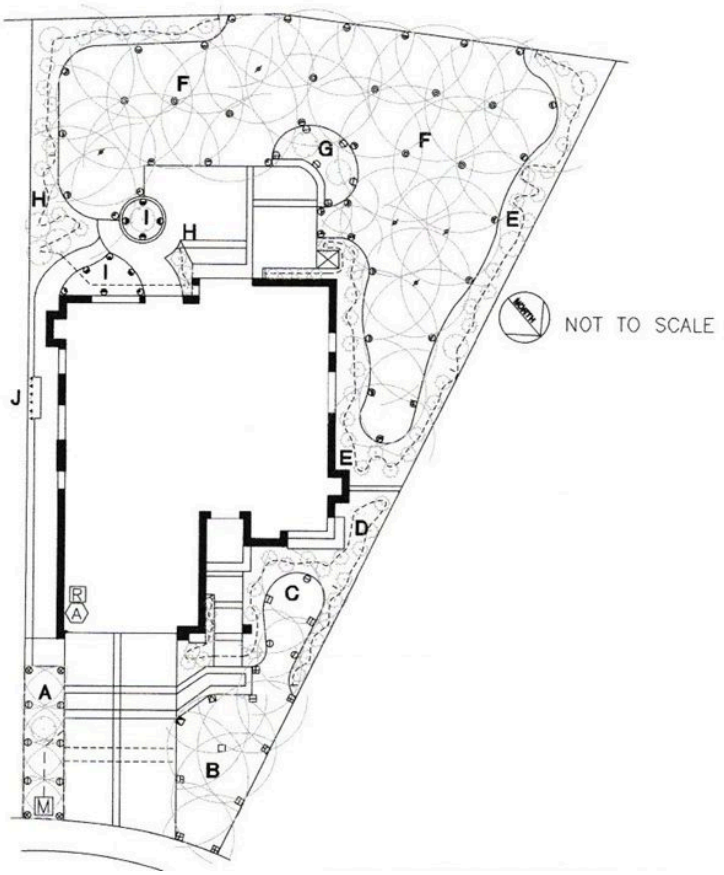



*Figure 8 Example of a site plan after plotting sprinklers*

Most sprinklers have interchangeable nozzles with differing radii, trajectory angles, spray patterns and flow rates. The distance that a nozzle “throws” water is referred to as its radius. The farther the radius, the higher the flow rate in GPM. For each sprinkler location, choose a nozzle with a radius that keeps the spray pattern within the area being watered. For instance, if a rectangular area is 24′ (7.2m) x 16′ (4.8m), using sprinklers with an 8′ (2.4m) radius would provide equal spacing and head-to-head coverage in a square pattern between all sprinklers.

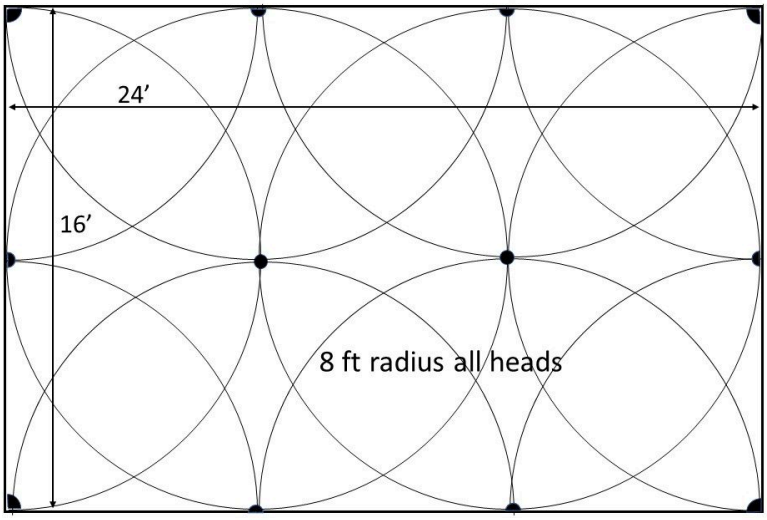



*Figure 9 Using spray heads with 8 foot radii*

5′ (1.5m), 8′ (2.4m), 10′ (3m), 12′ (3.6m) and 15′ (4.5m) are common radii of nozzles for fixed spray heads. Stream rotors for residential use are capable of radii from 20 to 25 feet (6 to 10.5 m).

The actual radius of a nozzle is affected by the pressure at the head. For example, a certain manufacturer’s spray nozzle listed as “12′ Series” has a radius of 11′ @ 20 psi, 12′ @ 30 psi and 13′ @ 40-50 psi. The precipitation rates and GPM will also increase with the increase in radius. This is illustrated in the table of nozzle data below.

| Nozzle | Pressure (psi) | Radius (ft) | Flow (GPM) | Precip (in/hr) ■ | ▲ |
|---|---|---|---|---|---|
| 90°  | 25 | 29 | 1.03 | 0.47 | 0.54 |
| | 35 | 30 | 1.23 | 0.53 | 0.61 |
| | 45 | 30 | 1.40 | 0.60 | 0.69 |
| | 55 | 30 | 1.56 | 0.67 | 0.77 |
| | 65 | 30 | 1.69 | 0.72 | 0.83 |
| 120°  | 25 | 29 | 1.34 | 0.46 | 0.53 |
| | 35 | 30 | 1.62 | 0.52 | 0.60 |
| | 45 | 30 | 1.85 | 0.59 | 0.69 |
| | 55 | 30 | 2.06 | 0.66 | 0.76 |
| | 65 | 30 | 2.24 | 0.72 | 0.83 |
| 180°  | 25 | 29 | 2.15 | 0.49 | 0.57 |
| | 35 | 30 | 2.59 | 0.55 | 0.64 |
| | 45 | 30 | 2.96 | 0.63 | 0.73 |
| | 55 | 30 | 3.30 | 0.71 | 0.82 |
| | 65 | 30 | 3.60 | 0.77 | 0.89 |
| 360°  | 25 | 29 | 4.24 | 0.49 | 0.56 |
| | 35 | 30 | 5.08 | 0.54 | 0.63 |
| | 45 | 30 | 5.78 | 0.62 | 0.71 |
| | 55 | 30 | 6.39 | 0.68 | 0.79 |
| | 65 | 30 | 6.92 | 0.74 | 0.85 |

*Figure 10 Example of nozzle data*

The designer can circle back to this stage of planning when assigning sprinklers to zones in a later step. Nozzle selection can be tweaked to ensure that the flow rate of the zone doesn't exceed the supply capability while still ensuring adequate coverage. It is important to note that sprinklers should be supplied with at least the pressure needed for correct radius of throw, but no higher pressure than the manufacturer suggests. Too much pressure at a head produces a mist rather than a stream of droplets. Mists will easily be carried away by the slightest gust of wind and not reach the intended target. Most design work assumes an operating pressure of between 25 and 65 psi (172 and 448 kPa).

## Step 5: Layout of Zone Valves and Main Lines

Now it is time to divide your sprinklers into groups, called zones. A zone is simply a group of sprinkler heads connected with pipe fed by a single valve. Each zone valve is controlled by the system's

controller/timer. The basic idea is to group together areas of the property that have the same watering needs, so the sprinkler heads supplying each area will water on the same schedule. In this way, you can tailor the watering needs of the different areas of plants. The idea is to divide similar sprinklers into groups such as lawn areas, shrub areas, shady areas and sunny areas.

There are two types of zone valves: anti-siphon and in-line. Before selecting either, check your local codes to determine which is appropriate in your area.

Anti-siphon zone valves have backflow prevention devices integrated into each individual valve to keep the water from the sprinkler system (and any contaminates that water could carry) from entering the clean potable water supply through backflow. The main disadvantage to the use of anti-siphon valves is that they must be installed above ground, 6” to 12” above the highest sprinkler or according to local codes. This may interfere with vehicle/foot traffic and is likely also to be an aesthetic issue. However, installing anti-siphon valves at every zone valve location negates the need for a single backflow preventer at the source of supply. Again, check with the local AHJ as well as the property owner to see if this is a viable option before designing the system.

In-line valves are most common and are installed below ground in valve boxes for out-of-sight operation. However, when using in-line valves, the system will need to be protected from backflow by the installation of an approved backflow preventer. A reduced pressure backflow assembly (RPBA) or a double check valve assembly (DCVA) is normally specified by the AHJ to be installed at the point where the irrigation system connects to the potable water piping.

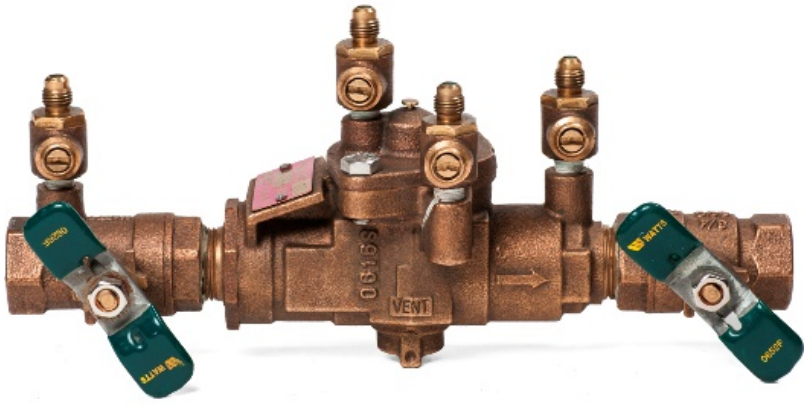



*Figure 11 RPBA*



*Figure 12 DCVA*

Alternatively, a pressure vacuum breaker assembly (PVBA) can be used in place of an RPBA or DCVA to protect the entire system from back siphonage backflow, provided it is installed and located appropriately.




*Figure 13 PVBA*

All three devices mentioned above are “in-line testable”, meaning they can be checked for correct operation without being removed from the piping. Annual testing of RPBAs, DCVAs and PVBs is a normal requirement for irrigation systems.

Some jurisdictions allow the use of a dual check valve (DCV) or a dual check with atmospheric port (DCAP) for system protection. These devices are not in-line testable and should not be used if a testable backflow preventer is required.




*Figure 14 DCV*



*Figure 15 DCAP*

Residential anti-siphon and in-line zone valves are a normally closed (NC) electrically operated globe-type valve that will open when supplied with 24VAC from the timer. They can also be opened manually if needed. Many zone valves contain a flow control feature that can throttle the water volume being supplied to the sprinklers to further fine-tune the water distribution.



*Figure 16 Anti-siphon zone valve*



*Figure 17 In-line zone valve*

Zone valves are usually located below ground in irrigation boxes. The boxes are available in different shapes and dimensions and are specifically designed to easily allow piping and zone valve installation within them while blending in with their surroundings. They are made of PVC or ABS plastic and have lockable lids that will withstand normal foot and light mower traffic.




*Figure 18 Round irrigation box*



*Figure 19 Rectangular irrigation box*

The idea behind locating zone valves is to try to group or consolidate them together into manifolds near to the sprinklers being served. Manifold fittings are available that allow two or more zone valves to be piped together in a compact fashion.




*Figure 20 Manifold fittings*

The manifold locations are entirely a matter of choice. Try to place them in areas where they won't interfere with pavement or concrete. Flower beds near the house are common locations for them.



*Figure 21 Manifolded zone valves in irrigation box*

Main lines run from the point of connection of the water supply to the zone valve boxes and should be installed as directly as possible between these two points. This will minimize pressure loss through excessive numbers of fittings. For residential irrigation these lines will normally be ¾″ or 1″ PVC Schedule 40 pipe. Class 200 PVC pipe is also popular for use in irrigation systems but is normally limited to use between the zone valves and sprinklers due to its thinner walls and lower burst strength. Polyethylene (PE) pipe is also an option. It comes in coils of up to 1000 feet (300m) and is connected using barbed fittings and gear clamps. There is more pressure drop through this type of piping due to the type of fittings being used, thus restricting flow. Also, the pipe is more difficult to install in a straight trench due to its tendency to recoil itself. However, this system requires less installation tools, fittings and associated knowledge than does a PVC system. 90-degree elbows aren't normally required because the pipe can be bent into a tight radius and trenches therefore can run directly between two points without needing to be straight and parallel. It is commonly installed by homeowners of small systems.



*Figure 22 Barbed fitting and gear clamp for PE systems*



*Figure 23 Polyethylene (PE) pipe*

Any threaded nipples used will be SCH 80 due to the wall thickness needed in order to be threaded.



*Figure 24 SCH 80 PVC nipples*

Each sprinklered area will need at least one zone valve. The number needed will depend on the available GPM as determined in Step 3 and the flow rate of the sprinklers in the area being watered from Step 4. For instance, if the available flow rate at 40 PSI was 7 GPM, and flow rate for all the sprinklers in a particular area totalled 16 GPM, then the sprinklers would need to be split between 3 zone valves unless nozzles can be changed resulting in lower flow rates. The piping would be run from the valves to the heads in as direct a line as possible and in a balanced manner. The diagrams below show a couple of examples of correct versus incorrect feed patterns to multiple heads.

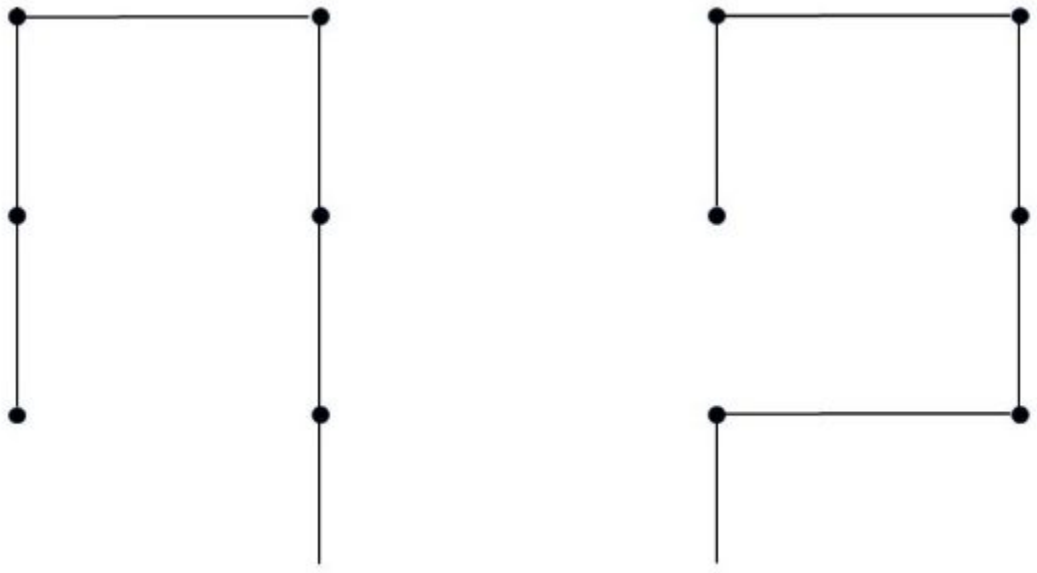


*Figure 25 Incorrect zone piping configurations*

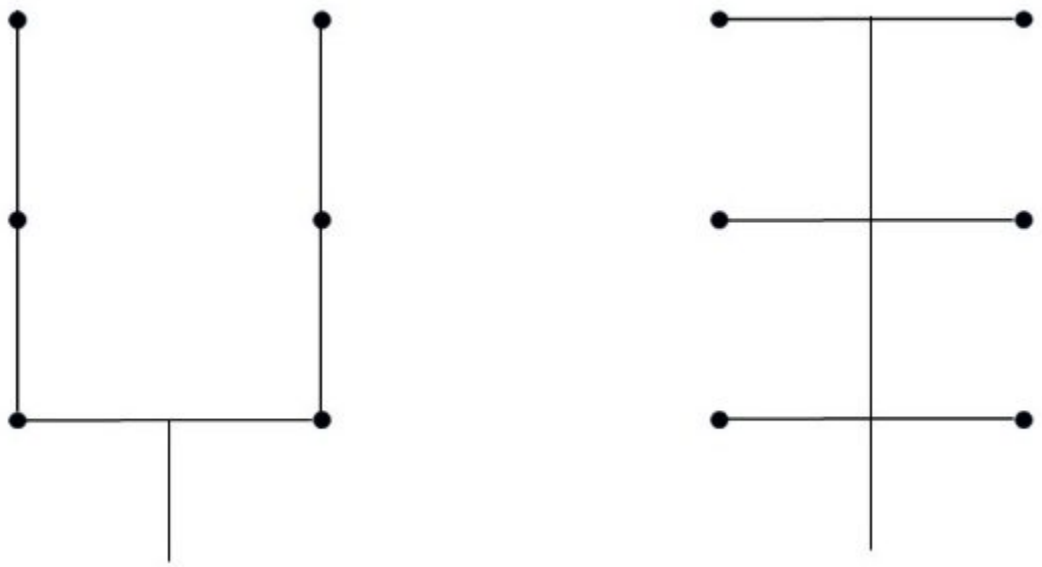


*Figure 26 Correct zone piping configurations*

## Step 6: Sizing Pipe and Valves and Calculating Total System Pressure Loss

### Sizing Pipe

Many designers of average-sized residential systems will use rule-of-thumb methods, such as using 1″ pipe to feed the valve manifolds and ¾″ pipe to supply stream rotors, with ½″ pipe to any fixed spray sprinkler from a ¾″ branch line. While this method may work in most cases, there are times when a more accurate method is needed to ensure the system isn't undersized. Designing PVC piping systems to keep water flows rates no higher than 5 ft/sec (1.5m/sec) is the accepted standard. This keeps pressure losses due to friction to a minimum which ensures adequate pressure to all the sprinklers and minimizes erosion due to excessive velocities. The two charts below are generic industry standards for Sch 40 and Class 200 PVC pipe. They list flow rates from 1 to 12 GPM which are typical for most residential installations. They also show pipe sizes from ¾″ to 1 ¼″ which are also typical for those installations.

**100 feet of Class 200 PVC Pipe**

| **SIZE** | **¾ IN** | | **1 IN** | | **1¼ IN** | |
|---|---|---|---|---|---|---|
| **flow gpm** | **velocity fps** | **psi loss** | **velocity fps** | **psi loss** | **velocity fps** | **psi loss** |
| 1 | 0.47 | 0.06 | 0.28 | 0.02 | 0.18 | 0.01 |
| 2 | 0.94 | 0.22 | 0.57 | 0.07 | 0.36 | 0.02 |
| 3 | 1.42 | 0.46 | 0.86 | 0.14 | 0.54 | 0.04 |
| 4 | 1.89 | 0.79 | 1.15 | 0.24 | 0.72 | 0.08 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 2.36 | 1.20 | 1.44 | 0.36 | 0.90 | 0.12 |
| 6 | 2.83 | 1.68 | 1.73 | 0.51 | 1.08 | 0.16 |
| 7 | 3.30 | 2.23 | 2.02 | 0.67 | 1.26 | 0.22 |
| 8 | 3.77 | 2.85 | 2.30 | 0.86 | 1.44 | 0.28 |
| 9 | 4.25 | 3.55 | 2.59 | 1.07 | 1.62 | 0.34 |
| 10 | 4.72 | 4.31 | 2.88 | 1.30 | 1.80 | 0.42 |
| 11 | 5.19 | 5.15 | 3.17 | 1.56 | 1.98 | 0.50 |
| 12 | 5.66 | 6.05 | 3.46 | 1.83 | 2.17 | 0.59 |

**100 feet of SCH 400 PVC Pipe**

| **SIZE** | **¾ IN** | | **1 IN** | | **1¼ IN** | |
|---|---|---|---|---|---|---|
| **flow gpm** | **velocity fps** | **psi loss** | **velocity fps** | **psi loss** | **velocity fps** | **psi loss** |
| 1 | 0.60 | 0.11 | 0.37 | 0.03 | 0.21 | 0.01 |
| 2 | 1.20 | 0.39 | 0.74 | 0.12 | 0.42 | 0.03 |
| 3 | 1.80 | 0.84 | 1.11 | 0.26 | 0.64 | 0.07 |
| 4 | 2.40 | 1.42 | 1.48 | 0.44 | 0.85 | 0.12 |
| 5 | 3.00 | 2.15 | 1.85 | 0.66 | 1.07 | 0.18 |
| 6 | 3.60 | 3.02 | 2.22 | 0.93 | 1.28 | 0.25 |
| 7 | 4.20 | 4.01 | 2.59 | 1.24 | 1.49 | 0.33 |
| 8 | 4.80 | 5.14 | 2.96 | 1.59 | 1.71 | 0.42 |
| 9 | 5.40 | 6.39 | 3.33 | 1.97 | 1.92 | 0.52 |
| 10 | 6.00 | 7.77 | 3.70 | 2.40 | 2.14 | 0.63 |
| 11 | 6.60 | 9.27 | 4.07 | 2.86 | 2.35 | 0.75 |
| 12 | 7.21 | 10.89 | 4.44 | 3.36 | 2.57 | 0.89 |

The tables are based on 100 feet (30m) of pipe. Using a size of pipe at a flow rate that lands within the shaded areas of the chart should be avoided. For example, trying to supply 9 GPM through a ¾″ SCH 40 pipe would incur a friction loss of 6.39 psi (44 kPa) for every 100 ft (30m) of pipe, and this would also operate at over 5 ft/sec (1.5m/sec) velocity as shown in the table below.

| SIZE | 3/4 IN | | 1 IN | | 1 1/4 IN | |
|---|---|---|---|---|---|---|
| flow | velocity | psi | velocity | psi | velocity | psi |
| gpm | fps | loss | fps | loss | fps | loss |
| 1 | 0.60 | 0.11 | 0.37 | 0.03 | 0.21 | 0.01 |
| 2 | 1.20 | 0.39 | 0.74 | 0.12 | 0.42 | 0.03 |
| 3 | 1.80 | 0.84 | 1.11 | 0.26 | 0.64 | 0.07 |
| 4 | 2.40 | 1.42 | 1.48 | 0.44 | 0.85 | 0.12 |
| 5 | 3.00 | 2.15 | 1.85 | 0.66 | 1.07 | 0.18 |
| 6 | 3.60 | 3.02 | 2.22 | 0.93 | 1.28 | 0.25 |
| 7 | 4.20 | 4.01 | 2.59 | 1.24 | 1.49 | 0.33 |
| 8 | 4.80 | 5.14 | 2.96 | 1.59 | 1.71 | 0.42 |
| 9 | 5.40 | 6.39 | 3.33 | 1.97 | 1.92 | 0.52 |
| 10 | 6.00 | 7.77 | 3.70 | 2.40 | 2.14 | 0.63 |
| 11 | 6.60 | 9.27 | 4.07 | 2.86 | 2.35 | 0.75 |
| 12 | 7.21 | 10.89 | 4.44 | 3.36 | 2.57 | 0.89 |

*¾" SCH 40 PVC @ 9 GPM*

A better choice for a 9 GPM flow rate would be to use 1″ SCH 40 pipe at a velocity of 3.33 ft/sec (1m/sec) and a friction loss of only 1.97 psi (13.6 kPa) per 100 ft (30m), as seen below.

| SIZE | 3/4 IN | | 1 IN | | 1 1/4 IN | |
|---|---|---|---|---|---|---|
| flow gpm | velocity fps | psi loss | velocity fps | psi loss | velocity fps | psi loss |
| 1 | 0.60 | 0.11 | 0.37 | 0.03 | 0.21 | 0.01 |
| 2 | 1.20 | 0.39 | 0.74 | 0.12 | 0.42 | 0.03 |
| 3 | 1.80 | 0.84 | 1.11 | 0.26 | 0.64 | 0.07 |
| 4 | 2.40 | 1.42 | 1.48 | 0.44 | 0.85 | 0.12 |
| 5 | 3.00 | 2.15 | 1.85 | 0.66 | 1.07 | 0.18 |
| 6 | 3.60 | 3.02 | 2.22 | 0.93 | 1.28 | 0.25 |
| 7 | 4.20 | 4.01 | 2.59 | 1.24 | 1.49 | 0.33 |
| 8 | 4.80 | 5.14 | 2.96 | 1.59 | 1.71 | 0.42 |
| 9 | 5.40 | 6.39 | 3.33 | 1.97 | 1.92 | 0.52 |
| 10 | 6.00 | 7.77 | 3.70 | 2.40 | 2.14 | 0.63 |
| 11 | 6.60 | 9.27 | 4.07 | 2.86 | 2.35 | 0.75 |
| 12 | 7.21 | 10.89 | 4.44 | 3.36 | 2.57 | 0.89 |

*1" SCH 40 PVC @ 9 GPM*

Because of the difference in wall thickness, Class 200 will allow more flow at lower friction loss than will the same size of SCH 40 pipe. Using ¾″ Class 200 for a 9 GPM flow rate would also keep velocity and pressure loss within acceptable limits (see below).

| SIZE | 3/4 IN | | 1 IN | | 1 1/4 IN | |
|---|---|---|---|---|---|---|
| flow gpm | velocity fps | psi loss | velocity fps | psi loss | velocity fps | psi loss |
| 1 | 0.47 | 0.06 | 0.28 | 0.02 | 0.18 | 0.01 |
| 2 | 0.94 | 0.22 | 0.57 | 0.07 | 0.36 | 0.02 |
| 3 | 1.42 | 0.46 | 0.86 | 0.14 | 0.54 | 0.04 |
| 4 | 1.89 | 0.79 | 1.15 | 0.24 | 0.72 | 0.08 |
| 5 | 2.36 | 1.20 | 1.44 | 0.36 | 0.90 | 0.12 |
| 6 | 2.83 | 1.68 | 1.73 | 0.51 | 1.08 | 0.16 |
| 7 | 3.30 | 2.23 | 2.02 | 0.67 | 1.26 | 0.22 |
| 8 | 3.77 | 2.85 | 2.30 | 0.86 | 1.44 | 0.28 |
| 9 | 4.25 | 3.55 | 2.59 | 1.07 | 1.62 | 0.34 |
| 10 | 4.72 | 4.31 | 2.88 | 1.30 | 1.80 | 0.42 |
| 11 | 5.19 | 5.15 | 3.17 | 1.56 | 1.98 | 0.50 |
| 12 | 5.66 | 6.05 | 3.46 | 1.83 | 2.17 | 0.59 |

*¾" Class 200 PVC @ 9 GPM*

Therefore, keeping flow rates from exceeding 5 ft/sec (1.5m/sec) keeps pressure losses to acceptable limits. This assumes that most residential pipe runs won't have much more than 200 ft (60m) of pipe in any one zone supplied with pressures in the range of 50 – 60 psi (345 – 415 kPa). The charts above are for straight runs of 100 feet of pipe. An industry standard is to add another 25% to the measured length to allow for fittings, like methods used when calculating losses through hydronic heating systems.

One well known supplier/manufacturer of sprinkler components suggests these flow limits for PVC pipe:

- ¾″ SCH 40 = 8 GPM
- 1″ SCH 40 = 13 GPM
- ¾″ Class 200 = 10 GPM
- 1" Class 200 = 15 GPM

As you can see, due to its greater internal area, Class 200 pipe allows slightly more flow than SCH 40.

Depending on local codes and zone GPM, consider using 1″ Schedule 40 PVC pipe upstream of control valves and at least ¾" Class 200 PVC pipe or ¾″ poly pipe downstream. Remember that the piping upstream of a zone valve will always be pressurized and SCH 40, because of its higher burst strength, may be the better choice than Class 200 for that location. Piping downstream of a zone valve is only subjected to dynamic pressure and can therefore be either Class 200 PVC or polyethylene pipe with a lower burst strength.

### Zone Valves

Sizing zone valves for residential use is fairly straightforward. Residential valves have plastic bodies with either ¾″ or 1” slip-fit (glued) or MIP threads at their inlets and outlets. In general, use the same size valve as the pipe it will be attached to. Bodies larger than 1” are readily available if needed. While using a valve that is one size smaller than the piping is an acceptable practice, never reduce to two sizes smaller.

### Calculating Pressure Losses

Pressure losses will be influenced by the type and size of pipe being used, the flow rate and the length of the piping. Once sprinklers are plotted on the site plan and their flow rates are written in adjacent to them, they are grouped together into zones so that the sums of the flows to each sprinkler stay within the general flow rate limits for the desired size of pipe listed above. Once this is done, to more accurately check the pressure losses on each zone, measure the distance from the source of supply through the zone valve to the furthest sprinkler and add 25% to compensate for fittings. Divide this number by 100 to come up with a multiplier for the length that will be used in a subsequent step. Then, using the friction loss table for the specific pipe being used, enter the table at a flow rate in GPM that is equal to or just above the actual flow to all the heads in that zone. Read across to the column for the size of pipe being used and note the number in the column for pressure loss in PSI. Multiply that number by the multiplier arrived at above. This will be the pressure loss in PSI for that zone. Then subtract that number from the pressure available to the zone. What this leaves you with is the pressure available to operate the sprinklers in that zone. Remember that, in general, a sprinkler should have at least 35 psi (241 kPa) for proper operation but always consult the manufacturer to see what their minimum operating pressure is. If what you are left with is less than what is needed, re-configure the zone piping to shorten it if possible, or remove a sprinkler to decrease the total flow rate and re-organize the zones. To not consider the pressure losses when sizing may lead to having zones operate where the water isn’t being thrown to the distances that were planned. This may result in having areas that aren’t being given enough water and plant die-off is likely.

Now complete Self Test 2 and check your answers. Answers are at the end of this learning guide.

## Self-Test 2

Self-Test 2

1. What type of sprinkler nozzle has almost no spray radius?
    a. 90° part circle
    b. Stream rotor
    c. Variable arc

d. Bubbler

2. What type of sprinkler is best suited for small areas that may require many heads?

    a. Stream rotor
    b. Fixed spray
    c. Bubbler
    d. Impact

3. What type of sprinkler is used in areas where there may be conflict with foot or vehicular traffic?

    a. Pop-up
    b. Impact
    c. Full circle
    d. Variable arc

4. What type of sprinkler has a paddle that “slaps” the water stream to cause the head to rotate?

    a. Stream rotor
    b. Fixed spray
    c. Impact
    d. Pop-up

5. What type of sprinkler is best for slopes and tight soils where lower precipitation rates are preferred?

    a. Pop-up
    b. Rotating
    c. Part circle
    d. Fixed spray

6. Which one of the following choices would not be an advantage of a rotating sprinkler over a spray sprinkler?

    a. Fewer fittings
    b. Less trenching
    c. Fewer sprinklers
    d. Ability to serve small areas

7. When plotting sprinklers on the site plan, what design aspect saves water and ensures its uniform application?

    a. Use head-to-head coverage
    b. Use spray heads for large open areas
    c. Use stream rotors for small, confined spaces
    d. Mix stream rotors and fixed spray heads on the same zone

8. Which component of a sprinkler system has its own backflow preventer built into it?

    a. A stream rotor
    b. A fixed spray head
    c. An inline zone valve
    d. An anti-siphon zone valve

9. Which two backflow preventers are normally specified by AHJs for installation on irrigation systems because of their ability to be in-line tested?

    a. RPBAs and DCVAs
    b. DCAPs and RPBAs
    c. DCVs and DCAPs
    d. DCVs and DCVAs

10. Which one of the following is not an in-line testable backflow preventer?

    a. DCVA
    b. DCAP
    c. RPBA
    d. PVBA

11. Which one of the following is likely not a good location for a zone manifold?

    a. In a planter
    b. In a driveway
    c. In a flower bed
    d. In the lawn near the water supply

12. Which one of the following acceptable irrigation pipes has the most pressure drop, fewest fittings and requires the least amount of trade knowledge to install but is most difficult to keep in alignment?

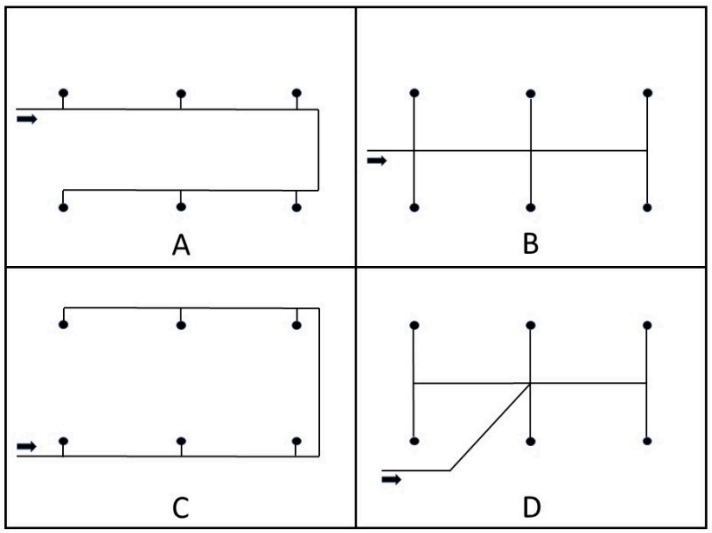
    a. Polyethylene (PE)
    b. Class 200 PVC
    c. SCH 40 PVC
    d. SCH 80 PVC

13. What factors determine the number of zone valves needed?

    a. Owner’s wishes and site geography
    b. Wind speed expected and local rainfall
    c. Available GPM and sprinkler flow rates
    d. Power supply available and house pressure

14. Which one of the following zone layouts would be most likely to cause the most even pressure at

the heads?




a. A
b. B
c. C
d. D

15. According to most pipe manufacturers, what is the industry-standard maximum velocity for PVC pipe used for irrigation systems so that friction loss is kept to a minimum?

a. 5 ft/sec (1.5 m/sec)
b. 8 ft/sec (2.4 m/sec)
c. 10 ft/sec (3.0 m/sec)
d. 15 ft/sec (4.5 m/sec)

16. Using the tables in the text, what would be the friction loss for 100 feet of ¾" SCH 40 PVC pipe if the flow rate was to be 5 GPM?

a. 0.66 psi
b. 2.15 psi
c. 3.44 psi
d. 8.46 psi

17. Why does Class 200 PVC allow more flow than SCH 40 PVC?

a. Because of its higher burst strength
b. Because it has better UV resistance
c. Because of its wall thickness difference
d. Because in the difference in its chemical makeup

18. According to industry standards, how much extra length should be added to the measured length to allow for friction loss through fittings in an irrigation system?

a. 10%
b. 25%
c. 40%
d. 50%

19. What is the body size of most residential irrigation zone valves?

a. ½″ and ¾″
b. ¾″ and 1″
c. 1″ and 1 ¼″
d. 1 ¼″ and 1 ½″

20. According to information in the preceding text, what is one manufacturer's "rule-of-thumb" flow rate for 1" PVC SCH 40 pipe?

a. 8 GPM
b. 10 GPM
c. 13 GPM
d. 15 GPM

Check your answers using the Self-Test Answer Keys in Appendix 1.

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# Learning Task 3

Installation and Wiring of Controllers

## Step 7: Locating Controllers and Sizing Wire

Once the number of zones needed is finalized, choose a controller that can operate at least that number of zones. A good option is to also allow for an extra zone or two for future alterations to the landscaping.

Controllers should be located close to a 120VAC wall plug. On a wall inside a garage is a common location as it is protected from the weather, however it may be difficult to observe the zones in operation from this location. If mounted on an outside wall near a weatherproof plug, it should be certified for outdoor installation and, as such, will need to be housed inside a weatherproof cabinet. This will undoubtedly incur extra cost but will prove advantageous for viewing system operation during initial setup or for routine maintenance. Remember that “weatherproof” doesn’t necessarily imply that it is waterproof so make sure it is protected from direct rain or snow and any spray from the system.

Wires must be run from the controller to each zone valve. The zone valves will have two wires, one of which will be a power lead (“hot” wire) and one that is a “common” or “ground” wire. Each zone in the controller is numbered and will have one hot wire terminal per zone. There will be a single common terminal on the controller that all the common wires will connect to.

Individual wires are insulated and contained within cables of 3 to 13 conductors. Any cables used must be acceptable for “direct earth burial”. Wholesalers and retailers of irrigation products will carry the correct type of cables for underground installation. Cables are run between the manifolds and the controller. They should have one hot wire per zone valve and one wire for all the zone valve grounds to gather and attach to. As well, it is a good idea to have at least one extra hot wire at any manifold location to accommodate an extra future zone.

The cables are run within the same trench as the main line to the manifold, often taped or strapped to the main pipe and tucked underneath it to lessen the chances of contact with shovels during the backfilling process. The most common size of wire for residential systems is 18-gauge (#18AWG). This gauge is more than heavy enough to carry 24 VAC from the controller to the zone valve location, considering that the zone manifolds are not usually very far from the supply water main. If excessive length to the manifold is anticipated, consult an electrician or wire manufacturer and have the voltage and amperage ratings of the controller, transformer and zone valve handy for reference.

## Step 8: Installing the System

Once the system is designed and checked for conformance to codes and bylaws, make sure the piping

routes between the water supply and manifolds and between the manifolds and sprinklers are drawn onto the plan. Multiple pipes can share trenches to minimize digging.

Make sure to use proper Personal Protective Equipment (PPE) that are CSA-approved and appropriate for the work before starting.

Mark the sprinkler locations on the site using small flags on wire stems. These are available through any of the equipment suppliers. This makes the sprinkler locations easy to spot and will help when laying out the trenching to them. Also, mark the location of any drip system risers. Although not discussed here, if you plan to install a drip system later, you can install any piping to drip risers in the trenches with the rest of your system. Next, determine the location of the valve manifold boxes. Use line-marking spray paint to mark the approximate size of the boxes and then mark the trenches between the water supply, manifolds and sprinklers. Do this as accurately as possible. You will be digging your trenches along these lines.

The trenches need not be too deep, usually between 8 inches (200 mm) and 12 inches (300 mm). Most installers will use the depth of the shovel's nose as a guide. If the piping connection at a sprinkler is below this level, the use of a swing joint at the head will accommodate the difference in elevations. An installer may choose to use a power trencher if there is a lot of trenching to do or moderately rocky ground is expected. Even the smallest machine is capable of depths up to 24 inches (600 mm). If trenching through existing lawn, use a square-nosed shovel to remove rectangular pieces of sod of approximately 2 inches (50 mm) thick. Lay heavy plastic film on each side of the trench. Place the sod on one side and spoils on the other. This makes it much easier to backfill and replace the sod in a way that minimizes unwanted excess soil left on the lawn and looks professional. Slightly mound the trench backfill to allow for settlement.

If trenching under a sidewalk is necessary, create a "pipe jetter" by taking a pipe of PVC pipe about 1 foot (300 mm) longer than the width of the sidewalk and gluing a hose adapter onto one end. On the other end, glue on a jet nozzle that is available through irrigation suppliers or make one from a PVC cap by drilling a few small holes in it. Dig out an entry and an exit point on either side of the sidewalk, attach a hose to the end of the jetter and turn on the water. You should be able to push and wiggle the assembly under the concrete without too much effort. Once through, cut off each end and couple the lateral line to it. Use a larger pipe for jetting to create a sleeve if two or more lines or control wires are needed to be run under the sidewalk.

Dig the hole at the manifold box location(s). It should be deep enough to allow the placing of approximately 6 to 12 inches (150 to 300 mm) of drain rock in the bottom. This helps drain the box and keeps it from becoming muddy.

Dig a hole at all sprinkler locations to allow the head to be attached to the pipe via a swing joint. Swing joints allow 3-directional movement for easier sprinkler placement as well as allowing some vertical movement in case the sprinkler encounters vehicular traffic on it. Swing joints can be either threaded PVC nipples and fittings or can be flexible high-strength composite pipe that uses friction-fit barbed-to-threaded fittings, as shown in the image below.



*Figure 1 Swing joint*

Most manufacturers have their own variety of this pipe. Toro® calls theirs “Funny Pipe” and suggests a length of “Funny pipe” of between 1 foot (300 mm) and 4 feet. Tees used on the laterals feeding the swing joints are available as SL × SL × FIP (slip × slip × female thread). Use Teflon® tape on all threaded joints except the base of the sprinkler; these are to be left bare.

Once the excavating is completed, lay out the piping on the ground beside the trenches. Pipes can be cut to length and assembled above grade before being placed into the trench. This makes the job easier and can help keep unwanted debris out of the pipe. Use the correct primers and glues for the material chosen. Connect all piping except the swing joints and sprinklers. This is done after flushing.

Connect the wiring at the zone valves and at the controller. Wire insulation is coloured so take note of the colour of the hot wire connected to each zone valve, assign each valve a number and connect the wires to the corresponding terminals at the timer. Remember that the common zone valve wires are connected in the valve box to a common wire in the cable and that wire connects to the common terminal on the controller. Wire connections made underground are done by using a waterproof twist-on connector, similar to a “Marrette”® as shown below. The bared wire ends are twisted together first, then the connector is threaded onto the twisted wires.



*Figure 2 Waterproof twist-on connectors for underground use*

## Step 9: Flushing, Testing and Commissioning

### Flushing and Testing the Supply Main to Zone Valves

While the glued joints are curing, backfill all the trenches leaving the space open around any joint. Make sure all system valves are manually closed and electrically deenergized. Disconnect the inlets to the zone valves if unions were used; if not, leave the pipe connected, as any debris in the zone valve may either pass through into the sprinkler laterals and be flushed through or can be removed from the valve by taking off its bonnet and flushing it. Once all the glued joints are sufficiently cured (see pipe manufacturer's literature), open the water source supply valve and flush the mains to the zone valves, then close the supply valve, reconnect the inlets to the zone valves and reopen the supply valve to pressurize the mains feeding the zone valves. Walk the mains' routes to ensure there are no leaks.

**NOTE: When opening valves, do it slowly to avoid creating water hammer.**

### Flushing the Zone Piping

Install all but the furthest head on a pipe run. This will allow dirt or debris to be pushed out the open end. Open the zone valve and flush until the water exiting the opening runs clear. Shut the valve and

install the last sprinkler. Repeat this procedure for each zone. Pressure testing is not normally performed on zone piping; this is the reason that the pipe joints are left uncovered up to this point.

### Operate the Timer to Cycle the Zones

Most controllers will have a setting for opening each zone, one at a time, for testing purposes. Each zone will stay energized for a short time, usually 2 minutes. Use this setting to operate each zone and walk the piping to check for leaks. Then, with all zones off, the entire system can be backfilled, and sprinklers can be set at their final desired height. To then set each sprinkler to its final intended arc, open its zone valve either manually or electrically. Consult the manufacturers' literature for instructions on sprinkler arc adjustments as they can differ.

### Commissioning the System

Once the system has been flushed and the sprinklers have been adjusted as to their intended patterns, the final aspect of commissioning can be undertaken. This involves the programming of the timer/ controller.

Most controllers perform the same duties which are to sequence the operation of the zone valves according to needs of the plants, the preferences of the owners and the allowances of the local water utility. Controllers range in complexity from small inexpensive ones that can control up to 4 "stations" (zones), to large elaborate units that can operate up to 75 stations. It is suggested to choose a controller that has 2 stations more than the current need, to allow for future expansion. Alternatively, controllers can add zone "modules" to them for the same purpose although this may be difficult to do if installed within a cabinet sized for the current model.

Step 2 ("Irrigation requirements") involved establishing an "evapotranspiration rate" for the local area. A table was offered that listed a maximum average amount of water, in inches (mm) per day that satisfies the evapotranspiration (ET) needs of most plants, depending on the local climate. The description of the climate used the terms "cool", "warm" and "hot" to indicate the local summer temperature and the terms "humid" and "dry" to describe the level of moisture in the air. From the table, determine the climate category that the house fits into. Take note of the upper number of inches or mm per day for that category.

Some equipment catalogs now include the precipitation rate of the sprinkler. This is the water delivery rate in inches per hour (millimeters per hour) at sprinkler spacings.

To arrive at a "base irrigation schedule" (starting point), first determine the weekly evapotranspiration rate for the area, using the information from the table in Step 2 as mentioned above. Use the higher value of the two numbers in the range for the climate and humidity level chosen. For our example, we'll use a "worst case scenario" of "hot/dry" climate which indicates an evapotranspiration rate of **0.45 inches (11mm) per day**. We'll multiply that by 7 to get a rate of **3.15 inches (77 mm) per week**. This is the average maximum amount of water that an irrigation system in a hot/dry climate needs to deliver in order to replace water that is lost both from the soil and through the plants' usage.

To determine the "run" time for a particular zone, first look up the precipitation rate for the sprinklers in that zone, using an average of the heads. In one manufacturer's catalog, a certain stream rotor's

precipitation rate for the pressure and spacing that was chosen averages out to **1.17 inches/hour**. If we divide that into **3.15 inches/week**, we have calculated that this sprinkler will have to operate for **2.69 hours** to put out the water needed for the week. In minutes, that would be **2.69 hours/week × 60 minutes/hour = 161.4 minutes/week**.

Next, determine how many days you intend to water per week. If your area only allows watering on 3 days per week, divide your minutes/week requirement by 3 to get the minutes/day for your schedule. In our case, we would set the timer to have the zone operate for **161.4 ÷ 3 = 53.8 minutes** each watering day. Some timers are adjustable to infinite amounts of minutes while others have run times of 10-minute increments. Always go longer than shorter if exact run times can't be entered.

Consult the timer manufacturer's literature for step-by-step setup of the controller.

Remember that this is a base irrigation schedule. If allowable watering days change, say from 3 days/week to 2 days/week, make sure to recalculate the "run" times. Many installers set run times for all the zones at 40 minutes to 1 hour without ever considering soil or climate factors. While this may be adequate in a lot of cases, it may also result in severe parching or drowning of plants. Thousands of dollars worth of sod and shrubs may be adversely affected by not considering a calculated approach to irrigation.

## General Watering Guidelines

These general guidelines can also be used as a rule-of-thumb base for scheduling watering times:

- In cool, non-arid climates apply 1″ of water per week. In most other areas, lawns require 1½″ (38 mm) to 2″ (50 mm) of water per week in the hottest months.
- In hot, arid climates apply 2″ or more of water per week.
- Clay soils with fine particles absorb water slowly. To avoid runoff, program the controller with shorter run times, increase the number of start time cycles per day and decrease the number of water days per week.
- Loam soils have medium-sized particles and an average absorption rate. Program the controller with longer run times and fewer start time cycles per week.
- Sandy soils have larger particles and will absorb water quite rapidly. Program the controller with longer run times, decrease the number of cycles per day and increase the number of water days per week.

**Some other guidelines:**

- Do not operate more than one valve at a time
- Water early in the morning when it is least windy, and pressure is the greatest. Early morning watering will also reduce water evaporation
- Watering in the early evening is not recommended. A lawn is more likely to get diseases when wet for a long duration, especially overnight during the summer. Watering on a hot summer day may also burn the plants

- Manually activate your system at regular intervals to make sure everything is operating correctly. Check and clean sprinklers to ensure proper functioning

Once you know your water needs, here's how to check any zone. Place a flat pan or other container on the affected area and measure how long it takes your sprinkler system to deliver the amount of water you are looking for and modify the run times to suit.

## Controller Options

Rain sensors are available so that water isn't wasted on days where it isn't needed. These are usually of a variety that are specific to each brand of controller. Consult manufacturers' literature for guidance on installing them.




*Figure 3 Irritrol® rain sensor*

Soil sensors do for below-ground moisture levels what rain sensors due for conditions above-ground. If enough moisture is detected in the soil at the sensor's location, the controller will adjust the run times to suit.




*Figure 4 Rain sensor*

Wifi-enabled controllers are available that allow their settings to be modified via computers and smartphones. This may be advantageous when the changing of settings needs to be done remotely.

If a house is on a rural property, its potable water supply is likely from a well, in which case the house's potable water connection and irrigation system supply is no different than one that would be served by a municipal utility's supply. On the other hand, if a pump is used to pull water from a creek or pond specifically for irrigation, then a pump start relay is wired to the controller so that the controller's power supply can operate the pump's 120 VAC or 240 VAC on/off control. Again, consult the equipment manufacturer's literature for compatibility and installation instructions.

## Step 10: Routine Maintenance and Troubleshooting

Once a system is filled and commissioned, usually in the late spring or early summer just as the need to irrigate arrives, there is not normally much maintenance required until end-of-season shutdown. A few routine maintenance items to consider may be:

- If damaged heads need to be replaced, dig out enough of the surrounding ground so that the head can be unscrewed from its male threaded connection without allowing dirt to slough into the hole and into the up-facing adapter.
- If pipe gets damaged due to penetrating tools such as a shovel or from winter freezing, dig out around and under the break so that two repair couplings and a short "pup" piece of pipe may be installed.
- If the water supply is hard due to calcium and magnesium content, the nozzles may become

partially plugged over time and spray erratically. Nozzles can be immersed in a de-scaling solution and reinstalled, or be replaced, so have replacement nozzles on hand.

- Under normal circumstances the piping should stay clear of obstructions, however it may be necessary to periodically remove the sprinklers and flush the system. Do this in the same manner as when the system was initially flushed, removing one head at a time, starting with the most distant one.

## Winterizing

All climates in Canada are prone to winter freeze. None are exempt so plan on draining or blowing out the system with compressed air once the watering season is over. It is extremely difficult, although not impossible, to drain a system by gravity. Blowing it out using compressed air is the norm. Here are the steps involved.

- Close the water supply valve and drain any water from the piping between the source and the zone valves if possible.
- If the backflow preventer is installed in a heated area, open all the test ports and place the ball valves in the half-open position. This will allow the cavity between the ball and the valve body to drain as well.
- If the backflow preventer is installed below ground or in an area where it may freeze, it should be removed. It will have to be replaced and re-tested in the spring. Plug any open pipe ends to prevent debris and insects from entering the open piping.
- Make sure there is a blowout fitting installed immediately downstream of the backflow preventer. This is where air will be introduced. If the backflow preventer is meant to be removed, make sure to install a shutoff between the preventer and blowout fitting; close the shutoff. If the backflow preventer is meant to remain installed after winterizing, a downstream valve would be redundant and need not be installed, in which case close the #2 shutoff on the backflow preventer
- Using a large rotary compressor (best) or a smaller high-volume variety, introduce compressed air at the blowout fitting, making sure to not exceed the maximum pressure allowance for the component with the lowest pressure threshold. 50 to 75 psi (345 to 515 kPa) is adequate to do the job.
- Open one zone valve at a time and let the air push all the water from the piping. Close the zone valve when no water mist is apparent from all the sprinklers in the zone.
- Go around the system and bleed each zone at least twice. This will pick up and move any water that tends to settle back into the low spots in the piping after the air flow stops.
- Once the blowout is finished, make sure that the handles of any ball valves that may freeze are left in the 45-degree position, to prevent the valve bodies from breaking.

It is important to note that it is more the volume of air that is needed rather than air pressure. A sustained volume of air ensures that water is completely pushed out of the system. If a low-volume compressor is used, it may take several cycles of zone opening/closing to satisfactorily get rid of all the water in the system.

Now complete Self-Test 3 and check your answers. Answers are at the end of this learning guide.

## Self-Test 3

Self-Test 3

1. Correctly complete the following statement: “Electrical cables for irrigation zone valves must be …..”
    a. nylon-jacketed
    b. acceptable for direct earth burial
    c. made up of stranded aluminum wires
    d. of the same type used in house construction
2. What is the most common gauge of wire used for residential sprinkler systems?
    a. #12 AWG
    b. #14 AWG
    c. #16 AWG
    d. #18 AWG
3. What does Toro® call their composite pipe used on barb fittings at sprinkler locations?
    a. “Weird Pipe”
    b. “Funny Pipe”
    c. “Ridiculous Pipe”
    d. “Composite Pipe”
4. When trenching through an existing lawn, what is a good way to minimize the amount of final cleanup required on the lawn?
    a. Discard the sod and lay the spoils on plastic
    b. Place the removed sod and spoils on plastic on the same side of the trench
    c. Remove all sod and spoils and truck them away; replace with fresh dirt and re-seed
    d. Place the removed sod on plastic on one side of the trench, spoils on the other side also on plastic
5. What is a relatively easy way to get a pipe under an existing concrete sidewalk?
    a. By “jetting” it
    b. By pre-planning for it when the house was being built
    c. By jackhammering out one section of sidewalk and re-pouring it

d. By cutting a narrow trench through the sidewalk and refilling the trench

6. What type of connectors are used for wiring at the zone valve locations?

    a. Soldered
    b. Marrettes®
    c. Waterproof twist-on
    d. Crimp-type within a sleeve

7. Which response listed below would be the recommended method of flushing the zone piping (zone valve to sprinklers)?

    a. Leave all heads off and open the zone valve
    b. Install all heads on the zone and manually open the zone valve
    c. Install all but the furthest head, open the valve and flush through the open end
    d. Leave off all heads at first, then open and close the zone valve after each head is installed

8. How many stations should a controller be capable of operating?

    a. Only as many as there are zones installed
    b. At least one more than are currently installed
    c. At least two more than are currently installed
    d. Twice as many as there are currently installed

9. Using the evapotranspiration rate for a hot/humid climate, calculate the run time for a zone that has sprinklers with an average precipitation rate of 1.06 in (27 mm) per hour, if the zone is being watered 4 days per week.

    a. 20 minutes
    b. 25 minutes
    c. 30 minutes
    d. 40 minutes

10. If a lawn has sandy soil, which one of the following would be the most logical approach to programming the controller?

    a. Set longer run times, decrease the number of cycles per day and increase watering days
    b. Set shorter run times, increase the number of cycles per day and increase watering days
    c. Set longer run times, decrease the number of cycles and decrease watering days
    d. Set shorter run times, increase the number of cycles and decrease watering days

11. If a well is used only for irrigation purposes, what feature does the controller need?

    a. A transformer

b. A separate timer
c. A pump start relay
d. An extra zone control

12. What characteristic of water that contains calcium and magnesium may cause the sprinklers to become plugged over time?

a. Debris
b. Low pH
c. Softness
d. Hardness

13. Where in the system should a blowout connection for winterizing be installed?

a. Downstream of the sprinklers
b. Downstream of all zone valves
c. Downstream of the backflow preventer
d. Upstream of the water supply connection

14. How should any ball valves be left after winterizing?

a. Half open
b. Removed
c. Fully open
d. Fully closed

15. What is the most important aspect of the air supply used to winterize a system?

a. Its temperature
b. Its pressure
c. Its volume
d. Its area

Check your answers using the Self-Test Answer Keys in Appendix 1.

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# Competency B4: Describe Alternative Green Water Supply Systems

The construction community supports the use of green building technologies in the design and construction of homes and buildings. The practice and process of rainwater harvesting for non-potable reuse is one example of green building technologies that increases the conservation of potable water and benefits both the homeowner and community. This module outlines the practice of collecting, storing, and reusing rainwater from roofs for non-potable purposes

Plumbing harvested rainwater into a home for permitted non-potable uses requires planning and design considerations which meet and/or exceed inspection requirements. The installation of a rainwater harvesting system requires permits and inspections. Due to the complexity of these systems, homeowners are often times required to employ a certified plumber, electrician and/or engineer to design and install a rainwater harvesting system.

Learning Objectives

When you have finished processing the information in this learning guide, you should be able to:

- Describe rainwater collection systems
- Describe grey water reuse systems
- Describe rainwater catchment and conveyance strategies
- Describe rainwater storage strategies
- Describe rainwater quality and treatment procedures
- Describe potable water protection
- Size pressurized systems
- Describe overflow provisions and management

# Learning Task 1

Describe Rainwater Collection Systems

## Introduction

### What is Rainwater Harvesting?

Rainwater harvesting (RWH) is the ancient practice of collecting and storing rainwater for future use. It makes sense to collect and re-use water from roofs for non-potable uses instead of disposing of it. Although the frequency of extreme weather events may suggest otherwise, the world supply of potable (safe for human consumption) water is slowly and steadily dwindling, and better stewardship of potable water supplies must be considered to preserve it for future generations. With careful planning, safety measures and education, the use of harvested rainwater can lessen our dependence on our potable water supplies for uses that don't require the water to be potable such as for toilet flushing and lawn irrigation. Any other uses of harvested rainwater, unless treated, inspected, and certified to acceptable standards, are discouraged and, in most cases, not permissible.

The following description of a rainwater harvesting system is found in the British Columbia Plumbing Code 2018, Division A: Compliance, Objectives and Functional Statements:

*"Harvested or recovered rainwater commonly refers to a type of auxiliary water supply that is collected from external surfaces of buildings or other hard-surfaced areas not exposed to vehicular or pedestrian traffic."*

The above reference of a RWH system being a type of "auxiliary system" prohibits it from being interconnected with a potable water system in any building, with or without backflow protection.

The construction community supports the use of green building technologies in the design and construction of homes and buildings. The practice and process of rainwater harvesting for non-potable reuse is one example of green building technologies that improves our housing stock, conserves water, and has multiple benefits for both the homeowner and community. This module outlines the practice of collecting, storing, and reusing rainwater from roofs for non-potable purposes.

### Why Rainwater is Non-Potable

Water quality is determined by its microbiological, chemical, and physical properties (e.g., pH, colour, odour, turbidity, and bacteria). Municipal tap water has been filtered, treated, and tested at a municipal facility to meet a mandated standard of quality, making it potable.

Although seemingly pure, rainwater has the potential to harbour pathogenic organisms (e.g., E. coli) that would be harmful to humans if consumed and is therefore considered non-potable. Currently, the intent of the National and BC Plumbing Codes is that non-potable systems be used only for the flushing

of toilets and urinals, and for sub-surface irrigation. With the supply of potable water becoming increasingly scarce and contaminated, this will likely change at some point in the future. However, at this time, any other use is prohibited.

Plumbing harvested rainwater into a home for permitted non-potable uses requires planning and design considerations to address site conditions and follow mandated installation and inspection requirements. The homeowner, homebuilder, or contractor installing a rainwater harvesting system is required to obtain the necessary permits and call for all the necessary inspections. Due to the complexity of these systems, homeowners are encouraged to consult with and employ a certified plumber, electrician and/or engineer to design and install a rainwater harvesting system.

## Installing a System

CAN/CSA B128.1-06 “Design and installation of non-potable water systems” and CSA B128.2:06 “Maintenance and field testing of non-potable water systems” are CSA (Canadian Standards Association) publications that can be relied upon for acceptable installations within most jurisdictions. Product suppliers may also provide guidance on the design of a system and can offer recommendations to contractors familiar with the installation of rainwater harvesting systems and associated components. The following information outlines key points in the process involved when one wishes to install a rainwater harvesting system for internal, non-potable use.

#### Permits

The installation of a rainwater harvesting system may require specific permits. Check with the local Authority Having Jurisdiction (AHJ) before beginning an installation. Permits usually require scaled drawings and the work may need to be done by a licensed contractor unless allowable through a homeowner’s permit. Regardless, if a permit is required it must be obtained before any work can start.

#### Rough-in for Future Use

Roughing-in for the future installation of a rainwater harvesting system in new construction provides homeowners and builders with an option for future use, while saving initial capital costs, meeting existing green building certification compliance, and providing future growth opportunities to the building. Homeowners and home builders must be aware that any portion of the system that is roughed-in will require inspections, and meet all safety codes, even if the system is not finalized or commissioned.

#### Inspections

The person or company who obtains the permit is also responsible for obtaining inspections at the frequency required by the AHJ.

## What are the Benefits of Rainwater Harvesting?

There are several benefits to a residential rainwater harvesting system for non-potable use, including:

1. *Protecting and conserving municipal and private potable water supplies.* Toilet flushing accounts for most of the water use in a house, so reducing water use by toilets and urinals on a municipal system would also reduce the water needed to be treated and delivered to customers. This may also lessen the need to upgrade sections of piping grids that supply new housing developments. On a private well, this translates to less depletion of the water table.
2. *Reducing the amount of stormwater runoff that must be safely handled.* Intercepting, treating, and using roof runoff lessens the volume of stormwater that has to be dealt with on both private and public property.
3. *Reducing homeowners' potable water use.* This means less water needed to be supplied by a municipal system or by a homeowner's well if on a rural property. Less water used that is supplied through a meter results in lower water costs to the consumer. Less well pump operation translates over time to lower maintenance costs.

## Plumbing Code References

A rainwater harvesting system is a non-potable water system, and as such is dealt with in Division B Part 2 of the BC and National Plumbing Codes.

### Section 2.7. Non-Potable Water Systems

#### 2.7.1. Connection

2.7.1.1. Not Permitted

1. A non-potable water system shall not be connected to a potable water system.

#### 2.7.2. Identification

2.7.2.1. Markings Required

1. The location of non-potable water discharge and non-potable water piping shall be identified by markings that are permanent, distinct, and easily recognized.

#### 2.7.3. Location

2.7.3.1. Pipes

1. Non-potable water piping shall not be located
    a. where food is prepared in a food-processing plant,
    b. above food-handling equipment,
    c. above a non-pressurized potable water tank, or
    d. above a cover of a pressurized potable water tank.

2.7.3.2. Outlets

1. An outlet from a non-potable water system shall not be located where it can discharge into
    a. a sink or lavatory,
    b. a fixture into which an outlet from a potable water system is discharged, or
    c. a fixture that is used for the preparation, handling or dispensing of food, drink or products that are intended for human consumption. (See Note A-2.7.3.2.(1).)

#### 2.7.4. Non-Potable Water Systems

2.7.4.1. Non-potable Water System Design

(See Note A-2.7.4.1.)

1. Non-potable water systems shall be designed, fabricated, and installed in accordance with good engineering practice, such as that described in the ASHRAE Handbooks, ASPE Handbooks and CAN/CSA-B128.1, “Design and Installation of Non-Potable Water Systems”.
2. Non-potable water systems shall only be used to supply water closets, urinals, and directly connected underground irrigation systems that only dispense water below the surface of the ground.

Now complete Self-Test 1 and check your answers.

## Self-Test 1

Self-Test 1

1. According to both the NPC and BCPC, what are the only acceptable uses for non-potable water systems?
    a. Exterior hosebibbs and toilet flushing
    b. Toilet flushing and underground irrigation
    c. Toilet flushing and above ground irrigation
    d. Laundry, exterior hosebibbs and toilet flushing
2. A harvested rainwater system is categorized in the plumbing codes as what type of system?
    a. Illegal
    b. Backup

c. Auxiliary
d. Unauthorized

3. What is the code requirement for interconnecting a potable water system with a non-potable water system?

    a. They may never be interconnected
    b. They may be removeable swing joint
    c. They may be interconnected through a DCVA
    d. They may be interconnected through an RPBA

4. Why is rainwater considered to be non-potable?

    a. It hasn't been treated to acceptable certified standards
    b. It hasn't been delivered through a water service pipe
    c. It hasn't been delivered by a tanker truck
    d. It hasn't been supplied from a well

5. What section of the plumbing code deals specifically with harvested rainwater systems?

    a. Division A Part 2
    b. Division A Part 7
    c. Division B Part 2
    d. Division B Part 7

Check your answers using the Self-Test Answer Keys in Appendix 1.

## Section 1: Catchment and Conveyance

### Rainwater Collection and Conveyance

Rainwater harvesting requires collection of rainwater from acceptable catchment areas and moving it to a storage tank, sometimes referred to as a "cistern". This section describes the preferred roof types for rainwater collection, an overview of gutters and leaders, and details for directing rainwater through conveyance pipes to a storage tank.

### Roof Types

Roofs are the only surface permitted for residential rainwater collection. Paved surfaces and lawns are not allowed as catchment areas because of their potential for contamination from pesticides, vehicle oils and other pollutants. A roof's composition will play a part both in its collection efficiency and the quality of rainwater it produces. If very high-quality rainwater is desired, roofing materials with NSF P151 certification should be used. Selection of roofing materials, coatings, paints, and gutters that have

this certification will not impart levels of contaminants greater than those specified in the U.S. EPA's "Drinking Water Regulations".

The most common roofing materials and their considerations are detailed below. The term "collection efficiency" refers to a material's ability to allow as much rainwater as possible to make its way to the gutter without being slowed or absorbed by the roofing material.

- *Asphalt shingle:* Asphalt is the most common roofing material in residential construction and is sufficient for rainwater collection. Collection efficiency from asphalt is reduced due to its rough surface and tendency slow down and evaporate surface water. Additionally, particulates and other contaminants can dislodge from asphalt shingles, which can negatively affect rainwater quality.
- *Metal roofing:* Because of its smooth, clean surface, metal roofing has higher collection efficiency and is generally the recommended option for rainwater harvesting systems. In some suburban communities with set architectural guidelines, homeowners may not be able to choose this roofing option.
- *Other roofing materials:* Wood shingles (or shakes), recycled or non-recycled rubber, clay tiles, and lightweight concrete tiles are also acceptable materials for catchment surfaces; however, because of their varied rough surfaces, they are subject to lower collection efficiencies.

Built-up roof membranes and "green roof" installations are not typically recommended for rainwater harvesting as they may add contaminants to the water collected. As well, overhanging foliage such as tree limbs should be avoided due to the increased likelihood of leaves and bird droppings landing on the roof.

#### How much water can be collected?

In theory, one litre of water can be collected for every millimetre of rainfall landing on one square metre of collection surface.

**Total roof area ($m^2$) × local rainfall intensity (mm) = Potential collection (Litres)**

This is the same procedure that was used during the storm drainage sizing exercises in previous modules.

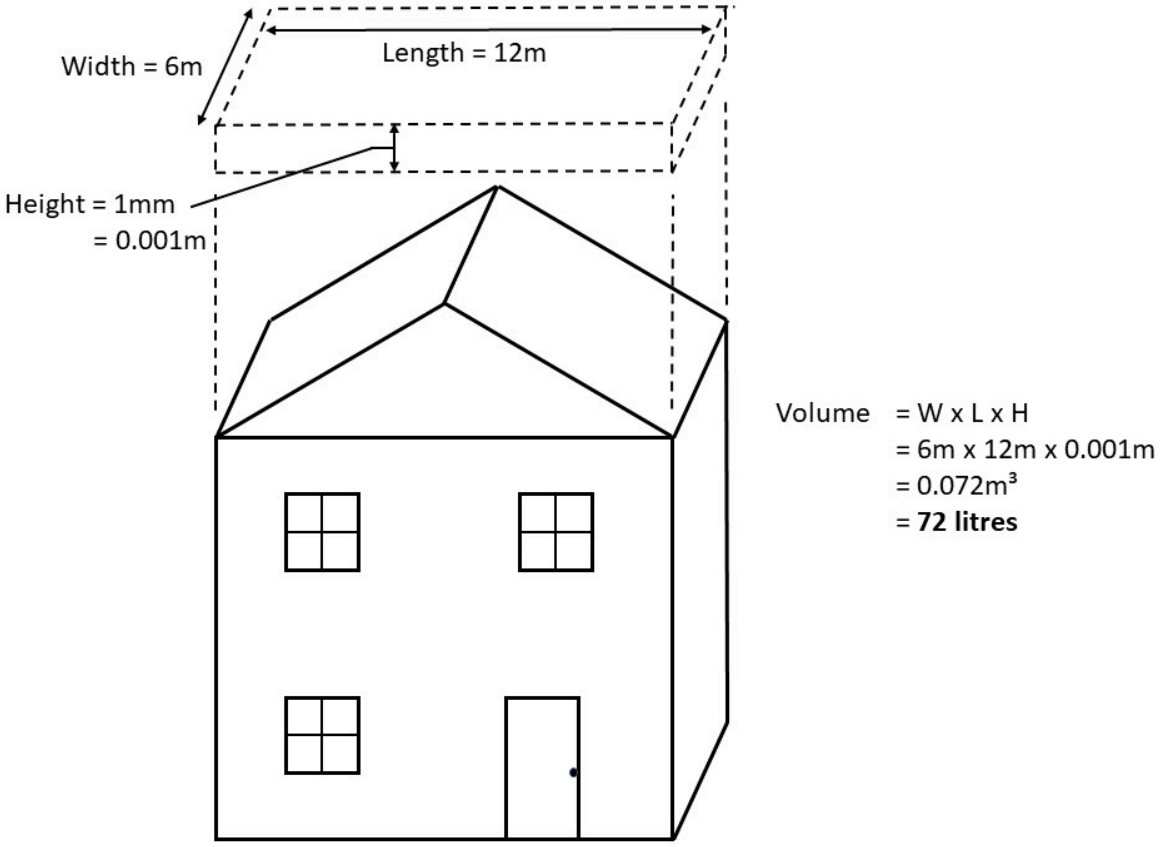



*Figure 1 Calculation of roof area catchment volume*

Although theoretically the calculation equation is very similar, in practice the calculation of potential collection volumes for a rainwater harvesting system is much more complex and consequently will not be covered in this module.

The relationship between the catchment area and the volume of rainwater collected is simple – the larger the catchment area, the greater the quantities of rainwater that can be collected.

The catchment area has a significant impact on both the design and water savings potential of RWH systems. In general, it is recommended that the size of the catchment area used for an RWH system be as large as possible to maximize water savings. For most RWH systems collecting rainwater from a roof catchment, the size of the catchment area is usually predetermined by the size of the existing house or building. In such cases, one means of collecting additional rainwater is to utilize multiple roof catchments and convey rainwater to one central or “communal” storage tank.

Alternatively, it may sometimes not be feasible or beneficial to collect rainwater from the entire catchment area due to rainwater quality concerns, location/placement of rainwater storage tank or for other reasons.

## Conveyance of Rainwater to the Storage Tank

Once collected from the catchment surface, rainwater is transferred to the rainwater storage tank

through a series of components, referred to as the “conveyance network”. An illustration of a typical conveyance network for a residential household is shown below.

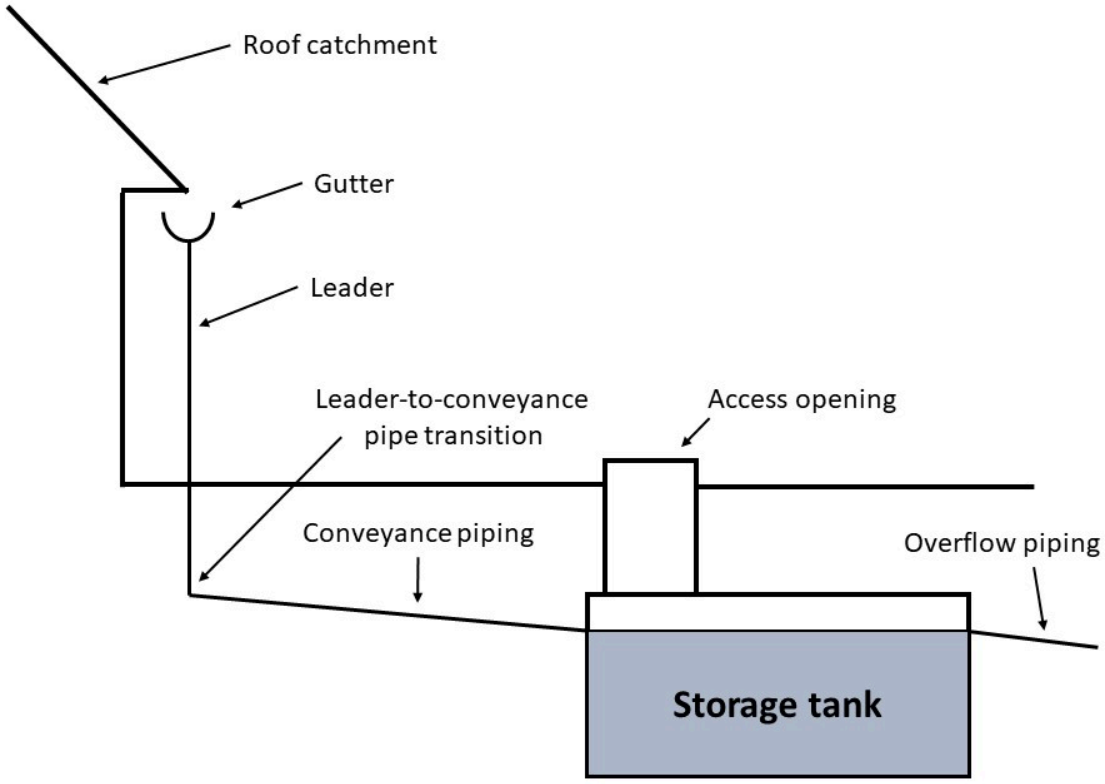



*Figure 2 Typical residential conveyance network*

**Gutters and leaders**

Rainwater will run from the roof surface, accumulate in the gutters (eavestroughs) and travel by gravity through leaders (downspouts) to piping that will carry it to the storage tank. Standard gutter and leader sizes and installation methods are sufficient for a residential rainwater harvesting system. Most gutters are 125 mm (5″) “K-style” aluminum or galvanized steel, with a slope toward the leader locations of between 0.5 and 2 percent. Slopes of less than 0.5% may cause the gutter to overflow in times of heavy rainfall; slopes of more than 2% will be noticeable to the eye from the street and are not aesthetically acceptable.

Typical leaders are 50mm × 75mm (2″ × 3″) or 75 x 75 mm (3″ × 3″) aluminum or galvanized steel. Aluminum is most common, however the plumbing codes list other materials that are also acceptable.

Screening systems for gutters are available that keep leaves and debris out while allowing roof runoff in. These are highly recommended when a roof is a catchment area for a RWH system.

If rainwater is to be collected during the winter months, extra consideration should be made to reduce ice buildup at gutter and leader bends and elbows.

#### Leader location

It is important to plan leader locations both in relation to the building's architecture and to the location of the rainwater storage tank. Downspouts should be as near the storage tank as possible to reduce the length of conveyance pipe while collecting rainwater from the full roof surface. Leaders should not be located at inside corners of walls nor inside the building envelope unless absolutely necessary. Additionally, leaders will require some form of inlet screen or filter and a connection to conveyance pipe at or near grade. For aesthetic reasons, homeowners may wish to hide downspout and filtration devices from sightlines.

#### Conveyance pipe

The conveyance pipe transports rainwater from the leader to the storage tank. Required materials and code issues are detailed below.

- *Material:* Where conveyance pipe is above grade and exposed to the sun, UV-rated pipe must be installed. For underground installation, a minimum of PVC sewer grade pipe (SDR35) or ABS pipe is required. Higher grades of pipe, such as Schedule 40 PVC, are preferred due to their thicker, more durable wall construction which can help minimize the possibility of breakage. Pipe material must meet the requirements of all applicable codes and standards.
- *Size:* In accordance with National and BC Building Code rainfall amounts, a minimum size conveyance pipe (storm building drain) is dictated with the pipe size appropriate for the load it carries and the slope it is installed at.
- *Slope:* 2 percent slope is industry standard although less slope is allowable for larger pipe sizes. Where conditions allow, greater than 2 per cent is ideal for increasing the drainage rate and decreasing the possibility of rainwater freezing during colder months.
- *Permanent warning tape and tracer wire:* In accordance with CAN/CSA B128.1-06 Clause 12.3.9, buried, non-metallic pipes should have permanent warning tape and tracer wire installed a minimum of 300 mm (12″) above the pipe. There is no such requirement within the plumbing codes.
- *Backfill:* Pipes must be located on a proper drainage bed in an appropriately sized trench and backfilled in accordance with applicable codes and regulations.
- *Winter considerations:* If a homeowner wishes to collect snow melt during the winter months and the conveyance pipes could not be buried below the local area frost penetration depth, then insulation should be installed above the pipes to prevent the snow melt from freezing inside the pipe. The preferred insulation type to use is rigid extruded polystyrene (XTPS) foam insulation. Using heat trace wire will keep water from freezing in the pipes, but it is energy intensive and not the suggested method for winterization.

When designing and installing a conveyance network, a few issues must be considered, including but not limited to:

- sizing and placement of conveyance piping
- site conditions and location/placement of storage tank

- cold weather issues
- rainwater quality.

#### Size, slope, and placement of conveyance network

To ensure that the conveyance network can handle the runoff from the catchment surface in severe storms, all sections of the conveyance network (gutters, leaders, and drainage piping) must be appropriately sized and sloped to promote rapid water drainage. While the design of gutters and leaders must always conform to building and plumbing code specifications, there are standard sizes and "rules of thumb" for residential applications using aluminum. However, conveyance drainage pipes connecting the bottoms of leaders to the storage tank are considered by plumbing codes to be "storm building drains" and must therefore be selected and installed in accordance with applicable codes and regulations.

When sizing pipes and other parts of the conveyance network, it is important to consider what proportion of the catchment surface a particular section of the network is handling. In most cases, the catchment surface will be divided into sections. For example, a peaked roof will have at least two distinct drainage areas from which rainwater will be collected. Accordingly, it may be necessary to have multiple smaller conveyance drainage pipes that transfer rainwater to a larger pipe leading into the rainwater storage tank.

#### Site conditions and tank location

When planning a conveyance network, it is important to take into consideration the site conditions and location/placement of the rainwater storage tank. It may be difficult to connect some sections of the catchment surface to the conveyance network due to grading and/or layout of the site, distance to the storage tank or complex roof shapes. For instance, when designing the layout of the conveyance drainage pipe transferring rainwater to a below-ground tank, the length of pipe and pipe slope can affect the burial depth of the tank (for example, force it to be buried deeper below ground). Some tanks, however, cannot be buried below a maximum rated burial depth and, consequently, the location of the tank or the pipe slope may need to be adjusted. Alternatively, a reinforced tank designed for deeper burial may have to be selected.

Another concern when designing conveyance networks leading to below-ground tanks is the presence of buried service lines (gas, water, phone, etc.). An inspection of the site to locate the service lines must be performed to ensure that the planned route is free from buried lines.

#### Conveyance network material selection

Part of planning the conveyance network involves selecting the appropriate material for each of the network components. Gutters and leaders are generally manufactured out of aluminum or galvanized steel, both of which are considered suitable for RWH systems. When selecting a pipe material, several criteria must be considered. The pipe selected must be rated as suitable for ultraviolet (UV) light exposure and burial (where applicable) and, if the highest rainwater quality is desired/mandated, it must be rated for handling potable water. In addition, the selected pipe must be approved by the applicable codes and regulations. In general, a type of polyvinyl chloride (PVC) pipe, referred to as "sewer grade pipe" or "SDR-35" is recommended for RWH systems, as it meets these criteria. Acrylonitrile-

butadiene-styrene (ABS) is another type of pipe that can be used and is typically less expensive than PVC SDR-35 but may not be appropriate for all RWH systems as it is not rated for UV exposure. It is important to note, however, that, even if rainwater is conveyed using a pipe suitable for potable water, this does not imply that rainwater is potable or suitable for potable use.

#### Cold weather issues

Throughout much of Canada, temperatures often drop below freezing (0°C) during the winter months. During periods of extreme cold weather, rainwater that is outdoors or in an environment that is not temperature controlled (maintained above 0°C) is at risk of freezing. Rainwater can freeze in the conveyance network if it is not drained adequately or if it must travel through extended portions of the network that are not temperature controlled. The installation of rigid polystyrene foam insulation, proper slope, and adequate burial depths will help to reduce the possibility of pipe freezes.

## Catchment and Conveyance Guidelines

### Catchment areas

- Only roof surfaces are allowable
- collection from green roofs is not recommended
- sections of the roof with overhanging foliage or trim should be avoided where possible
- if rainwater collected from the catchment surface must be of very high quality, materials with NSF P151 certification should be selected
- the catchment surface should be as large as possible
- if a roof catchment material is to be selected and installed in conjunction with the RWH system, material with minimal collection losses, such as steel, should be selected

### Gutters and leaders

- aluminum or galvanized steel are recommended
- copper, wood, vinyl and plastic gutter and downspout materials are not recommended
- gutter inlets should be screened to minimize the intrusion of leaves and debris
- if rainwater conveyed through gutters and downspouts must be of very high quality, materials with NSF P151 certification should be selected
- where possible, slope gutters toward the location of the rainwater storage tank
- ensure a minimum slope of 0.5% to 2% (the greater the slope the better) is maintained throughout the gutter length
- make sure gutters conform to applicable codes and regulations

### Conveyance piping

- convey rainwater using appropriately sized and sloped components, that conform to

applicable codes and regulations

- where possible, multiple roof catchments can be connected to a central or “communal” rainwater storage tank
- protect conveyance piping from freezing or from crushing loads
- record the depth and location of all buried RWH system piping and tanks
- make sure any required cleanouts remain accessible

Now complete Self-Test 2 and check your answers.

## Self-Test 2

Self-Test 2

1. Which one of the following would be an acceptable catchment area for a RWH system?
    a. A lawn area
    b. A parking lot
    c. A “green” roof
    d. An asphalt shingle roof
2. If a roof with an area of 200 m² is in an area that receives 8mm rainfall, how many litres of rainwater will be available to be collected?
    a. 1,600
    b. 200
    c. 25
    d. 8
3. What is the maximum suggested slope on a gutter?
    a. 0.5%
    b. 1.0%
    c. 1.5%
    d. 2.0%
4. Which one of the following types of pipes is preferred for underground conveyance piping?
    a. ABS
    b. SDR-35
    c. PVC sewer

d. PVC Sch 40

5. What is the preferred method for keeping underground conveyance piping from freezing?

    a. Heat tracing
    b. Heat tracing and insulation
    c. Polystyrene foam insulation
    d. Polystyrene foam insulation and adequate burial depth

6. According to plumbing codes, what is the horizontal conveyance pipe at the bottom of a leader known as?

    a. A lateral
    b. A conveyance pipe
    c. A storm building drain
    d. A sanitary building drain

7. Why is ABS pipe not a suggested material for exposed conveyance piping?

    a. Because it is not UV-rated
    b. Because it is not always available
    c. Because it is more expensive than PVC
    d. Because it doesn't have a smooth interior

Check your answers using the Self-Test Answer Keys in Appendix 1.

## Section 2: Rainwater Storage

Once rainwater passes through the conveyance network, it is deposited in a storage tank or cistern located in a basement or below grade outside the house. In certain cases, a rainwater cistern can be located above grade (for summer use only) or in a heated garage. As the storage tank is the most important and usually most expensive component of the rainwater harvesting system, it's best to consider the options during a home's design stage if possible. This will allow for some flexibility in the tank's location, configuration, and slope of conveyance pipe from downspouts.

As the central hub of an RWH system, the rainwater storage tank is directly connected to several pipes and houses some components internally. These components may include some, or all, of the following items shown in the graphic below.

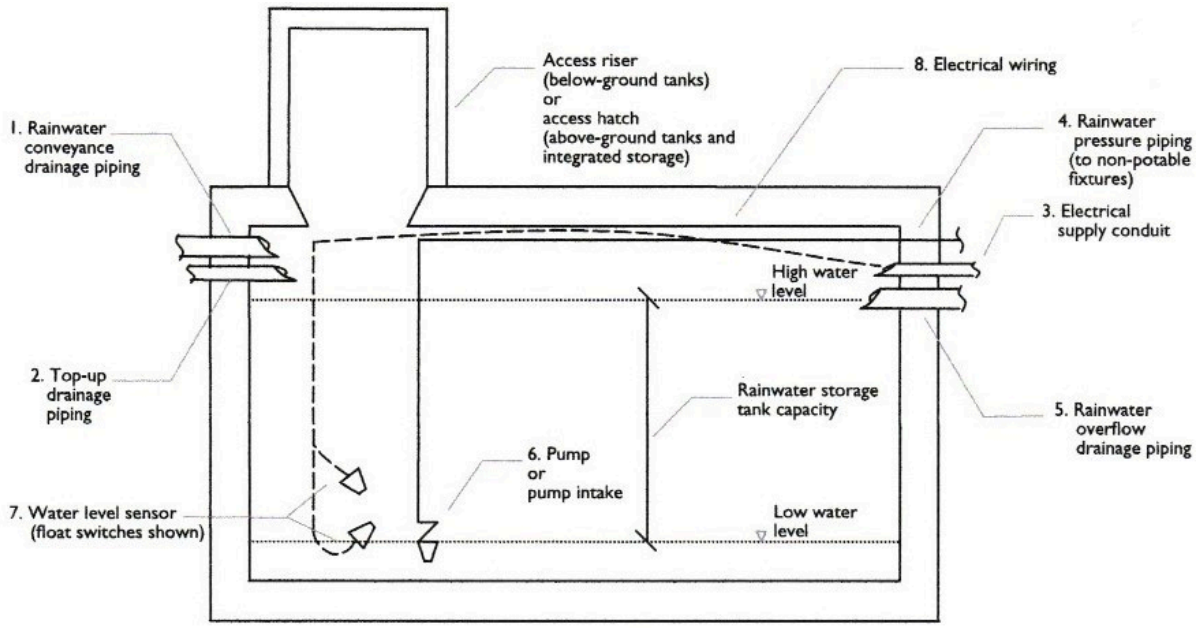



*Figure 3 Typical rainwater storage tank*

The storage capacity of rainwater storage tanks can also vary, from several hundred litres for a typical rain barrel to thousands of litres for commercially available above-ground or below-ground holding tanks. In addition to acting as the primary storage reservoir, the rainwater storage tank can also be considered as the central hub of an RWH system. It is the central location for handling all the rainwater going into (and coming out of) the RWH system and many important components, such as the pump and water level sensor, are often located directly within the tank itself.

Care must be taken during its selection, installation, and maintenance to ensure the proper functioning and optimal performance of the RWH system. A source of information for tanks for RWH systems is the CSA Standard B128.1:06/B128.2:06 (R2021) “Design and installation of non-potable water systems/Maintenance and field testing of non-potable water systems”. Section 7.0 “Storage Tanks” provides specifications for the design and installation of rainwater storage tanks, including access openings, piping connections, overflow, drainage and venting

## Selecting a Tank

Beyond the basic volume capacity, there are a great many factors to consider when choosing a storage tank. These include intended rainwater use, bearing loads, desired storage capacity, site conditions, buried service lines and utilities, site accessibility for excavation and installation, available space for the storage tank, property right-of-way, property setbacks, below-grade burial depth, local rainfall quantities, available roof catchment area, and budget. While the norm is to install only one storage tank, other factors such as property restrictions, structural limitations or buried utilities may require dividing a system into two or three separate tanks.

### Tank types

Storage tanks can be fabricated from many different materials, including high-density polyethylene

(plastic), fibreglass, steel, concrete, and crate-and-bag. A homeowner or system designer may choose to integrate a concrete storage tank into the foundation wall (a cast-in-place cistern), place it in an appropriate location in the front or back yard, or size the mechanical room with sufficient space to fit a plastic or fiberglass storage tank inside the home. An engineer's approval is required if a concrete storage tank will be integrated into the home's structure whether it be cast-in-place, located below a suspended concrete slab, or located on a floor other than a basement or garage.

The selection of one of these materials for a rainwater storage tank will largely depend on local availability, as well as on cost, tank placement (above ground or below ground or integrated), storage requirements, site accessibility and/or engineering specifications. In recent installations, above-ground tanks are often plastic while integrated tanks are usually cast-in-place concrete. Below-ground tanks are usually precast concrete or plastic. For an existing home, a more likely choice will be a plastic (high-density polyethylene), fiberglass, or precast concrete storage tank, located outside of the home at or below grade.

In general, greater economies of scale are seen for concrete tanks than for plastic tanks, making concrete a more desirable material for very large systems. Engineering specifications, such as maximum rated burial depth or minimum required water level, vary for different tank materials and designs. Installation and operational specifications can be sought from manufacturers.

Another consideration is the potential for chemicals to leach from the tank into the stored rainwater, although this is only a concern if rainwater must be of very high quality for a particular end use.

A summary of the types of tanks is as follows:

- *Concrete*: For longevity and strength, concrete is a tried-and-true option. Depending on its size, a tank can be prefabricated, delivered, and dropped into place using lifting equipment. Alternately, a concrete tank can be formed and poured in place. Concrete tanks are especially beneficial if there are heavy loads, such as vehicles, expected over them. Again, an engineer should be consulted if such an installation is proposed.
- *Plastic and fiberglass*: These tanks are good options if placement of the tank without the need for heavy lifting equipment is desired. They are very lightweight and strong but are not normally expected to have heavy loads over them so are best installed below ground in a lawn area. A rain barrel is an example of an above-ground plastic tank.
- *Steel*: Steel tanks are not advantageous due to expected corrosion and aesthetics, and are therefore not commonly found in rainwater harvesting systems. If used, they should be installed fully exposed so that any leakage caused by corrosion can be easily detected. An examples of a steel tanks might be a clean 45-gallon drum that has been used for no previous purpose.
- *Crate-and-bag*: These are a square plastic "bag" contained within a steel mesh crate. The bag can be light-gauge material due to the steel mesh surrounding it which supplies the strength needed. These are commonly seen on flatbed trucks and in the beds of pickups for portable liquid transport. Their construction makes them very portable but, like the steel tanks, they are not normally used in a RWH system. However, like the steel tanks, they could be utilized as a temporary means to establish the amount of collection onsite to determine the size of permanent tank needed.

**Tank sizing**

Sizing a rainwater storage tank may be the most comprehensive step to the overall system design. Sizing will typically be based on the amount of water a homeowner wishes to conserve annually and may involve either a general estimate or a detailed assessment of application use and water demands. Sizing of the storage tank will depend on the intended and combined rainwater "load" including the number of toilets in regular use, outdoor irrigation demands, roof catchment area, local rainfall quantities, and potential growth as well as the number of people in the house (toilet use).

Proportion of total rainfall collection expected ("collection efficiency")

In general, the larger the tank, the greater the volume of rainwater that can be collected and stored during rainfall events. However, this is true only up to a certain point, after which other factors, such as local rainfall patterns, roof catchment area and rainwater demand will limit the amount of rainfall that can be collected and utilized by the system.

Collection efficiency, defined as the percentage of rainfall landing on the roof that will find its way to the storage tank, depends on several site-specific and seasonal factors. Depending on geographic location and site specifics, the collection efficiency can fluctuate between 65% and 85%, with 75% used as the average. Common reasons for water loss include:

- site-specific water losses that are affected by roof material, overhanging branches, and prevailing winds
- collection system losses such as overflow and spillage from undersized piping and inefficient filters, and
- seasonal factors that decrease the proportion of the rain collected such as snowfall that does not melt, light shower rainfalls in the summer, the need to divert water during spring pollen season, and the need to shut down and clean the system after pollen season.

Remembering that 1 $m^2$ of catchment area x 1mm of rain will produce 1 litre of water, if 100% of the annual rainfall were expected to be captured and stored, then the roof catchment area (in $m^2$) multiplied by the annual precipitation (in millimeters) equals potential water collection (in litres). An example calculation of the annual amount of rainwater to be collected would be as follows:

If a roof is calculated to have a 100 $m^2$ roof catchment area and is in a city or municipality that has an annual precipitation rate of 1,538 mm, then an expected annual rainwater load can be calculated as:

$$100\ m^2 \times 1{,}538\ mm = 153{,}800\ litres$$

Using an average collection efficiency of 75%, then an expected actual amount of rainfall that could be captured and stored would be calculated as:

$$153{,}800\ litres \times 75\% = 115{,}350\ litres\ (approx.\ 25{,}351\ Imp.\ Gallons)$$

If the tank were expected to hold the entire year's worth of water, it would have to have a volume of:

$$115{,}350 \div 1{,}000\ l/m^3 = 115.35\ m^3\ (approx.\ 4{,}073\ ft^3)$$

Obviously, this tank would be enormous if it were expected to hold the full year's rainwater supply. Realistically, water would constantly be drawn off to supply toilet and irrigation needs, so therefore the tank would not have to be sized to hold a year's worth of water. There are a great many other factors involved in tank sizing, as were mentioned above, such as number of people in the household, month-by-month expected precipitation, lawn and shrub watering frequencies and amounts, available area, cost and so on.

Therefore, manufacturers and suppliers of tanks for rainwater harvesting systems should be consulted. Their expertise can offer more accurate estimations of tank size. Thus, the estimation of the tank size needed for an RWH system will have one of the following outcomes once in place:

1. Too small – much of the collected rainwater overflows during rainfall events. Significant improvements in collection efficiency can be achieved with minor incremental increases in storage volume.
2. Optimum range – rainwater tanks in this range provide the best balance between collection efficiency of the RWH system and minimizing its size and cost.
3. Too large – rainwater tanks in this range rarely fill to capacity. A smaller tank can be used without a significant drop in the collection efficiency of the RWH system. An oversized rainwater storage tank, however, may be desirable if stormwater management is a strong driver for installing an RWH system.

Ultimately the correct size of tank will truly only be discovered once it is in place and in operation over several years, therefore it is important to consult as many sources of information as possible before deciding on a tank size.

#### Tank location

The optimum location of a tank on a given site depends on many issues such as:

- required fall of the gravity flow conveyance network
- placement of tank (above or below ground, or integrated into a building)
- desired/required tank capacity
- regional climate (e.g., freezing issues)
- site conditions (site grading, accessibility, and space availability)
- proximity to other RWH components (catchment area, overflow discharge location, control components of pump and pressure system)
- potential interference with site services (gas, electricity, water, stormwater, wastewater, phone or cable lines)

Following consideration of each of these issues, it is likely that trade-offs must be made, for instance, the optimum tank storage capacity may be too large to be accommodated at the site, or the optimum location for the tank may be in an area that is difficult to access, and multiple smaller tanks may be a better choice.

### Tank placement

The following table outlines some of the advantages and disadvantages associated with the different placement options regarding rainwater storage.

| Tank Placement | Advantages | Disadvantages |
|---|---|---|
| **Above ground storage** | • There are no site excavation costs associated with below-ground storage<br>• Tank(s) may be substituted once the optimum size has been established | • Rainwater may freeze in tank unless located in temperature-controlled environment<br>• Tanks may be unsightly and aesthetically ugly<br>• Tank may interfere with lawns and gardens |
| **Below ground storage** | • Storage tank can be placed below frost penetration depth, permitting year-round operation<br>• Does not take up yard space | • Location must be free of buried service lines and accessible to excavation machinery<br>• Additional site work required, which increases cost of system<br>• More expensive to upsize, downsize or replace tank |
| **Integrated storage** | • Little or no excavation cost<br>• Storage tank capacity can be customized for each site<br>• Permits year-round operation | • Engineers must design storage reservoir such that it is structurally sound and does not leak into the building |

### Cold weather issues

Throughout much of Canada, temperatures often drop below freezing (0°C) during the winter months. Rainwater stored outdoors or in an environment that is not temperature controlled (maintained above 0°C) is at risk of freezing, either in the storage tank itself, in the pump pressure piping, or both. Water freezing in either location may cause short term blockages and service disruptions or, in the long term, the RWH system may become damaged through the expansion of ice in the system. To minimize these risks, the following two options should be considered.

1. Winter decommissioning: If an outdoor above-ground tank or other setup in a non-

temperature-controlled setting is used to store rainwater, the tank, pump, and pressurized lines shall be drained of all rainwater prior to the onset of cold weather and use of the system shall be discontinued during the winter months.

2. Winterizing the RWH system: An RWH system can be used year-round in cold climates if it is:
    a. located in a temperature-controlled environment such as a heated garage or basement in the case of above-ground or integrated rainwater storage; or
    b. located in a below-ground tank that is buried below the local frost penetration depth.

The first option is generally the simplest and least costly system to design and install. These benefits, however, are largely offset by the significant reduction in rainwater that can be collected and used throughout a given year, as well as by the potential damage to system components if decommissioning occurs too late or not at all. As well, the first option does not allow toilets to be supplied with harvested rainwater and is therefore limited to an irrigation-only RWH system.

The second option, to winterize the system, is more complicated and more costly but is preferred since it enables the RWH system toilets to operate throughout the entire year and ensures system components are protected from frost damage.

In either option, the sub-surface irrigation system would need to be properly valved so as to isolate and drain it before winter.

#### Additional details of the rainwater storage tank

**Installations:** If a prefabricated underground storage tank is used for a rainwater harvesting system, it must comply with Clause 4.1. of CSA B66:21 *"Design, material, and manufacturing requirements for prefabricated septic tanks and sewage holding tanks"*. If a storage tank is going to be integrated into the building or have heavy structural loads on top of it (i.e., vehicles), the design supporting the loads must be approved by a professional engineer.

**Call before you dig:** Provincial locating services (e.g., "BC One Call") should be contacted to locate any underground service lines where a storage tank and its associated underground piping is planned to be buried. This service combines all underground utilities' locations into one information request. The installation, bedding and backfilling of storage tanks should be carried out as per the manufacturer's installation requirements.

**Access:** The entryway (access hatch) of storage tanks needs to be easily accessible and sized with a dimension no smaller than 450 mm (18 in). A 24″ or larger access hatch is recommended to allow for physical entry and the installation and regular maintenance of any internal equipment inside the cistern. All access hatches need to be drip-proof and non-corrosive. Any persons entering the storage tank will need to comply with Provincial Confined Space Entry Regulations.

**Tank connection and pest control:** All connections to the storage tank must be properly sealed and watertight. Any additional openings that are connected to storage tanks which are larger than 150 mm

(6 inches) should have lockable covers. Any connections or openings exposed above grade should include insect or vermin screens to prevent access to the cistern.

**Overflow pipe:** The overflow pipe exiting the storage tank needs to be sized to match or exceed the size of the inlet conveyance pipe and should terminate with a screen.

**Calmed inlet:** The conveyance pipe entering the storage tank should be brought down near the bottom of the tank and have a 90-degree bend or a U-shaped bend. This ensures incoming rainwater is directed away from the bottom of the tank, not stirring up any potential sediment that has accumulated.

**Venting:** Storage tanks require venting to allow for proper drainage and to release any build-up of humidity or any noxious gases. Venting through the conveyance pipe and the overflow pipe is usually sufficient for a residential installation.

**Dead space:** There is normally a 4″ – 6″ unused portion of rainwater at the bottom of the storage tank, typically called the “dead space” and retained to ensure the submersible pump or the suction line does not run dry. This is established through the correct setting of the height of the pump on/off switch.

**Cold weather considerations:** Underground storage tanks should be installed below the frost penetration depth. If this is not possible, the storage tank should be covered with rigid XTPS (extruded polystyrene) foam insulation, or it could be located in a heated or temperature-regulated space (basement or heated garage). Above-grade storage tanks need to be drained and decommissioned during the winter.

### Management Guidelines

Rainwater tanks should be inspected at least once a year for the following:

- Leaks
    - For below-ground storage tanks, leaks may be identified through poor performance of the RWH system (for example, the make-up water system operates often), from moist soil conditions surrounding the tank and/or excessive settling of the tank in the excavated space
    - For above-ground storage tanks and integrated storage, leaks can be identified visually by examining the area surrounding the tanks, or through poor system performance or soil moisture (if applicable)
- Accumulation of debris
    - Sediment may accumulate on the bottom of the tank and, depending on the treatment provided, appear at the point of use. In such cases, the location (height) of the pump intake may need adjustment. Adjust the location of the pump intake so that it is located 100 – 150 mm [4 – 6 in.] above the bottom of the tank
    - If sediment is still detected at the point of use, pre-storage and/or post-storage treatment devices may need to be installed (or cleaned/maintained) to improve rainwater quality (refer to chapter
- Rainwater quality and treatment

    - In some cases, it may be necessary to remove the accumulated sediment at the bottom of the tank. Place a pump capable of handling large debris and/or solids (for example, a suitable sump pump or effluent pump) at the bottom of the tank to pump out the sediment layer.
    - Note: removal of sediment and/or tank cleaning is not generally recommended on an annual basis, as this can destroy beneficial “biofilms” in the tank. These biofilms may contribute to improved stored rainwater quality.

Winterizing or decommissioning are the two choices for protecting the RWH system from freezing.

### Winterizing

If the system must operate year-round, and the tank and all related components cannot be installed below the frost level, consider these steps:

- Install a heating system to maintain air temperatures above 0°C (if tank is indoors).
- Install a water heating system directly inside the rainwater tank
- Install heat trace wire around any components that are above the frost level
- Install insulation on the rainwater tank, around pipes, valves and/or pump

### Decommissioning

If the system *does not* need to operate year-round, consider these steps:

- Drain/blow out with air all the rainwater stored in the tank and the rainwater pressure piping
- Shut off the water supply to the make-up water system (if present) to prevent the tank from refilling
- Disconnect electrical supply to the pump and control equipment
- Disconnect leaders from the conveyance network and have them discharge to grade or other suitable location
- Disconnect fixtures, such as toilets, from rainwater supply and connect to the potable water system

Now complete Self-Test 3 and check your answers.

# Self-Test 3

Self-Test 3

1. Which one of the following tank placement options would require the approval of an engineer?
    a. Installing a below-ground plastic tank in a front yard
    b. Installing a below-ground concrete tank in a back yard
    c. Forming a concrete tank as a component of the house foundation
    d. Forming a poured-in-place concrete tank below-ground in the front yard
2. Which one of the following tank material choices would provide the most strength and likely last the longest?
    a. Steel
    b. Plastic
    c. Concrete
    d. Fiberglass
3. Tank sizing involves many varying factors. What or who should be consulted when attempting to accurately determine an appropriate tank size for a RWH system?
    a. The AHJ
    b. A plumbing wholesaler
    c. The local plumbing code in force
    d. Tank manufacturers and suppliers
4. Which of the following considerations would likely be most objectionable if choosing to install a plastic above-ground RWH tank in a front yard?
    a. Ease of handling
    b. Aesthetics
    c. Longevity
    d. Cost
5. Which one of the following choices would likely incur little or no extra excavating costs?
    a. An integrated tank
    b. A below-ground plastic tank
    c. A below-ground pre-cast concrete tank
    d. A below-ground poured-in-place concrete tank

6. Who should be consulted before excavating for placement of a RWH tank or its underground components?
    a. A provincial “One Call” service
    b. The local water/sewer utility
    c. The local telephone utility
    d. The local electrical utility
7. What determines the height of the “dead space” in the bottom of a RWH tank?
    a. The location of the tank overflow
    b. The height of the pressure pipe outlet
    c. The placement of the pump on/off switch
    d. The location of the rainwater conveyance inlet pipe
8. What is the purpose of the “dead space” in a RWH storage tank?
    a. To keep the sediment stirred up
    b. To ensure the pump does not run dry
    c. To make sure any sediment doesn’t collect
    d. To keep the overflow unobstructed from debris
9. Which one of the following choices would be considered the best approach to ensuring a RWH tank that has to operate year-round is protected from freezing?
    a. Install it and all related components below the frost level
    b. Drain/blow out with air the tank and all related components
    c. Install insulation around the tank and all related components
    d. Install heat tracing wire around the tank and all related components
10. Which one of the following choices would *not* be part of decommissioning a RWH system?
    a. Shut off the make-up water supply to the tank
    b. Install heat trace wire around the tank, pipes, valves, and pump
    c. Disconnect toilets from the RWH system and connect them to the potable system
    d. Disconnect leaders from the conveyance network and let them drain onto the ground

Check your answers using the Self-Test Answer Keys in Appendix 1.

## Section 3: Rainwater Quality and Treatment

### Rainwater Quality

There are currently no national water quality guidelines that pertain specifically to the use of rainwater. The *“Canadian Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing*

*(2010)"* are not intended for rainwater use but may be applied for multi-residential or commercial systems where there is the potential for direct contact. For single-family dwellings, the quality of rainwater and the need for treatment must be evaluated in the context of connected fixtures. Residentially, these would be toilets specifically, as the plumbing codes prohibit the use of harvested rainwater for any other fixtures.

The quality of rainwater runoff from a catchment surface can be affected in two ways. Firstly, dirt and debris can collect on the roof surface from direct atmospheric deposition (e.g., smog, acid rain, etc.), from overhanging foliage, or bird and rodent droppings. Secondly, the roof material itself can contribute both particulate matter and dissolved chemicals to runoff water. These issues are a concern for all RWH systems.

Treatment can be applied to improve rainwater quality and can take place:

- before storage in the rainwater storage tank (pre-storage treatment) and/or
- after storage in the rainwater storage tank (post-storage treatment).

Pre-storage treatment devices must be incorporated as part of the conveyance network and rely on gravity flow to facilitate the treatment process. Post-storage treatment devices tend to be more rigorous than pre-storage treatment devices and often require pressurized flow and/or electricity to aid in the treatment process. The table below lists some advantages and disadvantages of each.

| **Treatment location** | **Advantages** | **Disadvantages** |
|---|---|---|
| Pre-storage treatment | 1. Simple in design; operates using gravity flow (no electricity or high-pressure requirement)<br>2. Prevents large particles from accumulating in the storage tank<br>3. Reduces requirement for post-storage treatment devices (or can preclude their use altogether) | 1. Susceptible to freezing<br>2. Requires regular cleaning and maintenance. Poorly maintained devices may prevent rainwater from being conveyed to tank or may permit untreated rainwater to enter the tank<br>3. Multiple collection points may require a number of localized pre-treatment devices, increasing cost |

| | | |
|---|---|---|
| Post-storage treatment | 1. Very high quality of water can be achieved<br>2. Located inside building, so no freezing risk<br>3. Can be used to treat more complex quality issues (for example, pine needles in tank that create tannic acid) | 1. May require monitoring, maintenance, and replacement of filters, chemicals, or other materials<br>2. End quality depends on incoming rainwater quality and maintenance of pre-storage treatment devices<br>3. Generally, more expensive than pre-storage treatment |

## Pre-storage Treatment

Although there are various ways of treating rainwater prior to storage, methods tend to use one of three techniques: first-flush diversion, filtration or settling.
First-flush diversion involves diverting the first portion of runoff (collected from the catchment surface) away from the storage tank. This technique improves stored rainwater quality by preventing the entry of the dirt and debris that collect on the catchment surface between rainfall events, the majority of which are contained in the first portion of runoff (“first flush”).

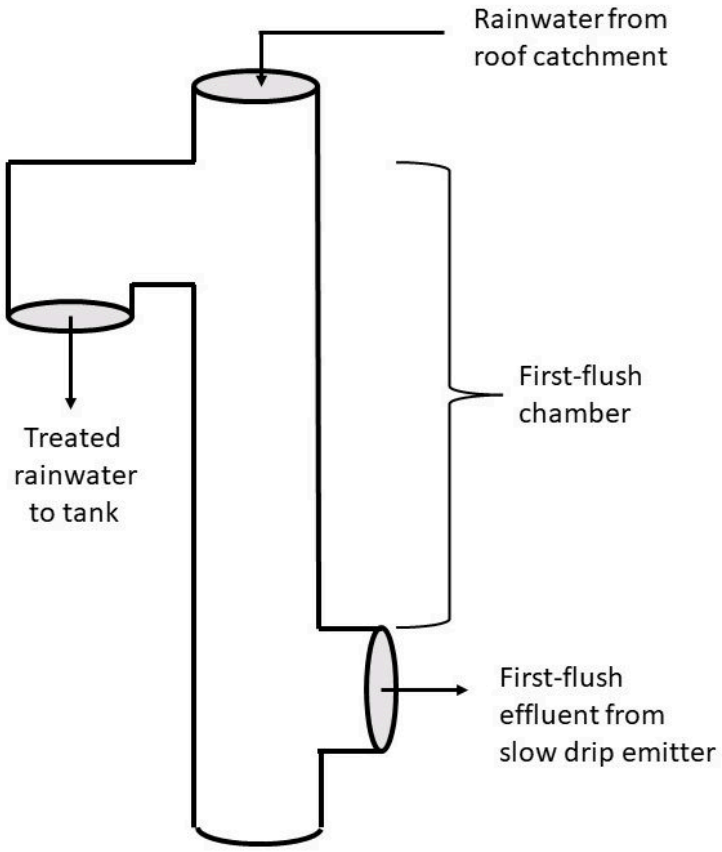



*Figure 4 Operation of "first-flush" diverter*

Any sediment or debris is deposited directly into the chamber bottom, which has an outlet with an orifice in it. This allows the chamber liquid to back up and spill the runoff water out to the tank via the upper opening while the liquid containing sediment slowly drains away to a satisfactory location.

The second method, filtration, involves screening out leaves and large debris from runoff, preventing their entry into the rainwater storage tank. Filtration can take place at or near the catchment surface in the form of screens placed over gutters (referred to as "gutter guards") or screens placed over roof drains/leaders on flat-roofed buildings. Filtration devices can also be integrated into leaders or other parts of the conveyance network.




*Figure 5a Pre-Storage Filter Device*

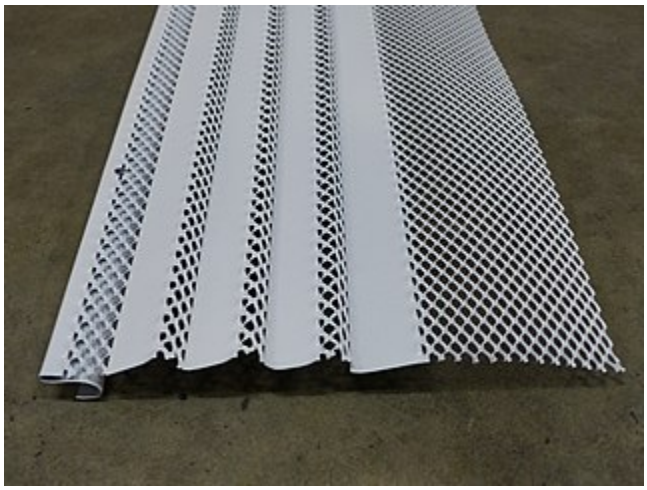


*Figure 5b Gutter guard*



*Figure 5c Gutter Guard*

Another pre-storage treatment method is a settling chamber in a rainwater storage tank or a dedicated settling tank. Rainwater from the roof catchment is first conveyed to the settling chamber, where the dirt and debris suspended in the rainwater can settle out and collect as sediment at the bottom of the chamber. The clarified water is then conveyed to the rainwater storage tank or the storage chamber of the tank. A two-compartment storage tank with a settling chamber is shown below.

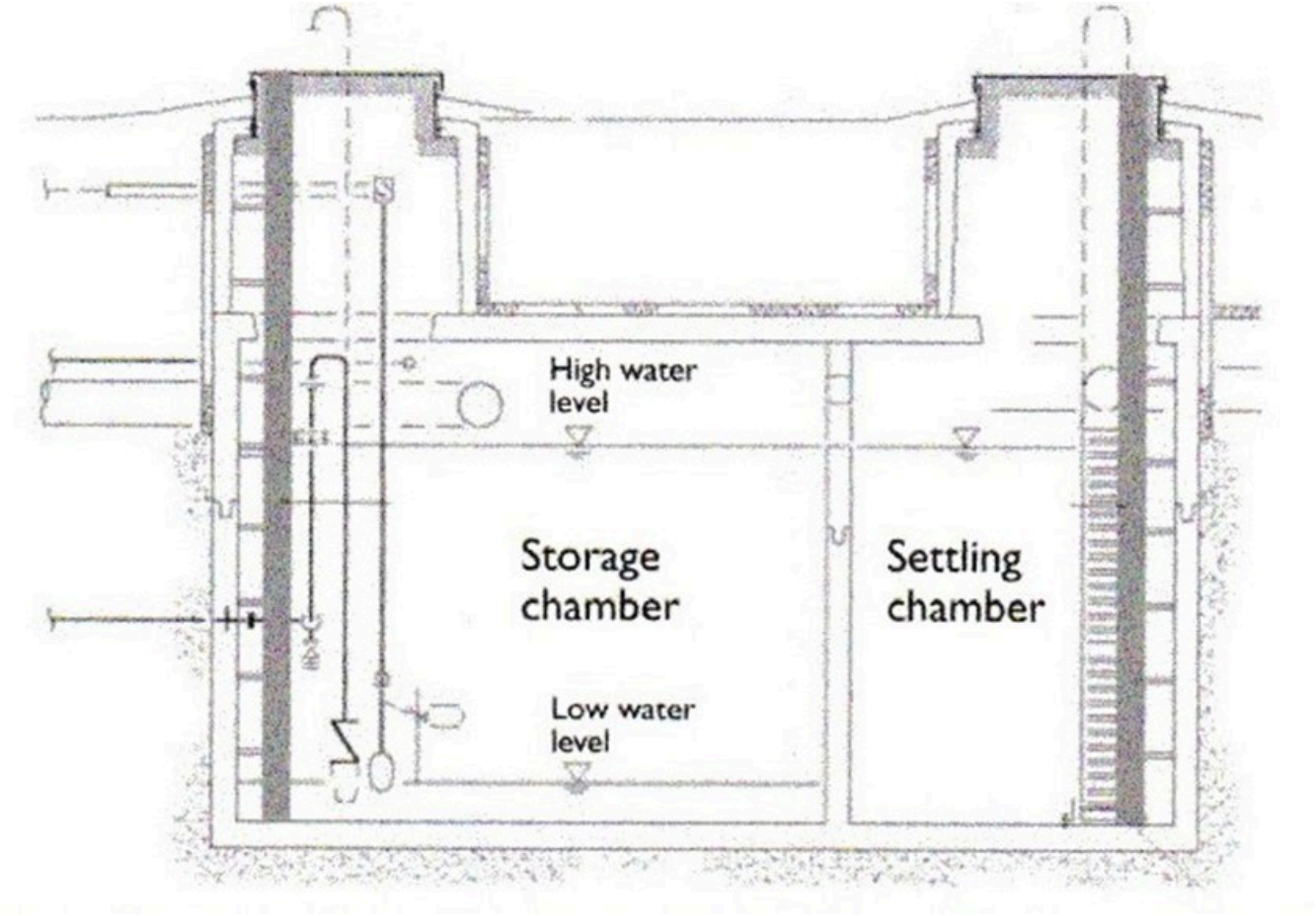



*Figure 6 Rainwater storage tank with settling and storage chambers*

## Post-storage Treatment

Post-storage treatment includes filtration, disinfection and/or treatment for aesthetic issues like colour, taste, or odour. As for pre-storage treatment, there are several different treatment devices available to perform these tasks. A description of these techniques, their applications and a list of available devices/ options are provided in the table below.

| Treatment Location | Details | Treatment Options Available |
|---|---|---|
| **Filtration** | Filtration removes suspended particles from water by passing it through a permeable material.<br><br>Water quality issues targeted:<br>• Turbidity<br>• Total suspended solids | Particle filtration (for example, bag/sock or cartridge filter)<br>• Slow sand filtration<br>• Membrane filtration |

| | | |
|---|---|---|
| **Disinfection** | Disinfection removes or inactivates micro-organisms by chemical or physical means.<br><br>Water quality issues targeted:<br><br>• Microbiological contaminants (viruses, bacteria, and protozoa) | • Ultraviolet (UV)<br>• Chlorine<br>• Ozonation<br>• Slow sand filter<br>• Membrane filtration<br>• Thermal treatment |
| **Aesthetic Issue Treatment** | Aesthetic issue treatment removes constituents from water that contribute to colour, taste or odour issues.<br><br>Water quality issues targeted:<br><br>• Hydrogen Sulphide<br>• Organic matter<br>• Manganese<br>• Iron | • Activated carbon<br>• Ozonation<br>• Slow sand filter<br>• Reverse osmosis<br>• Membrane filtration with chemical addition |

Despite having an initial filter which flushes the leaves and other debris from the rainwater, it is recommended that homeowners install some form of post-storage filtration and treatment device. Post storage filtration and treatment will improve the quality of water entering the home from the cistern. Typically, post storage filtration equipment requires a conditioned environment and location in the mechanical room for maintenance and electrical supply. Post storage water treatment typically consists of UV disinfection lamps, particle filters and, potentially, carbon or reverse osmosis filters.

It is important to note that post-storage treatment is normally only considered where harvested rainwater is to be used for potable purposes, which are not the focus of this literature due to being disallowed by plumbing codes.

## Treatment Device Selection

When determining the treatment devices required for a rainwater harvesting system, the following questions should be considered.

1. What applications will the rainwater be used for?
2. What quality requirements do applicable provincial, territorial and/or national codes and regulations specify for the uses under consideration?
3. Can the rainwater harvesting system supply enough rainwater to meet the desired uses?
4. Can treatment requirements be achieved through the proper design, installation and maintenance of the rainwater harvesting system?
5. What are the personal preferences of those using the rainwater and those who are managing

the rainwater harvesting system?

6. What treatment devices are locally available?
7. Are there methods of supplying rainwater of varying qualities to different fixtures, if allowable?
8. What is the waste stream that is going to be generated through treatment and how will it be disposed of?
9. What are the capital, operational and maintenance costs associated with the treatment devices?
10. Who will ensure that maintenance is performed, provide training to maintenance personnel, and pay for the replacement of filters or other components?

## Design and Installation Guidelines to Improve Rainwater Quality

Listed below are factors that impact the quality of rainwater in the rainwater harvesting system and can be mitigated through proper design and installation.

| Components of a RWH System | Risk Factors | Design and Installation Best Practices |
|---|---|---|
| **Catchment Surface** | • Overhanging tree branches and animal activity<br>• Leaching of chemicals and/ or metals from catchment material<br>• Grease and lint on catchment surface from kitchen cooktop vent and dryer vent, respectively<br>• Proximity to sources of air pollution (industry, major roadways, etc.) | • Trim overhanging tree branches<br>• Direct dryer and kitchen cooktop vents under gutters<br>• Do not collect runoff from sections of catchment area at risk for poor quality |
| **Conveyance Network** | • Entry of potentially poor-quality groundwater/ surface water from poorly sealed joints<br>• Entry of animals and/ or insects through poorly sealed joints | • Ensure underground pipe connections and fittings are secure<br>• Use downspout-to-PVC pipe adapters |

| | | |
|---|---|---|
| **Rainwater Storage Tank** | • Sediment on bottom of tank<br>• Ingress of insects, rodents or debris<br>• Algae growth in tank<br>• Leaching of chemicals and/or metals from tank material or components located inside tank | • Ensure tank hatch is properly covered and vents have screens<br>• Prevent entry of direct sunlight into tank<br>• Store rainwater in tank with proper certification<br>• Locate pump intake at a suitable distance above tank floor |
| **Overflow System** | • Backflow of storm sewage during extreme rainfall events (if overflow is connected to storm sewer) | • Ensure overflow system is adequately designed for intense rainfall events and use backwater valve on overflow drainage piping |

Consider other site-specific risk factors and adapt maintenance of the RWH system as appropriate to mitigate the risks to rainwater quality.

## Routine Care and Maintenance of Water Treatment Systems

Pre-storage treatment devices should be inspected at least twice a year, or more frequently as required by manufacturer's instructions and site conditions.

Observe rainwater passing through the devices during a rainfall event or simulate a rainfall event by discharging water from a hose onto the catchment surface. Look for potential problems such as

accumulated dirt and debris blocking flow through the filter, or loose fittings or other problems with the treatment devices such that rainwater is passing through without treatment taking place.

Clean the filtration devices according to the manufacturer's maintenance instructions and repair as required.

If pre-storage treatment devices need to be decommissioned during the winter:

- drain all the rainwater accumulated in the treatment devices
- disconnect the treatment devices from the conveyance network, and/or
- install pipe, downspouts, or other material to bypass the pre-storage treatment devices and direct untreated water to the tank

Post-storage treatment devices should be inspected at least quarterly, or more frequently depending on manufacturer's instructions and site conditions.

Observe the devices as water flows through the pressure system, looking for problems such as water leaking from treatment devices, or warning/indicator lights on treatment devices indicating fault with device and/or required replacement of components.

Maintain post-storage treatment devices as necessary through the regular cleaning of filtration devices and/or replacement of filter media, lamps or other components as specified by the product manufacturers.

While inspecting, cleaning, or repairing the pre-storage treatment and/or post-storage treatment devices or other components of the rainwater harvesting system, follow all necessary safety precautions.

Now complete Self-Test 4 and check your answers.

## Self-Test 4

Self-Test 4

1. Which one of the following residential fixtures is allowed to be connected to a RWH system?
    a. A toilet
    b. A urinal
    c. A clothes washer
    d. An outside hosebibb
2. Which one of the following would not be a method of pre-storage treatment?
    a. Settling
    b. Filtration
    c. Disinfection
    d. First-flush diversion
3. Which one of the following water treatment options involves the use of a two-compartment storage tank?
    a. Settling
    b. Filtration
    c. Disinfection
    d. First-flush diversion
4. Which one of the following water treatment options involves the use of an orifice and chamber that makes water back up and exit through an outlet to a cistern?
    a. Settling

b. Filtration
c. Disinfection
d. First-flush diversion

5. Which one of the following would only be used as a component of post-storage water treatment?

    a. Settling
    b. Filtration
    c. Disinfection
    d. First-flush diversion

6. Complete the following statement: “Post-storage treatment is normally only considered if the rainwater is to be used for _____ ”.

    a. Toilet flushing
    b. Urinal flushing
    c. Potable purposes
    d. Below ground irrigation

7. Regardless of the end use of the RWH system, why should overhanging branches or foliage be cleared away from above roof catchment areas?

    a. They contribute to leaves and bird droppings contaminating the collected rainwater
    b. They block the sun’s UV rays which are beneficial to water treatment
    c. They increase the area of direct contact of rain with the roof
    d. They contribute to taste issues in the rainwater

8. What would “gutter guards” be considered as?

    a. A form of post-storage treatment
    b. A form of pre-storage treatment
    c. A no-maintenance component
    d. Unnecessary

Check your answers using the Self-Test Answer Keys in Appendix 1.

## Section 4: Make-up Water System and Backflow Prevention

Regardless of the size of the rainwater storage tank or the catchment area, there may occasionally be times when there is insufficient rainwater to meet the demands on the RWH system, and the storage tank will run dry. RWH systems need to have a system in place to sense when there is insufficient rainwater stored, and either trigger an alarm or automatically switch to an alternative water supply. This strategy is often referred to as a “make-up” system.

The primary concern with a make-up system is that it requires potable water from a municipal or

private water source to be brought into close proximity with rainwater, which creates a risk of a cross-connection. If a physical connection is made between the RWH system and a municipal water system, there is a risk that rainwater can be drawn back into the potable water system by backflow. This must be avoided at all costs.

Given these concerns, much care must be taken when implementing and managing a make-up water system. This section provides an overview of the various components involved in a make-up system and provides guidance on how to assess and then mitigate the risks associated with cross-connection and backflow.

### Types of Make-up Water Systems

To ensure that rainwater demands are met during times when there is insufficient rainfall to keep enough useable water in the tank, there are two general options available:

1. Top-up: the rainwater storage tank can be partially filled, either manually or automatically, with make-up supplies of water from potable municipal or private water sources
2. Bypass: the rainwater supply from the pressure system can be shut off, either manually or automatically, and water from municipal or private sources can be directed through the rainwater pressure piping.

Of these options, only top-up systems are permitted by the NPC and BCPC. The bypass method contravenes Article 2.7.1.1. of the codes, which states that “a non-potable water system shall not be connected to a potable water system.” Therefore, the information to follow will not include the bypass method.

### Backflow Prevention for Top-up Make-up Systems

All installations of potable make-up water to RWH systems must comply with the applicable plumbing code in force. As well, if there is a municipal potable water system in place, its owner (the water purveyor) has the right to prescribe appropriate measures to prevent any non-potable water from getting back into the public system through backflow. Consequently, there are several agencies/codes/publications that may need to be consulted where a make-up water system is contemplated. Some of these are:

- The National Plumbing Code of Canada
- The British Columbia Plumbing Code
- The American Water Works Association Canadian Cross Connection Control Manual
- CSA Standard B64.10 “Manual for the Selection, Installation, Maintenance and Field Testing of Backflow Prevention Devices”
- The water purveyor
- Local bylaws/ordinances

The interpretation and application of the information from the sources noted above are tricky to

navigate through. Obviously, the ultimate determination of the appropriate backflow prevention measures falls upon the shoulders of the AHJ. Consult the AHJ in every case before contemplating the installation of a make-up water supply.

There are two areas of protection that the installation of backflow preventers addresses, which are “zone isolation” and “premise protection”.

#### Zone isolation

This is the practice of installing a backflow preventer at the point of use to protect the occupants in the building from backflow. An air gap is usually the only allowable way to introduce potable water into the rainwater storage system, as any direct connection between the two systems is not permitted.

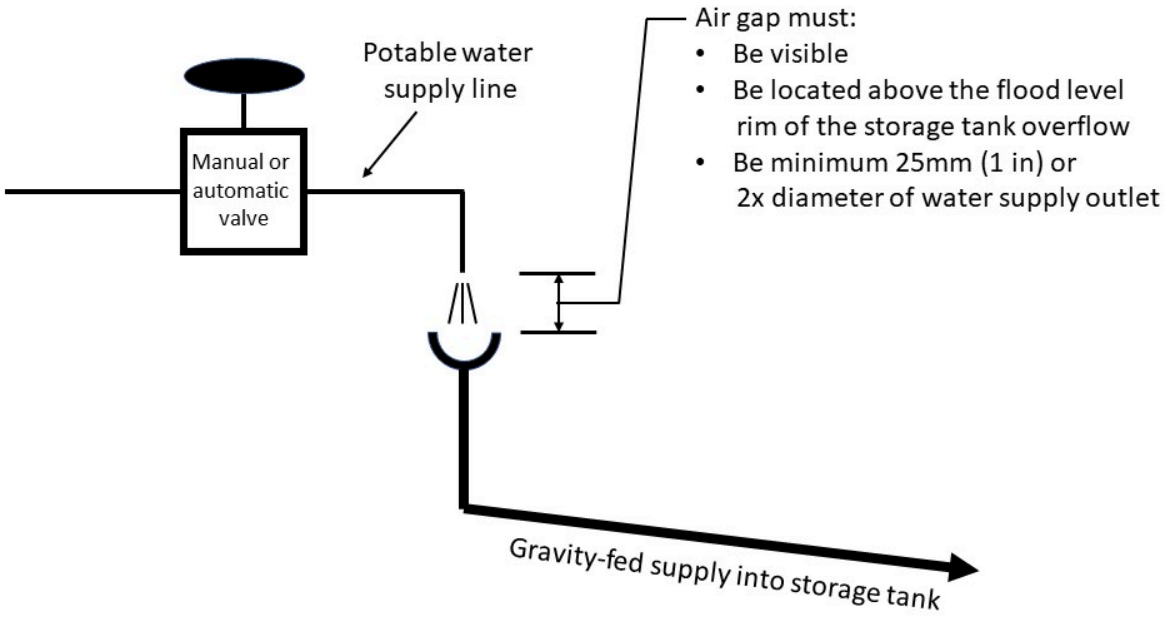



*Figure 7 Air gap as zone isolation for make-up water*

This physical break prevents the backflow of water since, even if rainwater backed up from the tank to the gap, it would spill from the gap and not encounter the potable water supply. The air gap must be located higher than the overflow drainage piping from the tank and the overflow drainage piping must remain free of blockage so that excess rainwater flows to the overflow system and does not back up and overflow at the air gap. The piping from the air gap to the tank must be sized large enough to allow the quantity of water that is exiting the pressurized outlet to be able to flow by gravity to the tank without backing up and spilling. The air gap must never be concealed and must be installed where occasional spitting from the air gap will not cause problems. The air gap is also never allowed to be bypassed by connecting a hose or extending the outlet below the flood level rim of the funnel.

**Premise protection**

In addition to the installation of an air gap for zone isolation, a backflow preventer is also required on the water service to the building if a RWH system is proposed or in existence. This is known as "premise protection" or "premise isolation". Premise protection assures that the public potable water system is protected from backflow that might occur through the water service. A backflow preventer, as specified by the AHJ, is installed on the water service either at the property line or immediately inside the building, to ensure that it is protected from vandalism and freezing, as well as to prevent being bypassed.

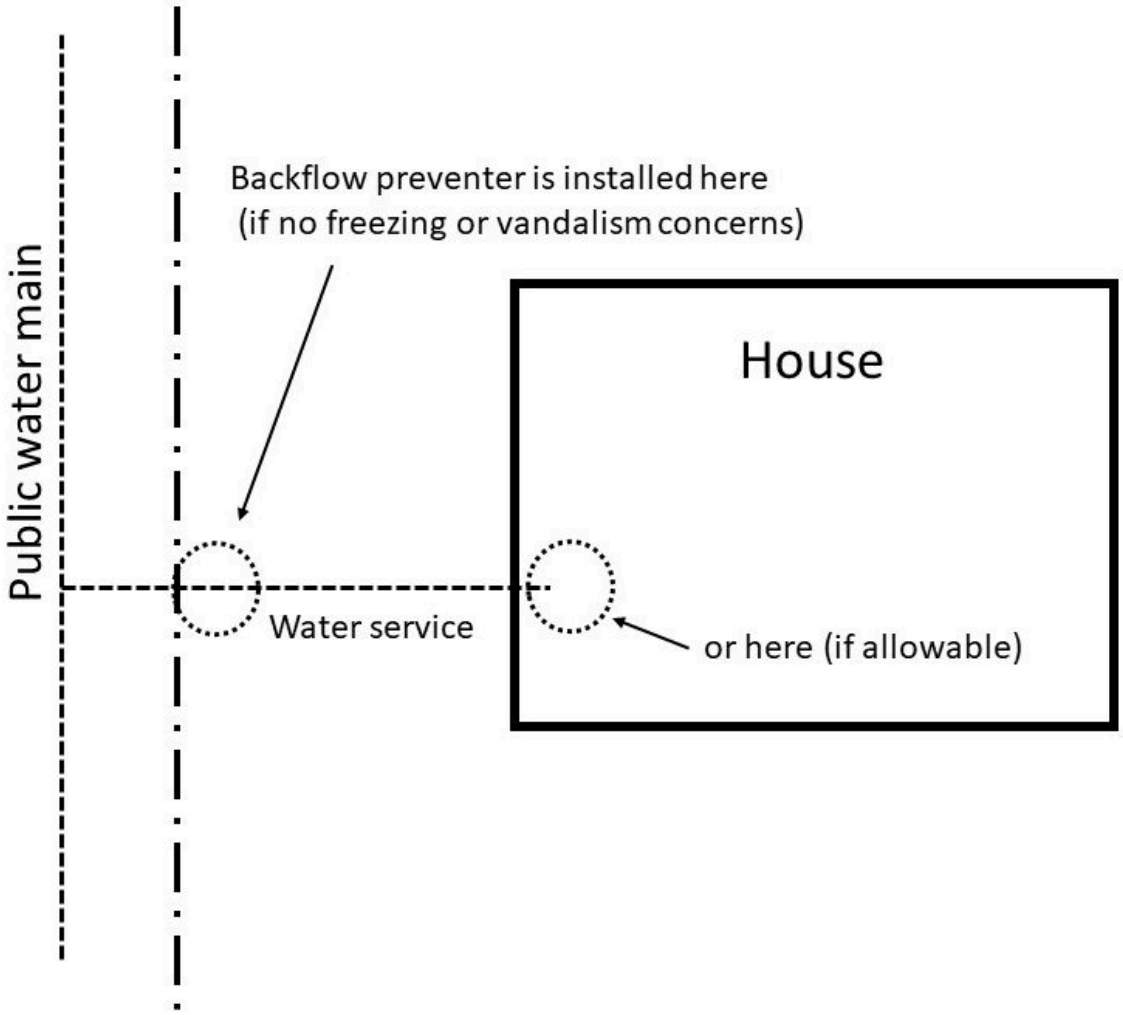



*Figure 8 Premise protection*

## Manual and Automatic Top-up Systems

Potable water can be admitted to the storage tank either manually or automatically to keep enough water in the tank for proper operation of toilets and irrigation systems. Below are some advantages and disadvantages of each type.

| Make-up Water Method | Advantages | Disadvantages |
|---|---|---|
| **Mobile Top-up** | • Simplest method to design and install due to reduced control equipment requirement<br>• Lowest cost alternative | • May result in service interruptions (for example, no water for flushing toilets) if tank not topped up prior to going dry<br>• Requires homeowner to monitor volume of stored rainwater in tank and top up pre-emptively if low |
| **Automatic Top-up** | • Reduces the number of service interruptions by automatically filling tank before it runs dry<br>• Make-up system operates without the need for monitoring or intervention by the homeowner | • Improper design or installation of control equipment may cause insufficient or excessive top-up volumes to be dispensed by the make-up system<br>• Service interruption during power failure |

For most residential applications, it is recommended that the automatic top-up be selected as it minimizes service interruptions and is the least onerous for the homeowner.

A simplified diagram of the control strategy for an automatic top-up system is depicted in the graphic below.

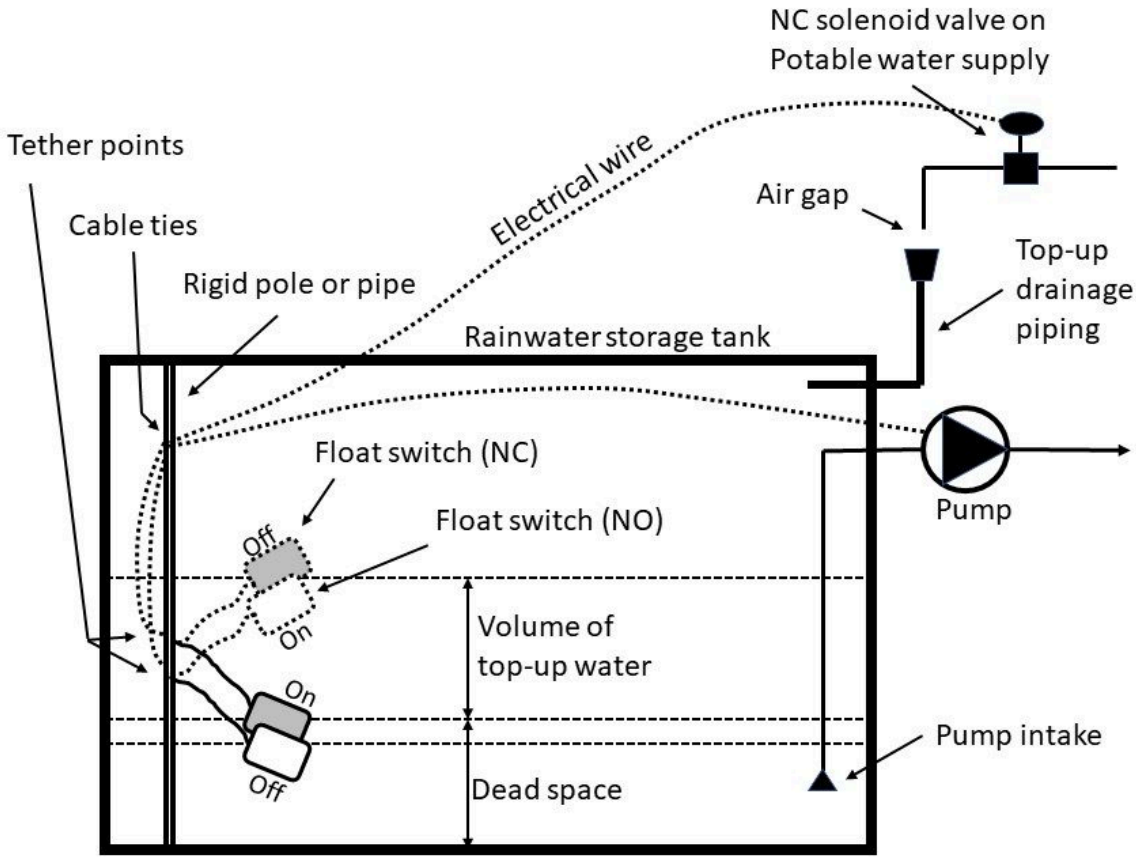



*Figure 9 Automatic top-up system*

A brief description of control components for both manual and automatic systems is listed below. Some of these are not shown in the previous diagram.

- *Water level sensor*: mounted inside the tank, they indicate the water level in the tank. Like those found in an RV water or waste tank, their reaction to the liquid level sends an electrical signal to a control board causing LEDs to light, which in turn indicates that the tank is empty, ¼ full, ½ full, etc. Sensors can also be used to operate pumps if desired.
- *Float switch*: a small buoyant cylinder that tips up or down (inverts) depending on the liquid level. These devices are the same as those used to control a pump in a sump. They must always be made to tip rather than float horizontally. To achieve this. they can either have a lead weight fixed to the cord approximately 6 inches from the float, or the cord can be tethered to a fixed point. Float switches are either of the N.O. (normally open) or N.C. (normally closed) variety. A NC float switch can de-energize the pump if it opens, indicating that there is not enough water in the tank and preventing the pump from running dry. A N.O. switch can be used to allow the pump to run if it tips upward to close, indicating there is enough water for the pump to operate.
- *Manual shutoff valves*: used to manually control make-up water to the tank. They are normally left open if a solenoid valve downstream is used to add water to the tank. These are

typically ball valves but can be of the gate or globe variety as desired. These are usually installed wherever isolation of water-operated components is necessary.

- *Solenoid valve*: a normally closed electrically operated valve that is used to automatically add potable make-up water to the tank when it reaches a critical level (dead space) and close when water reaches the "pump off" level as determined by the positioning of the float switches.
- *Pump*: these can either be mounted inside the tank (submersible) or outside the tank (jet-type). Regardless of the type used, the pump intake point must be set at 4" – 6" (100 mm – 150 mm) above the tank bottom to prevent any accumulated silt or debris from being pulled into it. Check valves must be installed on the intake pipe to prevent the pump from losing its "prime" (allowing water to fall back into the tank when the pump shuts off).
- *Foot valve*: a combination check valve/strainer used at the intake point of a jet pump to keep the pump primed with water when shut off, and to prevent debris from entering the intake piping.

## Operation of the Make-up Water System

When stored rainwater reaches a low level in the cistern, a control device, such as a float switch or water level sensor, activates a top-up system to replenish the rainwater system with enough water to continue functioning properly. A solenoid valve opens to allow pressurized municipal potable water to discharge through an air gap into a funnel. The funnel and piping downstream of it are sized and sloped to allow gravity to carry the water into the tank. This continues until the desired water level in the cistern is reached, whereby the solenoid valve is de-energized, and the municipal water flow shuts off. The make-up water simply replenishes the cistern water level with enough water so that the rainwater harvesting system output continues to function normally.

#### Routine maintenance

If the make-up system is operating properly, it is recommended that it still be inspected once every six months to:

- verify that the float switch wires are not tangled with other float switches, the pump, or other objects in the tank
- remove any dirt and/or debris that have accumulated on the float switches, as necessary
- observe the make-up system while operating to ensure that water is not overflowing from the top-up drainage pipe at the air gap or discharging from the backflow preventers. If any water is leaking or discharging, identify the cause and correct.

While inspecting, cleaning or repairing the make-up system, follow all necessary safety precautions, such as disconnecting the power supply, when necessary. A qualified electrical contractor should be engaged for installation and repair of any electrical equipment.

Now complete Self-Test 5 and check your answers.

# Self-Test 5

Self-Test 5

1. What is the strategy known as whereby potable water is added to the cistern to prevent the pump from running dry in times of little or no rainfall?

    a. Top-up
    b. Make-up
    c. Bypassing
    d. Bolstering

2. What is the primary concern regarding the question above?

    a. Creating a cross connection
    b. The need for extra piping and cost
    c. Depleting the potable water supply
    d. Finding a suitable contractor for the work

3. Which one of the following options is the only one allowable by the plumbing codes to ensure there is enough water for use in a RWH system during periods of insufficient rainfall?

    a. Top-up
    b. Make-up
    c. Bypassing
    d. Bolstering

4. What would the use of an air gap in a top-up system be considered?

    a. Unacceptable
    b. Not necessary
    c. Zone isolation
    d. Premise protection

5. Which one of the following choices protects the building occupants from the effects of a potential cross connection?

    a. Zone isolation
    b. Building isolation
    c. Premise protection
    d. Occupant protection

6. Which one of the following choices would *not* be a consideration for the installation of a backflow preventer on a water service at the property line?

    a. Freezing
    b. Aesthetics
    c. Vandalism
    d. Being bypassed

7. Which one of the following choices is commonly used to operate a pump in a rainwater cistern?

    a. An air gap
    b. A float switch
    c. A pump intake
    d. A solenoid valve

8. Which one of the following components of a RWH storage system is normally used to automatically add municipal water to the cistern?

    a. A foot valve
    b. A glove valve
    c. A solenoid valve
    d. A manual shutoff valve

9. Where is the air gap for a make-up water system located?

    a. Between the solenoid valve and the cistern
    b. Between the cistern and the overflow piping
    c. Between the first-flush diverter and the cistern
    d. Between the roof catchment area and the solenoid valve

10. In a make-up water system, when does the solenoid valve close?

    a. When the cistern water level spills into the overflow
    b. When the manual water fill valve has been turned off by the homeowner
    c. When a sensor or float switch is activated at the lowest water level desired
    d. When a sensor or float switch is activated at the highest water level desired

Check your answers using the Self-Test Answer Keys in Appendix 1.

## Section 5: Pumps and Pressurized Distribution

### Pressurized Distribution Systems

Pressurized water to toilets and irrigation systems is rarely gravity-fed, therefore pumps are needed to take water from the storage tank (cistern), pressurize it and deliver it to permitted fixtures which may

be located several stories above. The system is composed of a pump, a pressure tank to store pressurized water, a pressure switch or constant pressure components, possible post-storage treatment devices, and plumbing lines that are clearly marked and kept separated from the potable system.

To ensure the proper operation of these systems, care must be taken when selecting the type and size of the pump, pressure tank, and associated equipment. The pressure system must be capable of supplying water at a sufficient rate and pressure to all the fixtures it is connected to, especially those located the highest and furthest away from the pump. Most importantly, it must be designed and installed to minimize the risk of a cross-connection and potential backflow.

Homeowner maintenance is also critical, as homeowners must periodically inspect the system and be capable of troubleshooting any issues should they arise.

## General Operation and Equipment Selection

The pump and pressurized distribution system is composed of a series of interconnected components, located both inside the rainwater tank and inside the building. A typical pressure system for a rainwater tank in a below-ground application is shown below.

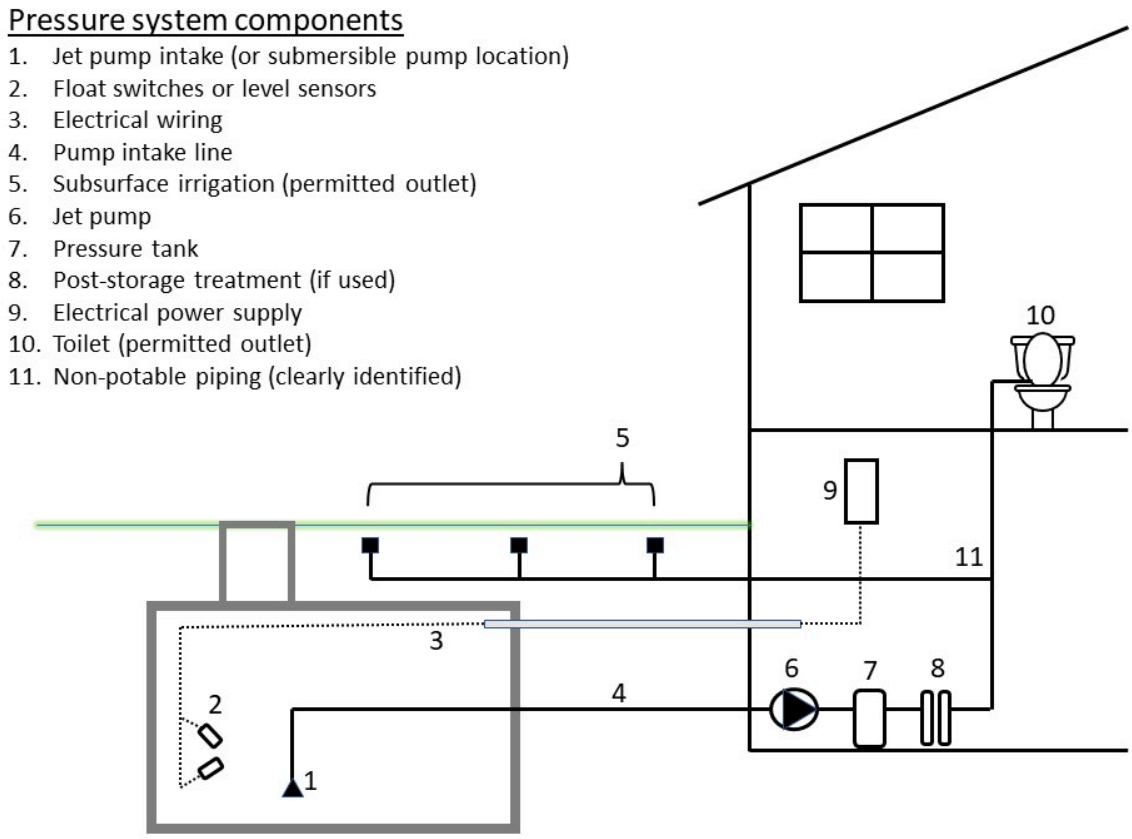



*Figure 10 RWH pressure distribution system*

### System operation

In the figure shown above, rainwater is pushed from the storage tank by a submersible pump located directly inside the tank or drawn from the tank by a jet pump located inside the building. The rainwater is moved through the intake line to a suitable location in the building, such as a mechanical room or basement utility room. Water level sensors, such as the float switches shown, are often used to protect the pump from running dry. The electrical wiring from the water level sensor(s) and pump (if applicable) are run through a watertight protective electrical supply conduit to an electrical supply panel. The panel supplies power and control for the pump operation.

Inside the building, the pump discharge is connected to a pressure tank with a pressure switch. The air charge in the tank provides pressure for the system piping so that the pump does not have to come on every time water is pushed through the piping. If the RWH system utilizes post-storage treatment units, these are installed downstream of the pump and pressure tank. The distribution piping then feeds the permitted fixtures, which are toilets and subsurface irrigation outlets only.

All piping for a RWH system must conform to the applicable sections of the plumbing code for factors such as pipe type, use, identification, and prohibited locations. Likely the most important feature of the distribution piping is that it must be clearly identified, either by labeling, tagging, or other easily identifiable means, as carrying non-potable water. Signs with statements such as “Danger! Non-potable water! Do not drink!” are expected to be posted in as many visible locations as possible, and either painting the piping or having the labeling display the colour purple is a universally known identifier for this purpose. Proper identification helps prevent unintended cross connections.

### Pump selection

To select the appropriate pump for a given RWH system, criteria must be considered such as:

- pump location, controller configuration and voltage
- pump flow rate (l/sec or GPM)
- pump system head (pressure)
- acceptability of service interruptions

#### Pump location, controller configuration and voltage

Either a submersible pump located inside the tank, or a jet pump located outside the tank in an indoor/enclosed location may be used. Other types of exterior pumps are available as an alternative to jet pumps, such as vertical multi-stage pumps, however these are generally more suited to multi-residential and commercial applications. For most homeowners, the use of a jet pump located in the basement is preferred due to its accessibility, although maintaining prime can be an issue. Submersible pumps, although better suited for priming purposes, aren’t seen by homeowners as an easily accessible option.

Pumps for RWH systems are normally operated at line voltage, which can be either 120 or 240 VAC (volts alternating current). Controllers for pumps are normally pressure switches that are located on the piping at the pressure tank. These can also be operated at line voltage. If water sensors located in the cistern are meant to control the pump operation but are not of the line voltage type, there will need to

be a relay or contactor wired into the circuit, allowing the sensors to operate on low voltage (e.g., 24 VAC) while still controlling the line voltage pump.

### Pump Flow Rate

The amount of flow that must be generated by the pump depends on the type and number of fixtures connected to the distribution system. One method of determining this flow rate is to sum up the required flow rates of all the fixtures, assuming a "worst case" scenario where all fixtures are operating at one time. This approach is not recommended, however, as it tends to over-size the pump, increasing the cost of the pump and pressure system. Instead, it is recommended that the pump flow rate be sized to handle a portion of this maximum flow, such as the ability to supply two toilets simultaneously. The irrigation system can be operated by a timer so that it isn't needing water through the times of day when the toilets are being used. Both subsurface irrigation and toilet operation require fairly low flow rates.

### Pump Head

Once the flow rate has been determined, the next task is to calculate the amount of pressure, or "head" the pump must provide. Two factors must be considered:

- *Required system pressure*: This is the pressure required by the fixtures to operate properly, and
- *Total dynamic head (TDH)*: This is the loss in pressure (or "head loss") that occurs when water is moved from a low elevation to a higher elevation (elevation loss), and the loss that occurs when water is being moved through a system of pipes and fittings (friction loss).

*Total dynamic* head has three components, which are:

- *Suction head*: the vertical distance or height that water must be lifted (pulled) before arriving at the pump (this only applies to systems utilizing a jet pump)
- *Discharge head*: the vertical height from the pump to the highest fixture, and
- *Friction head*: the loss in pressure resulting from water traveling through pipes and fittings

As learned through earlier levels of training, static (at rest) water pressure can easily be calculated by measuring the height differences that the water must overcome between two points. A head pressure of 0.433 psi is created or lost for every 1 foot of vertical height. This can also be expressed as 9.8 kPa for every 1m of height.

The friction head encountered is a little more difficult to establish. Pipe manufacturers publish head loss charts at varying flow rates for their products. Pipe types must be determined and chosen so that the appropriate head loss charts can be used to determine how much pressure will be lost through the piping at the estimated flow rate.

Once the total dynamic head is determined, it is added to the required system pressure to arrive at the total head that the pump must produce. The pump chosen must be capable of providing at least this amount of head pressure.

### Choosing the pump

Once both the pump head and the flow rate are determined, a pump can be selected, using pump literature, or "curves" provided by manufacturers. Pumps must be capable of supplying at least the pressure and flow rate that the system needs. As well, slightly oversizing the pump in both pressure and flow rate is suggested if there is a possibility of adding piping and fixtures to the system at a later date.

Pumps can be either constant speed or variable speed. There are advantages and disadvantages to both as are indicated below.

#### Constant speed pump

*Advantages*: generally, less expensive than VSD/VFD pumps; ideal for applications where minor variations in water pressure and flow rate are acceptable (for example, refilling toilet tanks after flushing and operating a garden hose); easiest for homeowners to understand and troubleshoot.

*Disadvantages*: pressure tanks can be quite large for applications requiring high flow rates; flow rate and system pressure may spike when pump activates, and pressure may drop if water demand is too high.

#### Variable speed drive/variable frequency drive pump

*Advantages*: provides constant pressure to fixtures, regardless of flow rate; uses very small pressure tanks, or a micro-pressure tank inside the pump or control unit; often has built in low/high voltage shut-off and dry run protection; smaller space requirements in the building; lower electricity consumption than comparable constant speed pumps.

*Disadvantages*: use of smaller pressure tanks requires a greater number of "pump starts", potentially increasing pump wear; more expensive than constant speed pump systems; more difficult for homeowners to understand and troubleshoot.

## Acceptability of Service Interruptions

A final issue to be considered when choosing a pump is whether it is acceptable for the non-potable water system to be interrupted by pump downtime or other potential problems associated with the RWH system. In a typical residential setting, where rainwater is used for toilet flushing and sub-surface irrigation, infrequent service interruptions are likely to be generally acceptable, and no added measures are necessary.

For multi-residential or commercial settings where water is needed for toilet and urinal flushing, service interruptions may not be as acceptable. For such settings, two options are available:

- A dual-pump arrangement, often referred to as a "duplex" pump setup, or
- An automatic bypass system. *(Note that any interconnection between potable and non-potable water is prohibited by plumbing codes, so this option would only be acceptable if the auxiliary supply (RWH system) has been checked and certified as an "approved auxiliary supply" (potable) by the water purveyor. In a residential scenario, this is not a likely option).*

A drawback of duplex pump arrangements is that they tend to be much more expensive than single-pump systems; however, many offer control equipment to periodically cycle or alternate the operation of the two pumps, which improves the lifespan of both. Another advantage of duplex pump arrangements is that they can often be purchased pre-assembled and installed in much the same manner as a typical single-pump arrangement.

The above are all valid considerations, with the system's owner ultimately having the final determination as to pump selection.

#### Pressure tanks

Pressure tanks perform two functions in a pressurized RWH distribution system:

1. They store water under pressure to minimize pump on/off cycling frequency; and
2. They maintain a constant pressure in the distribution system.

Pressure tanks are composed of an exterior shell of either steel or fiberglass, with an inner RWH water-filled bladder surrounded by pressurized air. A pressure switch is mounted on the distribution piping at the pressure tank. The pump starts when the pressure in the distribution system piping drops to the "cut-in" point and shuts off when the pressure reaches the "cut-out" point. Depending on the style of switch chosen, these points are adjustable in their "differential (difference in PSI or kPa between cut-in and cut-out) and their approximate operating pressures ("range"). A pressure range, including cut-in and cut-out, is selected based on the sums of required pressure at the top of the system, elevation pressure loss and dynamic friction pressure loss as well as by the suggested operating pressure needed by the fixtures.

Other than the pressure switch settings, the most important factor in ensuring proper operation of the pressure system is sizing the pressure tank so that it is compatible with the type of pump and the pump's flow rate.

Most inexpensive pumps operate at constant speeds; in other words, they are either on or off. Constant speed pumps require larger pressure tanks than a variable speed variety as they are designed to store the volume of water discharged by the pump over a 1–2-minute period. This is the minimum time the pump is suggested by manufacturers to operate once activated and is referred to as "pump run time". A longer pump run time requires a larger pressure tank but minimizes wear due to frequent pump starts.

A tank for a variable speed drive/variable frequency drive pump need not be as large in volume as one for a constant speed pump. The controls and operation are different as well, so it is important to make sure that the pressure tank is matched to the pump.

#### Distribution piping

All piping located on private property must conform to requirements of the governing codes and bylaws, although the piping feeding out from outside of the house to the subsurface irrigation system can be as determined by the needs of the irrigation components.

A key component of the rainwater harvesting system consists of the dedicated non-potable plumbing lines that comply with CAN/CSA B128.1-06 which states:

All installed pipes are required to be purple in colour, distinguishing them from potable water lines. To prevent cross-connection, they must be separated from potable water lines by 100 mm (4 inches) for above-grade, and 300 mm (12 inches) for below-grade installations. All end use appliances plumbed with purple pipe must be clearly marked with a non-potable warning label such as shown below.




*Figure 11 Example of warning label for non-potable water systems*

Colouring and labeling prevent misuse of the water as well as helping to avoid cross connections. Section 2.7 of the plumbing codes states the locations where the installation of non-potable pipe is prohibited, such as above food-handling equipment.

Now complete Self-Test 6 and check your answers

## Self-Test 6

Self-Test 6

1. Which one of the following components, located in the basement of a home, draws water from the cistern and pressurizes it?
    a. A jet pump
    b. A foot valve
    c. A pressure tank
    d. A submersible pump
2. What is likely the most important consideration of the RWH system's distribution piping?

a. That it is sized correctly
b. That it is clearly identified
c. That it is protected from damage
d. That it conforms to code requirements

3. Pumps used in RWH systems are normally of what voltage value(s)?

a. 208/240 VAC
b. 120/240 VAC
c. 24/120 VAC
d. 12/24 VAC

4. What would be required if a 24 VAC sensor was expected to turn on a 120 VAC pump?

a. An amperage sensor
b. A pressure switch
c. A float switch
d. A relay

5. What piece of equipment is installed to ensure that the pipe sizing doesn't have to allow for enough flow for the toilets and sub-irrigation system to operate simultaneously?

a. A timer
b. A bypass valve
c. A manual valve
d. A top-up make-up valve

6. Which one of the following choices would not be a consideration when sizing a submersible pump for a RWH pressure system?

a. Suction head
b. Elevation head
c. Discharge head
d. Total dynamic head

7. What type of pump is likely the most expensive, hardest for a homeowner to understand the operation of, and is therefore least likely to be chosen for a residential RWH system?

a. A jet pump
b. A constant speed pump
c. A submersible pump
d. A variable speed drive pump

8. What is the minimum suggested "run time" for a pump, as determined by manufacturers?

a. 15 to 30 sec

b. 30 sec to 1 min
c. 1 to 2 min
d. 2 to 5 min

9. What is the mandated colour scheme for any piping or equipment that conveys non-potable water?

a. Red
b. Blue
c. Green
d. Purple

10. How much physical separation must be maintained between buried potable and non-potable pipes?

a. At least 100 mm (4 inches)
b. At least 300 mm (12 inches)
c. No more than 6 inches (150 mm)
d. No more than 8 inches (200 mm)

Check your answers using the Self-Test Answer Keys in Appendix 1.

## Section 6: Overflow Provisions and Stormwater Management

In the event of an undersized cistern or excessive rainfall to the catchment area, the cistern may overflow. This can cause undesirable situations such as the conveyance piping backing up and spilling rainwater against the building, damaging the building's exterior and/or interior. The excessive flow from the tank's overflow piping could also negatively impact the surroundings. All rainwater harvesting systems must incorporate a suitable and permissible overflow discharge system to adequately distribute rainwater that can no longer fit within the cistern. Overflow system sizing must take into account the size of the conveyance piping entering the cistern, as well as other considerations such as whether the discharge is by gravity or by pump, potential landscaping issues, allowable tie-in to a municipal storm system, and other identifiable site constraints.

"*Stormwater management*" is the practice of collecting and disposing of stormwater so that soil erosion and flooding on private and public property are minimized or avoided. Stormwater management has evolved considerably over the past decades and has shifted from simply directing runoff from private property into off-site locations such as ditches and streams, to managing it through on-site practices and treatment facilities designed to mitigate its impacts. Because RWH systems are a relatively new addition to stormwater management practices in Canada, there is little guidance on how to integrate these systems into stormwater management programs. Despite lack of specific guidelines, many aspects of residential onsite stormwater management are directly applicable to RWH tank overflow handling.

## Code Requirements

Few regulations exist that deal specifically with onsite stormwater management. The NPC cites clauses that address sizing, pipe type, slope, etc. of leaders, storm building drains and sewers to their point of connection at the property line but doesn't address any types of on-site disposal. It does, however, prohibit the direct connection of an overflow from a rainwater tank to a storm sewer because of the possibility of storm sewage backing up into the rainwater tank during extreme rainfall events. CSA Standard B128.1 (2006) specifies that the capacity of the overflow drainage pipes from a RWH system must be equal to the capacity of the conveyance drainage pipes, and that overflows must be discharged in accordance with local regulations. Even if there are no special stormwater management requirements, provincial regulations and municipal bylaws may still restrict the locations where rainwater overflows can be discharged. Some municipalities may, however, accept such connections provided they are protected by a backwater valve. Alternatively, an indirect connection may be made, where the rainwater tank overflows into either a small inceptor tank or "soakaway pit", which in turn overflows into the storm sewer.

This section will describe the most common ways of dealing with excess runoff from a RWH system.

#### Main factors that apply to the choice of an overflow discharge location

1. *Local stormwater management requirements*: There may be special requirements enforced by the municipality. The home or building may be in an environmentally sensitive area, or the municipal stormwater system may not be able to handle extra stormwater flows. Connection to the public drainage system is subject to the AHJ as part of an overall stormwater management plan for the city or municipality.
2. *Applicable Provincial codes, regulations, and municipal bylaw*s: There may be restricted locations and methods of discharging overflows beyond those which are governed by the local AHJ. These must be satisfied along with, and not instead of, the local requirements.
3. *Location of the storage tank*: Discharging overflow from below-grade tanks by gravity drainage is more complicated than discharging from above-grade tanks. Excess runoff can be pumped to its destination as well.
4. *Site conditions*: Topography, available space and presence of buried service lines affect the overflow discharge location.

The options discussed below take into consideration the method of handling runoff (gravity or pumped) combined with the end destination for the overflow discharge (to grade, a storm sewer, or a soakaway pit).

#### Gravity drainage to grade

The easiest and most recommended method of overflow discharge is to gravity feed the overflow to grade and manage it within the homeowner's property. Advantages of this method include simplicity, and a low probability of rainwater backing up the overflow drainage piping. Disadvantages include possible soil erosion, safety/nuisance hazards, and freezing/ice buildup if not designed properly. Gravity fed systems require significant elevation changes in the property to allow an above-or-below-grade tank's overflow pipe to drain downhill and away from other structures.

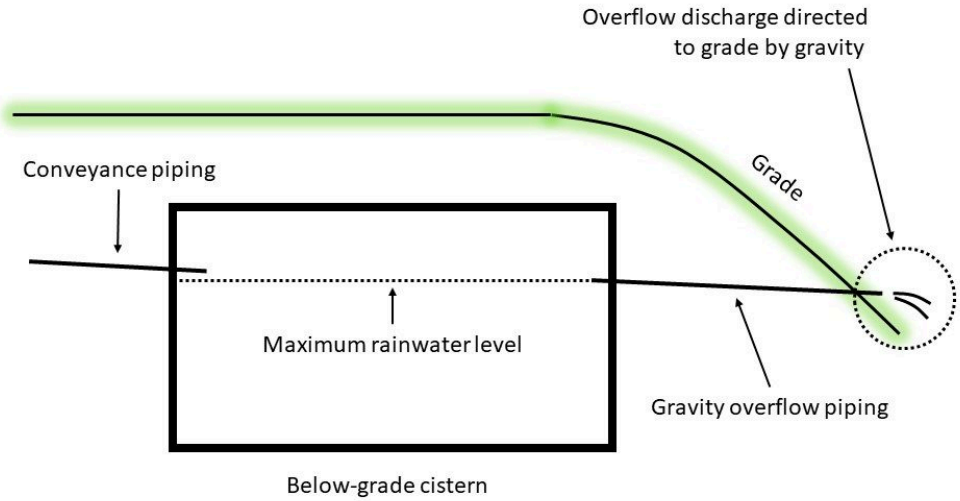



*Figure 12 To grade by gravity*

**Pumped drainage to grade**

This method is the least recommended. It is applicable to tanks located below ground or integrated into buildings, where the grade level is above the overflow. Used where grade elevations won't allow for gravity overflow drainage, the most common method of discharging overflow from a below-grade cistern is to pump the excess water to grade with a dedicated overflow pump. The pumped overflow should be directed to a landscaping feature, such as a rain garden or stormwater retention pond where water eventually evaporates or percolates into the ground. Advantages of this method include minimal reliance on grade elevations and ability to move overflow water over greater distance to get to the final disposal location. Disadvantages include increased cost of installation and maintenance, proper pump sizing, and inability to move water during power outages. The grade downstream of the pumped outlet must be carefully constructed to minimize soil erosion.

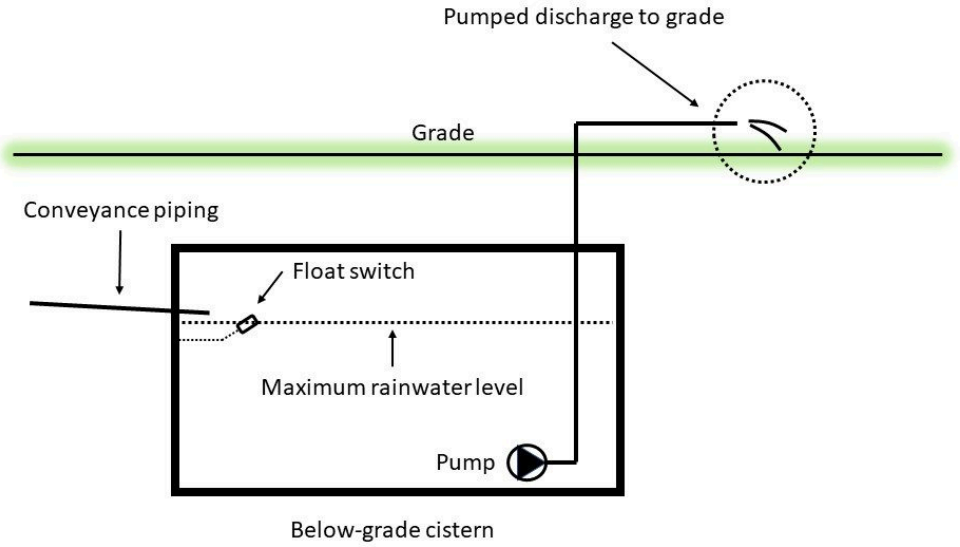



*Figure 13 To grade by pump*

**Gravity discharge to a storm sewer**

If allowed, the rainwater tank overflow may be connected to a storm sewer but must be done in a way that prevents backflow of storm water into the RWH tank, such as by the installation of a backwater valve, as seen below. Advantages include frost protection, aesthetics (all overflow piping is below ground), and non-reliance on electrically powered pumps. Disadvantages include possible prohibitions or restricted allowances as determined by the AHJ, and possible storm water backups affecting the tank.

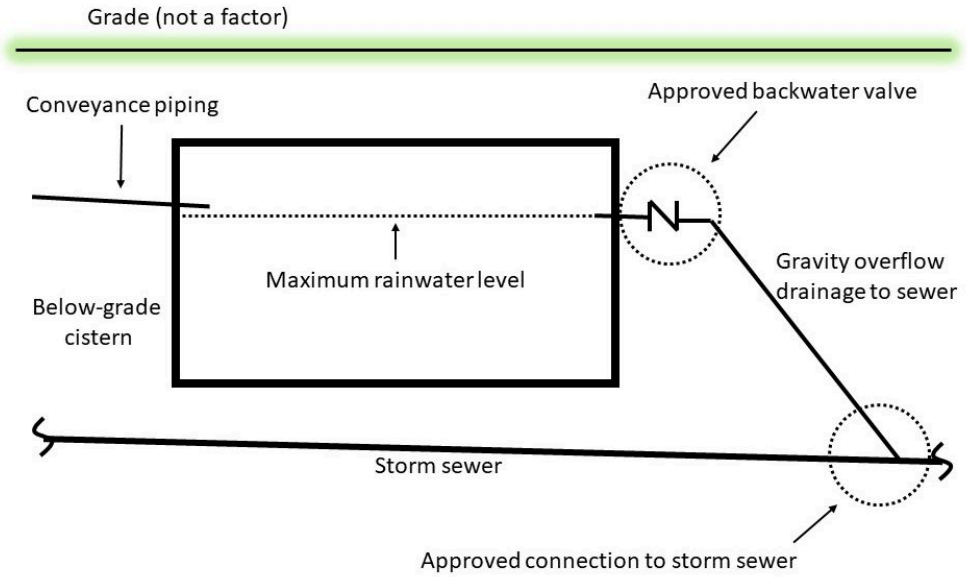



*Figure 14 To sewer by gravity*

**Pumped discharge to a storm sewer**

In cases where the tank is located deep underground (building sub-basements, parking garages, etc.) this may be the only method of handling overflows and would be listed as an advantage. However, the disadvantages include the pump is subject to failing during power outages, and it must be sized to handle potentially large volumes of water during intense rainfall events. Again, the AHJ will be the determiner of the allowance to use this type of system.

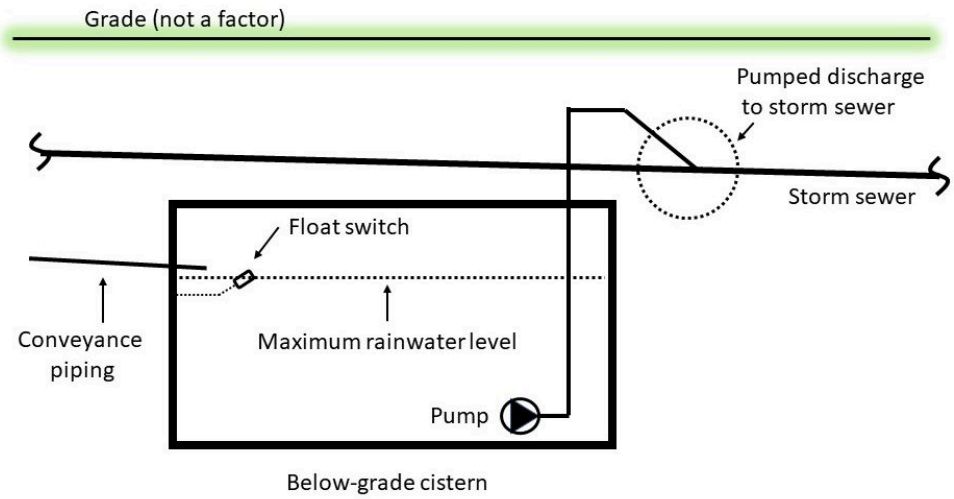



*Figure 15 To sewer by pump*

**Gravity discharge to a soakaway pit**

This method is applicable to situations where tanks are located below ground and rainwater must be kept onsite. A soakaway pit is simply a hole in the ground that is filled with rock of 2″ or larger aggregate. Advantages of soakaway pits include aesthetics, simple design and non-reliance on electrical power. Disadvantages are the need for large excavating and hauling equipment access, percolation rates of surrounding soils, and impact on the water table. Once again, the AHJ must be consulted before installing any soakaway pit.

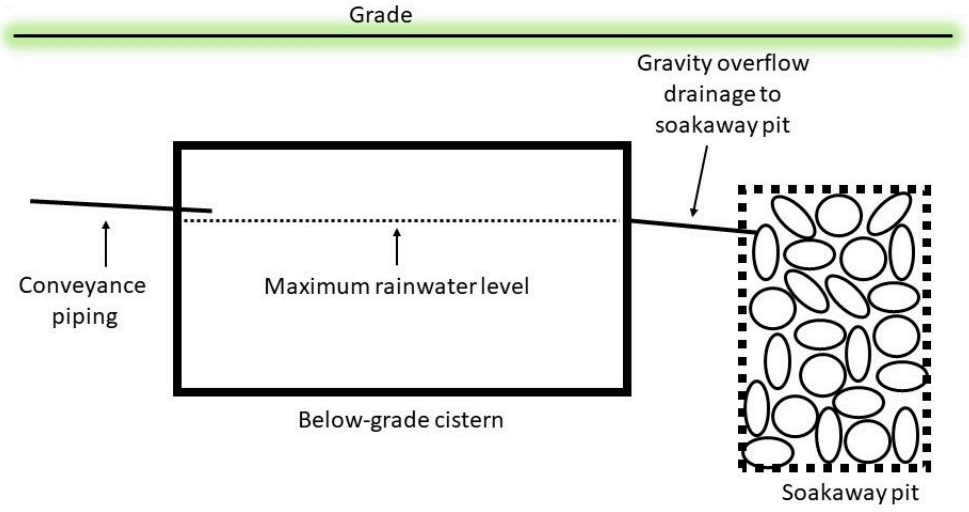



*Figure 16 To soakaway pit by gravity*

## Selecting the Most Appropriate Overflow Discharge Location

Selection of an overflow discharge location must take several factors into account, which include but are not limited to:

- stormwater management requirements
- applicable provincial/territorial regulations and municipal bylaws
- location/placement of the rainwater storage tank, and
- site conditions.

#### Stormwater management requirements

In some cases, overflow from the rainwater tank may need to be handled in accordance with special stormwater management requirements. These requirements may be imposed by a municipality or various conservation authorities for buildings located in an environmentally sensitive area, or in an area where the existing storm sewer infrastructure does not have sufficient capacity to accept additional stormwater flows, or for a variety of other reasons. Stipulations may include on-site retention of certain storm volumes with specified rates of release to the storm sewer and/or on-site management through infiltration or overland flow. Local authorities, including local conservation authorities, should be consulted during the RWH system design process, to verify whether special stormwater management practices are required. A certified hydrologist may need to be consulted, especially if all runoff is to be retained on site.

#### Applicable provincial/territorial regulations and municipal bylaws

Even if there are no special stormwater management requirements, provincial regulations and municipal bylaws may still restrict the locations where rainwater overflows can be discharged. The National Plumbing Code prohibits the direct connection of an overflow from a rainwater tank to a storm sewer because of the possibility of storm sewage backing up into the rainwater tank during extreme rainfall events. Some municipalities may, however, accept such connections if they are protected by a backwater valve. Alternatively, an indirect connection may be made, where the rainwater tank overflows into either a small inceptor tank or soakaway pit, which in turn overflows into the storm sewer.

#### Tank location

The location of the storage tank can also have an impact on the overflow discharge location selected. Overflow handling is simplest with above-ground tanks since overflows can typically be discharged to grade. Handling overflows is more challenging with below-ground tanks and/or tanks integrated into buildings (located below grade). For these tanks, proximity to a storm sewer connection or to greenspace (for infiltration or overland flow) often plays a much greater role in determining where overflows can be directed.

#### Site conditions

Site conditions, such as topography, space availability and accessibility, and the existence of other buried services, also affect the selection of an overflow discharge location. For instance, a flat terrain may preclude the discharge of overflow from a buried tank to grade. Similarly, space constraints and buried service lines may limit excavation for overflow drainage piping and/or a soakaway pit.

**Soakaway Pits**

Soakaway pits, likely more commonly called drywells, are particularly sensitive to site conditions. In addition to requiring significant space, they also require a degree of soil permeability, that is, soil cannot have a significant clay content. Sites with a large catchment area and/or low soil permeability may require a large infiltration area and/or the soakaway pit itself may require an overflow. In some cases, soakaway pits may not be feasible.

Soakaway pits are composed of an excavated space filled with a non-porous material, such as stone, surrounded by an outer filter fabric. If the catchment area is very large and/or the soil is not sufficiently permeable, the soakaway pit may require its own overflow drainage pipe to a storm sewer or to grade. If treatment is required (e.g., if the soil is very permeable and the pit is to be located near a well), a sand layer may be installed at the bottom of the trench.

Now complete Self-Test 7 and check your answers.

## Self-Test 7

Self-Test 7

1. What is the practice of collecting and disposing of rainfall runoff in a responsible manner known as?
    a. Code compliance
    b. Stormwater disposal
    c. Responsible drainage
    d. Stormwater management
2. The NPC prohibits the direct connection of a RWH overflow to a storm sewer system; however, it may be allowed by the AHJ provided there is what installed between the two systems?
    a. A three-way valve
    b. A backwater valve
    c. A first-flush diverter
    d. Pre-storage treatment
3. Which one of the following is considered the easiest and most recommended option for a RWH system overflow?
    a. Gravity drainage to grade
    b. Pumped discharge to grade
    c. Gravity drainage to a storm sewer

d. Pumped discharge to a storm sewer

4. Which one of the following is considered the least recommended option?

    a. Gravity drainage to grade
    b. Pumped discharge to grade
    c. Gravity drainage to a storm sewer
    d. Pumped discharge to a storm sewer

5. Which one of the options listed below may be the only method of handling overflow from a tank located in an underground parking garage?

    a. Gravity drainage to grade
    b. Pumped discharge to grade
    c. Gravity drainage to a storm sewer
    d. Pumped discharge to a storm sewer

6. What is another term for a soakaway pit?

    a. A cistern
    b. A drywell
    c. A septic tank
    d. A septic field

7. What type of soil listed below is least suitable for the use of a soakaway pit?

    a. Sand
    b. Rock
    c. Clay
    d. Loam

8. What type of tank would make overflow handling easiest, but would encounter issues stemming from freezing and aesthetics?

    a. Above-grade
    b. Below-grade
    c. Semi-buried
    d. Integrated

9. What may a soakaway pit require if the catchment area is very large and/or the the soil is not sufficiently permeable?

    a. An overflow
    b. More filter cloth
    c. Smaller aggregate
    d. A backwater valve

Check your answers using the Self-Test Answer Keys in Appendix 1.

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# Learning Task 2

Describe Greywater Reuse Systems

Despite the common perception that Canada has an unlimited supply of fresh water, the reality is that our water resources are under stress. Demand for water is rising because the population is increasing, lifestyles are changing, and the impacts of a changing climate are becoming clearer. Canadians are some of the highest per capita users of water in the world. According to Environment Canada's "Freshwater Website (https://science.gc.ca/eic/site/063.nsf/eng/h_70FE597E.html)", simple changes to water use habits and domestic equipment can reduce water consumption in the home by up to 40%. There are many measures and strategies that can make a significant contribution to reducing water use. Some are quite common, simple, and inexpensive, whereas others are relatively new or ground-breaking. One that fits into this latter category is greywater reuse.

Many environmental agencies favour a "twin track" approach; that is, developing resources and managing demand. Exploring ways to reduce demand for municipal potable water is essential to ensure a sustainable future for water resources. One of the options is to install greywater systems as a substitute for potable water for purposes where drinking water quality is not required.

Although wastewater does eventually make its way back into the earth where it may be once again captured, treated, and distributed for potable use, it may be more beneficial to intercept it at its source, treat it, and use it in ways that don't require it to be clean, pure, potable water. This reduces the demand for supplying more clean, fresh water for a growing population.

This learning module will describe how water from household fixtures may be reused for non-potable purposes such as flushing toilets and irrigating lawns and gardens.

## Greywater versus Blackwater

Both greywater and blackwater are types of wastewater. Greywater is used water sourced from bathtubs, showers, bathroom basins and laundries. It is wastewater that can contain some soap, salts, hair, suspended solids, and bacteria, but that is clean enough to water plants. Although wastewater from kitchen sinks and dishwashers doesn't contain fecal matter and is sometimes categorized as greywater (e.g., the kitchen sink discharge from a recreational vehicle), the high levels of organic materials such as oils and fats put them in the category of blackwater. Greywater (treated or untreated) is not the same as recycled water, which is highly treated wastewater from a centralized treatment facility.

Blackwater contains feces and urine and other bodily wastes from toilets, urinals, and bidets. Blackwater, therefore, needs more intensive treatment to kill any disease-carrying bacteria that may be present if it is desired to be recycled. This is beyond the scope and capabilities of most residential installations and therefore should not be attempted in a residential situation.

On the other hand, greywater can be recycled as its bacterial count, including the presence of

pathogens, is much lower than blackwater. Greywater may be re-used for low-risk purposes, such as the flushing of toilets and urinals, and subsurface irrigation of lawns and ornamental gardens.

## Benefits of Greywater Reuse

Reusing greywater from laundry, bathroom, and wash basin sources in urban households for garden watering/ irrigation, toilet flushing and laundry washing applications can on average reduce potable water demand by 41%, and this can vary from 30% – 70% *("Evolution of Water Recycling in Australian Cities Since 2003", J. C. Radcliffe*). Recycling greywater not only reduces the consumption of potable water, but it also reduces the volume of water discharged into the sewerage system. Less water going through a water meter translates to money saved on water bills. Beside that, there are many ecological benefits to greywater recycling. These can be summarized as follows:

- **Lowering freshwater use** – Greywater can replace fresh water in many instances, saving money on a regional level and increasing the effective water supply in regions where irrigation is needed. Residential water use in many regions is almost evenly split between indoor and outdoor purposes. With proper treatment, all except toilet and kitchen water could be recycled outdoors, achieving the same result with significantly less water diverted from nature.
- **Less strain on septic tank or treatment plant** – Greywater use greatly extends the useful life and capacity of septic systems due simply to the reduced volumes entering the tank or treatment plant. Less volume entering the plant means higher treatment effectiveness and lower treatment costs.
- **Less energy and chemical use** – Less energy and chemicals are used due to the reduced amount of both freshwater and wastewater that needs pumping on the upstream end and treatment on the downstream end. For those providing their own water or electricity, the advantage of a reduced burden on the infrastructure is felt directly. Also, for homeowners, treating their wastewater for use in the soil under their own fruit trees is a definite encouragement to dump fewer toxic chemicals down their drains.
- **Highly effective purification** – Greywater is purified to a high degree in the upper, most biologically active region of the soil, much the same as occurs in a septic field. This protects the quality of natural surface and ground waters.
- **Groundwater recharge** – Greywater application in excess of plant needs recharges groundwater levels.
- **Plant growth** – Greywater enables a landscape to flourish where potable water may not otherwise be available to support much plant growth.
- **Reclamation of otherwise wasted nutrients** – Loss of nutrients through wastewater disposal in rivers or oceans is a subtle, but highly significant form of erosion. Reclaiming nutrients in grey water helps to maintain the fertility of the land.

### Using Greywater for Irrigation

Owners of greywater systems need to be aware of potential environmental impacts related to grey

water system maintenance and household habits, with particular attention to chemicals used in the home, such as cleaning products and laundry detergents. Some important points to consider when disposing of greywater onsite are:

- Runoff of greywater from the property is not allowed and must be avoided. The escape of greywater onto public property would contravene health safety regulations. Properly manage grey water so it doesn't flow into the street, neighbouring properties, or down storm drains.
- Greywater to be used for irrigation must be discharged below ground to reduce the risk of human contact. Although prohibited by plumbing codes, surface discharge of grey water in the garden is possible by manual bucketing. Bucketing is a simple method to collect grey water directly from the bathroom and laundry and apply evenly on garden or lawn areas. If bucketing, consider the following suggestions:
    - Post warning signs to property users that the plants are surface irrigated with greywater (e.g., "avoid contact")
    - Apply greywater evenly to prevent ponding
    - For laundry water, select garden-friendly detergents that are biodegradable and low in phosphorus, boron, sodium, and chlorine
    - Avoid watering vegetables or fruit that are intended for raw consumption
    - Don't apply greywater in areas which are readily accessible to children, pets, or immunocompromised people
    - Don't reuse greywater when a household resident is sick (diarrhea, etc.)
    - Don't reuse greywater which contains cleaning products, hair dye, or other chemicals such as paint, etc.

## Using Greywater for Flushing

Although decreasing in its volume due to the advent of ultra-low consumption flushing technologies, it has been approximated that toilet flushing alone can account for anywhere between 10 to 35 percent of household potable water usage, so any reductions to this can amount to personal savings and greater resource conservation. Greywater flushing systems reuse wastewater from bathroom basins, bathtubs, showers, and clothes washers to substitute for toilet freshwater usage. The plumbing behind these systems can be simple enough but there are some practical and financial considerations to note before embarking on a greywater flushing project. A system that reuses greywater for irrigation may not require any treatment at all, whereas one used for toilet flushing will have many more requirements/constraints placed upon it, such as storage, filtration, disinfection, pressurization, labeling, and permits/inspections. Consequently, greywater reuse systems are more likely to be utilized for irrigation purposes only.

### Health concerns

While gray water has low amounts of organic matter compared to other types of wastewater, it is not clean water, so exposure could be unsafe to humans. The microbial content in untreated gray water can

thrive, potentially spreading bacterial sicknesses and disease to anyone who encounters it. These potential risks are the basis for strict regulations regarding water reuse and system installation, particularly for greywater use within the home. A greywater project that uses improper plumbing connections or ignores local regulations can potentially result in sickness as well as damage and lowered value to a home. Installing filters and disinfection measures within a greywater collection and storage system minimizes health risks and buildup of system impurities.

#### Storage and treatment

If a greywater system is other than a “laundry-to-landscape” type (covered later), the collected greywater will need to be stored and treated. This involves space, electrical, and chemical needs as well as constant monitoring by either manual or automatic means. Treated grey water can be stored for longer than 24 hours, whereas untreated grey water should be used as soon as possible and not stored. All grey water diversion and grey water treatment systems must be approved by the local authority and should be installed by a licensed plumber.

#### Backflow and cross connections

Of paramount importance is to ensure that there is no ability for greywater to enter the building’s potable water system through backflow or improper connections. Again, qualified installers such as licensed plumbers need to be involved in any greywater system installation.

## Developing a Greywater Irrigation System

#### Greywater source

Chances are that a household will produce more gray water than it can use, so one must be selective about which drains will be sources for a greywater system and how they are connected. There is an abundance of online help to make water usage calculations that will prevent long-term storage of unneeded gray water. Sources such as bathtubs and clothes washers may produce more consistent wastewater amounts and quality than bathroom basins. Diverters to the regular drainage system, such as 3-way valves, should be included to provide the option of not collecting gray water when it may be in excessive amounts or hold potential contaminants.

#### Greywater characteristics and volumes

Although an ideal target would be to recycle 100% of the greywater that enters a residential drainage system, it has been found that, depending on regions and individual usage practices, approximately 50% to 80% of it can be recycled. Deciding which type of treatment system to implement varies based on such factors as the size of the dwelling, the volume of wastewater generated, regional climate, personal habits, and desired use of the finished recycled water. For instance, a greywater system designed for a rural farmhouse may have different components, recycling options and end uses than would a small townhouse with no landscaping needs in a city.

Greywater from clothes washers may contain high levels of sodium, carbonates, boron, and phosphates, which may have long-term effects on plants or soils.

Greywater systems can range from the very simple to the very complicated so it's important to develop a systematic analysis of the proposed installation. This involves investigating a few fundamental concepts that should lead to the creation of a well-functioning and safe system.

Conversations with local equipment suppliers, installation contractors and current users is the most economical and environmentally friendly place to begin. It may be discovered that the current landscape doesn't require as much water as it's been getting, or that there are easy ways to greatly reduce the amount of water a household uses.

Determine which fixtures in the home are candidates for greywater capture. Washing machines are usually the easiest place to begin. If the clothes washer is in a room with an exterior wall, it's usually simple to pipe the discharge to the outside. If the machine is in an interior room, it will be a little more difficult, but piping can be run through either a crawl space or basement.

Another potential fixture for greywater capture is a shower/bathtub. Even though there may be trace amounts of fecal matter present, it is usually of such a low concentration and occurrence that it is not a factor, and bath/shower water can be considered a source of greywater.

To develop a greywater system, consider these points:

1. Estimate the quantity of greywater your chosen source produces.
2. Analyze how water drains on the site. Determine the soil type using an onsite test, such as a "soil ribbon test" and/or a low-cost laboratory analysis (required if your system needs a permit). In combination with flow calculations, this analysis will help determine how large the landscape distribution area will need to be.
3. Research types of greywater systems and decide which is best for the site. The flow chart below is a list of types of systems in order of increasing complexity and cost (descriptions of these systems is found further along in this package).

   Laundry-to-landscape → Branched drain → Pumped system → Manufactured system → Sand filter-to-drip irrigation

   If a laundry-to-landscape system is chosen, the only fixture used for greywater collection will be the clothes washer. Branched drain, pumped, and manufactured systems normally utilize clothes washers and can also incorporate showers, bathtubs, and bathroom basins for collection. Sand filter-to-drip irrigation systems are typically only used where high greywater volumes are expected.
4. Consult the AHJ regarding any setback requirements to determine a system layout.
5. Draw a sketch of the proposed system. If a permit is required, a plot plan and details about the system will need to be submitted.
6. Once installed, make sure the system is properly labeled and provide an operation and maintenance manual with it. If the home is sold, the manual must stay with the residence.

## Sizing the Greywater System

There are three steps to sizing a greywater system. It is important to follow these steps so that the system has adequate landscape distribution. Remember, local bylaws will require that greywater irrigation systems never cause pooling or runoff.

- Estimate greywater flows. There are different methods for estimating greywater flows based on whether the system requires a permit.
- Estimate the absorption capacity of soils based on the methods discussed earlier.
- Use greywater flow calculations and the soil absorption estimate to calculate the necessary size of mulch (irrigation) basins.

#### Estimating greywater flows

This can prove to be a complicated endeavour. There are a few different methods that rely on historical water usage, and these are probably the easiest and most reliable means available. Otherwise, records of water use (if available) and estimates of local daily per-person interior water usage are also acceptable sources of information.

Default Code Method

Some codes contain methods for estimating greywater amounts. The following information is published in the Uniform Plumbing Code for the State of Nevada.

**1503.8.1 Single Family Dwellings and Multi-Family Dwellings**

1. The number of occupants in your household must be calculated as:
    - 2 occupants in the first bedroom
    - 1 occupant in each additional bedroom.
2. Greywater flows must be calculated as follows:
    - Showers, bathtubs, and washbasins (combined): 25 US gallons (95L) per day/ occupant
    - Washing machines: 15 US gallons (57L) per day/occupant
3. Multiply the number of occupants by the estimated greywater flow per occupant to calculate the total estimated daily greywater flow.

Example greywater flow estimate using the Default Code Method

In a three-bedroom home, the following volumes of greywater would be estimated to be:

- Number of occupants = four (the three-bedroom home would have four occupants using the calculation method above)

- Shower/bathtub/basin greywater: 25 gpd (95 lpd) × 4 people = 100 US gpd (380 lpd)
- Washing machine greywater: 15 US gpd (57 lpd) × 4 people= 60 US gpd (228 lpd)
- **Total greywater produced: 160 US gpd (608 lpd)**

The above method can be used for any of the systems.

Another method, outlined below, can be used for laundry-to-landscape irrigation systems.

#### Irrigation supply calculation method

Irrigation supply calculations can also be used instead of the permitted systems method to size the landscape distribution area for systems that do not require a permit. Hence, they can only be used to size the landscape distribution area for laundry-to-landscape systems.

- **Washing machines (weekly flow):** _____ US gallons (litres)/load (the rating of your machine) × _____ loads per week = _____ US gallons (litres) per week.
- **Washing machines (daily flow):** _____ US gallons (litres)/load (the rating of your machine) × _____ loads on a typical laundry day = _____ US gallons (litres) per typical laundry day.
- **Showers:** _____ US gallons per minute (litres/sec)(the flow rate of your showerhead) × ___ ___ minutes taken for a typical shower × _____ showers per day × actual number of home occupants = US gallons (litres) per day.

Note that if higher amounts of greywater are produced in a single day, (e.g., multiple baths or loads of laundry) you'll need to consider this when designing the system. Situations where atypical amounts of greywater are produced in one day will also need to be considered. For instance, if five loads of laundry are sometimes produced in one day, rather than spreading them out over the week, this will need to be factored in when the system is designed and operated.

In cases of high flows, one option is to redirect the laundry water to the sanitary system using a 3-way valve. Remember that the system must be designed and operated to avoid greywater pooling and runoff.

Note that performing calculations for specific household fixtures yields the most accurate estimate of the amount of graywater available for plants, yet it does not consider future changes. Volumes could vary if the size or habits of a household change over time or if a new owner moves in.

##### Example estimation of greywater produced using the irrigation supply calculation method

In a three bedroom, three-person household with a laundry-to-landscape system, each person takes an 8-minute shower @ 2 US gpm (7.6 lpm) every day, each person does one load of washing a week, plus there is an extra load for towels, totaling four loads per week. Washing machine use is spread out across the week, sometimes two loads of laundry in one day. The household's frontloading washing machine is rated at 20 US gallons (76 L) per load.

- Washing machine greywater (weekly flow): 4 loads per week × 20 USG (76 L) per load = 80

USG (302 L) per week

- Washing machine greywater (daily flow): 2 loads per day × 20 USG (76 L) per load = 40 USG (151 L) per day
- Shower greywater: 2.0 gpm (7.6 lpm) × 8 minutes/person per day × 3 people = 48 USG (181 L) per day
- Totals:

**Totals per week**

| | |
|---|---|
| **Washing machine** | 80 USG (302 L) |
| **Showers** | 336 USG (1,270 L) |
| **Total** | 416 USG (1,572 L) |

**Totals per day**

| | |
|---|---|
| **Washing machine** | 40 USG (151 L) |
| **Showers** | 48 USG (181 L) |
| **Total** | 88 USG (332 L) |

The irrigation system would have to be able to accommodate these amounts to prevent pooling and runoff. Information on irrigation system sizing is covered in a subsequent section of this module.

## Greywater Regulations

The regulations for greywater reuse will differ between locales. Areas with regular drought problems are likely to encourage greywater systems, whereas some will prohibit their use. Local codes and regulations must be researched to determine what type of permit, inspection or monitoring is needed before installing a site constructed greywater system.

Technically, under the British Columbia Sewerage System Regulation, greywater is considered sewage, and discharging it onto land, into a source of drinking water, surface water, or tidal waters is considered a health hazard and is prohibited. All domestic sewage originating from a building must go into a public sewer or a sewerage system unless otherwise authorized under the prevailing edition of the BC Building Code. The 2018 BC Building Code, *Part 7 Plumbing Services* and the National Plumbing Code of Canada allow for the construction of non-potable water systems and subsurface irrigation using non-potable water. The *"Health Canada Guidelines for Domestic Reclaimed Water for use in Toilet and Urinal Flushing"* publication provides further guidance for greywater systems and is also referenced in the codes. Like in rainwater collection systems, the National and BC Plumbing Codes specify the use of "good engineering practice" in the design of a greywater reuse system and cite ASHRAE and ASPE Handbooks and CAN/CSA-B128.1 "Design and Installation of Non-Potable Water Systems" as resources. The plumbing codes only allow greywater systems to be used for the flushing of toilets and urinals, and for sub-surface irrigation. Any other use is not allowed.

The NSF/ANSI 350 (National Sanitation Foundation/ American National Standards Institute) standard establishes material, design, construction, and performance requirements for onsite residential and commercial water reuse treatment systems. They also set water quality requirements for the reduction of chemical and microbiological contaminants for non-potable water use. In North America many states and provinces provide greywater regulations that are continually changing, allowing for lower-cost greywater systems to be installed. Some of these areas may or may not require a permit for the installation. Always consult the AHJ to determine if a permit is required for a system and any setback requirements for such systems on a property.

## Sample Regulation

The following sample is a current regulation from a major US city showing where an installation permit is and is not required.

#### When a permit is not required

A greywater system for outdoor irrigation may be installed without a permit if the following requirements are met:

- greywater comes from the washing machine only.
- greywater system does not alter the household plumbing (greywater is accessed from the hose of the machine, not by cutting into the plumbing).
- greywater system is for a one- or two-unit residential building.
- greywater system follows all guidelines set forth in the prevailing plumbing code

#### When a permit is required

A permit is required for a greywater system for outdoor irrigation that includes any of the following conditions:

- a greywater system collects water from showers, sinks, or baths.
- a greywater system alters the plumbing (the drainage plumbing is cut into to access the greywater).
- a greywater system is installed in a building that is not a one- or two-unit residential building.
- a greywater system includes a pump (excluding the washing machine internal pump) or a tank.

Now complete Self-Test 8 and check your answers.

# Self-Test 8

Self-Test 8

1. Which one of the following correctly defines greywater?
    a. Used water from laundries, bathtubs, showers, and bathroom basins
    b. Fresh water supplied to laundries, showers, bathtubs, and bathroom basins
    c. Used water from toilets, bathtubs, showers, laundries, and bathroom basins
    d. Used water from laundries, showers, bathtubs, kitchens, and bathroom basins
2. According to the NPC and BCPC, what are the permitted uses for greywater?
    a. Flushing toilets only, and subsurface irrigation
    b. Flushing toilets and urinals, and subsurface irrigation
    c. All uses as long as the water has been properly treated
    d. Above ground and subsurface irrigation, and toilet flushing
3. Which one of the following statements regarding the use of greywater is *not* correct?
    a. Greywater must not be allowed to pool or run off of a property
    b. Pooling of greywater is acceptable as long as it stays on private property
    c. Laundry detergents should be low in phosphorus, sodium, boron, and chlorine
    d. Greywater should not be used for irrigating vegetables or fruit for raw consumption
4. What is the only allowable way to discharge greywater above ground?
    a. By using a dedicated sprinkler
    b. By bucketing onto gardens or lawns
    c. By pumping it from a sealed container
    d. By allowing it to only contact trees and shrubs
5. If greywater is not intended to be stored and treated, which one of the following is correct?
    a. It should only be used for urinal flushing
    b. It should only be used for toilet flushing
    c. It should only be used for irrigation
    d. It must not be used if untreated
6. How many people would be allowed for if estimating the greywater flow, using the Default Code method, from a 3-bedroom house?
    a. 2

b. 3
c. 4
d. 5

7. Using the Default Code sizing method, how many litres per day should be allowed for showers, bathtubs, washbasins, and washing machines for each occupant?

a. 40
b. 57
c. 95
d. 152

8. Which one of the following is not listed in the NPC and BCPC as being a source of "good engineering practice" in the design of a greywater reuse system?

a. CAN/CSA-B128.1
b. ASHRAE and ASPE Handbooks
c. Kohler's Handbook for Water Pipe Sizing
d. Health Canada Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing

9. According to the sample regulation, which one of the following is true if a permit is *not* required?

a. The system has a separate pump
b. The system is in a 4-unit residential complex
c. The greywater comes from only the clothes washer
d. Water can be collected from showers, sinks, and baths

10. According to the sample regulation, which one of the following choices would result in a permit being required?

a. The greywater system alters the plumbing
b. The greywater system uses a greywater tank
c. The greywater comes from only a washing machine
d. The greywater system is for a one-or-two-unit dwelling

Check your answers using the Self-Test Answer Keys in Appendix 1.

## Irrigation Using Greywater

An essential component of most greywater systems, mulch basins are trenches dug around the root system of a plant that are filled with coarse woodchip mulch. They are the outlet terminals for the greywater and the mechanism by which the greywater is absorbed and infiltrated to the root system of plants. Greywater is piped underground, is released into the mulch basins, and soaks laterally through the basins to the roots via capillary action.



*Figure 1 Mulch basins*

The size of the basin varies depending on the size and water needs of the plants, the soil type, the number of basins, and the quantity of water needed to be distributed across the whole system. Average basins are 1 ft. (300 mm) deep x 1 ft. (300 mm) wide x 3 ft. (900 mm) long. Some basins may entirely encircle a plant or irrigate multiple plants. They can be half-circles, kidney shaped, rectangular, or essentially any shape depending on needs and the landscape design.

## Soil Absorption and Distribution Area

Understanding the infiltration capacity of the soils in the proposed area is critical for designing a greywater system and sizing your landscape distribution area. The distribution area must be sized to allow the graywater to soak into the soil without pooling or runoff.

If the system requires a permit, the AHJ must be provided with the results of a laboratory soil analysis to confirm soil type. A “soil ribbon test”, as described below, is a simple test that can help to unofficially determine soil type if a permit isn’t required.

After the soil type(s) have been identified via laboratory analysis (required for permitted systems) and/or a ribbon test, a simple drainage test, called a “percolation test”, can also be conducted to find out how well water drains on the property. This drainage test will help ensure that good locations for greywater outlets have been chosen.

### Soil ribbon test

The soil ribbon test is a fast way to remotely assess soil type in the field. By knowing the ribbon length

and texture, it can be approximated if the soil is clay, sandy, or loamy, and how it will drain and hold nutrients. This test only requires some soil, water, and a tape measure to perform. Here are the steps:

1. Gather a soil sample. Collect a sample of the soil by taking a handful of soil from the top 4-6 inches.
2. Wet the soil. Spray a small amount of water onto the soil. Start trying to form the soil into a ball. Keep adding water until you are able to do so.
   *Note – if it is not possible to form a ball, then it is likely that you just have sand for soil.
3. Knead the soil sample. Work the ball in your hands, similar to kneading dough. Remove any bits of organic matter (leaves, stems) and any small pebbles. Keep working the ball of soil until no dirt sticks to your hand. It should feel similar to “silly putty” or “play dough”.
4. Make a ribbon. Start to form the ball into a ribbon by squeezing it in your hand like you would hold a tool handle. Press your thumb so that a ribbon begins to form, extending out over your index finger. As the ribbon grows, move the mass of soil up in your hand, and press your thumb to continue forming a ribbon. Keep doing this until the ribbon breaks.




*Figure 2 Ribbon*

5. Measure the ribbon length and record the length.
   *Note: Soil specialists often will make several ribbons in a sample area. This way they can ensure that there is no random pebble or piece of wood that causes a ribbon to break prematurely.




*Figure 3 Measure ribbon length*

6. Check the texture and feel of the soil. Take a small piece of the ribbon, about the size of a pea and place it in the palm of your hand. Add a significant amount of water to the soil so that it becomes fully saturated or over-wet.
7. Rub your index finger on the soil sample. Press your finger on your palm and rub in a circular motion so that you can really feel the soil texture.




*Figure 4 Using index finger to feel the soil texture*

At this point, you want to classify how the soil feels into 3 categories:

- Gritty – A gritty texture has the sensation of rubbing dried sugar or sand between your fingers.
- Smooth – A smooth texture feels like rubbing flour between your fingers
- Neither – If neither gritty nor smooth texture dominates

8. Determine the soil type by comparing it to the matrix key below. By using the rows as classified by ribbon length, and the columns classified by texture, the soil type can be approximated.

| Ribbon Length | Gritty | Smooth | Neither |
|---|---|---|---|
| **0** | Sand | Sand | Sand |
| **0-1″** | Sandy Clay Loam | Silt Loam | Loam |
| **1-2″** | Sandy Clay Loam | Silt Clay Loam | Clay Loam |
| **+2″** | Sandy Clay Loam | Silt Clay Loam | Clay Loam |

A soil ribbon that is less than 1″ in length is typically sandy or silt loam with minimal clay content. A ribbon that is between 1-2 inches long is loam. A ribbon that is longer than 2″ long has a heavier clay content. If you cannot form a ribbon, or a ribbon is less than 1″, it is sandy loam.

#### Laboratory test

If the system requires a permit, the AHJ must be provided with the results of a soil analysis. This requirement can be fulfilled by submitting a soil sample to a laboratory for a soil texture analysis or by providing an existing soil analysis to the AHJ. The soil sample must be taken from the area to be irrigated with greywater. If there is more than one type of soil, representative samples from different areas must be taken. An example of an existing soil analysis is a geotechnical study done for your property. Note that the geotechnical report must be signed and stamped by a licensed engineer or geologist.

#### Drainage (percolation) test

Identifying soil type (either by ribbon test or laboratory analysis) does not always provide enough information about how well water will infiltrate in a particular location, as deeper soils could differ from surface soils. To ensure that water drains properly in the locations chosen to be irrigated with greywater, a percolation test should be conducted, as described below.

1. Dig a hole, approximately 1 foot deep, in the area where mulch basins are proposed. Insert a ruler or stick marked at inch increments into the hole
2. Fill the hole with water and let it soak in. Repeat this several times so that the surrounding soil is saturated when the reading is taken.



*Figure 5 Timing the percolation rate*

3. Fill the hole with water again, and this time record how long it takes for the water level to go down a few inches. If it drains approximately 1 inch per hour or faster, the drainage is adequate for irrigating the area with greywater.
4. If it takes longer than two hours for the water level to go down 1 inch, or the hole doesn't drain all day, don't use greywater to irrigate this area. Try another location to see if the drainage is better. If you irrigate an area that does not have adequate drainage, you could have pooling and runoff. Plants could also be damaged by water-logged soil, so make sure to irrigate only properly draining soils, or amend your soil by adding compost to improve drainage.

## Greywater Guidelines and System Components

Greywater is a unique source of water and must be handled differently from potable water and rainwater. Greywater can be used untreated, or it can be treated to varying degrees to reduce nutrients and disease-causing microorganisms. The appropriate uses of grey water depend on both the source of greywater and the level of treatment desired.

These are some basic guidelines for residential greywater systems.

- do not store greywater more than 24 hours. If stored, the nutrients in it start to break down and create bad odours
- minimize contact with greywater, as it can contain pathogens. All systems must be designed

so that greywater soaks into the ground and is not accessible to contact by people or animals.

- infiltrate greywater into the ground; do not allow it to pool or run off. As previously mentioned, soil tests should be performed to assess how fast water soaks into the soil to properly design a system. Pooling greywater is a perfect breeding habitat for mosquitoes, as well as being offensive and possibly a contravention of codes and bylaws
- keep the system as simple as possible. Simple systems last longer, require less maintenance, use less energy, and cost less. Keep in mind that systems with pumps and filters require more commitment and regular maintenance
- install a diverter valve at a convenient location to allow for easy switching between the greywater system and the sewer system
- match the amount of greywater directed to plants with their irrigation needs. Be aware that some laundry products are harmful to plants so do some research to determine any potential problems

System configurations vary significantly in their complexity and size from small systems with very simple treatment to large systems with complex treatment processes. However, most have common features such as:

- A tank for storing the treated water
- A pump
- A distribution system for transporting the treated water to where it is needed, and
- Some form of treatment.

All systems that store greywater must incorporate some level of treatment, as untreated greywater deteriorates rapidly in storage. This rapid deterioration occurs because greywater is often warm and rich in organic matter such as skin particles, hair, soap, and detergents. This warm, nutrient-rich water provides ideal conditions for bacteria to multiply, resulting in odour problems and poor water quality. Greywater may also contain harmful bacteria, which could present a health risk without adequate water treatment or with inappropriate use. The risk of inappropriate use is higher where children have access to the water.

The main components of a greywater reuse system are:

- greywater source(s): washing machine, shower, bathtub, and bathroom basin
- collection plumbing: pipes that transport greywater inside the house to a storage area (for irrigation) or to a treatment system (for treatment and use for flushing)
- surge/storage tank, filter, and pump: optional elements that add complexity and cost but allow greywater to be used for other than irrigation if desired
- make-up water: in times of reduced greywater availability, the greywater stored may be supplemented by potable water for irrigation or flushing. The potable water line must be protected from cross-connection for both in-house consumption issues and off-premises backflow contamination risks
- distribution plumbing: pipes that transport greywater from the system to receiving locations

(toilets or irrigation system). This part of the system must be constructed of purple pipe if pressurized, and all outlets labeled to reduce risk of accidental consumption

- toilets and urinals: if used, should be standard or low-flush versions of the typical CSA B45 certified products
- receiving landscape: soil, roots, plants, and mulch basins that use, contain, cover, and purify the greywater

## System Types

Greywater systems can be grouped according to the type of treatment they use. There are commercially available systems mentioned in this guide and are for illustration only as we are not recommending any particular manufacturer or system.

### Laundry-to-landscape systems

Laundry-to-landscape systems are simple, low-tech greywater irrigation systems that use the washing machine's internal discharge pump to distribute water through underground piping in the yard. They have no filters, storage tanks or external pumps and can be legally installed anywhere in most jurisdictions without permits or inspections. This type of system is easy to adjust flow levels to different irrigation basins, and easy to modify to accommodate new landscaping. It can be used on flat lots and in homes with no access to plumbing, such as slab-on-grade houses if the washer is near an exterior wall. It is generally trouble-free and easy to maintain, with once-a-year maintenance recommended.




*Figure 6 Manual 3-way diverter valve*

A diverter valve, either manual or automatic, is installed behind the washing machine, allowing greywater flow to be directed to either the landscape (normal use) or to the sewer (for bleach or harsh detergents). The clothes washer's pump provides positive pressure which can be used to push water fairly long distances horizontally or even slightly uphill. It also simplifies irrigation lines, allowing for a single main line supplying multiple irrigation branch lines. Each branch runs to an emitter in a mulch basin, which is a hole or trench filled with wood chips or a sheathed drip line, also covered in mulch.

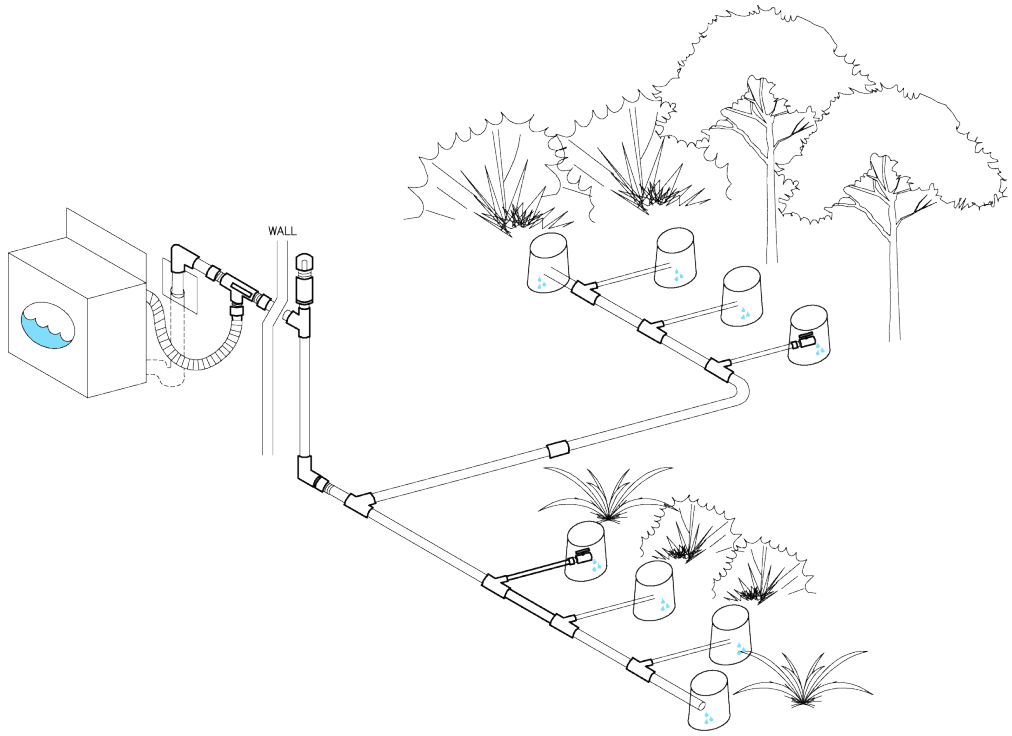



*Figure 7 Typical laundry-to-landscape greywater irrigation system*

Below are general guidelines to help select appropriate locations to irrigate using a laundry-to-landscape system. It is the owner's responsibility to determine what is safe and appropriate for a particular situation. If the existing washing machine is not operating properly or draining well, it is probably not a good idea to install a laundry greywater system. When in doubt, contact a pump specialist, the washer's manufacturer, or a greywater professional.

- **Sloped yards**: don't distribute water uphill. The washing machine has an internal pump, but it is designed more for volume output rather than pressure. If the yard slopes downhill from the location of the washing machine, the greywater distribution piping can extend as far as needed. On steep slopes, the tubing should be installed in a serpentine pattern to slow down the water. Otherwise, it will rush to the bottom of the hill, and will likely not sufficiently irrigate the upper plants.
- **Flat yards**: for most machines, it is generally safe to distribute greywater up to 50 feet across a flat yard. Greater distances could result in damage to the washing machine pump since friction losses increase with distance and add resistance to the machine's pump.

#### Gravity, branched drain system

This system harnesses the power of gravity to irrigate areas downhill from the home. Its simplicity

makes it easy to maintain, but also less flexible. This greywater system expands on the idea of the single fixture system but uses a branched drainpipe network to distribute the greywater to multiple landscape areas. The greywater is still distributed by gravity so the main issue with this type of system is ensuring an even distribution of the greywater to all of the landscape areas desired. The main benefit of this system is the low capital cost, but the main disadvantage is that the distribution pipes can become clogged over time.

### System overview

The branched drain system is the ultimate in simple, low- tech greywater systems, designed for decades of trouble-free irrigation. There are no filters to clean or change, no storage tanks, no pumps, and no controllers to program. The system relies on natural processes: gravity, capillary action, and microbes in the soil to distribute and process greywater in the landscape. The only control is a single on-off switch that operates a motorized 3-way valve, as seen below.



*Figure 8 Electric motorized 3-way valve*

In this system, drain lines from greywater fixtures in the house (bathtubs, showers, bathroom basins, and washing machines) are reconfigured to drain to an electrically operated diverter valve, which can direct greywater to either the sewer or the greywater system. This feature allows the user to “turn off”

the greywater system if needed, for example if doing a load of laundry with bleach, and instead direct it to the sewer system.

#### Irrigation installation

Irrigation is through a branched network of flow-splitters and underground emitters that divide and subdivide the flow, spreading it out in the landscape. Emitters are subsurface, each set in a protective valve box enclosure within a mulch basin. The wood chips are an organic greywater filter, catching laundry lint and soap and breaking down impurities through natural microbial action.

#### Maintenance

Maintenance is minimal as there are no filters, pumps, or storage tanks to clean or replace. Wood-chip mulch beds are a vital component of the system and should be replenished every few years as they subside and turn into rich, healthy soil.

### Pumped greywater system

A pumped greywater reuse system collects greywater by gravity from the various fixtures in the house, and in turn pumps it to the desired landscape areas. The main advantage of this type of system is that the greywater can be distributed over a larger area, even at points uphill from the house. The main disadvantage is the higher capital cost.

Greywater from indoor sources drains to a pump basin, which sends it out to the landscape. There are no filters or storage tanks, so maintenance is minimal. However, a filter may be installed in the system to intercept any debris that could clog the distribution pipes.

Features of these systems are:

- they can irrigate anywhere on the lot, even uphill
- subsurface emitter outlets are placed at mulch infiltration basins
- typically, 16-20 emitters per zone, with either one or two zones
- they can irrigate an entire landscape with greywater
- best for fruit trees, shade trees, and larger ornamentals
- easy to reconfigure if landscaping changes

#### System overview

The greywater pumped system is a low-tech, high-functioning greywater system designed for years of trouble-free, low maintenance irrigation with gently used water that would otherwise go down the drain and be wasted. It is low-tech in the sense that there are no filters to clean or change, no storage tanks, and no electronic controllers to program. The only control is a single on-off switch which is connected to a motorized 3-way valve.

Like the branched drain system, drain lines from greywater fixtures in the house (bathtubs, showers,

bathroom basins and washing machines) are reconfigured to drain to a diverter valve, which can send water to either the sewer or the greywater system.

Unlike the branched drain system, the pumped greywater system includes a pump basin that contains a submersible greywater pump. As water enters the basin it automatically turns the pump on, sending water out to the irrigation piping. The pump basin has a safety overflow connected to the sewer line and protected by a backwater valve.

### Underground pump basins

The heart of this system is a pump that sends greywater directly out to mulch- basin emitter outlets in the landscape. The pump allows the system to spread greywater out efficiently and to irrigate uphill from the house if needed. The pump basin should be located outdoors if possible due to the expected odours from the collected greywater.

A common configuration is to put a submersible pump in an underground basin. The basin isn't considered a storage tank for greywater but rather a housing for the pump. At around half-full it activates a float switch which turns on the pump, sending greywater out to irrigation emitters in the yard. The pump basin also has a safety overflow – if the power is out, for example, greywater will fill the basin and simply overflow to the sewer or septic system until power is restored and the pump activates.

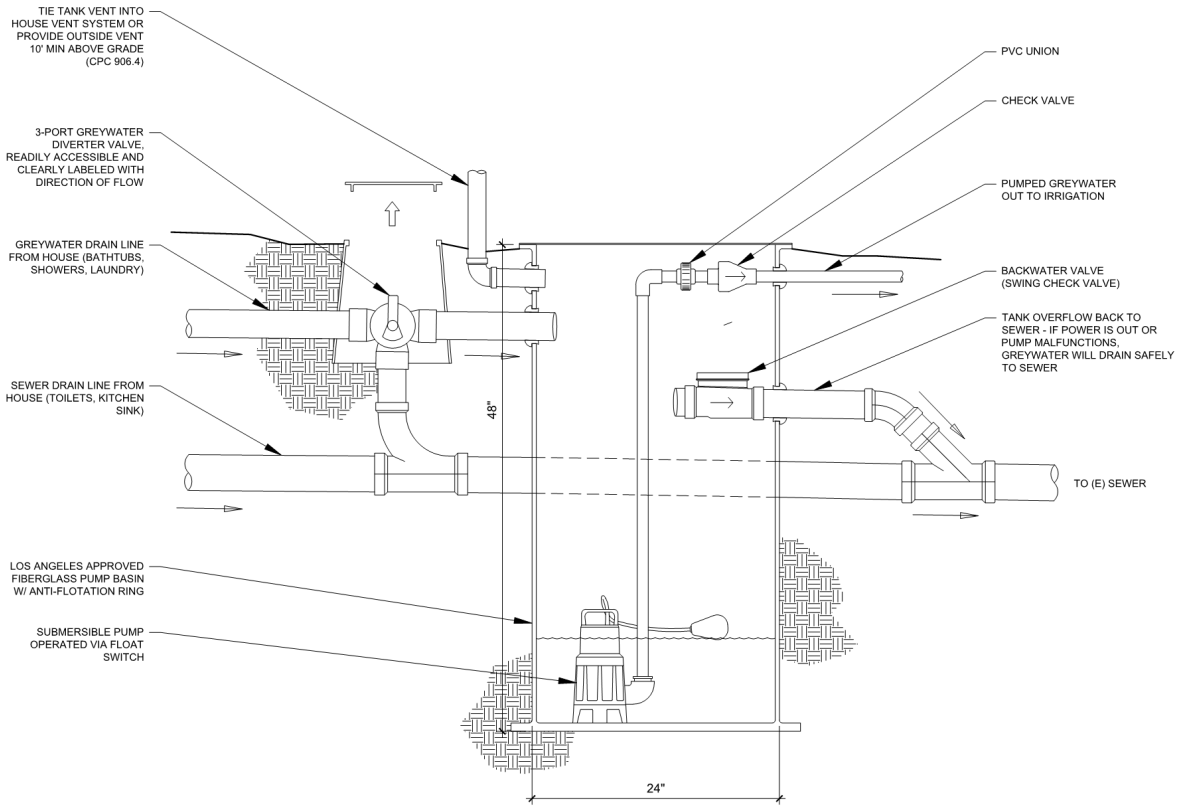



*Figure 9 Greywater pump basin*

### Irrigation installation

Irrigation distribution is through a network of subsurface ball valves, each set in a protective enclosure within a mulch basin. The wood chips are an organic greywater filter, catching laundry lint and soap and breaking down impurities through natural microbial action. An alternate mode of irrigation often incorporated is via sheathed drip lines, which are also covered with mulch.

### Maintenance

Maintenance is minimal as these systems are designed for easy access and visibility. There are no filters to clean. The pumps are specifically designed for greywater and have an expected lifespan of many years. Wood-chip mulch is a living part of the system; mulch beds should be replenished every few years as they subside and turn into rich soil.

An anti-siphon valve, often known as an air admittance valve or “cheater vent”, should be installed to prevent any siphoning of the washing machine when using a laundry-to-landscape, gravity branch or pumped branch system.



*Figure 10 Anti-siphon valve*

### Manufactured Systems

The intent of the systems described up to this point have been solely concerned with reusing greywater to supply subsurface irrigation needs, as this is one of the two permitted uses for greywater. The other allowable use is for toilet and urinal flushing, which would require that greywater be stored and treated before being pumped to the fixtures. As previously mentioned, any storage of greywater creates odour and bacterial growth issues. This creates scenarios that require more costs and associated treatment and maintenance which will pose problems for homeowners. Reduced or ignored maintenance will undoubtedly result in issues that threaten the safety of the home's inhabitants as well as that of the users of a public potable water system. Onsite-constructed systems that are intended for toilet flushing may end up being bulky, ineffective, and hard to manage, and so there is a need for manufactured systems that take the engineering and oversight out of the hands of persons that might be ill-equipped to construct a safe system.

In order to treat greywater to a high standard compatible with toilet flushing requirements and any type of irrigation system, manufactured systems utilize various forms of treatment, from filtration to UV sterilization. These systems are tailor-made for each project and connect via an air gap to the municipal water supply in case of a shortfall of greywater, for example if the house were vacant. Multi-stage purification processes make greywater from these advanced systems safe for any type of irrigation, from drip lines to conventional sprinklers.

Generally, these units are a self-contained module that treats greywater to reuse standards before pump or gravity discharge.

Figure 11 Greyter® residential packaged greywater module – TO BE ADDED

Unit features and cost vary with manufacturer and technology used. For instance, some manufacturers have the greywater flow by gravity through the contact chamber and around a UV lamp, where it is disinfected. The UV unit uses no chemicals and has no moving parts and meets or exceeds the performance of other residential UV disinfection systems. Other systems require periodic refilling of chlorine reservoirs that can be done by homeowners. Manufactured greywater treatment systems are also quiet, low-odour, and low-profile so they can blend right into the landscaping or be housed in small areas of a basement.

#### Sand filter to drip irrigation systems

Manufactured systems are examples of high-tech filtration and treatment. Sand filters are examples of low-tech filtration using natural treatment methods. In low-tech greywater filters, the wastewater flows through a filter medium – sand or gravel. The main treatment process encompasses the retention of particles by the filter material (filtration), and processes that occur due to biological activity in the biofilm on the sand or gravel (treatment). After passing the filter media, the treated greywater can be used for irrigation if desired or may be discharged to a safe location such as surface waters (with permits). If disposal rather than irrigation is the intended end use, it can be infiltrated into the soil if the groundwater level (water table) is deep enough below it

There are generally two different types of greywater sand filters: (a) vertical flow system and (b) horizontal flow system. The selection of the type of filter system depends on several criteria such as

ground water level and the elevation at which the greywater pipe leaves the house. The different schemes are described below.

- Vertical greywater filter – The simplest greywater filter is a vertical sand filter where the wastewater is distributed to a basin filled with sand and gravel. There are basic differences of vertical filter design depending on how the effluent is dealt with. The treated effluent can be infiltrated to the soil, or, if permitted, it can be discharged to surface water. At a high groundwater level (< 1m below ground level), it is recommended to construct the filter above the ground and discharge the treated water to surface water, such as a lake, river, or channel. If the groundwater level is lower than 1m below ground, the outflow water can be infiltrated into the soil. In case the treated greywater is meant to be used for irrigation, a storage tank is installed from which the water can be taken, or an irrigation channel can be connected.
- Horizontal greywater filter- The function of the horizontal greywater filter design is in principle the same as in the vertical sand filter, but gravel is used as filter material. In this case the water is not flowing vertically through the filter but horizontally across vertical gravel and stone layers. In contrast to the vertical filter, the horizontal filter is filled with water up to the outlet. The horizontal flow allows a flat construction but requires more horizontal space between inlet and outlet compared to the vertical greywater filter. The basin can be built in the soil providing the outflow pipe ends up above the ground. The height difference required between inflow pipe and outflow pipe of the filter is minimum 5 cm. Within this construction, even pipes from greywater sources that are low above the ground, can be handled if the groundwater level allows an excavation.

A significant downside to sand filters is that they are prone to clogging up over time. While a sand filter used in a swimming pool effectively screens particles from the pool water, it can be backwashed whenever the buildup of particles clinging to the sand reduces the flow through the bed to levels that are not acceptable. Greywater sand filters don’t have this same ability. For this reason, oils and fats from kitchen sinks must be kept out of the discharge to sand filters. Because sand filters require much area, planning, construction and permits, their use as a filtration method is severely limited, and manufactured systems are a better filtration and treatment choice for a house on a residential-sized lot.

## Summary

While the reuse of greywater is an ecologically noble cause, it must be noted that, on a fiscal scale, greywater reuse will cost a homeowner more than using potable water over a system’s expected 20-year life expectancy and will require more oversight and maintenance if not installed properly and logically (Econnics, 2010). Consequently, and presently, where there is no immediate need nor legislation to recycle water, there is little consumer interest in embarking on any water conservation measure that has no direct monetary advantage. As well, greywater reuse for the flushing of toilets is all but discouraged due to these same reasons. So, until the water supply situation becomes dire, the need for reusing water in most areas of Canada will remain low, and any greywater reuse will be the result of ecological awareness and responsibility.

Now complete Self-Test 9 and check your answers.

# Self-Test 9

Self-Test 9

1. When using a mulch basin to irrigate, how is water delivered laterally (sideways) to roots through the soil?
    a. By ponding
    b. By drip irrigation
    c. By capillary action
    d. By spraying over the ground
2. What type of “unofficial” test can be performed by homeowners, in determining the infiltration capacity of soil where a permit is not required?
    a. A laboratory test
    b. A soil ribbon test
    c. A soil rejection test
    d. A lateral soakaway test
3. After the soil type(s) have been identified, what type of test will determine how well water drains from the property?
    a. A seepage test
    b. A soakaway test
    c. A greywater test
    d. A percolation test
4. When conducting a ribbon soil test, what type of soil would be indicated if the ribbon had a smooth texture and a length of 1-2”?
    a. Silt loam
    b. Sandy loam
    c. Silty clay loam
    d. Sandy clay loam
5. What is the expected result of storing greywater for more than 24 hours?
    a. A bad odour
    b. Purified greywater
    c. Clarified greywater
    d. Unusable greywater

6. What device allows for switching between the greywater system and the sewer system?
    a. A ball valve
    b. A diverter valve
    c. A backflow preventer
    d. A pressure relief valve
7. What type of greywater system usually needs no permits or inspections?
    a. Pumped
    b. Manufactured
    c. Laundry-to-landscape
    d. Gravity, branched drain
8. What type of system relies on gravity, capillary action and soil microbes to distribute and process greywater in the landscape?
    a. Pumped
    b. Manufactured
    c. Laundry-to-landscape
    d. Gravity, branched drain
9. What type of self-contained system would treat greywater so that it could be used for toilet flushing?
    a. Pumped
    b. Manufactured
    c. Laundry-to-landscape
    d. Gravity, branched drain
10. What is listed in the literature as being a system that would only be used where the expected daily amounts of greywater are very high?
    a. Pumped
    b. Sand filter
    c. Manufactured
    d. Laundry-to-landscape

Check your answers using the Self-Test Answer Keys in Appendix 1.

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- Figure 11 Greyter® residential packaged greywater module – TO BE ADDED

# Appendix 1: Self-Test Answer Keys

## Competency B1

### Self-Test 1

1. d. Water that meets the prescribed standard(s), and is safe to drink and fit for domestic purposes without further treatment
2. d. pipe that conveys water from a public water main or private water source to the inside of the building
3. a. True
4. a. True
5. a. Used water
6. b. Increases
7. d. Equivalent lengths of straight pipe
8. b. Pump head and pump capacity
9. c. Dead end configuration
10. c. 550 kPa
11. a. Direct-acting
12. b. Two-stage pressure reduction
13. d. On a municipal water main to permit joining of the water service pipe
14. a. Allow for water meter servicing
15. b. No interconnection is permitted

### Self-Test 2

1. d. Pressure drop caused by friction in pipe
2. c. 4.05 psi
3. b. American Society of Heating, Refrigeration and Air Conditioning Engineers

### Self-Test 3

1. d. Push-on, mechanical joints and flanged joints
2. b. False

3. d. Thrust blocks, thrust anchors, and joint restraint
4. a. For push-on joints only
5. 9.06 $ft^2$ (18,120 lbs ÷ 2000 lbs/$ft^2$)
6. 3.44 $ft^2$ (13,770 lbs ÷ 4000 lbs/$ft^2$)
7. 42.75 $ft^2$ (128,260 lbs ÷ 3000 lbs/$ft^2$)
8. 46.24 $ft^2$ (138,720 lbs ÷ 3000 lbs/$ft^2$)
9. 20.7 $ft^2$ (20,700 lbs ÷ 1000 lbs/$ft^2$)

## Competency B2

### Self-Test 1

1. d. Bottom
2. c. Main stop and drain
3. c. Rotating disk meter
4. c. Decreases in size when in use
5. d. To allow for settlement or movement of the water main
6. d. When the water service pipe is rated for cold-water only
7. b. Riser
8. a. True
9. a. The heating source is located at the hot water storage tank
10. d. To the cold water inlet to the storage tank, or to the bottom inlet of the tank
11. b. Balancing valves
12. a. Bronze body
13. b. 60 °C
14. c. CSA F383

### Self-Test 2

1. b.¾ inch [BCPC 2.6.3.4.(1)]
2. c. 6 fixture units [BCPC Table 2.6.3.2.-A]
3. d. 10 fixture units [BCPC Table 2.6.3.2.-A]
4. a. 58 fixture units [BCPC Table 2.6.3.2.-B]
5. b. 2.4 m/sec
6. c. Sized for peak demand flow and not less than 3/4” [BCPC 2.6.3.4.(1)]

7. a. Simplified method [BCPC 2.6.3.4.(5)]
8. Size the lettered building water supply system pipes on the drawing below.
   Single family dwelling

**Individual fixture unit loads**

| Abbreviation on sketch | Fixture or device description | Minimum size of supply pipe, inches | Private EU (Total column) | Public FU (Total column) |
|---|---|---|---|---|
| BT | Bathtub with or without shower head | ½ inch ID | 1.4 | |
| CW | Clothes Washer 3.5 kg | ½ inch ID | 1.4 | |
| FTWC | Water closet, 6 LPF or less with flush tank | $\frac{3}{8}$ inch ID | 2.2 | |
| FTWC | Water closet, 6 LPF or less with flush tank | $\frac{3}{8}$ inch ID | 2.2 | |
| HB | Hose Bibb ½ inch | ½ inch ID | 2.5 | |
| HB | Hose Bibb ½ inch | ½ inch ID | 2.5 | |
| KS | Sink, kitchen domestic, 8.3 LPM | $\frac{3}{8}$ inch ID | 1.4 | |
| LAV | Lavatory, 8.3 LPM or less | $\frac{3}{8}$ inch ID | 0.7 | |
| LAV | Lavatory 8.3 LPM or less | $\frac{3}{8}$ inch ID | 0.7 | |
| | Total fixture unit load | | 15 | |

**Competency B2 Learning Task 2 Quiz: Simplified method Copper tubing version**

| Pipe or tube identifier | Cold or hot piping | WSFU load | Notes | Maximum water velocity based on material | Pipe or tube size |
|---|---|---|---|---|---|
| A | Cold | N/A | Supply pipe | N/A | ½″ |
| B | Cold | N/A | Supply pipe | N/A | $\frac{3}{8}$″ |
| C | Hot | 2.8 | Size on Table 2.6.3.4 | 1.5 m/s (5 ft/s) | ½″ |
| D | Cold | 9.7 | Size on Table 2.6.3.4 | 2.4 m/s (8 ft/s) | ¾″ |
| E | Cold | 3.9 | Size on Table 2.6.3.4 | 2.4 m/s (8 ft/s) | ½″ |
| F | Cold | 2.9 | Size on Table 2.6.3.4 | 2.4 m/s (8 ft/s) | ½″ |

| | | | | | |
|---|---|---|---|---|---|
| G | Hot | 5.6 | Size on Table 2.6.3.4 | 1.5 m/s (5 ft/s) | ¾″ |
| H | Cold | 5.6 | Size on Table 2.6.3.4<br>National Plumbing Code 2.6.3.4.(4) | 2.4 m/s (8 ft/s) | ½″<br>¾″ |
| I | Cold | 15 | Size on Table 2.6.3.4 | 2.4 m/s (8 ft/s) | ¾″ |
| J | Cold | 15 | Water service pipe: PL to PRV, Size on Table 2.6.3.4 | 2.4 m/s (8 ft/s) | ¾″ |

9. Size the lettered building water supply system pipes on the drawing below.

**Small commercial method**

| **Water service pipe minimum static pressure available** | **PSI** | **kPa** |
|---|---|---|
| Minimum available pressure at the property line (PL) during peak demand[1] | | 410 |
| Pressure loss from PL to entry point of the building[2] | | subtract 25 |
| Pressure gain from PL to entry point of the building[3] | | add 0 |
| Adjusted pressure at water service entry to the building | | equals 385 |
| Select the pressure range for sizing from Table A-2.6.3.1.(2)-A | | 200-310<br>311-413<br>over 413 |

| **Cold and hot distribution systems minimum static pressure available** | **PSI** | **kPa** |
|---|---|---|
| Adjusted pressure at water service entry to the building from above | | 385 |
| Pressure loss due to water meter installed inside the building (use manufacturer’s specifications) | | subtract 20 |
| Pressure loss due to pressure-reducing valve (use manufacturer’s specifications) | | subtract 0 |
| Pressure loss due to backflow preventer (use manufacturer’s specifications) | | subtract 0 |
| Pressure loss due to other components (water treatment systems, etc.) | | subtract 0 |
| Pressure loss due to elevation change[4] | | subtract 35 |

1. Where there is a wide fluctuation of pressure in the main throughout the day, the minimum static pressure available.

2. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

3. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

4. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

| | | |
|---|---|---|
| Pressure gain due to elevation change[5] | | add 0 |
| Cold and hot distribution systems minimum static pressure available | | equals 280 |
| Select the pressure range for sizing from Table 1-2.6.3.1.(2)-A | | 200-310<br>311-413<br>over 413 |

**Individual fixture unit loads and TOTAL FU load**

| Abbreviation on sketch | Fixture or device description | Minimum size of supply pipe, inches | Private FU(Total column) | Public FU (Total Column) | Number of same fixtures | Total FU load for same fixtures |
|---|---|---|---|---|---|---|
| BT | Bathtub with or without shower head | ½ inch ID | 1.4 | | 4 | 5.6 |
| CW | Clothes Washer 3.5 kg (Public) | ½ inch ID | | 3 | 2 | 6.0 |
| FTWC | Water closet, 6 LPF or less with flush tank | $\frac{3}{8}$ inch ID | 2.2 | | 4 | 8.8 |
| HB | Hose Bibb ½ inch | ½ inch ID | 2.5 | | 2 | 5.0 |
| KS | Sink, kitchen domestic, 8.3 LPM | $\frac{3}{8}$ inch ID | 1.4 | | 4 | 5.6 |
| LAV | Lavatory, 8.3 LPM or less | $\frac{3}{8}$ inch ID | 0.7 | | 4 | 2.8 |
| SS | Sink, service | ½ inch ID | | 3.0 | 1 | 3.0 |
| | Total number of fixtures in the building | | | | 21 | |
| | Total fixture unit load | | | | | 36.8 |

**Competency B2 Learning Task 2 Quiz: Small commercial building method Copper tubing version**

| Pipe or tube identifier | Cold or hot piping | WSFU load | Notes | Maximum water velocity based on material | Pressure Range | Pipe or tube size |
|---|---|---|---|---|---|---|
| A | Cold | N/A | Supply pipe | N/A | N/A | $\frac{3}{8}''$ |

5. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

| | | | | | | |
|---|---|---|---|---|---|---|
| B | Cold | N/A | Supply pipe | N/A | N/A | $\frac{3}{8}$″ |
| C | Hot | 3.5 | Size on Table A-2.6.3.1.(2)-A | 1.5 m/s (5 ft/s) | 200-310 kPa | $\frac{5}{8}$″ |
| D | Cold | 5.7 | Size on Table A-2.6.3.1.(2)-A | 2.4 m/s (8 ft/s) | 200-310 kPa | $\frac{5}{8}$″ |
| E | Hot | 7.0 | Size on Table A-2.6.3.1.(2)-A | 1.5 m/s (5 ft/s) | 200-310 kPa | 1″ |
| F | Cold | 11.4 | Size on Table A-2.6.3.1.(2)-A | 2.4 m/s (8 ft/s) | 200-310 kPa | ¾″ |
| G | Hot | 9.0 | Size on Table A-2.6.3.1.(2)-A | 1.5 m/s (5 ft/s) | 200-310 kPa | 1″ |
| H | Cold | 11.5 | Size on Table A-2.6.3.1.(2)-A | 2.4 m/s (8 ft/s) | 200-310 kPa | ¾″ |
| I | Cold | 13.9 | Size on Table A-2.6.3.1.(2)-A | 2.4 m/s (8 ft/s) | 200-310 kPa | 1″ |
| J | Hot | 23.0 | Size on Table A-2.6.3.1.(2)-A | 1.5 m/s (5 ft/s) | 200-310 kPa | 1¼″ |
| K | Cold | 23.0 | Size on Table A-2.6.3.1.(2)-A | 2.4 m/s (8 ft/s) | 200-310 kPa | 1″ |
| L | Cold | 36.8 | Size on Table A-2.6.3.1.(2)-A | 2.4 m/s (8 ft/s) | 200-310 kPa | 1¼″ |
| M | Cold | 36.8 | Water service pipe: Size on left column of Table A-2.6.3.1.(2)-A | 2.4 m/s (8 ft/s) | over 413 kPa | 1½″ |

10. Size the lettered building water supply system pipes on the drawing below.

**Average pressure loss method**

| **Water service pipe minimum static pressure available** | **PSI** | **kPa** |
|---|---|---|
| Minimum available pressure at the property line (PL) during peak demand[6] | | 410 |
| Pressure loss from PL to entry point of the building[7] | | subtract 25 |
| Pressure gain from PL to entry point of the building[8] | | add 0 |

6. Where there is a wide fluctuation of pressure in the main throughout the day, the minimum static pressure available.

7. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

8. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

| | | |
|---|---|---|
| Adjusted pressure at water service entry to the building | | equals 385 |

| **Cold and hot distribution systems minimum static pressure available** | **PSI** | **kPa** |
|---|---|---|
| Adjusted pressure at water service entry to the building from above | | 385 |
| Pressure loss due to water meter installed inside the building (use manufacturer's specifications) | | subtract 20 |
| Pressure loss due to pressure-reducing valve (use manufacturer's specifications) | | subtract 0 |
| Pressure loss due to backflow preventer (use manufacturer's specifications) | | subtract 0 |
| Pressure loss due to other components (water treatment systems, etc.) | | subtract 0 |
| Pressure loss due to elevation change[9] | | subtract 35 |
| Pressure gain due to elevation change[10] | | add 0 |
| Cold and hot distribution systems minimum static pressure available | | equals 280 |
| Minimum pressure necessary at the fixture for operation (governing fixture) | | subtract 105 |
| Final adjusted pressure loss to find pressure available for pressure loss | | 175 |

**Step 1(e)**

$$\underset{\text{Total pressure available for friction loss}}{175\ \text{kPa}} \div \underset{\text{developed length} \times 1.5 \text{ for fittings and/or additional losses if insert fittings are used}}{40.5\text{m}} = \underset{\text{Average pressure loss must be minimum 2.6 kPa per metre}}{4.32\ \text{kPa per metre}}$$

**Competency B2 Learning Task 2 Quiz: Simplified method Copper tubing version**

| **Pipe or tube identifier** | **Cold or hot piping** | **WSFU load** | **Notes** | **Maximum water velocity based on material** | **Pipe or tube size** |
|---|---|---|---|---|---|
| A | Cold | N/A | Supply pipe | N/A | $\frac{3}{8}''$ |
| B | Cold | N/A | Supply pipe | N/A | $\frac{3}{8}''$ |

9. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

10. 1 foot of head = 0.443 psi loss or gain and 1 meter of head = 10 kPa loss or gain

| | | | | | |
|---|---|---|---|---|---|
| C | Hot | 3.5 | Size on Table A-2.6.3.1.(2)-F | 1.5 m/s (5 ft/s) | ½″ |
| D | Cold | 5.7 | Size on Table A-2.6.3.1.(2)-F | 2.4 m/s (8 ft/s) | ½″ |
| E | Hot | 7.0 | Size on Table A-2.6.3.1.(2)-F | 1.5 m/s (5 ft/s) | ¾″ |
| F | Cold | 11.4 | Size on Table A-2.6.3.1.(2)-F | 2.4 m/s (8 ft/s) | ¾″ |
| G | Hot | 9 | Size on Table A-2.6.3.1.(2)-F | 1.5 m/s (5 ft/s) | ¾″ |
| H | Cold | 11.5 | Size on Table A-2.6.3.1.(2)-F | 2.4 m/s (8 ft/s) | ¾″ |
| I | Cold | 13.9 | Size on Table A-2.6.3.1.(2)-F | 2.4 m/s (8 ft/s) | ¾″ |
| J | Hot | 23 | Size on Table A-2.6.3.1.(2)-F | 1.5 m/s (5 ft/s) | 1¼″ |
| K | Cold | 23 | Size on Table A-2.6.3.1.(2)-F | 2.4 m/s (8 ft/s) | 1″ |
| L | Cold | 36.8 | Size on Table A-2.6.3.1.(2)-F | 2.4 m/s (8 ft/s) | 1¼″ |
| M | Cold | 36.8 | Water service pipe: Size on Table A-2.6.3.1.(2)-F | 2.4 m/s (8 ft/s) | 1¼″ |

### Self-Test 3

1. a. Polyethylene series 160 [Summary Table A-2.2.5, 2.2.6, and 2.2.7]
2. d. Quickly closing a valve
3. a. No [BCPC 2.6.1.3.(1) or NPC 2.6.1.7.(7)]
4. a. True [BCPC 2.6.1.2.(1) or NPC 2.6.1.2.(1)]
5. d. Have the hot water control on the left and the cold on the right[BCPC 2.6.1.1.(1)]
6. a. Water closets [BCPC 2.6.1.3.(4)]

## Competency B3

### Self-Test 1

1. c. Cost of installation
2. a. Drip
3. b. BC 1 Call
4. c. Gutter downspouts
5. a. Evapotranspiration
6. b. Warm dry
7. a. Jar test
8. d. Clay loam

9. c. Loam
10. c. Runoff and erosion
11. c. 10
12. d. Proximity to the house water supply

### Self-Test 2

1. d. Bubbler
2. b. Fixed spray
3. a. Pop-up
4. c. Impact
5. b. Rotating
6. d. Ability to serve small areas
7. a. Use head-to-head coverage
8. d. An anti-siphon zone valve
9. a. RPBAs and DCVAs
10. b. DCAP
11. b. In a driveway
12. a. Polyethylene (PE)
13. c. Available GPM and sprinkler flow rates
14. d. D
15. a. 5 ft/sec (1.5 m/sec)
16. b. 2.15 psi
17. c. Because of its wall thickness difference
18. b. 25%
19. b. ¾” and 1”
20. c. 13 GPM

### Self-Test 3

1. b. acceptable for direct earth burial
2. d. #18 AWG
3. b. “Funny Pipe”
4. d. Place the removed sod on plastic on one side of the trench, spoils on the other side also on plastic

5. a. By “jetting” it
6. c. Waterproof twist-on
7. c. Install all but the furthest head, open the valve and flush through the open end
8. c. At least two more than are currently installed
9. c. 30 minutes
10. a. Set longer run times, decrease the number of cycles per day and increase watering days
11. c. A pump start relay
12. d. Hardness
13. c. Downstream of the backflow preventer
14. a. Half open
15. c. Its volume

## Competency B4

### Self-Test 1

1. b. Toilet flushing and underground irrigation
2. c. Auxiliary
3. a. They may never be interconnected
4. a. It hasn’t been treated to acceptable certified standards
5. c. Division B Part 2

### Self-Test 2

1. d. An asphalt roof
2. a. 1,600
3. d. 2.0%
4. d. PVC Sch 40
5. d. Polystyrene foam insulation and adequate burial depth
6. c. A storm building drain
7. a. Because it is not UV-rated

### Self-Test 3

1. c. Forming a concrete tank as a component of the house foundation
2. c. Concrete

3. d. Tank manufacturers and suppliers
4. b. Aesthetics
5. a. An integrated tank
6. a. A provincial “One Call” service
7. c. The placement of the pump on-off switch
8. b. To ensure the pump does not run dry
9. a. Install it and all related components below the frost level
10. b. Install heat trace wire around the tank, pipes, valves, and pump

### Self-Test 4

1. a. A toilet
2. c. Disinfection
3. a. Settling
4. d. First-flush diversion
5. c. Disinfection
6. c. Potable purposes
7. a. They contribute to leaves and bird droppings contaminating the collected rainwater
8. b. A form of pre-storage water treatment

### Self-Test 5

1. b. Make-up
2. a. Creating a cross connection
3. a. Top-up
4. c. Zone isolation
5. a. Zone isolation
6. b. Aesthetics
7. b. A float switch
8. c. A solenoid valve
9. a. Between the solenoid valve and the cistern
10. d. When a sensor or float switch is activated at the highest water level desired

### Self-Test 6

1. a. A jet pump

2. b. That it is clearly identified
3. b. 120/240 VAC
4. d. A relay
5. a. A timer
6. a. Suction head
7. d. A variable speed drive pump
8. c. 1 to 2 min
9. d. Purple
10. b. At least 300 mm (12 inches)

### Self-Test 7

1. d. Stormwater management
2. b. A backwater valve
3. a. Gravity drainage to grade
4. b. Pumped discharge to grade
5. d. Pumped discharge to a storm sewer
6. b. A drywell
7. c. Clay
8. a. Above-grade
9. a. An overflow

### Self-Test 8

1. a. Used water from laundries, bathtubs, showers, and bathroom basins
2. b. Flushing toilets and urinals, and subsurface irrigation
3. b. Pooling of greywater is acceptable as long as it stays on private property
4. b. By bucketing onto gardens or lawns
5. c. It should only be used for irrigation
6. c. 4
7. d. 152
8. c. Kohler’s Handbook for Water Pipe Sizing
9. c. The greywater comes from only the clothes washer
10. b. The greywater system uses a greywater tank

## Self-Test 9

1. c. By capillary action
2. b. A soil ribbon test
3. d. A percolation test
4. c. Silty clay loam
5. a. A bad odour
6. b. A diverter valve
7. c. Laundry-to-landscape
8. d. Gravity, branched drain
9. b. Manufactured
10. b. Sand filter

# Versioning History

This page provides a record of edits and changes made to this book since its initial publication. Whenever edits or updates are made in the text, we provide a record and description of those changes here. If the change is minor, the version number increases by 0.01. If the edits involve substantial updates, the version number increases to the next full number.

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| Version | Date | Change | Details |
|---|---|---|---|
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