Block A: Fuel Gas

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BC Plumbing Apprenticeship - Level 2

SKILLED TRADES BC

BC PIPING ARTICULATION AND CURRICULUM SUBCOMMITTEE; ROD LIDSTONE; AUDREY CURRAN; AND PAUL SIMPSON

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Block A: Fuel Gas Introduction

In the field, there are many similarities or overlaps with the work of plumbers and gas fitters. Many plumbing and heating contractors employ both plumbers and gas fitters as well as tradespeople with dual certifications.

Upon completion of a Plumbing Apprenticeship, a plumber can receive cross-program credit for a portion of the Gas fitter apprenticeship. As such, training in fuel gas has been incorporated into all levels of the Plumbing Apprenticeship.

Block A of the **Plumbing Apprenticeship Program Level 2 Series** focuses on the fundamentals of fuel gas systems, providing apprentices with a solid understanding of gas-fired appliances, regulations, and safety standards. This section gives apprentices the skills they need to safely work with fuel gas systems, make sure they follow industry rules, and properly install and maintain gas-fired equipment.

Plumbing Apprenticeship Program Level 2 Series

The *Plumbing Apprenticeship Program Level 2 Series* offers comprehensive training materials designed to build on foundational skills and knowledge. The series is divided into four main blocks, each focusing on critical areas of plumbing systems and installations.

Block A: Fuel Gas Systems (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/)

A-1: Gas Fired Appliances
A-2: Gas Codes Regulations and Standards
A-3: Gas Appliance and Building Air Requirements
A-4: Technical Instruments and Testers

Block B: Heating and Cooling Systems (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/)

B-1: Types of Heating and Cooling Systems
B-2: Hydronic Heating and Cooling Generating Equipment
B-3: Hydronic Heat Transfer Units
B-4: Hydronic Heating Piping and Components

Block C: Install Fixtures and Appliances (https://c-plumbfixappliance-bcplumbingapprl2.pressbooks.tru.ca/)

C-1: Plumbing Fixtures and Trim
C-2: Plumbing Appliances

Block D: Drainage Systems (https://d-drainagesystems-bcplumbingapprl2.pressbooks.tru.ca/)

D-1: Sanitary Drain, Waste and Vent Systems
D-2: Planning and Installation of DWV Systems
D-3: Storm Drainage Systems
D-4: Test and Drainage Systems
D-5: Drainage System Maintenance and Repairs

Plumbing Apprenticeship Program Overview and Upcoming Resources

- **Plumbing Apprenticeship Program Level 1 Series** (https://openpress.trubox.ca/2024/12/13/plumbing-apprentice-level-1/) can be found in the TRU Open Press Collection.
- **Plumbing Apprenticeship Program Level 3 Series (https://collection.bccampus.ca/search/?q=%22pl3%22)** can be found in the BCCampus Open Collection (https://collection.bccampus.ca/).
- **Plumbing Apprenticeship Program Level 4 Series** (https://bccampus.ca/projects/archives/zed-cred-z-degrees/ztc-open-educational-resources-for-trades/) can be found in the BCCampus Open Collection. (https://collection.bccampus.ca/) (Block F: Commission and Service will be available soon.)

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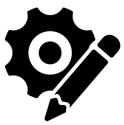
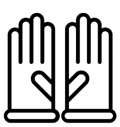
Safety Advisory

The current Standards and Regulation in BC can be obtained at the WorkSafeBC (http://www.worksafebc.com) website: http://www.worksafebc.com

Please note that it is always the responsibility of any person using these materials to inform themselves about the Occupational Health and Safety Regulation pertaining to their areas of work.

Symbol Legend

	**Important Information**
	**Potentially Toxic/ Poisonous Situation**
	**Required or Optional Resources**
	**Potentially Flammable Situation**
	**Complete a Self-Test**
	**Possibly Explosive Situation**
	**Use Protective Equipment**
	**Potential Electric Shock**

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The development of the *Piping Trades Learning Guides* was a collaborative effort driven by a commitment to excellence in trades education. These guides were created to support apprentices and journeypersons in mastering the skills and knowledge essential to the piping trades. This achievement would not have been possible without the dedication and expertise of *Skilled Trades BC* and the *Piping Trades Articulation Committee*, whose leadership and guidance have been instrumental in shaping high-quality training resources. We extend our sincere gratitude for their contributions and ongoing stewardship in advancing the piping trades.

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Resource Development Team 2024/2025

Content Review, Revision, and Development: BC Plumbing Articulation Curriculum Subcommittee and Rod Lidstone
Final Content Review and Revisions: Audrey Curran
Project Lead (TRU Plumbing Trades): Paul Simpson, Curriculum Subcommittee Chair
Publishing Manager: Dani Collins, MEd
Copy Editing: Kaitlyn Meyers, BA
Production: Jessica Obando Almache, BCS

- Co-op Students:
  - Greg Vilac
  - Riley Phillips
  - Vansh Sethi
  - Jesse Perkins

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    - 3mm silicone rubber tubing connected to static pressure tip
    - Pitot tube
    - P/T plub
    - 1/8″ NPT inlet pressure tap plug
    - Outlet pressure tap connected to clear plastic manometer tubing
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    - Dial stem thermometers
    - Flexible capillary dial thermometer
    - Dial thermometer partially insterted into thermowell
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    - 10 kΩ NTC thermistor
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Skilled Trades BC. (2021). Book 1: Fuel gas systems, Heating and cooling Systems. Plumber apprenticeship program level 2 book 1 Harmonized. Crown Publications: King's Printer for British Columbia.

SkilledTradesBC. (2022, December 1). Introducing Skilled Trades BC. YouTube. https://www.youtube.com/watch?v=OQgwdP0rNog

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A-1 GAS-FIRED APPLIANCES

Plumber Apprenticeship Program – Level 2

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A-1 Gas-Fired Appliances Introduction

On the job, under the supervision of a certified gasfitter, you may be required to install and service a variety of gas-fired appliances. This section is designed to familiarize you with some of the appliances you may encounter and provide a brief overview of their operational characteristics.

Learning Objectives

After completing the chapters in this section, you should be able to:

- Describe the appliance characteristics that impact the operational environment and installation of gas appliances.
- Describe various gas-fired appliances.
- Use manufacture and supplier documentation for gas appliances.

Terminology

The following terms will be used throughout this section. A complete list of terms for this section can be found in the **Glossary**.

- **carbon monoxide (CO) sensor:** A safety device that detects dangerous levels of carbon monoxide gas and may activate a shut-off mechanism on gas appliances. (Section A-1.2)
- **certification organizations:** Groups that check if products are made and work safely and correctly. They put special labels on products to show they meet safety rules. (Section A-1.3)
- **concentric coaxial pipe:** A type of pipe made of two pipes, one inside the other. The outer pipe carries air, while the inner pipe carries the fuel or exhaust, helping to safely vent gases while bringing in fresh air for combustion. (Section A-1.1)
- **direct vent appliance:** A sealed combustion gas appliance that draws air from outside for combustion and vents exhaust gases directly outside, improving safety and efficiency. (Section A-1.2)
- **energy efficiency standards:** Rules that set the minimum level of energy use for appliances, making sure they use energy in a smart way and help save power. (Section A-1.3)
- **ENERGY STAR®:** A program that identifies products meeting high-efficiency standards for energy use, helping consumers choose energy-saving appliances. (Section A-1.3)
- **flammable vapour ignition resistant (FVIR)**: A safety design feature in gas water heaters that prevents the ignition of flammable vapours outside the combustion chamber. Especially important in areas like garages where flammable liquids may be stored. (Section A-1.2)
- **heat output:** The amount of heat a machine or appliance, like a water heater, can produce. It shows how

much energy it transfers to heat things up. (Section A-1.3)

- **hybrid tankless water heater:** A type of tankless water heater equipped with a small buffer tank and a circulation pump. This design supports hot water recirculation systems and helps maintain consistent temperature delivery. (Section A-1.2)
- **installation, operation, and service manuals:** Guides provided by manufacturers with information on how to safely install, use, and maintain appliances, including safety warnings, wiring diagrams, and troubleshooting tips. (Section A-1.3)
- **manufacturers specifications (datasheets)**: Instructions or details provided by the maker of a product, explaining how the product should be used, installed, and maintained. (Section A-1.3)
- **moisture exhaust duct:** The ductwork used in gas dryers to vent humid air and combustion by-products to the outdoors, as required by code. (Section A-1.2)
- **MOSFET adaptor:** (Metal-Oxide-Semiconductor Field-Effect Transistor); A small electronic part that helps turn gas appliances on or off safely. It controls how electricity flows to important safety parts like sensors or shut-off devices. (Section A-1.2)
- **rating plate:** A metal or plastic tag on an appliance that shows important details, like how much power it uses, how to install it safely, and any safety standards it meets. (Section A-1.3)
- **thermocouple interrupter:** A component used in some gas appliances to shut off the gas supply in case of sensor failure or unsafe operating conditions, often used with CO detectors. (Section A-1.2)
- **thermal trap:** (Also known as combustion air pot), a part of a heating system that helps improve efficiency and safety. It works by trapping heat that would otherwise escape, ensuring that the hot air stays where it's needed. This trapped heat can then be used to warm up the air needed for combustion, making the system more efficient. The combustion air pot also prevents dangerous gases from leaking out by keeping them contained. (Section A-1.1)
- **ventilation:** The intentional introduction of outdoor air into a space to control indoor air quality by diluting and displacing indoor pollutants; can also be used for purposes of thermal comfort or dehumidification. (Section A-1.2)
- **warranty:** A guarantee from the manufacturer that a product will be free from defects for a certain period, with free repairs or replacements offered if needed. (Section A-1.3)

A-1.1 Characteristics of Gas Appliances

Installing and commissioning gas appliances requires a thorough knowledge of the most common characteristics that will affect the installation and operating environment of the gas appliance.

All of the characteristics identified in this chapter are covered in much greater detail in future studies. The primary objective at this level of study is to make installers aware of the significance of these characteristics. This means they should find more information about each specific appliance when performing installation, operation, or maintenance.

Appliance Design

The gas appliance design can include many characteristics. Some of these are more internal to the appliance and will predominately be component-related and impact the operation and maintenance of the appliance. Other characteristics are more external to the appliance and therefore may have a greater effect on the environment and installation.

Internal (Component) Characteristics

Internal characteristics will include types of burners, ignition systems, controls, and safeties.

Burners

Burners are designed in many shapes and sizes to accommodate the wide variety of heat exchangers and combustion chamber requirements. The type of burner an appliance contains will have an effect on the installation and service requirements of the appliance. The two primary categories of burners, non-mechanical and mechanical, are distinguished by how the combustion air is supplied.

Non-mechanical or "atmospheric burners" rely on natural draft to supply the required combustion air. Because atmospheric burners have lower efficiency and are more susceptible to flue gas spillage, they are becoming less common in contained combustion chamber appliances.

High-efficiency appliances contain mechanical burners, which use a fan or blower to deliver the combustion air and can therefore achieve a more controlled gas/air mixture and higher efficiency.

Pilots and Ignition Systems

A pilot is a flame that ignites a main burner or burners. Most pilot burners are controlled by a safety device that shuts off the gas supply to the main burner(s) if the pilot flame is extinguished. There are different types of pilot burners. Some will remain lit continuously while others will only be lit on a call for main burner ignition. It is important for the installer to be familiar with the type of pilot that each appliance contains, as there will be specific start-up requirements for each.

Many appliances today do not use a pilot burner to ignite the main burner. The main burner is ignited directly by a spark or hot surface igniter. These will also have specific service and troubleshooting procedures that the installer will need to be familiar with.

Controls and Safeties

The control system of an appliance must initiate a safe light-up, supervise the run period, and provide a safe shutdown of the appliance. Should overheating, overpressure, or flame failure occur, the control system must be able to safely shutdown the appliance. If any part of the control system is improperly installed or improperly wired, a safe shutdown may not occur, which could lead to a potentially dangerous situation.

The appliance controls will be individual components of distinct circuits with specific functions. For example, among other components, the combustion safety circuit could include a thermocouple and safety shut-off valve. The main burner control circuit could, on the other hand, include a thermostat, high temperature limit, and main gas valve. The ability to interpret the appliance wiring diagram(s) is an essential skill for identifying each control component and its function.

The individual control components within each circuit relies upon a variety of physical characteristics for their operation. For example, expansion of solids and liquids, electromagnetism, the thermoelectric effect, and electricity are all used in varying capacities. A person troubleshooting gas appliances will require a good knowledge of these concepts

Gas Appliance External Characteristics

The external characteristics, such as the venting or the heat exchange process, require consideration of such things as:

- Location (indoor, outdoor, type of living space)
- Clearances from combustibles to the appliance and vent
- Type of venting materials to be used
- Method of air supply

Vented or Non-Vented

Vented gas appliances typically have an enclosed combustion chamber and vent the combustion products to the outside atmosphere. Non-vented gas appliances, as the name implies, do not have a vent. Therefore, all of the combustion gases are released directly into the immediate surroundings.

Indoor non-vented gas appliances are primarily used for cooking equipment. Emissions from these appliances can contribute to poor air quality, if the appliances are used for extended periods without a venting hood. Commercial kitchens will be equipped with large exhaust systems to ensure adequate air change. Unvented gas space-heating appliances are not permitted for use in indoor applications.

Venting and Air Supply Characteristics

Non-vented appliances such as ranges will have an open flame. Therefore, all of the air for combustion is immediately available from the surrounding air. On the other hand, the combustion air supply for a vented appliance will be drawn in through intake openings in the combustion chamber or forced combustion fan.

There are two common methods of air supply for vented gas appliances:

- Direct vent systems
- Room air systems (non-direct vent)

The size, location, installation methods, and type of material employed in venting systems are largely determined by the manufacturers of the appliance and vent system. Each method is appliance specific and will require different installation considerations. These are detailed in the manufactures installation instructions and Clause 8 of the CSA B149.1 Gas Installation Code.

Direct Vent

Direct vent systems have a sealed combustion chamber where all of the air for the appliance is taken directly from the outside, and the flue gas is discharged directly to the outdoors. Direct vent systems typically have two piping options; **concentric coaxial pipe** or twin pipe.

For coaxial vents, the combustion air and exhaust flow directly through a single connection to the appliance. Hot exhaust exits through the interior tube, while combustion air enters through the outer layer (Figure 1, left).

For twin pipe systems, the combustion air and exhaust flow directly through separate pipes and penetrations (Figure 1, right).

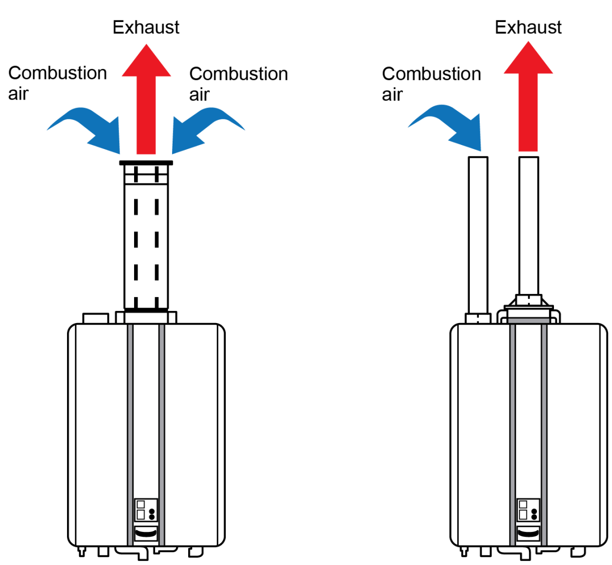

Figure 1 *Direct vent systems. (Skilled Trades BC, 2021) Used with permission.*

There are many termination options available for direct vent systems, including adapters that enable the installer to convert a two-pipe system to a concentric termination. Because manufacturers of venting materials make fittings for many brands of appliances, appliance manufacturers must list which given brand of venting is acceptable for use on a specific appliance.

Room Air System

Non–direct vent gas appliances draw all of their air supply requirements from the internal room air, which requires an outdoor air supply dedicated to the gas appliance. For gas appliances dependent on room air, outside air is normally brought to the proximity of the gas appliance via a duct. This is referred to as passive air supply, in contrast to a mechanical air supply such as a fan. If a mechanical air supply is used, it must be properly sized and interlocked with the appliances to shut-off the gas in the event of an air supply failure.

Some jurisdictions encourage the use of a **thermal trap** (combustion air pot, Figure 2) at the termination of the passive air supply duct to inhibit the flow of heated air out of the duct when the combustion equipment is not firing (Figure 2).

Figure 2 *Combustion air pot on a steam boiler. (Skilled Trades BC, 2021) Used with permission.*

With such a large selection of the venting options to choose from, the manufactures' vent installation instructions have become more detailed than the general installation instructions, to the point that they are often a separate installation document.

Heat Exchange Characteristics

The purpose of gas appliances is to transfer heat energy by way of conduction, convection, radiation, or a combination of these.

One type of heat exchange is called direct fired, in which the burner is fired directly into the process air stream to heat it. An example is a direct fired make-up air (DFMA) unit, which is used in commercial and industrial applications to preheat the ventilation air. Figure 3 illustrates a common rooftop-type unit. Direct fired heaters have an exposed flame similar to a stove top or grill, in which the combustion products are added to the heated air. Because of this, direct fired heaters are not used for places where people may sleep (hotels, homes, clinics, etc.).

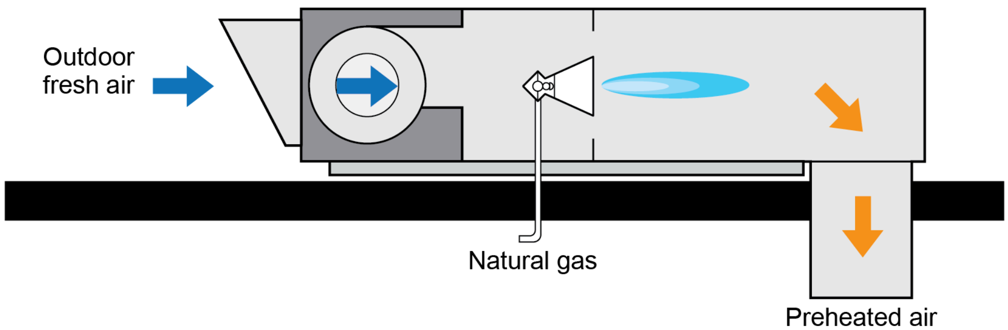

Figure 3 *Direct fired make-up air unit. (Skilled Trades BC, 2021) Used with permission.*

In an indirect fired heater, the burner is fired into a heat exchanger. The product (air or water) is heated by passing over the heat exchanger, allowing the combustion byproducts to remain within the heat exchanger, which is then exhausted through a flue (Figure 4). Furnaces and boilers are both examples of indirect fire gas appliances.

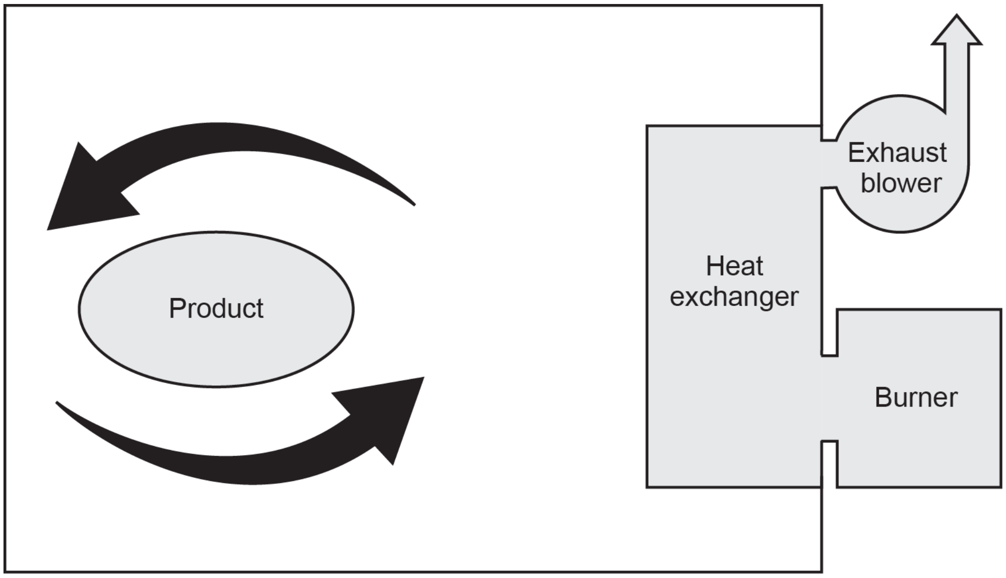

Figure 4 *Indirect fired concept. (Skilled Trades BC, 2021) Used with permission.*

Efficiency

Because direct fired appliances convert nearly all of the combustion gasses used into hot air, they are considered to be 100% combustion efficient, although approximately 8% of that energy is used for water vapour formation during combustion.

The efficiency of indirect fired gas appliances is determined by the appliance's ability to extract heat from the flue products. Efficiency factors include the type of heat exchanger materials, number of internal passes of the flue gas, and temperature of the process fluid (air or water) on the other side of the heat exchanger walls.

If the gas appliance extracts enough heat energy, condensing of the water vapour in the flue gas occurs. For every pound of water condensed from the flue gas, the heat exchanger gains approximately 970 BTUs of heat energy, referred to as "latent heat."

The latent heat increases the efficiency levels well into the 90% range but also presents new problems. The condensate has been exposed to CO_2 in the flue gases, which creates carbonic acid. Therefore, the heat exchanger has to be constructed of a material that can be exposed to condensate — usually a stainless-steel alloy. Many jurisdictions now require acid neutralizers (Figure 5) to be installed to raise the pH level prior to discharging the condensate to the building's drainage system.

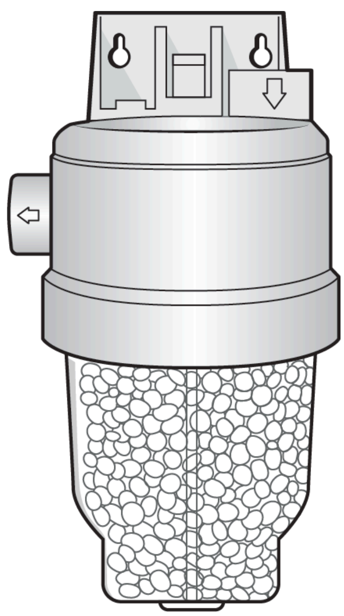

Figure 5 *Acid neutralizer. (Skilled Trades BC, 2021) Used with permission.*

Characteristics Summary

Each appliance is designed for a specific application, giving it unique characteristics. We can see that these characteristics will affect the installation, operation or maintenance of the appliance. It is therefore critical that gasfitters make themselves familiar with the specific documents and regulations relative to each appliance they are working on.

Self-Test A-1.1: Characteristics of Gas Appliances

Complete Self-Test A-1.1 and check your answers.

If you are using a printed copy, please find Self-Test A-1.1 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=31#h5p-2 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=31#h5p-2)

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Trades Training BC. (2021). A-1: Introduction to gas-fired appliances. In: *Plumber Apprenticeship Program: Level 2.* Industry Training Authority, BC.

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- **Figure 2** Combustion air pot on a steam boiler by Rod Lidstone, is used under a CC BY (https://creativecommons.org/licenses/by/4.0/) license.

A-1.2 Types of Gas Fired Appliances

As a gasfitter, you may be required to install and service many different gas-fired appliances, some simple, some complex, some vented, and some non-vented. This chapter will familiarize you with some of the most common appliances encountered and provide a brief overview of some of their operational characteristics. In addition to the manufacturers' installation instructions, refer to Section 7 of the CSA B149 Gas Installation Code for general installation requirements.

Gas Ranges and Commercial Cooking Equipment

Cooking with gas has the benefit of instant heat and immediate cool down. Numerous styles of gas ranges, types of ignition systems, and temperature controls are used. The most common domestic gas ranges are the zero-clearance, free-standing models (Figure 1). They are self-contained, self-supported, and equipped with top burners and an oven. A range must not be installed in a bedroom because it might produce carbon monoxide. However, a range may be installed in a bed-sitting room if the range is not used as a space heating appliance.

Figure 1 *Domestic gas range. (Maytag, 2023) Used with permission.*

Commercial restaurant cooking equipment often comprises separate units, designed to be installed in batteries (Figure 2). They can include ovens, various types of cooktops, and deep fat fryers. Cooktops can be equipped as all open burners, all griddle, or a combination of burners and griddles.

Figure 2 *Commercial cooking equipment. (Adapted/pxhere) CC0 1.0 Universal (https://creativecommons.org/publicdomain/zero/1.0/)*

The following factors must be considered when installing a gas range:

- Specific installation requirements, including manufacturer's instructions
- Leveling the range
- Anti-tipping devices
- Restraining device for commercial cooking appliances on wheels
- Clearance to combustibles

Specific installation requirements, such as proper positioning and adequate space for the appliance, include the following:

- Compliance with clearance requirements to combustibles, in accordance with manufacturer's instructions, the rating plate, and applicable codes
- Access for cleaning, repairs, and servicing
- Proper distance to venting hoods, flues, or ductwork, if installed
- Proper positioning with respect to adjacent cabinets, countertops, and other appliances

Gas-Fired Refrigerators and Freezers

Gas-fired refrigerators are popular for off-grid applications. They operate on an absorption principle in which heat from a gas flame provides the energy needed to drive the cooling process. Thus, the system silently provides the mechanical circulation for the refrigerant, without a compressor. Non-vented models for use in areas such as shops, sheds, screened porches, and other unoccupied areas come equipped with a carbon monoxide alarm and a safety shut-off.

There are four basic components to an **absorption refrigerator** (Figure 3):

- Generator (boiler)

- Condenser
- Evaporator
- Absorber

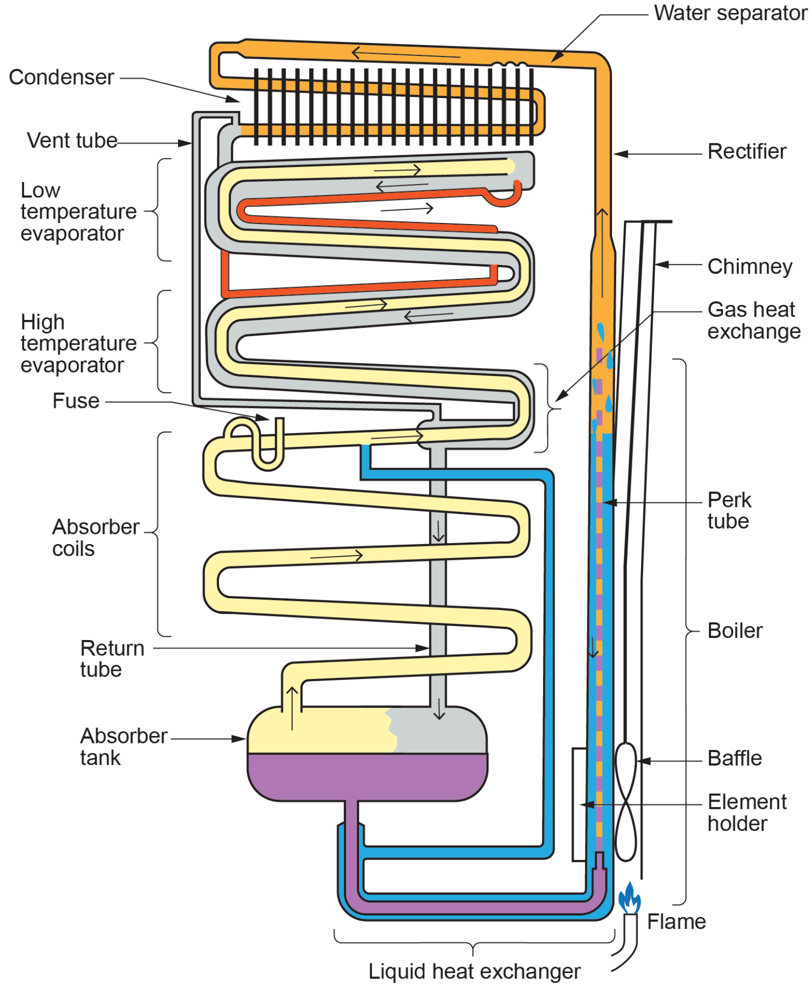

Figure 3 *Gas refrigerator operating components. (Skilled Trades BC, 2021) Used with permission.*

Briefly described, ammonia is liquefied in the finned condenser coil located at the top rear of the refrigerator. The liquid ammonia then flows into the evaporator inside the freezer section, where it is exposed to a circulating flow of hydrogen gas. This exposure causes the ammonia to evaporate, creating a cooling effect in the freezer.

One of the most important factors for trouble-free operation is proper venting behind the refrigerator. Since the refrigerator works on the principle of absorbing and releasing heat, it is of utmost importance to have proper air circulation.

Since refrigerator burners are tucked away in an enclosed space, the burners must be supplied with sufficient combustion air, and exhaust gases must be vented outside. **Direct vent** fridges need to be located/installed on an outside wall.

Some models of gas refrigerators come with a **carbon monoxide (CO) sensor**, which may also have a safety shut-off device. After locating and mounting the detector, connect it to the appliance. Some appliances have a matching plug on the lower back of fridge. Other fridges may require the use of a **thermocouple interrupter** body and **MOSFET adapter** (Figure 4).

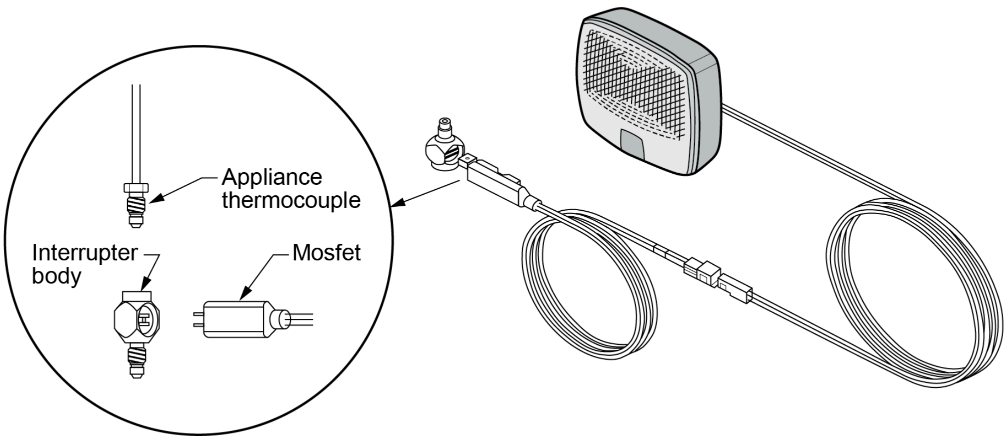

Figure 4 *CO safety shut-off. (Skilled Trades BC, 2021; adapted from Unique, n.d.) Used with permission.*

For units supplied with a CO sensor, manufacturers recommend testing the alarm operation at least once per week during use or if the appliance has been turned off for a period of time.

Clothes Dryers

A gas-fired clothes dryer (Figure 5) looks and operates very similar to an electric tumble dryer. Tumble dryers continuously draw in the ambient air around them and heat it before passing it through the tumbler. The resulting hot, humid air is vented outside with a **moisture exhaust duct**, which makes room for more air to continue the drying process.

A gas burner generates the heat in a gas dryer, but electricity still powers the motors within the appliance. As such, gas dryers require both a 110-volt electrical outlet and a gas hookup.

For gas units, in addition to removing the moisture that evaporates from the wet clothing, the moisture exhaust duct vents the products of combustion that are mixed with the moist air. The code sets specific requirements for the placing and type of moisture exhaust ducts that may be used.

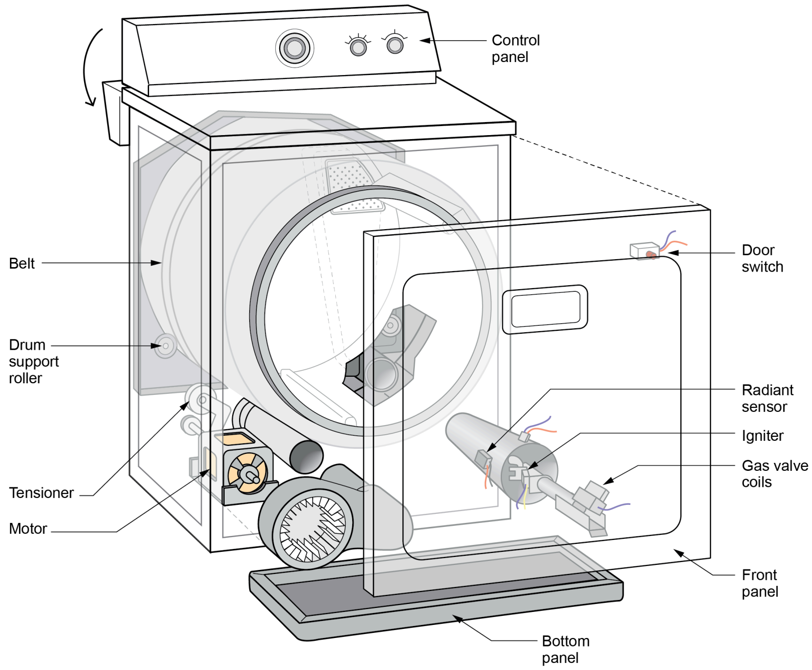

Figure 5 *Gas tumble clothes dryer components. (Skilled Trades BC, 2021; adapted from Family Handyman, 2023) Used with permission.*

Space Heaters, Fireplaces, and Decorative Appliances

For certain spaces, it is not realistic to put in a central furnace or boiler system, so a space heater or gas fireplace may better meet the needs. Likewise, if a person wishes simply to add ambience or atmosphere to a room, a decorative appliance will do the job.

Space Heaters

There are many types of gas space heaters available. To ensure satisfied customers, a gasfitter must be familiar with the capabilities and uses of different space heaters. What follows are some of the more common types of space heaters.

Room Heaters

A room space heater is a self-contained, free-standing, non-recessed, gas-burning appliance that furnishes direct warm air to the space in which it is installed without ducting (Figure 6).

It converts the fuel energy to convection and radiant heat by transferring heat from flue gases to the circulating air through a heat exchanger. The heated air can be distributed through natural convection or with a circulating air blower.

Modern room heaters, like the unit shown in Figure 6, are often coaxial direct vent units mounted onto the interior surface of an outside wall.

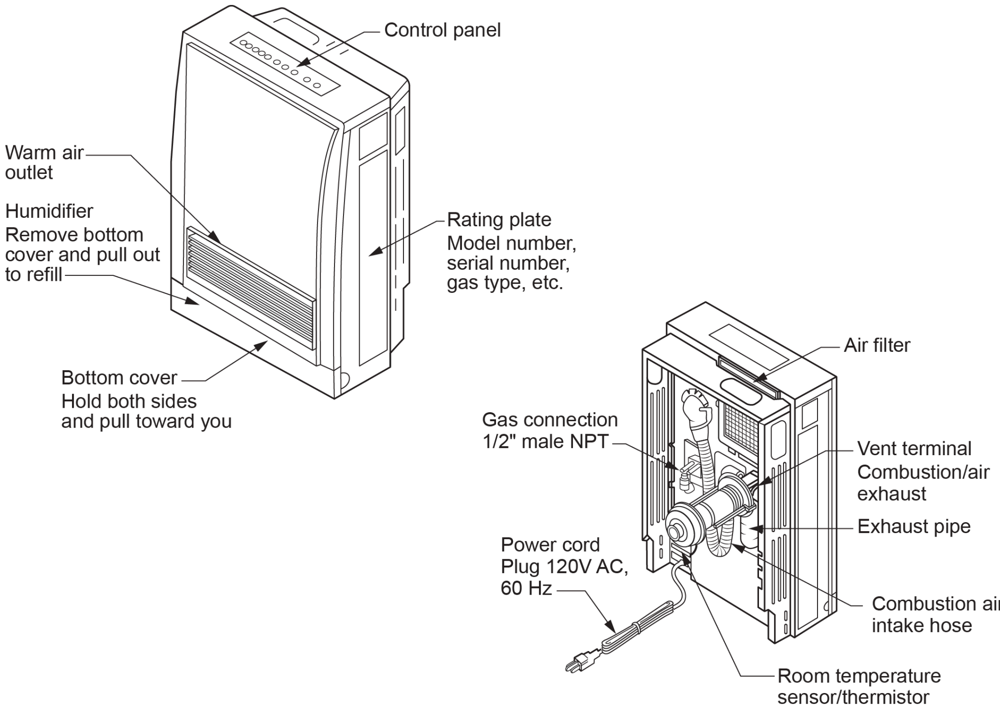

Figure 6 *Rinnai direct vent wall type room heater. (Skilled Trades BC, 2021; adapted from Rinnai, 2018) Used with permission.*

Recessed Wall Furnace

The modern use of the term “gas wall heater” typically refers to the previously shown type of room heaters, which are mounted against the wall. Another wall-mounted type of room heater is the recessed wall furnace designed to fit in a wall cavity. These are still sold but are not as commonly used for new installations, as they are natural draft units that require a special oval vent (**BW vent**) configuration designed to fit inside a stud wall (Figure 7).

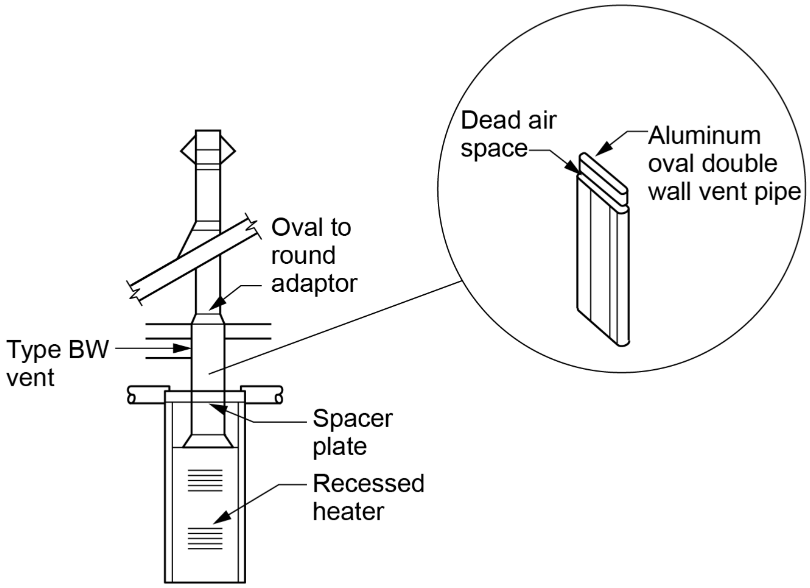

Figure 7 *Recessed wall furnace. (Skilled Trades BC, 2021) Used with permission.*

Unit Heaters

Unit heaters are self-contained, ductless, vented, fan-type commercial space heaters that are typically suspended in garages or shop areas (Figure 8). There are a variety of gas fired unit heaters for various applications. The different characteristics are defined by some of the component options, such as type of airflow fan, venting, combustion air supply, and efficiency.

Figure 8 *Suspend gas fired unit heater. (Rod Lidstone)* CC BY 4.0 *(https://creativecommons.org/licenses/by/4.0/legalcode.en)*

Infrared Heaters

Infrared heaters are typically used to heat large open areas, such as outdoor eating spaces, arenas, and warehouses, where spot heating is required. They are suspended from beams or joists and radiate heat toward the ground.

High-Intensity Infrared Heaters

High-intensity infrared heaters have burners made of porous material, such as ceramic or a metallic screen (Figure 9). A combustible mixture of gas and air flows through the refractory material, at which point the gas ignites. The surface temperature may rise as high as 980°C (1,800°F), which helps retain the flame on the surface, increasing radiating efficiency. Because high-intensity units are non-vented, there usage is quite restricted.

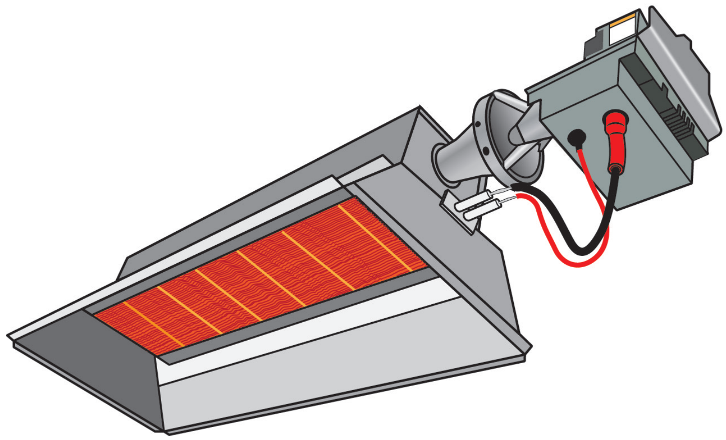

Figure 9 *Permanent mount suspended high-intensity infrared heater. (Skilled Trades BC, 2021) Used with permission.*

Parasol heaters are another style of high-intensity gas unit heater designed specifically for patio areas. Units can be free-standing or permanent post installations (Figure 10).

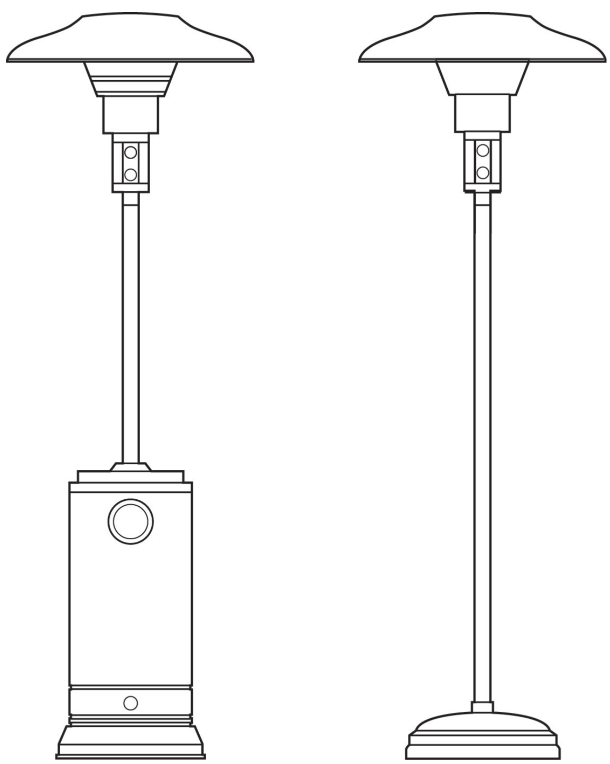

Figure 10 *Portable parasol infrared heaters. (Skilled Trades BC, 2021) Used with permission.*

Low-Intensity Infrared Heaters

In low-intensity infrared heaters (tube heaters), combustion occurs in tubes or panels made of metal or ceramic. The tubes radiate heat to reflectors, which in turn direct the heat source to the floor. The surface temperature may be as high as 650°C (1,200°F), and the units are generally vented to the atmosphere. There are straight and u-shaped styles. As the length increases, the input will also increase (Figure 11).

Figure 11 *Low-intensity infrared heaters. (Skilled Trades BC, 2021; modified from Space Ray/ GFP INC., n.d.) Used with permission.*

Emmitt guards or screens are installed to cover the exposed tubes for safety or cosmetic reasons, as shown in Figure 12.

Figure 12 *Tube heaters with emitter guards. (Rod Lidstone)*

Gas Fireplaces

There are two categories of gas fireplaces: decorative or heating. Decorative appliances are not designed for efficiency or intended for use as heaters. They are used to add atmosphere and ambience to a room and typically do not have a thermostat. Heating gas fireplaces, also known as vented gas fireplace heaters, have higher efficiency ratings (minimum 50%) and additional temperature controls. All units must have a direct vent configuration, unless it is marked for replacement use only.

For both categories, there are three common gas fireplace configurations (Figure 13):

- Gas fireplace inserts: used to convert existing wood-burning masonry or factory-built fireplaces to gas.
- **Zero-clearance gas fireplaces**: used in installations where there is no existing fireplace. They have a lot of installation location flexibility because they can be built into a wall, a corner, a peninsula or even an island in the home. This involves building the space and framing in the unit.
- Free-standing gas fireplaces: typically resemble wood-burning stoves and, therefore, are often referred to as gas stoves. Some units may require the installation of insulating materials to protect combustible walls and floors from high temperatures.

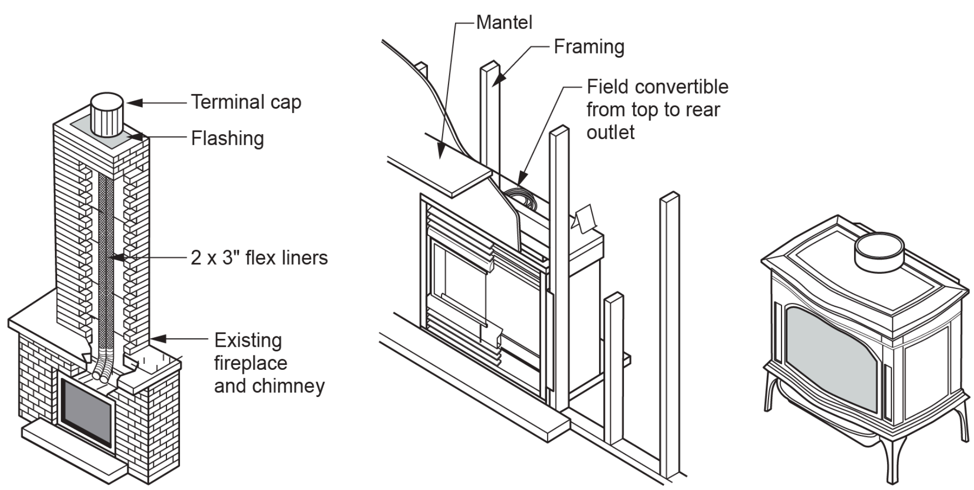

Figure 13 *Three common fireplace configurations: (left to right) fireplace insert, zero-clearance fireplace, and free-standing fireplace. (Skilled Trades BC, 2021) Used with permission.*

A type of gas fireplace to avoid in Canadian housing is the “vent-free gas fireplace,” which is available in the United States. These units do not vent to the outdoors; all the combustion gases are released directly into the house. Even though most of these fireplaces are equipped with an oxygen depletion sensor, they can still cause serious indoor air quality problems, particularly in airtight Canadian homes and are not approved for use in Canada.

Each fireplace will have some unique installation, operation, and maintenance procedures. Be sure to follow the manufacturer's instructions carefully to ensure proper clearances from combustibles and that approved venting materials are used.

The core component of the gas fireplace is called the engine. To maximize the number of exterior styles options, manufacturers will often have many different exterior casings for the same engine. The amount of installer onsite assembly will vary with different types of fireplaces. The optional features that have been ordered will also affect the installation. For example, some models may have a circulation blower, which requires a separate 120 VAC power outlet.

The installation of the venting system is one of the most important aspects of the gas fireplace installation. Manufacturers design fireplaces to give the maximum amount of installation flexibility, which often means multiple venting options for a single model such as:

- Direct vent coaxial top exit, horizontal or vertical termination (Figure 14)
- Direct vent coaxial rear exit, horizontal or vertical termination (Figure 15)
- Direct vent collinear top exit, vertical termination (Figure 16)
- Direct vent power vent (Figure 17)
- Natural draft B-vent (Figure 18)

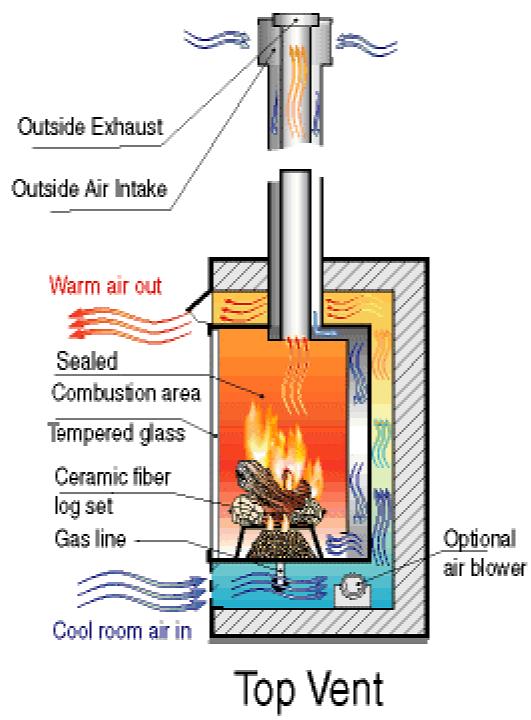

Figure 14 *Direct vent coaxial top exit, horizontal or vertical termination. (adapted from Chew/Fireside Group Inc., 2017). Used with permission.*

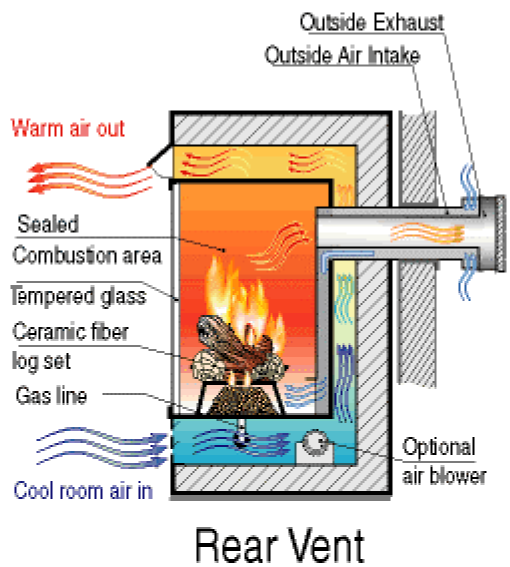

Figure 15 *Direct vent coaxial rear exit, horizontal or vertical termination. (adapted from Chew/Fireside Group Inc., 2017). Used with permission.*

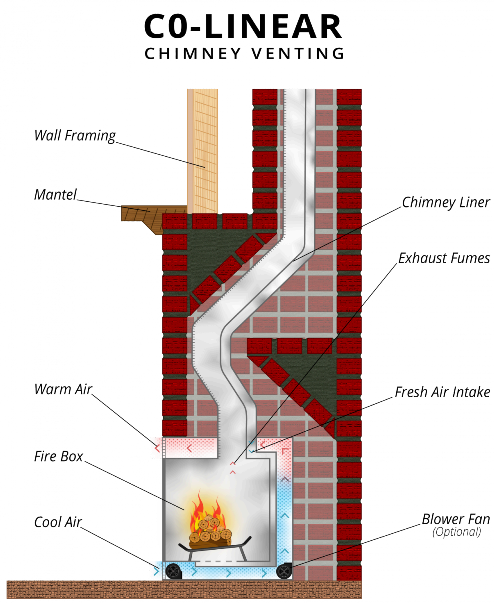

Figure 16 *Direct vent collinear top exit, vertical termination. (adapted from MFI, n.d.). Used with permission.*

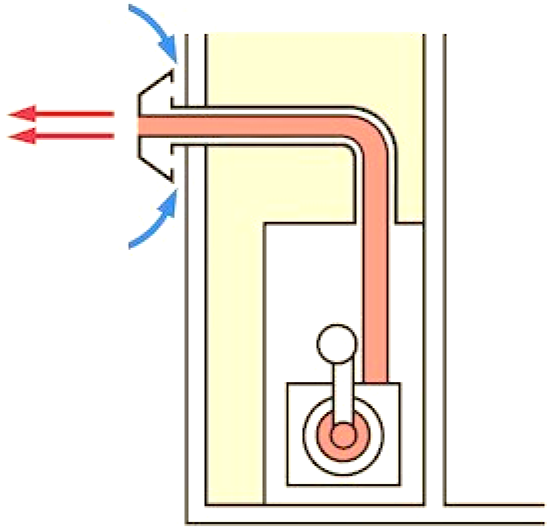

Figure 17 *Direct vent power vent. (adapted from ServiceWhale, n.d.). Used with permission.*

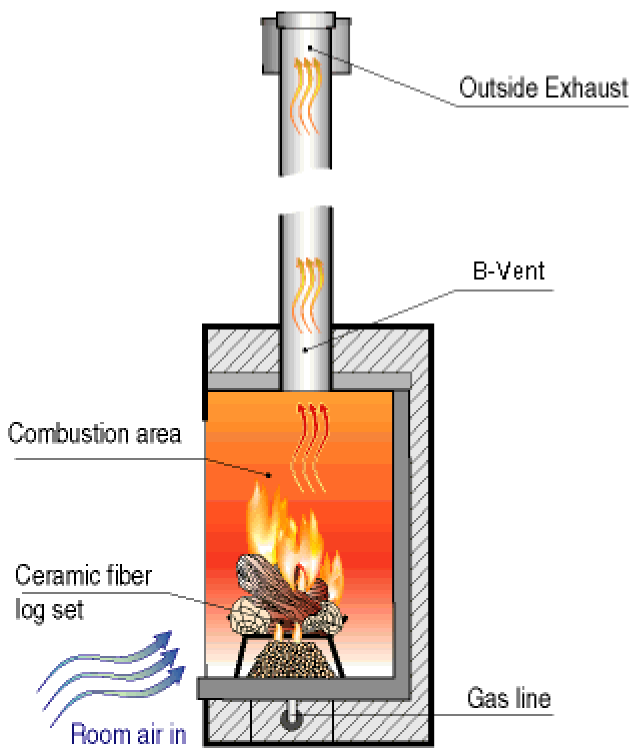

Figure 18 *Natural draft B-vent. (adapted from Chew/Fireside Group Inc., 2017). Used with permission.*

Often homeowners like to use gas fireplaces as an auxiliary backup heater in the event of a power outage. For those applications, a continuous pilot system used to be the best choice because those units did not rely on electricity for their burner operation. To meet efficiency standards, continuous pilot fireplaces are being phased out by DC voltage electronic ignition systems, which use common dry cell batteries as the backup or main power source. This gives intermittent pilot models the same auxiliary heat benefit as the continuous pilot models. The receiver/control module has a compartment to install four AA batteries or a separate battery holder that plugs into the module (Figure 19).

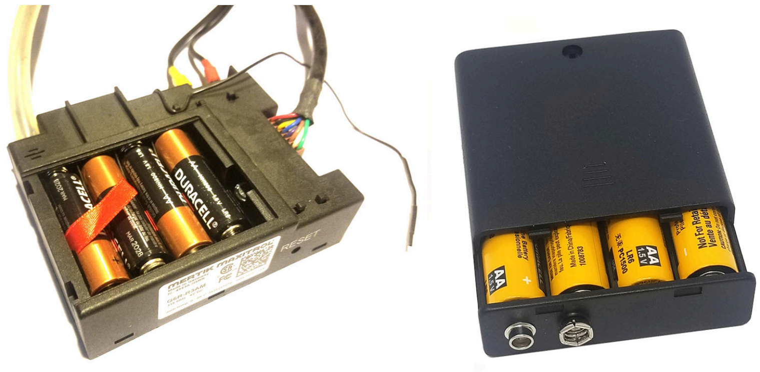

Figure 19 *DC Fireplace control module (left) or separate battery holder (right). (Skilled Trades BC, 2021) Used with permission.*

Firepits

Firepits are used as a focal point for outdoor entertaining. They are a decorative appliance that provides heat to the surrounding area. Typically, a firepit consists of concrete blocks placed on a base assembly (Figure 20). The burner is located at the bottom of the pit, and a grate assembly, covered with lava rock, is placed above the burner.

Figure 20 *Gas firepit. (Matt Bango/ StockSnap) CC0 (https://creativecommons.org/publicdomain/zero/1.0/)*

Water Heaters

Water heaters are used primarily to heat domestic water for bathing, cooking, cleaning clothes, washing dishes, and more. Some water heaters now provide the option of hydronic heating along with their domestic duties and are called “combination units.”

There are two basic design categories:

- Under-fired storage
- On-demand (tankless)

Storage Type

Automatic, under-fired storage tank heaters are the most common type of gas-fired water heater. In this type of water heater, the burner, storage tank, outer jacket, insulation, and controls are combined into one unit (Figure 21).

The ignition source for the burner may be a constant (standing) pilot, intermittent pilot, or direct ignition.

The products of combustion from the burner heat the bottom of the tank, then travel through a central pipe heat exchanger to the flue outlet. Within the heat exchanger is a flue baffle that slows down the vent gases to better take advantage of the heat. Incoming cold water is directed to the bottom of the tank near the burner through a pipe called a “dip tube.”

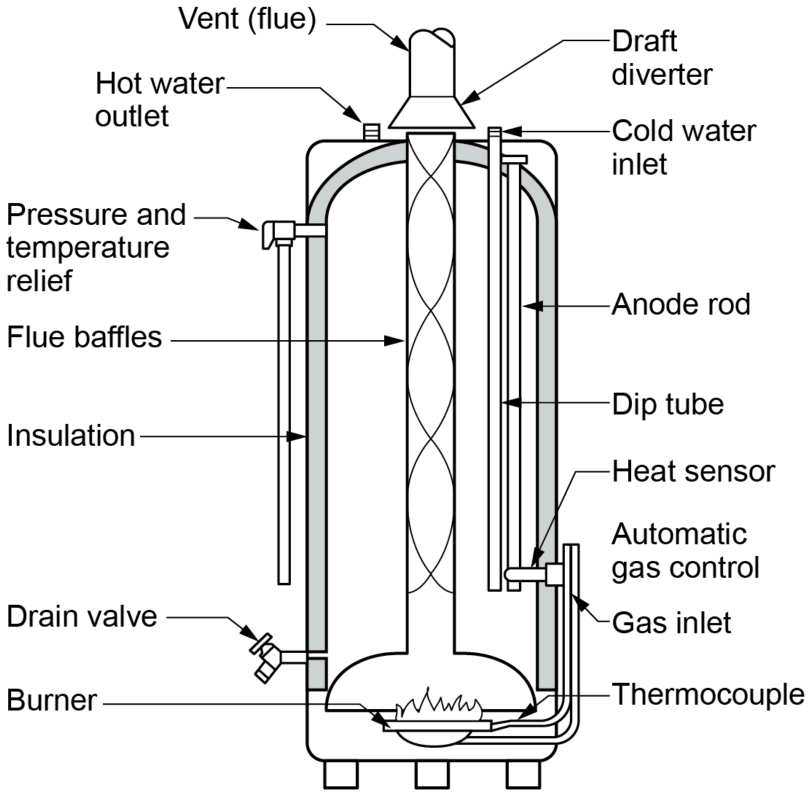

***Figure 21** Gas storage tank type water heater. (Skilled Trades BC, 2021) Used with permission.*

Gas storage water heaters are available with one of the following venting systems to best suit the installation: natural draft, direct vent, power vent, or power direct vent.

All newly installed 30- to 50-gallon residential gas storage water heaters with firing rates up to 75,000 BTUs/h must be equipped with a **flammable vapour ignition resistant (FVIR)** combustion chamber. Because the air intake is very low to the ground, the FVIR system is designed to prevent accidental or unintended ignition of flammable vapours outside of the combustion chamber. This is particularly applicable in garages, where spilled gasoline or other combustible fluids are prevalent.

The components of the FVIR burner assembly shown in Figure 22 are:

1. Stainless steel flame arrestor plate: provides a one-way path for air to travel through
2. Resettable thermal cut-off: shuts down the gas flow to the pilot and burner if flammable vapours enter the combustion chamber and ignite
3. Sight glass: provides view of the operation of the pilot and burner in the sealed chamber
4. Upshot multiport burner
5. Piezo igniter: ignites the pilot burner in the sealed chamber

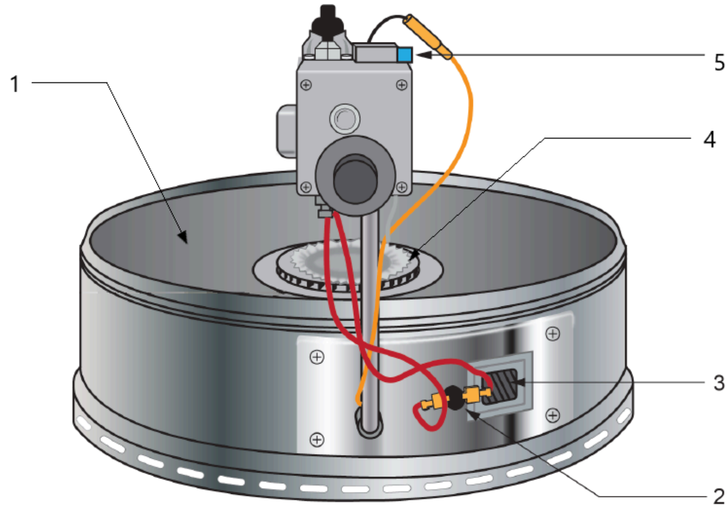

Figure 22 *FVIR burner assembly. (Adapted from Skilled Trades BC, 2021) Used with permission.*

Tankless Type

Instead of storing the heated water, tankless water heaters heat the water as it flows through the heat exchanger coils and delivers the heated water to the distribution piping on demand from the fixtures (Figure 23). The amount of hot water that tankless heaters can produce is expressed in gallons per minute, or litres per minute, which varies depending on the burner input and the difference in temperature between the incoming cold supply and the hot water delivery temperature setting. Tankless heaters have the advantage that, if they are sized correctly within their rated capacity (GPM) flow rate, they will deliver a constant supply of hot water.

The size of gas pipe to a tankless water heater is typically larger than that required for an under-fired storage water heater. This is necessary because the tankless style has a very high firing rate (normally ranging from 100,000 BTU/h to 200,000 BTU/h for residential units) compared to under-fired storage water heaters (normally 35,000 Btu/h to 80,000 BTU/h).

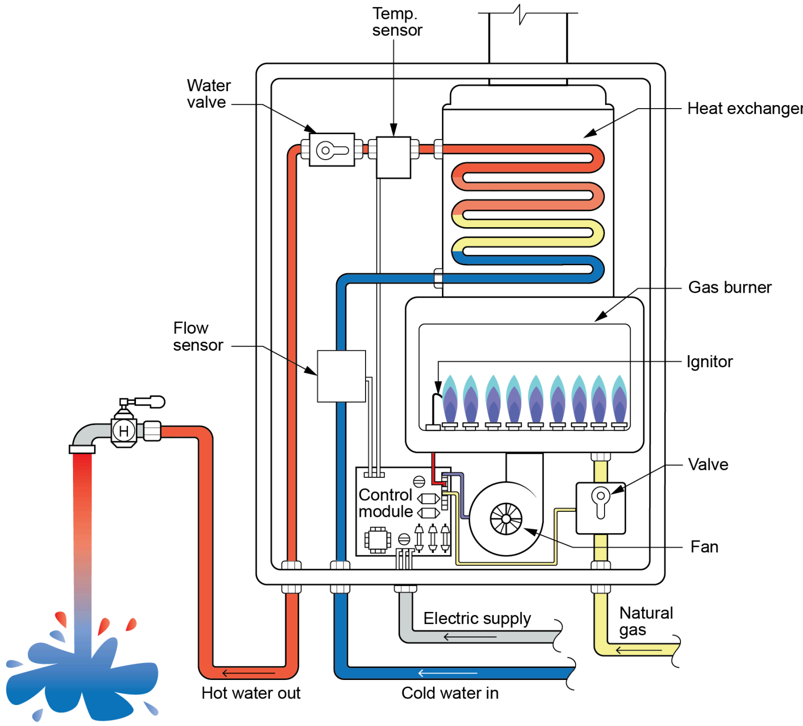

Figure 23 *Tankless water heater components and operation. (Skilled Trades BC, 2021) Used with permission.*

The basic operation of the on-demand system shown in Figure 18 is as follows:

1. A hot water faucet is opened.
2. Cold water enters the heater through the flow sensor, alerting the control module that hot water is needed.
3. The control module turns on the fan, opens the gas valve, and ignites the burner.
4. The water is drawn through the heat exchanger and heated by the gas burner.
5. The temperature sensor alerts the control module as the water temperature begins to rise.
6. The control module may reduce the gas valve's flow rate, which modulates the burner flame as the desired water temperature is reached.
7. When the hot water faucet is closed, the flow sensor signals the control valve to turn off the unit.

Tankless water heaters are typically available as condensing indoor direct vent units, as well as outdoor units (Figure 24). Outdoor units are unvented because they receive their combustion air from the environment around them and expel the exhaust the same way.

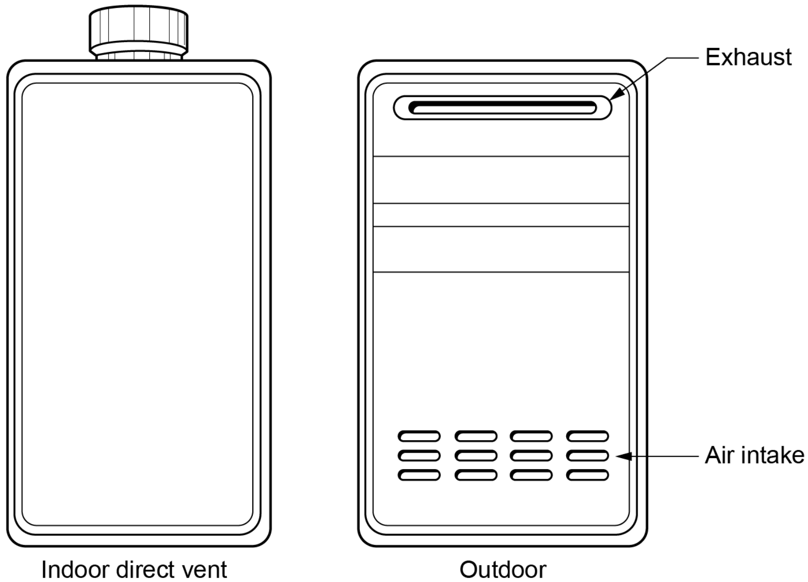

Figure 24 *Tankless water heaters. (Skilled Trades BC, 2021) Used with permission.*

Plumbers often install a hot water recirculation system to ensure immediate hot water at distant fixtures. The low recirculation flow rate and very low heat demand that occur during recirculation are difficult for a standard on-demand water heater to accommodate. If a recirculation system is used with a tankless water heater, the water heater must be approved for recirculation. The approved models, sometimes referred to as hybrids, use a small storage tank (buffer tank) immediately after the heat exchanger (Figure 25). By using a circulating pump with the buffer tank, water can be circulated through the buffer tank and system without operating the tankless heater until the water temperature leaving the buffer tank drops below the setpoint. Water is then diverted through the tankless heater for reheat.

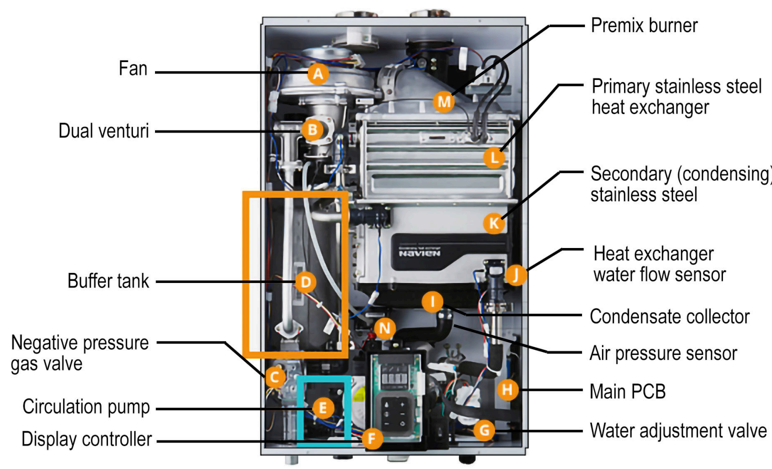

Figure 25 *Hybrid tankless water heater. (Skilled Trades BC, 2021) Used with permission.*

Furnaces

Many houses and small commercial buildings use a central forced air system for space heating. This section focuses on the heart of the system, the furnace, which includes a blower that circulates the air through a heat exchanger through ductwork to the rooms. Forced air heating systems will be discussed in greater detail in B-1.3 Residential Forced Air Heating Systems.

Although the minimum efficiency for residential furnaces sold in Canada is now 90%, a gasfitter can still be expected to work on older, lower-efficiency models. Some common terms used to classify furnaces by their efficiency are:

- Conventional furnace, standard-efficiency, or low-efficiency: below 78% efficient
- Medium or mid-efficiency (sometimes called standard-efficiency): 78% to 89% efficient
- High-efficiency or condensing: 90% efficient and above
- Energy Star: 95% efficient and above

A modern high-efficiency furnace could work as a standalone heat source or could be used as a companion to other heating, **ventilation**, air conditioning, and refrigeration (HVACR) equipment. For example, a furnace can be a single-stage, two-stage, or multi-stage (modulating) model and can be combined with a heat pump, solar system, air conditioning, or any other alternate heating or cooling source. This can be challenging for installers and service technicians, so a strong understanding of all the components and installation requirements is necessary.

A condensing furnace uses two heat exchangers, a primary and secondary. The secondary heat exchanger is much more restrictive to the flue gas, allowing more heat energy to be removed to the point that condensing occurs (Figure 26).

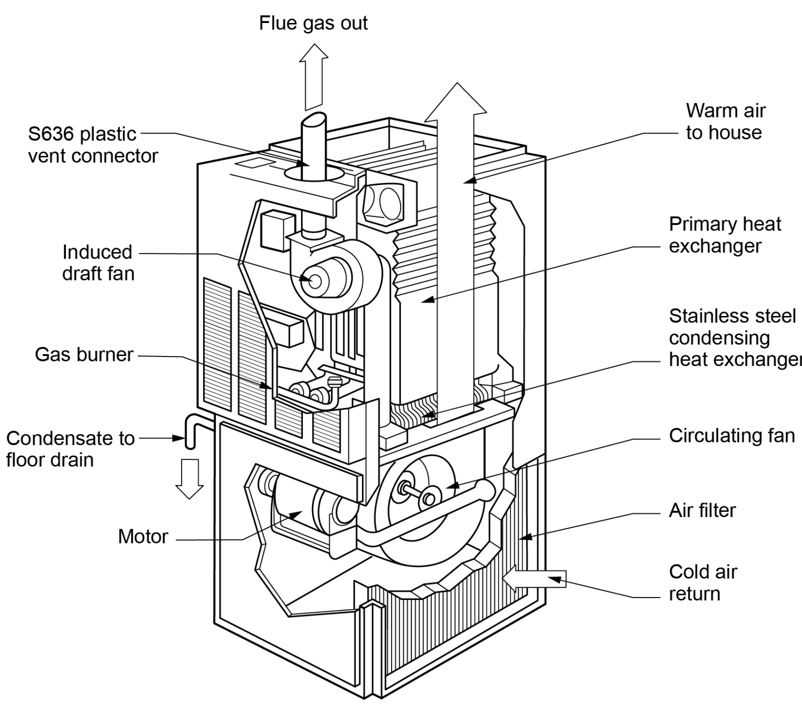

Figure 26 *High-efficiency gas furnace. (Skilled Trades BC, 2021) Used with permission.*

Because of the restrictive nature of the secondary heat exchanger and the loss of heat energy from the flue gas, the appliance cannot vent naturally. The inducer fan must be able to draw the flue gas from the secondary heat exchanger and create sufficient pressure to force it through the venting system to the outdoors.

Since the venting system operates with a positive vent pressure and lower flue gas temperatures, a plastic sealed vent is typically used.

Hot Water Boilers

Domestic and commercial space heating is commonly done with hydronic heating systems. The information here is a very brief introduction to gas hot water boilers, which are one of the more common hydronic heating energy sources. Hydronic heating systems will be discussed in greater detail in B-2 – Hydronic Heating and Cooling Generating Equipment (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/chapter/b-2-hydronic-heating-and-cooling-generating-equipment-introduction/).

A hot water boiler is completely filled with water, and the combustion control system is used to maintain a preset operating temperature in the boiler water space. Hot water produced by a boiler is pumped through piping and delivered to heat-emitting equipment throughout the building. Once the heat has been extracted, the water is returned to the boiler through heating return mains, and the cycle begins again.

Boilers can be classified in many ways, such as by the fuel they use, heat output rating, construction material, heat exchanger geometry, and methods for exhausting combustion gases. However, from the standpoint of hydronic heating system design, it is important to distinguish between conventional "non-condensing" boilers and condensing boilers. Conventional boilers (Figure 27, left) are intended to operate so that the water vapour produced during combustion does not condense on a sustained basis within the boiler combustion chamber. Nearly all boilers with cast iron, carbon steel, or copper heat exchangers fall into this category.

The inlet water temperature at which condensation begins to form on the boiler's heat exchanger is approximately 54°C (130°F). This temperature is known as dewpoint. The lower the entering water temperature, the more condensate that forms. Therefore, it is imperative that conventional boilers are operated with inlet water temperatures above 60°C (140°F) so that sustained flue gas condensation does not occur within the boiler.

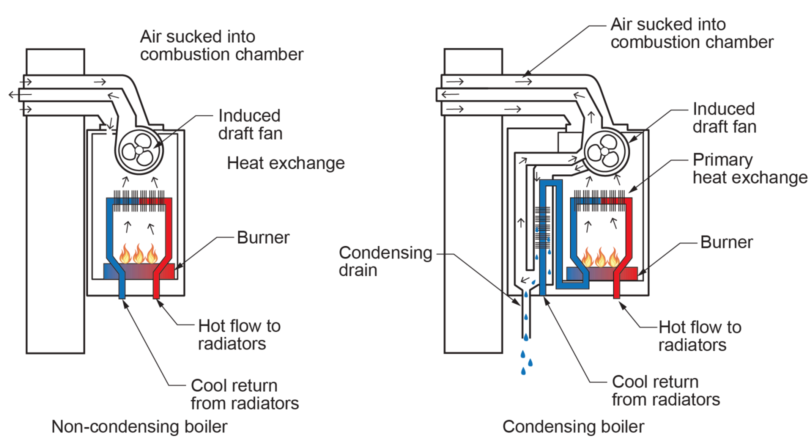

Figure 27 *Boiler types. (Skilled Trades BC, 2021/adapted from Gas Boilers, 2019) Used with permission.*

Condensing boilers are constructed with more heat exchanger surfaces made of stainless steel or aluminum. These heat exchangers are capable of extracting more heat from the exhaust gases compared to the heat exchangers used in conventional boilers. When operated with suitably lower inlet water temperatures, these boilers can easily cool the exhaust stream below the dewpoint temperature of the water vapour, thus causing condensation to occur (Figure 27, right). The lower the entering water temperature, the greater condensing and efficiency it will achieve.

Nearly all condensing boilers can vary their heat output from a maximum rate down to approximately 20% of that maximum output. These boilers are said to be modulating and often referred to as "mod/con" boilers (Figure 28).

Figure 28 *Wall-mounted Mod/Con Boiler. (Rod Lidstone)* CC BY 4.0 *(https://creativecommons.org/licenses/by/4.0/legalcode.en)*

Condensing boilers can provide significant energy savings due to operating efficiencies, from as high as 98%, compared to a peak efficiency of 87% for a conventional boiler. However, installing a condensing boiler does not guarantee achieving anticipated savings. A condensing boiler is not a compact LED light bulb; an installer cannot simply plug it into a typical system and expect it to save energy. Careful attention must be paid to the heating water system as a whole.

Designing an energy-efficient heating system using condensing boilers is completely different than designing a conventional boiler system, where the goal is to keep the boiler return water temperature above 60°C (140°F). This difference requires significant variations in systems, including distribution piping design, operating system temperatures, heat emitter selection, boiler sequencing, and system control.

If an existing system cannot be redesigned to return water near or well below 54°C (130°F) for a good portion of the heating season, consider a non-condensing boiler, which can operate with an efficiency of up to 87% with a return water temperature of 60°C (140°F). Depending on market demand and efficiency regulations in the area, however, a non-condensing boiler may not be available. In this case, system design modifications will be required in addition to the boiler replacement.

Steam Boilers

Steam heating is not commonly used for domestic purposes. Steam boilers (Figure 29) are used to heat large spaces or used in industrial processing. A steam boiler is partially filled with water, and a space at the top of the boiler allows steam to accumulate. The combustion safety control system monitors the pressure in the steam space. As steam is drawn from the boiler, the pressure drops and the boiler fires to generate more steam.

The pressurized steam can flow from the boiler through piping, unaided by an external energy source, such as a pump. Once the steam utilization equipment takes advantage of the latent heat in the system, steam traps allow the condensate to enter the condensate return main. The condensate is collected in a tank and returned to the boiler by a pump, as required, to maintain the boiler water level.

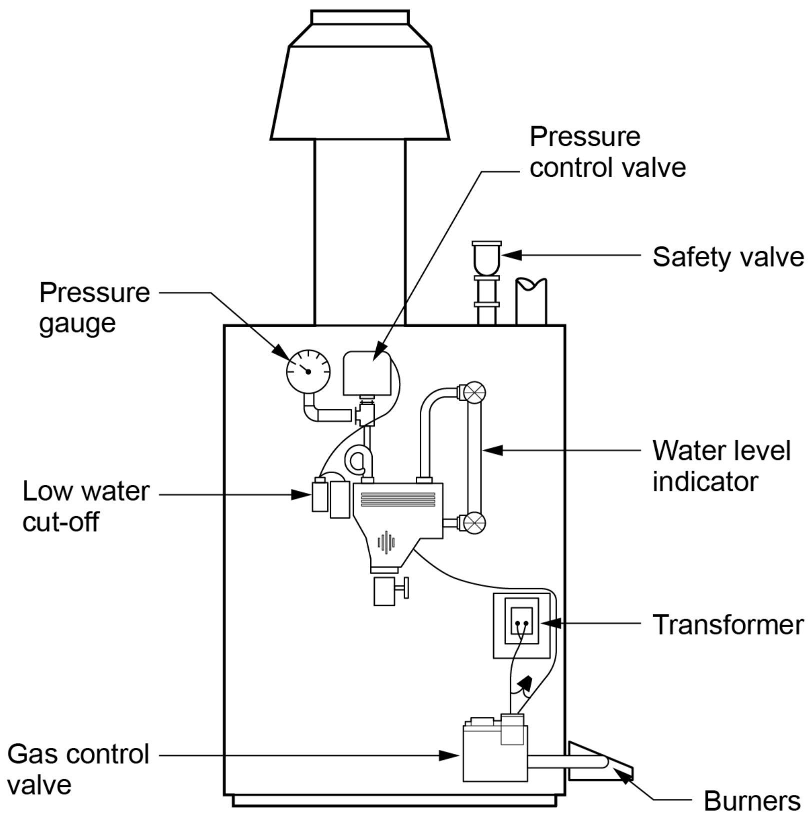

Figure 29 *Steam boiler. (Skilled Trades BC, 2021) Used with permission.*

Self-Test A-1.2: Types of Gas Fired Appliances

Complete Self-Test A-1.2 and check your answers.

If you are using a printed copy, please find Self-Test A-1.2 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=33#h5p-3 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=33#h5p-3)

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- **Figure 1** Domestic gas range (https://www.maytag.ca/en_ca/kitchen/cooking/ranges/single-oven-freestanding/p.MGR8800FZ.html) (Model: MGR8800FZ) is from Maytag Canada (n.d.) and is used with permission for educational purposes only.
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- **Figure 4** Image originally adapted from Model UGP-9RV-SSO-C-REV-E (https://uniqueappliances.com/collections/refrigerators-freezers/products/unique-10-cu-ft-white-propane-refrigerator-with-co-alarming-device) by Unique Off Grid (n.d.) under Fair Dealing Guidelines for educational purposes.
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- **Figure 17** *Direct vent (https://servicewhale.com/pages/what-is-power-vent-water-heater) vs power vent* (left side – adapted) from "What is power vent water heater?" by ServiceWhale, (2021), is used with permission.
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- **Figure 27** Boiler types was originally adapted from Gas Boiler Diagram: the Basics Everyone Should Know | Gas

Boilers (gasboilerguide.com) (https://gasboilerguide.com/gas-boiler-diagram/) by Trades Training BC (2021).

- **Figure 28** Wall-mounted Mod/Con Boiler, by Rod Lidstone, is used under a CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/legalcode.en) license.

A-1.3 Documents, Regulations and Specifications

Before installing any gas-fired appliance, it is important to review all the following information to ensure the installation will conform to the necessary requirements:

- Manufacturer's specifications
- Applicable codes
- Installation, operation, and service instructions

If there is a discrepancy between the manufacturer's instructions and the codes — for example, in terms of clearances of vent terminations — the most stringent requirements shall prevail. The authority having jurisdiction (AHJ) can provide guidance in case of conflicting requirements.

Failure to follow the manufacturer's instructions may result in:

- Fire or explosion hazards
- Personal injury or fatalities
- Operating and service problems
- Equipment damage

Manufacturer's Specifications

Manufacturer's specification sheets (or datasheets) summarize the performance and other technical characteristics of a product in sufficient detail to enable a tradesperson to integrate the component into a system. Typically, the product manufacturer creates a spec sheet. Figure 1 shows an example of the performance section of a spec sheet for a storage-type gas water heater.

PERFORMANCE									
Tank Warranty	Model	Series	Capacity	Input	Recovery Rate at 90°F Temperatue Rise	First Hour Rating	Energy Factor	UEF	BC/ON Compliant
Years***			USG (L)	BTU/h	GPH(LPH)	GPH(LPH)			
NATURAL GAS									
6	G640S40N-PDV-ES2	300/301	40 (151)	40,000	45 (170)	71 (269)	0.71	0.68	✓
6	G650T45N-PDV-ES2	300/301	50 (189)	45,000	50 (189)	93 (352)	0.70	0.72	✓
6	G650T62N-PDV-ES2*	300/301	50 (189)	62,000	73 (276)	100 (379)	0.71	0.73	✓
6	G675T72N-PDV-ES2*	300/301	75 (284)	72,000	82 (310)	154 (582)	0.69	0.68	✓

For propane models sub N for P. Natural gas models are series 300. Propane models are series 301.
All models rated for installation at altitudes up to 10,100 ft (3,078 m)
***In residential applications. Reduced warranty in commercial applications. Parts warrantied for 1 year.
*Side connections standard.

Figure 1 *Gas water heater performance table. (Skilled Trades BC, 2021/ adapted from original GSW, n.d.) Used with permission. Long description (#Fig1_longdesc)*

Rating Plates

Notice that the manufacturer's specifications shown in Figure 1 supplied information regarding more than one model of this product line. To confirm the actual model, an installer will need to check the information found on the **rating plate** attached to the appliance at the factory. Figure 2 shows two examples of gas hot water boiler rating plates. The boiler on the left is a modern modulating condensing type, and the one on the right is a conventional atmospheric boiler.

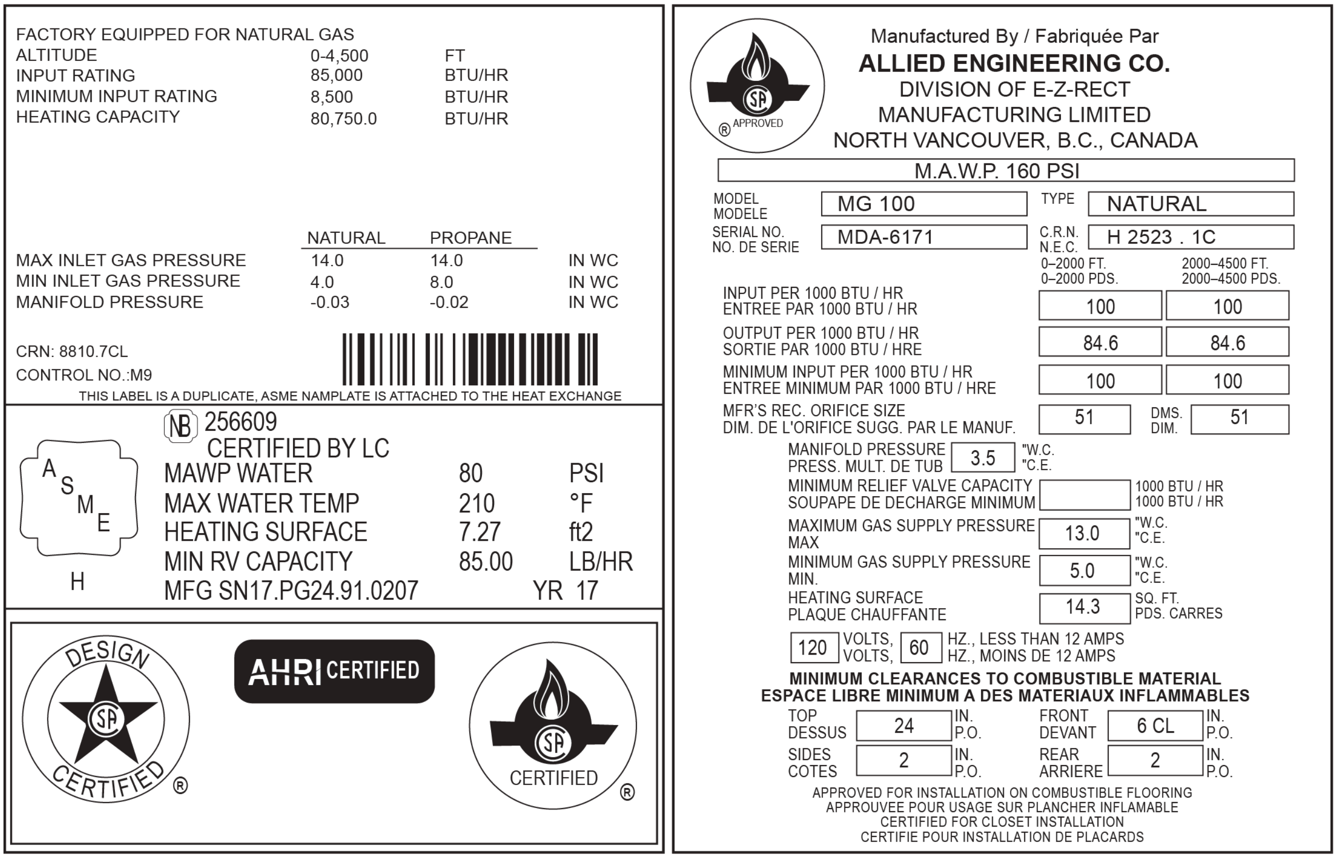


***Figure 2** Hot water boiler rating plate. (Skilled Trades BC, 2021) Used with permission. Long description (#Fig2_longdesc)*

Depending on the type of appliance, some of the common information shown on rating plates include:

- Approvals by regulating authorities and agencies
- Input rating
- Heat output (BTU/h, LPH, LB/h)
- Approved altitude
- Gas supply pressure (minimum and maximum)
- Gas manifold pressure (high fire and low fire)
- Orifice size
- Temperature rise
- Static pressure range (force air furnaces)
- Maximum water pressure (boilers and water heaters)
- Maximum water temperature (boilers and water heaters)
- Minimum relief valve capacity (lb/h steam or BTU/h)
- Appliance clearances
- Operating voltage and current
- Maximum overcurrent protection
- Electric motor HP

Approvals

Gas industry and governmental regulatory agencies must approve all gas appliances before they are sold by the manufacturer. Regulatory authorities recognize the service of third-party **certification organizations** and demonstrate their approval by insisting that gas appliances be certified by a recognized certification organization.

Certification Organizations

Where a nationally recognized standard exists, the accredited certification organization applies the certification symbol. The official logo, symbol, or seal that indicates the certification of the appliance appears on the appliance's rating plate. The Standards Council of Canada regulates the certification symbols that must appear on the rating plate of a gas appliance sold in Canada. The table in Figure 3 shows the certification/approval marks that are recognized for gas appliances.

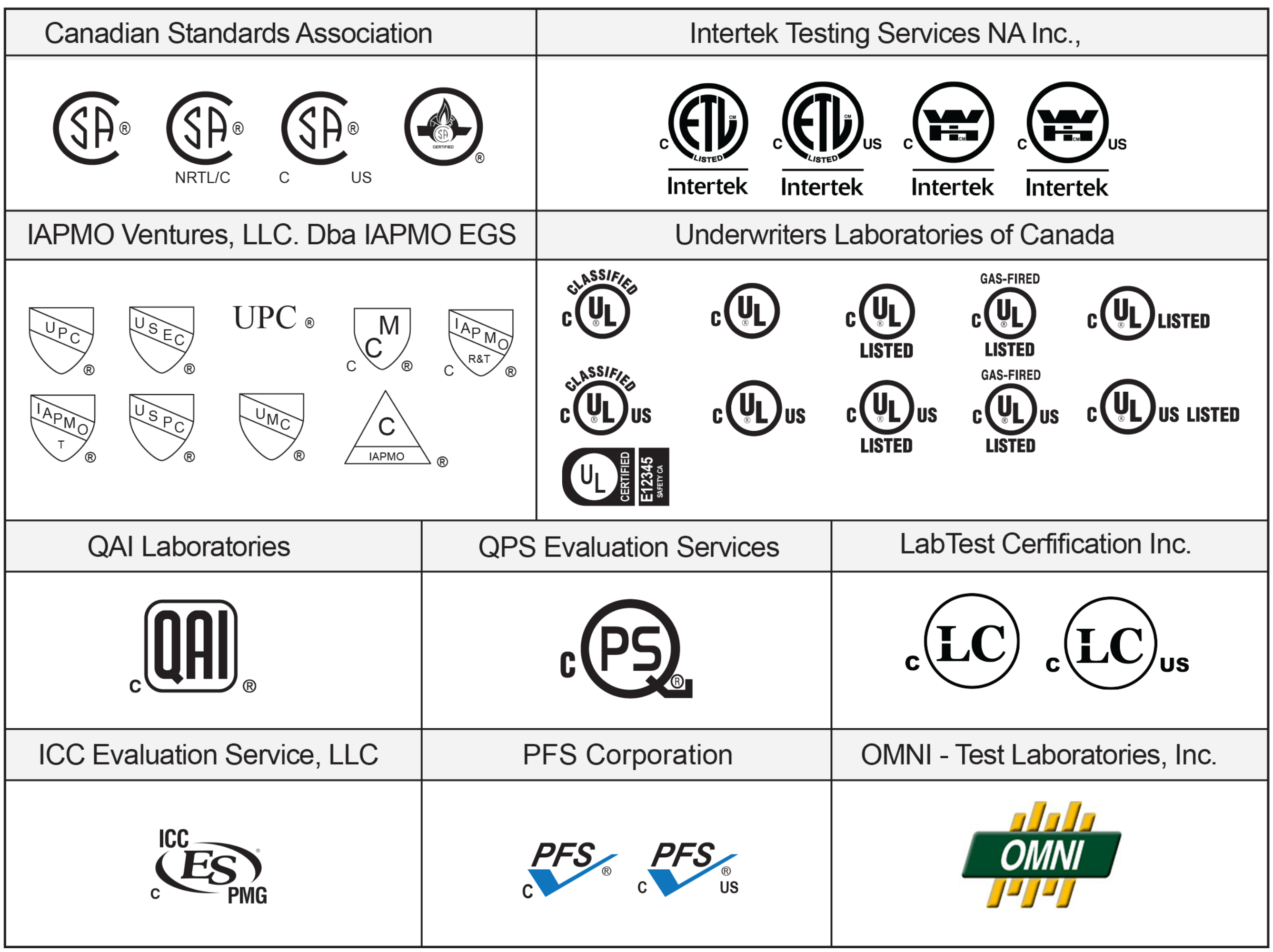
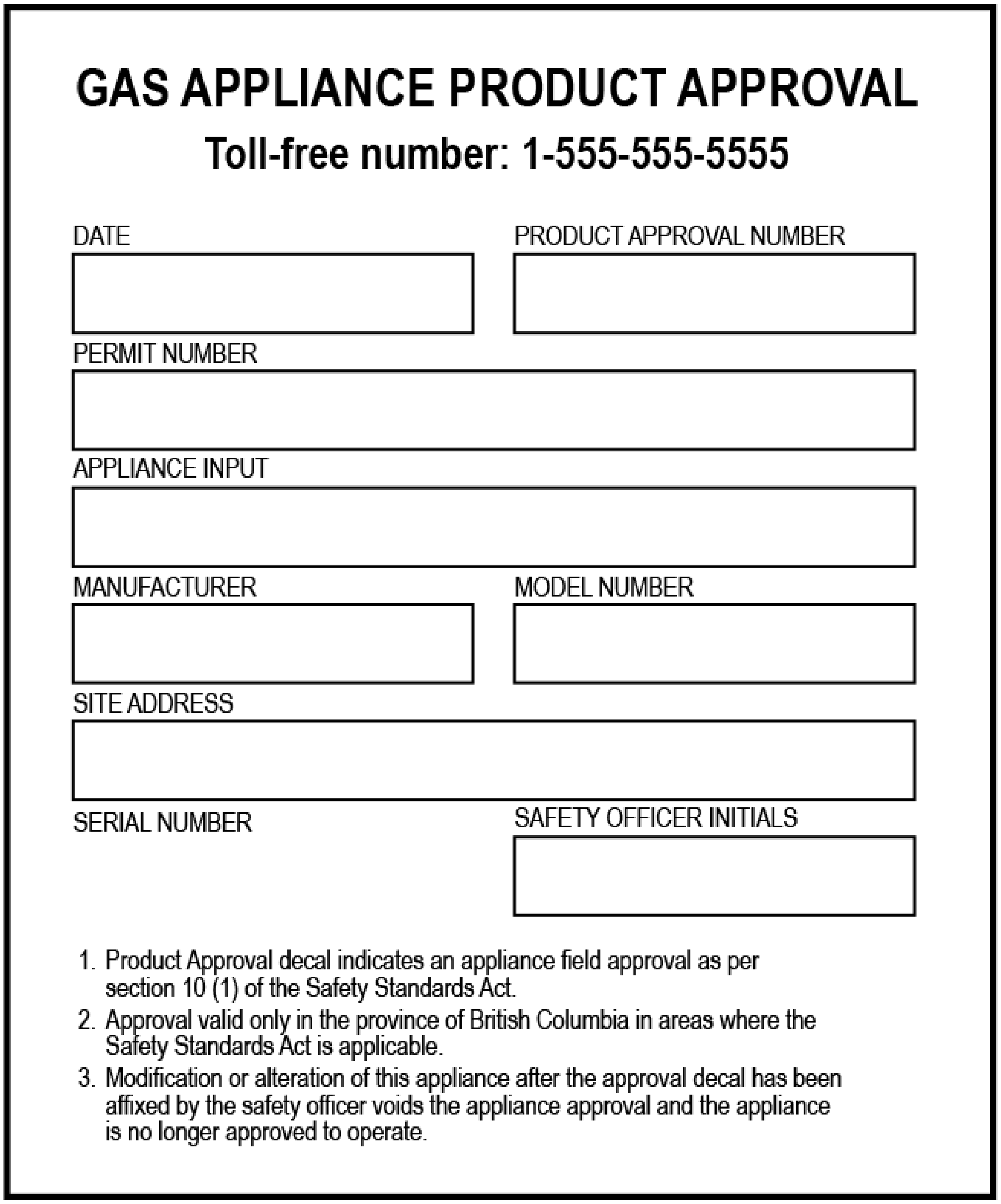


***Figure 3** Accredited certification body marks. (Skilled Trades BC, 2021) Used with permission. Long description (#fig3_longdesc)*

For special gas equipment where a nationally recognized standard does not exist, an inspection body accredited by the

Standards Council of Canada is permitted to apply an approval label. This is also known as a "field approval," and it is void if the appliance is altered or relocated after its original inspection. Figure 4 is an example of a provincial inspection body's product approval label.



GAS APPLIANCE PRODUCT APPROVAL

Toll-free number: 1-555-555-5555

DATE

PRODUCT APPROVAL NUMBER

PERMIT NUMBER

APPLIANCE INPUT

MANUFACTURER

MODEL NUMBER

SITE ADDRESS

SERIAL NUMBER

SAFETY OFFICER INITIALS

1. Product Approval decal indicates an appliance field approval as per section 10 (1) of the Safety Standards Act.
2. Approval valid only in the province of British Columbia in areas where the Safety Standards Act is applicable.
3. Modification or alteration of this appliance after the approval decal has been affixed by the safety officer voids the appliance approval and the appliance is no longer approved to operate.

Figure 4 *Gas appliance field approval decal. (Skilled Trades BC, 2021) Used with permission. Long description (#Fig4_longdesc)*

Additionally, boilers and storage water heaters must be designed, constructed, and inspected to the appropriate boiler pressure vessel code and stamped accordingly. The American Society of Mechanical Engineers (ASME) uses various markings to indicate products that they certify. Figure 5 shows some of these approval markings.

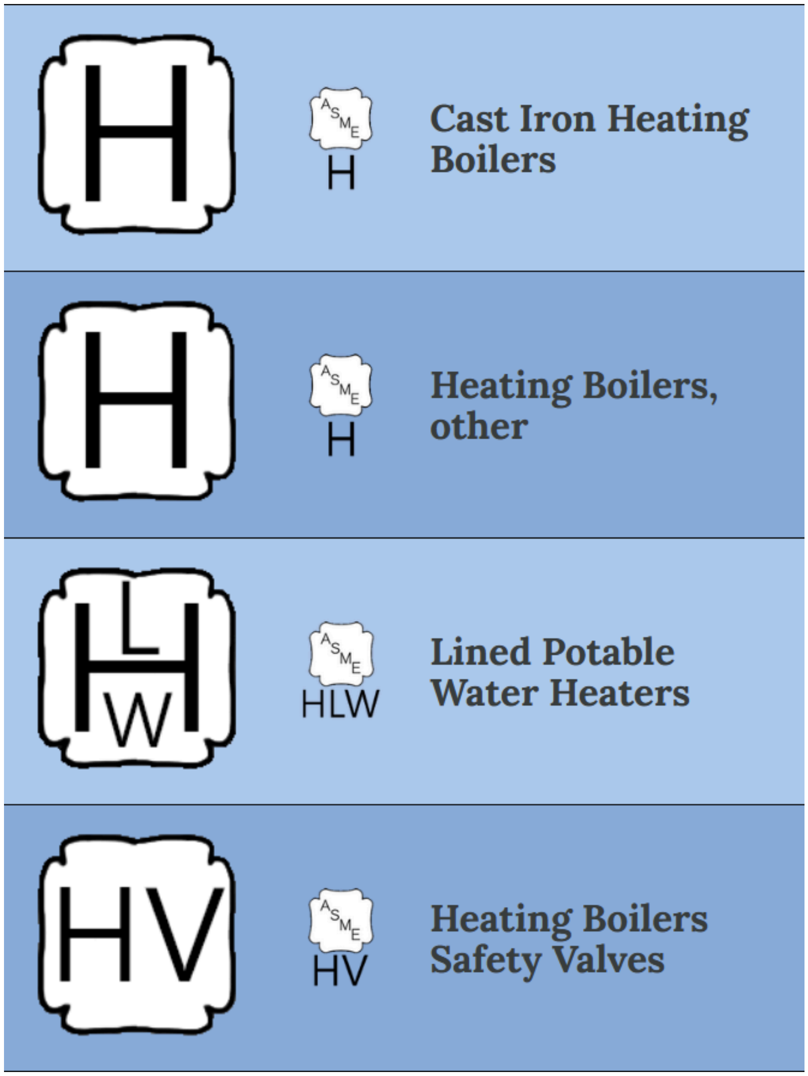


Figure 5 *Sample certification stamps by from the American Society of Mechanical Engineers ([modified] ASME (https://www.asme.org/), n.d.). Used with permission. Long description (#Fig5_longdesc)*

Heat Output

The **heat output** represents how much of the heat from the combustion process (input energy) is transferred into the product being heated. For a water heater, the output is called the recovery rate, which represents the amount of water that can be heated to a specific temperature every hour. Figure 6 shows two water heater rating plates. The one on the left, from a tankless unit, has a recovery rating of 183.3 GPH, whereas the label on the right, from storage tank type unit, has a recovery rating of 136.72 GPH. Both water heaters could be used for similar load requirements considering that the storage heater has 60 gallons of reserve capacity in the tank.

Figure 6 *Water heater rating plates. (Skilled Trades BC, 2021) Used with permission. Long description (#fig6_longdesc)*

If a water heater recovery rate needs to be converted to BTU/hr, the installer will need to know the temperature rise that the rating was based on; for example, the gas water heater performance table shown in Figure 1 stipulated that the recovery rate was based on a 90°F temperature rise. The volume referred to is typically US gallons; therefore, the first storage tank in Figure 1 would have a BTU/hr heat of:

$$45 \text{ GPH } \times 8.33 \text{ lb/US Gallon } \times 90^{\circ}\text{F}\Delta\text{T} = 33\,737 \text{ BTU/h}$$

These manufactures heat output ratings are based on the efficiency of the unit when it is in steady state conditions. Steady state refers to the efficiency of the unit when the system is running continuously, without cycling on and off. This steady state efficiency can be measured by performing a flue gas analysis and concluding the amount of energy being lost into the vent.

Steady state does not give a true measurement of the system's seasonal efficiency, since it does not account for the cycling or standby losses that take place over the course of the heating season. For example, older gas furnaces may have steady state efficiencies of 78% to 80%, but seasonal efficiencies could be 20% lower, partly due to their standing pilot lights.

Energy Efficiency Standards

Most gas appliances are subject to Canada's Energy Efficiency Regulations, which set a minimum performance standard for their energy efficiency. The regulation will also identify the Canadian Standards Association (CSA) performance testing procedure. Some provinces also have their own **energy efficiency regulations or standards** for many federally regulated products.

The accepted benchmark for seasonal efficiencies in heating equipment is the Annual Fuel Utilization Efficiency (AFUE) measure. This rating is influenced by how the furnace is vented, if it has a standing pilot, and its cycling performance.

Separate EnerGuide information appears on manufacturers' product literature. On the appliance, there is also a separate EnerGuide label or an addition to the rating plate.

For more information, visit the EnerGuide (https://www.nrcan.gc.ca/energy-efficiency/energuide/12523) website.

An appliance may have both the black-and-white Canadian EnerGuide label and the black-and-yellow American EnergyGuide. Figure 7 shows examples of these labels.

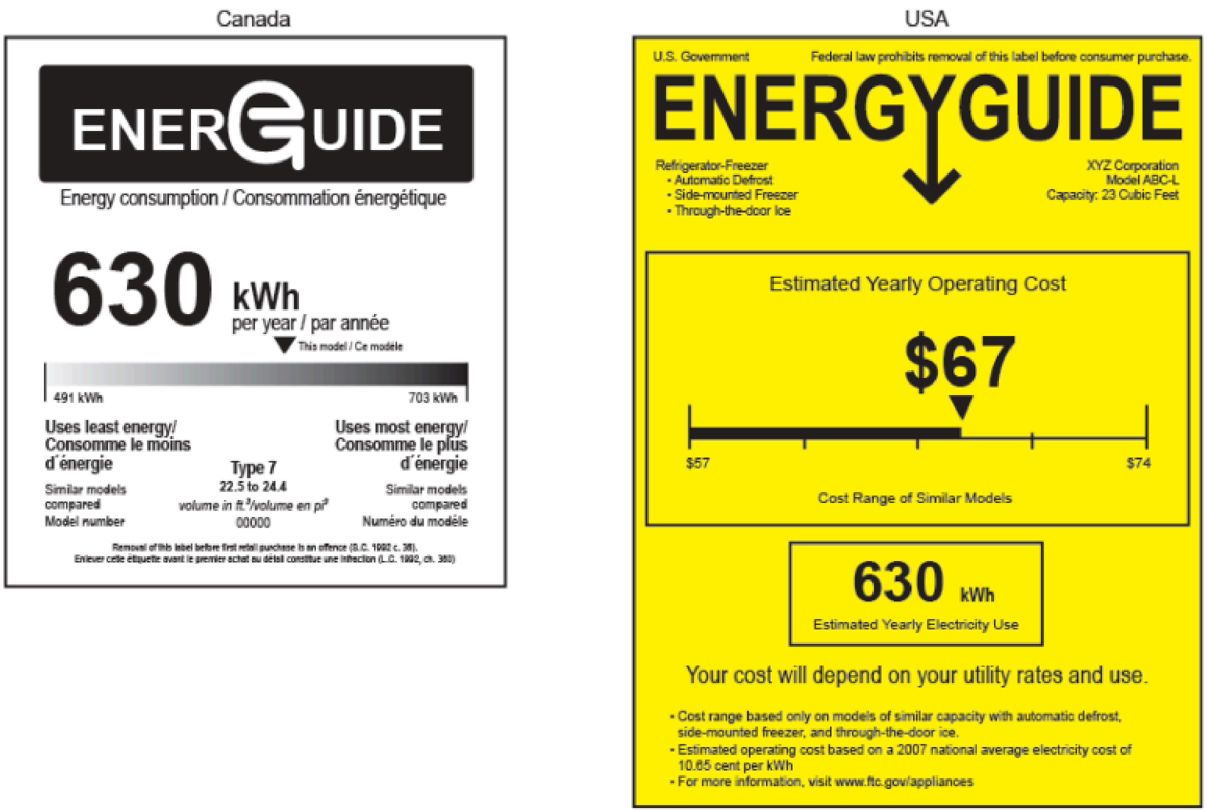


Figure 7 *Canadian and American energy efficiency labels. (Government of Canada) Non-Commercial Reproduction (https://natural-resources.canada.ca/terms-and-conditions/10847)*

The Canadian EnerGuide information labels display four main items:

1. Annual energy consumption of the model in kilowatt hours (kWh)
2. An energy consumption indicator, which positions the model compared with the most efficient and least efficient models in the same class
3. Type and capacity of models that make up this class
4. Appliance model number

ENERGY STAR® Canada is a voluntary partnership between the Government of Canada and industry to make high-efficiency products readily available and visible to Canadians. More than 1,000 businesses and organizations across the country have signed a formal arrangement with Natural Resources Canada (NRCan) to promote energy efficiency in the manufacture, sale, and operation of products and equipment. Participants include manufacturers, retailers, utilities, energy efficiency, environmental advocates, and provincial, territorial, and municipal governments.

The ENERGY STAR symbol (Figure 8) identifies products that have met or exceeded technical specifications for high efficiency.

Figure 8 The ENERGY STAR® symbol is a registered trademark in Canada by the U.S. Environmental Protection Agency and is administered and promoted by Natural Resources Canada. Used with permission.

Installation, Operation, and Service Manuals

Most appliances are supplied with manufacturers' instructions. These provide information on the installation, operation, service, and maintenance requirements.

Information contained in the instruction manual typically includes:

- **Safety instructions:** for liability reasons, these can be extensive, often including warnings against doing things that no reasonable person would ever consider.
- **Assembly instructions:** for products that arrive in pieces for easier shipping.
- **Component diagrams:** for identifications of each component and cross references to numbers for replacement parts.
- **Installation instructions:** for field installation of the equipment.
- **Set-up instructions:** for devices that keep track of time or temperature, which maintain a user-accessible state.
- **Normal usage instructions.**
- **Programming instructions:** for microprocessor-controlled products, such as boiler control, programmable thermostats, and building automation controllers.
- **Wiring diagrams:** for identification of field wiring as well as integral component schematics and ladder diagrams for troubleshooting purposes.
- **Maintenance instructions.**
- **Troubleshooting instructions:** for when the product does not work as expected.
- **Service locations:** for when the product requires repair by a factory authorized technician.
- **Regulatory code compliance information:** for example, with respect to different regional vent termination clearances.
- **Product technical specifications.**
- **Warranty information:** sometimes provided as a separate sheet.

Depending on the type of equipment and complexity this information can become too vast for one manual, in which case the information is often compiled into two separated manuals:

- **Installation manual:** contains detailed installation and operation information.
- **Owner's manual:** contains service and maintenance information and basic operating instructions.

Once the equipment is installed, these instructions should be left with the customer for future reference.

Other Installation Requirements

Along with the manufacturer's certified installation instructions, all installations must also conform to the requirements of applicable building, gas, and electrical codes. Part 7 of the CSA B149.1 outlines specific types of appliances, and Part 4 of the CSA B149.1 contains general requirements. Be sure to consult and review these sections when installing any gas appliance.

Warranty

The standard equipment **warranty** is a commitment from a manufacturer that a product has no defects at the time of manufacture. Services, such as repairs and partial or complete exchange of defective parts, are guaranteed for a particular period of time.

An extended warranty — sometimes called a service agreement, a service contract, or a maintenance agreement — is a prolonged warranty offered to consumers in addition to the standard warranty on a new item. Extended warranties cost extra, usually a percentage of the item's retail price.

All products must be properly registered online by the purchaser within a specified period, typically 60 days after the commissioning date, to receive the registered warranty terms. Registration is typically done online and may have to be completed by the certified installer to ensure the appliance was properly installed, operated, and maintained by a licensed professional. To make a warranty claim, the manufacture may request written documentation showing the proper preventive maintenance.

Typically, all damaged parts replaced under warranty must be returned to the manufacturer.

Web Sourcing Manufacturer Documents

All equipment manuals must be left with the customer for future reference on site. However, if the owner misplaces these, they would not be available to the installer for future reference. Fortunately, most manufacturers offer PDF copies of manuals that can be accessed or downloaded from their websites. This has the added advantage of providing convenient access to information for all the current makes and models, as well as archives of discontinued equipment.

Most equipment manufacturers' websites are set up in a similar format so that the navigation and sourcing of information is quite intuitive. A typical manufacturers' website has the following menus and features:

- **Site search:** a search tool that enables the user to enter a term and search the manufacturers' website for matching results.
- **Contact information:** may include contacts for technical support, warranty validations, and customer service.
- **Dealer locator:** with built-in Google Maps integration.
- **Products:** for searching the entire range of products available; often separated by application, such as residential or commercial.
- **Resources:** contains a library of downloadable documents for each product, including product brochures, videos, news items, specification sheets, and manuals.
- **Emergency call number.**

- **Warranty:** for registering the appliance or filing claims.
- **Parts:** for searching and ordering replacement parts; typically, electronically searchable with the component serial number.

This web information is often compiled into separate user sections for homeowners, contractors, and engineers. This also enables the manufacturer to limit access to some propriety documents, by requiring contractors or engineers to register with the manufacturer prior to accessing certain information.

Self-Test A-1.3: Documents, Regulations, and Specifications

Complete Self-Test A-1.3 and check your answers.

If you are using a printed copy, please find Self-Test A-1.3 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=35#h5p-4 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=35#h5p-4)

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- **Figure 1** Product performance table is originally adapted from Spec Sheets & Manuals – GSW Water Heaters Canada (gsw-wh.com) (https://gsw-wh.com/spec-sheets-manuals/) by Trades Training BC (2021) for educational purposes only.
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Long Descriptions

Figure 1 Long Description: Performance Specifications for a Series of Natural Gas Water Heaters

(Skilled Trades BC, 2021/ adapted from original GSW, n.d.) Used with permission.

The following is a detailed description of the Figure 1 table which outlines the performance specifications for a series of natural gas water heaters.

1. **Model G640S40N-PDV-ES2**
    - **Tank Warranty**: 6 years
    - **Series**: 300/301

- **Capacity**: 40 USG (151 L)
- **Input**: 40,000 BTU/h
- **Recovery Rate**: 45 GPH (170 LPH)
- **First Hour Rating**: 71 GPH (269 LPH)
- **Energy Factor**: 0.71
- **UEF**: 0.68
- **BC/ON Compliant**: Yes (✓)

2. **Model G650T45N-PDV-ES2**

    - **Tank Warranty**: 6 years
    - **Series**: 300/301
    - **Capacity**: 50 USG (189 L)
    - **Input**: 45,000 BTU/h
    - **Recovery Rate**: 50 GPH (189 LPH)
    - **First Hour Rating**: 93 GPH (352 LPH)
    - **Energy Factor**: 0.70
    - **UEF**: 0.72
    - **BC/ON Compliant**: Yes (✓)

3. **Model G650T62N-PDV-ES2***

    - **Tank Warranty**: 6 years
    - **Series**: 300/301
    - **Capacity**: 50 USG (189 L)
    - **Input**: 62,000 BTU/h
    - **Recovery Rate**: 73 GPH (276 LPH)
    - **First Hour Rating**: 100 GPH (379 LPH)
    - **Energy Factor**: 0.71
    - **UEF**: 0.73
    - **BC/ON Compliant**: Yes (✓)

4. **Model G675T72N-PDV-ES2***

    - **Tank Warranty**: 6 years
    - **Series**: 300/301
    - **Capacity**: 75 USG (284 L)
    - **Input**: 72,000 BTU/h
    - **Recovery Rate**: 82 GPH (310 LPH)
    - **First Hour Rating**: 154 GPH (582 LPH)
    - **Energy Factor**: 0.69
    - **UEF**: 0.68
    - **BC/ON Compliant**: Yes (✓)

Additional Notes

- For propane models, substitute N for P in the model number. Natural gas models are series 300, while propane

models are series 301.
- All models are rated for installation at altitudes up to 10,100 feet (3,078 meters).
- ***In residential applications. Warranty period is reduced for commercial applications. Parts are warrantied for 1 year.
- *Models with side connections as standard.

Back to Figure 1

Figure 2 Long Description: Hot Water Boiler Rating Plate Example

The following is a comprehensive description of the detailed specifications presented on the label for a natural gas appliance manufactured by Allied Engineering Co. This label provides comprehensive information about the appliance, including its operating specifications, pressure ratings, certification details, and installation requirements.

Left Side of the Label

General Information

- **Factory Equipped for Natural Gas**
- **Altitude**: 0-4,500 FT
- **Input Rating**: 85,000 BTU/HR
- **Minimum Input Rating**: 8,500 BTU/HR
- **Heating Capacity**: 80,750.0 BTU/HR

Gas Pressure Specifications

- **Max Inlet Gas Pressure**:
  - Natural Gas: 14.0 IN WC
  - Propane: 14.0 IN WC
- **Min Inlet Gas Pressure**:
  - Natural Gas: 4.0 IN WC
  - Propane: 8.0 IN WC
- **Manifold Pressure**:
  - Natural Gas: -0.03 IN WC
  - Propane: -0.02 IN WC

Certification and Additional Information

- **CRN**: 8810.7CL
- **Control No.**: M9

- **ASME Certification**:
  - **MAWP Water**: 80 PSI
  - **Max Water Temp**: 210 °F
  - **Heating Surface**: 7.27 ft²
  - **Min RV Capacity**: 85.00 LB/HR
  - **Manufacturing Serial No.**: SN17.PG24.91.0207
  - **Year of Manufacture**: 17

Right Side of the Label

Manufacturer Information

- **Manufactured By**: Allied Engineering Co., Division of E-Z-Rect Manufacturing Limited, North Vancouver, B.C., Canada
- **Model**: MG 100
- **Serial No.**: MDA-6171
- **Type**: Natural
- **CRN**: H 2523 . 1C
- **N.E.C.**:
  - 0–2000 FT: 0–2000 PDS.
  - 2000–4500 FT: 2000–4500 PDS.

Input and Output Specifications

- **Input per 1000 BTU/HR**: 100
- **Output per 1000 BTU/HR**: 84.6
- **Minimum Input per 1000 BTU/HR**: 100
- **Manufacturer's Recommended Orifice Size**: 51 DMS. DIM.

Pressure and Electrical Specifications

- **Manifold Pressure**: 3.5 W.C. (Water Column)
- **Minimum Relief Valve Capacity**: 1000 BTU/HR
- **Maximum Gas Supply Pressure**: 13.0 W.C. (Water Column)
- **Minimum Gas Supply Pressure**: 5.0 W.C. (Water Column)
- **Heating Surface**: 14.3 SQ. FT.
- **Electrical Requirements**: 120 Volts, 60 HZ., Less Than 12 AMPS

Installation Specifications

- **Minimum Clearances to Combustible Material**:
  - **Top**: 24 IN.
  - **Sides**: 2 IN.
  - **Front**: 6 IN.
  - **Rear**: 2 IN.
- **Approved for Installation on Combustible Flooring**

Certifications

- **Certified by LC**
- **AHRI Certified**
- **Design Certified**

Back to Figure 2

Figure 3 Long Description: Accredited Certification Body Marks

This image showcases various certification marks from different organizations that test and certify products for safety and compliance standards.

Canadian Standards Association (CSA)

- **CSA**: A standard CSA certification mark.
- **CSA NRTL/C**: Indicates certification by CSA's Nationally Recognized Testing Laboratory (NRTL) for Canada and the United States.
- **CSA C US**: Certification by CSA for both Canada and the United States.
- **CSA Flame**: Indicates a product has been certified for safety in gas-fired applications.

Intertek Testing Services NA Inc.

- **ETL C**: Intertek's ETL mark indicating compliance with Canadian standards.
- **ETL C US**: Intertek's ETL mark indicating compliance with both Canadian and U.S. standards.
- **ETL**: Standard ETL mark.
- **Intertek Flame C**: Intertek's mark indicating compliance with Canadian standards for gas-fired products.
- **Intertek Flame C US**: Intertek's mark indicating compliance with both Canadian and U.S. standards for gas-fired products.

IAPMO Ventures, LLC. Dba IAPMO EGS

- **UPC**: Uniform Plumbing Code certification mark.
- **USEC**: Uniform Solar Energy Code certification mark.
- **USPC**: Uniform Swimming Pool, Spa, and Hot Tub Code certification mark.
- **UMC**: Uniform Mechanical Code certification mark.
- **M C**: Certification mark indicating compliance with mechanical standards.
- **IAPMO R&T C**: Certification mark indicating compliance with IAPMO's research and testing standards.
- **IAPMO Triangle C**: IAPMO's certification mark for various standards.

Underwriters Laboratories of Canada (ULC)

- **UL Classified C US**: Indicates a product classified by UL for both Canadian and U.S. standards.
- **UL Classified C**: Indicates a product classified by UL for Canadian standards.
- **UL C US**: UL's certification mark for both Canadian and U.S. standards.
- **UL Listed Gas-Fired C US**: Indicates UL listing for gas-fired products meeting both Canadian and U.S. standards.
- **UL Listed Gas-Fired C**: Indicates UL listing for gas-fired products meeting Canadian standards.
- **UL Certified**: Standard UL certification mark.

QAI Laboratories

- **QAI C**: QAI Laboratories certification mark indicating compliance with Canadian standards.

QPS Evaluation Services

- **QPS C**: Certification mark indicating compliance with Canadian standards.

LabTest Certification Inc.

- **LC C**: LabTest Certification mark indicating compliance with Canadian standards.
- **LC C US**: LabTest Certification mark indicating compliance with both Canadian and U.S. standards.

ICC Evaluation Service, LLC

- **ICC ES C**: Certification mark indicating compliance with Canadian standards for plumbing, mechanical, and fuel gas products.

PFS Corporation

- **PFS C**: PFS Corporation certification mark indicating compliance with Canadian standards.
- **PFS C US**: PFS Corporation certification mark indicating compliance with both Canadian and U.S. standards.

OMNI – Test Laboratories, Inc.

- **OMNI**: Certification mark indicating compliance with safety and performance standards.

These marks indicate that the products have been tested and certified for safety, performance, and compliance with relevant standards in Canada and the United States.

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Figure 4 Long Description: Gas Appliance Field Approval Decal.

(Skilled Trades BC, 2021) Used with permission.

Gas Appliance Product Approval Label

- **Header**: "GAS APPLIANCE PRODUCT APPROVAL" with a toll-free number: 1-555-555-5555.
- **Fields to Fill**:
    - Date
    - Permit Number
    - Product Approval Number
    - Applicant
    - Appliance Input
    - Manufacturer
    - Model Number
    - Serial Number
    - Site Address
    - Safety Officer Initials
- **Approval Information**:
    1. Indicates appliance field approval as per section 10 (1) of the Safety Standards Act.
    2. Valid only in British Columbia after the approval decal is affixed by a safety officer.
    3. Modification or alteration voids the approval and the appliance is no longer approved to operate.

This label ensures that gas appliances meet safety standards before operation.

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Figure 5 Long Description: Sample Certification Stamps by from the American Society of Mechanical Engineers

Image modified from ASME (n.d.). Used with permission.

The image shows four symbols used in plumbing and HVAC systems to represent different types of heating equipment.

1. **Top Left**: A capital 'H' for **Cast Iron Heating Boilers**.
2. **Top Right**: An 'H' with a smaller 'H' in the corner for **Other Heating Boilers**.
3. **Bottom Left**: An 'H' with a 'W' below it for **Lined Water Heaters**.
4. **Bottom Right**: An 'HV' for **Safety Valves**.

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Figure 6 Long Description: Water Heater Rating Plates

([modified] Skilled Trades BC, 2021) Used with permission.

The image shows a detailed label from a Rinnai Corporation direct vent tankless water heater. The label is divided into two sections, with information in both English and French.

- **Left Side:**
  - **Title:** Direct-Vent Automatic Instantaneous Water Heater
  - **Model Number:** V2532W
  - **Serial Number:** 03.1004.0159
  - **Gas Type:** Natural Gas
  - **Electrical Rating:** 120V, 60Hz
  - **Manufacturer:** Rinnai Corporation, Nagoya, Japan
- **Right Side:**
  - **Barcode and Product Information:**
    - **BTU/hr Ratings:** 180,000 BTU/H (maximum), 10,300 BTU/H (minimum)
    - **Gas Pressures:** Maximum Inlet Gas Pressure: 10.5″ W.C., Minimum Inlet Gas Pressure: 5.0″ W.C.
    - **Water Pressure:** Maximum: 150 PSI
    - **Temperature Settings:** Various settings for different functions
  - **Manufacturing Details:** Made in Japan, Manufacturer's address in Peachtree City, GA

Back to Figure 6

Self-Test A-1.1: Characteristics of Gas Appliances

Complete Self-Test A-1.1 and check your answers.

1. The internal characteristics of a gas appliance include types of burners, ignition systems, controls, and safeties.
   a. True
   b. False

2. “High efficiency” type appliances use what type of gas burner?
   a. Non-mechanical
   b. Mechanical
   c. Atmospheric
   d. Natural draft

3. What is the purpose of a pilot flame?
   a. Light the main burner
   b. Heat the flame supervisor
   c. Light the basement
   d. Prime the flue

4. Which of the following are common components of the main burner control circuit?
   a. Thermostat
   b. High temperature limit
   c. Main gas valve
   d. All of the above

5. What is an example of a non-vented gas appliance?
   a. Boiler
   b. Furnace
   c. Incinerator
   d. Range

6. What type of appliance takes all of the air for the appliance directly from the outside, as well as discharging all the flue gas directly to the outdoors?
   a. Indirect-vent
   b. Direct-vent
   c. Indirect flue
   d. Direct flue

7. What is the purpose of a direct fired make-up air unit?

a. Preheats ventilation air
b. Space heating applications
c. Preheats domestic water
d. Raises boiler efficiency

8. For every pound of water condensed from the flue gas, the heat exchanger of a condensing appliance gains approximately how many BTU's of heat energy?
   a. 144
   b. 324
   c. 970
   d. 1,700

Answer Key: Self-Test A-1.1 is on the next page.

Answer Key: Self-Test A-1.1

1. a. True
2. b. Mechanical
3. a. To light the main burner
4. d. All of the above
5. d. Range
6. b. Direct-vent
7. a. Preheats ventilation air
8. c. 970

Self-Test A-1.2: Types of Gas Fired Appliances

Complete Self-Test A-1.2 and check your answers.

1. What section of the CSA B149.1 Code would you reference for general appliance installation requirements?
    a. 4
    b. 6
    c. 7
    d. 8

2. When a commercial cooking appliance is mounted on wheels, what other component is required?
    a. Side bollards
    b. GPS tracking
    c. Steering mechanism
    d. Restraining device

3. Gas-fired refrigerators operate differently than typical electric compression refrigeration units. What component does the gas-fired refrigerator not require?
    a. Compressor
    b. Condenser
    c. Evaporator
    d. Absorber

4. Gas clothes dryers require both a 110/120 VAC electrical outlet and a gas connection.
    a. True
    b. False

5. A recessed wall furnace uses what type of distinctive oval venting material?
    a. B
    b. C
    c. O
    d. BW

6. What makes a gas fired room heater different than most space heaters?
    a. Not self-contained
    b. No heat exchanger
    c. No venting
    d. No ducting

7. High-intensity infrared heaters have burners made of porous material that may reach surface temperatures up to:

a. 980°C
b. 800°C
c. 650°C
d. 440°C

8. Heating gas fireplaces, also known as vented-gas fireplace heaters, will have what minimum efficiency rating?
   a. 95%
   b. 83%
   c. 65%
   d. 50%

9. For gas fireplace applications that are not dependent on external electricity for their burner operation, what type of ignition system would be the best choice?
   a. Direct spark
   b. Hot surface
   c. Intermittent pilot
   d. DC electronic ignition

10. All newly installed 30- to 50-gallon residential gas water heaters with firing rates up to 75,000 BTUs/hr must be equipped with what additional feature?
    a. PRV
    b. FVIR
    c. Drain pan
    d. Restraining device

11. When a recirculation system is added to a tankless water heater, what other system component is usually required?
    a. Small buffer tank
    b. Pressure relief
    c. Heat exchanger
    d. Gas burner

12. What is the minimum efficiency required for all new gas furnaces installed in Canada?
    a. 65%
    b. 78%
    c. 90%
    d. 95%

Answer Key: Self-Test A-1.2 is on the next page.

Answer Key: Self-Test A-1.2

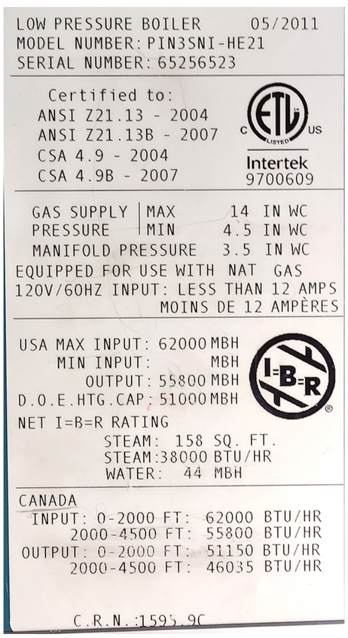
1. c. Section 7
2. d. Restraining device
3. a. Compressor
4. a. True
5. d. Type BW
6. d. No ducting
7. a. 980°C
8. d. 50%
9. d. DC electronic ignition
10. b. FVIR
11. a. Small buffer tank
12. c. 90%

Self-Test A-1.3: Documents, Regulations, and Specifications

Complete Self-Test A-1.3 and check your answers.

1. If there is a discrepancy between the manufacturer's instructions and the codes, the most stringent requirements shall prevail.
    a. True
    b. False

Use the image below to answer Questions 2 through 5.



2. What is the manifold pressure setting for this boiler?
    a. 3.5 in. WC
    b. 4.5 in. WC
    c. 10 in. WC
    d. 14 in. WC

3. If the boiler is installed in Canada at and elevation of 3,000 ft. above sea level, what is the maximum input rating?
    a. 46,035 BTU/h
    b. 51,150 BTU/h
    c. 55,800 BTU/h
    d. 62,000 BTU/h

4. What is the Department of Energy (DOE) HTG CAP?
    a. 38,000 BTU/h
    b. 51,000 BTU/h
    c. 55,800 BTU/h
    d. 62,000 BTU/h

5. Given an output of 55,800 BTU/h, what is the steady state efficiency of this boiler at maximum input?
    a. 80%
    b. 90%
    c. 92%
    d. 100%

6. Who regulates what certification symbols that must appear on the rating plate of a gas appliance sold in Canada?
    a. Technical Safety BC
    b. Standards Council of Canada
    c. Canadian Standard Association
    d. Underwriters Laboratories of Canada

7. A field approval label certifies an appliance for use at any location.
    a. True
    b. False

8. What expression is used to indicate a water heater's output?
    a. AFUE
    b. BTH/h
    c. Recovery rate
    d. Heating capacity

9. Steady state gives a true measurement of the system's seasonal efficiency since it accounts for the cycling or standby losses that take place over the course of the heating season.
    a. True
    b. False

10. When equipment has more than one manual, the installation manual will contain detailed installation and operating information, and the owner's manual will have only basic operating instructions, service, and maintenance information.
    a. True
    b. False

11. Typically, the servicing provider must dispose of all damaged parts replaced under warranty.

a. True
b. False

Answer Key: Self-Test A-1.3 is on the next page.

Answer Key: Self-Test A-1.3

1. a. True
2. a. 3.5 in. WC
3. c. 55,800 BTU/h
4. b. 51,000 BTU/h
5. b. 90%
6. b. Standards Council of Canada
7. b. False
8. c. Recovery rate
9. b. False
10. a. True
11. b. False

A-2 GAS INSTALLATION CODE

Plumber Apprenticeship Program – Level 2

CSA B149.1:20
National Standard of Canada

Natural gas and propane installation code

REVISED MAY 2021

A-2 Gas Installation Code Introduction

You must be able to recognize and access pertinent codes, regulations, and standards related to the gas equipment installations. This section will familiarize you with the most important codes and standards in the field.

Learning Objectives

After completing the chapters in this section, you will be able to:

- Identify codes, regulations, and standards for the gas industry.
- Explain the purpose of the different sections contained within the B149.1 Gas Installation Code.

Terminology

The following terms will be used throughout this section. A complete list of terms for this section can be found in the **Glossary**.

- **air supply:** (For combustion); The air required by a gas appliance to support proper combustion, which may need to come from outside depending on appliance type and building design. (Section A-2.2)
- **B149.1 code:** The Canadian standard that governs the installation of natural gas and propane appliances and equipment. It's a critical document for all gas-related work. (Section A-2.2)
- **combustible material:** Any material that can ignite and burn. The code contains specific clearance requirements to prevent fire hazards. (Section A-2.2)
- **gas pressure regulators:** A device used to control and maintain gas pressure at a safe, usable level for gas appliances. (Section A-2.2)
- **natural gas:** A fossil fuel primarily composed of methane, used as a common energy source in residential, commercial, and industrial applications. (Section A-2.2)
- **piping and tubing systems**: Approved assemblies of pipes, tubes, hoses, and fittings used to safely transport gas from the meter or tank to appliances. (Section A-2.2)
- **propane:** A hydrocarbon gas used as a fuel, often stored in tanks or cylinders, commonly used where natural gas service is unavailable. (Section A-2.2)
- **psi:** The pressure exerted by a force of one pound-force applied over an area of one square inch is defined as 1 psi (pound per square inch). In the International System of Units (SI), 1 psi is approximately equal to 6,895 pascals. PSI is a unit of pressure in both the US customary and imperial systems. It is also sometimes referred to as pound-force per square inch. (Section A-2.1)
- **psia:** The term "pound per square inch absolute" (psia) specifies that the pressure measurement is relative to a vacuum, as opposed to ambient atmospheric pressure. Note: pounds per square inch gauge is "psig"

whereas pounds per square inch absolute is "psia." (Section A-2.1)

- **psig:** PSIG stands for "pounds per square inch gauge" and refers to the pressure measured by a gauge or other pressure measurement device. It indicates the difference between the pressure inside a pipe or tank and the atmospheric pressure (atm). Note: pounds per square inch gauge is "PSIG" whereas pounds per square inch absolute – PSIA. (Section A-2.1)
- **purge:** The process of removing air or other gases from piping systems before gas is introduced, critical for safe appliance operation. (Section A-2.2)

A-2.1 Introduction to Gas Standards, Codes, Acts, and Regulations

Gas standards, codes, acts, and regulations are crucial for ensuring the safe and efficient operation of gas systems. They establish guidelines for the design, installation, maintenance, and inspection of gas appliances, pipelines, and equipment. By setting minimum safety requirements, these codes promote consistency and reliability across gas installations, enhancing public confidence and facilitating regulatory enforcement.

Canadian Standards Association

The Canadian Standards Association (CSA) exists to develop standards. Among the 57 different areas of specialization are business management, safety, and performance standards, including those for electrical and electronic equipment, industrial equipment, boilers and pressure vessels, compressed gas handling appliances, environmental protection, and construction materials.

Most standards are voluntary, meaning there are no laws requiring their application. Despite that, adherence to standards is beneficial to companies because it shows products have been independently tested to meet certain standards. The CSA mark is a registered certification mark that can only be applied by someone who is licensed or otherwise authorized by the CSA to do so.

Laws and regulations in most municipalities, provinces, and states in North America require certain products to be tested to a specific standard or group of standards by a nationally recognized testing laboratory (NRTL). Currently, 40% of all the standards issued by CSA are referenced in Canadian legislation. CSA's sister company, CSA International, is a nationally recognized testing laboratory that manufacturers can choose, usually because the law of the jurisdiction requires it or the customer specifies it.

CSA B149 Gas Code Series

The CSA B149 Gas Code Series provides important guidance on how to work as a gasfitter safely — from the handling and storage of natural gas and propane to the safe and effective installation of related appliances and equipment. The CSA B149 Gas Code Series is a Canadian Standards Association (CSA) publication. In 1958, the CSA published the first edition of the B149.1, Installation Code for Gas-Burning Appliances and Equipment. Following the publication of the 1966 edition, the decision was made to split the code into two parts: B149.1, dealing with the installation of appliances and equipment burning natural gas, and B149.2, dealing with the installation of appliances and equipment burning propane. As a first step, B149.2 was prepared and first published in 1969.

In 1974, the Canadian Gas Association (CGA) was accredited by the Standards Council of Canada as the standards development organization responsible for preparing standards for gas-burning appliances and equipment and took over responsibility for the B149 code at that time. Many new editions of the code have been published since that time (a typical code cycle is about every five years).

On June 30, 1997, the CSA Group acquired International Approval Services (IAS), which, until then, was a joint venture of the American Gas Association (AGA) and the Canadian Gas Association (CGA).

Under this agreement, CSA acquired the complete range of IAS standards administration, certification, and registration products and services for appliances and accessories fuelled by natural and liquefied petroleum gases. In 1998, the CSA B149 Installation Code Committee agreed to publish a natural gas and propane installation code that would amalgamate the first seven sections of CAN/CGA-B149.1 and CAN/CGA-B149.2 to become CAN/CSA-B149.1-00. This merger was in response to the trend among the authorities having jurisdiction (AHJ) in many provinces toward having combined licensing and training for both natural gas and propane.

The remaining sections, 8 to 14 of CAN/CGA-B149.2, then became CAN/CSA-B149.2-00, Propane Storage and Handling Code.

It is important to note that when a new edition of these codes is adopted by the enforcing jurisdiction (Technical Safety BC (TSBC)), it supersedes all previous editions.

CSA B149.1: Natural Gas and Propane Installation Code

CSA B149.1 Natural Gas and Propane Installation Code targets Canadian gas and propane industry workers. This code is an extremely important reference for all gasfitters. It is intended to protect public health and safety for all building systems that use fuel gas. It addresses system design, installation, and inspection of such systems by providing minimum safeguards and corresponding safety requirements. It has been reviewed by regulatory authorities across Canada and has been adopted into law in every Canadian province and territory.

CSA B149.1 applies to the installation of:

- Appliances, equipment, components, and accessories where gas is used for fuel purposes
- Gas piping and tubing systems
- Vehicle-refuelling appliances and associated equipment
- Stationary gas engines and turbines

CSA B149.2: Propane Storage and Handling Code

The CSA B149.2 Propane Storage & Handling Code reflects the latest advances in industry best practices and the most current safety requirements.

CSA B149.2 applies to the:

- Storage, handling, and transfer of propane
- Propane used as an engine fuel in other than highway vehicles
- Installation of containers and equipment used for propane in distribution locations and filling plants

CSA B149.3: Code for the Field Approval of Fuel-Related Components on Appliances and Equipment

The CSA B149.3 Code for the Field Approval of Fuel-Related Components on Appliances and Equipment provides requirements for fuel-related components and accessories and their assembly on appliances and equipment using gas.

This document is used predominantly in the commercial and industrial gas industry for large volume equipment and appliances that use a programmable logic controller (PLC) or microprocessor-based controls used for flame safety. Many of these types of equipment may be designed beyond the scope of any existing standards, and the appliances or equipment may not already be certified. In these cases, the B149.3 would apply. This code pertains mostly within the scope of qualification of Class A Gasfitters in Canada.

Technical Safety BC

Although CSA codes have been adopted as the standard for the design and installation of fuel gas systems across Canada, each province maintains regulation, licensing, and registration of gas in various ways.

Gas systems are usually installed under the regulatory authority in that province. In British Columbia, that authority is Technical Safety BC (https://www.technicalsafetybc.ca/) (formerly BC Safety Authority).

Technical Safety BC is an independent, self-funded organization that oversees the safe installation and operation of technical systems and equipment across the province. In addition to issuing permits, licences, and certificates of qualification, they work with the industry to reduce safety risks through inspections, assessment, education and outreach, enforcement, and research.

Technical Safety BC has been given powers to enforce and create public safety rules in the following areas:

- Natural gas and propane appliances and systems, including hydrogen
- Boilers, pressure vessels, and refrigeration systems
- Passenger ropeways, such as aerial trams and ski lifts
- Elevating devices, such as elevators and escalators
- Electrical equipment and systems
- Alternative safety approaches
- Amusement devices
- Railways

Technical Safety BC administers the Safety Standards Act and Railway Safety Act throughout British Columbia. Anyone who installs, operates, manufactures, maintains, or sells equipment in any of the technologies they regulate is within Technical Safety BC jurisdiction.

Although Technical Safety BC oversees the safe installation and operation of technical systems across the province, some exemptions do exist in certain municipalities. Ten municipalities are delegated portions of the Safety Standards Act to issue electrical and/or gas permits and perform inspections. Technical Safety BC typically does not issue permits or perform inspections for electrical or gas work and equipment in these areas (e.g., the City of Kelowna is permitted to issue gas installation permits within their jurisdiction).

For gas, the local governments (municipalities) can issue natural gas installation permits for:

- Fully detached dwellings serviced by a single meter at 2 **psig** (14 kPa) or less
- Any premise other than a fully detached dwelling if the gas meter pressure is 2 **psi** (14 kPa) or less and the total connected load is 409,600 BTU/hr (120 kW) or less

Technical Safety BC has jurisdiction over all other regulated gases, such as propane, methane, and hydrogen. Although these ten jurisdictions have oversight for electrical and/or gas, Technical Safety BC still oversees contractor licensing and certification of qualified individuals and provides oversight for all other technologies they regulate.

Gas Installation Permits

There is sometimes misconceptions about who actually has the authority to apply for a gas installation permit. The process is different from applying for a plumbing installation permit, for example.

Gasfitting work in BC must be performed by certified gasfitters. Gas permits are allocated only to registered gas contractors (or, in some cases, a homeowner working under the regulations). Gas contractors are licensed to do work in BC if they are registered with TSBC, employ qualified individuals, and pay an annual licensing fee. Each contractor must also be able to supply a performance bond to do gasfitting work (minimum $10K bond, held in trust with TSBC). Bonding helps ensure that contractors are reputable and that they will complete their work to the regulations.

If a contractor is registered with TSBC to perform regulated gas work, then they must employ certified gasfitters to do the work.

A gas permit is required to perform any regulated gas work, including the installation, alteration, or replacement of any gas-fired appliance. Gas permits are also required if installing or altering the associated gas piping or appliance venting. Gas installation permits must be obtained before any work begins.

When constructing a new dwelling, a building permit is required prior to a gas or plumbing permit being issued. Plumbing permits are issued by the local municipal building department, whereas gas permits are typically issued by TSBC.

The permit process is generally the same for all types of projects, but more specific requirements may be required for some commercial construction and industrial projects.

Review Process

During the review process, staff determine if the project is in compliance with the applicable codes and other local ordinances and statutes. The length of the review process depends on the type and complexity of the project.

Permit Approval

When compliance with the code and other applicable statutes is determined, the permit application is approved. Once all final permit fees are paid, the permit is issued.

However, if the permit application is not approved or a review has failed, the permit application, as submitted, will be denied. When a permit application is denied, corrections to the application shall be made and the application resubmitted for final approval.

Non-Compliance Enforcement Process

An enforcement action typically begins with the safety officer. The safety officer may address a non-compliance by taking actions, such as suspending a permit, issuing a compliance order, or recommending that a safety manager impose a monetary penalty. The next step involves the Provincial Safety Manager, who may impose more significant sanctions, such as monetary penalties or suspending contractors' licences, or qualification certificates. Enforcement decisions by safety officers and safety managers are generally subject to review or appeal.

The Safety Standards Appeal Board is created under the Safety Standards Act. This appeal board can review certain TSBC decisions when clients request a review.

Safety Standards Act (BC)

The Safety Standards Act sets out the general requirements for regulated work performed by contractors involved in the operation and installation of technical systems and equipment in BC. It also includes information on the legal requirements for permits and qualifications. The Safety Standards Act authorizes TSBC to take enforcement actions if they discover a non-compliance with the act or regulations.

Products and work regulated under the act include:

- Boilers and boiler systems
- Electrical systems and equipment
- Elevating devices and passenger conveyors
- Gas systems and equipment
- Pressure vessels, pressure piping, refrigeration systems, and equipment
- Amusement rides
- Ski lifts

Gas Safety Regulation

The Gas Safety Regulation applies to everyone who installs, alters, maintains, or operates gas technologies in British Columbia.

All licensed contractors and gasfitters are required to keep up to date with changes in the act and regulations. In BC, there are a few distinct differences to the National CSA B149.1 code that pertain to gas installations in this province. These variations are contained at the end of the Gas Safety Regulation as an additional schedule. It is important to be familiar with these BC variances.

Contractors and gasfitters must have access to a current edition of the Canadian CSA Gas Code (https://www.csagroup.org/store/), BC Gas Safety Regulation (https://www.bclaws.gov.bc.ca/civix/document/id/

complete/statreg/15_103_2004) and BC Variations to the National Code (https://www2.gov.bc.ca/gov/content/industry/construction-industry/building-codes-standards/bc-codes/2024-bc-codes).

Gas Safety Orders, Directives, and Information Bulletins

Safety orders are instruments issued to prevent or reduce the risk of personal injury or damage to property. Compliance is mandatory and enforceable by TSBC.

Directives are instruments that clarify or provide a new interpretation of a regulation or code. Compliance is mandatory.

Information bulletins provide helpful information and clarification on existing regulations or code that affect a particular technology.

Self-Test A-2.1: Identify Gas codes, Regulations, and Standards

Complete Self-Test A-2.1 and check your answers.

If you are using a printed copy, please find Self-Test A-2.1 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=39#h5p-5 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=39#h5p-5)

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A-2.2 Interpret Sections of the B149.1 Gas Code

This chapter briefly explains what information is contained in the various sections of the gas installation code. For installers, the majority of requirements in Code Sections 1 through 8 of the **B149.1 code**, except for pressure controls and pipe sizing, are common to **natural gas** and **propane**.

Section 1: Scope

The scope of the code is confined to the installation of typical appliances, equipment, components, and accessories that use gas for fuel purposes, and to the installation of piping and tubing systems extending from the termination of the utility installation (in the case of natural gas) or from the tank or cylinder (in the case of propane).

Where the term "gas" is used, the contents of the code are intended to apply equally to and include any of the following gases or mixtures of them: natural gas, manufactured gas, propane, and mixtures of propane and air.

Where the term "natural gas" is used, it is intended to apply only to natural gas (methane).

Where the term "propane" is used, the contents of the code are intended to apply specifically to and include any material that is composed predominantly of any of the following hydrocarbons or mixtures of them: propane, propylene, butanes (normal butane or isobutane), and butylenes.

In the B149 Gas Code, unless approved otherwise by the authority having jurisdiction, the word "shall" indicates a mandatory requirement; "should" indicates a recommendation or that which is advised but not mandatory; and "may" indicates an advisory or optional statement.

Section 2: Reference Publications

The reference publications listed in Section 2 of the B149.1 code refer to codes or standards that govern equipment, components, methods, or materials cited in the code. Refer to Section 2 of the code for a complete list of reference publications. Installers must ensure they use the proper reference publication when interpreting and applying the B149 codes. Always check the title and year of any reference publication being used, since versions earlier or later than those listed may contain requirements that have not been approved by the code committees or authority having jurisdiction.

Section 3: Definitions

Definitions, sometimes referred to as defined terms, appear throughout the code as bold-faced, italicized text. These terms should be clearly understood when applying or interpreting the code and should not be confused with definitions cited in other codes or standards, dictionaries, manufacturers' terminology, or trade slang. Therefore, industry and regulatory agencies should attempt to apply these definitions consistently in practice. When in doubt, consult the authority having jurisdiction for clarification.

Section 4: General

Section 4 of the code explains the general application of the B149.1 Code. The general requirements set out criteria for the approval of appliances, accessories, components, equipment, and materials. Section 4 also outlines the responsibilities of the appliance installer and defines the skills and training they require. In addition, it provides general requirements applicable to all gas-burning appliance installations in areas such as suitability of use, electrical safety, clearances to **combustible material**, and accessibility.

Installation requirements for specific appliances are provided in Section 7 of the B149.1 code.

Section 4 clearly points out that the requirements of the B149 codes take precedence over those found in referenced standards or manufacturers' instructions, unless otherwise approved by the authority having jurisdiction. This serves to remind designers and installers to carefully review applicable code requirements in relation to specific installations, particularly where new or unfamiliar products are being considered.

Installers must ensure that they are fully familiar with the requirements of Section 4 and should use them as a checklist when planning or performing an installation.

Section 5: Pressure Controls

Gas pressures in service supply mains and from storage tanks are generally higher than the safe operating pressures of connected appliances. For this reason, gas pressures must be controlled to fall within an appropriate range, depending on the operating characteristics of installed appliances. The requirements for pressure control in Section 5 of the code are intended to limit the range of gas pressure to ensure safe and reliable appliance operation.

Section 5 requirements also give practical consideration to the safe relief of gas pressure surges, the isolation of pressure control devices (like **gas pressure regulators**), using manual shut-off valves to permit servicing and replacement, and the installation of pressure controls in locations that are accessible and protect the devices from physical or chemical damage.

Section 6: Piping and Tubing Systems, Gas Hose, and Fittings

Section 6 of the B149.1 code provides requirements for **piping and tubing systems**, hose, and fittings. These requirements represent conventional industry practice, and it should be noted that a large number of new technologies and systems are constantly entering the marketplace. For such proprietary products, manufacturers' certified installation instructions serve as additional requirements over those found in Section 6 of the code.

Section 6 deals primarily with gas piping and tubing, as well as hose, from the meter into all the appliances served, and between buildings. Gas piping from the main supply to the meter is normally the responsibility of the gas utility.

Piping and tubing systems, as well as hose, must incorporate approved materials that are properly sized, located, and protected. All piping outlets, drip pockets, and valves must be installed as required. The entire system must be properly pressure-tested and **purged**, then appropriately identified.

Section 7: Installation of Specific Types of Appliances

Section 7 of the code provides requirements for the installation of specific types of appliances. Due to the large number and variety of gas appliances available, the requirements in Section 7 should be viewed as largely generic in nature and be limited to the general types of appliances commonly installed. More accurate information may be found by referring to the manufacturer's certified installation instructions for the appliance being installed.

Before proceeding with any installation, review the general requirements in Clause 4, which are applicable to the appliance being installed. As well, review Section 6 for relevant supply piping requirements and Section 8 for the appropriate venting requirements. By taking the time to correctly identify all the applicable requirements pertaining to the installation of an appliance, and installer will find it easier to properly plan any work. Following these suggestions will result in a more economical and efficient execution of their installations.

Section 8: Venting Systems and Air Supply for Appliances

Section 8 of the B149.1 code provides requirements for venting systems and **air supply** for appliances. Careful consideration of these requirements is recommended prior to the specification and installation of appliances, since the methods of venting and air supply required by specific appliances may render them impractical in some situations.

Always consider venting and air supply requirements together because different requirements apply to natural draft and fan-assisted appliances as opposed to, for example, induced draft and direct vent appliances. When natural draft and fan-assisted appliances are being installed, it is necessary to determine the airtightness of the building envelope and consider any large-capacity air exhausting appliances operating in the building or enclosure in which the appliances are located.

Several other factors must also be considered relating to clearances to combustible materials, the suitability of vent and chimney types, and the termination of vents or chimneys. A well-planned and well-integrated venting system and air supply provides an economical installation, which ensures effective venting and proper appliance performance.

Self-Test A-2.2: Identify Sections of the B149.1 Gas Code

Complete Self-Test A-2.2 and check your answers.

If you are using a printed copy, please find Self-Test A-2.2 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=41#h5p-6 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=41#h5p-6)

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Self-Test A-2.1: Identify Gas Codes, Regulations, and Standards

Complete Self-Test A-2.1 and check your answers.

1. What year did the CSA publish the very first edition of the B149.1 Gas Code?
   a. 1942
   b. 1958
   c. 1969
   d. 2010

2. Which B149 code is specific to the storage and handling of propane?
   a. B149.1
   b. B149.2
   c. B149.3
   d. B149.4

3. Who is the independent, self-funded organization that oversees the safe installation and operation of technical systems and equipment (including gas systems) across the British Columbia?
   a. CSA
   b. CBC
   c. TSSA
   d. TSBC

4. At what point must you obtain a gas installation permit?
   a. Before any work begins
   b. After the rough-in is complete
   c. Before the first pressure test
   d. At final completion

5. Gas directives and safety orders are mandatory and enforceable by Technical Safety BC.
   a. True
   b. False

Answer Key: Self-Test A-2.1 is on the next page.

Answer Key: Self-Test A-2.1

1. b. 1958
2. b. B149.2
3. d. TSBC
4. a. Before any work begins
5. a. True

Self-Test A-2.2: Identify Sections of the B149.1 Gas Code

Complete Self-Test A-2.2 and check your answers.

1. In reference to the B149.1 gas code, the term "natural gas" is intended to apply to both natural gas (methane) and propane.
   a. True
   b. False

2. In reference to the B149.1 gas code, which term indicates that a requirement is mandatory?
   a. May
   b. Might
   c. Shall
   d. Should

3. In reference to the B149.1 gas code, which section contains information regarding reference publications that are cited in the code?
   a. Section 1
   b. Section 2
   c. Section 3
   d. Section 4

4. Defined terms appear throughout the code as bold-faced, italicized text.
   a. True
   b. False

5. When in doubt regarding a definition in the code, who should be consulted for clarification?
   a. The authority having jurisdiction
   b. An online search engine
   c. Popular opinion
   d. A buddy

6. Unless otherwise approved by the authority having jurisdiction, do the requirements of the B149 codes take precedence over those found in referenced standards or manufacturer's instructions?
   a. Yes
   b. No

7. In reference to the B149.1 gas code, which section contains information regarding the appliance installer's

responsibilities?

a. Section 2
b. Section 3
c. Section 4
d. Section 6

8. Gas service piping from the main supply (street main) to the meter is normally whose responsibility?

a. Any certified gasfitter
b. Homeowner
c. Gas utility
d. Builder

9. The manufacturer's certified installation instructions contain the most accurate installation information for the appliance being installed.

a. True
b. False

10. Which code section contains requirements for the installation of gas pressure regulators?

a. Section 4
b. Section 5
c. Section 6
d. Section 7

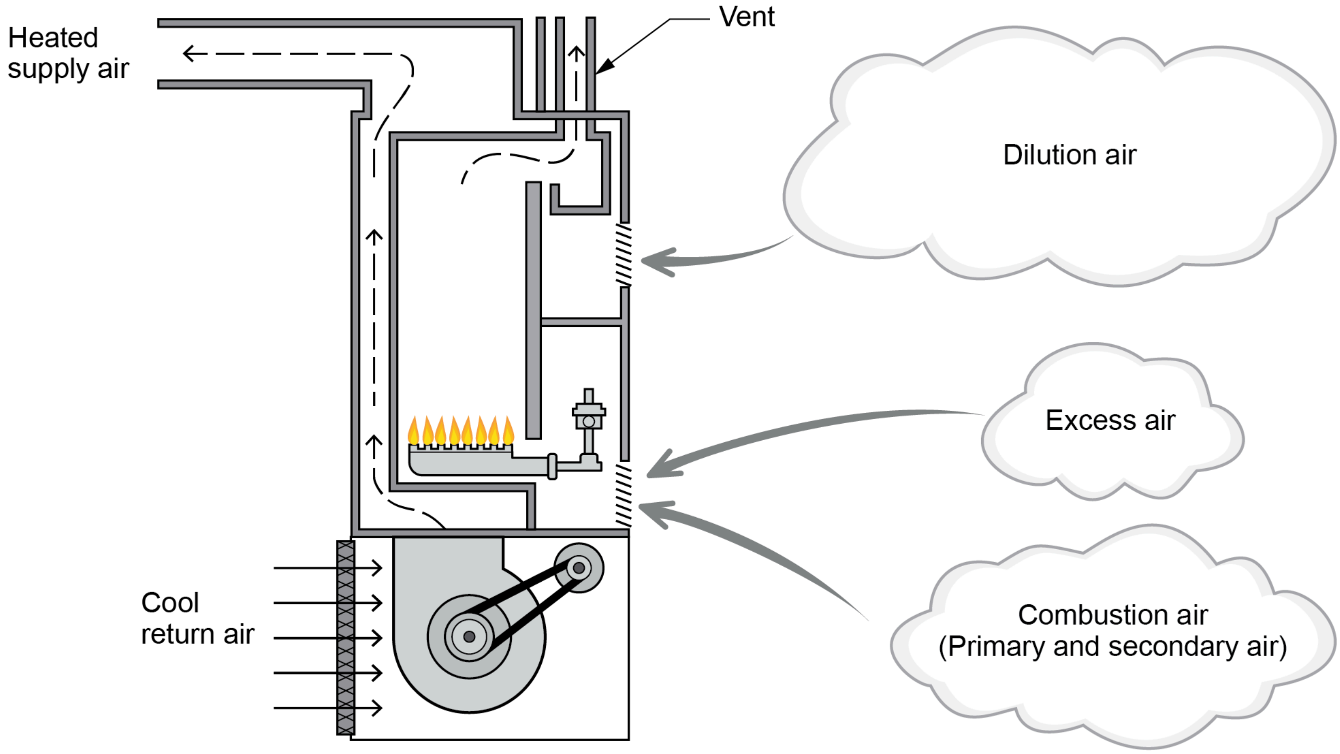
Answer Key: Self-Test A-2.2 is on the next page.

Answer Key: Self-Test A-2.2

1. b. False
2. c. Shall
3. b. Section 2
4. a. True
5. a. The authority having jurisdiction
6. a. Yes
7. c. Section 4
8. c. Gas utility
9. a. True
10. b. Section 5

A-3 GAS APPLIANCE AND BUILDING AIR REQUIREMENTS

Plumber Apprenticeship Program – Level 2



Type of gas appliance air supply. (Skilled Trades BC, 2021) Used with permission.

A-3 Gas Appliance and Building Air Requirements Introduction

A gasfitter must be able to determine air requirements for buildings with gas appliances and ensure that safe and controlled combustion is occurring in all gas appliances. An understanding of the combustion process and the chemical reactions involved will assist you in understanding the gas appliance air requirements and how they affect the installation and servicing of the equipment.

Learning Objectives

After completing the chapters in this section, you should be able to:

- Describe methods of combustion air supply.
- Calculate air requirements and products of combustion.
- Describe draft.
- Describe the building as a system.

Terminology

The following terms will be used throughout this section. A complete list of terms for this section can be found in the **Glossary**.

- **backdrafting:** The reverse flow of gas in the flues of fuel-fired appliances that results in the intrusion of combustion by-products into the living space. (Section A-3.4)
- **BTU (British Thermal Unit):** A unit of energy used to measure the heat content of fuel. (Section A-3.2)
- **complete combustion:** The ideal burning process where there is enough oxygen to burn all the fuel completely, producing only carbon dioxide (CO_2), water vapor (H_2O), and heat as byproducts. (Section A-3.1)
- **dilution air:** Ambient air introduced into the venting system of natural draft appliances, used to control draft and cool vent gases. (Section A-3.2)
- **excess air:** Extra air supplied to the combustion process beyond the amount required for perfect combustion, typically 20-30% more than the theoretical amount needed for stoichiometric combustion. This ensures that all fuel is burned efficiently and completely. (Section A-3.1 and Section A-3.2)
- **energy recovery ventilator (ERV):** A ventilation system similar to HRV but also transfers moisture between the outgoing and incoming air streams to maintain balanced humidity levels in the building. (Section A-3.4)

- **exfiltration:** The leakage of room air out of the building. (Section A-3.4)
- **flue gases:** The gases produced as a result of combustion, including carbon dioxide (CO_2), water vapor (H_2O), and nitrogen (N_2). (Section A-3.2)
- **gas flow rate:** The amount of gas flowing through an appliance, typically measured in cubic feet per hour (CFH), and used to calculate air supply requirements. (Section A-3.2)
- **heat recovery ventilator:** A system that recovers heat from outgoing exhaust air and transfers it to incoming fresh air, helping to improve energy efficiency and indoor air quality. (Figure 5, Section A-3.4)
- **incomplete combustion:** Occurs when there is insufficient oxygen for the fuel to burn completely, producing hazardous byproducts like carbon monoxide (CO), soot, and aldehydes. (Section A-3.1)
- **induced-draft burner:** A type of power burner where the fan or blower is located downstream of the combustion zone, creating draft by drawing gases out of the combustion chamber. (Section A-3.3)
- **infiltration:** The unintentional introduction of outside air into a building; also referred to as air leakage. (Section A-3.4)
- **power burner:** A burner with mechanical draft that generates sufficient pressure to overcome resistance in the combustion chamber, appliance, and venting system. (Section A-3.3)
- **power venter:** A mechanical draft system used to assist venting in natural draft appliances, often used to overcome venting challenges like excessive negative pressure. (Section A-3.3)
- **primary air:** The portion of combustion air mixed with the fuel gas before ignition, typically one-third of the total combustion air. (Figure 2, Section A-3.2)
- **radon mitigation:** Methods used to reduce the presence of radon gas in a building, such as installing a subfloor depressurization system to create a pressure difference that prevents radon from entering the building. (Section A-3.4)
- **secondary air:** The additional air required to complete the combustion process, typically two-thirds of the total combustion air. (Section A-3.2)
- **soil gas:** A mixture of air, water vapour, and pollutants, such as radon, that enters a building through below-grade leaks in the building envelope, potentially affecting indoor air quality. (Section A-3.4)
- **stack effect (chimney effect):** The phenomenon where hot air rises due to its lower density, creating a natural flow of air into and out of buildings, chimneys, and vents. (Section A-3.3)
- **ventilation:** The intentional introduction of outdoor air into a space to control indoor air quality by diluting and displacing indoor pollutants; can also be used for purposes of thermal comfort or dehumidification. (Section A-3.4)

A-3.1 The Chemistry of Combustion

Combustion is the rapid oxidation of fuel accompanied by the production of heat or heat and light.

Requirements for Combustion

Starting and sustaining combustion requires three ingredients mixed together in the correct proportions and one reaction:

- **Fuel:** most fuels are a chemical structure of carbon and hydrogen and, for that reason, are called **hydrocarbons**. In the gasfitting trade, these are normally natural gas, propane, or butane, which are burned in a gaseous state.
- **Heat:** enough heat must be supplied to bring the fuel up to its ignition temperature. This initial heat can be supplied by a pilot flame, spark ignition, or hot surface igniter. Ignition temperatures vary according to the type of gas used:
    - Natural gas, approximately 1,300°F; 700°C
    - Propane, 920°F; 495°C
    - Butane 900°F; 480°C
- **Oxygen:** the combustion process consumes oxygen, which is obtained from the surrounding air or by a combustion fan or blower. Because air contains only 20% oxygen and 80% nitrogen, the process requires a much larger volume of air than it would require if using pure oxygen.

Combustion is a chemical chain reaction that creates heat, some of which will provide enough energy to make the reaction self-sustaining (Figure 1).

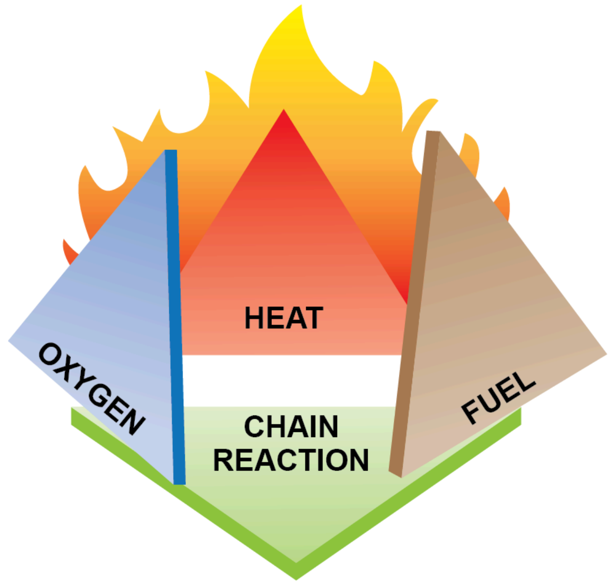


Figure 1 *Fire tetrahedron. (Adapted from Gustavb (https://en.wikipedia.org/wiki/User:Gustavb)/Wikimedia Commons) Public Domain (https://en.wikipedia.org/wiki/en:public_domain).*

If any one of the three elements are absent, combustion will not take place nor will it support itself after an element is removed.

The chemistry of combustion shows the reaction that takes place between fuel gas and oxygen when heated to ignition temperature. Using hydrocarbon fuels with enough oxygen to support combustion produces carbon dioxide (CO_2), water vapour (H_2O), and heat.

The type of hydrocarbon fuel used will determine the amount of oxygen required as well as the quantity of CO_2 and H_2O the reaction will yield. The chemical formula for the combustion reaction of natural gas and oxygen is:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{Heat}$$

Figure 2 illustrates the chemical combustion of natural gas (methane) and oxygen.

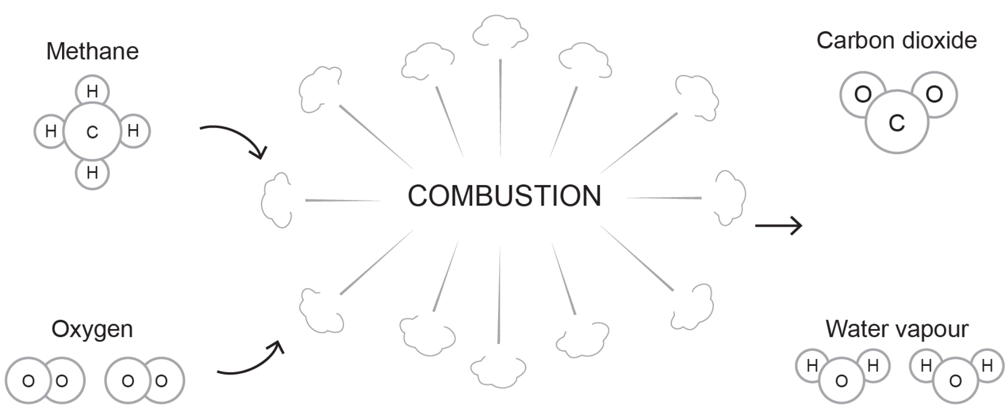


Figure 2 *Combustion of methane and oxygen. (Skilled Trades BC, 2021) Used with permission.*

The chemical formula expressing the combustion reaction for propane and oxygen is:

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O + \text{Heat}$$

Notice that the yield of CO_2 and H_2O creates a balanced formula driven by the number of individual carbon and hydrogen atoms in the hydrocarbon fuel compound. This determines the number of O_2 elements required.

For gas appliances, the source of oxygen is air, which has approximately 20% oxygen, 79% nitrogen, and 1% of other gases. This section describes three types of combustion, each determined by the initial air supply:

- Perfect combustion
- Incomplete combustion
- Complete combustion

Perfect (Stoichiometric) Combustion

Perfect (stoichiometric) combustion refers to the theoretical (or mathematically exact) volume of air that must be mixed with fuel gas to achieve perfect combustion. The formula for perfect combustion is used for theoretical calculations only. This is because most gas burners are not capable of mixing mathematically exact gas and air volumes together to produce **complete combustion**.

As previously stated, air is composed of approximately 20% oxygen (O_2) and 80% nitrogen (N_2).

Therefore, the perfect combustion formula for natural gas is expressed as follows:

$$CH_4 + 2O_2 + 8N_2 \rightarrow CO_2 + 2H_2O + 8N_2 + \text{Heat}$$

Notice that the ratio of oxygen required for each unit of natural gas is still 2:1, but now that air is being used, for every one unit of oxygen comes four units of nitrogen.

Figure 3 illustrates the formula.

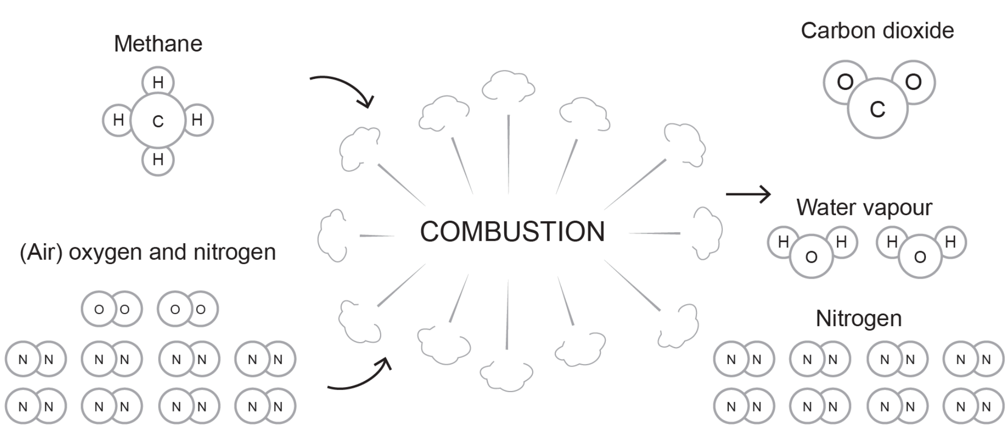


***Figure 3** Perfect combustion of methane and air. (Skilled Trades BC, 2021) Used with permission.*

Notice that, compared to Figure 2, we have now introduced nitrogen into the combustion process. Nitrogen is an inert gas that remains stable and will not chemically react, provided that the temperatures are not too high. Nitrogen does increase the total volume of flue gas, thereby absorbing some of the heat produced by the reaction. At high temperatures, some nitrogen will bind to oxygen to form nitric oxide and nitrogen dioxide, commonly referred to as NOx gases. Burner design can affect NOx production

As mentioned earlier, the number of individual carbon and hydrogen atoms in the hydrocarbon fuel compound determines the number of O_2 elements required. Therefore, propane would yield the following perfect combustion formula, requiring 25 units of air for every one unit of C_3H_8.

$$C_3H_8 + 5O_2 + 20N_2 \rightarrow 3CO_2 + 4H_2O + 20N_2 + \text{Heat}$$

Incomplete Combustion

Where there is not enough oxygen to burn the fuel gas completely, **incomplete combustion** occurs, leaving unburned fuel in the flue gas. Over-firing a burner can also cause incomplete combustion because it affects gas/air mixtures. Depending on the degree of incomplete combustion, the flue gas will contain varying amounts of the following products of incomplete combustion:

- Carbon (C)
- Hydrogen (H_2)
- Carbon monoxide (CO)
- Complex chains of alcohols called aldehydes

Carbon is easily observed because it forms a black powdery substance known as soot. Soot is an immediate visible indicator of incomplete combustion. However, the absence of visible soot does not necessarily indicate complete combustion.

Free hydrogen in the combustion process indicates that there is a high level of incomplete combustion. Normally, H_2 is not present unless the CO level is very high.

Carbon monoxide is a toxic, odourless, tasteless gas that, if inhaled in even small quantities, may cause death. Because it is one of the first products of incomplete combustion, it may be present before any of the other products are created.

Aldehydes are very toxic and poisonous. Because they are acrid in odour and irritate the eyes, nose, and throat, they are easily detected. Whenever aldehydes form, it is quite likely that CO is also present in the flue gas, but CO can be present without aldehydes.

Carbon monoxide and aldehydes in any quantity are toxic and life threatening.

The following formula and accompanying Figure 4 express the incomplete combustion of natural gas when only half of the theoretical air for perfect combustion was supplied.

$$CH_4 + 1O_2 + 4N_2 \rightarrow CO + H_2O + H_2 + 4N_2 + \text{Heat}$$

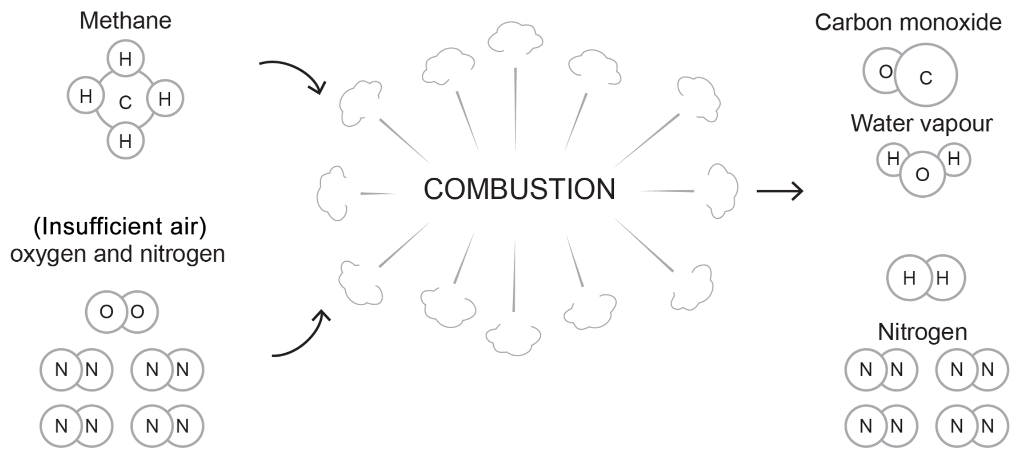


***Figure 4** Incomplete combustion of methane and air. (Skilled Trades BC, 2021) Used with permission.*

It is important to remember that incomplete combustion occurs not only from a lack of oxygen. Temperature, time, and fuel-air mixing also affect the combustion process.

If the flame is cooled to or just below its ignition temperature, incomplete combustion will occur. Conditions that could cool the flame include the flame impinging on a cold metal surface, such as a heat exchanger or boiler refractory, or a high draft through the combustion chamber, possibly caused by a cracked heat exchanger.

A dirty or poorly designed burner that does not allow for proper gas/air mixing can also produce higher levels of carbon monoxide and aldehyde.

Complete Combustion

If the burner is supplied with only the exact amount of theoretical air required, some of the carbon and hydrogen atoms would not be united with enough oxygen in the short period of combustion time and, therefore, incomplete combustion would occur.

To achieve complete combustion, the combustion process must have more air than perfect combustion would require. This **excess air** supply ensures that all atoms of carbon and hydrogen unite with enough atoms of oxygen to complete the combustion process.

The complete combustion formula for natural gas is expressed as:

$$CH_4 + 2O_2 + 8N_2 + \text{Excess Air} \rightarrow CO_2 + 2H_2O + 8N_2 + \text{Excess Air} + \text{Heat}$$

Figure 5 illustrates this formula when using 50% more air than required for perfect combustion (excess air).

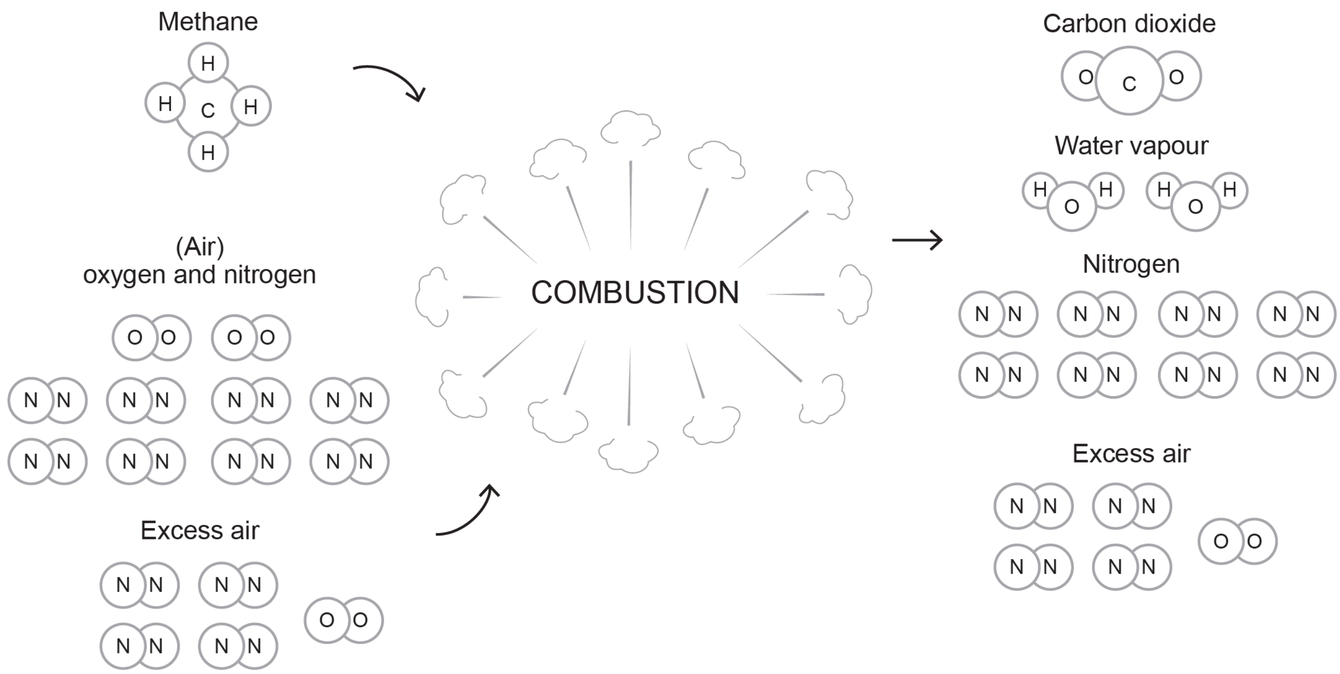


Figure 5 *Complete combustion of methane and air. (Skilled Trades BC, 2021) Used with permission.*

The complete combustion formula for propane is expressed as follows:

$$C_3H_8 + 5O_2 + 20N_2 + \text{Excess Air} \rightarrow 3CO_2 + 4H_2O + 20N_2 + \text{Excess Air} + \text{Heat}$$

Self-Test A-3.1: The Chemistry of Combustion

Complete Self-Test A-3.1 and check your answers.

If you are using a printed copy, please find Self-Test A-3.1 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=47#h5p-7 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=47#h5p-7)

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- **Figure 1** Fire tetrahedron (https://commons.wikimedia.org/wiki/File:Fire_tetrahedron.svg) (adapted) by Gustavb (https://en.wikipedia.org/wiki/User:Gustavb), via Wikimedia Commons, is in the public domain (https://en.wikipedia.org/wiki/en:public_domain).

A-3.2 Calculating Air Requirements and Products of Combustion

The efficient and safe operation of gas-fired appliances relies on an adequate supply of air. Later studies will involve sizing and installing the air supply openings and ducts. Understanding the volume of air that a gas-fired appliance requires will help when sizing and installing air supply openings and ducts.

Section A-3.1 The Chemistry of Combustion (#chapter-a-3-1-chemistry-of-combustion) looked at the products of the combustion process. The quantity of these flue gases will affect the design of the venting systems.

Future studies will involve performing a flue-gas analysis to ensure the safe operation and maximum efficiency of gas appliances. Knowledge of the proper proportions of each product is essential for interpreting the results of the flue-gas analysis.

Air Requirements

Air supply (Figure 1) has three main categories:

- Combustion air (theoretical)
- Excess air
- Dilution air

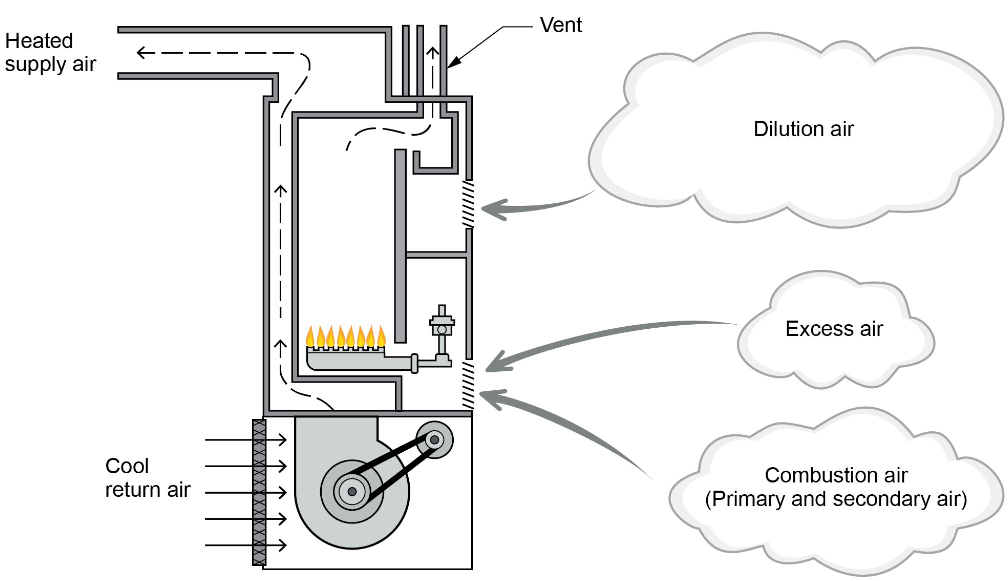

Figure 1 *Types of gas appliance air supply. (Skilled Trades BC, 2021) Used with permission.*

Combustion Air

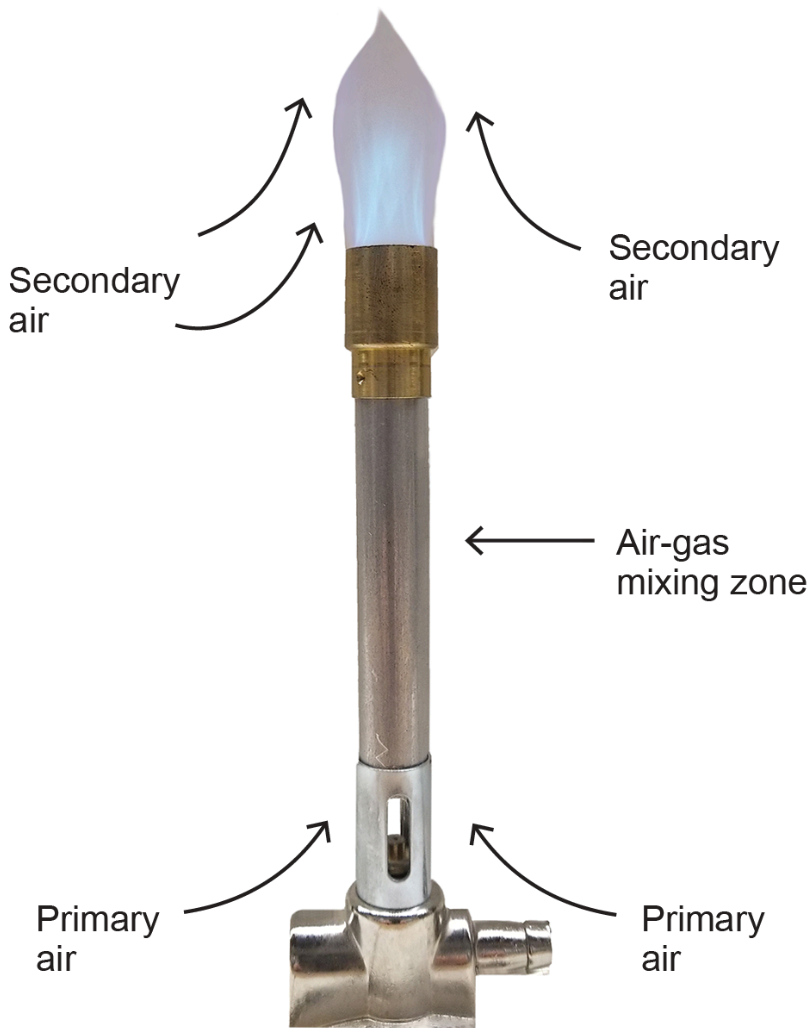

Figure 2 *Combustion air flow. (Skilled Trades BC, 2021) Used with permission.*

Combustion air (the theoretical amount of air required for the combustion process) is expressed as an air/gas ratio and is 10:1 for natural gas and 25:1 for propane. Combustion air can be further subdivided into two classifications: primary and secondary air. The combustion air mixed with the fuel gas before the ignition point is referred to as "**primary air**" (Figure 2). For a typical non-mechanical burner, the amount of primary air used is normally considered to be one-third of the combustion air. Depending on the mixing capability of a mechanical burner, the primary air ratio will be much higher.

The **secondary air** is required to complete the combustion process and is supplied at the flame. Secondary air is generally considered to be the other two-thirds of the combustion air required for perfect combustion (Figure 2).

Excess Air

To ensure that all fuel is completely burned, **excess air** must be introduced, often half as much again as would be needed for stoichiometric combustion.

When extra air is introduced, more gases must be heated by the same amount of **BTU's**. This decreases the initial temperature of the flue gas. At the same time, a larger volume of flue gas is forced through the heat exchanger in a shorter period of time, causing a rapid fall in heating efficiency. Therefore, enough excess air must be made available to ensure **complete combustion** without drastically reducing the appliance's efficiency.

Compared to the combustion air supply, most mechanical burners can achieve complete combustion with as little as 20% to 30% excess air, while some atmospheric burners require as much as 50% excess air.

Considering worst-case scenarios, the amount of excess air that must be available to a gas-fired appliance is another 50% of that required for perfect combustion.

Dilution Air

Natural draft appliances are equipped with a draft control device that draws additional ambient air into the venting system to control the draft influence on the combustion chamber. This air also cools the hot vent gases prevalent in these lower-efficiency appliances.

If an appliance has a draft control device, such as a draft hood, draft diverter, or barometric damper, the required volume of **dilution air** usually equals the total of the combustion and excess air supplied to the burner.

Modern high-efficiency appliances have much lower flue-gas temperatures and, therefore, will not have a draft control device because they do not require dilution air.

Air Supply Volumes

The chemical formula for perfect combustion was examined in Section 3.1 The Chemistry of Combustion (#chapter-a-3-1-chemistry-of-combustion). There, in terms of volume, it described every unit of natural gas as combining with 10 units of air and every unit of propane requiring 25 units of combustion air. The other air volumes needed were then given as percentages of the theoretical combustion air requirements. Therefore, the total air requirements can be calculated based on the appliance input and type of gas. The calculations for the different categories of air supply are shown below for natural and propane gas.

Air Requirements for Natural Gas

$$\frac{\text{Input}}{\text{Caloric Value}} = \text{Gas Flow Rate}$$

$$\text{Combustion Air} = \text{Gas Flow Rate} \times 10 \, (10:1)$$

- Primary Air = $\frac{1}{3}$ of Combustion Air
- Secondary Air = $\frac{2}{3}$ of Combustion Air

$$\text{Excess Air} = \text{Gas Flow Rate} \times 5 \, (50\% \text{ of Combustion Air}, 5:1)$$

$$\text{Dilution Air} = \text{Gas Flow Rate} \times 15 \, (\text{Combustion Air} + \text{Excess Air}, 15:1)$$

$$\text{Total Air} = \text{Gas Flow Rate} \times 30 \, (\text{Combustion Air} + \text{Excess Air} + \text{Dilution Air}, 30:1)$$

Air Requirements for Propane Gas

$$\frac{\text{Input}}{\text{Caloric Value}} = \text{Gas Flow Rate}$$

$$\text{Combustion Air} = \text{Gas Flow Rate} \times 25 \, (25:1)$$

- Primary Air = $\frac{1}{3}$ of Combustion Air
- Secondary Air = $\frac{2}{3}$ of Combustion Air

$$\text{Excess Air} = \text{Gas Flow Rate} \times 12.5 \, (50\% \text{ of Combustion Air}, 12.5:1)$$

$$\text{Dilution Air} = \text{Gas Flow Rate} \times 37.5 \, (\text{Combustion Air} + \text{Excess Air}, 37.5:1)$$

$$\text{Total Air} = \text{Gas Flow Rate} \times 75 \, (\text{Combustion Air} + \text{Excess Air} + \text{Dilution Air}, 75:1)$$

In reality, the combustion air supply requirements should be the same, whether the appliance operating on propane or natural gas (10 ft^3 of air for each 1,000 BTU/h of input). Because a 100,000 BTU/h appliance requires a **gas flow rate** of 100 CFH when fired on natural gas but only 40 CFH on propane, it maintains the air to gas ratios.

Calculating the Volume of Combustion Gases

As discussed in the previous section, the products of complete combustion are carbon dioxide (CO_2), water vapour (H_2O), and nitrogen (N_2). The composition of these flue gases depends on the type of gas and the air-gas ratio.

The following is the complete combustion formula for natural gas with excess air:

$$CH_4 + 2O_2 + 8N_2 + \text{Excess Air} \rightarrow CO_2 + 2H_2O + 8N_2 + \text{Excess Air} + \text{Heat}$$

Figure 3 shows that every unit of natural gas consumed produces one unit of carbon dioxide, two units of water vapour, and eight units of nitrogen. The amount of excess air found in the flue gas equals the exact amount of excess air introduced prior to combustion.

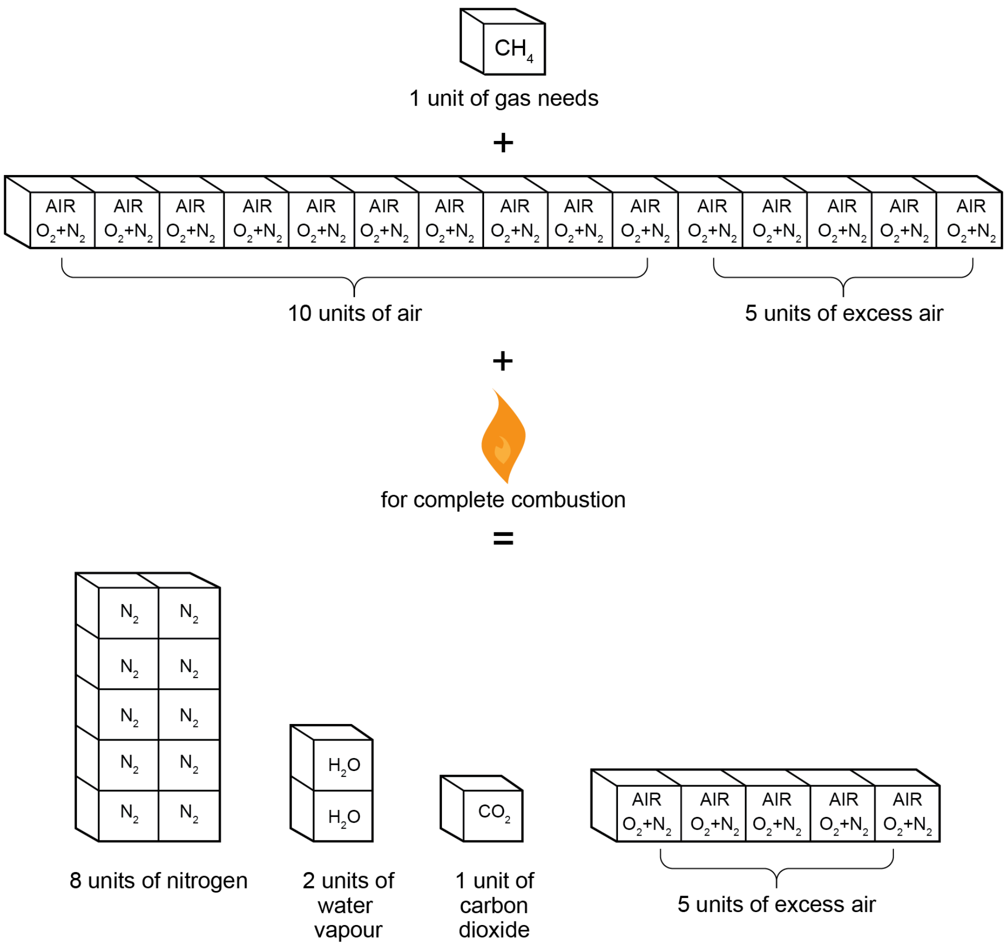

Figure 3 *Products of combustion from burning natural gas. (Skilled Trades BC, 2021) Used with permission.*

The following is the complete combustion formula for propane gas with excess air:

$$C_3H_8 + 5O_2 + 20N_2 + \text{Excess Air} \rightarrow 3CO_2 + 4H_2O + 20N_2 + \text{Excess Air} + \text{Heat}$$

In terms of volume, every unit of propane gas consumed produces three units of carbon dioxide, four units of water vapour, and 20 units of nitrogen. Just as with the natural gas, the amount of excess air found in the flue gas equals the exact amount of excess air introduced prior to combustion.

Do not conclude from this equation that a given appliance operating on propane instead of natural gas would have 2.5 times as much flue gas. As was mentioned previously, the appliance would only require 40% as much initial propane fuel for the same heat energy input; therefore, the result would be the same volume of flue gas.

The calculated quantities of the different products of combustion based on the appliance input and type of gas are below.

Products of Combustion for Natural Gas

$$\frac{\text{Input}}{\text{Caloric Value}} = \text{Gas Flow Rate}$$

$$\text{Gas Flow Rate} \times 1 = \text{Carbon Dioxide}$$

$$\text{Gas Flow Rate} \times 2 = \text{Water Vapour}$$

$$\text{Gas Flow Rate} \times 8 = \text{Nitrogen}$$

Products of Combustion for Propane Gas

$$\frac{\text{Input}}{\text{Caloric Value}} = \text{Gas Flow Rate}$$

$$\text{Gas Flow Rate} \times 3 = \text{Carbon Dioxide}$$

$$\text{Gas Flow Rate} \times 4 = \text{Water Vapour}$$

$$\text{Gas Flow Rate} \times 20 = \text{Nitrogen}$$

In further studies, evaluations of combustion efficiency will be made by analyzing the actual composition of the flue-gas products compared to the theoretical values.

The following is a sample calculation of both the air supply and products of combustion for a 100,000 BTU/h natural gas boiler with a draft control operating at 50% excess air:

Gas Flow Rate

$$\frac{(100\,000 \text{ Btuh})}{(1\,000 \text{ Btu/ft}^3)} = 100 \text{ CFH}$$

Total Air Supply Calculation

Combustion Air:

$$100\ \text{CFH} \times 10 = 1\,000\ \text{CFH}$$

- $\frac{1}{3}$ Primary Air = 333.333 CFH
- $\frac{2}{3}$ Secondary Air = 666.667 CFH

Excess Air ($\text{Combustion Air} \times 50\%$):

$$100\ \text{CFH} \times 5 = 500\ \text{CFH} \quad \text{or} \quad 1\,000\ \text{CFH} \times 0.5 = 500\ \text{CFH}$$

Dilution Air ($\text{Combustion Air} + \text{Excess Air}$):

$$100\ \text{CFH} \times 15 = 1\,500\ \text{CFH} \quad \text{or} \quad 1\,000\ \text{CFH} + 500\ \text{CFH} = 1\,500\ \text{CFH}$$

Products of Combustion Calculation

CO_2: $100\ \text{CFH} \times 1 = 100\ \text{CFH}$

H_2 : $100\ \text{CFH} \times 2 = 200\ \text{CFH}$

N_2 : $100\ \text{CFH} \times 8 = 800\ \text{CFH}$

Self-Test A-3.2: Calculating Air Requirements and Products of Combustion

Complete Self-Test A-3.2 and check your answers.

If you are using a printed copy, please find Self-Test A-3.2 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=49#h5p-8 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=49#h5p-8)

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Trades Training BC. (2021). A-3: Air supply for gas appliances. In: *Plumber Apprenticeship Program: Level 2*. Industry Training Authority, BC.

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A-3.3 Gas Appliance Draft

Proper operation of gas appliances requires a draft to move the hot flue gases and air through the combustion chamber, heat exchanger, and venting system. The draft movement can occur naturally (**natural draft**), or it can be created by a blower (**mechanical draft**).

For combustion efficiency, the amount and force of the draft must be controlled. A too strong draft will pull in too much combustion air and affect the efficiency of the appliance. A too weak draft will smother the flame and reduce combustion efficiency. Therefore, draft control equipment is an essential part of a venting system.

Natural Draft

When the draft is created naturally, without any mechanical influence (e.g., using a fan), it is referred to as "natural draft." The natural draft is created because the hot gases from combustion are lighter than the ambient heavy (cool) air and, therefore, move upward and out the vent. The displaced air is replaced by cool outside air coming in.

The movement of air into and out of the buildings, chimneys, and flue-gas vents as a result of air buoyancy is referred to as **stack effect or chimney effect**. Large temperature differences between the outside air and flue gases can create a strong stack effect in chimneys and vents. The taller the stack, the more draft it creates. There can be limitations on the gains in stack effect created by height. For example, if a stack is overly tall in relation to the heat being sent out of the stack, the flue gases may cool before reaching the top. This condition may result in poor draft.

Natural draft equipment controls the amount of draft by admitting dilution air into a relief opening, breaking the stack effect on the combustion chamber and cooling the hot vent gases.

There are different types of natural draft control equipment, depending on the type of burner and appliance: **draft hoods** (Figure 1), draft diverters, and **barometric dampers**.

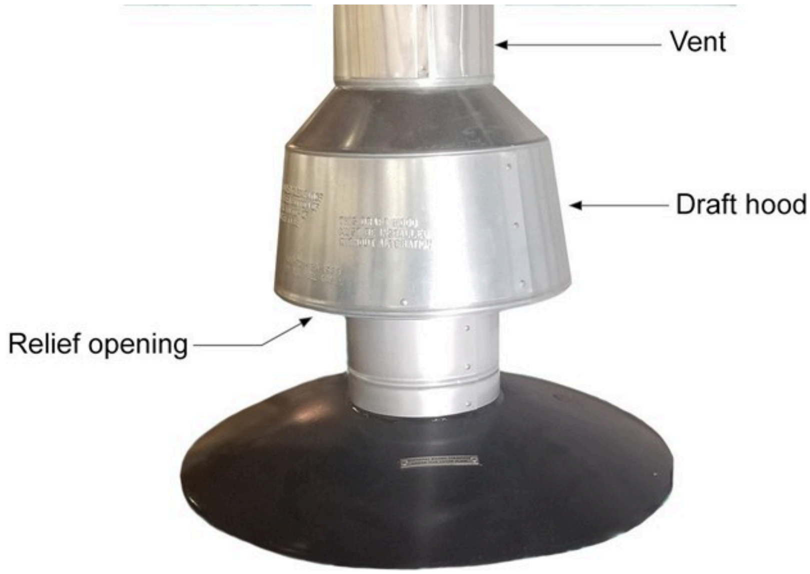

Figure 1 Draft hood on top of stream boiler. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)

Another purpose of a draft hood is to prevent any downdrafts from entering the combustion chamber of the appliance. The draft hood also allows the draft to spill through the relief opening if the appliance vent is blocked or restricted (Figure 2). For additional protection, the appliance often has a heat-activated safety device called a spill switch that will shut down the burner in the event of flue-gas spillage.

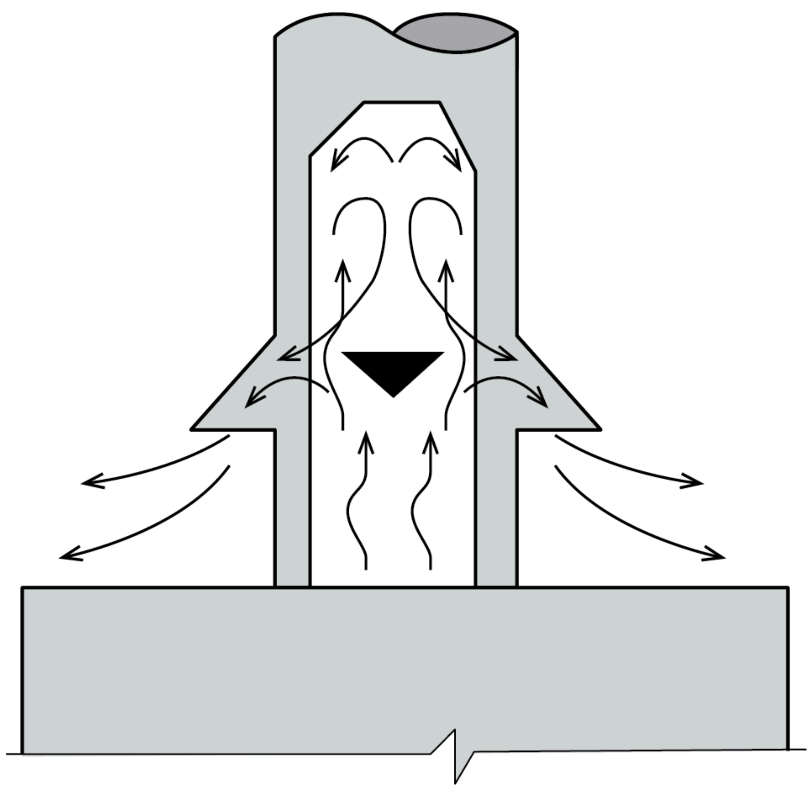

Figure 2 Draft hood spillage. (Skilled Trades BC, 2021) Used with permission.

Since the heat inside a natural draft vent system represents the power available to operate the vent, a natural draft vent will not operate properly on high-efficiency appliances. High-efficiency appliances require a mechanical fan or blower to assist in delivering the combustion air and venting the products of combustion.

Mechanical Draft

There are three types of mechanical draft systems:

- Fan-assisted appliances
- Power venters
- Power burners

Fan-Assisted Appliances

Fan-assisted combustion systems use mechanical means (Figure 3) to either draw or force the products of combustion through the combustion chamber or heat exchanger. This also gives the appliance more accurate control over the air supply, which reduces the amount of excess and dilution air, increasing efficiency. These are mid-efficiency appliances, and the flue products are still hot enough to create a natural draft to remove the flue gases.

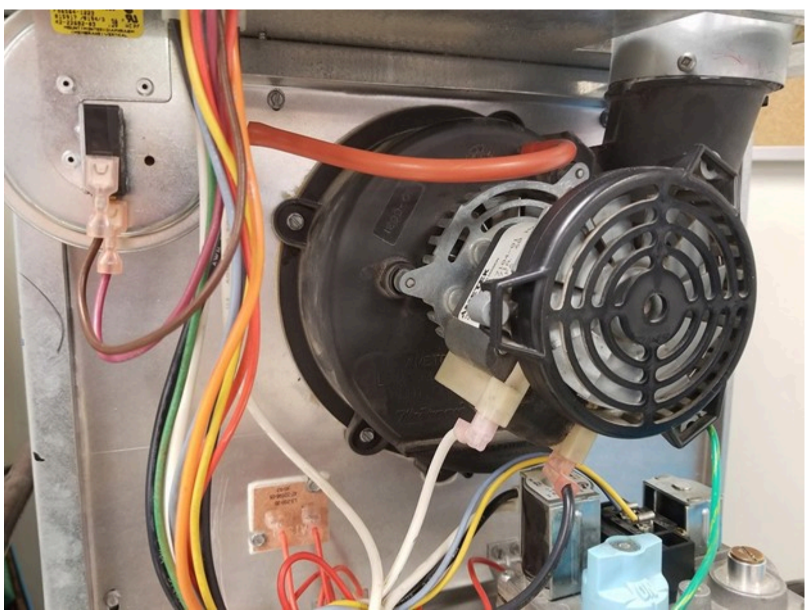

Figure 3 *Fan-assisted furnace.* (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)

Power Venters

One type of mechanical draft is referred to as power venting. **Power venters** are sometimes used to overcome particular venting problems, such as extra-long vents, excessive negative pressures, or improper venting design. Power venters are used on natural draft appliances and installed at or near the vent outlet, thus maintaining a negative pressure within the venting system (Figure 4).

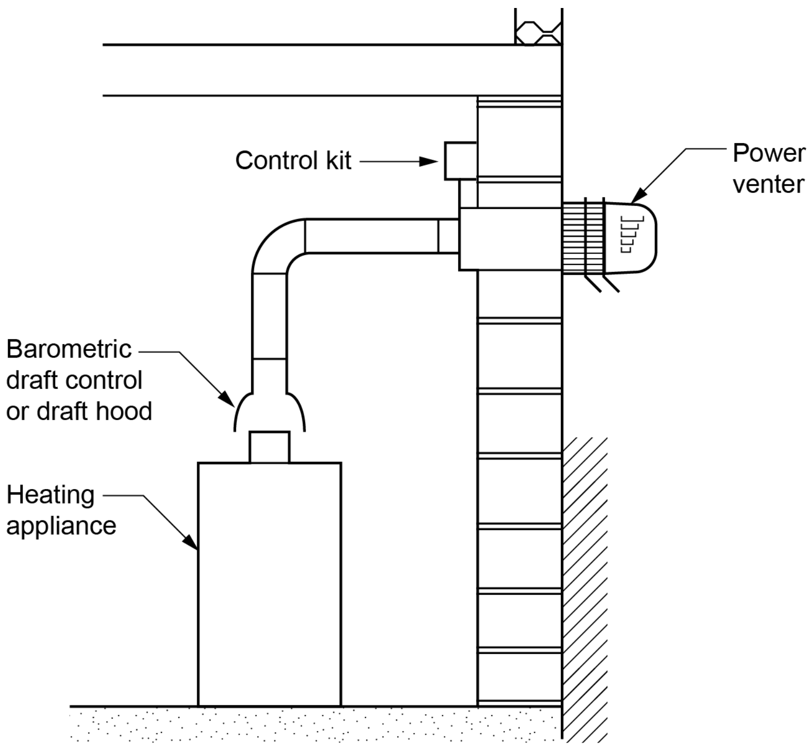

Figure 4 *Power venter. (Skilled Trades BC, 2021) Used with permission.*

Power Burners

Appliances that have mechanical draft burner systems are often referred to as **power burners**. Power burners generate sufficient pressure to overcome the resistance of the burner, appliance, and venting system. These burners are categorized according to the location of the fan or blower in relation to the combustion chamber, either forced-draft or **induced-draft burners**.

A **forced-draft burner** has the fan or blower located upstream of the combustion zone (Figure 5).

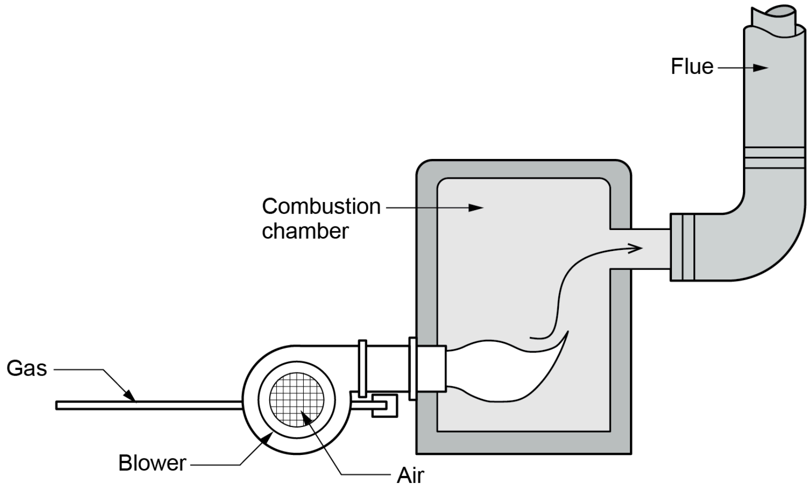

***Figure 5** Forced-draft burner. (Skilled Trades BC, 2021) Used with permission.*

An induced-draft burner uses the mechanical draft produced by a fan located on the downstream (chimney side) of the combustion zone, as shown in Figure 6.

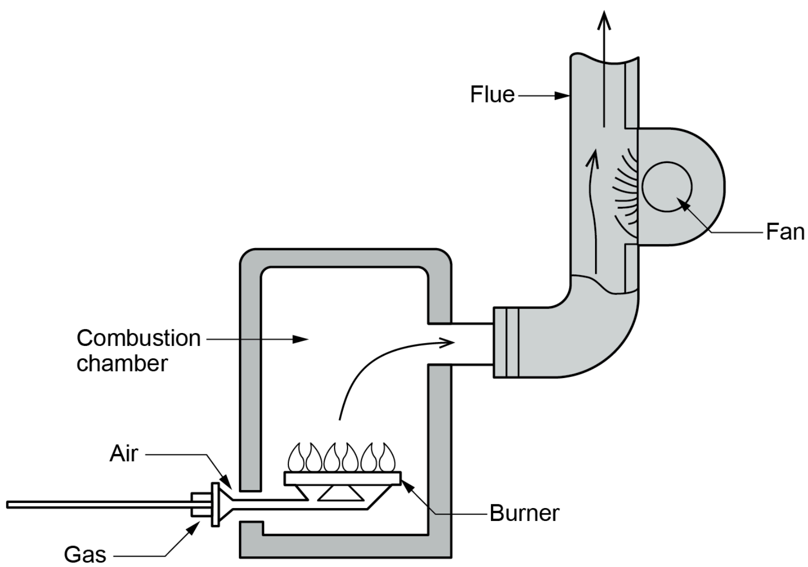

***Figure 6** Induced-draft burner. (Skilled Trades BC, 2021) Used with permission.*

Appliances that rely on mechanical drafts are equipped with an air-proving control interlocked with the burner to confirm the flow of combustion air or flue gas.

Gas Appliance Categories

The type of draft system that is used by a gas appliance greatly affects the efficiency and vent pressure of the appliance, which also has significance to the installation of the appliance.

Therefore, the CSA B149.1 Natural Gas and Installation Code splits appliances into **categories** based on their vent pressures and efficiencies (flue losses).

Category I

An appliance with a flue loss not less than 17% (not greater than 83% efficiency) that operates with a nonpositive vent static pressure. Example: A standard, non-condensing gas furnace. This type of furnace typically operates at around 80% efficiency and uses a natural draft system where the flue gases are vented through a chimney. The vent pressure is nonpositive, relying on the natural buoyancy of hot gases to rise and exit.

Category II

An appliance with a flue loss less than 17% (greater than 83% efficiency) that operates with a nonpositive vent static pressure. Example: A high-efficiency, non-condensing gas water heater. This appliance is more efficient than Category I, operating at greater than 83% efficiency, but still has a nonpositive vent pressure. It might use a more advanced heat exchanger to extract additional heat from the combustion gases.

Category III

An appliance with a flue loss not less than 17% (not greater than 83% efficiency) that operates with a positive vent static pressure. Example: A tankless gas water heater. This appliance is also non-condensing with an efficiency of around 80-83%, but it requires a power vent system (positive vent static pressure) to expel the combustion gases. The venting system is often sealed and uses a fan to push the gases out, allowing more flexibility in vent placement.

Category IV

An appliance with a flue loss less than 17% (greater than 83% efficiency) that operates with a positive vent static pressure. Example: A condensing gas furnace. These are highly efficient (above 90% efficiency) appliances that condense water vapor from the exhaust gases to extract additional heat. They operate with a positive vent static pressure and often use a PVC vent pipe since the flue gases are cooler.

Self-Test A-3.3: Gas Appliance Draft

Complete Self-Test A-3.3 and check your answers.

If you are using a printed copy, please find Self-Test A-3.3 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

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A-3.4 The Building as a System

The purpose of a building is to provide comfort for its occupants. Technological advances in the construction industry that make buildings more energy-efficient, comfortable, and cost-effective have carried with them the need for tradespeople to understand the building as a whole system.

The **building system** is made up of four major subsystems:

- Occupants
- Building envelope
- Outside environment
- Mechanical and electrical equipment

These subsystems all affect the flow of air, heat, and moisture to and from the building. Although these flow factors are often interrelated, this section will focus on air flow.

Types of Buildings

There are many different ways of categorizing building types, including:

- The purpose they are used for, such as residential, educational, institutional, business, storage/warehouse, industrial, and so on
- Design and height, such as multi-storey or high rise, detached, or semidetached
- Whether or not the building was designed and built using strategies aimed at improving performance in areas of energy efficiency and environmental responsibility

For the purpose of HVAC systems, the tightness of the building is often used to categorize the building because it has the greatest effect on the flow factors. With the introduction of new building materials and techniques and the growing emphasis on energy efficiency, modern buildings have become increasingly airtight.

Having a sound knowledge of “building as a system” principles helps to minimize conditions that can affect appliance performance and ensures the health and safety of the occupants. For example, combustion appliances that operated quite well in the relatively leaky buildings of the past may not operate safely in air-sealed modern buildings or retrofitted homes.

Building Envelope

The **building envelope** is the physical separator between the conditioned and unconditioned environment.

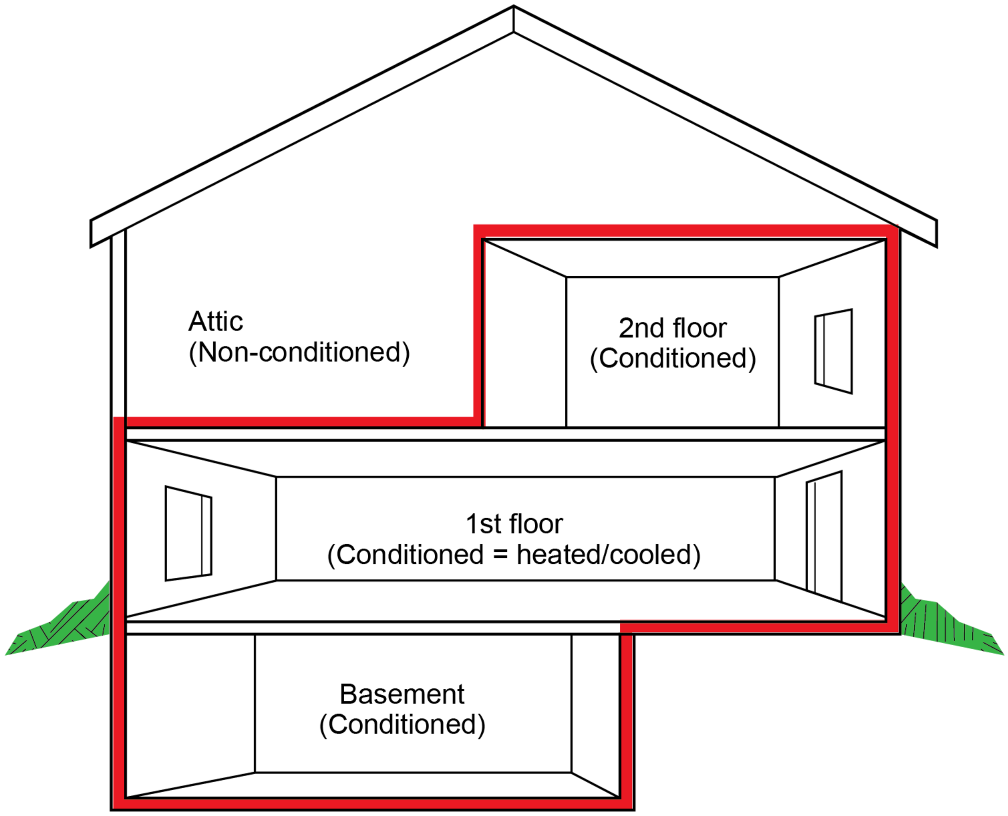

Figure 1 *Building envelope.* (ABCB, 2016) CC BY 4.0 (*https://creativecommons.org/licenses/by/4.0/*)

While the building envelope is a silhouette of sorts, each part of the building envelope must be thought of as a collection of smaller pieces working together to provide structural support.

Building envelope components work together to perform two basic but critical functions: provide structural support and control the flow factors. The function of controlling the flow of moisture, heat, and air is at the core of good building performance.

The control of air flow, including flow through the enclosure, is important to ensure indoor air quality.

The physical components of the envelope include the foundation, roof, walls, doors, windows, ceiling, and related barriers and insulation. Building envelopes are often characterized as either "tight" or "loose." A loose building envelope allows more of a natural air transfer to occur. These types of building envelopes make the building draftier, more uncomfortable, and harder to regulate temperature levels. A tight building envelope allows for a high level of control over indoor air quality, temperature, humidity levels, and energy consumption. Additionally, good building envelopes that prevent drafts and other air leaks allow for better control of the inside air pressure.

It is impossible and unsafe to completely seal a building; however, every effort should be made to limit air and moisture leak points and increase insulation. The region and location of the building will have different environmental conditions (e.g., weather and ground conditions) that will affect the selection of the available materials used to make up the layers of the building envelope.

Building Ventilation Air

Indoor air quality is directly related to levels of air pollution. **Ventilation** is the main method used to control indoor air quality by removing indoor contaminants and replenishing stale or over-moist air with fresh outside air. Inadequate ventilation can lead to mould, high concentrations of CO_2, and other indoor air pollutants, which can lead to adverse health outcomes. Frequent air exchange ensures that pollutants from household air are removed with speed and efficiency. The BC Building Code (BCBC) requires the installation of a principle ventilation system to ensure that an adequate amount of ventilation air is provided.

There are a number of ventilation options found in the BCBC that are categorized as either mechanical ventilation, natural ventilation, or mixed-mode ventilation.

Soil Gas

Outdoor air entering a dwelling through above-grade leaks in the building envelope normally improves the indoor air quality in the dwelling by reducing the concentrations of pollutants and **water vapour**. On the other hand, air entering a dwelling through below-grade leaks in the envelope may increase the water vapour content of the indoor air and may also bring in a number of pollutants picked up from the soil. This mixture of air, water vapour, and pollutants is sometimes referred to as "**soil gas**." Air contaminants of concern, such as radon, must be removed at their point of origin.

Radon Mitigation

Radon is a colourless, odourless radioactive gas that occurs naturally as a result of radium decaying. It is found to varying degrees as a component of soil gas in all regions of Canada and is known to enter dwelling units by **infiltration** into basements and crawlspaces. The presence of radon in sufficient quantity can lead to an increased risk of lung cancer.

The principal method of resisting the ingress of all soil gases is to seal the interface between the soil and the occupied space as much as is reasonably practicable. In addition, various sections of the BCBC require the application of certain radon exclusion measures in all dwellings. The completion of a subfloor depressurization system may be necessary to reduce the radon concentration to a level below the guideline specified by Health Canada.

The principal method of excluding radon is to install a subfloor depressurization system to ensure that the pressure difference across the ground/space interface is positive (i.e., toward the outside) so that the inward flow of radon through any remaining leaks will be minimized.

The most common and efficient soil depressurization systems require the following (see Figure 2):

- Space for the movement of soil gases between the ground and the air barrier system (see the gas permeable layer in Figure 2) into which a radon vent pipe is inserted.
- Extension of the radon vent pipe to the exterior of the building, terminating in a safe location.
- The radon vent pipe can be mechanically assisted, typically by means of a fan installed along the pipe, to create a negative pressure in the space between the air barrier system and the ground and to exhaust soil gases outside the building.

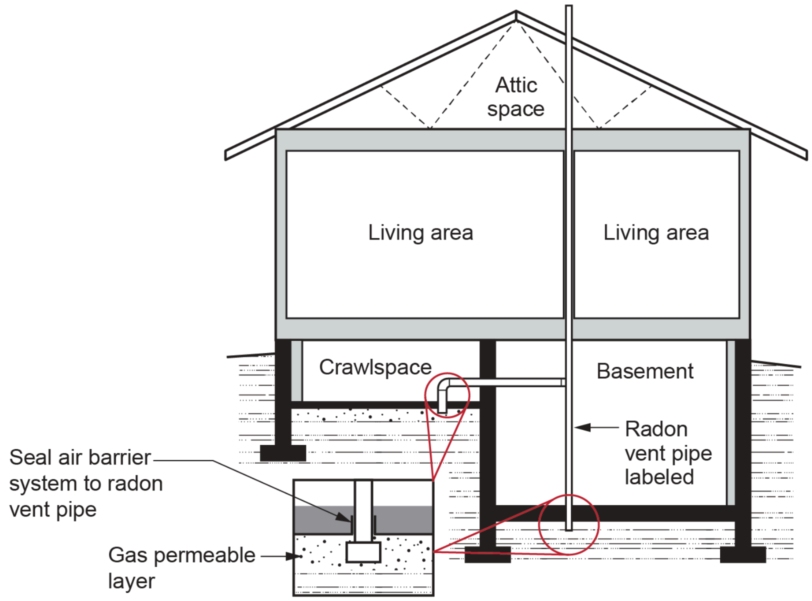

Figure 2 Soil gas depressurization system. (Government of BC/ Skilled Trades BC, 2021) Used with permission.

Building Make-Up Air

Proper air flow throughout a building depends upon balanced pressures. Excessive removal of air can create a negative pressure in the building that leads to inward pressure (Figure 3). Additionally, **make-up air** may be required to offset the air removed by appliances with large exhaust fans. The additional make-up air supply equipment must supply outdoor air at a rate that matches the exhaust appliance.

Oversupply of air to the building can drive the warm, moist indoor air into the walls, causing greater heat loss and moisture damage. If the building contains any natural draft gas appliances, the building depressurization must be limited to 5 Pa to eliminate the risk of **backdrafting**. A balanced flow of incoming and outgoing air is required for comfort and safety.

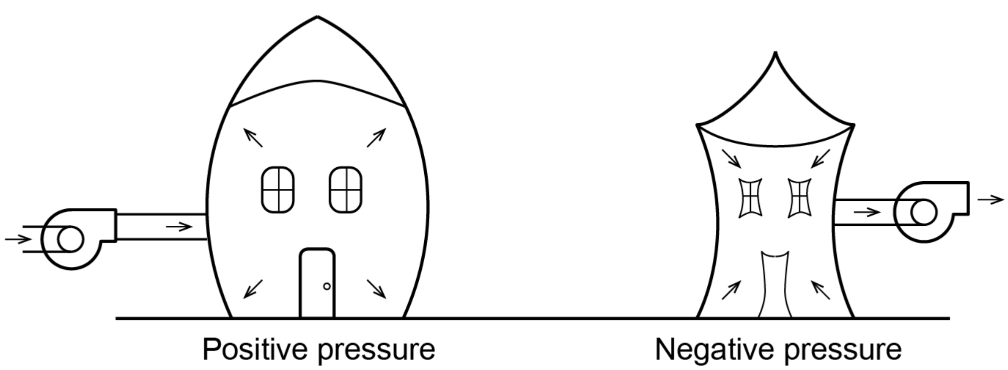

Figure 3 Unbalanced houses. (Skilled Trades BC, 2021) Used with permission.

Ventilation Equipment

Every dwelling unit must include a principal ventilation system. There are many ways of ventilating residential dwellings, and the codes and standards play a large part in deciding what type is appropriate.

There are three basic concerns related to the mechanical ventilation of a building:

- Bringing in the proper amount of ventilation air
- Distributing the air to the required locations
- Avoiding excessive pressurization or depressurization

Previous editions of the British Columbia Building Code relied on ventilation through the building envelope in combination with an exhaust or supply fan. However, with the increased attention on the continuity of the building's air barrier system, relying on the **exfiltration** or infiltration through the building envelop creates an unbalanced house. Combined mechanical ventilation systems are superior because they use both supply and exhaust fans in tandem to create a balanced system.

Air Supply Equipment

The ventilation air supply is often drawn through a controlled outdoor inlet connected to the return air ducting of the forced air recirculating system.

For buildings whose make-up air requirements require large-scale exhaust equipment, a separate supply fan must be interconnected with the exhaust fan. The outdoor air is tempered to at least 1°C before being introduced to a normally unoccupied area of the dwelling unit or house or to at least 12°C before being introduced to occupied areas.

Outside air intakes must be located away from sources of contaminants, such as vehicle exhaust or chemical vapours, and shielded from weather.

Some residential balanced systems rely upon an exhaust fan to create the building suction needed to draw in outside air. Proper sizing of the return air system and location of the outdoor air inlet connection are critical to ensure that the furnace air-circulating fan does not influence the amount of ventilation air being drawn into the building (Figure 4). If the proportion of cold outside to warm return air is too high, the resulting mixed-air temperature could lead to excessive condensation in the furnace heat exchanger and possible premature failure of the heat exchanger.

Exhaust Equipment

A residential mechanical ventilation system has a principal ventilation exhaust fan with an adequate air-flow rate designed to run continuously. The fan size and air-flow rate are based on the number of bedrooms and the floor area of the dwelling. The principal exhaust fan will create a slightly negative pressure (max negative 5 Pa) that draws ventilation air into the building through the outdoor air inlet (Figure 4).

In buildings where natural draft appliances are installed, care must be taken when selecting exhaust fans; oversized exhaust fans may cause backdrafting of flue gases into indoor areas through appliance venting systems.

Odour-producing and moisture-producing areas in dwelling units, such as kitchens and bathrooms, also require dedicated exhaust fans and ductwork.

Commercial and industrial buildings may have other exhaust equipment, such as dust extractors or kitchen hoods, that need to be interlocked with make-up air equipment to maintain balanced building pressure.

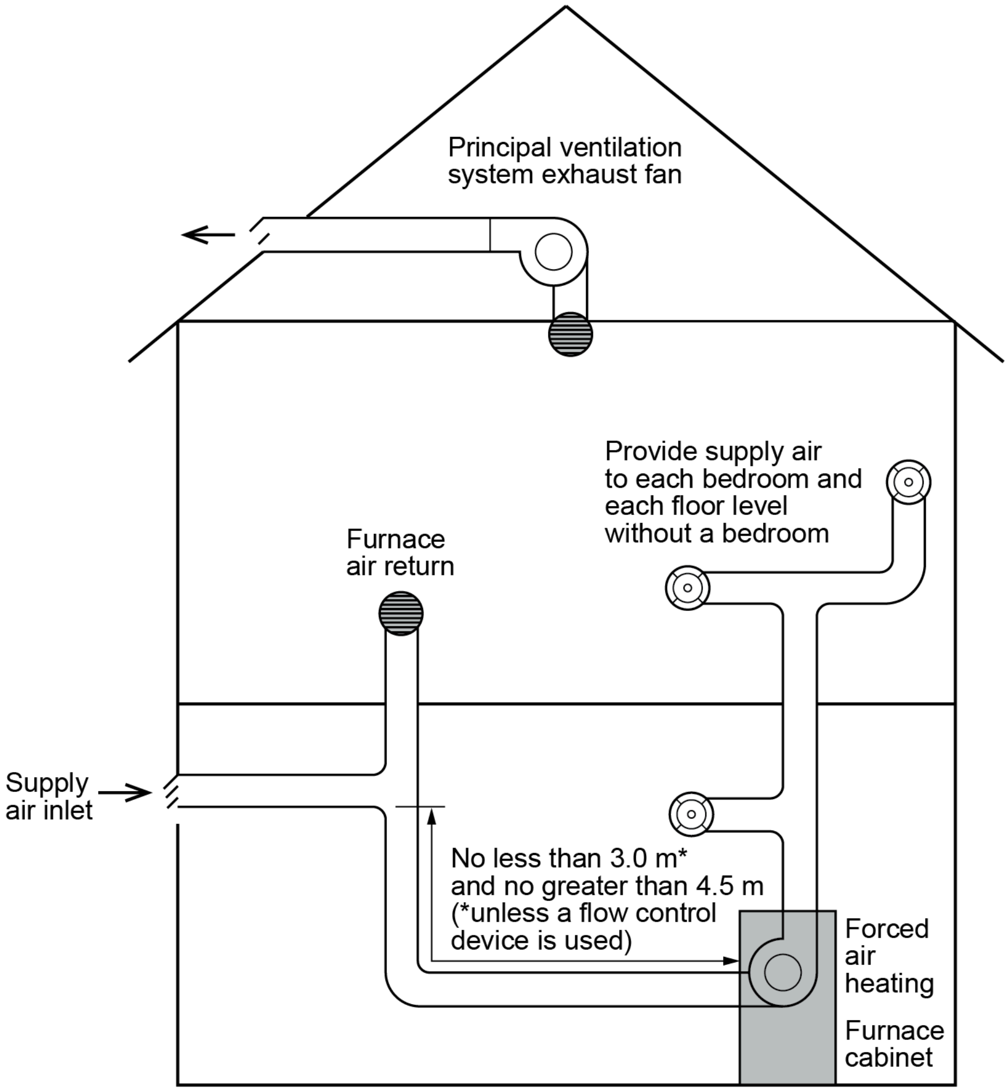

Figure 4 *Simple balanced ventilation system. (Skilled Trades BC, 2021) Used with permission.*

The major disadvantage of the simple system shown in Figure 3 is the heat lost via the exhaust air during the heating season. Any home built to the R-2000 or Energy Star standards must have equipment that will recover the energy from the air being expelled.

Air Exchange Equipment (HRV)

In housing and small buildings, the most common method of recovering heat energy is by preheating the ventilation supply air with the exhaust air using a **heat recovery ventilator (HRV)**. An HRV consists of two fans, creating a balanced air flow, and an in-built “air to air” heat exchanger, which transfers available heat from the exhaust air stream to the cold fresh air supply (Figure 5).

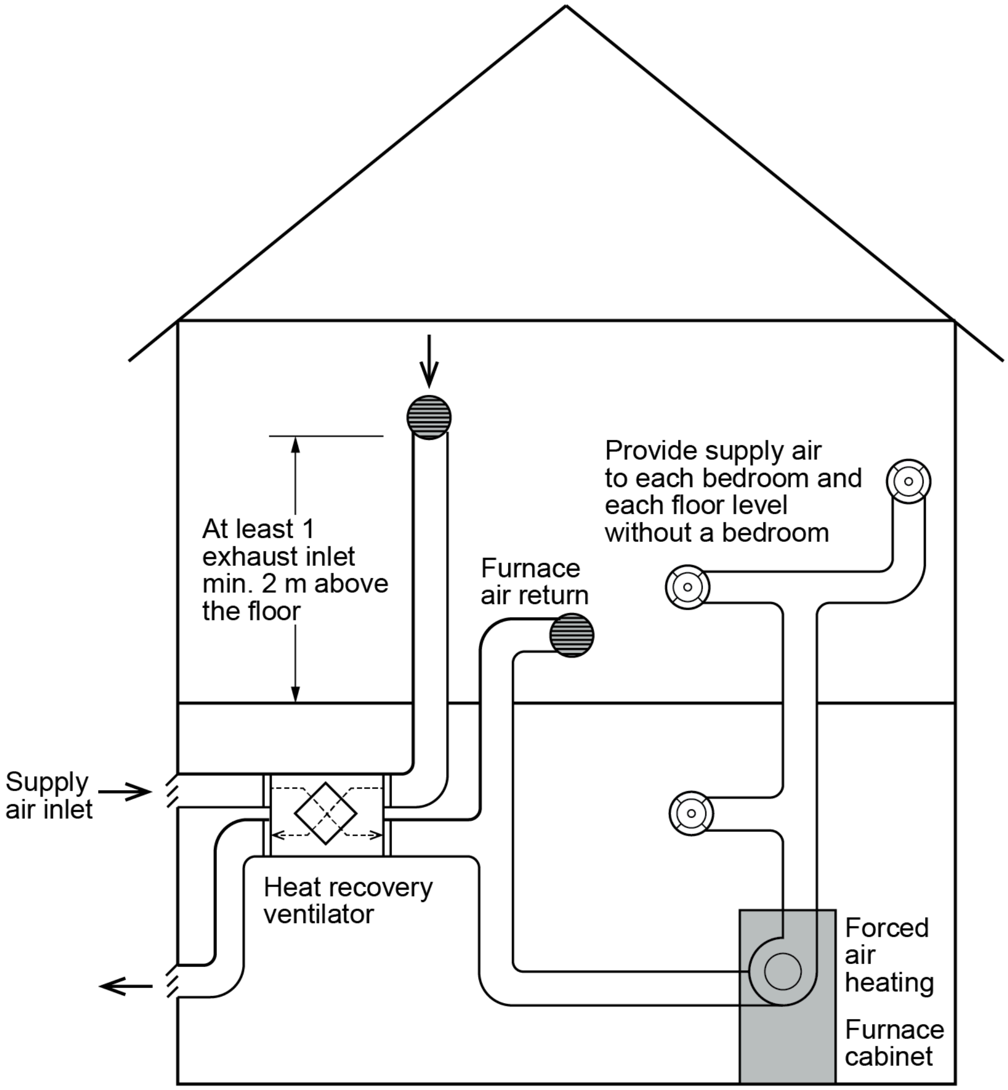

Figure 5 *HRV balanced ventilation system. (Skilled Trades BC, 2021) Used with permission.*

An alternative system, called an **energy recovery ventilator (ERV)**, works in a similar way, but it also transfers some of the moisture from the outgoing airstream into the incoming air to keep the humidity in the home at a constant level. As a general rule, ERV is a better option for an air-conditioned home or a humid climate because it helps keep moisture outside, reducing the load on the air conditioner. HRV is often better when there is no air conditioning or if the building is located in a less humid climate, since it will help keep the humidity down by transferring excess indoor moisture outside.

Combustion Air Requirements

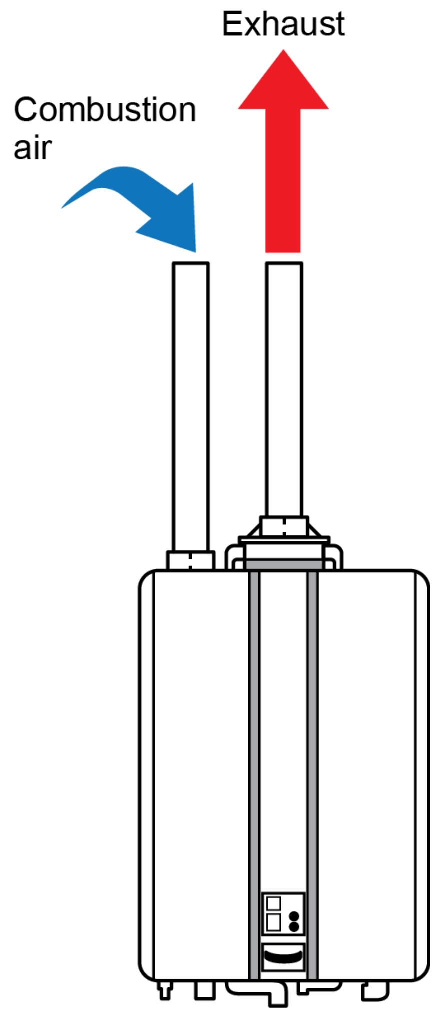

Figure 6 *Two-pipe direct vent gas appliance.*
(Skilled Trades BC, 2021) Used with permission.

Installers must also consider air consumed by any fuel-burning appliances to maintain a balanced building. The efficient and safe operation of gas-fired appliances relies on an adequate supply of air over and above that required for ventilation or make-up air. Learning Task 2 identified that the gas appliance could use as much a 30 ft^3 of total air for each 1,000 BTU/hr of input. There are two common methods of gas appliance air supply:

- Direct vent systems
- Room air systems (non-direct vent)

For a direct vent system, all air for the appliance is taken directly from the outside and the flue gas is discharged to the outdoors. Therefore, the direct vent appliance will have no effect on the air balance of the building (Figure 6).

Non–direct vent gas appliances draw all their air supply requirements from the internal room air, which would create a negative pressure in the room if there was not an air supply dedicated to the gas appliance. For gas appliances dependent on room air, the outside air is normally brought to gas appliance burners via a duct, but a hole in the wall can be used if it is located within the same area as that required for the duct (Figure 7). These methods could be referred to as passive air supply compared to a mechanical air supply, such as a fan. If a mechanical air supply is used, it must be properly sized and interlocked with the appliances to shut off the gas in the event of an air supply failure.

The regulations regarding the installation and sizing of passive combustion air supply openings and ducts are detailed in Section 8 of the B149.1 Gas Installation Code.

Whether the air supply duct or pipe is being used for a direct vent or a room air system, if the pipe or duct is too long, it will restrict the flow of air. Fittings also create addition resistance to flow, so pipe should be routed as directly as possible with as few bends as possible.

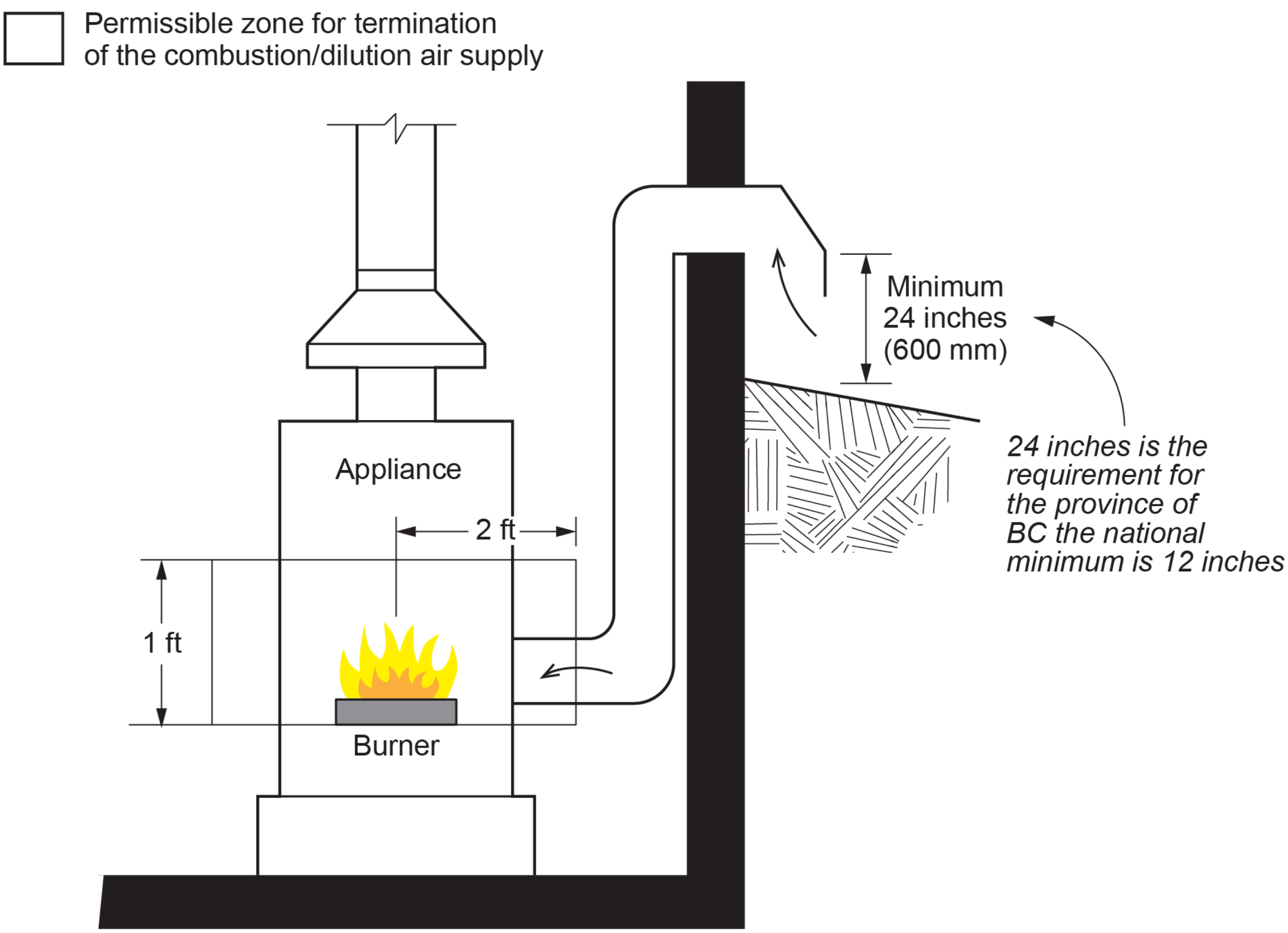

Figure 7 *Passive air-gas appliance air supply. (Skilled Trades BC, 2021) Used with permission.*

Self-Test A-3.4: The Building as a System

Complete Self-Test A-3.4 and check your answers.

If you are using a printed copy, please find Self-Test A-3.4 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=53#h5p-10 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=53#h5p-10)

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Self-Test A-3.1: The Chemistry of Combustion

Complete Self-Test A-3.1 and check your answers.

1. What is the ignition temperature of natural gas?
    a. 900°C
    b. 700°C
    c. 495°C
    d. 480°C

2. Select the perfect combustion formula for natural gas.
    a. $CH_4 + 2O_2 + 8N_2 \rightarrow CO_2 + 2H_2O + 8N_2$ + Heat
    b. $CH_4 + 1O_2 + 4N_2 \rightarrow CO + H_2O + H_2 + 4N_2$ + Heat
    c. $C_3H_8 + 5O_2 + 20N_2 \rightarrow 3CO_2 + 4H_2O + 20N_2$ + Heat
    d. $CH_4 + 2O_2 + 8N_2$ + Excess Air $\rightarrow CO_2 + 2H_2O + 8N_2$ + Excess Air + Heat

3. At high temperatures, nitrogen can bind to form what type of gases?
    a. C
    b. H_2
    c. CO
    d. NOx

4. For each unit of propane, how many units of air are required for perfect combustion?
    a. 10
    b. 15
    c. 25
    d. 30

5. What is the primary purpose of excess air?
    a. To increase efficiency
    b. To increase premixing
    c. To ensure complete combustion
    d. To cool the flame and decrease NOx production

Answer Key: Self-Test A-3.1 is on the next page.

Answer Key: Self-Test A-3.1

1. b. 700°C
2. a. $CH_4 + 2O_2 + 8N_2 \rightarrow CO_2 + 2H_2O + 8N_2$ + Heat
3. d. NOx
4. c. 25
5. c. To complete combustion

Self-Test A-3.2 Calculating Air Requirements and Products of Combustion

Complete Self-Test A-3.2 and check your answers.

1. How many cubic feet of combustion air is required for every cubic foot of propane gas?
   a. 10 ft^3 (0.28 m^3)
   b. 16 ft^3 (0.45 m^3)
   c. 25 ft^3 (0.71 m^3)
   d. 32 ft^3 (0.91 m^3)

2. A volume of natural gas is burned to create 2,000,000 BTU/h of heat. The volume of carbon dioxide produced would be ______.
   a. 2,000 ft^3
   b. 4,000 ft^3
   c. 10,000 ft^3
   d. 20,000 ft^3

3. What do you call air that is premixed with the gas as it enters the burner?
   a. Excess
   b. Dilution
   c. Primary
   d. Secondary

4. A natural draft appliance has an input of 100,000 BTU/h. The appliance is designed to burn natural gas (C.V. 1,000 BTU/cubic feet). How much theoretic combustion air per hour will this appliance require?
   a. 500 ft^3
   b. 1,000 ft^3
   c. 1,500 ft^3
   d. 3,000 ft^3

5. A natural draft appliance has an input of 100,000 BTU/h. The appliance is designed to burn natural gas (C.V. 1,000 BTU/Cu.Ft.). How much excess air per hour will this appliance require?
   a. 500 ft^3
   b. 1,000 ft^3
   c. 1,500 ft^3
   d. 3,000 ft^3

Answer Key: Self-Test A-3.2 on next page.

Answer Key: Self-Test A-3.2

1. c. 25 ft^3 (0.71 m^3)
2. a. 2,000 ft^3
3. c. Primary
4. b. 1,000 ft^3
5. a. 500 ft^3

Self-Test A-3.3 Gas Appliance Draft

Complete Self-Test A-3.3 and check your answers.

1. What is a natural draft in a vent created by?
   a. The height and diameter of the vent.
   b. Atmospheric pressure and the height of the vent.
   c. The outdoor design temperature and diameter of the vent.
   d. The difference in densities of vent gases and ambient room air.

2. What is a down draft?
   a. A draft produced by a mechanical device downstream from the combustion zone.
   b. A draft produced by a mechanical device upstream from the combustion zone.
   c. A draft produced by the upward movement of hot gases, creating a negative pressure.
   d. A condition in which a draft is forced downward and can cause flue-gas spillage.

3. There is no limit to the benefits gained by increasing the vent height.
   a. True
   b. False

4. Other than admitting dilution air, what is the other function of a draft hood?
   a. Allows for spillage
   b. Keeps the vent cold
   c. Neutralizes excess air
   d. Prevents back drafts in the common vent

5. What is the maximum efficiency of a Category I appliance?
   a. 17%
   b. 70%
   c. 83%
   d. 90%

6. What is an induced draft?
   a. A draft produced by a mechanical device downstream from the combustion zone.
   b. A draft produced by a mechanical device upstream from the combustion zone.
   c. A draft produced by the upward movement of hot gases, creating a negative pressure.
   d. A condition in which a draft is forced downward, possibly causing flue-gas spillage.

Answer Key: Self-Test A-3.3 is on the next page.

Answer Key: Self-Test A-3.3

1. d. The difference in >densities of vent gases and ambient room air.
2. d. A condition in which a draft is forced downward and can cause flue-gas spillage.
3. b. False
4. a. Allow for spillage
5. c. 83%
6. a. A draft produced by a mechanical device downstream from the combustion zone.

Self-Test A-3.4 The Building as a System

Complete Self-Test A-3.4 and check your answers.

1. The building envelope can and should completely separate the indoors from the outdoors.
   a. True
   b. False

2. Cool air can contain more water vapour than warm air.
   a. True
   b. False

3. What term describes the process of air exiting a building?
   a. Infiltration
   b. Exfiltration
   c. Stack effect
   d. Distribution effect

4. What term describes the process of air entering a building?
   a. Infiltration
   b. Exfiltration
   c. Stack effect
   d. Distribution effect

5. The combustion air supply openings required by CSA B149.1 code are designed to replace the air exhausted by mechanical exhaust devices as well as the air used by gas appliances.
   a. True
   b. False

6. Pressure-induced backdrafting is the reversal of the flow of flue gases out of the building caused by negative pressure in the building.
   a. True
   b. False

7. What is the maximum house depressurization limit (HDL) that a natural draft vented appliance should be exposed to?
   a. 1 Pa (0.004 in. WC)
   b. 5 Pa (0.02 in. WC)
   c. 10 Pa (0.04 in. WC)
   d. 15 Pa (0.06 in. WC)

Answer Key: Self-Test A-3.4 is on the next page.

Answer Key: Self-Test A-3.4

1. a. True
2. b. False
3. b. Exfiltration
4. a. Infiltration
5. b. False
6. a. True
7. b. 5 Pa (0.02 in. WC)

A-4 TECHNICAL INSTRUMENTS AND TESTERS

Plumber Apprenticeship Program – Level 2

Using a Manometer for Gas Pressure (Rheem Furnace) (HVAC tips (https://www.youtube.com/watch?v=pE03Zt8zVxg), 2020 (video still: 4:18). Used under Fair Dealing for educational purposes.

A-4 Technical Instruments and Testers Introduction

Commissioning equipment requires the use of various sensors and instruments. Often, one piece of equipment may require the use of multiple instruments to ensure proper and safe operation.

Learning Objectives

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

- Describe pressure and temperature-measuring tools.
- Interpret pressure readings.
- Use U-tube and digital manometers.
- Use temperature-measuring instruments.
- Use electrical testing meters to test voltage, amperage, resistance and continuity.
- Use combustible gas indicators.

Terminology

The following terms will be used throughout this section. A complete list of terms for this section can be found in the **Glossary**.

- **absolute pressure:** When the pressure is relative to a perfect vacuum, it is referred to as "absolute pressure," which equals gauge pressure plus atmospheric pressure. (Section A-4.1)
- **differential pressure gauge:** A type of gauge with two inlet ports, each connected to one of the volumes whose pressure is to be monitored; this gauge can be used to monitor air flow, check the amount of filter clogging, and test equipment operation; it performs the mathematical operation of subtraction through mechanical means. (Section A-4.1)
- **digital instruments:** Instruments that use electronics to read and display exact numerical data or measurements using LEDs or LCDs as numbers on a screen, like a calculator; easier to read than analogue instruments since you don't have to interpret the numbers on a scale. (Section A-4.3)
- **digital manometer:** The most common portable field pressure-measuring tool due to its many advantages over traditional instruments; it uses micro-pressure sensors that alter electrical resistance when pressure is applied and can measure positive, negative, or differential pressures; this tool is compact, can be used in any position, and does not require fluid. (Section A-4.1)
- **distance-to-spot ratio (D:S):** A ratio that tells you how far you need to be from an object to measure its temperature accurately with a thermometer; a higher D:S ratio means you can measure temperature from farther away, like using a zoom on a camera to focus on something far off. (Section A-4.2)

- **emissivity:** A number from 0 to 1 that indicates how much heat a material lets out as radiation; 1 means it gives off radiation well, like a perfect black object; lower numbers mean less heat is released. This matters in infrared thermometers, where knowing emissivity helps get accurate temperature readings by adjusting for how materials reflect or emit heat. (Section A-4.2)
- **infrared (IR) thermometer:** An Instrument that measures temperature by detecting thermal radiation emitted by the object being measured, often referred to as black-body radiation; also known as a laser thermometer due to use of a laser for aiming, or as a non-contact thermometer or temperature gun because it can measure temperature from a distance; by assessing the amount of infrared energy emitted and considering emissivity, infrared thermometers can estimate the object's temperature within a specified range; belongs to the category of devices known as "thermal radiation thermometers." (Section A-4.2)
- **ohmmeter:** A tool used to measure how much something resists the flow of electricity (electrical resistance); it tells you the resistance in units called ohms (Ω); multimeters can serve as ohmmeters when set to resistance-measuring mode; to measure resistance, an ohmmeter applies a current to the circuit or component under test. (Section A-4.2 and Section A-4.3)
- **Positive temperature coefficient (PTC) thermistors:** Resistors with a positive temperature coefficient, which means that the resistance increases with increasing temperature; they are made from materials such as silicon or barium titanate, known for their high resistance properties, and they have various uses such as temperature sensors, self-regulating heaters, and resettable fuses. (Section A-4.2)
- **pressure measurement:** The analysis of an applied force by a fluid (liquid or gas) on a surface; pressure is measured in units of force per unit of surface area. (Section A-4.1)
- **RTD thermometer:** A device that measures temperature by detecting changes in electrical resistance; RTDs can have a range of −200°C to +500°C. (Section A-4.2)
- **thermocouple:** Also referred to as a "thermoelectrical thermometer," an electrical device composed of two different electrical conductors that form an electrical junction; through the Seebeck effect, generates a voltage that varies with temperature, allowing for temperature measurement; extensively used as temperature sensors. (Section A-4.2)
- **water column (WC):** A method for measuring pressure, defined as the pressure produced by a 1-inch by 1-inch column of water of a specified height; useful for expressing low pressures, such as describing 0.072 psi as 2 inches of water. (Section A-4.1)

A-4.1 Pressure Measuring Tools

Pressure measurement is the analysis of an applied force by a fluid (liquid or gas) on a surface. Pressure is measured in units of force per unit of surface area. Many instruments are used to measure fluid pressures, with different advantages and disadvantages. Pressure range, sensitivity, dynamic response, and cost all vary from one instrument design to the next.

Describe Pressure-Measuring Tools

Instruments used to measure and display pressure in an integral unit are called pressure meters, pressure gauges, or vacuum gauges. The most common mechanical pressure-measuring instrument is the Bourdon tube pressure gauge (Figure 1).

Figure 1 *Bourdon tube pressure gauge. (Skilled Trades BC, 2021) Used with permission.*

Types of Pressure Measurements

A variety of units are used to express pressure, depending on the application or discipline. Some units are derived from the method originally used to measure and indicate pressure. For example, one of the earliest methods of pressure measurement, still used today, is observing the level that a column of liquid, such as water or mercury, could be supported or elevated by the pressure.

These units are still used as standard increments on many analogue gauges, while digital gauges typically offer multiple scale display options. Table 1 shows the more common pressure units and their conversion factors. The use of the unit atm (standard atmosphere) has become obsolete and been replaced by the "bar," which is defined as exactly 100 kPa (slightly less than the current average atmospheric pressure on Earth at sea level). The inches-of-water scale, which is commonly used for low-pressure measurements, can be expressed as in H_2O, in.WC, or in.Wg.

Table 1: Pressure Conversion Factors

Pressure Units	kPa	psi	in.Hg	in.WC	atm	bar
1 kPa	1	0.145	0.295	4.015	0.009869	0.01
1 psi	6.895	1	2.036	27.68	0.0680	0.0689
1 in. Hg	3.386	0.491	1	13.6	0.03342	0.03386
1 in. WC	0.249	0.036	.07355	1	.002458	0.00249
1 atm	101.325	14.73	29.92	406.793	1	1.01325
1 bar	100	14.5	29.53	401.859	0.9869	1

Most gauges measure pressure relative to atmospheric pressure as the zero point, so this form of reading is simply referred to as "**gauge pressure.**" However, anything greater than total vacuum is technically a form of pressure. When the pressure is relative to a perfect vacuum, it is referred to as **absolute pressure**, which equals gauge pressure plus atmospheric pressure. At sea level, the pressure from the atmosphere is about 101.3 kPa; therefore, a gauge pressure of 300 kPa equals 401.3 kPa (abs).

The height above, or in some cases below, the earth's surface, has a direct effect on atmospheric pressure. Atmospheric pressure varies with weather conditions. A **barometer** is a type of pressure gauge used specifically to measure atmospheric pressure. The units of measure used are inches of mercury (in.Hg). One standard atmosphere (atm) equals 29.92 in.Hg.

A **vacuum gauge** registers the amount of pressure below the atmospheric pressure. The gauge shown in Figure 2 is called a **compound gauge** because it can measure pressures both above and below atmospheric pressure. Notice that it is registering a vacuum reading of 12 in.Hg below atmospheric pressure, which is equivalent to an absolute pressure of about 18 in.Hg (30 −12 = 18).

Figure 2 *Compound gauge. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

When the instrument registers the difference in pressure between two contained working fluids, it is called **differential pressure**. **Differential pressure gauges** have two inlet ports (Figure 3), each connected to one of the volumes whose pressure is being monitoring. In effect, such a gauge performs the mathematical operation of subtraction through mechanical means. Differential pressure gauges can be used to monitor air flow, check the amount of filter clogging, and test equipment operation.

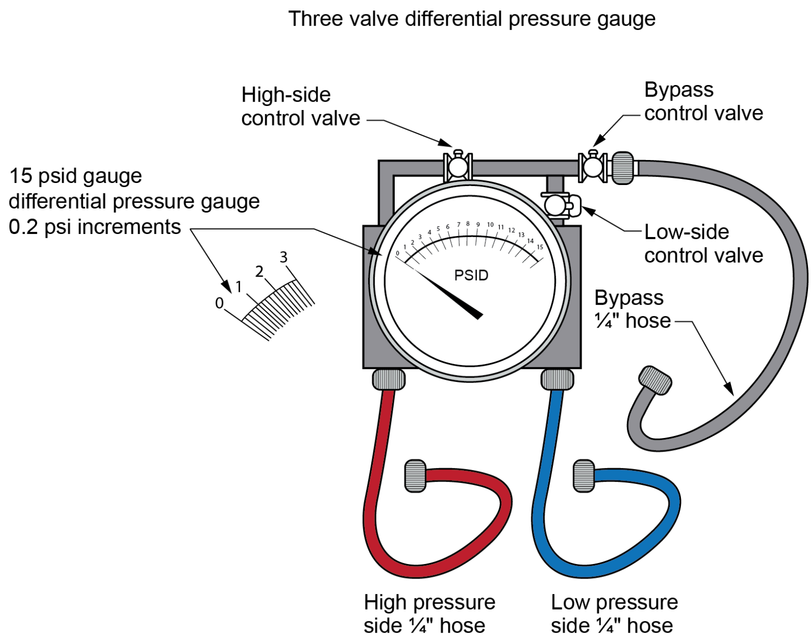

Figure 3 *Differential pressure gauge used for testing backflow prevention assemblies. (Adapted from Richard Mawle/BCcampus)* CC BY NC 4.0 *(https://creativecommons.org/licenses/by-nc/4.0/)*

Fluid Manometers

Fluid manometers consist of a liquid column in a clear tube whose ends are exposed to different pressures. The column rises or falls until the weight of the liquid column balances the pressure differential between the two ends of the tube. The simplest version is the U-tube manometer (Figure 4). With the tube half full of liquid and both legs open to the atmosphere, the level is the same on both sides, and the reading is zero. If the p^1 leg were connected to check the manifold pressure of a gas appliance and the p^2 leg were still open to atmosphere, the manifold gas pressure would be measured by the difference in the liquid heights in the two legs. If the fluid were water, dimension h would measure 3.0 in.

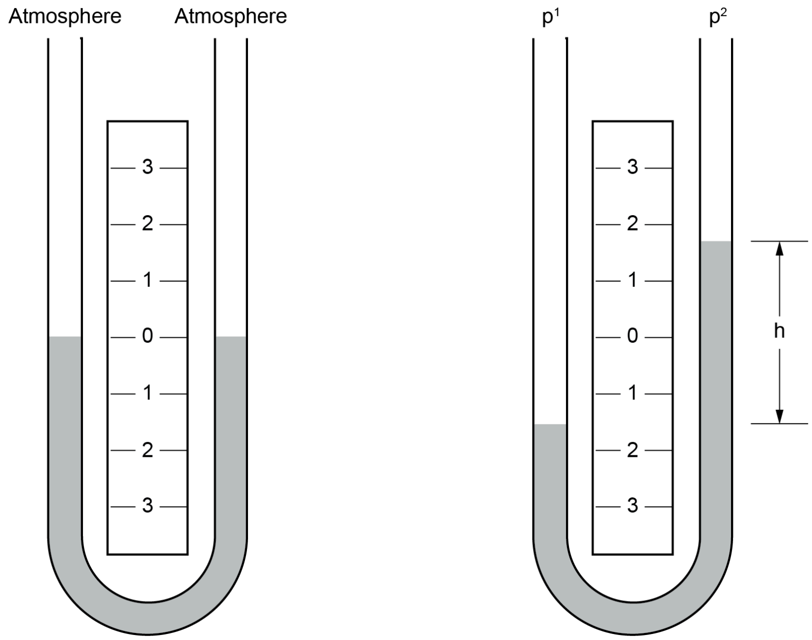

Figure 4 *Fluid-filled U-tube manometer. (Skilled Trades BC, 2021) Used with permission.*

Fluids

Some manometers are designed to use liquids with a different specific gravity (SG) than water, such as coloured oils (Figure 5). In these cases, the monometer's scale may still read as inches of **water column (WC)**, but the actual physical measurement would be adjusted. This enables the manufacturer to change the length of the instrument or design it so that the measurement is only taken on one leg.

Manufacturers will colour-code the fluid. It is important to use the correct fluid that the manometer scale is designed for. The manufacturers also make a coloured fluid that has the same SG as water for easier reading than pure water. This fluid is concentrated and needs to be mixed with water to get the larger quantity needed for a water manometer.

Figure 5 *Blue fluid (SG-1.9), fluorescein green concentrate (SG 1.0), red fluid (SG-0.826). (Rod Lidstone)* CC BY *(https://creativecommons.org/licenses/by/4.0/)*

Slack Tube

The **Slack Tube manometer** (Figure 6) has a flexible tube that can be rolled up compactly for easy handling and storage. When unrolled, it can be attached to vertical steel surface with the built-in magnetic clips. The tube connectors are also shutoff valves that prevent the loss of fluid.

The flexible, centre-mounted scale has two inches of vertical movement for adjusting the zero location.

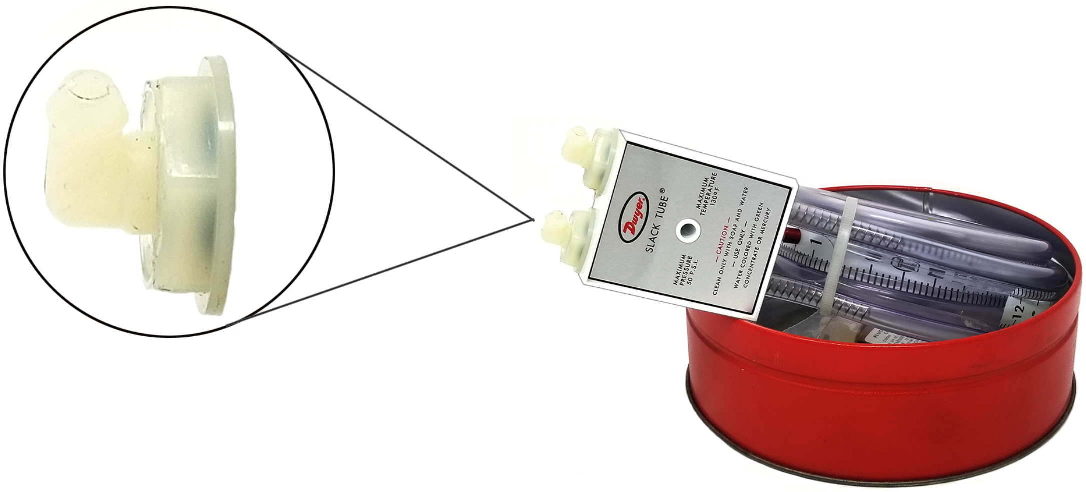

__Figure 6__ Dwyer Slack Tube manometer with magnification of shutoff-type tube connectors. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)

Inclined

An **inclined manometer** (Figure 7) is more accurate for lower range pressure readings, such as air flow measurements. Inclining the manometer spreads one inch of vertical lift over a much greater length, allowing the scale to be accurate to hundredths of an inch of WC.

Portable models have a swing-away foot and levelling screw setting on horizontal surfaces as well as magnets for mounting to vertical steel surfaces. They also come with shutoff pressure connections to prevent fluid loss when transporting and storing. For portable use, each time the gauge is used, the connections must be opened by turning the barbed connections one or two turns from the closed (clockwise) position, the gauge must be levelled and zeroed, and then, prior to storage, the gauge connections must be reclosed.

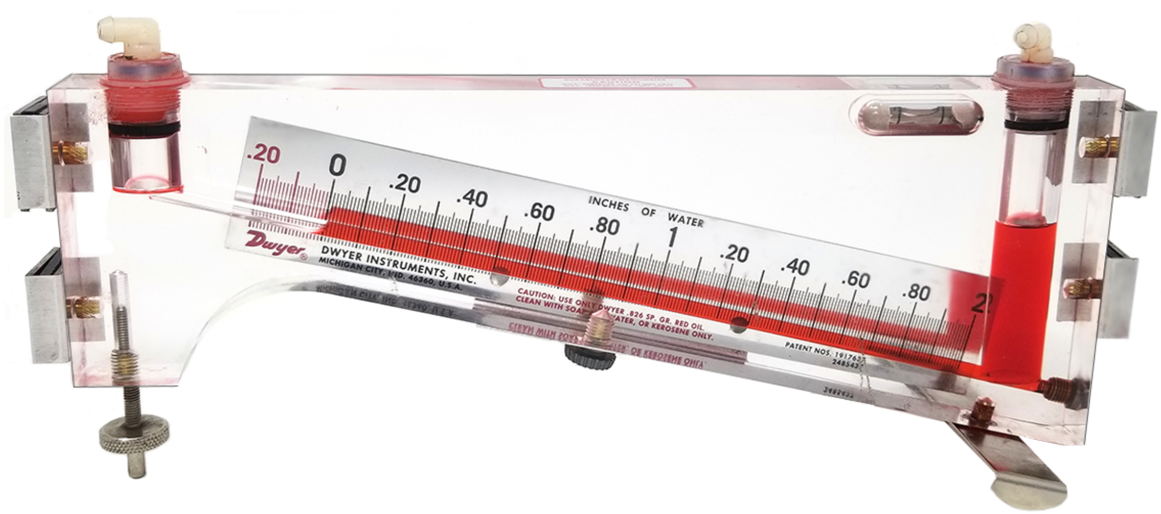

__Figure 7__ Inclined manometer. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)

The U-tube manometer shown in Figure 8 has two scales, allowing single readings in two ranges. The higher-pressure range on the right can be used for gas pressures from 0 to 16 in.WC, or the unit can be inclined and read from the left low-range scale (0 to 2.6 in.WC) for air velocity measurement. Set the proper angle by starting with the fluid level zeroed on the right-side scale, then rotating the manometer until the fluid level is at zero on the left scale.

Figure 8 *Dual range manometer.* (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)

The combined inclined-vertical manometer shown in Figure 9 provides a higher range and more easily read increments at the low readings. There is also a zero-adjusting knob for fine adjustment of the liquid reservoir level.

Figure 9 *Automatic level and levelling rod. (Dwyer, n.d.). Used with permission.*

Filling Manometers

To fill a manometer:

1. Open both fittings to atmosphere.
2. Slide the scale to the midpoint of travel.
3. Add liquid to zero on the scale.
4. Clean all fluid from the exterior of the unit.

The curvature of the fluid in a tube is called the meniscus and is caused by the adhesion between the fluid and the tube. Water and gauge oil create a U-shaped meniscus that should be read at the bottom of the curvature, whereas mercury creates an upward bulge or hump and should be read at the top.

Filling Inclined Manometers

It is important to note that when filling a manometer in preparation for a pressure reading, the water level must come to zero on both sides of the manometer. The weight of the water is critical to getting the correct pressure readings. Overfilling and underfilling will render inaccurate readings. The advantage of manometers over gauges when measuring fine pressures such as in.WC is that there is no mechanical resistance like what is encountered in a mechanical instrument, such as a **Bourdon tube gauge**.

To fill an inclined manometer:

1. Use a $\frac{3}{4}$ in. wrench to unscrew the entire low-pressure (right) shutoff connection fitting body (Figure 10).
2. Vent the left connector by turning the elbow one or two turns counter-clockwise.
3. Slowly fill the gauge with the fluid provided until the fluid rises in the indicating tube to the vicinity of zero on the scale.
4. Replace the low-pressure shutoff connection fitting, opening the fitting before reinstalling it to stop fluid from being displaced out the left side.
5. Close both fittings before storing.

Figure 10 *Low-pressure shutoff removed.* (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)

Check the manufacturer's specifications (specs) for the proper fluid. Different models may use fluid with different specific gravities.

When working with manometer fluids other than water, always check the manufacturer's safety data sheet for specific hazard information, safe handling, and emergency procedures.

When filling inclined-vertical manometers with a zero-adjustment knob, turn the knob fully counter-clockwise until it stops; then, turn it clockwise approximately four full turns to centre the adjustment to allow room for adjusting either side of zero after filling (Figure 9).

Magnehelic Gauges

A **Magnehelic gauge** (Figure 11) is another highly accurate pressure gauge for measuring draft conditions, determining pressure drop, or adjusting gas regulators. It uses a very sensitive diaphragm that has a pressure connection to each side. A helix turns the indicating pointer in response to the position of the magnet connected to the diaphragm. There are no mechanical linkages between the magnet and helix. The gauge must be used or mounted in the vertical position because the internal vertical diaphragm could sag and cause inaccurate readings if out of level.

Figure 11 *Magnehelic gauge. (Dwyer, n.d.). Used with permission.*

Digital (electronic) manometers are the most common portable field pressure-measuring tool because they have many advantages over the previously mentioned instruments. They can measure positive, negative, and differential pressures. **Digital manometers** are smaller, can be used in any position, and do not require fluid. They use micro-pressure sensors that change electric resistance when pressure is applied. Figure 12 shows a digital manometer that has been opened.

As can be seen, the micro-sensor has been removed from one pressure connection and is still connected to the other connection by a clear tube.

Figure 12 *Zeroed electronic manometer (left) disassembled (right). (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Digital manometers are available in a variety of models, depending on the range of pressures and accuracy required. A basic unit, like that shown in Figure 12, has a measurement range of 60 in. WC and is accurate to 0.03 in. WC. There is also a choice of scale displays, including psi, in. WC, mBar, or Pa. Digital manometers usually come with a protective cover, which has an internal magnet for holding onto the side of equipment.

Another digital manometer option is to use a “smart” differential pressure adapter (Figure 13) designed to connect to a downloaded app on a mobile device. The app gives the mobile device all the capabilities of a typical digital manometer, with additional data logging, data sharing, and graph options.

Figure 13 *Differential pressure adaptable for the smartphone. (Adapted from UEI Test, n.d.)*

Operation

Most electronic manometers operate similarly. Some of their typical characteristics and displays include the following:

- **Negative and positive pressure sensor ports:** use either port to measure a single source by venting the other port to atmosphere. Connect hose to both ports for a pressure differential reading. Some meters will also require that the pressure differential (ΔP) button be activated. If the input exceeds the meter range, some form of overload (OL) symbol will be displayed; immediately disconnect from the pressure supply safely to reduce chances of damage to the unit.

- **Digital display with optional backlight:** using the backlight when it is not needed will significantly reduces the battery life. Some units will automatically turn off the backlight after approximately one minute.
- **Power button:** press to turn the device on or off. If the battery is weak, the Low Battery indicator will display. A built-in auto power-off function will turn off the meter after approximately 30 minutes of inactivity. For some units, the auto power-off function can be disabled.
- **Zero button:** zero the meter before using. Make sure that the meter is not pressurized, then press and hold the button. A display will indicate that the zero function has occurred.
- **Hold button:** press during a reading to freeze and capture the values on display. There will also be a Hold symbol on the display to flag to the user that this is not an actual measurement. Pressing the button again will return the meter to live readings.
- **Scale button:** repeated presses of this button will scroll through the units of measure options.
- **Min/Max button:** captures values for the minimum or maximum pressure measured while analyzing.

Using Portable Pressure-Measuring Instruments

Portable pressure-measuring instruments are critical diagnostic tools for proper commissioning, inspection, and maintenance of equipment. The following list includes examples of common pressure tests performed in the piping industry. Studying the specific equipment involved will provide a more thorough explanation of each procedure.

Potable Water Tests

- **Initial installation pressure test:** performed with test equipment that often includes a pressure gauge.
- **Static system pressure test:** checks the city supply pressure or verify a PRV setting. Often performed with a simple hose bib test gauge assembly.
- **Operating pressure test:** diagnoses system pressure loss problems. If there is a restriction in the system, it will cause a loss of pressure when the water is flowing. It may require multiple test locations to identify the problem.
- **Backflow preventer operation test:** ensures that the drinking water supply is protected. To perform these test procedures, use special certified differential pressure gauge assemblies.
- **Air pre-charge test:** checks air pre-charge on well pump pressure tanks or expansion tanks when on a municipal water supply. A simple tire gauge can be used to verify or check the pre-charge of an expansion tank when the system pressure is bled.
- **Filter pressure drop tests:** checks the amount of restriction caused by a filter, which would indicate whether the filter requires cleaning or replacement. Typically, pressure gauges should be permanently installed on the supply and return of the filter piping. If not, they would need to be connected.

Hydronic Heating System Tests

- **Initial installation pressure test:** performed with test equipment that often includes a pressure gauge.
- **System pressure test:** verifies the proper setting of the PRV. Typically, there would be a permanent pressure gauge on the outlet that could be used.

- **Setting flow rates on circuit balancing valves:** a water pressure differential gauge measures the pressure loss across balancing valves to calibrate the proper flow rate.

Gas System Tests

- Initial installation pressure test: performed with test equipment that often includes a pressure gauge.
- Gas delivery pressure check: verifies that the utility meter set or propane service regulator matches the system design. Pressure-measuring equipment needs sufficient pressure range; residential systems are maximum 2 psi, but a commercial system could be higher. The utility meter set may have pressure test plugs for connecting, or a propane service regulator may have pressure inlet and outlet test plugs built into the regulator body.
- System regulator operating pressure settings test: verifies that the regulator is able to maintain the required flow rate. If the regulator flow capacity is inadequate, the outlet pressure will drop. The regulator may have an outlet test plug, or the appliance gas valve may have an inlet test plug or port.
- Piping operating pressure loss test.
- Appliance regulator pressure settings check: (also referred to as a manifold pressure test) verifies that the gas valve regulator has been set up correctly. If an appliance is underfired, this is one of the first checks that should be made. The manometer can be connected to the outlet pressure port of the appliance gas valve, or there may be a test plug in the manifold piping.
- System static pressure leak test: troubleshoots components, such as automatic gas valves, that would not have been connected during the installation pressure test. If a manometer is connected to a charged gas supply system, all gas equipment is shut down and the manometer is observed for any change. If the pressure drops and all connections have been checked, an appliance gas valve may be faulty.
- Regulator lockup (tightness of closure) pressure test: keeps the inlet pressure to an appliance below 14 in.WC; otherwise, the internal gas valve will be damaged. For example, a propane service regulator may be set to an operating pressure of 10 in.WC. When all appliances are shut off, the pressure will increase slightly before the regulator achieves positive lockup. A manometer connected to the inlet pressure port of one of the appliances can confirm that the pressure does not continue to increase.
- Appliance pressure switches test: senses proper combustion blower operation. If they are malfunctioning, it may be the electro-mechanical contacts. Test them first in place to confirm that they are getting adequate pressure by connecting a manometer into the sensing line.

Air Duct Pressure Tests

- Low pressure tests: performed to high accuracy with an inclined manometer, Magnehelic gauge, or digital manometer.
- Duct static pressure tests: checks the amount of resistance to air flow within an operating duct system. This information is used to check the fan capacity and speed settings. Multiple static pressure readings can be used to analyze the pressure drop across sections of ducting, fittings, filters and coils, or total pressure drop across the fan.
- Velocity pressure tests: measures the air pressure in a duct that parallels the direction of air flow. Special probes are required that are inserted into the air stream and connected to the pressure instrument. The velocity pressure reading is then used to calculate the air speed and volume of air flow in the duct.

Pressure Connection Ports and Adapters

Use the pressure-measuring instruments requires flexible clear vinyl or silicone rubber tubing and an assortment of adapters to match the different types of equipment connection ports. The pressure-measuring instrument and some equipment ports have tapered, barbed connections designed to fit a range of tube sizes, from 5 mm to 8 mm ID.

Assess the connection port on the equipment and select the appropriate adapter. The following are some examples of adapters and connection ports.

Figure 14 *Brass ¼ MIP (0.25 MIP) barbed hose adapters. (Rod Lidstone)*

Figure 14 shows 5 mm and 8 mm barbed adapters for connecting to $\frac{1}{8}$ in. NPT. This is a common type of connection on the test ports of gas valves. A $\frac{3}{16}$ in. hex key is often required to remove the $\frac{1}{8}$ in. NPT plug.

The gas valve shown in Figure 15 has $\frac{1}{8}$ in. NPT plugs on each end for testing the inlet and outlet pressure. The picture on the right shows the manometer tubing connected to the outlet pressure port to check the manifold pressure.

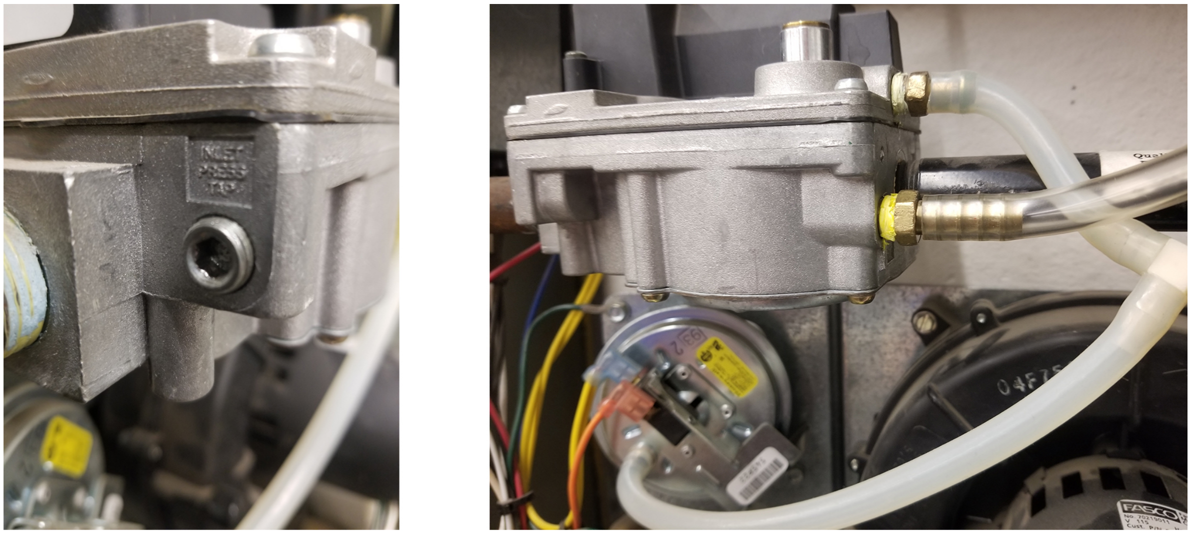

Figure 15 ⅛ *in.* (0.125 *in.*) *NPT inlet pressure tap plug (left), outlet pressure tap connected to clear plastic manometer tubing (right). (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Many modern gas valves no longer have $\frac{1}{8}$ in. pipe taps for test ports. Instead, they have a tapered boss with a small screw valve inside. The valve shown in Figure 16 has, from left to right, inlet, intermediate, and outlet pressure test ports.

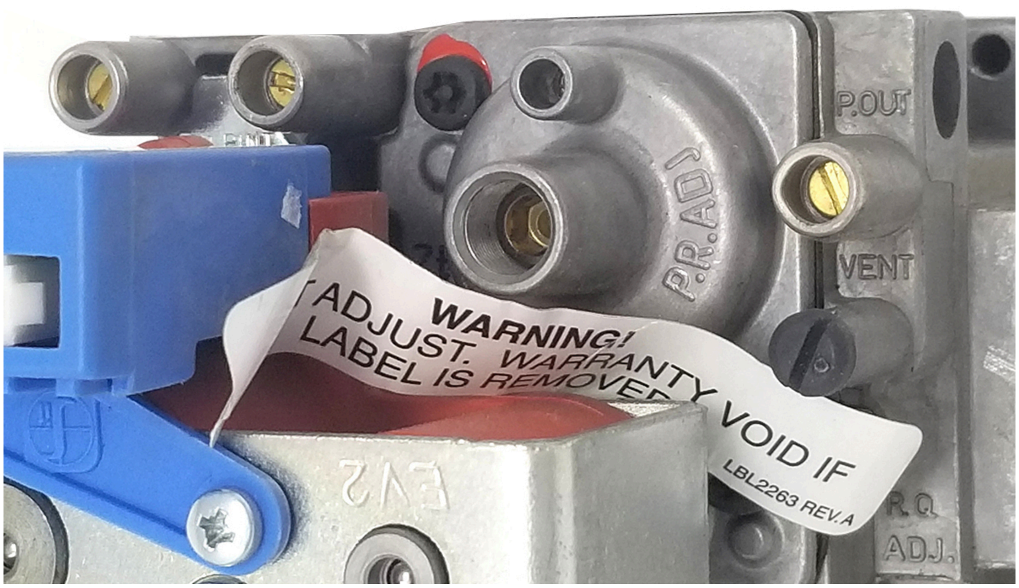

Figure 16 *Combination gas valve with three tapered boss test ports. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

To connect the test equipment, with the gas shut off, simply open the internal screw valve about one turn and slip a hose directly over the boss (Figure 17). No adaptor is needed. Then, turn on the gas supply and measure the pressure.

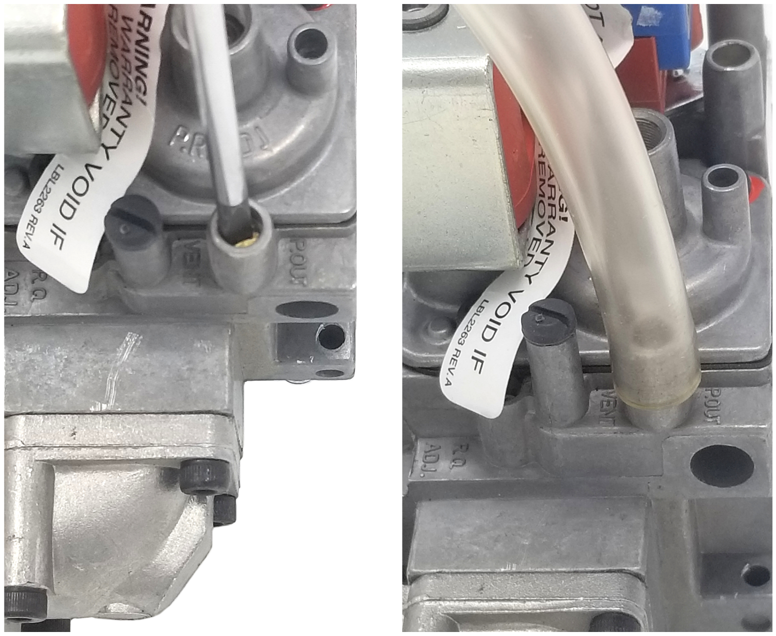

Figure 17 *Opening (left) and connecting (right) pressure test ports. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

For some connections, the tube may require a barbed reducer or a tee (Figure 18). The reducer shown on the left increases the 3 mm silicone rubber to the 8 mm vinyl tube. The image on the right shows an 8 mm barbed tee being inserted into a sensing line to check the pressure switch operation for a furnace inducer fan.

Figure 18 *Barbed reducer and barbed tee (left), manometer being connected into pressure switch sensing line (right). (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

For duct air flow measurements, special tips are inserted into the ducting through 9 mm drilled holes. The tips are then connected to the pressure-measuring instrument with silicone rubber tubing (Figure 19). The image on the left shows a static pressure tip with a barbed connection. The silicone rubber tubing is very flexible and can be expanded to fit over the device, as shown by the pitot tube in Figure 19 on the right.

Figure 19 *3 mm silicone rubber tubing connected to static pressure tip (left); pitot tube (right). (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Another useful method of checking system pressure is by way of special pressure and temperature test port plugs (P/T plug and Pete's Plug ®). The $\frac{1}{4}$ in. MIP (male iron pipe) plug shown third from the left in Figure 20 is permanently mounted in a pipe line at recommended test points. The plug has an internal self-sealing pierceable diaphragm made of neoprene or Nordel, depending on the fluid pressure or temperature of the application. The cap protects the valve and provides an additional seal.

After the cap has been removed, the pressure probe adapter shown on the left is inserted through the self-sealing diaphragm, shown on the right. The probe comes with an aluminum sleeve to protect the $\frac{1}{8}$ in. probe when not in use. Notice the inserted probe has a $\frac{1}{4}$ in. MIP by $\frac{1}{4}$ in. flare adapter installed onto it for use with the water hose connections of a differential pressure gauge.

Figure 20 P/T plug, Pete's Plug®. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)

Test port plugs can also be used for temperature tests with the proper $\frac{1}{8}$ in. insertion probe. P/T plugs are commonly used in the natural gas and hydronic industries. Figure 21 shows two examples of pressure tests being taken using the P/T plugs. The meter's gas pressure is being checked on the left. The image on the right shows two test probes measuring the pressure differential while setting the flow on a hydronic balancing valve.

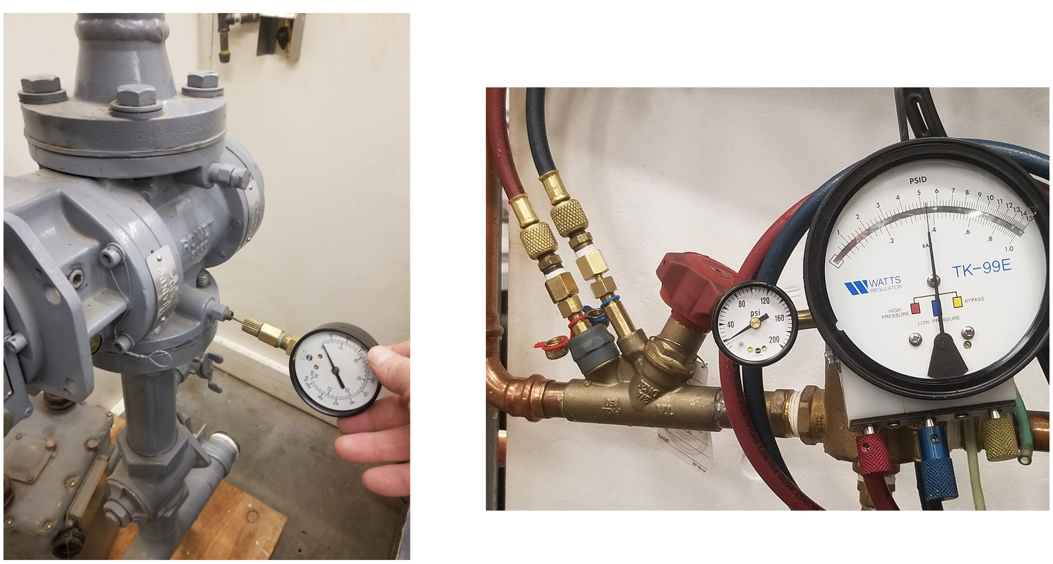

Figure 21 *Two examples of pressure tests using P/T plugs. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Self-Test A-4.1 Temperature Measuring Instruments

Complete Self-Test A-4.1: Pressure Measuring Tools and check your answers.

If you are using a printed copy, please find Self-Test A-4.1 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=55#h5p-18 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=55#h5p-18)

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A-4.2 Temperature Measuring Instruments

The heat that causes a change in temperature of a substance is called **sensible heat**. Heat energy is really a rate of molecular vibration; because these vibrations cannot be readily seen or evaluated, it might seem that temperatures would be difficult to determine. However, the fact that matter behaves in predictable ways when heated provides methods to measure temperature. For example, matter expands when heated, a property that can be used to indirectly determine the matter's temperature.

Describe Temperature-Measuring Instruments

Any instrument used for measuring temperature is called a thermometer. Many sizes and types of thermometers have been developed. The choice of which type of thermometer to use depends on factors such as convenience, required accuracy, and range of temperature being measured. Almost all thermometers are calibrated in either degrees Celsius or Fahrenheit.

Both these degree systems are based on the freezing point (0°C and 32°F) and boiling point (100°C and 212°F) of water. The major difference in types of thermometers is not in calibration but in the method used to arrive at the reading.

Analogue Thermometers

The **liquid-in-glass (glass-stem) thermometer** consists of a small reservoir and a fine tube. The reservoir or bulb is filled with fluid, such as coloured alcohol or mercury (Figure 1). A change in temperature changes the volume of the liquid. Change in volume raises or lowers the level of the liquid in the tube. The temperature scale can be printed onto a mounted panel (left) or etched onto the glass tube (right). The longer the stem length, the smaller the graduations can be, and the more accurate the readings.

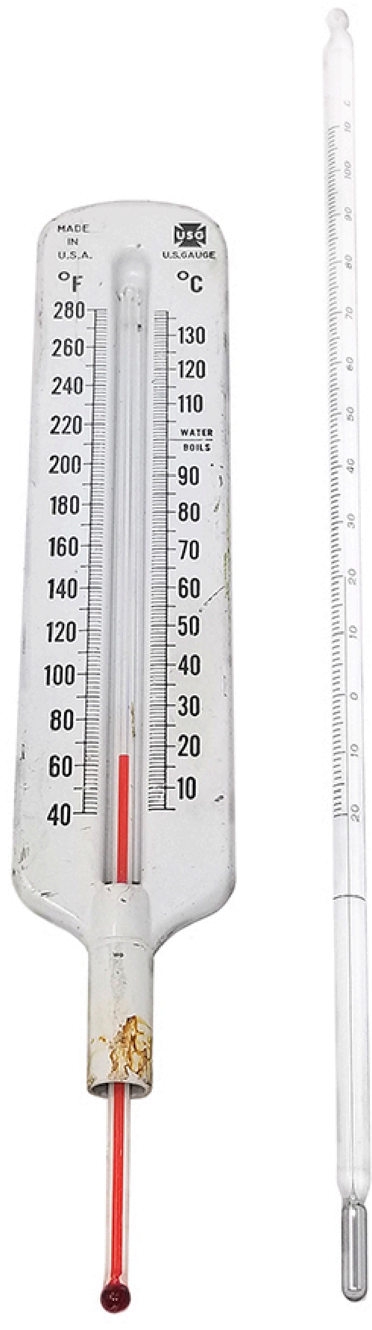

Figure 1 *Glass-stem thermometers. (Rod Lidstone)* CC BY *(https://creativecommons.org/licenses/by/4.0/)*

Glass-stem thermometers can be easily broken. Mercury is a very toxic or poisonous substance and must be handled and disposed of with great care if spilled.

Dial thermometers are another common type of analogue thermometer. There are two general types: stem and flexible capillary.

Dial stem thermometers are made in a wide variety of dial sizes, stem lengths, and temperature ranges (Figure 2). They are more rugged and easily read than glass-stem thermometers. Their stems are small in diameter so that they can easily be inserted into small holes in ducts or through test port plugs. Dial stem thermometers usually use a bimetallic temperature-sensing element in the stem. Temperature changes cause a bend or twist of the element, and this movement is transmitted by a mechanical linkage to the pointer.

Figure 2 *Dial stem thermometers. (Rod Lidstone)*

The other, less common type of dial thermometer is the **flexible capillary** type. It uses a large temperature-sensing bulb connected to the instrument with a capillary tube. The instrument contains a bourbon tube and operates the same way as a pressure gauge: as the temperature of the contained liquid or gas changes, the pressure exerted within the tube changes. These are also known as **vapour tension thermometers** and have the advantage of being able to read the temperature from a remote location. The capillary tube is usually covered with a braided metal protector. Capillary type dial graduations are non-linear (Figure 3). Notice that the distance between graduations increases as the temperature range increases. They are most accurate in the upper half of their range.

Figure 3 *Flexible capillary type dial stem thermometer. (Rod Lidstone)* CC BY *(https://creativecommons.org/licenses/by/4.0/)*

For permanently installed thermometers, the probe is often mounted in a cylindrical fitting called a **thermowell** (Figure 4), which is closed at one end and mounted in the process stream. The thermowell protects the sensor from the process fluid. If the sensor fails, it can easily be replaced without draining the vessel or piping. Thermodynamically, the process fluid transfers heat to the thermowell wall, which in turn transfers heat to the sensor. Since more mass is present with a sensor-well assembly than with a probe directly immersed into the process, the sensor's response to process temperature changes is slowed by the addition of the well.

***Figure 4** Dial thermometer partially inserted into thermowell. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Digital Thermometers

Although analogue gauges are still used, digital thermometers are the most popular temperature-measuring instrument used today because they have better accuracy and a larger temperature range. For example, the simple folding digital pocket thermometer shown in Figure 5 has a temperature range of −50°C to 300°C, with an accuracy of ±1°C.

***Figure 5** Folding digital pocket thermometer.* (*Rod Lidstone*) CC BY (*https://creativecommons.org/licenses/by/4.0/*)

The only disadvantage of electronic/digital thermometers is the potential of a depleted battery. Digital thermometers have a sensor known as a **temperature transducer**. The transducer creates a voltage, current, or resistance change when there is a change of temperature. These are all analogue signals, which the thermometer takes and converts into a digital signal that it sends to the display drive.

There are three common types of sensors used by digital thermometers:

- Resistance temperature detectors (RTDs)
- Thermistors
- Thermocouples

All digital thermometers look similar, no matter which type of sensor the manufacturer uses. The following is a brief description of each of these sensors.

RTD

Electrical conductors change their electrical resistance as their temperature changes. Resistance drops as temperature drops and rises as temperature rises. The RTD wire is a pure material, typically platinum, which has a near linear resistance change with temperature. If the resistance of the platinum wire at a certain temperature is known (typically 100 Ω @ 0°C), this information is used to determine the temperature of the wire when the resistance changes. Therefore, an **RTD thermometer** is, in essence, an **ohmmeter** because it measures the resistance of the sensor and converts it into a temperature reading. RTDs can have a range of −200°C to +500°C.

Figure 6 *Cutaway of RTD probe. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Many RTD elements consist of a length of fine wire wrapped around a ceramic or glass core, but other construction methods may be used. Because RTD elements are fragile, they are often housed in protective probes, as shown in Figure 6. The pencil is shown to give a size perspective.

Thermistor

The **thermistor** is a resistance sensor that changes its resistance in a non-linear way. Compared to RTDs, thermistors are more sensitive to small temperature changes and have a quicker response time because the resistance change is very large. However, thermistors have a smaller temperature range and stability. The typical operating temperature range of a thermistor is −55°C to +150°C.

Thermistors are of two opposite fundamental types:

- **Negative temperature coefficient (NTC) thermistors:** the resistance decreases as temperature rises. An NTC is commonly used as a temperature sensor.
- **Positive temperature coefficient (PTC) thermistors:** the resistance increases as temperature rises. PTC thermistors are commonly installed in series with a circuit and used to protect against overcurrent conditions, such as resettable fuses.

NTC thermistor elements come in many styles, such as glass-coated chips, epoxy-coated with bare or insulated lead wire, surface-mount, and rods and disks. Figure 7 shows a type of 10 kΩ (@ 25°C) NTC sensor commonly used in the HVAC industry. This thermistor's resistance change would range from approximately 490 kΩ @ −46°C to approximately 0.55 kΩ @ 107°C.

Figure 7 *10 kΩ NTC thermistor. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Thermocouple

A **thermocouple** consists of two dissimilar electrical conductors joined at the hot junction. As temperature changes at the hot junction, a temperature proportional millivolt signal is read at the cold ends (Figure 8). This voltage can be interpreted to measure temperature.

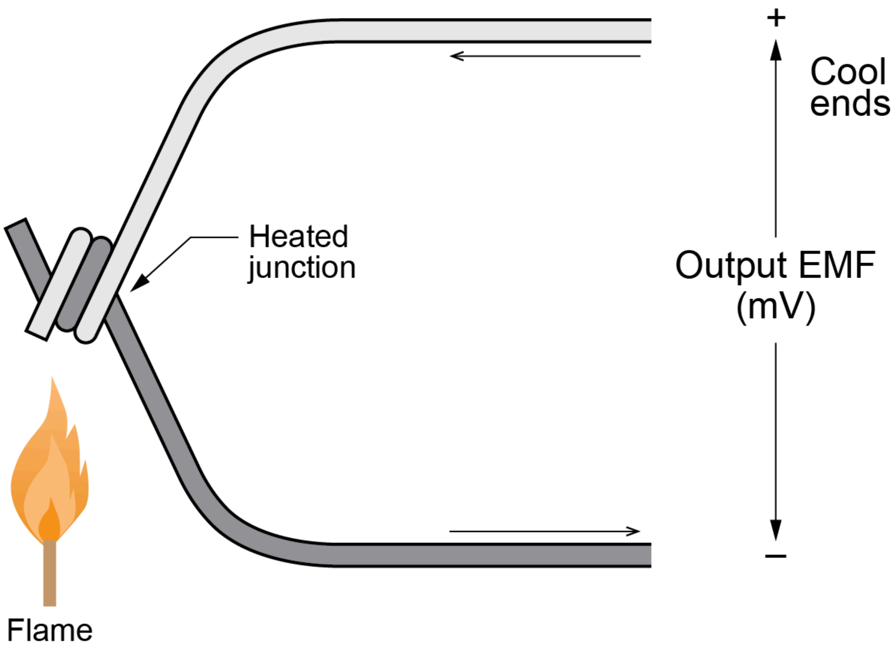

Figure 8 *Thermocouple. (Skilled Trades BC, 2021) CC BY-NC-SA (http://creativecommons.org/licenses/by-nc-sa/4.0/)*

There are different types of thermocouples, based on the different conductor types used. One of the most common types is the **Type K**, which is a coupling of Chromel and Alumel alloy wires. A Type K thermocouple has a wide temperature range from −270°C to 1,260°C and an output of 6.4 mV to 54.9 mV over this range. This wide range, combined with its ability to function in rugged environmental conditions and various atmospheres, makes it a commonly used temperature sensor. Type K thermocouples are less suitable for applications where smaller temperature differences need to be measured with an accuracy better than ±0.7°C.

There are also different styles of thermocouples. Figure 9 is a grounded thermocouple, where the outer sheath and wire are welded together to form one junction at the probe tip. The outer copper sheath becomes part of the circuit. This thermocouple is used in a fail-safe circuit to sense when a gas pilot light is burning. The tip of the thermocouple is placed in the pilot flame, generating a voltage that operates the supply valve that feeds gas to the pilot.

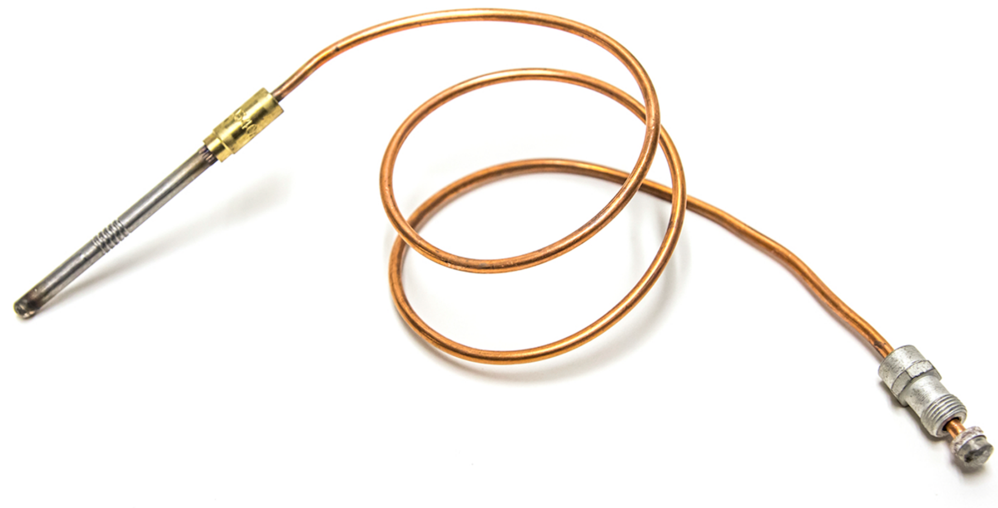

Figure 9 *Pilot safety thermocouple. (Rod Lidstone)* CC BY *(https://creativecommons.org/licenses/by/4.0/)*

For exposed (bare wire) thermocouples, the wires are exposed where they are welded together, and this junction is inserted directly into the process (Figure 10).

All wires that make up the thermocouple must be insulated from each other, except at the sensing junction (hot junction). Any additional electrical contact between the wires or contact of a wire to other conductive objects can modify the voltage and give a false temperature reading.

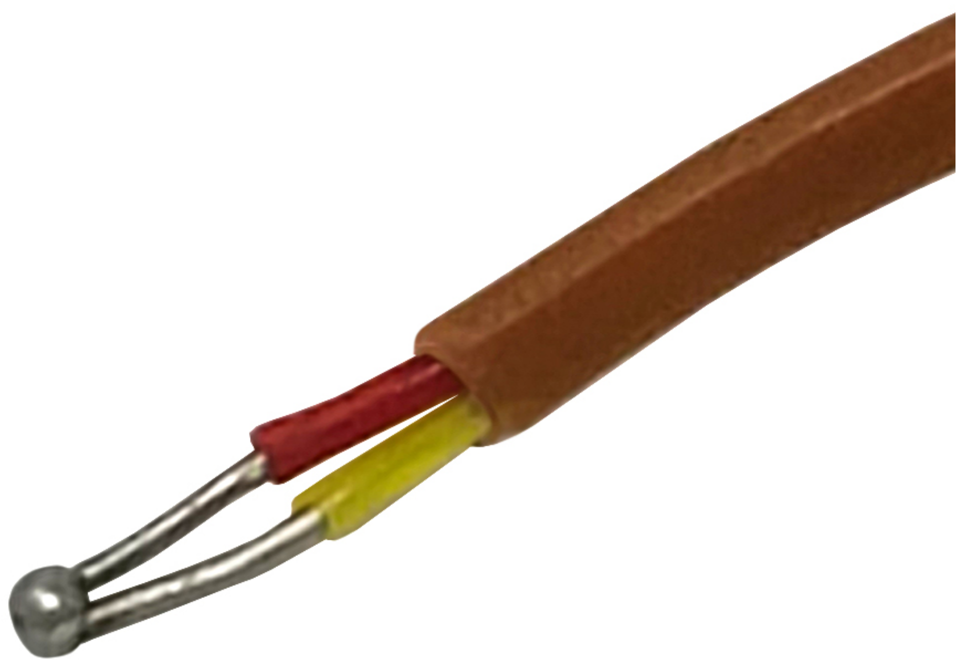

Figure 10 *Type* K *exposed-wire thermocouple. (Rod Lidstone)* CC BY *(https://creativecommons.org/licenses/by/4.0/)*

Plastics are suitable insulators for low-temperature parts of a thermocouple, whereas other materials are be used for higher temperature applications. Because the entire wire makes up part of the thermocouple, the wire cannot be repaired or lengthened with ordinary conductors.

Type K thermocouples are commonly used on **digital multimeters (DMM)** (Figure 11), which have a temperature setting on the selector dial. The meter converts the output voltage level to temperature using a conversion formula.

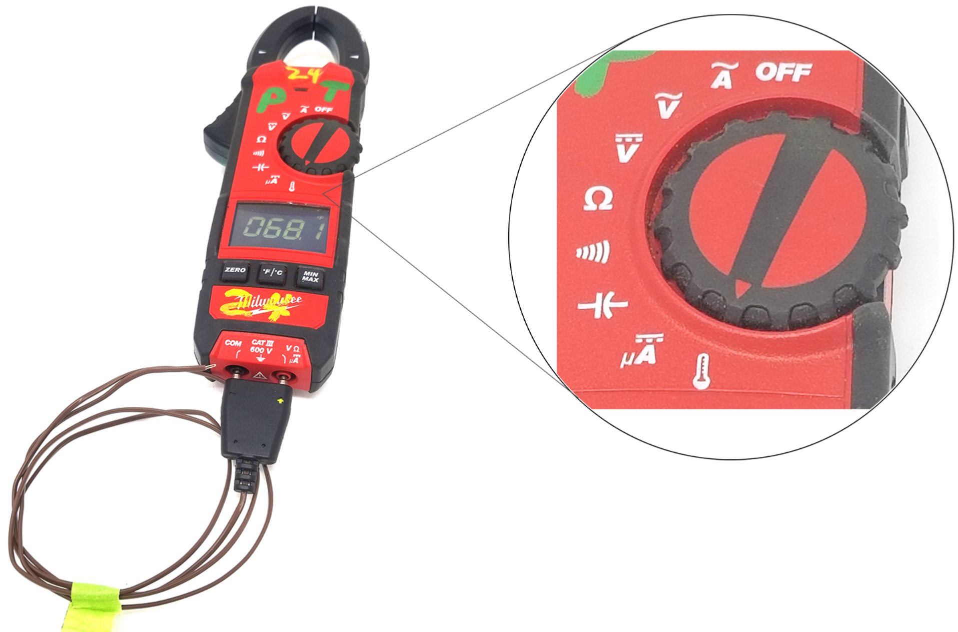

Figure 11 *DMM with temperature setting. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Figure 12 shows a couple of Type K thermocouples with different types of connectors. The type on the left is a very common universal flat-pin miniature thermocouple connector. Notice that when the switch is in the TEMP position, two partial black shutters block the electrical connection openings. Moving the switch out of the TEMP position opens the connection openings and thermocouple connections. The type in the middle image connects directly to the same terminals used for the electrical test leads. Alternatively, the adapter shown on the right can be used to connect the flat-pin style.

***Figure 12** Type k thermocouple connections. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Pyrometer

A **pyrometer**, by definition, refers to any remote-sensing thermometer. The modern pyrometer is a device that can determine the temperature of a surface from a distance, with no need for contact with the object. A pyrometer determines the temperature of a surface by the amount of thermal radiation it emits, which increases with temperature (Figure 13). The most common hand-held type is the **infrared (IR) thermometer**, which detects the invisible thermal infrared radiation the surface emits and translates the signal into a temperature reading.

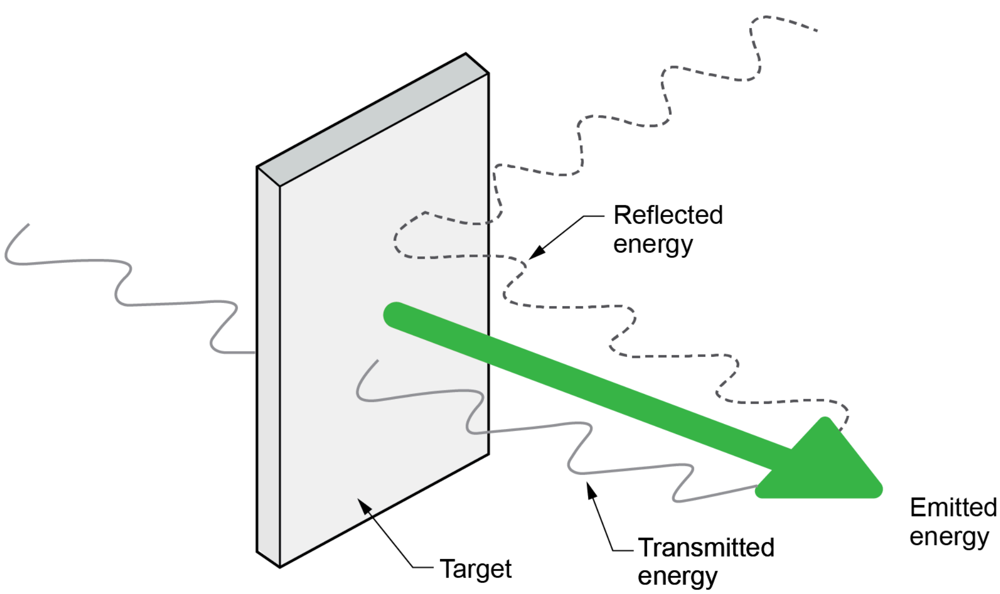

***Figure 13** Emitted energy. (Skilled Trades, 2021; adapted from Fluke, 2010). Used with permission.*

IR thermometers are also called temperature guns, non-contact thermometers, or laser thermometers because they have a laser to help aim the thermometer (Figure 14).

Figure 14 *IR thermometer. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

The IR thermometer has a relatively wide temperature range, from about −50°C to 400°C, with an accuracy of ±2°C. These optical pyrometers are especially suited for measuring moving objects or any surfaces that cannot be reached or touched.

Some types of infrared thermometers also include an input jack for connecting a Type K thermocouple probe to make contact temperature measurements. The probe can be used simultaneously while the thermometer is taking non-contact measurements, and both readings will be displayed.

Although the class of visible light lasers typically used are relatively safe, intentionally staring at the beam could lead to eye injury.

Use Temperature-Measuring Instruments

The operation of many mechanical systems that we use or install involves the flow or transfer of heat energy from one place to another. Whether it be the use of heating irons for poly fusion or the commissioning of space heating equipment, we need to observe temperatures to verify the proper transfer of heat energy.

Checking Accuracy

Always check the accuracy of a new thermometer or one that is unfamiliar. Portable dial thermometers can get out of calibration due to the presence of mechanical linkages and by being dropped. There are two basic methods for checking a thermometer's accuracy.

The freezing point method is the simplest and most accurate:

1. Fill a glass with crushed ice.
2. Add clean water (distilled water is best) and stir.
3. Wait for about three minutes.
4. Insert the sensor of the thermometer into the ice filled water.
5. Once the thermometer has adjusted, its reading should be holding steady at 0°C.

Another method is the boiling point method:

1. Boil about six inches of water in a suitable container.
2. When the water reaches its boiling point, place the sensor in the water, away from the sides and bottom of the container.
3. Once the thermometer has adjusted its reading, it should be holding steady at 100 °C if you are below 300 metres in elevation. Higher elevations will have a lower boiling temperature.

Calibration

Some dial thermometers have a calibration nut on the back of the dial head. Hold the nut securely with a wrench and rotate the head until it reads correctly (Figure 15). Other styles may include a separate adjustment or reset screw for calibration, as shown on the right.

Figure 15 *Calibrating analogue dial thermometers. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

For digital thermometers, it is important to check the manufacturer's instructions regarding calibration. Inexpensive digital pocket thermometers may not be able to be calibrated. Others may have a reset button that can be used when the freezing point test is performed.

Digital contact temperature meters, which use plug-in thermocouples, may have an adjustable potentiometer for calibration. Use a fine-tip standard screwdriver to make adjustments through the access port (Figure 16, left). Other meters may require the instrument to be sent to the manufacturer's service facility for calibration.

When using a meter designed to check temperature differential, perform a simple accuracy test by holding the two thermocouples together while on T1-T2 setting (Figure 16, right), which should result in a reading of zero once the probes stabilize.

Figure 16 *Calibrating DMM temperature readings. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

Digital contact thermometers that do not give physical access to the calibration **potentiometer** may have a display "Offset" function. This function is one of the setup options, which allows the operator to adjust the display to compensate for the errors of a specific thermocouple.

Taking Measurements

Be sure to read the manufacturer's operating instructions and pay particular attention to all safety warnings.

The probe of a contact thermometer may be damaged if the specified measurement range is exceeded. When using any type of contact thermometer, it is important that the end of the probe be in contact only with the product being measured. The sensor is located at the end of the probe, therefore, contact with the stem or wire does not affect the reading. Verify that the initial reading indicates the ambient air temperature before inserting the probe. Digital instruments have a number of display functions, such as Scale (°C/°F), HOLD, MAX/MIN, AVG, OFFSET, T1, T2, T1-T2, LOG, and time elapsed. Pay attention to the LCD display function descriptions to ensure correct interpretations of the readings. Digital meters typically have an auto off function that automatically powers down the thermometer after a period of inactivity.

For some temperature measurements, the bare-wire or needle-style probes can be difficult to use. For these measurements, many probe designs are available for special applications. As long as they are a matching thermocouple type (typically Type K), they will plug directly into any digital meter.

Figure 17 shows a couple of other thermocouples configured with clamps or straps, which free up the operator's hands to make adjustments or record readings.

Figure 17 *Pipe clamp thermocouples. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

The probe shown in Figure 18 is designed for use on any flat surfaces. These types of probes are convenient for checking the temperature of heating irons, such as those used for poly fusion. The weighted probe also has a teflon coating to stop it from scratching surfaces that it comes into contact with.

Figure 18 *Flat-surface thermocouple probe. (Skilled Trades BC, 2021; adapted from Cooper Atkins/ Copeland, n.d.) Used with permission.*

IR Measurements

To take a measurement with an IR thermometer, point the thermometer at the object and pull the trigger. This will turn the unit on, and the object's temperature will show on the display. As long as the trigger is depressed, the unit will continue to update the present reading and other functions, such as minimum or maximum temperatures, measured during that period. Once the trigger is released, it will hold its reading for a short period of time.

The laser pointer is used only to help aim the thermometer. It is not related to temperature measurement. As the distance (D) from the object being measured increases, the spot size (S) of the area measured by the unit becomes larger. This is called the **distance-to-spot ratio (D:S)** and must be considered when determining field of view.

Figure 19 shows a unit with a 10:1 D:S; therefore, measurements taken from a distance of 1 m (1,000 mm) would have a circular field of view with a diameter of 0.1 m (100 mm). For accurate measurements, make sure that the target is larger than the unit's spot size. The smaller the target, the closer the thermometer should be.

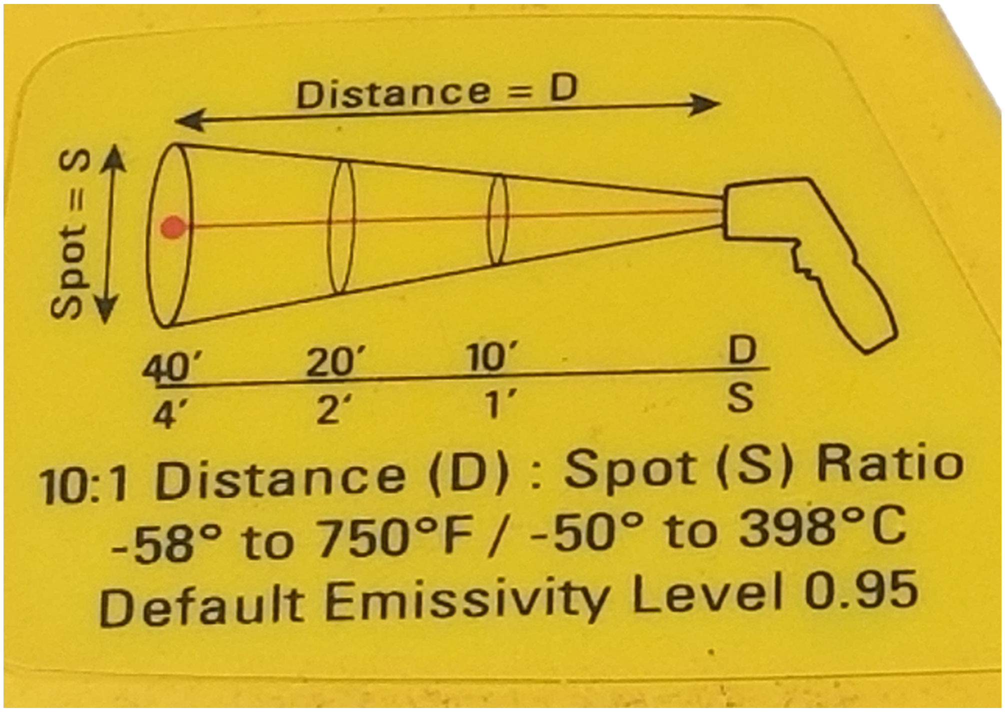

Figure 19 *D:S = 10:1. (Rod Lidstone) CC BY (https://creativecommons.org/licenses/by/4.0/)*

The other factor that affects the accuracy of an infrared thermometer is **emissivity**. Emissivity compares the energy-emitting characteristics of materials to the energy emitted from a **black-body source**. Surfaces closest to the black-body level would be flat black, and those farthest from it would be mirror or chrome surfaces. Although most infrared thermometers have a fixed emissivity of 0.95, most items measured provide a reasonably accurate result. To compensate for inaccurate readings that may result from measuring shiny metal surfaces, the surface to be measured can be covered with electrical tape or flat black paint. Some instruments have a fully adjustable emissivity, which enables the instrument to be fine-tuned for a specific application.

Applications

Temperature measurements are necessary to verify the proper operation of any heating equipment and are commonly taken when working on any type of HVAC and hydronic equipment. Some common examples include:

- Checking temperature difference between supply and return air on a forced air furnace
- Checking return water temperatures on individual loops of a hydronic heating system to balance flow or troubleshoot
- Checking floor surface temperatures of a hydronic radiant system to verify that it is operating as designed
- Measuring flue-gas temperature of gas-fired appliances to check efficiency
- Measuring a faucet’s hot water temperature when adjusting a mixing valve or high-limit stop

Self-Test A-4.2 Temperature Measuring Instruments

Complete Self-Test A-4.2 and check your answers.

If you are using a printed copy, please find Self-Test A-4.2 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=57#h5p-15 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=57#h5p-15)

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A-4.3 Electrical Testing Instruments

Electrical measuring and test instruments include various types of meters, recorders, and analyzers. These instruments may be analogue or digital types of units (Figure 1).

Analogue instruments indicate measured values with a scale and pointer display. The pointer's movement is directly and continuously related to the measured quantity.

Digital instruments interpret the measured quantity electronically in discrete numerical data (digits). They have a numerical display formed by light-emitting diodes (LEDs) or liquid crystal displays (LCDs). Reading a digital meter involves little or no interpretation, and digital meters can often read current in the range of microamps. Therefore, the digital multimeter (DMM) is the most common type in use today.

Figure 1 *Digital and analogue multimeters. (Skilled Trades BC, 2021) Used with permission.*

Describe Electrical Meters

A digital multimeter (DMM) combines the features of a voltmeter, ammeter, and ohmmeter. Digital multimeters also have advanced features that vary among models and manufacturers.

The DMM has a function control switch to select the electrical quantity to be measured (Figure 2). Some DMMs require manual setting of ranges, although most have an **autoranging** feature that automatically selects the range with the best accuracy and resolution for the measurement. When the meter leads are connected to the device to be tested, the meter automatically selects the proper range and displays the values.

Figure 2 *Rotary function switch. (Skilled Trades BC, 2021) Used with permission.*

Many meters use symbols on the display, switch, and connections. Figure 3 shows some common symbols used.

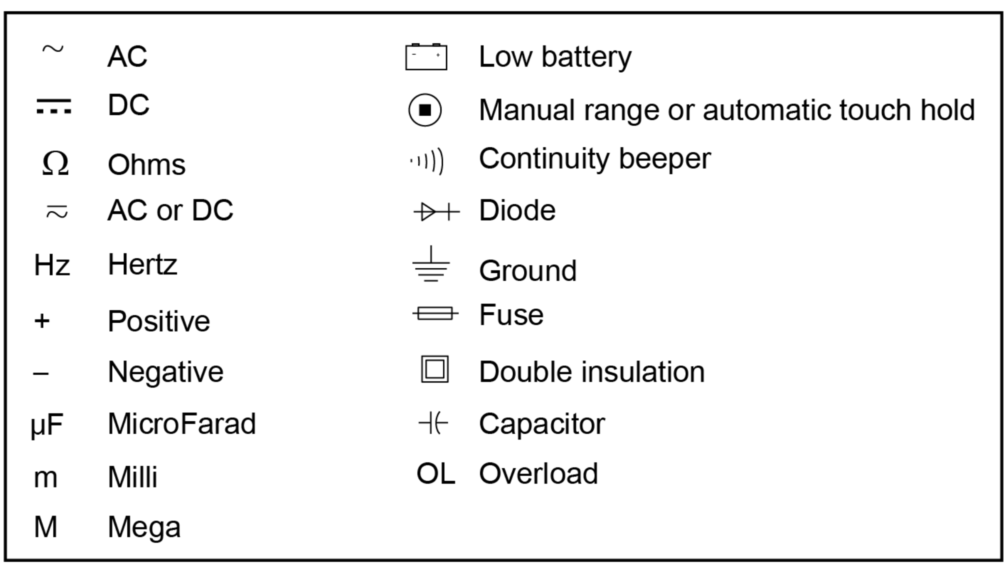

Figure 3 *Common DMM symbols. (Skilled Trades BC, 2021) Used with permission.*

Voltmeter Functions

Voltage is the electrical force that drives current through an electrical circuit. Voltage drop is defined as the potential difference between two points in an electrical circuit. There are two types of voltage sources: AC voltage and DC voltage. The current flow caused by an AC voltage source changes in both magnitude and direction at regular intervals. The current flow caused by a DC voltage source does not change direction. Voltage measurements are taken using the DMM voltmeter functions.

The AC (~) voltage function is commonly used to test and troubleshoot receptacles, gas appliance power supply, transformers, and other AC control circuits. A DMM set for the DC (~) voltage function can be used to test battery banks and gas pilot thermocouples and troubleshoot DC motors, DC generators, and other DC circuits. Some meters have function switches with multiple options at some selections. These may require that the operator push an additional select button to choose the alternate unit.

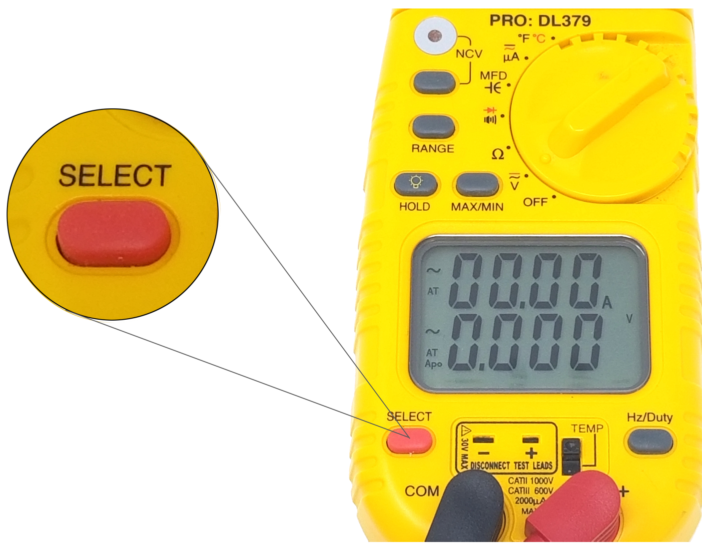

Figure 4 *Switching from AC to DC using the SELECT button. (Skilled Trades BC, 2021) Used with permission.*

Ammeter Function

The **ammeter** function is used to measure current in an electrical circuit. Current flows through a circuit when a power source is connected to a device or load. Current is the flow of electrons in a circuit when voltage is applied to the circuit. This current flow is inversely proportional to the resistance of the load. Current is measured in amperes (A), milliamperes (mA), or microamperes (μA). The word “ampere” is commonly shortened to “amp.” Current measurements are taken to ensure that the electrical circuit or components are not overloaded.

Using a DMM to measure current (amperage) requires connecting the meter in series with the circuit being tested. This involves disconnecting a wire from a terminal and connecting the test leads between the wire end and the terminal it was removed from.

This means that the meter is now part of the circuit, and the amperage that flows through the circuit will also flow through the meter. This creates a problem in that the meter leads must be heavy enough to allow current flow, which causes heat, without burning up. Therefore, most multimeters do not have the ability to measure any AC or DC amperage above the milliamp range when using test leads to reduce risk of overloading. There are DMMs available with clamp-on current probe accessories to measure higher current values and safely take current readings without opening a circuit (Figure 5). The most common clamp-on accessories are available for AC currents only, but there are also types for both AC and DC currents.

Figure 5 *Clamp-on DMM. (Skilled Trades BC, 2021) Used with permission.*

Ohmmeter Function

A DMM has an **ohmmeter** function that measures the amount of resistance in a component or circuit. The ohmmeter function is powered by a small battery that causes current flow through the tested circuit's resistance. Therefore, a DMM set for ohms must not be used on an energized circuit. A DMM set for ohms can be used to test the continuity of a circuit or its individual components, such as a fuse or a switch. As shown in Figure 6, resistance of an open switch or faulty fuse would indicate OL (infinity) on the display, and a closed switch or good fuse would indicate a very small resistance value on the display.

Most DMMs have a similar function with an audible continuity setting. If the fuse or switch is good, the DMM will emit an audible signal, usually a steady tone whenever there is continuity. This allows the operator to test without removing their eyes from their work. The circuit must also be de-energized when using this function.

***Figure 6** DMM resistance readings; faulty fuse (left), and good fuse (right). (Skilled Trades BC, 2021) Used with permission.*

Use Digital Multimeters (DMMs)

Digital meters are commonly used for troubleshooting and testing electrical circuits. Before a tradesperson performs any tests on electrical equipment, they must have a thorough knowledge of electrical safety and the equipment being used. Always read the manufacturer's operation and maintenance instructions for testing instruments and equipment prior to use. If you are unsure how to use them, contact your supervisor for clarification.

Precautions in Handling and Using Electric Meters

The proper care of test equipment and instruments is of utmost importance, whether they are analogue or digital. The length of time an instrument retains its original usefulness and accuracy depends largely on the care it receives in the hands of the user.

The following precautions apply equally to digital and analogue meters:

- Do not drop any meter.

- Avoid tampering with precision instruments. Have them serviced by a qualified repair technician.
- Ensure that proper test leads are used when using test equipment; they must have a category rating that equals or exceeds the rating of the tester.
- Perform a resistance test of the leads to confirm that they are reliable and well-connected.
- Test a meter and leads on a known source before using the meter to test a circuit or component to ensure that the meter is working properly.
- Assume that a circuit is energized until it has been positively identified as de-energized by taking proper measurements: “Test before touch.”
- Wear appropriate personal protective equipment (PPE), as specified in CSA Z462, “Standard for Electrical Safety in Workplace.”
- Observe correct polarity on DC measurements.
- Before connecting a meter to a circuit, ensure that the function and range is set to an appropriate position. When in doubt, use a high range that you know will not be overloaded. You can always switch to a lower range, if necessary.
- Carefully check circuit connections before applying power to meters.
- Be careful not to touch any other electronic components within the equipment.
- Be careful not to touch the probe tips to each other while connected to anything else.

Voltage Measurement

AC and DC digital voltmeters must be connected in parallel with the device or circuit being measured. If the voltmeter is connected in series, its high internal impedance will act as part of the series circuit and cause a false reading on the display.

An AC voltage waveform changes polarity constantly with time, so it is not necessary to ensure correct polarity when connecting the test leads. A DC voltage should be measured with the black lead in the COM jack and connected to the negative lead of the circuit or component. The red lead should be in the V/Ω jack and connected to the positive lead of the circuit or component.

The manufacturer recommends that the black lead always be connected first when taking measurements. If a negative sign (−) is displayed in the display window, the polarity is incorrect, and the meter leads should be reversed.

Voltage Measurement with DMM

Follow these steps to measure voltage, referring to Figure 7:

1. Set the function switch to DC or AC volts.
2. If the voltage being measured is not known, set the range to the highest voltage. An autorange DMM will automatically select the range based on the voltage present.
3. Plug the test probes into the appropriate probe jacks on the meter.
4. Touch the probe tips or connect alligator clips across the source or load.
5. View the reading on the display unit. Be sure to note the unit of measurement. When testing DC voltage, if a negative sign appears in the display, the polarity of the probes is incorrect and needs to be reversed.

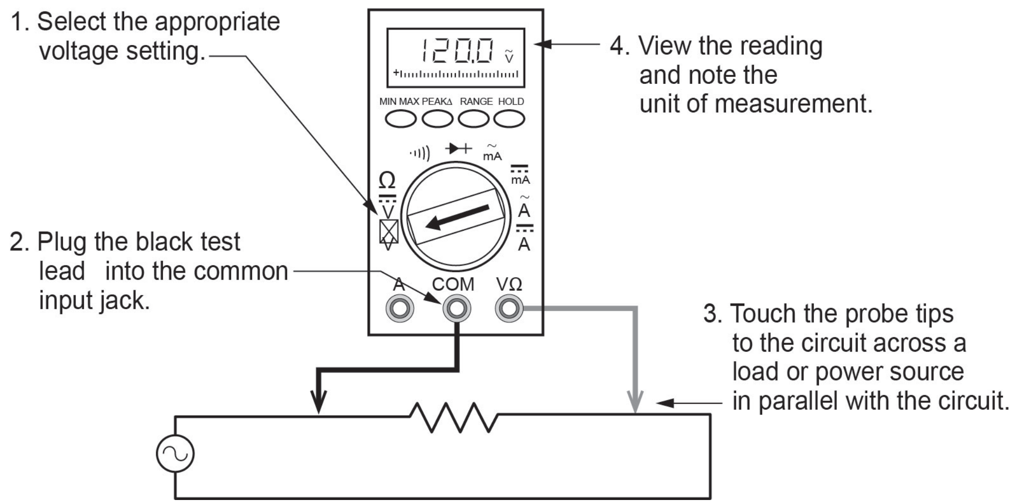

***Figure 7** AC voltage measurement with a DMM. (Skilled Trades BC, 2021) Used with permission.*

Current Measurement

It is often necessary to measure the current flowing in a circuit to check its operation. There are two common methods of measuring current using a DMM:

- In-line ammeter method
- Clamp-on ammeter method

Most of the DMMs designed for use in the HVAC industry measure DC microamperes (μA) using only the in-line method; all AC current is measured using the clamp-on method.

Connecting a DMM In-Line to Measure Amps

As previously seen, the placement of meter leads for voltage measurements is straightforward. The leads are simply connected across or in parallel with the points of voltage to be measured.

For in-line current measurements, however, the process is slightly more complex. First, the circuit must be opened at the test points and the meter inserted in series at that opening (Figure 8). The total current must flow through the meter. To allow the measurement to be made without disturbing the circuit itself, the current meter must have very little internal resistance.

This is where a beginner must be particularly alert. If the meter is inadvertently connected across a potential difference (PD) or in parallel with a component instead of in series, the small internal resistance will permit a very large current to flow through the meter. This will most certainly damage the meter severely and perhaps the circuit as well.

Follow these steps to measure low amperage current with test leads and refer to Figure 8:

1. Turn off the power to the circuit to be measured and confirm with a voltage test.
2. Open the circuit by disconnecting or unsoldering a connection at a point where you wish to measure current.

3. Select the DC or AC amps function by turning the function switch to DC or AC amps.
4. Plug the test probes into the appropriate probe jacks. Note that the jacks used may not be the same ones used to measure volts. Plug the red test lead into the highest current jack. If the current is higher than what the meter is rated for, use a clamp-on ammeter.
5. Connect the tips of the probes across the break in the circuit, as shown in Figure 8, so that the current to be measured flows through the meter. Note that this is a series connection. Never connect the ammeter in parallel with the source or load, as this will cause a short circuit and damage the meter.
6. Ensure that the ammeter is properly placed in the circuit, turn on the circuit, and read the measurement in the display window.
7. Turn off the power to the circuit, and remove the in-line ammeter.
8. Once the current measurements have been taken, to avoid accidentally connecting the meter in parallel, which would damage the meter, turn the function selector switch to the OFF position, then place the test leads in the common jack and the voltage jack.

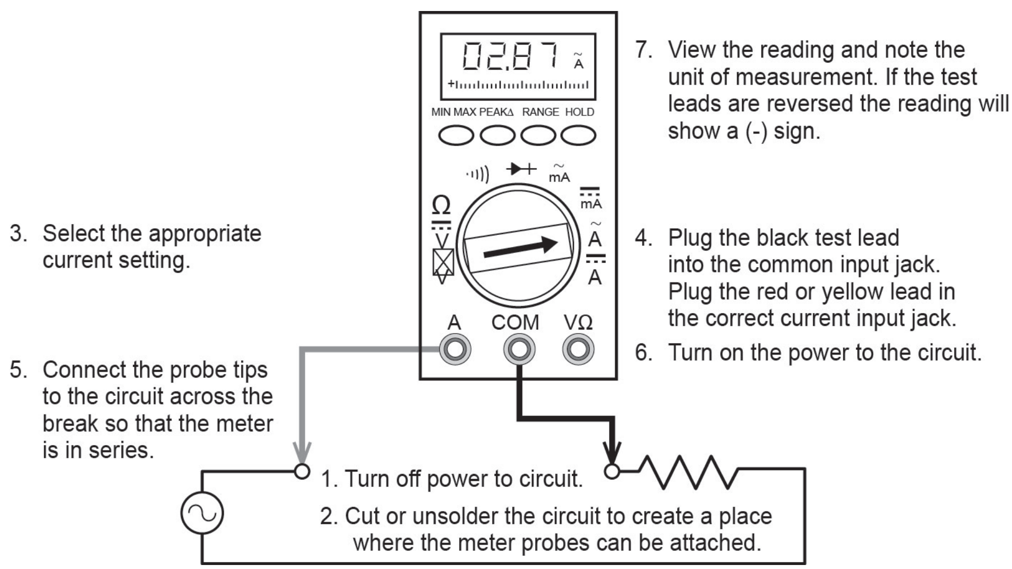

Figure 8 *AC amperage measurement with a DMM. (Skilled Trades BC, 2021) Used with permission.*

Connecting a DMM Clamp Ammeter to Measure Amps

Some types of DMMs have a clamp-on or fork amperage sensing head. The spring-loaded expandable jaws, or the open fork, are positioned around a single conductor (Figure 9). This feature allows you to measure the magnetic field created by the current flowing through the wire to give an ampere reading without having to make physical contact or disconnect the circuit. This is useful when checking loads, such as those for electric motors.

It is important to realize that the current flow through two conductors in a circuit cannot be read together. In a two-wire circuit, the direction of the two electromagnetic fields is opposite to each other and cancel each other out if the meter is clamped around both wires at once.

Figure 9 *DMM with clamp and fork-sensing heads. (Skilled Trades BC, 2021) Used with permission.*

Current measurement with a clamp-on ammeter is done as follows:

1. Open the jaws of the ammeter by squeezing the handle.
2. Close the jaws over the conductor, as shown in Figure 10. For best results, try to position the wire between the arrows, although there may not be enough room. This is where the fork type is advantageous because the prongs of the fork do not require as much room.
3. Ensure that only one conductor is enclosed in the jaws. If the live and neutral conductors are both enclosed by the jaws, the meter will read zero.*
4. The current reading is indicated on the ammeter display.

For the clamp style, ensure that the jaws of the ammeter are completely closed. If the contact points of the jaws are dirty or obstructed and do not make good contact, the reading will be inaccurate.

Figure 10 *Using the clamp meter to measure pump motor amperage. (Skilled Trades BC, 2021) Used with permission.*

Many clamp meters have a non-contact voltage tester built into one of the tongs of the clamp. Figure 11 also shows a pocket version. Non-contact voltage testers provide an easy and safe way of ensuring that electrical conductors do not have power without having to connect to the bare wire. The tester works by detecting the electric fields associated with AC voltages. The devices indicate the presence of a voltage by lighting up, making a sound, or both.

Figure 11 *Using non-contact voltage testers. (Skilled Trades BC, 2021) Used with permission.*

Measuring Resistance

Even though it reads out resistance, the ohmmeter is still a current-measuring device at heart. The ohmmeter is created from a DC current meter by the addition of a group of resistors and an internal battery. The battery supplies the current flow that is eventually measured by the meter. For this reason, when using an ohmmeter, the circuit must not be live.

Since current can flow either way through a pure resistance, there is no polarity requirement for attaching the meter leads. The meter's battery sends a current flow through the unknown resistance, the meter's internal resistors, and the current meter.

The ohmmeter is designed so that it displays 0 Ω when the test leads are clipped together (zero external resistance). The meter reads infinite (I) resistance or over limit (OL) resistance when the leads are left open. When a resistance is placed between the leads, the readout increases according to how much current that resistance allows to flow.

To conserve its battery, an ohmmeter should never be left on the ohms function when not in use. Since the current available from the meter depends on the state of charge of the battery, the DMM should be zero-adjusted to start. This may require no more than a test of touching the two probes together.

Using the DMM Ohms Function to Measure Resistance

To measure resistance using the DMM ohms function, follow these steps and refer to Figure 12:

1. Ensure that the power to the circuit is off. Never connect a DMM set for ohms to an energized circuit, as this will damage the meter. Always remove or isolate the component to be tested.
2. Set the function switch on the DMM to resistance (Ω).
3. Plug the black lead into the common jack.
4. Plug the red lead into the resistance jack (Ω).
5. Connect the leads together. If the battery symbol appears in the display, replace the battery. The meter should display a small amount of resistance (from about 0.2 Ω to 0.5 Ω). This is the test lead resistance. With the test leads held apart, the meter should display OL or 1, depending on the manufacturer. This indicates an infinite amount of resistance.
6. Connect the test leads across the component under test and read the display. Make sure there is a good connection between the test leads and the component under test to get an accurate reading.
7. After all the resistance readings have been completed, turn the DMM off to prevent the battery from draining.

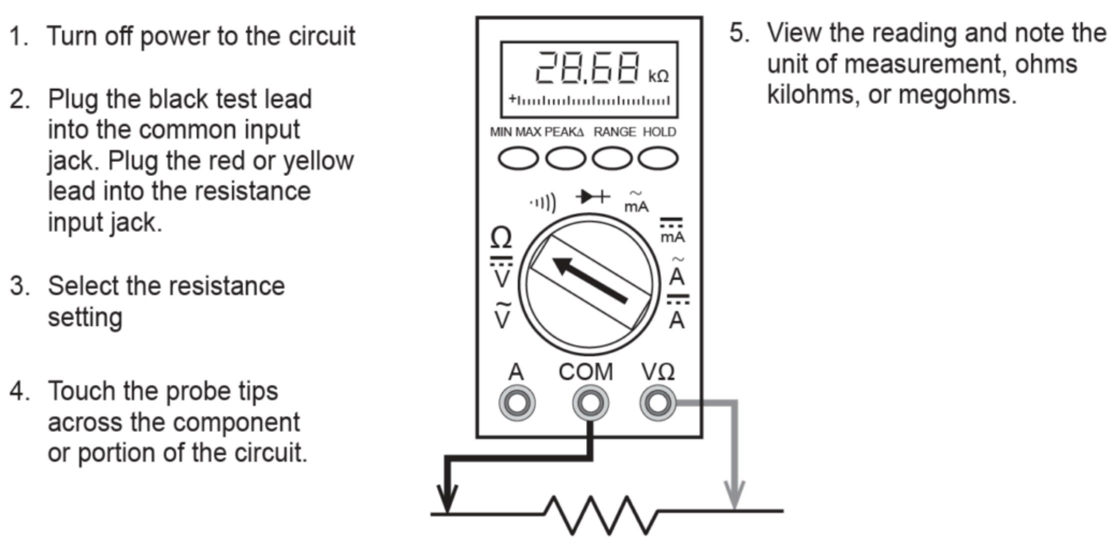

Figure 12 *Resistance measurement with a DMM. (Skilled Trades BC, 2021) Used with permission.*

Applications

The hand-held digital multimeter is one of the most valuable tools used for equipment troubleshooting in industrial, commercial, and residential applications. Some examples of where a piping tradesperson will use a DMM include:

- Gas pilot thermocouple tests
- Gas appliance millivolt control circuit tests
- 24 VAC control circuit tests on heating equipment
- Class 2 transformer tests
- Potable water heater, element, and control circuit tests
- Well pump motor and control circuit tests
- When verifying that equipment is electrically isolated for service or maintenance

Self-Test A-4.3 Electrical Testing Instruments

Complete Self-Test A-4.3: Electrical Testing Instruments and check your answers.

If you are using a printed copy, please find Self-Test A-4.3 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=59#h5p-14 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=59#h5p-14)

References

Skilled Trades BC. (2021). Book 1: Fuel gas systems, Heating and cooling systems. *Plumber apprenticeship program level 2 book 1 Harmonized*. Crown Publications: King's Printer for British Columbia.

Trades Training BC. (2021). A-4: Use technical instruments and testers. In: *Plumber Apprenticeship Program: Level 2*. Industry Training Authority, BC.

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A-4.4 Combustible Gas Indicators

Gas leaks are very dangerous because even a small gas leak may gradually build up to an explosive concentration. **Combustible gas indicators (CGIs)**, also known as gas leak detectors, are used to identify the presence of gaseous products from a pipeline or other contaminants in an area where they should not be.

Types of Leak Detectors

Gas leak detectors come in two main forms: portable devices and fixed gas detectors.

Portable detectors monitor the atmosphere around personnel and are either handheld or worn on clothing or a belt/harness. These gas detectors are usually battery-operated. They transmit warnings via audible and visible signals, such as alarms and flashing lights, when gas vapours are detected.

Fixed detectors are generally mounted near the process area of a plant or control room, or an area to be protected, such as a residential bedroom. Generally, fixed sensors used in an industrial application are installed on fixed structures and a cable connects the detectors to a continuous monitoring system.

Gas detectors can also be classified according to the operation mechanism or sensor (Figure 1). Some common sensor types include:

- Electrochemical sensors
- Electrocatalytic sensors
- Infrared sensors
- Flame ionization detectors

Figure 1 *Various types of gas leak detectors. Clockwise from top left: electrochemical type, electrocatalytic type, flame ionization type, infrared type. (Skilled Trades BC, 2021) Used with permission.*

Electrochemical Sensors

Electrochemical gas sensors measure the concentration of a target gas by oxidizing or reducing the target gas at an electrode semiconductor. The absorption or desorption of the gas on the metal oxide semiconductor changes either the conductivity or the resistivity. The resulting current is measured and compared to a known baseline value.

Electrocatalytic Sensors

Electrocatalytic (catalytic bead) sensors function on the principle that a combustible gas can be oxidized to produce heat. The resulting temperature change can be converted to a sensor signal. Catalyst sensors are often used to detect hydrocarbons and rely on the presence of oxygen to function.

Flame Ionization Detectors

Flame ionization detectors pass a sample through a hydrogen-air flame. The hydrogen-air flame alone creates few ions, but any hydrocarbons burned in the sample produce an increase in ions proportional to the concentration of the hydrocarbons. A polarizing voltage attracts these ions to a collector plate located near the flame, and upon hitting the plate, they induce a current that is measured. The kit includes a portable hydrogen cylinder.

Infrared Sensors

Infrared (IR), also known as laser, sensors are based on absorption of infrared radiation as it passes through a volume of gas. The laser light beam emits a specific wavelength absorbed by methane. When the laser hits methane, the methane absorbs some laser energy. The concentration of gas is proportional to the amount of specific IR light absorbed and is displayed in ppm concentrations. This type of sensor does not have to be placed into the gas to detect it and can be used for remote sensing at distances up to 30 metres.

The type of sensor the detector incorporates is not as significant to the operator as how to use and maintain it. Although the detectors often look similar, the type of sensor system used will affect the calibration, operating, and maintenance procedures.

Investigating Gas Leaks

First, if responding to a gas leak call, safety is the primary concern.
If at any time you experience very high readings that are near or above the **lower explosive limits (LEL)** of the fuel, immediately execute the emergency make-safe precautions.

This checklist outlines the steps to take when responding to a gas leak call.

Steps to Take When Attending a Gas Leak Call

1. Prepare. Activate the combustible gas detector. Gather other tools, such as soap solution, manometer, safety flashlight (Class 1), and pipe wrenches.

2. Knock on the door. Do not ring the bell because a spark could ignite the gas.
3. Communicate with the occupants.
    - Inquire about the situation.
    - Instruct occupants not to smoke or use any electrical equipment.
4. Take readings.
    - Determine if the gas supply is natural gas or propane.
        - Natural gas: investigate high locations initially.
        - Propane: investigate low locations initially.
    - If any reading is near or above the LEL, execute emergency make-safe precautions.
5. If a leak is detected, cut off ignition sources.
    - Open the master breaker at the electrical panel.
6. If readings are below the LEL, determine the source of the leak.
    - Use your nose and a gas detector to zero in on the location of the leak.
    - When closing manual valves at gas appliances, listen for the sound of gas passing.
    - If readings are strong but the smell is faint, there may be an outside below-ground leak that has infiltrated the building.

Emergency Make-Safe

- Evacuate occupants from the building, including yourself.
    - In larger buildings, instruct the building manager to activate the emergency evacuation plan.
- Do not cross-ventilate because you do not want to move a potentially explosive concentration to a possible source of ignition.
- On your way out, turn off gas riser valve or the propane cylinder/tank service valve.
    - Do not return to a building to turn off the main shutoff valve. If you happen to pass by the service riser as you exit the building, and you have wrench with you, shut it off.
- Call for help when you are a safe distance from the building. Contact the police department and gas utility.

Leak Detector Operation

There are a wide range of gas sensor products available. The type that is best suited depends on the working environment and what types of gas might be present, such as natural gas, carbon monoxide, or airborne organic compounds.

The following list represents some common operating guidelines. It is imperative that an operator read and understand the manufacturer's manual fully before using any detector.

- The detector performs an automatic zero during start up. To ensure proper zero, always start the detector in a clean-air environment similar in temperature and relative humidity to the environment where the instrument will be used. Some units may require the unit to be manually zeroed.
- Some detectors have accessories that need to be connected before the unit is turned on, such as external probes or hydrogen cylinders for flame ionization units.
- Detectors have some form of low battery signal and or LED symbol.
- Once initial calibration is complete, use a combustible gas source (such as an unlit lighter) to confirm that the gas detector senses the gas. If the gas detector does not sense the gas, do not use the unit until it has been properly serviced.
- The detector may have one or more of the following methods of alarm signals: audible beeps, Geiger counter-style ticks, vibration alerts, light signals, or an LED concentration display.
- Some detectors use an internal pump; an initial test of the pump and tubing may be required.
- Enter the area to be monitored. Pay close attention to the gas-level indicators. As gas levels increase, alarm levels increase. If the concentration of fuel gas is near or above the lower explosive limit, there is explosion potential, and you must take immediate actions to make the area safe.
- If the gas concentration is well below the LEL, you can proceed to investigate further. Use the gas detector to find areas of lower gas concentration and follow it back to the source. In a piping system, trace the system, stopping at the joints to monitor the gas levels. For detectors that use Geiger-style ticks, as the sensor head moves closer to a leak source, the tick rate increases. When the tick becomes a steady tone, rotate the thumbwheel in a clockwise direction while keeping the sensor head in the same position. This slows down the tick and allows the operator to find a higher concentration using the same procedure. The tick rate increases as the higher concentration of gas increases as you move closer to the leak source.
- If the sensor is overexposed to some gases, the unit may take an extended period of time to return to calibrated ready condition.

Maintenance

- To increase battery life, always turn the unit off when not in use.
- If the batteries require replacement, always change them in an environment free of combustible gases.
- Remove the batteries before any long period of storage or shipping to avoid battery leakage.
- Some types of detectors do not require calibration other than that done at regular start up.
- For some portable detectors, replacement sensors are available so that an operator can replace the expired sensor (Figure 2).
- Some detectors require that sensor calibration or replacement be performed by an authorized service centre.
- Some manufacturers have calibration kits complete with regulator and calibration gas available for purchase (Figure 3).

Figure 2 *Sensor head disassembled, replaceable sensor lower left. (Skilled Trades BC, 2021) Used with permission.*

Figure 3 SENSIT *calibration kit. (Skilled Trades BC, 2021) Used with permission.*

Self-Test A-4.4 Combustible Gas Indicators

Complete Self-Test A-4.4: Combustible Gas Indicators and check your answers.

If you are using a printed copy, please find Self-Test A-4.4 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=61#h5p-11 (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/?p=61#h5p-11)

References

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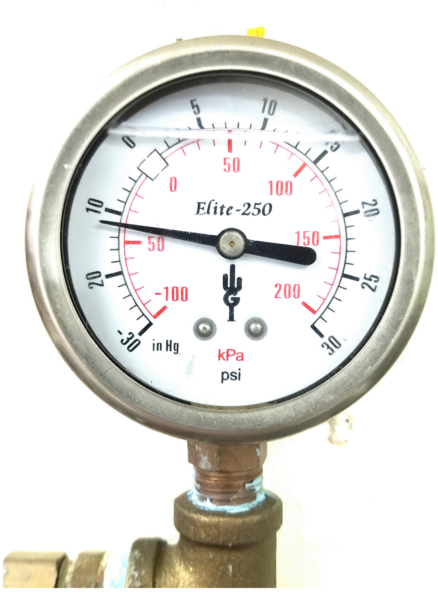
Self-Test A-4.1 Temperature Measuring Instruments

Complete Self-Test A-4.1 and check your answers.

1. 1 in. Hg equals how many inches of WC?
    a. 4.05 in.
    b. 14.73 in.
    c. 13.6 in.
    d. 27.68 in.

2. A gauge pressure of 400 kPa would equal what absolute pressure?
    a. 101.3 kPa
    b. 401.3 kPa
    c. 414.73 kPa
    d. 501.3 kPa

3. What does the reading on the gauge image (shown below) indicate?

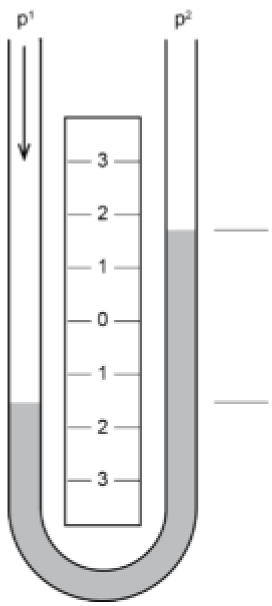


    a. 12 in. Hg below atmospheric pressure
    b. 12 psi below atmospheric pressure
    c. 18 in. Hg below atmospheric pressure
    d. 40 in. Hg below atmospheric pressure

4. What is the name for the type of pressure reading in which the instrument registers the difference in pressure between two contained working fluids?
    a. Gauge pressure
    b. Absolute pressure

c. Differential pressure
d. Referenced pressure

5. If P^1 is connected and P^2 is open to atmosphere, how much pressure (inches of WC) is being applied?



a. 1 in. WC
b. 1.5 in. WC
c. 2 in. WC
d. 3 in. WC

6. When using a water or gauge oil manometer, the reading should be taken at the bottom of the U-shaped meniscus.

a. True
b. False

7. When filling inclined-vertical manometers with a zero-adjustment knob, turn the knob fully counter-clockwise until it stops to centre the adjustment and allow room for adjusting either side of zero after filling.

a. True
b. False

8. One of the advantages of a magnehelic gauge is that it does not have to be used in the vertical position.

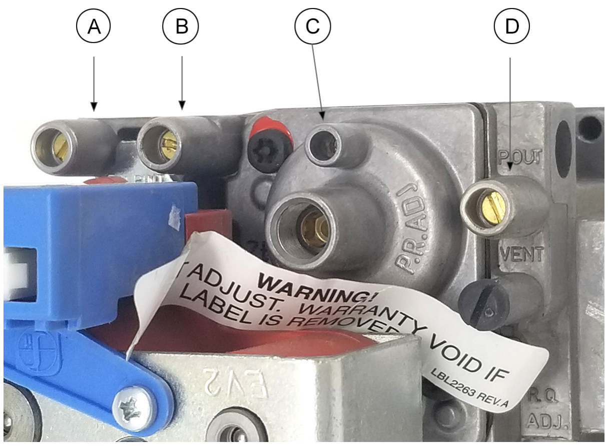
a. True
b. False

9. When connecting a digital manometer, you should “zero” the meter before connecting the hoses to the equipment pressure connections.

a. True
b. False

10. Prior to storing an inclined manometer, what must be done?
    a. Drain the fluid.
    b. Close the shutoff valves.
    c. Joint the two hoses together to avoid spillage.
    d. Set the storage case on a level surface to avoid spillage.

11. Which tapered boss test port is used to check the inlet pressure of the gas valve shown below?



    a. A
    b. B
    c. C
    d. D

Answer Key: Self-Test A-4.1 is on the next page.

Answer Key: Self-Test A-4.1

1. c. 13.6 in.
2. d. 501.3 kPa
3. a. 12 in. Hg below atmospheric
4. c. Differential pressure
5. d. 3 in. WC
6. a. True
7. a. True
8. b. False
9. b. True
10. b. Close the shutoff valves.
11. a. A

Self-Test A-4.2 Temperature Measuring Instruments

Complete Self-Test A-4.2 and check your answers.

1. Liquid glass thermometers with longer stem lengths will give more accurate readings
   a. True
   b. False

2. The red-coloured fluid found in some glass-stem thermometers is mercury.
   a. True
   b. False

3. What type of sensing elements do dial stem thermometers use?
   a. Mercury bulb
   b. Bimetallic element
   c. Gas-filled sensing bulb
   d. Thermistor

4. What is the advantage of mounting a thermometer probe in a thermowell?
   a. Electrically grounds the sensor
   b. Increases the accuracy to the sensor
   c. Slows the sensor response to process temperature change
   d. Can easily change the thermometer/sensor without draining the piping or vessel

5. Dial thermometers have better accuracy and larger temperature range than digital thermometers.
   a. True
   b. False

6. RTDs and thermistors are both which type of sensor?
   a. Bimetallic coil sensors
   b. Capillary tube sensors
   c. Variable millivolts sensors
   d. Variable resistance sensor

7. What statement best describes a negative-coefficient thermistor (NTC)?
   a. Resistance increases as temperature rises.
   b. Resistance decreases as temperature rises.
   c. As temperature rises, an increased millivolt signal is created.
   d. As temperature rises, the amount of thermal radiation emitted increases.

8. What statement best describes a thermocouple?
    a. Resistance increases as temperature rises.
    b. Resistance decreases as temperature rises
    c. As temperature rises, an increased millivolt signal is created.
    d. As temperature rises, the amount of thermal radiation emitted increases.

9. What does the most common type of hand-held non-contact thermometer detect?
    a. Gamma rays
    b. Microwaves
    c. Infrared energy
    d. Ultraviolet energy

10. Because the intensity of the light lasers used for heat guns is low, it is OK to stare at the beam.
    a. True
    b. False

11. When using an IR thermometer with a 10:1 D:S, if the size of the target is about 12 in. in diameter, what is the maximum distance the measurement should be taken from?
    a. 0.83 ft
    b. 1.2 ft
    c. 10 ft
    d. 12 ft

Answer Key: Self-Test A-4.2 is on the next page.

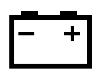
Answer Key: Self-Test A-4.2

1. a. True
2. b. False
3. b. Bimetallic element
4. d. Can easily change the thermometer/sensor without draining the piping or vessel
5. b. False
6. d. Variable resistance sensor
7. b. The resistance decreases as the temperature rises.
8. c. As temperature rises, an increased millivolt signal is created.
9. c. Infrared energy
10. b. False
11. c. 10 ft

Self-Test A-4.3 Electrical Testing Instruments

Complete Self-Test A-4.3 and check your answers.

1. Match the digital multimeter symbol to its correct description.

AC Voltage	___________	a.	⎓
DC voltage	___________	b.	
Resistance	___________	c.	
AC or DC voltage	___________	d.	~
Low Battery	___________	e.	µA
Continuity beeper	___________	f.	Ω
Overload	___________	g.	≂
Microamperes	___________	h.	OL

2. The most common clamp-on ammeters are available for AC currents only.
   a. True
   b. False

3. When using an in-line ammeter to measure current in a circuit, what must you ensure when connecting the multimeter?

a. The power is off in the circuit
b. The multimeter is connected near the source
c. The multimeter is connected in series with the circuit
d. The multimeter is connected in parallel with the source or load

4. When testing for ohms, the power must be left on in the circuit.
   a. True
   b. False

5. When testing a circuit for voltage, how must the meter be connected?
   a. In parallel with the circuit
   b. In series with the circuit
   c. To a de-energized circuit
   d. With both leads grounded

6. When testing for continuity in a circuit, what must be ensured?
   a. That the circuit is powered
   b. That the meter is grounded
   c. That the source has a short circuit
   d. That the circuit is de-energized

7. Test leads must have a category rating that is equal to or less then the rating of the tester.
   a. True
   b. False

8. An AC voltage waveform changes polarity constantly with time, so it is not necessary to ensure correct polarity when connecting the test leads.
   a. True
   b. False

9. When using a clamp ammeter on a two-wire circuit, the two electromagnetic fields will cancel each other out if the meter is clamped around both wires at once.
   a. True
   b. False

10. The ohmmeter is designed so that it will display 0 ohms when the test leads are left open. (zero external resistance)
    a. True
    b. False

Answer Key: Self-Test A-4.3 is on the next page.

Answer Key: Self-Test A-4.3

1.

AC voltage	d	~
DC voltage	a	⎓
Resistance	f	Ω
AC or DC voltage	g	≂
Low battery	c	🔋
Continuity beeper	b	·)))
Overload	h	OL
Microamperes	e	μA

2. a. True
3. c. That the multimeter is connected in series with the circuit
4. b. False
5. a. In parallel with the circuit
6. d. That the circuit is de-energized
7. b. False
8. a. True
9. a. True
10. b. False

Self-Test A-4.4 Combustible Gas Indicators

Complete Self-Test A-4.4 and check your answers.

1. What type of gas detector requires a separate hydrogen gas cylinder to operate?
    a. Infrared
    b. Electrochemical
    c. Electrocatalytic
    d. Flame ionization

2. What type of sensor does not have to be placed into the gas to detect it and can be used for remote sensing at distances up to 30 metres?
    a. Infrared
    b. Electrochemical
    c. Electrocatalytic
    d. Flame ionization

3. To ensure proper zero, you must always start the detector in a clean-air environment.
    a. True
    b. False

4. For detectors that use Geiger-style ticks: as the sensor head moves closer to a leak source, the tick rate will decrease.
    a. True
    b. False

5. All gas leak detectors require the sensors to be replaced by an authorized service centre.
    a. True
    b. False

Answer Key: Self-Test A-4.4 is on the next page.

Answer Key: Self-Test A-4.4

1. d. Flame ionization
2. a. Infrared
3. a. True
4. b. False
5. b. False

Glossary - Block A: Fuel Gas

absolute pressure

When the pressure is relative to a perfect vacuum, it is referred to as "absolute pressure," which equals gauge pressure plus atmospheric pressure. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

absorption refrigerator

A gas-fired refrigerator that uses heat from a gas flame to drive a chemical process involving ammonia, water, and hydrogen to produce cooling—without a compressor. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

air supply

(For combustion); The air required by a gas appliance to support proper combustion, which may need to come from outside depending on appliance type and building design. (Section A-2.2 (#chapter-a-2-2-interpret-sections-of-the-b149-1-gas-code))

ammeter

A device used to measure electric current in a circuit. It shows the amount of current flowing through the circuit in units called amperes (amps). (Section A-4.3) (#chapter-a-4-3-electrical-testing-instruments)

analogue instruments

Instruments that show measured values using a scale and pointer; the pointer moves in a direct and continuous way to show how much of something is being measured. (Section A-4.3 (#chapter-a-4-3-electrical-testing-instruments))

autoranging

A device automatically selects the best measurement range for what you're testing; this makes it easier because you don't have to set the range yourself—it adjusts on its own to give you the most accurate reading. (Section A-4.3 (#chapter-a-4-3-electrical-testing-instruments))

B149.1 code

The Canadian standard that governs the installation of natural gas and propane appliances and equipment. It's a critical document for all gas-related work. (Section A-2.2 (#chapter-a-2-2-interpret-sections-of-the-b149-1-gas-code))

backdrafting

The reverse flow of gas in the flues of fuel-fired appliances that results in the intrusion of combustion by-products into the living space. (Section A-3.4) (#chapter-a-3-4-the-building-as-a-system)

barometer

A type of pressure gauge used specifically to measure atmospheric pressure. The units of measure used are inches of mercury (in. Hg). (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

barometric damper

A device used in heating systems to help control the airflow going in and out of the chimney. It automatically adjusts to make sure the right amount of air is flowing through the system, which helps the appliance burn fuel more efficiently. This keeps the system working properly and prevents problems like too much smoke or wasted energy. (Section A-3.3 (#chapter-a-3-3-gas-appliance-draft))

black-body source

A "black-body source" is an object that is perfect at absorbing and giving off heat energy. It doesn't reflect any light; instead, it takes in all the energy that hits it and then emits the maximum amount of energy possible for its temperature. When we talk about "emissivity," we're comparing how much energy a real object emits compared to this perfect black body. So, if a material has high emissivity, it's very good at emitting heat energy, like the black body. If it has low emissivity, it's not as good at emitting heat. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

Bourdon tube gauge

A type of gauge that measures the pressure of liquids and gases; it uses an elastic tube that bends under pressure, moving a pointer to indicate the pressure on a scale. This device can measure pressures up to 100,000 psi (70,000 newtons per square cm). (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

BTU (British Thermal Unit)

A unit of energy used to measure the heat content of fuel. (Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion))

building envelope

The physical boundary between the conditioned and unconditioned parts of a building, which includes the foundation, roof, walls, doors, windows, and insulation, and controls the flow of air, heat, and moisture. (Section A-3. (#chapter-a-3-4-the-building-as-a-system)4)

building system

A framework made up of different subsystems, including occupants, the building envelope, outside environment, and mechanical/electrical equipment, that work together to manage air, heat, and moisture flow. (Section A-3. (#chapter-a-3-4-the-building-as-a-system)4)

BW vent

A specialized oval-shaped vent system designed for use with natural draft appliances like recessed wall furnaces, allowing installation within wall cavities. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

carbon monoxide (CO) sensor

A safety device that detects dangerous levels of carbon monoxide gas and may activate a shut-off mechanism on gas appliances. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

categories

(CSA B149.1); The different types of natural gas appliances classified based on their efficiency and the pressure of their venting system. The classification helps determine how the appliance operates and how the combustion gases are vented. There are four main categories: Category I, Category II, Category III, and Category IV, with each category indicating a specific range of efficiency and venting pressure. (Section A-3.3 (#chapter-a-3-3-gas-appliance-draft))

certification organizations

Groups that check if products are made and work safely and correctly. They put special labels on products to show they meet safety rules. Accredited certification organizations apply a special certification symbol. (Section A-1.3 (#chapter-a-1-3-documents-regulations-and-specifications))

combustible gas indicator (CGI)

Also called a gas leak detector, this device is used to detect and measure the presence of flammable gases in the air, it helps to identify potentially hazardous levels of gases that could ignite or pose health risks. (Section A-4.4) (#chapter-a-4-4-combustible-gas-indicators)

combustible material

Any material that can ignite and burn. The code contains specific clearance requirements to prevent fire hazards. (Section A-2.2 (#chapter-a-2-2-interpret-sections-of-the-b149-1-gas-code))

combustion

The rapid oxidation of fuel, accompanied by heat or heat and light. Combustion is essential for gas appliances to operate properly. (Section A-3.1 (#chapter-a-3-1-chemistry-of-combustion))

combustion air

The air required for the combustion process, expressed as an air/gas ratio (10:1 for natural gas, 25:1 for propane). (Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion))

complete combustion

The ideal burning process where there is enough oxygen to burn all the fuel completely, producing only carbon dioxide (CO_2), water vapor (H_2O), and heat as byproducts. (Section A-3.1 (#chapter-a-3-1-chemistry-of-combustion))

compound gauge

A type of gauge that can measure pressures both above and below atmospheric pressure. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

concentric coaxial pipe

A type of pipe made of two pipes, one inside the other. The outer pipe carries air, while the inner pipe carries the fuel or exhaust, helping to safely vent gases while bringing in fresh air for combustion. (Section A-1.1 (#chapter-a-1-1-characteristic-of-gas-appliances))

dial thermometer

A common type of analogue thermometer available in two general types: stem and flexible capillary. They typically use a bimetallic temperature-sensing element in the stem, where temperature changes cause the element to bend or twist, moving the pointer via a mechanical linkage. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

differential pressure

The difference in pressure between two contained working fluids. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

differential pressure gauge

A type of gauge with two inlet ports, each connected to one of the volumes whose pressure is to be monitored; this gauge can be used to monitor air flow, check the amount of filter clogging, and test equipment operation; it performs the mathematical operation of subtraction through mechanical means. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

digital instruments

Instruments that use electronics to read and display exact numerical data or measurements using LEDs or LCDs as numbers on a screen, like a calculator; easier to read than analogue instruments since you don't have to interpret the numbers on a scale. (Section A-4.3) (#chapter-a-4-3-electrical-testing-instruments)

digital manometer

The most common portable field pressure-measuring tool due to its many advantages over traditional instruments; it uses micro-pressure sensors that alter electrical resistance when pressure is applied and can measure positive, negative, or differential pressures; this tool is compact, can be used in any position, and does not require fluid. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

digital multimeter (DMM)

An electronic tool that combines the features of a voltmeter, an ammeter, and an ohmmeter; it measures electricity, voltage, and resistance and shows these measurements on a digital screen using numbers, making it easy to read and understand. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments) and Section A-4.3) (#chapter-a-4-3-electrical-testing-instruments)

dilution air

Ambient air introduced into the venting system of natural draft appliances, used to control draft and cool vent gases. (Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion))

direct vent appliance

A sealed combustion gas appliance that draws air from outside for combustion and vents exhaust gases directly outside, improving safety and efficiency. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

distance-to-spot ratio (D:S)

A ratio that tells you how far you need to be from an object to measure its temperature accurately with a thermometer; a higher D:S ratio means you can measure temperature from farther away, like using a zoom on a camera to focus on something far off. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments))

draft control device

Equipment, such as a draft hood or damper, used in natural draft appliances to regulate airflow and ensure proper combustion. (Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion))

draft hood

A device that helps control draft in natural draft systems, preventing downdrafts and allowing for safe venting even if the vent is blocked. (Figure 1, Section A-3.3)

electrocatalytic sensors

Sensors that function on the principle that a combustible gas can be oxidized to produce heat; the resulting temperature change can be converted to a sensor signal; catalyst sensors are often used to detect hydrocarbons and rely on the presence of oxygen to function. (Section A-4.4) (#chapter-a-4-4-combustible-gas-indicators)

electrochemical gas sensors

Sensors that measure the concentration of a target gas by oxidizing or reducing the target gas at an electrode semiconductor; the absorption or desorption of the gas on the metal oxide semiconductor changes either the conductivity or the resistivity and the resulting current is measured and compared to a known baseline value. (Section A-4.4) (#chapter-a-4-4-combustible-gas-indicators)

emissivity

A number from 0 to 1 that indicates how much heat a material lets out as radiation; 1 means it gives off radiation well, like a perfect black object; lower numbers mean less heat is released. This matters in infrared thermometers, where knowing emissivity helps get accurate temperature readings by adjusting for how materials reflect or emit heat. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments))

energy efficiency regulations (or standards)

Rules that set the minimum level of energy use for appliances, making sure they use energy in a smart way and help save power. (Section A-1.3 (#chapter-a-1-3-documents-regulations-and-specifications))

energy recovery ventilator (ERV)

A ventilation system similar to HRV but also transfers moisture between the outgoing and incoming air streams to maintain balanced humidity levels in the building. (Section A-3.4 (#chapter-a-3-4-the-building-as-a-system))

ENERGY STAR®

A Canadian program that identifies products meeting high-efficiency standards for energy use, helping consumers choose energy-saving appliances. (Section A-1.3 (#chapter-a-1-3-documents-regulations-and-specifications))

excess air

Extra air supplied to the combustion process beyond the amount required for perfect combustion, typically 20-30% more than the theoretical amount needed for stoichiometric combustion. This ensures that all fuel is burned efficiently and completely. (Section A-3.1 (#chapter-a-3-1-chemistry-of-combustion) and Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion))

exfiltration

The leakage of room air out of the building. (Section A-3.4 (#chapter-a-3-4-the-building-as-a-system))

flame ionization detector (FID)

A device that measures the amount of hydrocarbons in a sample; it burns the sample in a hydrogen-air flame, which produces ions if hydrocarbons are present; these ions create an electric current when they hit a metal plate, and the FID measures this current to determine the concentration of hydrocarbons; the device includes a portable hydrogen cylinder for the flame. (Section A-4.4) (#chapter-a-4-4-combustible-gas-indicators)

flammable vapour ignition resistant (FVIR)

A safety design feature in gas water heaters that prevents the ignition of flammable vapours outside the combustion chamber. Especially important in areas like garages where flammable liquids may be stored. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

flexible capillary dial thermometer

A device that features a large temperature-sensing bulb connected to the instrument via a capillary tube; it employs a Bourdon tube mechanism similar to a pressure gauge: as the temperature of the enclosed liquid or gas varies, so does the pressure within the tube; these devices, also referred to as vapor tension thermometers, offer the advantage of remote temperature reading capabilities. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

flue gases

The gases produced as a result of combustion, including carbon dioxide (CO_2), water vapor (H_2O), and nitrogen (N_2). (Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion))

fluid manometer

An instrument designed to measure the pressure of fluids, usually gases or liquids; it features a U-shaped tube filled with a liquid like mercury, water, or light oils; the column will rise or fall until the weight of the liquid column balances the pressure differential between the two ends of the tube. The simplest version is the U-tube manometer. (Section A-4.1) (#chapter-a-4-1-pressure-measuring-tools)

forced-draft burner

A type of power burner where the fan or blower is located upstream of the combustion zone to force air into the combustion chamber. (Section A-3.3 (#chapter-a-3-3-gas-appliance-draft))

gas flow rate

The amount of gas flowing through an appliance, typically measured in cubic feet per hour (CFH), and used to calculate air supply requirements. (Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion))

gas pressure regulators

A device used to control and maintain gas pressure at a safe, usable level for gas appliances. (Section A-2.2 (#chapter-a-2-2-interpret-sections-of-the-b149-1-gas-code))

gauge pressure

The pressure measurement by most gauges, this is the pressure measurement relative to atmospheric pressure as the zero point. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

heat output

The amount of heat a machine or appliance, like a water heater, can produce. It shows how much energy it transfers to heat things up. (Section A-1.3 (#chapter-a-1-3-documents-regulations-and-specifications))

heat recovery ventilator (HRV)

A system that recovers heat from outgoing exhaust air and transfers it to incoming fresh air, helping to improve energy efficiency and indoor air quality. (Figure 5, Section A-3.4 (#chapter-a-3-4-the-building-as-a-system))

high-intensity infrared heaters

A non-vented heating appliance that uses a porous burner surface to radiate high levels of heat, often used in large open areas like warehouses or patios. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

hybrid tankless water heater

A type of tankless water heater equipped with a small buffer tank and a circulation pump. This design supports hot water recirculation systems and helps maintain consistent temperature delivery. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

hydrocarbons

A compound made of hydrogen and carbon atoms. Most fuel gases, like natural gas, propane, and butane, are hydrocarbons. (Section A-3.1 (#chapter-a-3-1-chemistry-of-combustion))

inclined manometer

A device used to measure lower range pressure readings, such as air flow measurements. By inclining the manometer, you can spread one inch of vertical lift over a much greater length, allowing the scale to be accurate to hundredths of an inch of WC [water column]. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

incomplete combustion

Occurs when there is insufficient oxygen for the fuel to burn completely, producing hazardous byproducts like carbon monoxide (CO), soot, and aldehydes. (Section A-3.1 (#chapter-a-3-1-chemistry-of-combustion))

induced-draft burner

A type of power burner where the fan or blower is located downstream of the combustion zone, creating draft by drawing gases out of the combustion chamber. (Section A-3.3 (#chapter-a-3-3-gas-appliance-draft))

infiltration

The unintentional introduction of outside air into a building; also referred to as air leakage. (Section A-3.4 (#chapter-a-3-4-the-building-as-a-system))

infrared (IR) sensors

Also known as laser sensors, are based on absorption of infrared radiation as it passes through a volume of gas; the laser light beam emits a specific wavelength that is absorbed by methane, and when the laser hits methane, the methane absorbs some laser energy; the concentration of gas is proportional to the amount of specific IR light absorbed and is displayed in ppm concentrations; this sensor does not have to be placed into the gas to detect it and can be used for remote sensing at distances up to 30 metres. (Section A-4.4) (#chapter-a-4-4-combustible-gas-indicators)

infrared (IR) thermometer

An Instrument that measures temperature by detecting thermal radiation emitted by the object being measured, often referred to as black-body radiation; also known as a laser thermometer due to use of a laser for aiming, or as a non-contact thermometer or temperature gun because it can measure temperature from a distance; by assessing the amount of infrared energy emitted and considering emissivity, infrared thermometers can estimate the object's temperature within a specified range; belongs to the category of devices known as "thermal radiation thermometers." (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

ingress

The entry or movement of soil gases. (Section A-3. (#chapter-a-3-4-the-building-as-a-system)4)

light-emitting diodes (LEDs)

A light-emitting diode (LED) is a semiconductor device that emits light when current flows through it. (Section A-4.3 (#chapter-a-4-3-electrical-testing-instruments))

liquid crystal displays (LCDs)

A liquid-crystal display (LCD) is a flat screen that uses liquid crystals to change how light passes through. It doesn't make its own light but uses a backlight or reflector to show images in color or black and white. (Section A-4.3 (#chapter-a-4-3-electrical-testing-instruments))

liquid-in-glass (glass-stem) thermometer

A thermometer that consists of a small reservoir and a fine tube; the reservoir, or bulb, is filled with a fluid like colored alcohol or mercury; when the temperature changes, the liquid's volume changes, causing the liquid level in the tube to rise or fall. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments))

lower explosive limits (LEL)

Lower explosive limits (LEL) is the lowest concentration of a flammable gas or vapor in the air that can ignite or explode when there is a source of ignition present. It's important to know LEL to stay safe when working with potentially explosive gases. (Section A-4.4) (#chapter-a-4-4-combustible-gas-indicators)

magnehelic gauge

A highly accurate pressure gauge for measuring draft conditions, determining pressure drop, or adjusting gas regulators. It uses a very sensitive diaphragm that has a pressure connection to each side. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

make-up air

The air supplied in sufficient quantity to make up for air exhausted to outdoors. (Section A-3.4 (#chapter-a-3-4-the-building-as-a-system))

manufacturer's specification sheets (or datasheets)

Instructions or details provided by the maker of a product, explaining how the product should be used, installed, and maintained. (Section A-1.3 (#chapter-a-1-3-documents-regulations-and-specifications))

mechanical draft

Draft that is created with the help of a mechanical fan or blower to move air and combustion gases, often used in high-efficiency appliances. (Section A-3.3)

moisture exhaust duct

The ductwork used in gas dryers to vent humid air and combustion by-products to the outdoors, as required by code. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

MOSFET adapter

(Metal-Oxide-Semiconductor Field-Effect Transistor); A small electronic part that helps turn gas appliances on or off safely. It controls how electricity flows to important safety parts like sensors or shut-off devices. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

natural draft

A type of draft where the movement of air is created by the buoyancy of hot combustion gases, which are lighter than cooler outside air. (Section A-3.3)

natural gas

A fossil fuel primarily composed of methane, used as a common energy source in residential, commercial, and industrial applications. (Section A-2.2 (#chapter-a-2-2-interpret-sections-of-the-b149-1-gas-code))

negative temperature coefficient (NTC) thermistors

Resistors with a negative temperature coefficient, which means that their resistance decreases as the temperature increases; primarily used as resistive temperature sensors and current-limiting devices; unlike RTDs, which are made from metals, NTC thermistors are generally made of ceramics or polymers; their temperature sensitivity ranges from approximately -3% to -6% per degree Celsius. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments))

ohmmeter

A tool used to measure how much something resists the flow of electricity (electrical resistance); it tells you the resistance in units called ohms (Ω); multimeters can serve as ohmmeters when set to resistance-measuring mode; to measure resistance, an ohmmeter applies a current to the circuit or component under test. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments) and Section A-4.3) (#chapter-a-4-3-electrical-testing-instruments)

Pascal (or pascals)

A pascal is the SI unit of pressure, equal to one newton per square meter (approximately 0.000145 pounds per square inch, or 9.9 × 10 atmospheres). (Section A-2.1) (#chapter-a-2-1-introduction-to-gas-codes-regulations-and-acts)

perfect (stoichiometric) combustion

When fuel burns with just the right (theoretical or mathematically exact) amount of oxygen, leaving only carbon dioxide (CO_2) and water (H_2O) as products. It’s a perfectly balanced reaction, but it's hard to achieve in real life because it's difficult to get the exact mix of oxygen and fuel. (Section A-3.1 (#chapter-a-3-1-chemistry-of-combustion))

piping and tubing systems

Approved assemblies of pipes, tubes, hoses, and fittings used to safely transport gas from the meter or tank to appliances. (Section A-2.2 (#chapter-a-2-2-interpret-sections-of-the-b149-1-gas-code))

Positive temperature coefficient (PTC) thermistors

Resistors with a positive temperature coefficient, which means that the resistance increases with increasing temperature; they are made from materials such as silicon or barium titanate, known for their high resistance properties, and they have various uses such as temperature sensors, self-regulating heaters, and resettable fuses. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments))

potentiometer

An instrument for measuring or adjusting small electrical potentials. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments))

power burner

A burner with mechanical draft that generates sufficient pressure to overcome resistance in the combustion chamber, appliance, and venting system. (Section A-3.3 (#chapter-a-3-3-gas-appliance-draft))

power venter

A mechanical draft system used to assist venting in natural draft appliances, often used to overcome venting challenges like excessive negative pressure. (Section A-3.3 (#chapter-a-3-3-gas-appliance-draft))

pressure measurement

The analysis of an applied force by a fluid (liquid or gas) on a surface; pressure is measured in units of force per unit of surface area. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

primary air

The portion of combustion air mixed with the fuel gas before ignition, typically one-third of the total combustion air. (Figure 2, Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion))

propane

A hydrocarbon gas used as a fuel, often stored in tanks or cylinders, commonly used where natural gas service is unavailable. (Section A-2.2 (#chapter-a-2-2-interpret-sections-of-the-b149-1-gas-code))

psi

The pressure exerted by a force of one pound-force applied over an area of one square inch is defined as 1 psi (pound per square inch). In the International System of Units (SI), 1 psi is approximately equal to 6,895 pascals. PSI is a unit of pressure in both the US customary and imperial systems. It is also sometimes referred to as pound-force per square inch. (Section A-2.1 (#chapter-a-2-1-introduction-to-gas-codes-regulations-and-acts))

psia

The term "pound per square inch absolute" (psia) specifies that the pressure measurement is relative to a vacuum, as opposed to ambient atmospheric pressure. **Note:** pounds per square inch gauge is "psig" whereas pounds per square inch absolute is "psia." (Section A-2.1 (#chapter-a-2-1-introduction-to-gas-codes-regulations-and-acts))

psig

PSIG stands for "pounds per square inch gauge" and refers to the pressure measured by a gauge or other pressure measurement device. It indicates the difference between the pressure inside a pipe or tank and the atmospheric pressure (atm). **Note:** pounds per square inch gauge is "psig" whereas pounds per square inch absolute is "psia." (Section A-2.1 (#chapter-a-2-1-introduction-to-gas-codes-regulations-and-acts))

purge

The process of removing air or other gases from piping systems before gas is introduced, critical for safe appliance operation. (Section A-2.2 (#chapter-a-2-2-interpret-sections-of-the-b149-1-gas-code))

pyrometer

A type of remote-sensing thermometer that measures the temperature of a surface without making direct contact; it determines temperature by detecting the thermal radiation emitted by the surface, which rises as the temperature increases. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

radon mitigation

Methods used to reduce the presence of radon gas in a building, such as installing a subfloor depressurization system to create a pressure difference that prevents radon from entering the building. (Section A-3.4 (#chapter-a-3-4-the-building-as-a-system))

rating plate

A metal or plastic tag on an appliance that shows important details, like how much power it uses, how to install it safely, and any safety standards it meets.(Section A-1.3 (#chapter-a-1-3-documents-regulations-and-specifications))

resistance temperature detector (RTD) thermometer

A device that measures temperature by detecting changes in electrical resistance; RTDs can have a range of −200°C to +500°C. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

secondary air

The additional air required to complete the combustion process, typically two-thirds of the total combustion air. (Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion))

Seebeck effect

The Seebeck effect happens when two different metals or materials are connected at two points and there is a temperature difference between those points; the temperature difference creates a small electric voltage; this effect can be used to measure temperatures or convert heat into electricity. The effect was discovered in 1821 by Thomas Johanan Seebeck. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments) and Section A-4.3) (#chapter-a-4-3-electrical-testing-instruments)

sensible heat

The heat that causes a change in temperature of a substance and can be felt or measured by a thermometer; it is the heat exchanged by a body or system that changes its temperature without altering its phase, volume, or pressure; for instance, sensible heat warms water but does not melt ice or evaporate water. (Section A-4.2 (#chapter-a-4-2-temperature-measuring-instruments))

slack tube manometer

Devices used for measuring velocity and static pressures, conducting leakage, fan, and blower tests, calibrating control devices, checking gas pressure, and various other applications; consist of a flexible tube that can be rolled up compactly for easy handling and storage, and when unrolled, it can be attached to vertical steel surface with the built-in magnetic clips; the tube connectors are also shutoff valves that prevent the loss of fluid. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

soil gas

A mixture of air, water vapour, and pollutants, such as radon, that enters a building through below-grade leaks in the building envelope, potentially affecting indoor air quality. (Section A-3.4 (#chapter-a-3-4-the-building-as-a-system))

stack effect (chimney effect)

The phenomenon where hot air rises due to its lower density, creating a natural flow of air into and out of buildings, chimneys, and vents. (Section A-3.3 (#chapter-a-3-3-gas-appliance-draft))

temperature transducer

A device that transforms thermal energy into other physical forms such as mechanical energy, pressure, or electrical signals. For instance, a thermocouple generates an electrical potential difference based on temperature variations across its terminals. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

thermal trap (combustion air pot)

A thermal trap prevents cold air from entering the system while allowing hot air to escape, helping maintain the right temperature for combustion air and ensuring safe fuel burning. (Figure 2, Section A-1.1 (#chapter-a-1-1-characteristic-of-gas-appliances))

thermistor

A type of semiconductor resistor whose resistance varies significantly with temperature, unlike standard resistors (the term "thermistor" combines "thermal" and "resistor"); these serve as temperature sensors in diverse applications and are categorized into two types: NTC (negative temperature coefficient) and PTC (positive temperature coefficient). (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

thermocouple

Also referred to as a "thermoelectrical thermometer," an electrical device composed of two different electrical conductors that form an electrical junction; through the Seebeck effect, generates a voltage that varies with temperature, allowing for temperature measurement; extensively used as temperature sensors. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

thermocouple interrupter

A component used in some gas appliances to shut off the gas supply in case of sensor failure or unsafe operating conditions, often used with CO detectors. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

thermowell

A cylindrical fitting designed to shield temperature sensors used for monitoring industrial processes; consists of a closed-end tube that is installed on the wall of piping or vessels where the fluid flows, safeguarding the temperature sensor inside. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

Type K

A thermocouple with Chromel and Alumel alloy wires, offering a broad temperature range from −270°C to 1,260°C; it generates an output of 6.4 to 54.9 mV across this range and excels in rugged environments and diverse atmospheres; Due to its versatility, widely employed as a temperature sensor, though it may not provide optimal accuracy for measuring smaller temperature differentials better than ±0.7°C. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

unit heaters

A self-contained, fan-forced, vented gas heater typically suspended from ceilings in garages or industrial spaces for localized space heating. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

vacuum gauge

A type of gauge that will register the amount of pressure below the atmospheric pressure. (Section A-4.1) (#chapter-a-4-1-pressure-measuring-tools)

vapour tension thermometers

See flexible capillary dial thermometer. (Section A-4.2) (#chapter-a-4-2-temperature-measuring-instruments)

ventilation

The intentional introduction of outdoor air into a space to control indoor air quality by diluting and displacing indoor pollutants; can also be used for purposes of thermal comfort or dehumidification. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances); Section A-3.4 (#chapter-a-3-4-the-building-as-a-system))

warranty

A guarantee from the manufacturer that a product will be free from defects for a certain period, with free repairs or replacements offered if needed. (Section A-1.3 (#chapter-a-1-3-documents-regulations-and-specifications))

water column (WC)

A method for measuring pressure, defined as the pressure produced by a 1-inch by 1-inch column of water of a specified height; useful for expressing low pressures, such as describing 0.072 psi as 2 inches of water. (Section A-4.1 (#chapter-a-4-1-pressure-measuring-tools))

water vapour

Microscopic water molecules that are suspended in air. (Section A-3.1 (#chapter-a-3-1-chemistry-of-combustion), Section A-3.2 (#chapter-a-3-2-calculating-gas-appliance-air-requirements-and-products-of-combustion), and Section A-3.4 (#chapter-a-3-4-the-building-as-a-system))

zero-clearance gas fireplaces

A gas fireplace that can be safely installed close to combustible materials because it is heavily insulated. It is designed for new construction or renovations where no existing fireplace is present. (Section A-1.2 (#chapter-a-1-2-types-of-gas-fired-appliances))

Plumbing Apprenticeship & Trade Resources in BC

A successful career in plumbing requires a strong foundation of skills, knowledge, and workplace safety awareness. Below are key resources to support plumbing apprentices in BC, including educational pathways, trade certifications, workplace safety guidelines, and mental health and wellness support.

Plumbing Apprenticeship & Certification Resources

- **SkilledTradesBC – Plumbing Apprenticeship (https://skilledtradesbc.ca/plumber)** — Overview of plumbing training, certification requirements, and apprenticeship pathways in British Columbia.
- **Red Seal Program – Plumber (https://www.red-seal.ca/eng/trades/plumbers/overview.shtml)** — National certification program with exam prep guides and trade mobility information.
- **BC Building Codes & Standards (https://www.bccodes.ca/)** — Official building and plumbing codes for British Columbia.

Workplace Safety & Regulations

- **WorkSafeBC (https://www.worksafebc.com/en)** — Essential safety resources for plumbers, including:
    - Health & Safety – WorkSafeBC (https://www.worksafebc.com/en/health-safety)
    - Report Unsafe Working Conditions (https://www.worksafebc.com/en/contact-us/departments-and-services/health-safety-prevention)
    - Report a Workplace Injury or Disease (https://www.worksafebc.com/en/claims/report-workplace-injury-illness)
    - Submit a Notice of Project Form (https://www.worksafebc.com/en/for-employers/just-for-you/submit-notice-project)
    - Get Health and Safety Resources (Videos, Posters, Publications, and More) (https://www.worksafebc.com/en/resources-health-safety)
    - Search the OHS Regulations (and Related Materials) (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation)
    - Conduct an Incident Investigation (https://www.worksafebc.com/en/health-safety/create-manage/incident-investigations/conducting-employer-investigation)
- **CCOHS: OHS Answers Fact Sheets – Plumber (https://www.ccohs.ca/oshanswers/occup_workplace/plumber.html)** — Safety guidelines and best practices for plumbers in various work environments.

Financial Supports

- **Financial Support (SkilledTradesBC)** (https://skilledtradesbc.ca/financial-support) — Information about grants, tax credits, Canada apprentice loans, employment insurance, and the Indigenous Skills and Employment Training

(ISET) program.

- **StudentAidBC (https://studentaidbc.ca/)** — Complete post-secondary education through student loans, grants, and scholarships. There is also programs that help with loan repayment.
- **WorkBC (Government of BC)** (https://www.workbc.ca/find-loans-and-grants/students-and-adult-learners/services-apprentices-and-employers) — Services for apprentices and employers.

Mental Health & Wellness Support

- **HealthLink BC – Mental Health and Substance Use** (https://www.healthlinkbc.ca/mental-health-and-substance-use) — HealthLink BC resources for mental health and wellness support.
- **Here2Talk** (https://here2talk.ca/) — Free and confidential counseling services available to all post-secondary students registered at a BC school.
- **Help Starts Here** (https://helpstartshere.gov.bc.ca/) — A database with over 2,500 listings of services related to mental health and substance use supports.
- **Hope for Wellness Helpline** (https://www.hopeforwellness.ca/) — 24/7 online chat and phone line with experienced and culturally competent counselors available to all Indigenous people in Canada.
    - First Nations Health Authority Mental Health Supports Info Sheet [PDF] (https://www.fnha.ca/Documents/FNHA-mental-health-and-wellness-supports-for-indigenous-people.pdf) by First Nations health Authority — List of culturally safe services for Indigenous people.
- **HeretoHelp – BC** (https://www.heretohelp.bc.ca/) — Mental health resources, including videos, articles, and support services in BC.
- **BC Construction Industry Rehabilitation Plan** (https://www.constructionrehabplan.com/) — Mental health and substance use services for CLRA and BCBT members and their families.
- **Virtual Mental Health Supports (Government of BC)** (https://www2.gov.bc.ca/gov/content/health/managing-your-health/mental-health-substance-use/virtual-mental-health-supports) — Virtual services are available for British Columbians who are experiencing anxiety, depression, or other mental health challenges.

Crisis Support

- **Interior Crisis Line Network** — Call 1-888-353-2273 (tel:+1-888-353-2273) for 24/7 emotional support, crisis intervention, and community resource information.
- **Talk Suicide Chat Service** (https://talksuicide.ca/) — An alternative if calling is difficult; available for crisis intervention.
- **310Mental Health Support** — Call 250-310-6789 (tel:+1-250-310-6789) for emotional support, information, and resources specific to mental health.
- **1-800-SUICIDE** — Call 1-800-784-2433 (tel:+1-800-784-2433) if you are experiencing feelings of distress or despair, including thoughts of suicide.
- **Opioid Treatment Access Line** — Call 1-833-804-8111 (tel:+1-833-804-8111) between 9 am and 4 pm to connect with a doctor, nurse, or healthcare worker who can prescribe opioid treatment medication that same day.
- **KUU-US Crisis Response Service** — Call 1-800-588-8717 (tel:+1-800-588-8717) for culturally-aware crisis support for Indigenous peoples in BC.
- **Alcohol and Drug Information and Referral Service** — Call 1-800-663-1441 (tel:+1-800-663-1441) to find resources and support.

Emergency Services — For life-threatening situations, call 911 or visit your nearest emergency department.

Version History

This page provides a record of changes made to this learning resource, Plumbing Apprenticeship Level 2, Block A (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/). Each update increases the version number by 0.1. The most recent version is reflected in the exported files for this resource.

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If you identify an error in this resource, please report it using the TRU Open Education Resource Error Form (#back-matter-tru-open-education-resource-error-form).

Version	Date	Change	Details
1.0	September, 2025	Plumbing Apprenticeship Level 2 Block A learning resource from STBC content converted to open and freely accessible digital platform and published at TRU.	
1.1	January 7, 2025	Correction to A-2.1 Self-Test.	Block A2 – page 84 – Self Test A-2.1 question #1 – correct answer changed to 1958 (Page 73, bottom, shows CSA first published in 1958). H5P and self-test answer key at the end of the section are corrected.
1.2	April 20, 2026	Correction to A-4.3 Self-Test	Block A-4, p.213, self-test A-4.3, questions #6-10 were missing – they were added to print-ready PDFs (Print answer key is fine and H5P and self-test answer key are fine.