

Block A: Fuel Gas



Plumbing Apprenticeship Program Level 2 Series

Block A: Fuel Gas

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** is coming soon to TRU Open Press in 2025–2026!
- **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

Acknowledgments

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

Resources

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 - Brass 1/4" MIP x barbed hose adapters
 - 1/8" NPT inlet pressure tap plug
 - Outlet pressure tap connected to clear plastic manometer tubing
 - Combination gas valve with three taper boss test ports

- Bared reducer and barbed tee
- Manometer being connected into pressure switch sensing line
- 3mm silicone rubber tubing connected to static pressure tap
- Pitot tube
- P/T plug
- 1/8" NPT inlet pressure tap plug
- Outlet pressure tap connected to clear plastic manometer tubing
- Glass-stem thermometers
- Dial stem thermometers
- Flexible capillary dial thermometer
- Dial thermometer partially inserted into thermowell
- Folding digital pocket thermometer
- Cutaway of RTD probe
- 10 k Ω NTC thermistor
- Type K exposed wire thermocouple
- DMM with temperature setting
- K type thermocouple connections
- IR thermometer
- Calibrating analogue dial thermometers
- Calibrating DMM temperature readings
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Starting December 1, 2022, Industry Training Authority was officially renamed to SkilledTradesBC. Hear more in this video from SkilledTradesBC CEO, Shelley Gray, on what this means for the trades industry and British Columbians. Closed captioning and transcripts are available with this video, Introducing Skilled Trades BC (<https://www.youtube.com/watch?v=OQgwdP0rNog>) (2022) on YouTube.



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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-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 $+500^{\circ}\text{C}$. (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 H₂O, 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).

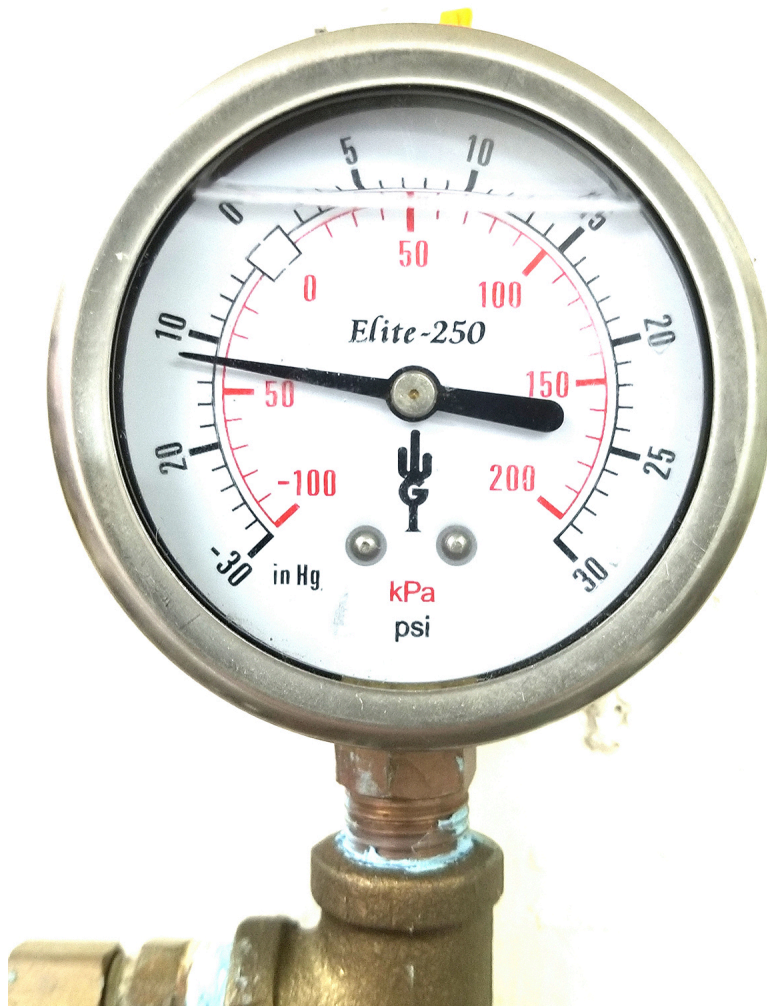


Figure 2 Compound gauge. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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.

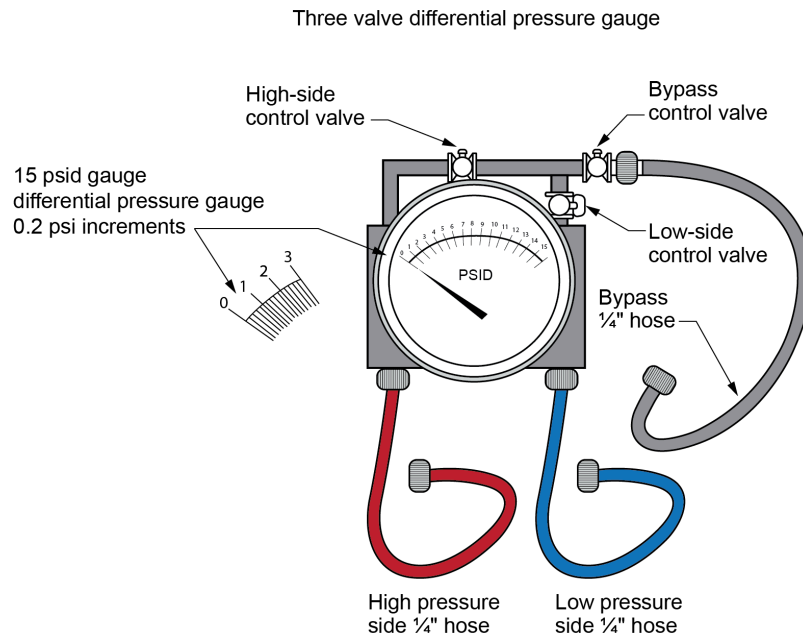


Figure 3 Differential pressure gauge used for testing backflow prevention assemblies. (Adapted from Richard Mawle/BCcampus) CC BY NC 4.0 (<https://creativecommons.org/licenses/by-nc/4.0/>)

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.

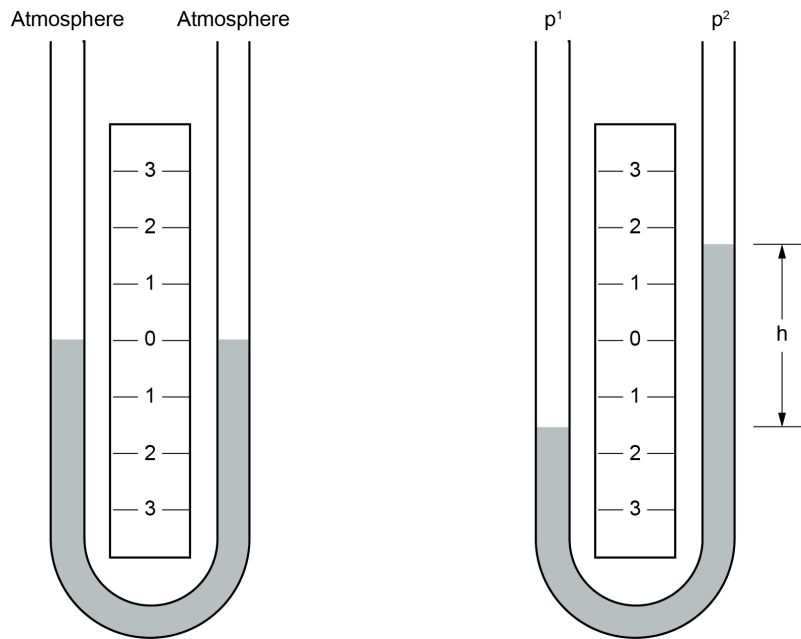


Figure 4 Fluid-filled U-tube manometer. (Skilled Trades BC, 2021) Used with permission.

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.

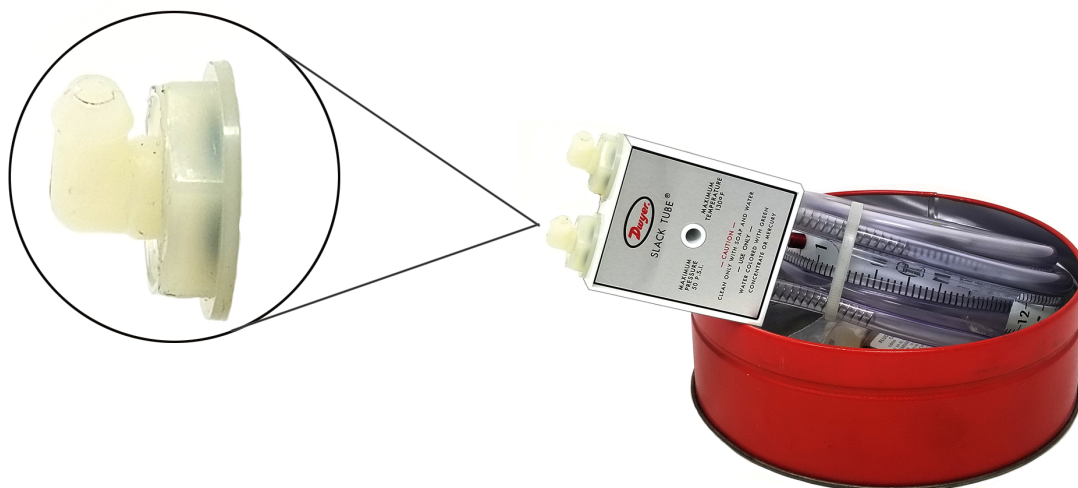


Figure 6 Dwyer Slack Tube manometer with magnification of shutoff-type tube connectors. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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.

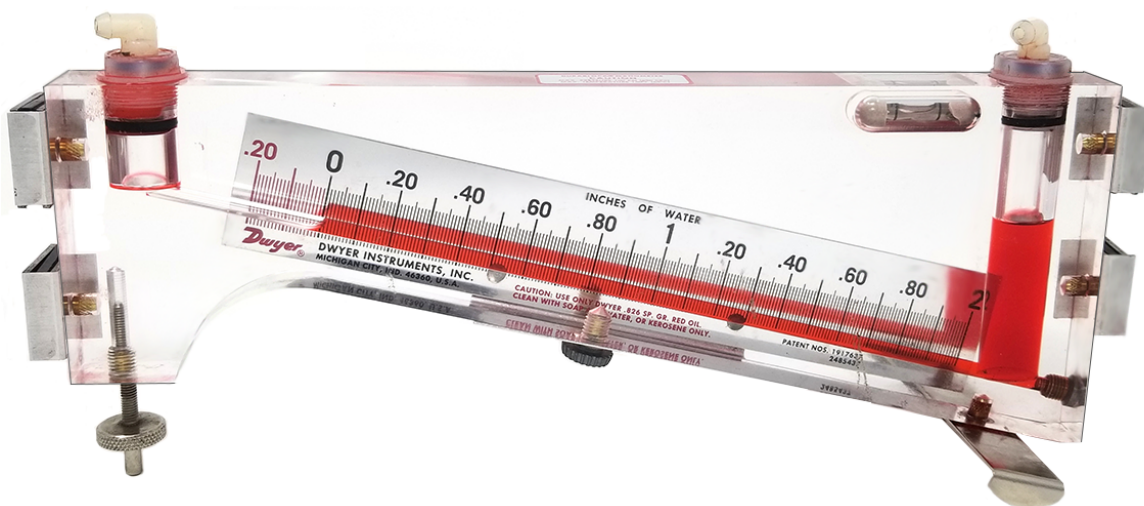


Figure 7 Inclined manometer. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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.

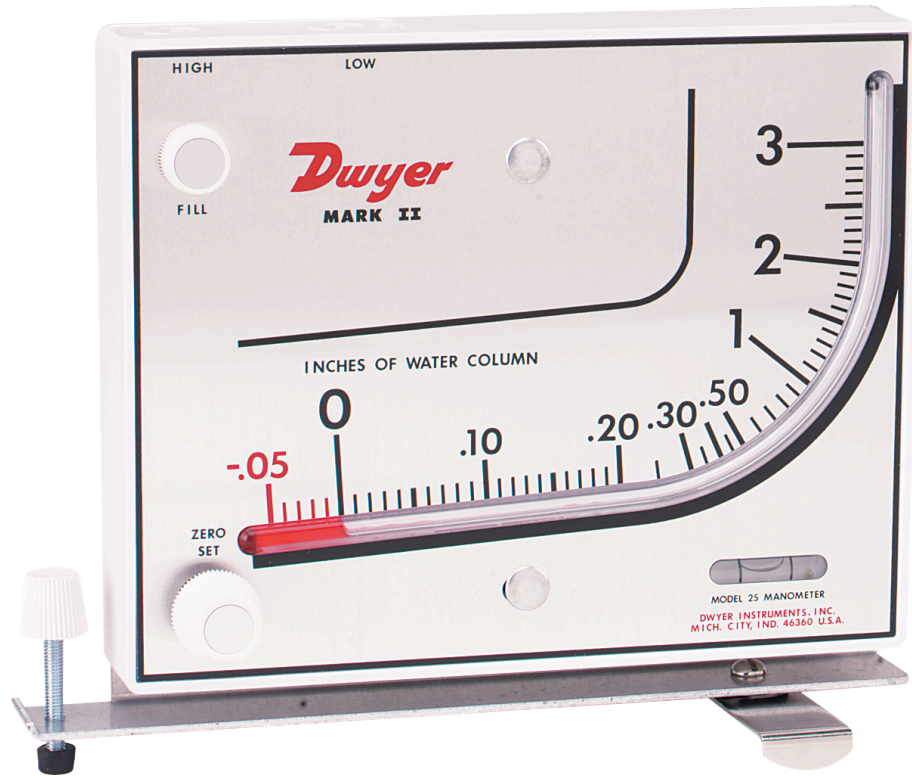


Figure 9 Automatic level and levelling rod. (Dwyer, n.d.). Used with permission.

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.

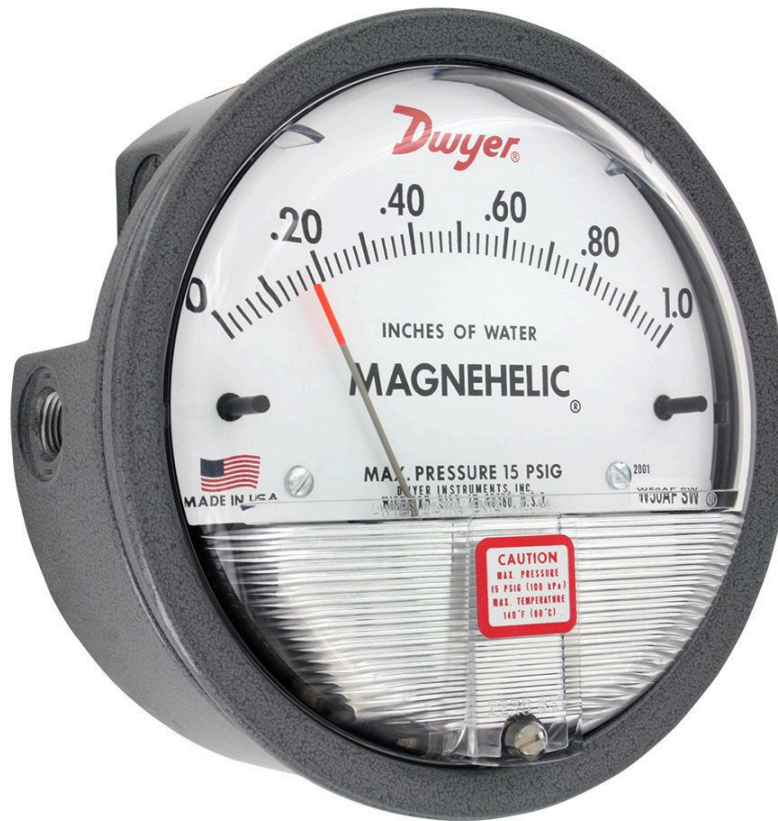


Figure 11 Magnehelic gauge. (Dwyer, n.d.). Used with permission.

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 reduce 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 $\frac{1}{4}$ MIP (0.25 MIP) barbed hose adapters. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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.

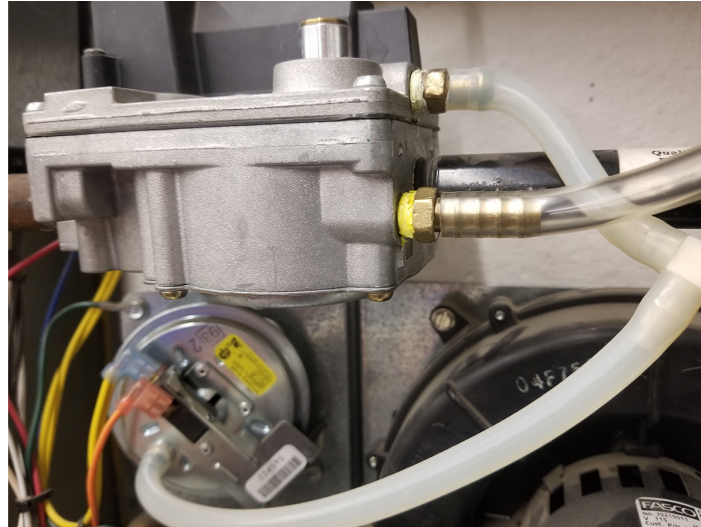


Figure 15 $\frac{1}{8}$ in. (0.125 in.) NPT inlet pressure tap plug (left), outlet pressure tap connected to clear plastic manometer tubing (right). (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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.

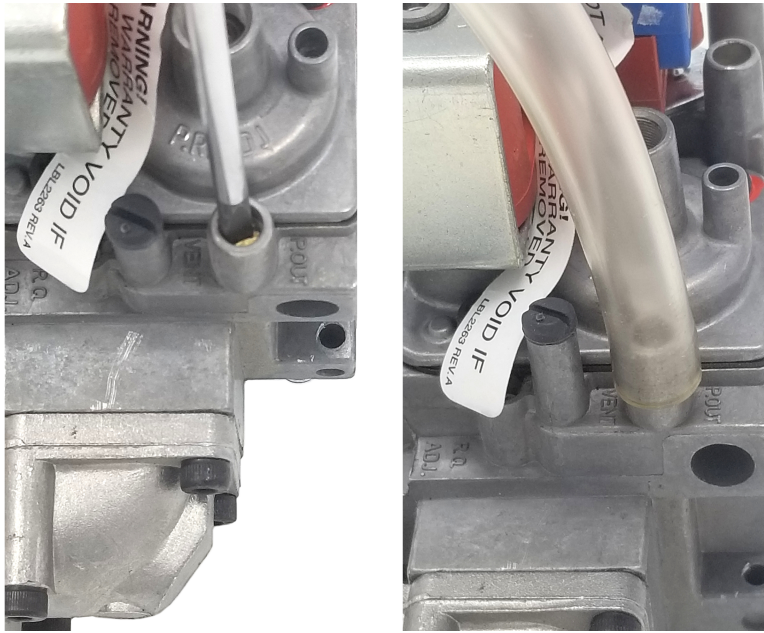


Figure 17 Opening (left) and connecting (right) pressure test ports. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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.

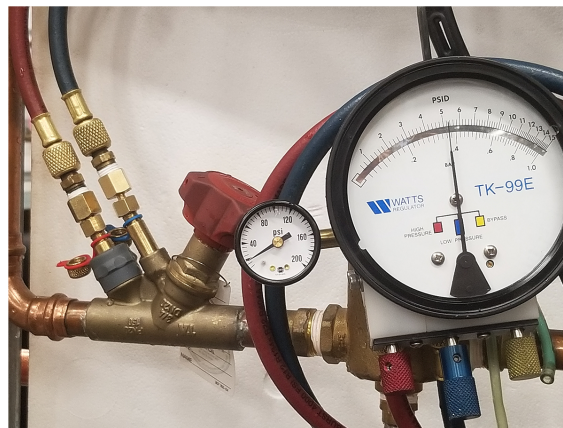
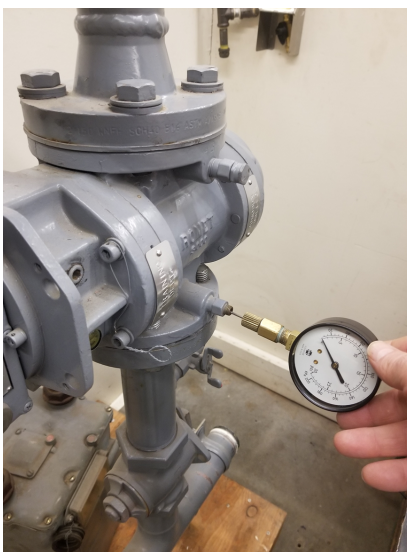


Figure 21 Two examples of pressure tests using P/T plugs. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)



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.

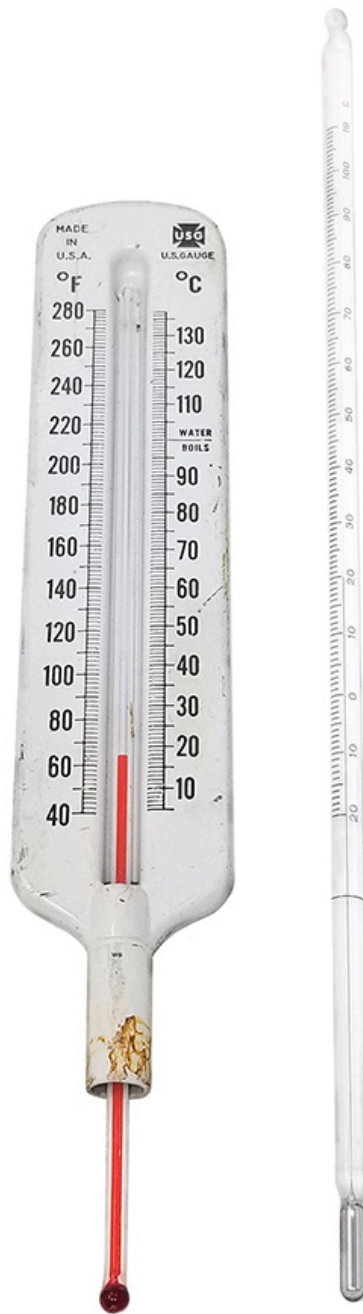


Figure 1 Glass-stem thermometers. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)



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) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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 $\pm 1^{\circ}\text{C}$.



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 thermostats:

- 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 $100\ \Omega$ @ 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 $+500^{\circ}\text{C}$.



Figure 6 Cutaway of RTD probe. (Rod Lidstone) CC BY
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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 $+150^{\circ}\text{C}$.

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 k Ω (@ 25°C) NTC sensor commonly used in the HVAC industry. This thermistor's resistance change would range from approximately 490 k Ω @ -46°C to approximately 0.55 k Ω @ 107°C.



Figure 7 10 k Ω 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.

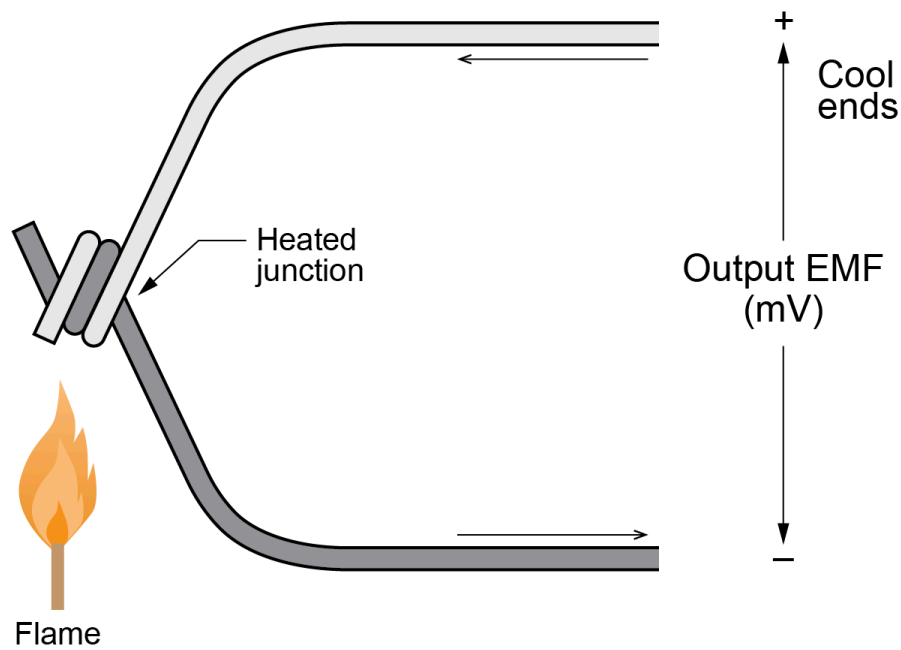


Figure 8 Thermocouple. (Skilled Trades BC, 2021) CC BY-NC-SA
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There are different types of thermocouples, based on the different conductor types used. One of the most common types is the **Type K**, which is a coupling of Chromel and Alumel alloy wires. A Type K thermocouple has a wide temperature range from -270°C to $1,260^{\circ}\text{C}$ 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 $\pm 0.7^{\circ}\text{C}$.

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.

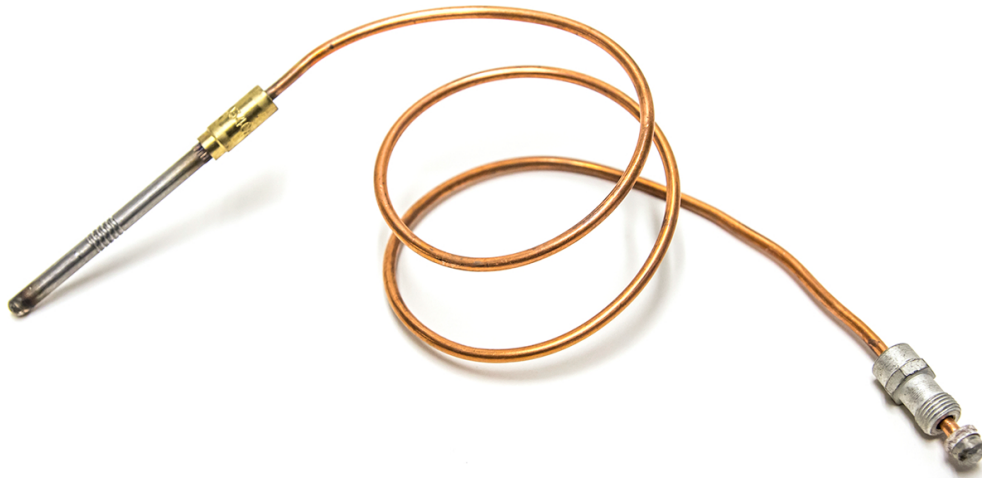


Figure 9 Pilot safety thermocouple. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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.

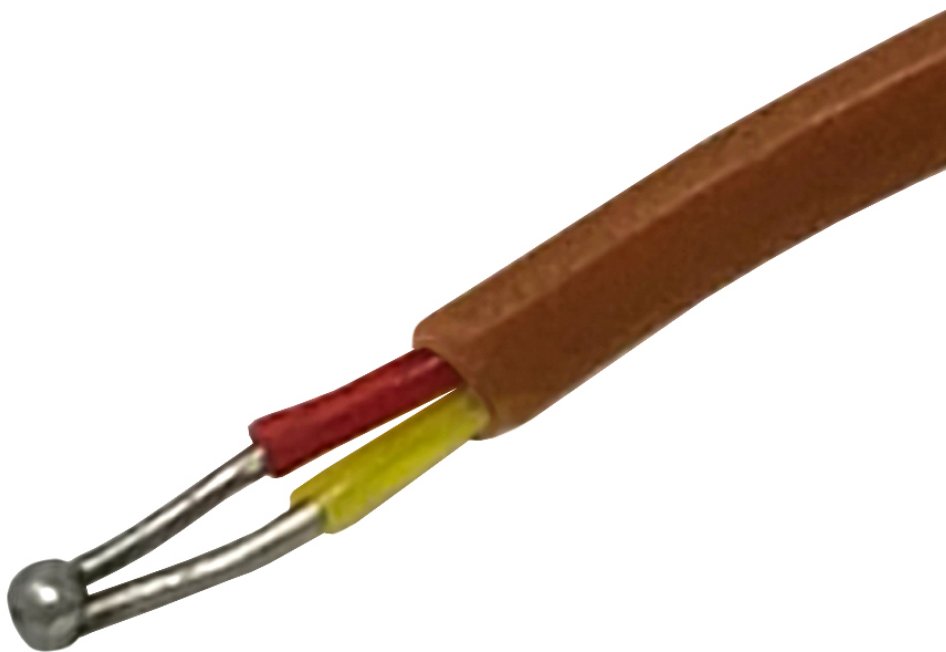


Figure 10 Type K exposed-wire thermocouple. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

Plastics are suitable insulators for low-temperature parts of a thermocouple, whereas other materials are 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.

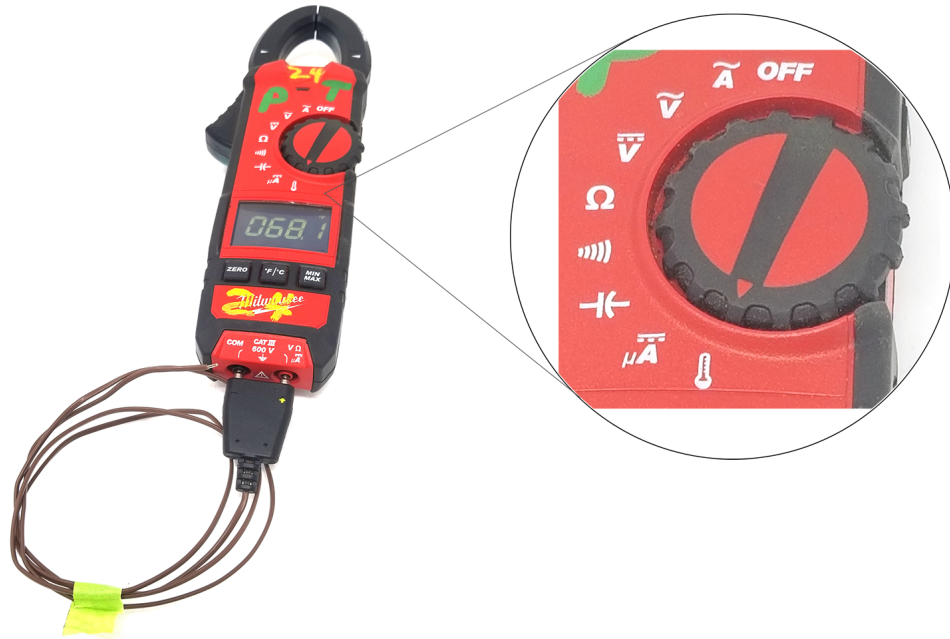


Figure 11 DMM with temperature setting. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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.

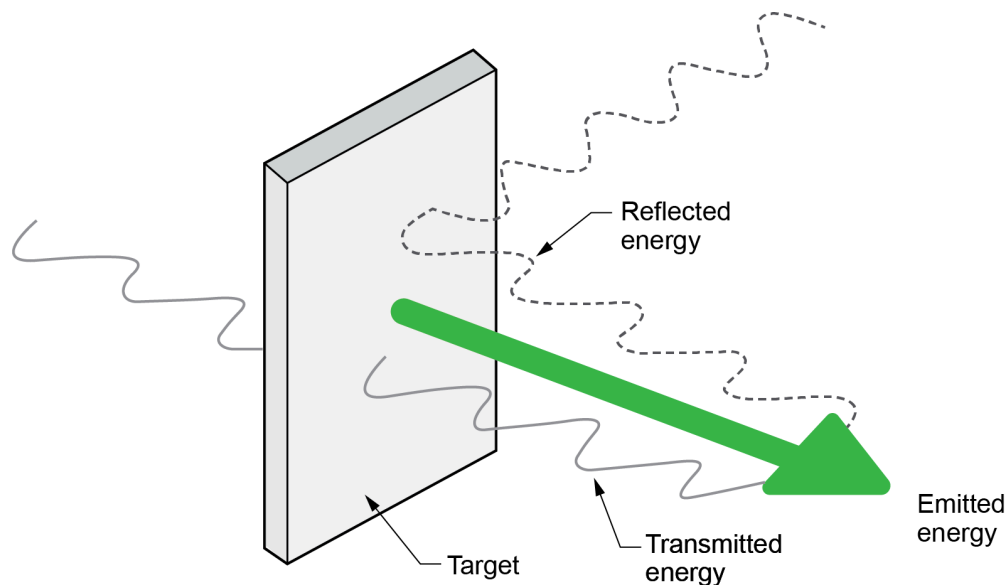


Figure 13 Emitted energy. (Skilled Trades, 2021; adapted from Fluke, 2010). Used with permission.

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 $\pm 2^{\circ}\text{C}$. 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 ($^{\circ}\text{C}/^{\circ}\text{F}$), 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.

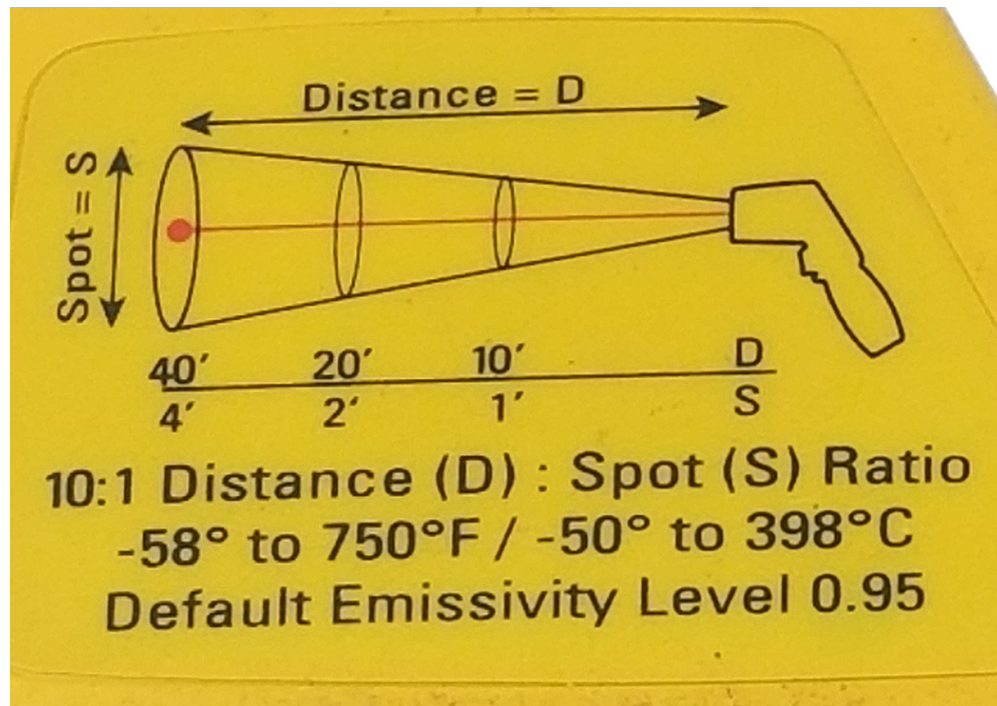


Figure 19 D:S = 10:1. (Rod Lidstone) CC BY (<https://creativecommons.org/licenses/by/4.0/>)

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.

~	AC		Low battery
⋯	DC		Manual range or automatic touch hold
Ω	Ohms		Continuity beeper
⎓	AC or DC		Diode
Hz	Hertz		Ground
+	Positive		Fuse
-	Negative		Double insulation
μF	MicroFarad		Capacitor
m	Milli	OL	Overload
M	Mega		

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 (μ A). 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

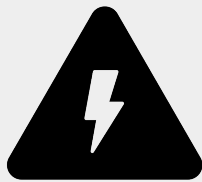
A DMM has an **ohmmeter** function that measures the amount of resistance in a component or circuit. The ohmmeter function is powered by a small battery that causes current flow through the tested circuit's resistance. Therefore, a DMM set for ohms must not be used on an energized circuit. A DMM set 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.

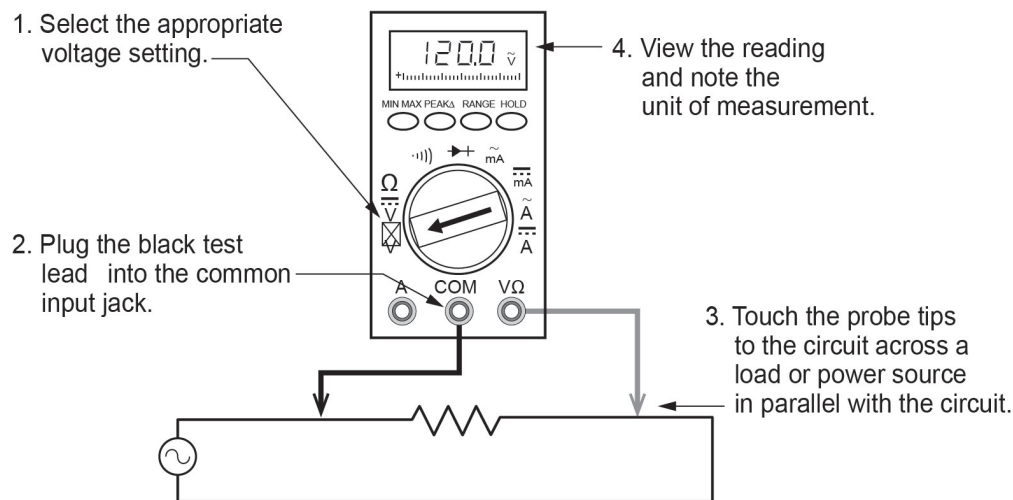


Figure 7 AC voltage measurement with a DMM. (Skilled Trades BC, 2021) Used with permission.

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.

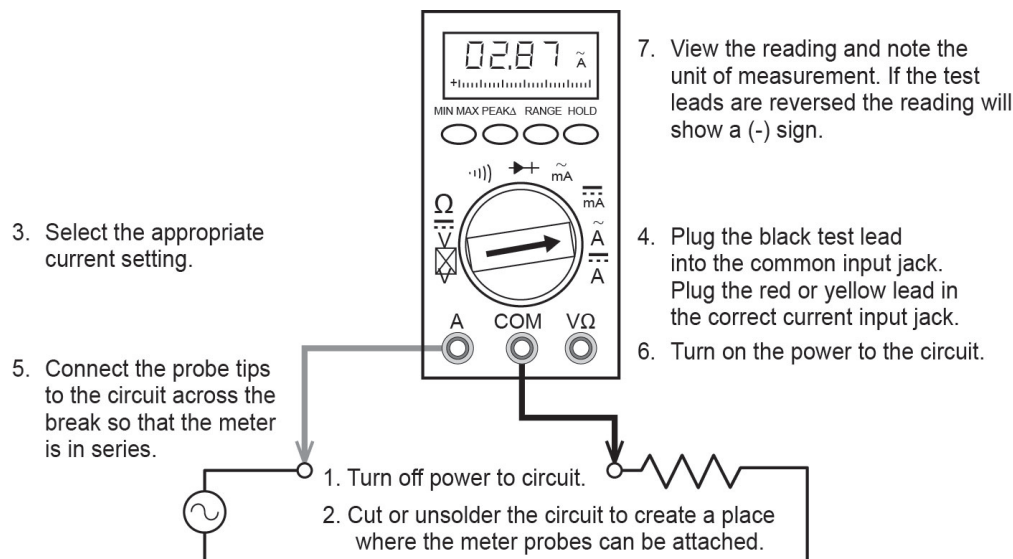


Figure 8 AC amperage measurement with a DMM. (Skilled Trades BC, 2021) Used with permission.

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 $0\ \Omega$ when the test leads are clipped together (zero external resistance). The meter reads infinite (∞) 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 0.2Ω to 0.5Ω). 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.

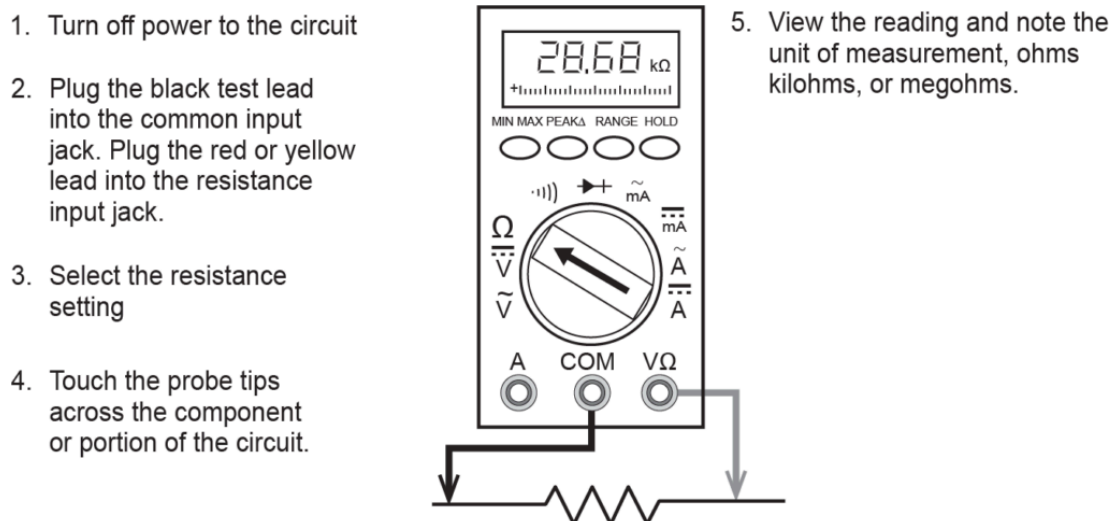


Figure 12 Resistance measurement with a DMM. (Skilled Trades BC, 2021) Used with permission.

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.

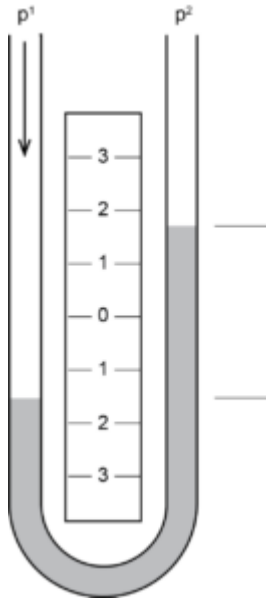
- 1 in. Hg equals how many inches of WC?
 - a. 4.05 in.
 - b. 14.73 in.
 - c. 13.6 in.
 - d. 27.68 in.
- A gauge pressure of 400 kPa would equal what absolute pressure?
 - a. 101.3 kPa
 - b. 401.3 kPa
 - c. 414.73 kPa
 - d. 501.3 kPa
- What does the reading on the gauge image (shown below) indicate?



- 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
- 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?

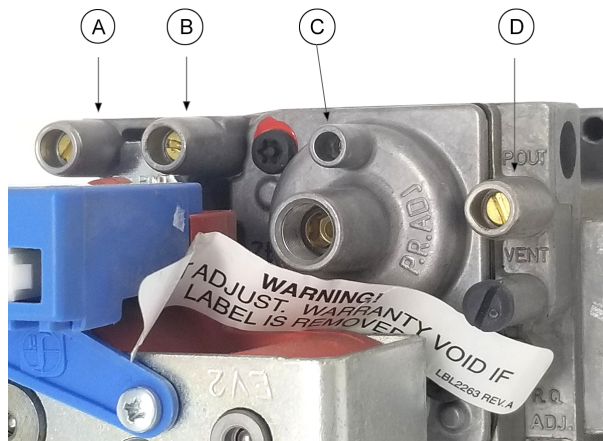


- a. 1 in. WC
 - b. 1.5 in. WC
 - c. 2 in. WC
 - d. 3 in. WC
6. When using a water or gauge oil manometer, the reading should be taken at the bottom of the U-shaped meniscus.
- a. True
 - b. False
7. When filling inclined-vertical manometers with a zero-adjustment knob, turn the knob fully counter-clockwise 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. False
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. 

Continuity beeper _____ f. 

Overload _____ g. 

Microamperes _____ h. 

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

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

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.	