CSA Unit 11

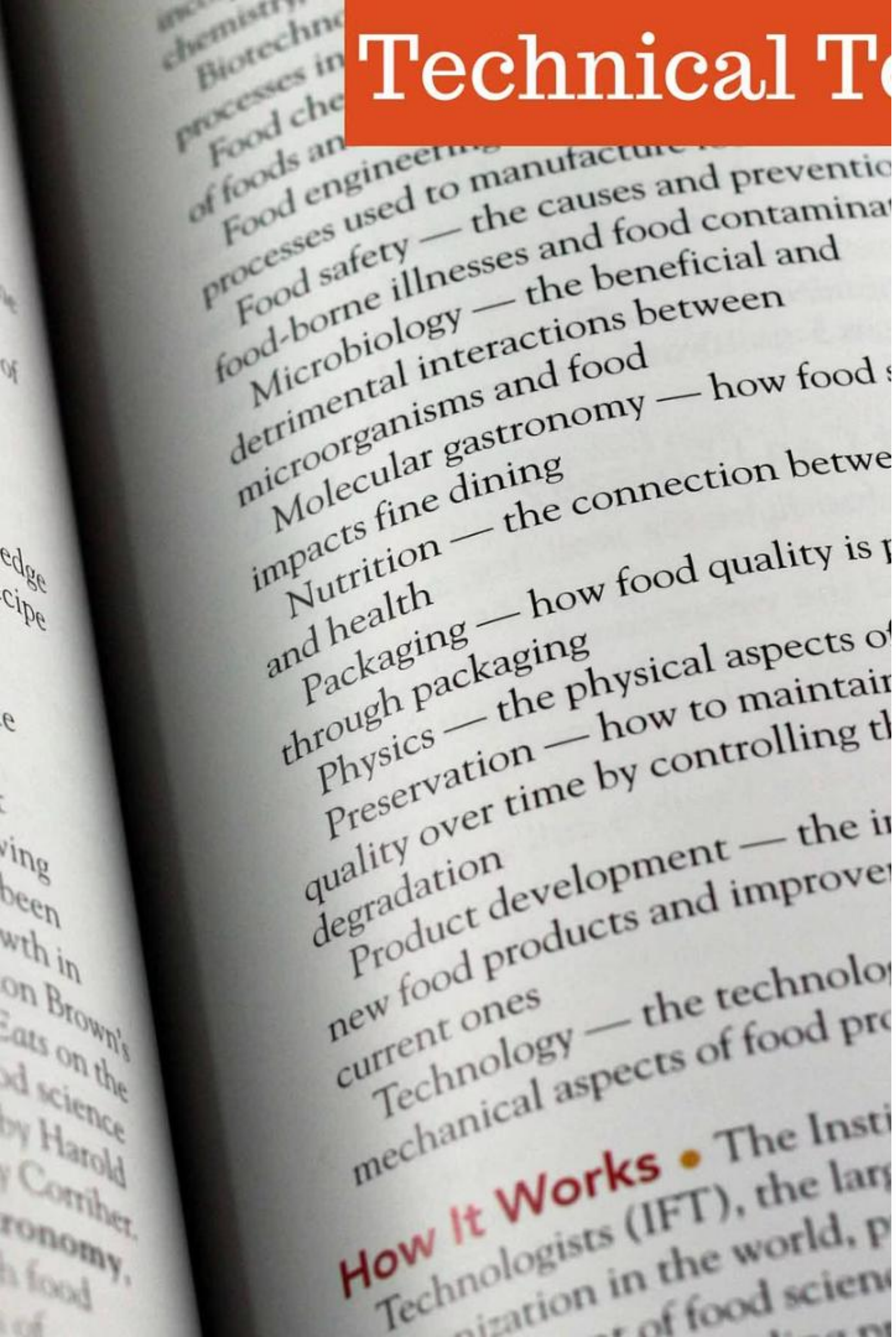
Chapter 1
Pressure Regulators

Pressure regulators are installed in a gas piping system to reduce and maintain the downstream pressure and flow rate that allow downstream appliances to operate safely and efficiently. A thorough understanding of the principal elements of pressure regulators and their operation is necessary in order to properly install and service gas equipment.

MK Created
by Mike Kapin

Objectives

1. Describe the need for pressure regulators
2. Describe the basic operation of a regulator
3. Locate the codes and regulations pertaining to regulators
4. Distinguish between the different types of regulators
5. Describe the selection requirements
6. Describe the location and piping practices
7. Troubleshoot common regulator problems



Terminology

Term	Abbreviation (Symbol)	Definition
An air/gas proportioning regulator (ratio regulator)		Is similar to a zero requlator, except that air pressure is applied to the vent opening on the spring side of the diaphragm through a sensing line connected to an air supply line delivering combustion air to the nozzle mix burner
Droop and offset		The downstream pressure drop below setpoint
Lockup		The pressure above setpoint that is used to shut the regulator off tight
Servo		A mechanism set in operation by other mechanisms
Setpoint		The desired outlet pressure
Zero governor (requlator)		Designed to deliver an outlet pressure equivalent to atmospheric pressure

The Need for Pressure Regulators

Gas pressures in supply mains (natural gas) and from storage containers (propane) are higher than the maximum allowed inlet pressure of connected appliances. For this reason, gas pressures must be controlled to fall within an appropriate pressure range, depending on the operating characteristics of installed appliances.

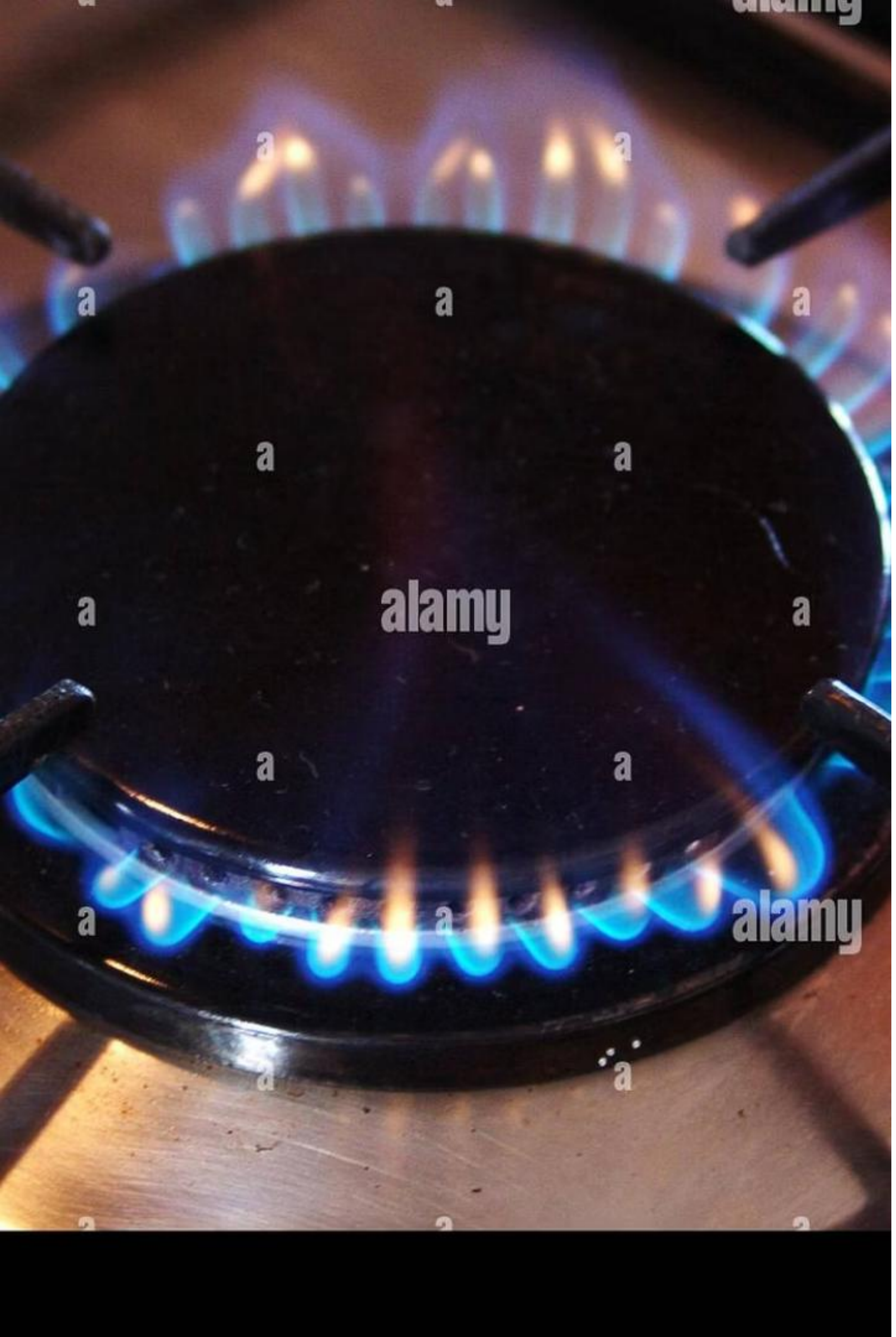
Purpose of Gas Pressure Regulators

Reduce and maintain safe operating pressure

For the building and/or connected appliances regardless of changes in the gas flow or upstream pressure.

Provide means for pressure adjustment

By which the pressure to connected appliances or burners can be adjusted, set, and maintained.

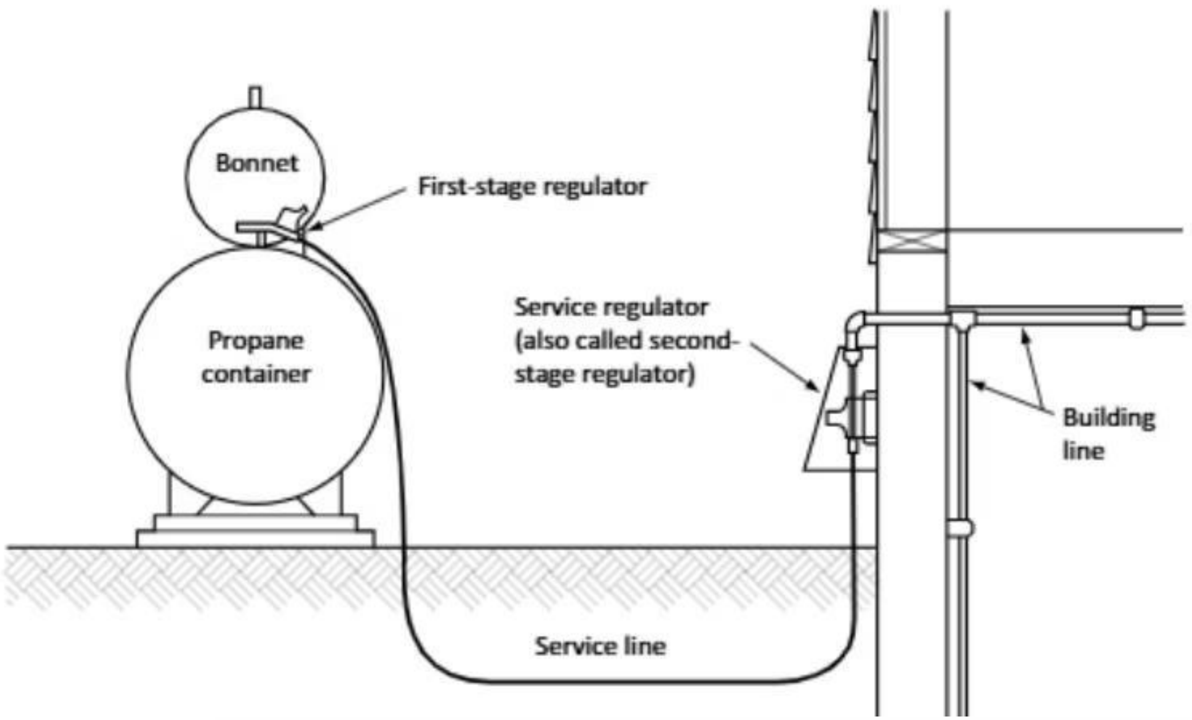


Consequences of Incorrect Gas Pressure

If	Then
The inlet pressure to the regulator is over 0.5 psi (3.5 kPa)	The requlator must provide an additional function to act as a positive shut-off device to ensure that downstream pressure does not build up to unsafe levels under no flow conditions.
A gas appliance receives too much fuel because the gas pressure is too great	It will overfire.
If the gas appliance receives too little fue	It will underfire.
If an appliance is overfired or underfired	▪ It will produce too much (overfired) and too little (underfired) heat. ▪ Combustion characteristics could change, resulting in carbon monoxide generation. ▪ The appliance may not work properly or efficiently.

Main Categories of Gas Pressure Regulators

Figure 1-1
Propane installation



Category	Description
First-stage regulators	• Used in all permanently installed propane systems to reduce the propane container pressure to service line pressure delivered to the second stage requlator See Figure 1-1
Service regulators (commonly called second-stage regulators in propane systems)	• Used in both natural gas and propane systems to reduce the service line pressure to building line pressure at the gas meter set See Figure 1-2 • Commonly called second-stage regulators in line propane systems See Figure 1-1
Line pressure regulators	• Used to reduce the building line pressure in a branch line where the pressure required by appliances or equipment on that branch line is less than the pressure in the main building line See Figure 1-2 • Referred as "system regulators" in CSA B149.1, prior to 2005

Natural Gas Installation: Service and Line Pressure Regulators

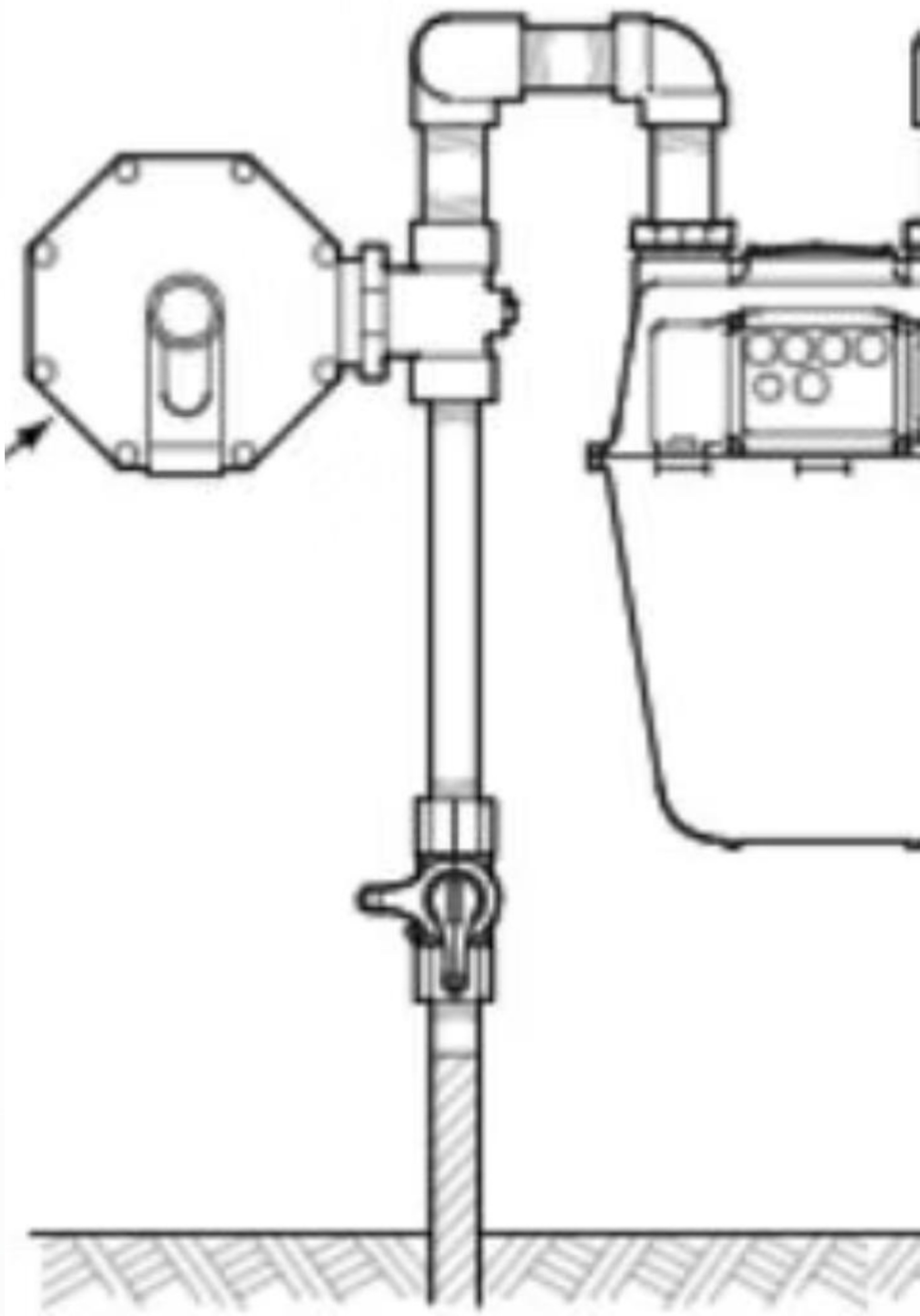
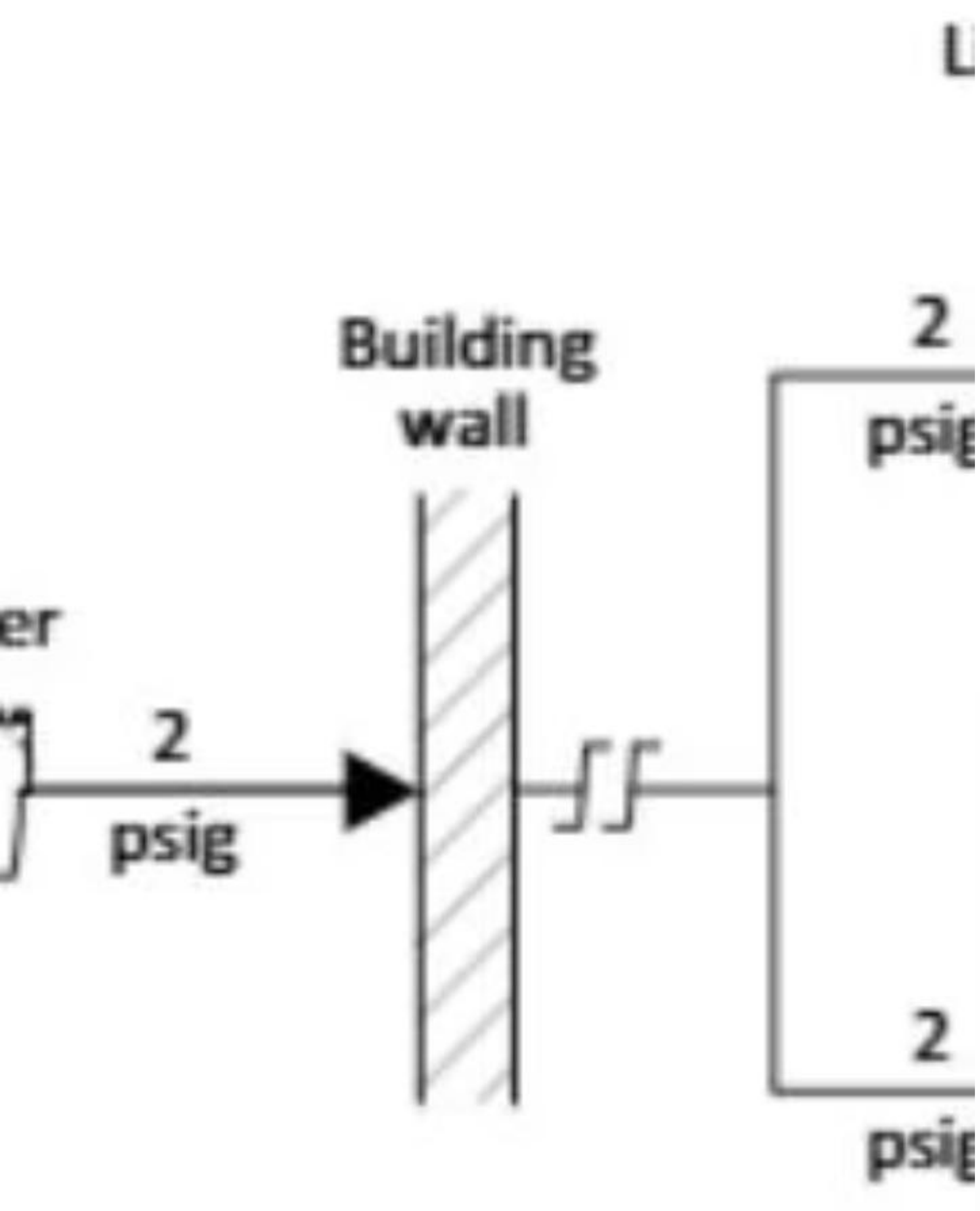


Figure 1-2 Natural gas installation showing location of service regulator and line pressure regulators



Direction of Flow in Pressure Regulators

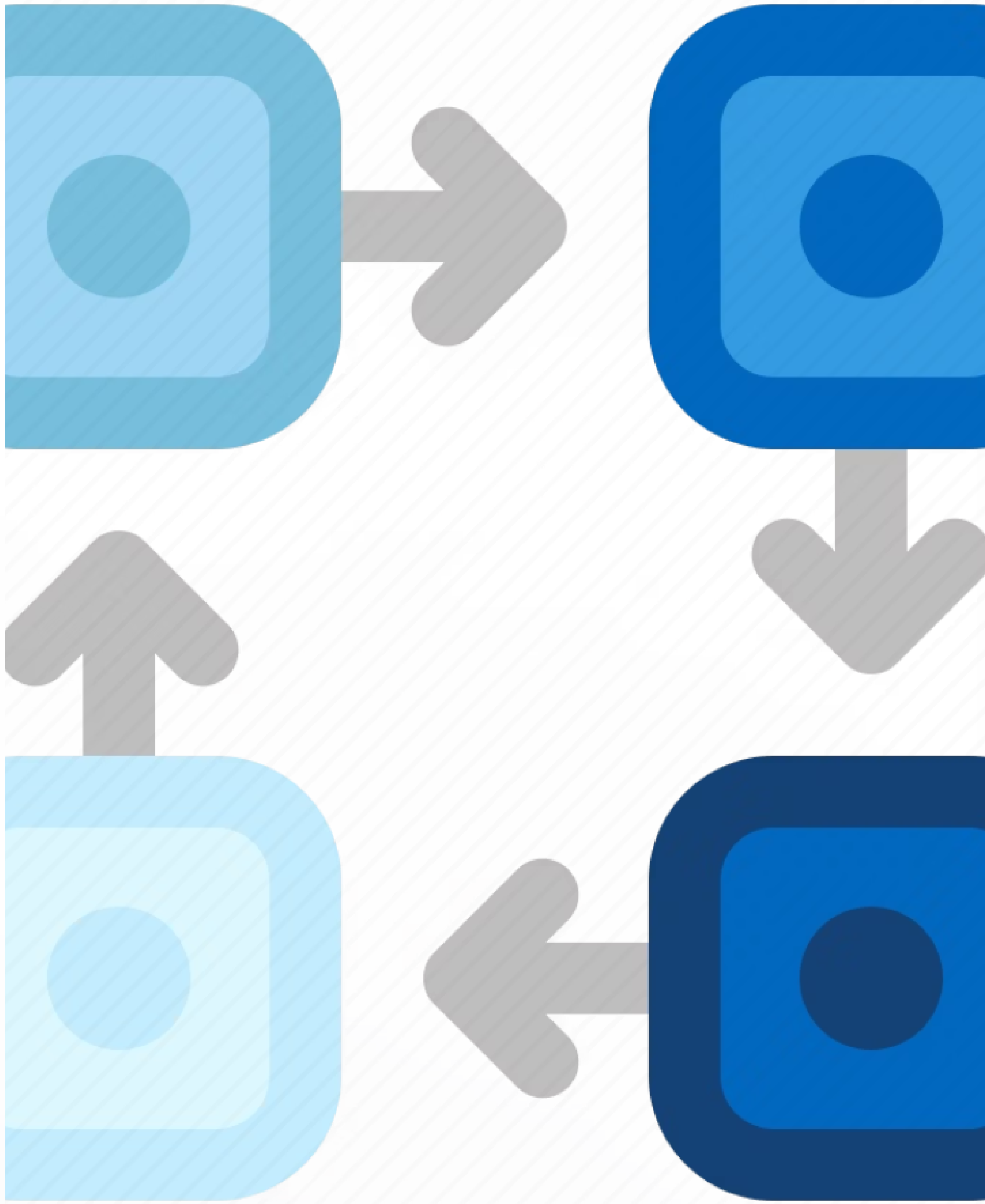
When installing a pressure regulator, the direction of gas flow is critical for proper operation of the regulator. An arrow on the regulator casing indicates the direction of flow. Be certain that you install the regulator so the flow arrow points in the direction of flow. (Direction of flow will be covered in more detail later in this chapter.)

Understanding Gas Flow Terminology

Knowing these two commonly used terms is important since they are used often to explain where to place appliances. These refer to the placing of an item in the system according to the flow of the gas:

- downstream; and
- upstream.

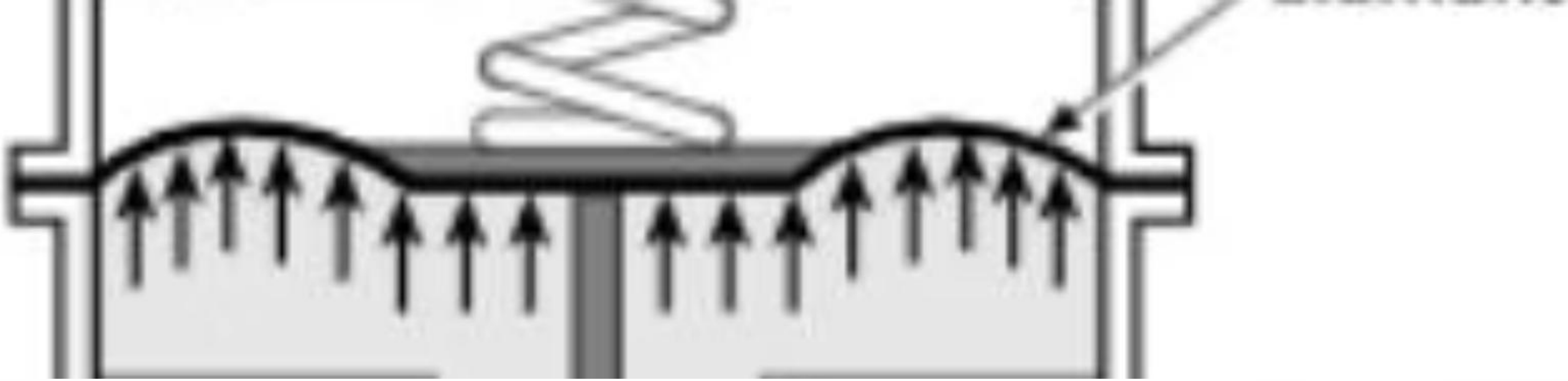
Flow	Description
Gas downstream of the regulator	Refers to the gas flow after it has passed through the regulator
Gas upstream of the regulator	Refers to the gas flow before it passes through the regulator



Pilot-Operated vs. Direct-Operated Regulators

Most pressure regulators are either pilot-operated or direct-operated. Pilot-operated regulators consist of two requlators with the same essential components as direct-operated units. The pilot can simply and effectively be considered a second requlator, providing additional control to the main regulator, improving overall sensitivity and, ultimately, accuracy. Pilot-operated regulators are used for high-capacity applications to supply gas to commercial, institutional, and industrial buildings.

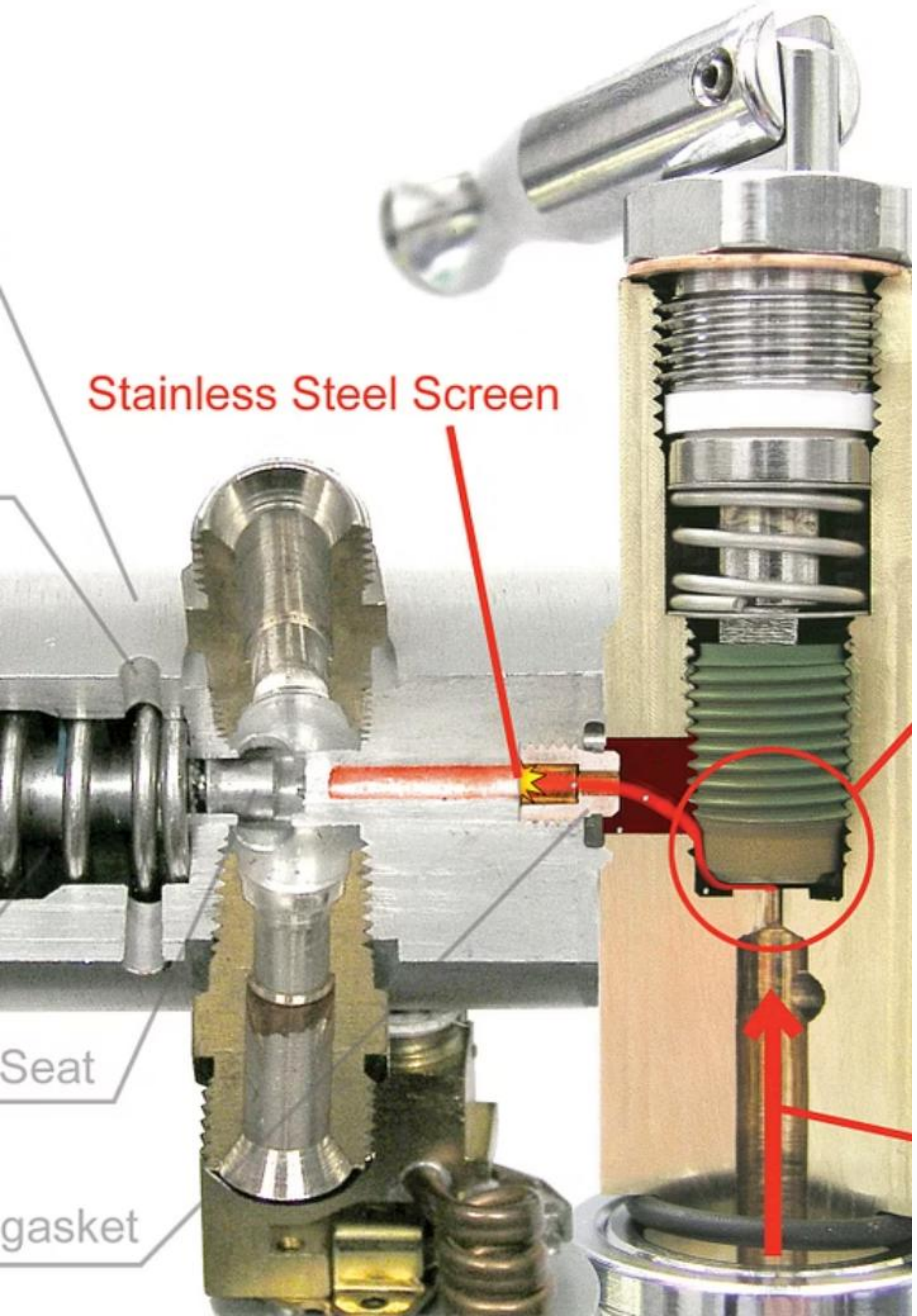
This level of training focuses on the operation of direct operated regulators, although, it covers servo regulation, which by definition is a type of pilot operated control, as it applies to the appliance regulators built into combination gas valves.



Basic Operation of a Regulator

Most service, system, and appliance regulators are direct-operated regulators that work in basically the same way.

A direct-operated regulator is defined as any self-contained valve and actuator combination that automatically adjusts the flow in direct response to changes in downstream pressure, thereby matching the gas demand. Figure 1-3 illustrates a direct-operated regulator.



Essential Elements of a Direct-Operated Regulator

As shown in Figure 1-3, these regulators have four essential elements.

Element	Description
Loading element	Usually a spring
Measuring element	Usually a diaphragm
Restricting element	An orifice and valve seat
Atmospheric vent	A vent on the atmospheric side of the diaphragm

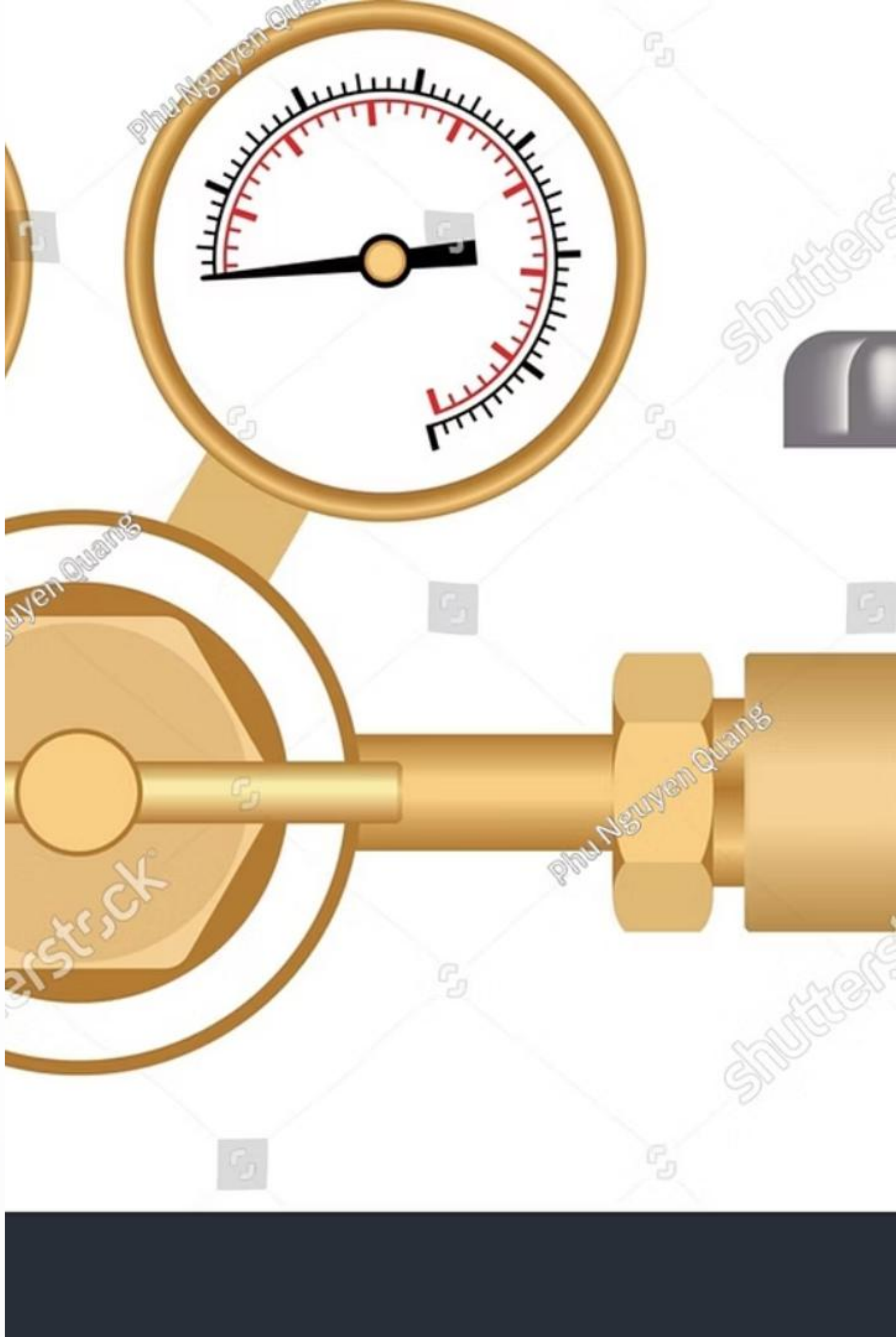
How a Regulator Works: Appliance Shut-off

Here is how a regulator works:

1. When the appliance shuts off, the pressure increases under the diaphragm (or measuring element), pushing it up with greater force than the spring (or loading element) is exerting downward. As a result, the valve closes against the orifice (in a configuration known as the restricting element). Air exiting the vent allows the diaphragm to move freely.

How a Regulator Works: Appliance Start-up

2. When the appliance starts, the loss in pressure downstream causes the spring to overcome the downstream pressure exerted on the measuring element. As a result, the diaphragm moves downward, thus opening the valve. Air entering the vent allows the diaphragm to move freely.



How a Regulator Works: Equilibrium

3. The balancing of forces acting on the measuring element determines the position of the valve in relation to the orifice. The diaphragm and valve stabilize when the force under the diaphragm equals the force exerted by the spring. At this point, the regulator has found its point of equilibrium and the flow rate and pressure downstream match that which is required by the system.

Regulator Response to Gas Demand Changes

If additional appliances start or an increase in firing rate occurs, the diaphragm moves downward and the valve stabilizes in a new position to the orifice, allowing more gas flow at the same pressure.

If gas demand decreases, the diaphragm moves upward and the valve stabilizes in a new position in relation to the orifice, allowing less gas flow at the same pressure. Air entering and exiting the vent allows the diaphragm to move freely.

Note: The closing force in a regulator is the downstream gas pressure.

The Loading Element: Spring

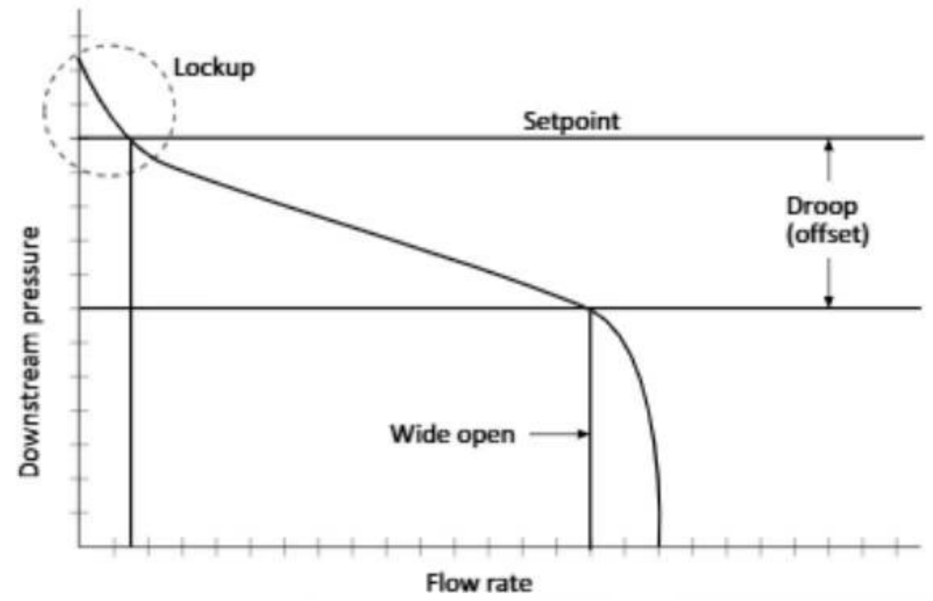
The loading element is used to counterbalance the downstream pressure. It is usually a spring.

The amount of spring pressure on the diaphragm determines the position of the restricting element.

Changing the spring load can adjust the amount of flow through the regulator.

Flow and Pressure Regulation Terminology

Figure 1-4
Graph depicting the performance of a typical regulator



Flow and pressure regulation	Description
Setpoint	• The desired outlet pressure is known as the setpoint. • A perfect regulator could maintain downstream pressure equal to setpoint under all flow rates, but in reality, as flow rate increases, the downstream pressure decreases.
Lockup	• Lockup is the pressure above setpoint that is used to shut the requlator off tight. In many requlators, the orifice has a machined edge, while the disk is made of a soft material. To make a tight seal, the requlator must increase the downstream pressure to force the disk onto the machined edge. This extra amount of pressure required is called the lockup pressure. • Regulators that have an inlet pressure over 0.5 psi (3.5 kPa) must provide a positive shut-off when there is no gas demand downstream. These regulators usually lock up to within 10% of the original outlet pressure setting.
Droop and offset	• Droop and offset describe the downstream pressure drop below setpoint. At this point, the valve is fully open, and there is an increased gas demand downstream. Droop can be expressed as a percentage of setpoint pressure. Manufacturers publish regulator capacities according to their amounts of droop. These are generally for 10% droop and 20% droop. The accuracy of a regulator is determined by the amount of flow it can pass for a given amount of droop. The closer the requlator is to setpoint, the more accurate it is. • If the performance of a typical regulator is plotted on a graph, the graph will show how the flow rate of gas drops off drastically as the gas flow increases above its designed droop or offset.

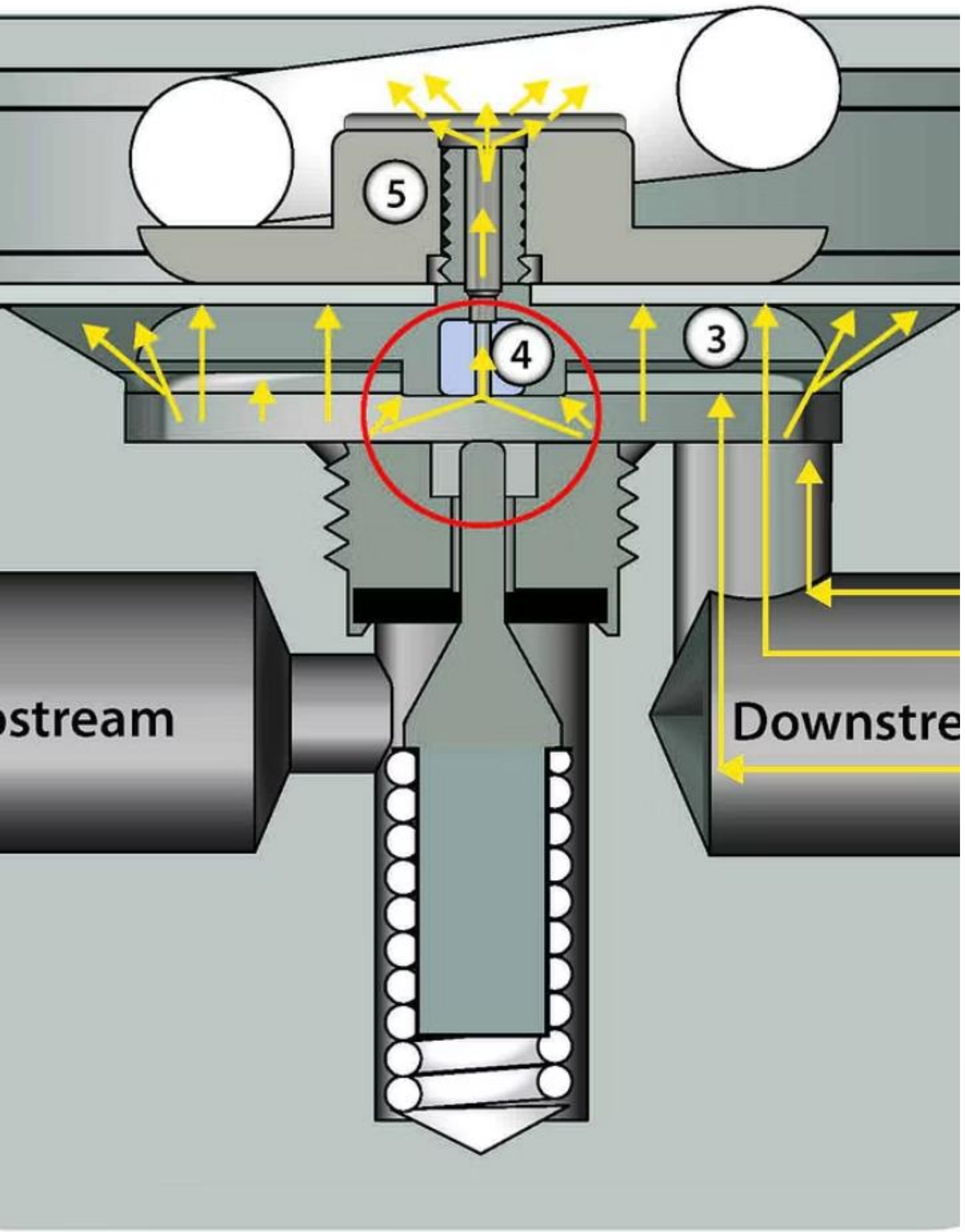
The Measuring Element: Diaphragm

The measuring element is usually a diaphragm. It is used to measure the changes in the downstream pressure.

The diaphragm is attached by a stem to the restricting element so that they both move together.

Made of neoprene, it is extremely flexible and usually is supported by a metal plate that allows downstream pressure to act upon the diaphragm evenly.

The diaphragm is slightly permeable to gas, so it is not unusual to detect a slight odour of gas at the vent opening. However, a significant odour around the regulator may indicate a damaged diaphragm. Diaphragms do wear out and may crack or tear due to age or exposure to chemicals.



ure 2: Self Relieving Valve in Closed Positic
when equalization occurs (P2 > set point)

The Restricting Element: Valve and Orifice

When the downstream pressure changes, the restricting element moves in response to the movement of the measuring element.

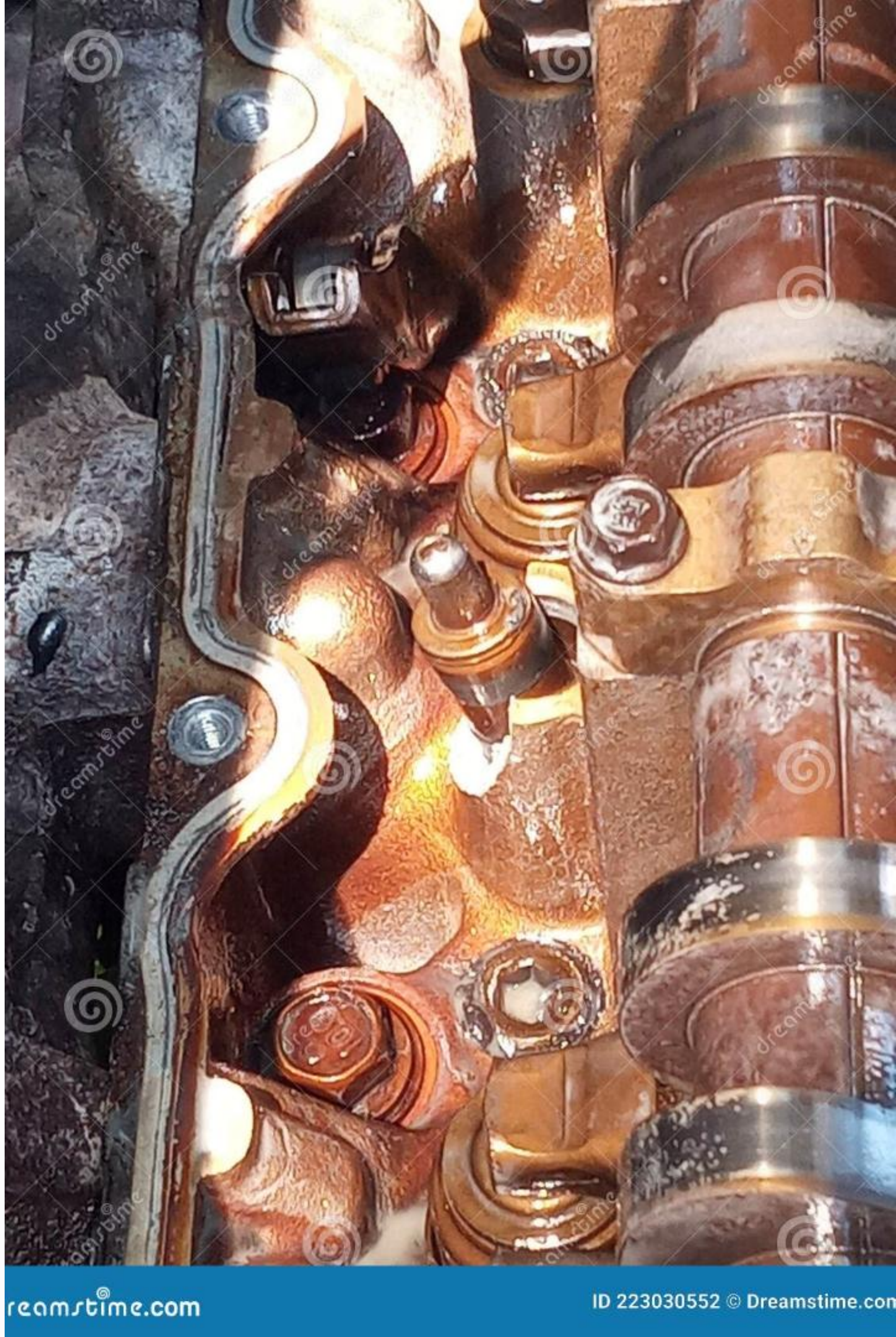
Usually, the restricting element is a valve and orifice that together control the amount of flow through the orifice opening.

It is important that the orifice and seat are properly maintained. They must be smooth and undamaged so that the seat may seal the orifice. If dirt such as pipe dope or tape or metal cuttings from threading operations lodges between the orifice and the valve seat, the regulator cannot shut off.

Consequences of a Damaged Restricting Element

Upstream pressure will leak downstream when the appliances are shut off. This may damage downstream components or cause gas to escape through burners and build up in the heat exchanger and vent.

The dirt may also damage the soft valve seat.



The Atmospheric Vent

The atmospheric vent (requlator vent) is an essential part of the requlator. It allows the air above the diaphragm to escape or enter as the diaphragm moves up or down. If the vent is blocked or restricted, the diaphragm will not be able to move properly. For example, if the vent was completely blocked, it would cause the air above the diaphragm to become locked in and prevent the diaphragm from raising enough to close the restricting element. This would lead to the rise of the downstream pressure above the required setpoint.


Honeywell
American Meter
Pi = 10 BAR (150 PSIG)
EN334 TEMP. RANGE/CLASS 2 (-20/+150°F)
WARNING

Effects of a Partially Blocked Vent

If the vent were partially blocked or restricted, the air movement would be delayed as the diaphragm attempts to force air out and pull air through the vent opening. This would in turn cause wide swings in downstream pressure above and below the setpoint known as "hunting or cycling".

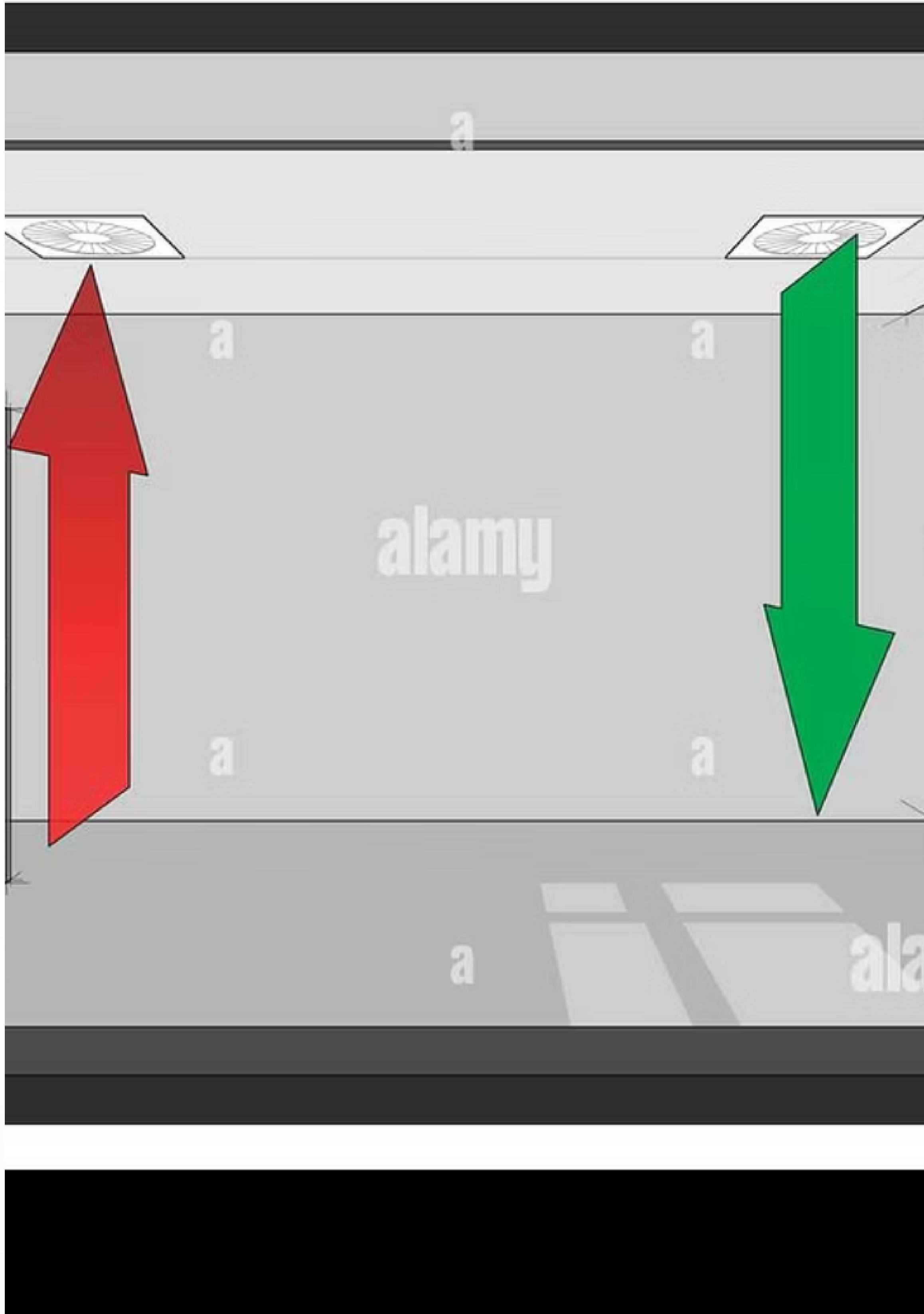
Ventilation and Safety Measures for Regulators

Most small appliance regulators vent to the indoors through a very small (#78 drill size) opening that is considered safe and acceptable by appliance standards as long as the requlator is located in a ventilated area.

Older appliances may have the appliance regulator vented into the appliance combustion chamber adjacent to the continuous pilot.

Newer appliances are usually vented outdoors or have the vent equipped with a leak limiter as discussed later in this section.

The vent also allows gas to escape if the diaphragm ruptures or an internal relief valve (installed in some regulators) opens. Safety measures are required to control this escaping gas as discussed later in this section.



Performance Characteristics of Regulators

The amount of flow it can pass for a given amount of droop determines the accuracy of a regulator. The closer the regulator is to setpoint, the more accurate it is. The following four factors mainly affect droop:

- spring rate;
- diaphragm area;
- orifice size; and
- inlet pressure.

Spring Rate and Regulator Accuracy

The control springs for regulators are rated by the amount of force required to compress it one inch. For example, a spring with a rate of 25 pounds per inch (lbs/in) needs 25 pounds of force to compress it one inch, 50 pounds of force to compress it two inches, etc. This force is opposing the total force created by the setpoint pressure spread over the area of the diaphragm. Adjustable regulators usually have a selection of springs to choose from in order to achieve the desired setpoint for each application. The spring ranges often have overlap within the range of settings each can deliver. Since a lighter spring is more sensitive to changes in downstream pressure, choosing the lightest available spring rate causes the least droop and the most accurate pressure control.

Spring Selection Chart Example

For example, in the spring chart shown in Figure 1-5, there are several spring ranges available for this model of requlator. If our system required a setpoint of 12 inches water column (w.c.), the spring with a pressure range of 4 - 12 inches w.c would be more accurate for our application and, therefore, has less droop than the spring with a pressure range of 10 – 22 inches w.c.

Figure 1-5 Spring selection chart

model	Part number Adjustable models:	Colour code	Outlet pressure (in w.c.)	Approximate inner diameter	Approximate length
325-3	R325C10-26	Plated	2.0 to 6.0	5/8"	1 3/4"
	R325C10-59	Plated	5.0 to 9.0		2 5/16"
	R325C10-412*	Violet	4 0 to 12		1 3/4"
	R325C10-711	White	7.0 to 11		2 5/8"
	R325C10-1022	Red	10 to 22		2 1/8"
	R325C10-1530	Yellow	15 to 30		2 5/16"
	R325C10-P12	Taqqed	1 psi — 2 psi		2 5/16"

Diaphragm Area and Regulator Accuracy

Because a larger diaphragm area produces more force change for a given change in downstream pressure ($F = P \times A$), larger diaphragms are often used in applications that require minimum droop and, therefore, better accuracy.

Orifice Size and Flow Capacity

As shown in Figure 1-6, moving the valve disc away from the orifice increases the flow rate of the regulator only to a certain point. Once the restricting element is wide open (when the disc clears the orifice by a distance equal to 1/4 of the orifice diameter), the orifice size and the pressure difference on either side of the orifice dictate the maximum flow capacity of the requlator. In many models of service and line pressure regulators, you can change the flow capacity by changing the orifice size. Figure 1-6 Regulator threaded removable orifice Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

Caution When Changing Orifice Size

When changing the orifice size, you must be careful not to oversize it, as this can lead to unstable operation and faster wear.

Inlet Pressure and Regulator Capacity

As mentioned, the orifice size and the pressure difference on either side of the orifice dictate the maximum flow capacity of the regulator. The pressure difference is determined by the outlet pressure and the operating inlet pressure. It is important when selecting a requlator that its maximum capacity be determined by analyzing the minimum inlet pressure. The minimum inlet pressure will be during operation and will be a result of the piping pressure losses at maximum design conditions.

Adjusting Pressure on Non-Utility Regulators

There are three main types of regulators when it comes to adjusting the pressure, namely:

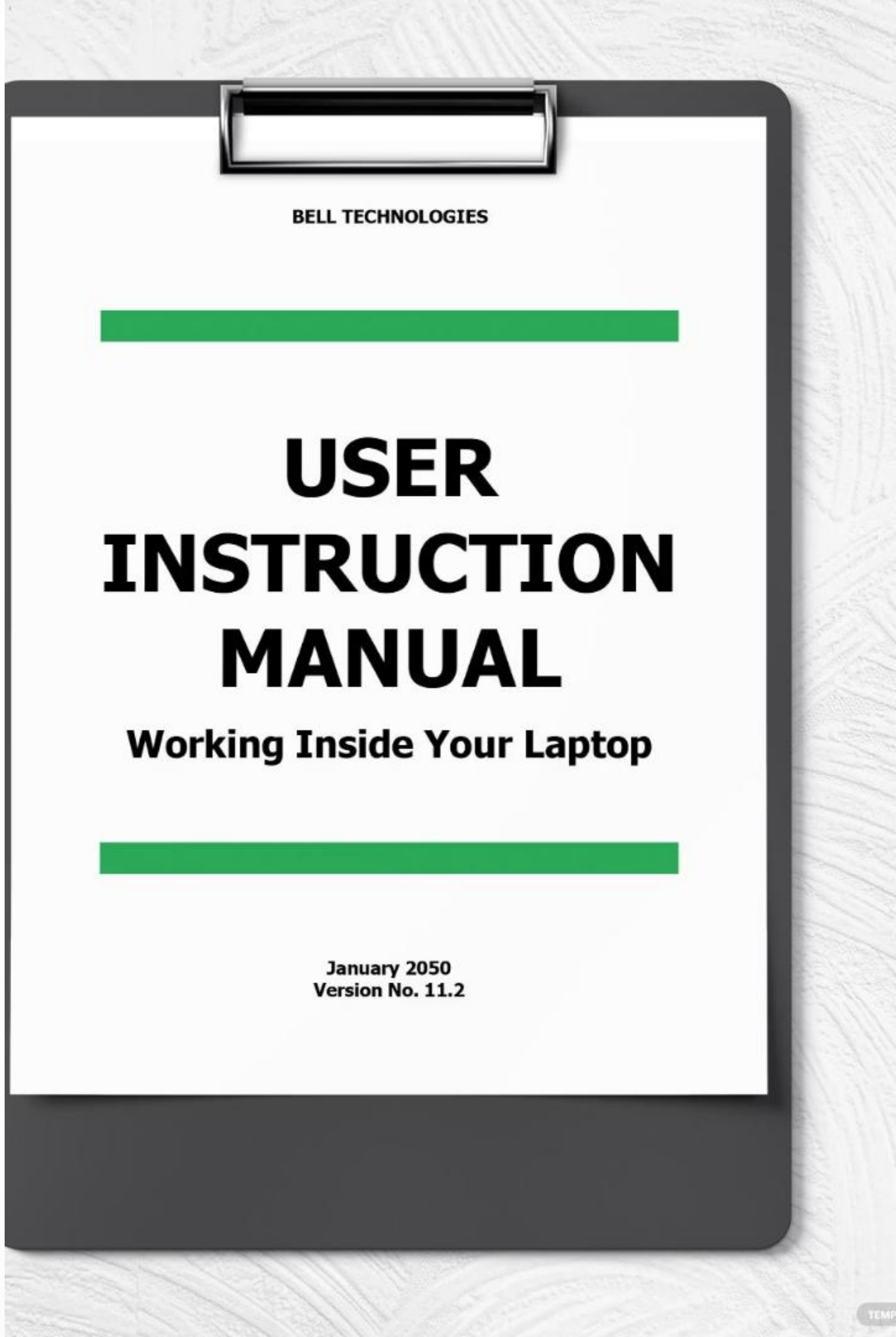
- non-adjustable requlators;
- minimal adjustment regulators; and
- fully adjustable regulators.

Unless a gas technician/fitter is authorized to do so by the distributor, CSA B149.1 prohibits a gas technician/fitter from working on a service regulator that is part of the distributor's system.

Pre-Adjustment Considerations for Non-Utility Regulators

Before beginning any adjustments on non-utility regulators, consult the manufacturer's instructions for the regulator and for the appliance(s) served by the regulator, and take note of the following:

- Adjustments should only be made to meet appliance manufacturer's pressure specifications . using the adjustment method recommended by the regulator manufacturer.
- Always use the proper tools and make sure that your pressure measurement instrument has the proper range and accuracy for the job.



Procedure for Adjusting Regulator Pressure

If the pressure from the regulator is too high or too low, use the following procedure to change the pressure setting:

1. Turn off the gas.
2. Install the pressure test equipment to sense downstream pressure.
3. Remove the regulator adjusting screw cap.
4. Turn on the gas.
5. Turn the equipment on, allowing the gas to flow.
6. Look at the pressure and make the appropriate adjustment (Figure 1-7).

Figure 1-7 Adjusting regulator Courtesy of Camosun College, Rodney Lidstone,

Adjusting Regulator Pressure: High vs. Low

If	Then
The pressure is too high	▪ Turn the adjusting screw counter-clockwise. Doing this will reduce the spring tension. ▪ Keep turning the screw until the correct pressure is achieved.
The pressure is too low	▪ Turn the adjusting screw clockwise. Doing this will increase the spring tension. ▪ Keep turning the screw until the correct pressure is achieved.

Post-Adjustment Procedure

1. Replace the cap.
2. Shut off the gas.
3. Remove the test equipment.
4. Properly plug any test points.
5. Turn on the gas
6. Leak test the test points.
7. Check the operation of the appliances or burners downstream of the regulator to ensure that they are in safe operating condition.

Safety Features: Vent Limiting Orifice

Figure 1-8
Vent limiting orifice
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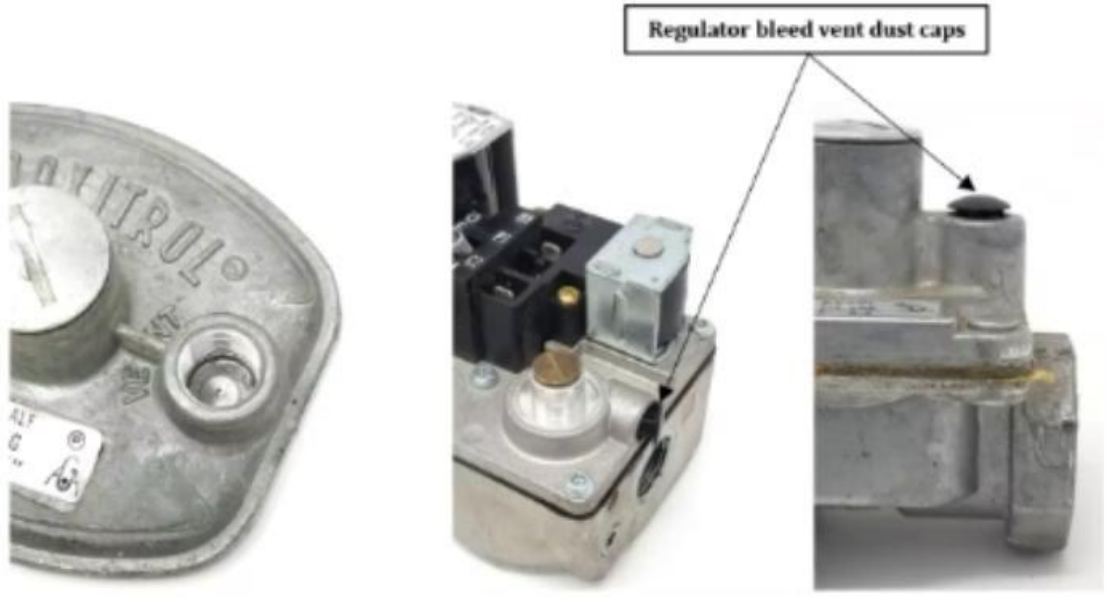


(a) Integral vent orifice (b) Dust cap partially removed for viewing (c) Vent dust cap

Regulators on smaller input appliances are usually constructed with a vent opening that has an integral orifice, usually a #78 drill size, to limit the escape of gas from the upper diaphragm chamber [Figure 1-8(a)]. The vent opening is threaded to enable it to be piped to away if the regulator is installed in a non-ventilated space.

If the diaphragm ruptures, the leakage is limited to less than 1 ftv/h (0.02832 m^3/h) at 7 inches w. c. (1.74 kPa) gas pressure. The vent opening (especially on combination gas valves) is usually covered by a loose-fitting cap to prevent dirt from plugging the opening [Figure 1-8(b) and (c)].

Vent Limiting Orifice Accessory

As the requlator size increases, the larger diaphragm will need to move more air through the vent opening, and an integral orifice restriction will affect the reactions time of the regulator. In some cases, the manufacturer may offer a fixed orifice accessory that can be installed, but the individual load capacity of the regulator will need to be reduced. Figure 1-9 shows a fixed vent limiting orifice accessory sitting on the regulator, the orifice opening is difficult to see as it is on the side of the body under the hex head. You can also see that the bleed vent hole in the regulator is much larger than the #78 integral orifice. If this regulator was required to respond at its full capacity for a single appliance, then the vent limiting orifice could not be used and the vent would need to terminate outside or use an automatic vent leak limiting device.

Figure 1-9 Vent limiting orifice accessory Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

Leak Limiting Device

In certain regulators, such as 2 psig (14 kPa) line pressure regulators, a leak limiting device can be installed in the threaded vent opening (Figure 1-10).

In this device, a ball check or disc check allows free movement of air at atmospheric pressure above the diaphragm to ensure fast regulator response. However, if the diaphragm ruptures, the high pressure flow of gas causes the ball check or disc check to limit the flow of gas to a maximum flow rate of 2.5 ft3/h (0.0706 m^3/h) for natural gas or 1 ft3/h (0.02832 m^3/h) for propane, as allowed by CSA B149.1. In most cases, the opening in the leak limiter is a #78 drill size.

Figure 1-10 Leak limiting devices Courtesy of Maxitrol Company

Installation Guidelines for Leak Limiting Devices

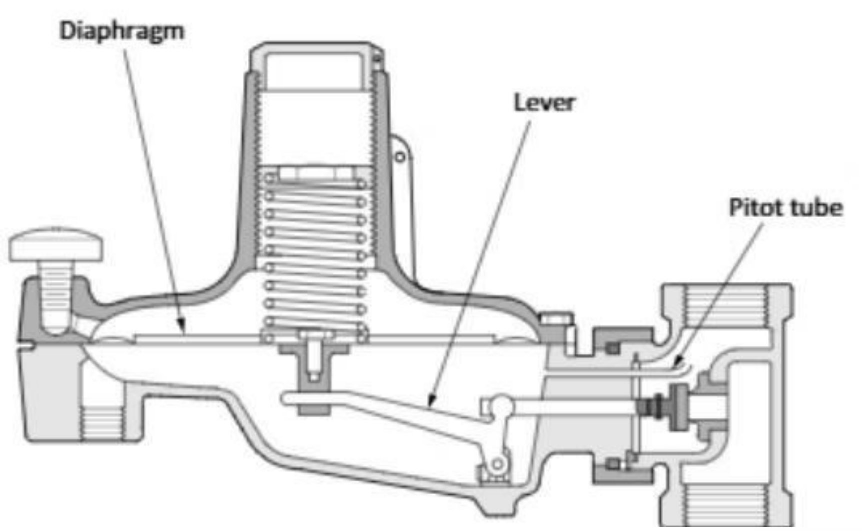
A regulator equipped with a leak limiter must be in a ventilated space. Keep the small opening on the leak limiter free of dirt or paint. Do not use vent limiting devices outdoors; if they are exposed to the environment, they may become clogged by moisture or insects. You can only install vent limiters in regulators for which they are certified. Install them directly into the vent connection of the regulator without intermediate pipe or fittings. Manufacturers may have more than one leak limiter available that fits the regulator. It is important that you use the proper model specified by the manufacturer.

Multi-Position 2 psi Regulator

When using ball check vent limiters, mount the regulator in the horizontal position to keep the vent limiter in the vertical up position. Some manufacturers have regulator designed with two vent connections that enable the regulator to be installed either vertically or horizontally using the appropriate location for the vent limiter and a plug in the other (Figure 1-11).

Figure 1-11 Multi position 2 psi regulator Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

Performance Features: Pitot Tubes and Levers



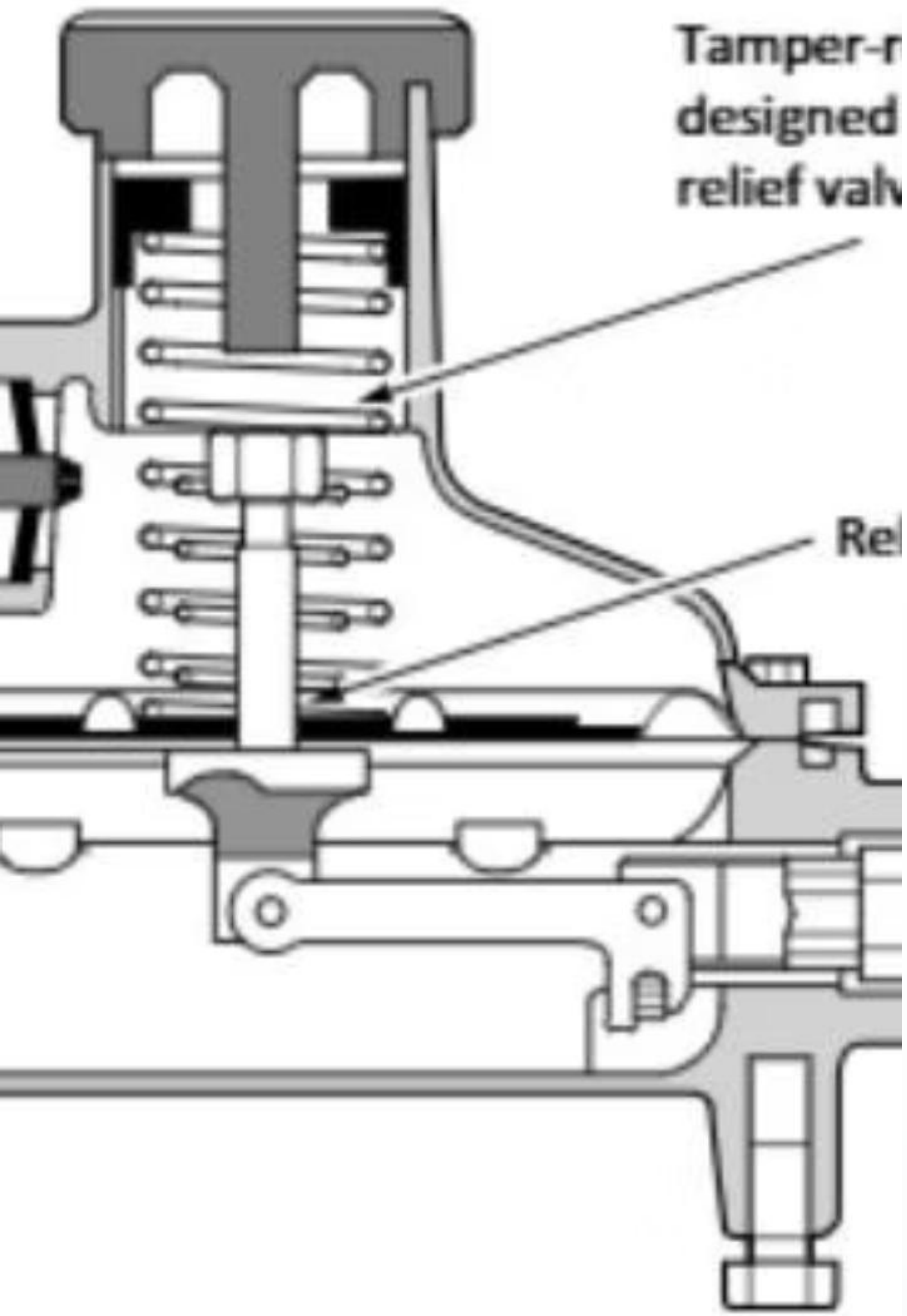
Besides the four performance factors previously mentioned, there are additional features that are used to improve regulator performance. Two common ones (Figure 1-12) include:

- pitot tubes; and
- levers.

The pitot tube design is used to decrease regulator droop. Inside the regulator, the pitot tube connects underside of the diaphragm to an area called the vena contracta, which has a lower pressure when exposed to increased gas velocity. By sensing the setpoint pressure at this point, the diaphragm will be tricked into opening wider, therefore, responding quicker to increase demands. This phenomenon - the reverse of droop - is called boost.

Lever controlled regulators provide increased force necessary for lockup against higher inlet pressures. The extra mechanical force also keeps the disk in a stable position, thereby opposing tendencies of the disk to cycle or buffet.

Figure 1-12 Pitot tube and lever features Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY



Internal Safety Relief Valve

Some regulators with an inlet pressure over 0.5 psi (3.5 kPa) are equipped with internal relief valves. This kind of valve usually consists of a second spring mechanism acting against a valve opening between the diaphragm and its supporting metal plate (Figure 1-13).

The internal relief valve only opens if downstream pressure exceeds a set amount and automatically resets when the pressure drops below the setpoint. The relief valve will then open to allow the overpressure to escape through the vent. This escaping gas must be piped to a safe location outdoors.

Figure 1-13 Regulator with internal relief valve

Relief Valve Set Pressure and Capacity

The set pressure for the relief cannot be adjusted and is an important factor in selecting a regulator. Under full flow conditions from the relief valve and relief piping, the regulator outlet pressure must never exceed the pressure rating of the weakest component downstream.

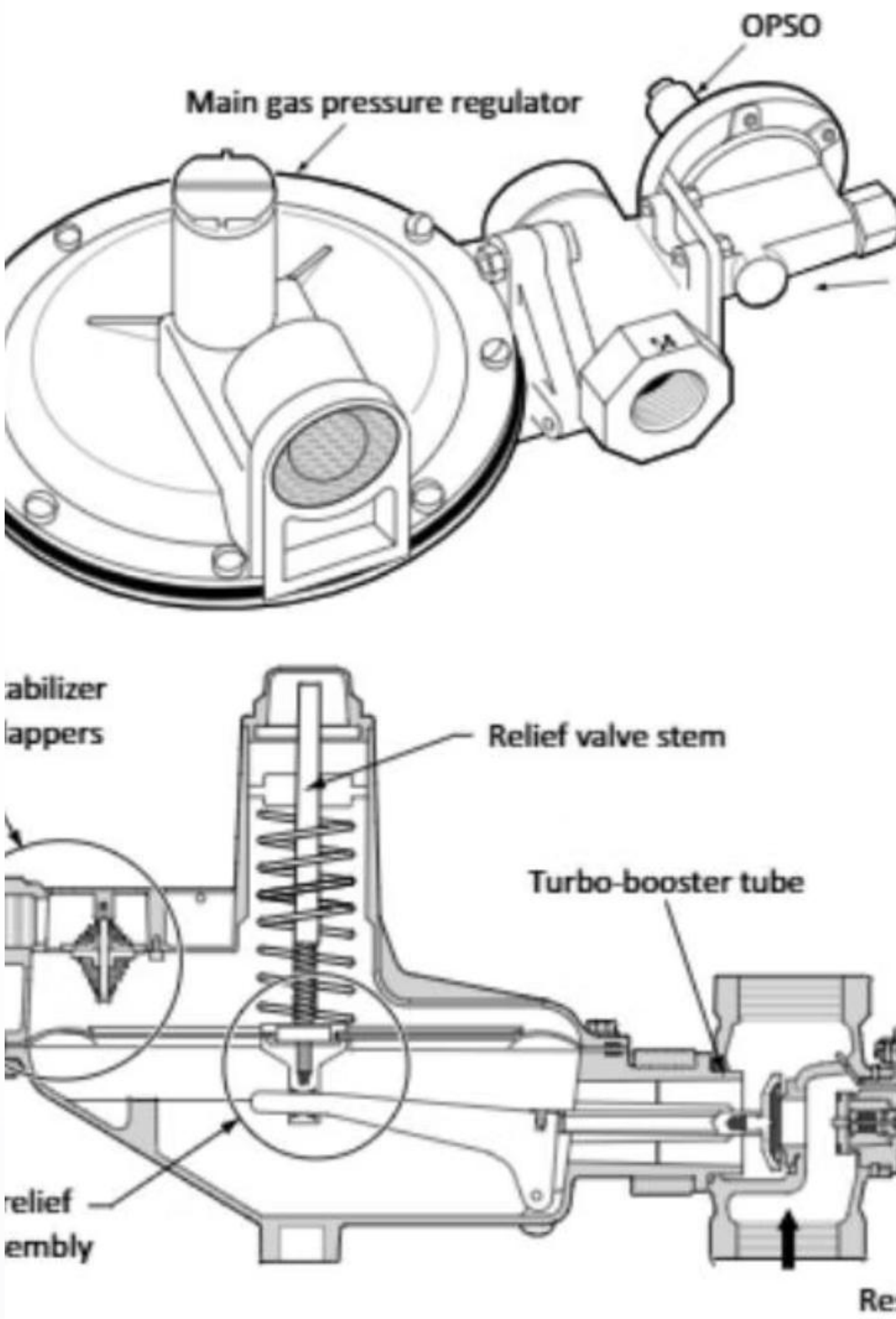
Review manufacturer's specifications for both the regulator and the downstream components when determining if the relief capacity is sufficient. Remember that the piping attached to the relief vent must never reduce the relief capacity or exert back-pressures on the regulator.

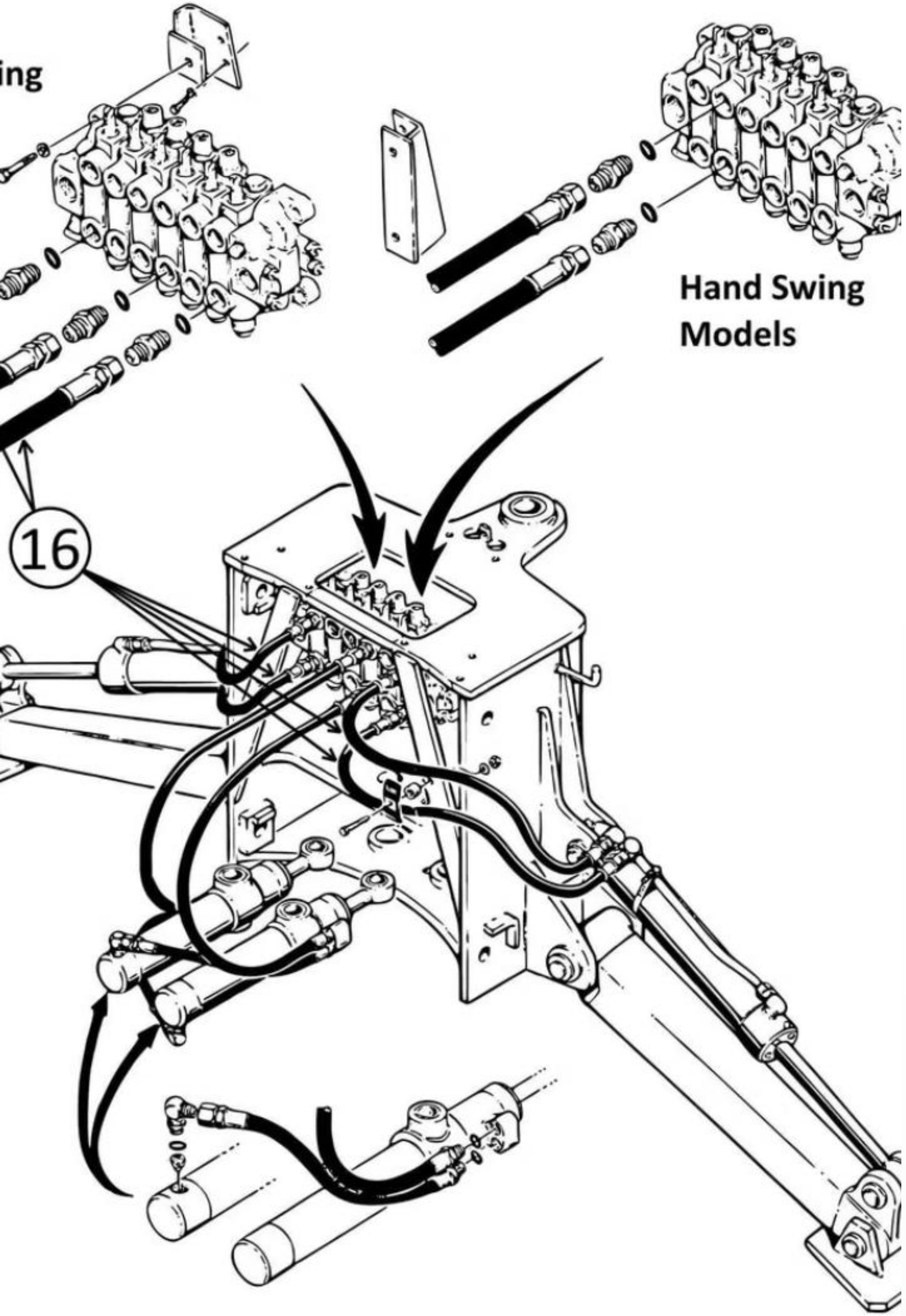
Where large volume relief of gas pressure is required to profect components, a separate relief valve may be installed on the piping system. These automatically reset valves function in the same way as the internal relief device in regulators. Set pressures are established by a spring holding down a valve seat. Within the range of the valve, the set pressure can be adjusted to relieve pressure before damage occurs to the downstream components.

Overpressure Shut-Off (OPSO)

OPSO is used on some service regulators and on line pressure regulators where it is impractical or undesirable to pipe the vent outdoors. A reverse-acting pressure-activated device closes, shutting off the flow of gas through the regulator if the outlet pressure is too high. Under these conditions, the OPSO locks off and must be manually reset (Figure 1-14).

Figure 1-14 Regulator with overpressure shut-off and two-way stabilizer vent valves





Two-Way Stabilizer Vent Valve

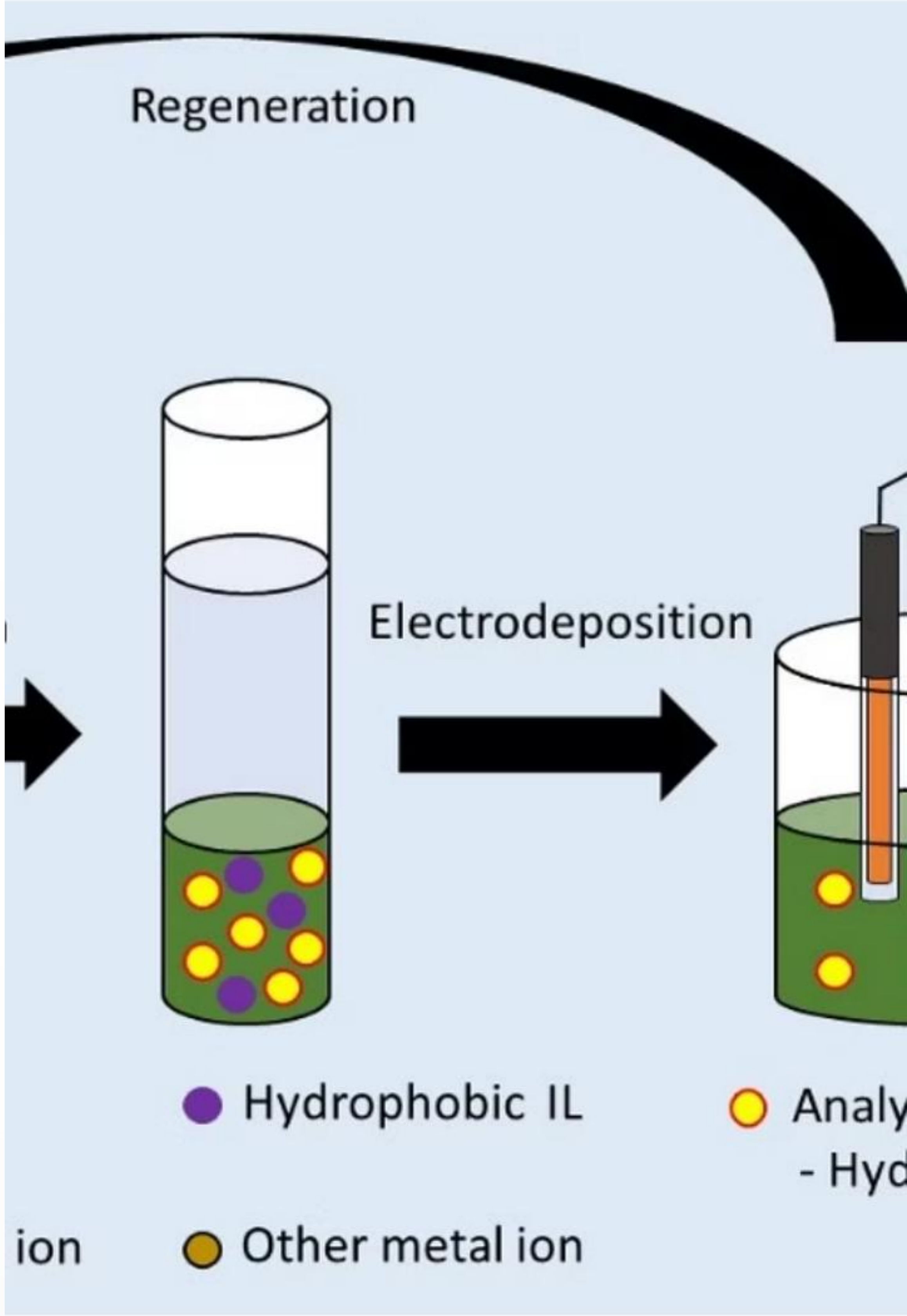
A two-way stabilizer vent valve provides quick but controlled reaction to rapid downstream pressure changes. As the diaphragm responds to rapid changes, the increase or decrease in pressure above the diaphragm must overcome the spring pressure located above and below the stabilizer vent valve (Figure 1-14). The stabilizer valve is closed during equilibrium.

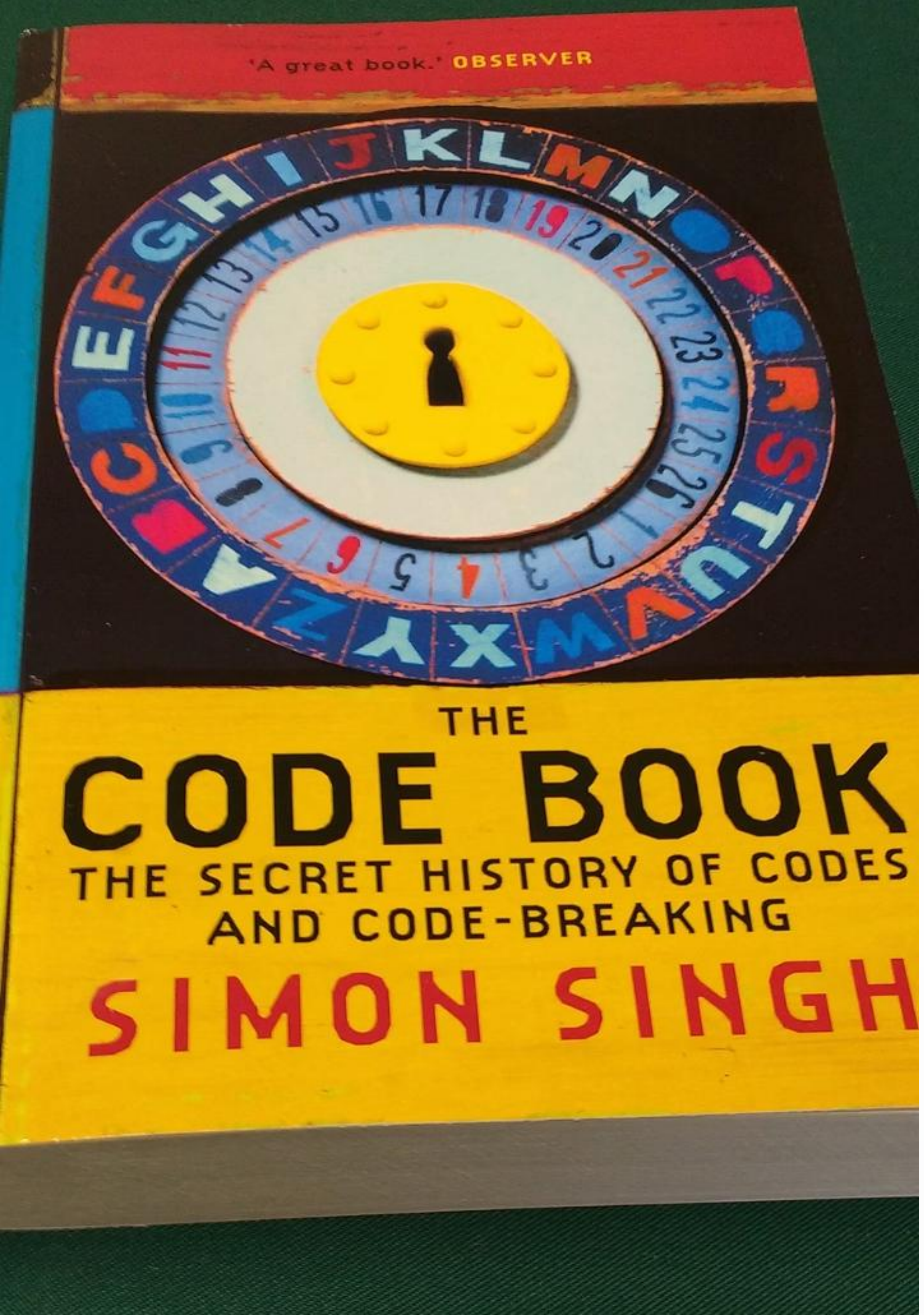
Materials of Construction for Regulators

Regulators are made from corrosion-resistant materials. Typical construction materials are shown in Table 1-1.

Typical regulator construction materials

Part	Material
Body	Cast aluminum Cast iron Steel
Spring case, lower diaphragm casing, union ring, seat ring, disk holders	Aluminum
O-ring, disks, diaphragms	Nitrile
Closing cap gasket, relief valve pad	Neoprene
Diaphragm head, adjusting screw	Delrin TM Aluminum
Relief/monitor piston ring	Graphite
Vent flappers	Cycolac TM Nylon
Other metal parts	Aluminum Brass Cast iron Monel™ Steel Stainless steel Zinc





Codes and Regulations for Regulators

The applicable code requirements for regulators are in CSA B149.1 and CSA B149.2. This section identifies the key requirements and explains some of the reasons for these requirements. Unless otherwise stated, code references are to the most current version of CSA B149.1. Refer directly to the Clauses identified since the presentation usually paraphrases the Code and it is important that you become familiar with the layout of the Code.

Prohibited Work on Regulator Systems

Clause 4.6.2 states that no person other than an employee or person authorized by the supplier/ distributor shall perform work on the supplier/distributor system. The service regulator on natural gas systems is part of the supplier/distributor system.

The system regulator (or second stage regulator) and the first stage regulator may be considered part of the propane supplier/distributor system in some areas. Check with the propane distributor and/or authority having jurisdiction before working on these regulators.

Pressure Inside Buildings

Most of the requirements applicable to regulators are found in Clause 5 of CSA B149.1. Table 5.1 sets maximum levels for the gas pressure inside buildings. Higher gas pressures are permitted in certain areas in buildings (such as a central boiler or mechanical room) because problems that may be caused by leaking gas are reduced in these areas.

For natural gas installations, the distributor determines and sets the building pressure in compliance with Table 5.1. For propane systems where the first and/or second stage regulators are not considered part of the distributor's system, it is the responsibility of the gas technician/ fitter to set the building line pressure so it meets appliance requirements but does not exceed the maximum pressures set in Table 5.1.

In both natural gas and propane systems, the maximum pressures allowed by Code are seldom employed for safety reasons.

General Requirements for Regulators

The following requirements apply to both natural gas and propane regulators.

Clause 5.2.1.1 contains some relatively new requirements that first appeared in the 2007 Supplements to CSA B149.1. Although it has always been required that a regulator be certified and be of sufficient size to provide the required flow of gas at the extremes of inlet pressures to which the regulator can be exposed the reference to three recognized standards is new. When installing a new regulator that is not approved as part of the appliance approval, check that it is certified to a recognized standard.

A pressure regulator shall not be bypassed (Clause 5.2.1.5).

Prohibited Regulator Installation Locations

Any regulator in the gas supply line shall not be installed in any of the following three locations (Clause 5.2.1.9):

- where it is inaccessible for repair, replacement, servicing, or inspection:
- in a concealed location; or
- where it could be reasonably expected to be subject to physical or chemical damage.

Clauses 5.2.1.7 and 6.18.2 require that pressure regulators have a manual shut-off valve installed upstream. This valve is necessary for servicing and for emergency response.

Line Pressure Regulators: Requirements

Line pressure regulators are defined in the Code as a gas pressure regulator intended for installation in a gas distribution system between the utility service regulator or 2 psi propane regulator and gas utilization equipment.

These regulators are only used on piping systems where the building pressure exceeds 0.5 psi (3.5 kPa). As such, the code requirement (Clause 5.2.1.6) stating that a line pressure regulator with an inlet pressure over 0.5 psi (3.5 kPa) be a positive shut-off type applies to all line pressure regulators.

Clause 5.2.1.8 requires that a line pressure regulator be equipped with a line relief device or an overpressure protection device. However, an exception is allowed in Clause 5.2.2.4 for propane systems and in Clause 5.2.3.1 for natural gas systems when the line pressure regulator is equipped with a leak limiting device (as discussed previously).

For piping systems with a supply pressure over 2 psi, a line pressure regulator must be equipped with either a line relief device or an overpressure protection device (see definition in CSA B149.1). These devices are covered in Chapter 2. Overpressure protection > Relief valves

Additional Requirements for Delivery Pressures of 2 psig (14 kPa) or Less

CSA B149.1 specifies additional requirements in Clause 5.2.2 that apply to regulators delivering a pressure of 2 psig (14 kPa) or less. This section would have particular importance to propane regulators. Under this Clause, propane regulators must:

- be firmly secured to the container valve or the regulator bracket on the wall or hood; or
- be secured in some other appropriate manner.

When installed outdoors and subject to inclement weather, the requlator has to be protected as necessary from exposure to weather conditions. A regulator installed outdoors or in an unheated area must be positioned so that the bonnet vent opening discharges vertically downward. Clause 5.2.2.4 allows two exceptions to this requirement.

All permanent propane installations must employ two-stage regulation (see Figure 1-1). Reducing container pressure in two stages ensures a much more consistent delivery pressure to appliances compared to single-stage requlation. It also reduces the chance of internal freeze-ups caused by large drops in pressure through the small orifice required in a single-stage regulator.

Leak Limiters and Hydrostatic Relief Devices

As previously discussed, line pressure regulators on a piping system operating at 2 psi (14 kPa) or less do not have to be vented outdoors if the regulator is equipped with a leak limiter. In the case of propane systems, the leak limiter must limit escaping gas from a ruptured diaphragm to no more than 1 ft3/hour (0.0283 m^3/h). Clause 5.2.2.5 requires that a regulator with a leak limiter be installed in a ventilated space only. Leak limiters are also allowed in place of a vent on natural gas piping systems operating at 2 psi (14 kPa) or less. However, the natural gas leak limiter must limit escaping gas from a ruptured diaphragm to no more than 2.5 ft^3/hour (0.0706 m3/h).

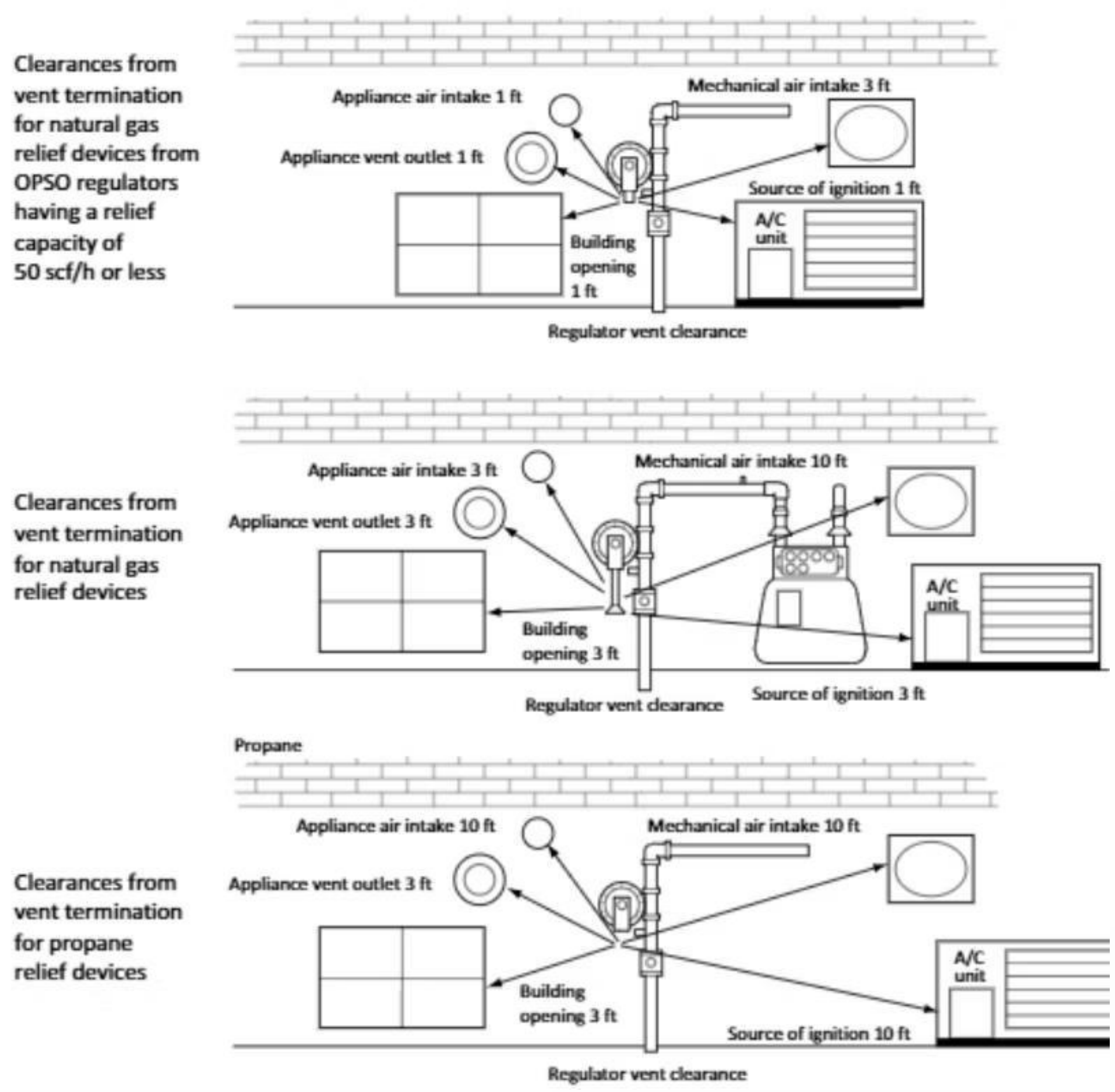
A hydrostatic relief device is required on liquid propane systems where the propane can be trapped between two valves. If liquid propane is trapped between two closed valves in piping or a hose, it will expand as its temperature increases. The hydrostatic relief device relieves this pressure, thus preventing the piping from bursting. The minimum relief pressure setpoint is 375 psi (2500 kPa) and the maximum is 500 psi (3500 kPa). See Clause 5.4.1 of CSA B149.1.

Additional Requirements for Delivery Pressures Greater Than 2 psig (14 kPa)

Clause 5.2.3 establishes additional requirements that apply only to regulators delivering pressures of 2 psig (14 kPa) and greater.

There is a Clause in CSA B149.1 that allows the use of leak limiters on natural gas systems operating above 2 psi, provided that the system has an overpressure protection device set to a pressure either below 2 psig (14 kPa) or 2 times the delivery pressure on the system and that the requlator is certified to ANSI Z21.80/CSA 6.22 Line pressure requlators. There is no similar allowance for propane systems operating above 2 psi.

Venting of Regulators: Outdoor Termination



When venting a regulator vent outdoors, a technician/fitter must pay special attention to Clause 5.5 of CSA B149.1. It specifies the material that can be used for the vent, the size of single and combined vents, and the permissible locations for vent terminations. Compliance with the regulator manufacturer's instructions is also required.

The vent line shall be made of steel pipe, copper, seamless aluminum, or steel tubing that meets the standards specified in Clause 6.2. However, aluminum vents are not allowed on combined vent systems with an inlet pressure over 0.5 psi (3.5 kPa).

For dedicated vents serving a single regulator, the vent size must be at least that of the nominal pipe size of the vent outlet of the pressure regulator, but its inside diameter must not be less than 0.25 inches (6 mm). Individual vent lines may be connected to a single vent line, but the size of the common vent depends on the types of devices that are common vented and the inlet pressure to these devices; refer to Clauses 5.5.1.3 to 5.5.2.2.

Appliance and Pilot Regulators

Although most of the requirements regarding appliance regulators and pilot regulators are found in the Standard to which the appliance was built and certified, CSA B149.1 provides a few additional requirements in Clause 5.7.

Propane appliances must have an appliance regulator and a separate pilot regulator when the supply pressure to the appliance could be subjected through supply pressure, design, creepage, or fluctuation to propane pressure in excess of that for which the appliance is rated.

Since older propane appliances may not have an appliance regulator, a gas technician/fitter must ensure that either the second-stage regulator provides a consistent pressure within the pressure rating of the appliance or appliance and pilot regulators are installed in accordance with Clauses 5.7.1.1 and 5.7.1.2.

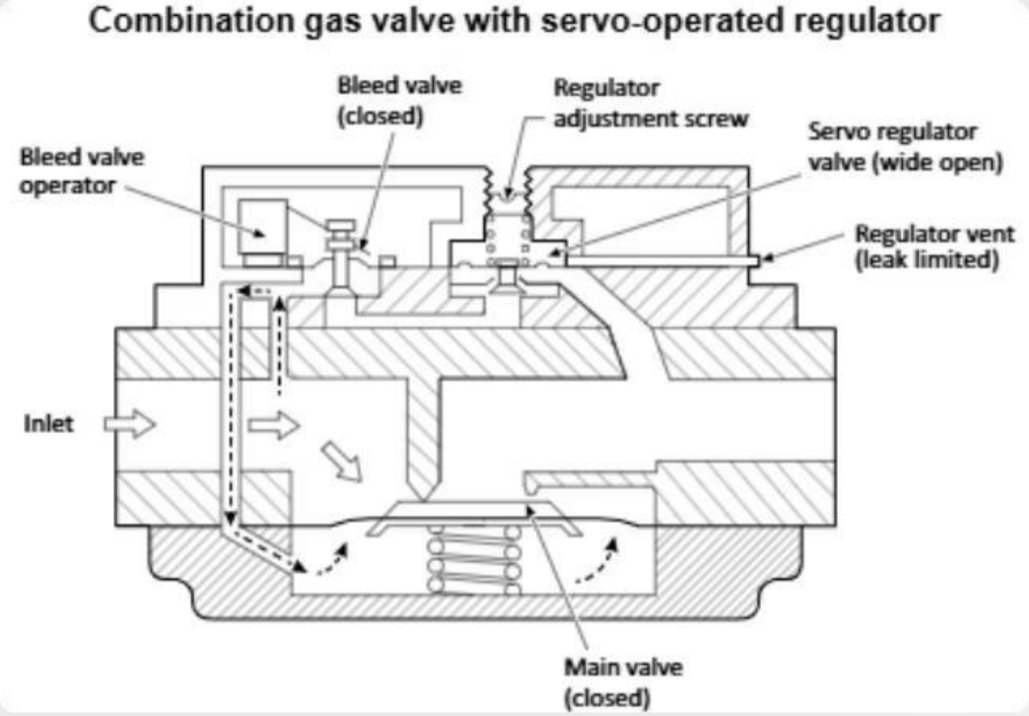
To comply with the code requirements that apply to regulators, a technician/fitter must fully have a sound understanding of how regulators work.

Different Types of Regulators: Appliance Regulators

The appliance regulator works on the same principle as all other regulators. Appliance regulators are designed to reduce the inlet pressure of an appliance to the appropriate manifold pressure for proper burner operation. Most natural gas appliances require a manifold pressure of 3 – 4 inches w.c. while propane appliances typically require 10 - 11 inches w.c. The appliance regulator typically has a maximum inlet pressure of 0.5 psi. The appliance input determines the type of appliance regulator required.

There are three types of appliance regulators. They are:

Regulator	Description
Low-capacity-type appliance regulator	▪ Used to provide safe and uniform gas pressure to residential gas appliances. ▪ May be used on smaller input appliances for supplying gas to either the main burner or pilot burner or both burners. ▪ Usually have a high resistance to flow through the regulator but provide fine pressure control.
High-capacity-type appliance requiator	▪ Used on larger residential and commercial appliances. ▪ Are only used to regulate the gas pressure to higher input burners. ▪ Usually have a low resistance to flow through the regulator by employing a large orifice in the restricting element or a straight-flow-through design.
Regulator component of a combination gas control valve	▪ Performs the same function as a low capacity type appliance requilator except that it forms part of the combination control valve. ▪ May be a simple direct-acting regulator or a servo regulator. A combination gas valve usually consists of a manual shut-off valve, pilot gas control device, main gas pressure regulator, as well as one or two automatic safety shut-off valves. ▪ Gas flow to the pilot burner is controlled by a throttling valve (needle valve), sometimes called the B cock.



Inlet Gas Pressure and Valve Closure

Inlet gas pressure passes through the restrictor and down the bleed line to build pressure under the main valve diaphragm. The gas pressure is equal above and below the diaphragm.

The force of the spring and the fact that the area of the lower diaphragm surface is greater keep the valve closed.

Figure 1-19

1

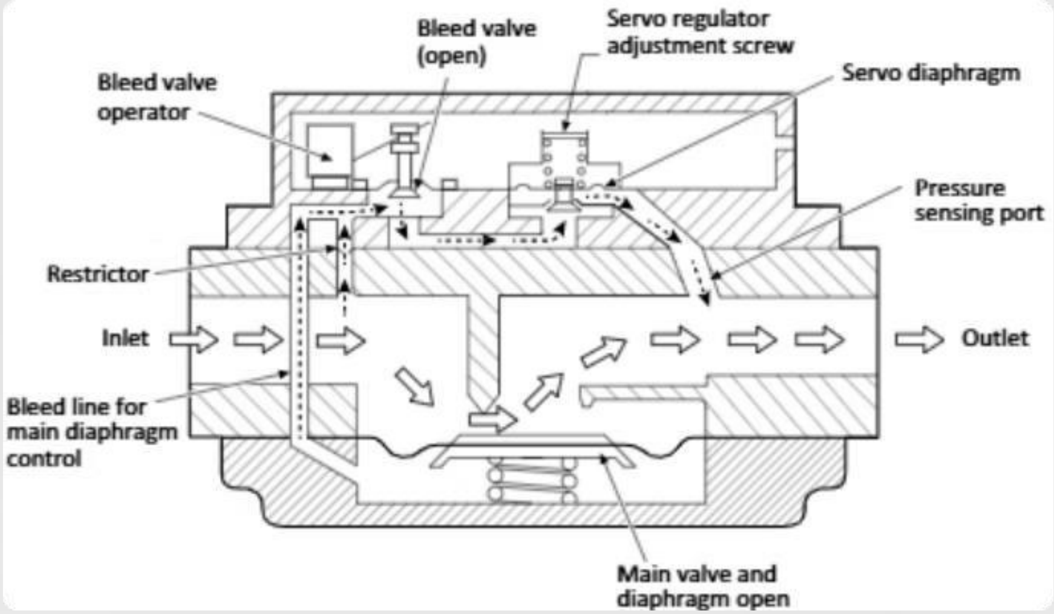
Pressure Equalization

Inlet gas pressure builds under the main valve diaphragm, equalizing pressure above and below it.

2

Valve Closure Mechanism

The valve remains closed due to the spring force and the larger area of the lower diaphragm surface.



Main Gas Valve Operation

When there is a call for heat, the bleed valve operator opens the bleed valve. This allows gas from below the main valve to escape through the servo regulator restricting element, which is wide open because there is no downstream pressure. As a result, the main gas valve starts to open allowing gas to the burner (Figure 1-20).

Figure 1-20 Combination gas valve with servo-operated regulator (open)

Call for Heat

Bleed valve opens, allowing gas to escape from below the main valve.

Gas Flow

Servo regulator restricting element is wide open, enabling the main gas valve to open.

Gas to Burner

Gas flows to the burner as the main valve opens.

Servo Regulator Function

As gas pressure downstream of the main valve starts to build (due to restrictions in flow through the orifice and burner ports), this back-pressure acts upon the diaphragm in the servo regulator, causing it to move upward and reducing the flow rate through the servo regulator's restricting element. The upstream gas pressure that cannot pass through the servo regulator again starts to flow into the chamber below the main valve, causing it to close.

The servo regulator restricting element stops moving when the force of the downstream gas pressure equals the force of the spring in the servo regulator. This maintains the main valve in a position necessary to reduce the upstream gas pressure (usually 7 inches. w.c. for natural gas systems and 13 inches w.c. for propane systems) to the manifold pressure (usually 3.5 inches w.c. for natural gas systems and 11 inches w.c. for propane systems). Essentially, the servo regulator causes the main valve to act as a restricting element to regulate gas pressure to the burner.

1. **Downstream Pressure Build-up**

   Back-pressure acts on the servo regulator diaphragm, reducing flow.

2. **Main Valve Closure**

   Upstream gas flows back into the chamber below the main valve, causing it to close.

3. **Pressure Regulation**

   Servo regulator maintains main valve position to reduce upstream gas pressure to manifold pressure.

Closing the Bleed Valve

When the call for heat is satisfied, the bleed valve operator closes the bleed valve and the upstream pressure flows only to the chamber below the main valve, causing it to close. Most combination gas valves have a second solenoid operated main valve for added safety.

Bleed Valve Closure

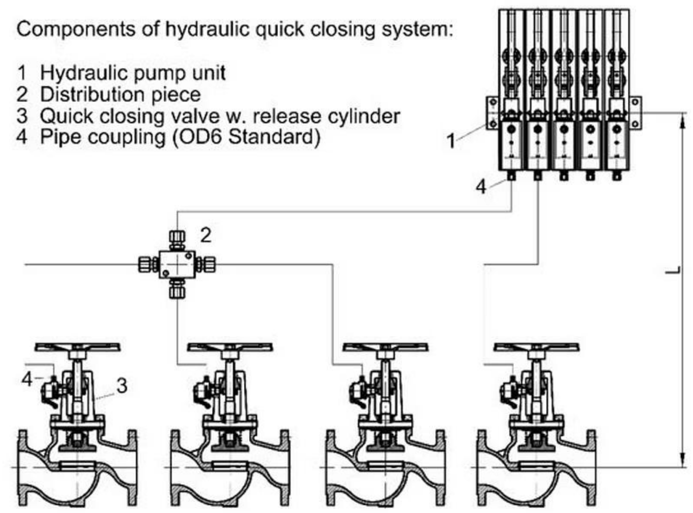
When heat is no longer needed, the bleed valve closes.

Main Valve Closure

Upstream pressure flows to the chamber below the main valve, causing it to close.

Safety Feature

Most combination gas valves include a second solenoid-operated main valve for enhanced safety.



Servo Regulator Adjustment and Replacement

Figure 1-21
Electronic modulating servo-regulated combination gas valve
Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

A gas technician/fitter can adjust the spring on the servo regulator to increase or decrease downstream pressure to meet the appliance manufacturer's specifications. Like most small input regulators, servo regulators cannot be repaired. If they fail, the entire combination gas valve must be replaced.

Adjustment

Gas technicians can adjust the servo regulator spring to meet appliance specifications.

Repair Limitations

Servo regulators are typically not repairable.

Replacement

If a servo regulator fails, the entire combination gas valve must be replaced.

Modulating Appliances and Stepper Motors

Some modulating appliances achieved their firing rate modulation by way of connecting an electronic stepper motor at the servo regulator adjustment screw. This motor operator receives a signal from the controller and adjusts the setting of the servo regulator to the required manifold pressure. These valves can achieve a full range of modulation from 35 - 100% with 1% increments

Stepper Motor

Electronic stepper motors connect to the servo regulator adjustment screw.

Controller Signal

The motor receives signals from the controller to adjust manifold pressure.

Modulation Range

Valves can modulate from 35% to 100% in 1% increments.

Servo Regulator with Referenced Connection

Proper manifold pressure is critical to ensure the correct amount of gas flow through the burner orifices. For older style appliances, the combustion chamber pressure was atmospheric, so the manifold pressure was to sole force affecting the flow of gas through the burner orifices. But for most high efficiency appliances, the combustion chamber is sealed and the pressure in the burner enclosure can fluctuate depending on venting conditions. These pressure fluctuations on the discharge side of the burner orifice would affect the flow of gas if the appliance regulator did not make adjustments. In order for these adjustments to be automatically compensated for, a burner enclosure reference tube is connected into the appliance regulator vent outlet (Figure 1-22). The pressure within the combustion chamber is now applied to the top of the diaphragm, causing an adjustment to the loading element. For example, if the regulator spring was set at 3 inches w.c., and the burner enclose was experiencing a positive pressure of 1 inch w.c., the appliance regulator would set the manifold pressure at 4 inches w.c. This is also called a referenced pressure of 3 inches w.c.

Figure 1-22 Combination gas valve Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

Diaphragm Adjustment

Balanced Regulators

A balanced-type regulator is designed to have the inlet pressure acting in two opposing directions on the orifice seat(s), thus producing a balancing effect that prevents an increase in set pressure through an increase in the inlet pressure.

Large changes in the inlet pressure make it difficult for a regulator to maintain constant downstream pressure. Many regulators therefore add a second diaphragm or port to create a balanced regulator. Balanced regulators are classified as:

- single-ported; and
- double-ported.

Balancing Effect

Inlet pressure acts in opposing directions on orifice seats, preventing set pressure increase.

Constant Downstream Pressure

Balanced regulators maintain constant downstream pressure despite large inlet pressure changes.

Single-Ported Balanced Regulator

Single-ported balanced regulators have the four basic elements common to all regulators. The regulator is also equipped with a pitot tube and a balancing diaphragm, as shown in Figure 1-23.

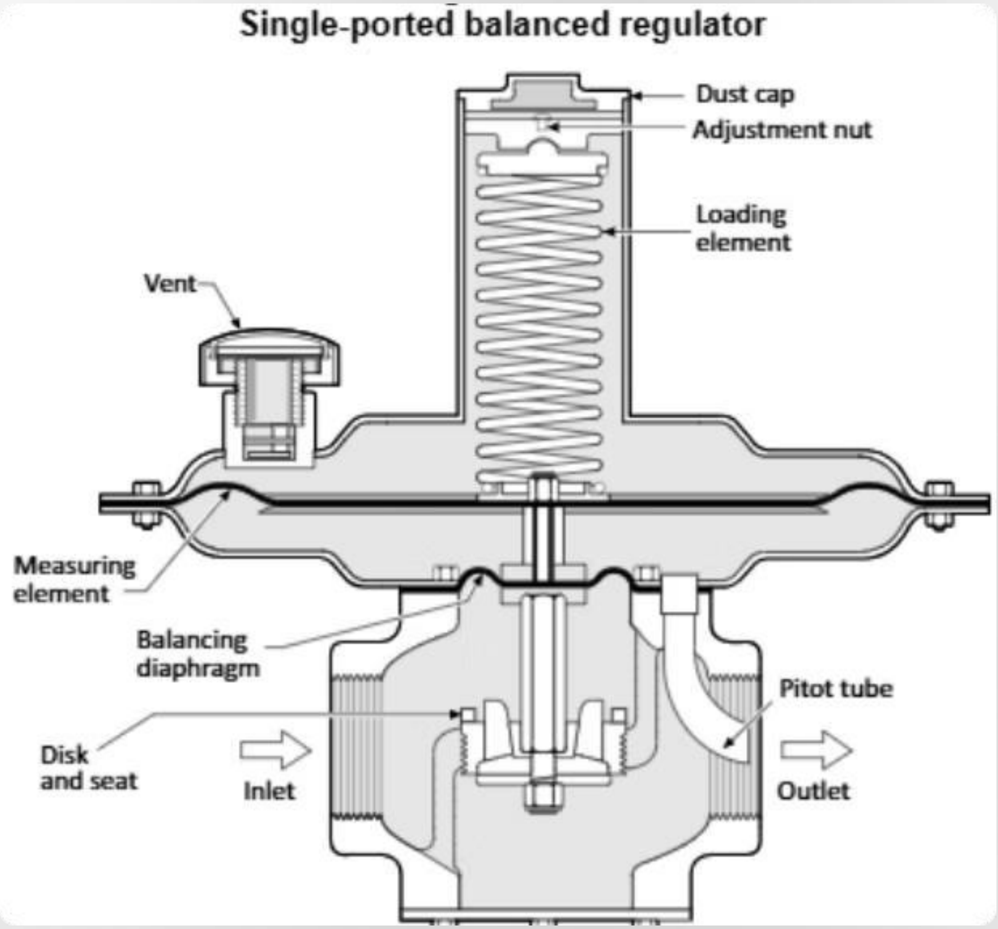
Figure 1-23

Basic Elements

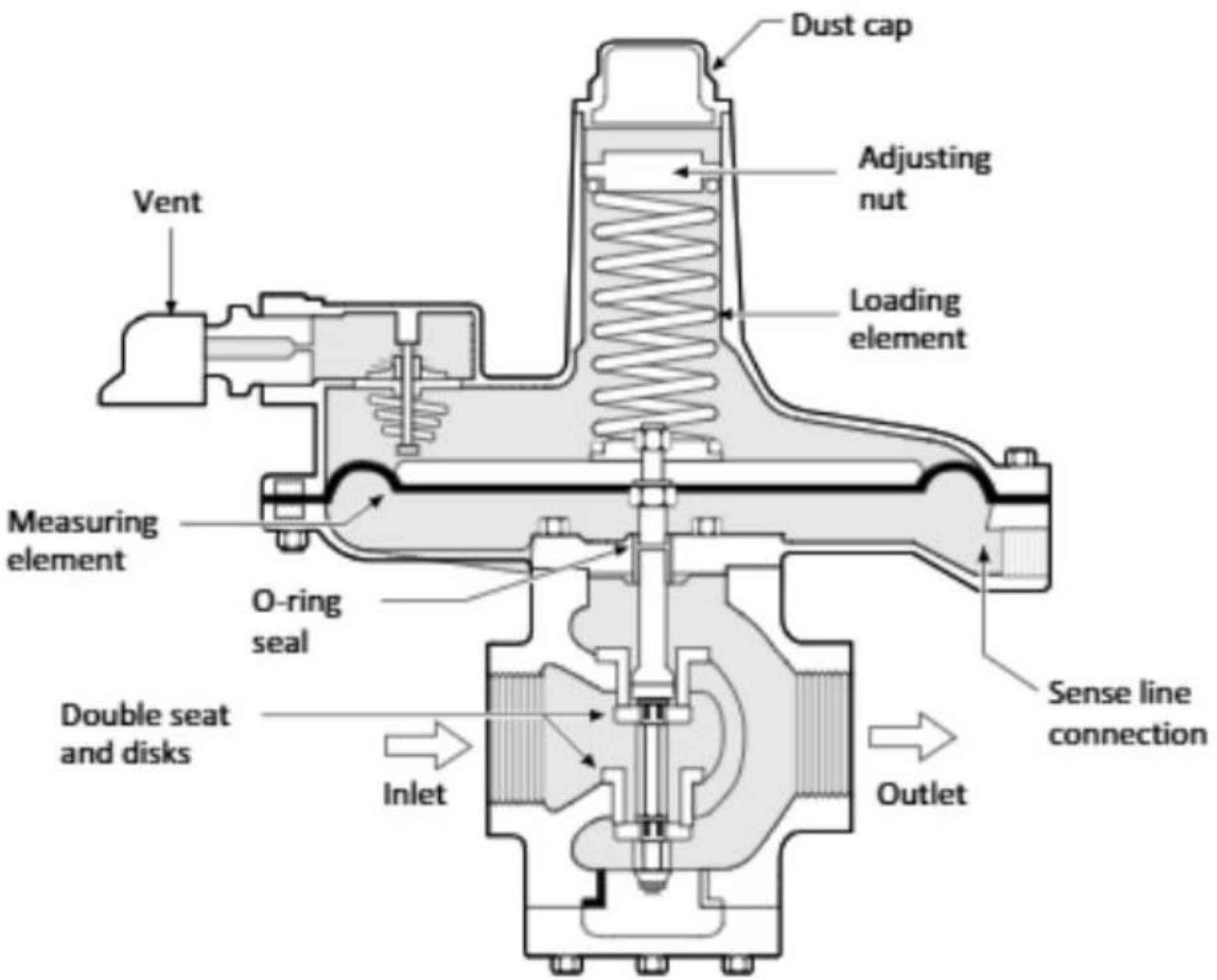
Possesses the four fundamental elements found in all regulators.

Additional Components

Equipped with a pitot tube and a balancing diaphragm for enhanced performance.



Double-Ported Balanced Regulator - Basic Type



Double-ported regulators have the same four basic elements of all regulators, except that the restricting element has two disks and seats (Figure 1-24). The equal port diameters balance the opposing forces across the valve disks, resulting in minimum lockup with either high or low inlet pressures.

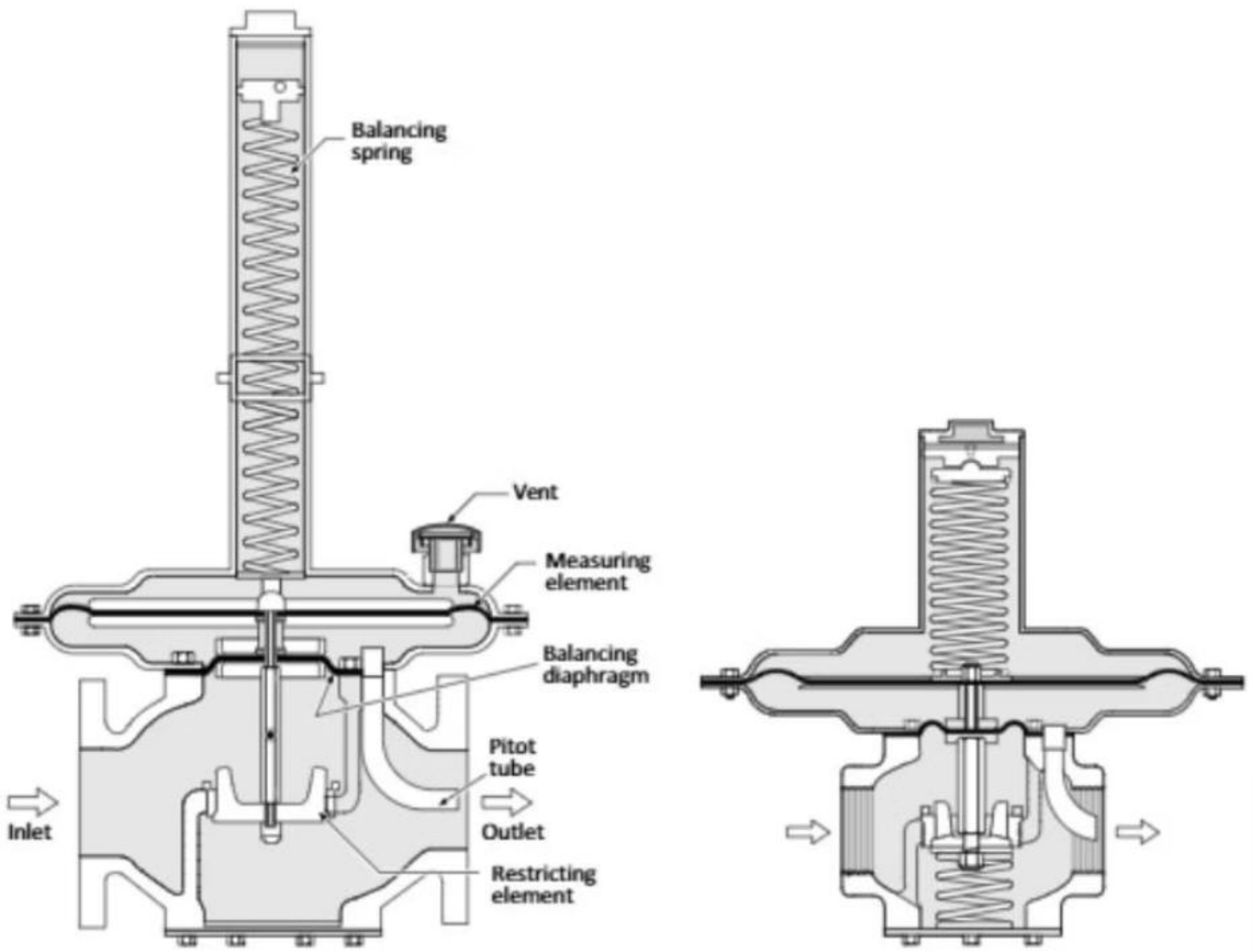
Figure 1-24 Double-ported balanced regulator

The shaft connecting the two disks or plugs to the main diaphragm is sealed with an O-ring where it passes through the valve body. The double-ported regulator does not use a pitot tube to sense outlet pressure. Instead, a tapping is provided under the main diaphragm, which must be connected to the downstream piping.

Balanced regulators allow for more stable operation and precise control of pressure.

Zero Governors

Figure 1-25
Zero governors



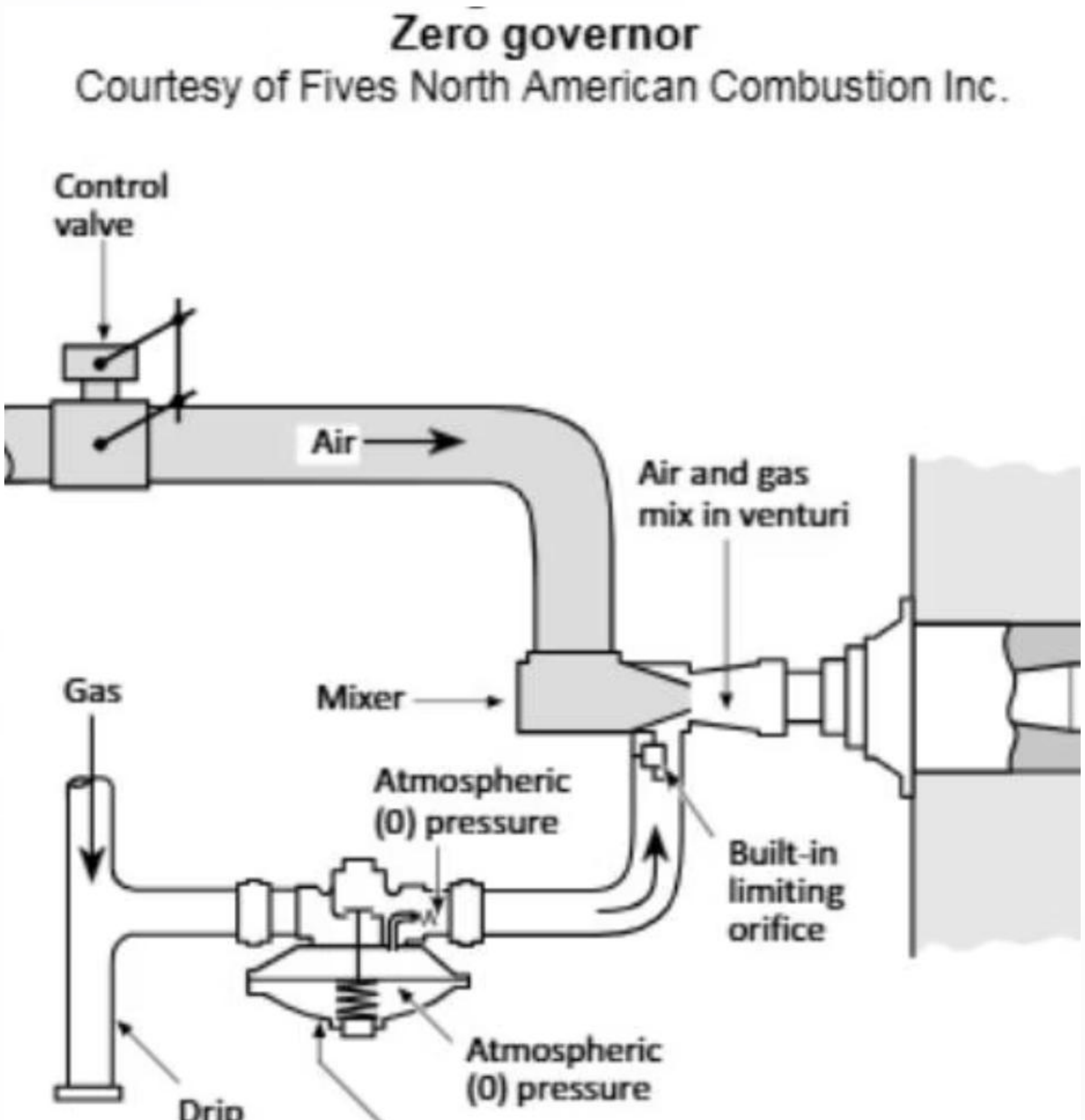
Zero governors, or regulators, are designed to deliver an outlet pressure equivalent to atmospheric pressure. They are normally double-diaphragm units equipped with an O-ring seal diaphragm (balancing diaphragm), as shown in Figure 1-25. This isolates the inlet gas pressure from the lower chamber of the main control diaphragm.

The balancing diaphragm is set so that its effective area equals the effective area of the valve disk.

The spring of these regulators counterbalances the weight of the internal parts. This provides just enough additional tension to close the valve.

As the spring always just counterbalances the internal parts, the outlet pressure of the governor will always be the same pressure that is applied to the top side of the main diaphragm. Since the vent above the diaphragm is open to the atmosphere (Figure 1-25), the zero

Zero Governor in Burner Systems



Modulating Premix Burner Systems

By changing the air flow through the blower or mixer, the gas flow through the zero governor changes automatically. These systems are ideal for modulating premix burner systems. Although Figure 1-26 shows a large zero governor normally used on industrial appliances, a zero governor can be incorporated into a combination gas valve for smaller input premix modulating burners, as shown in Figure 1-27.

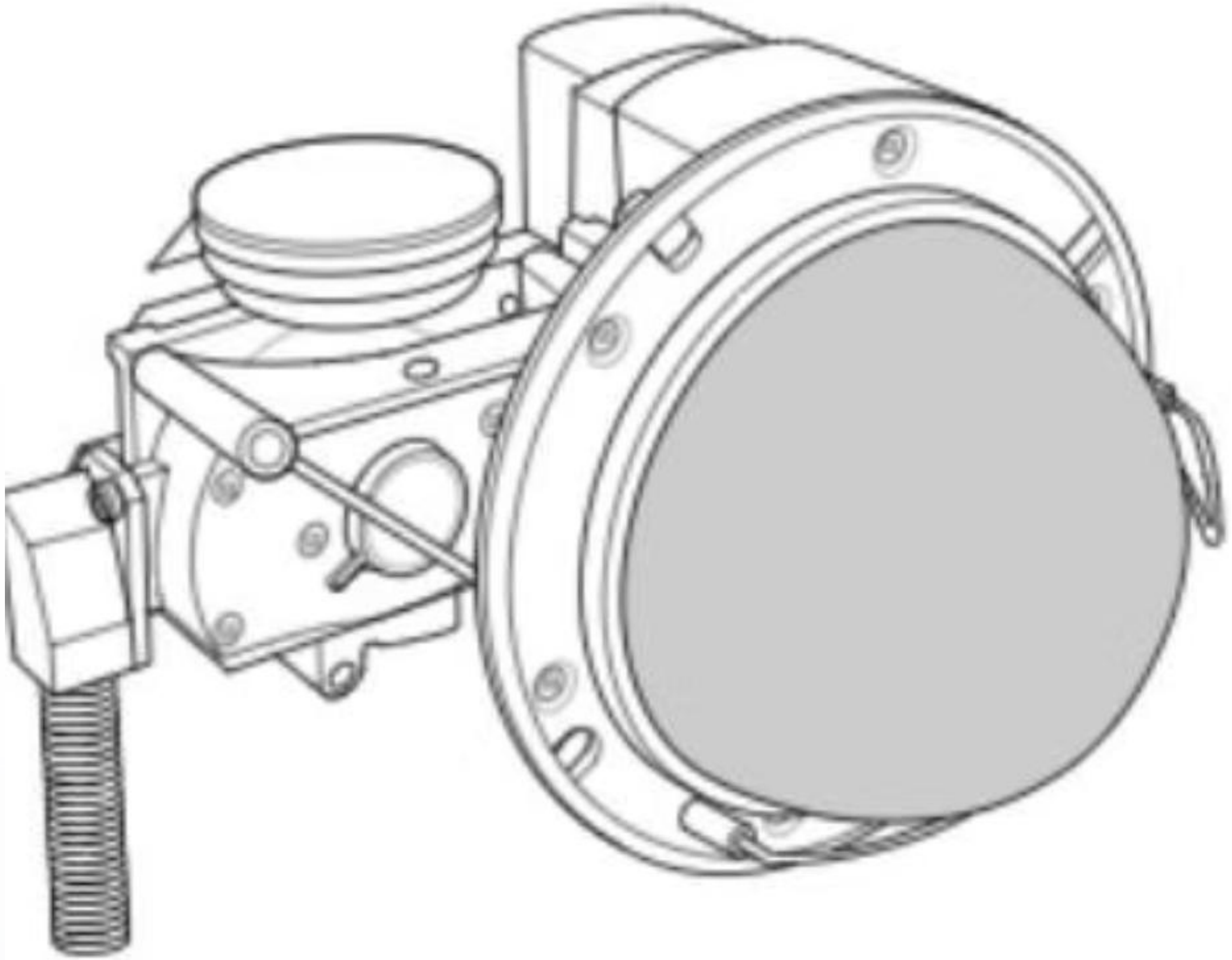


Figure 1-27
The combination gas valve on a Viessmann matrix burner incorporates a zero governor

Automatic Gas Flow Adjustment

Gas flow changes automatically with air flow

Ideal for Modulating Premix Burners

These systems are well-suited for modulating premix

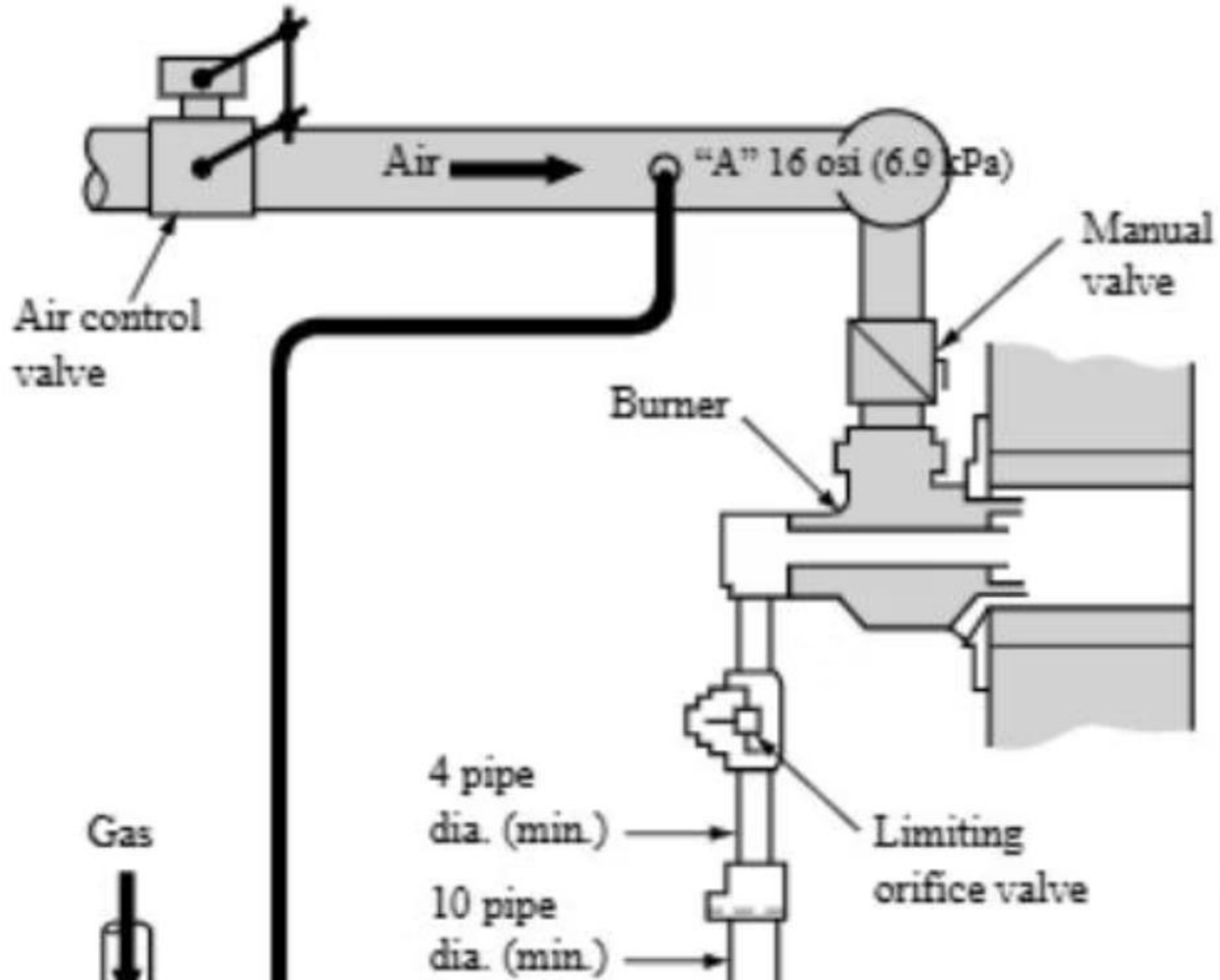
Integrated into Combination Gas Valves

Zero governors can be integrated into combination

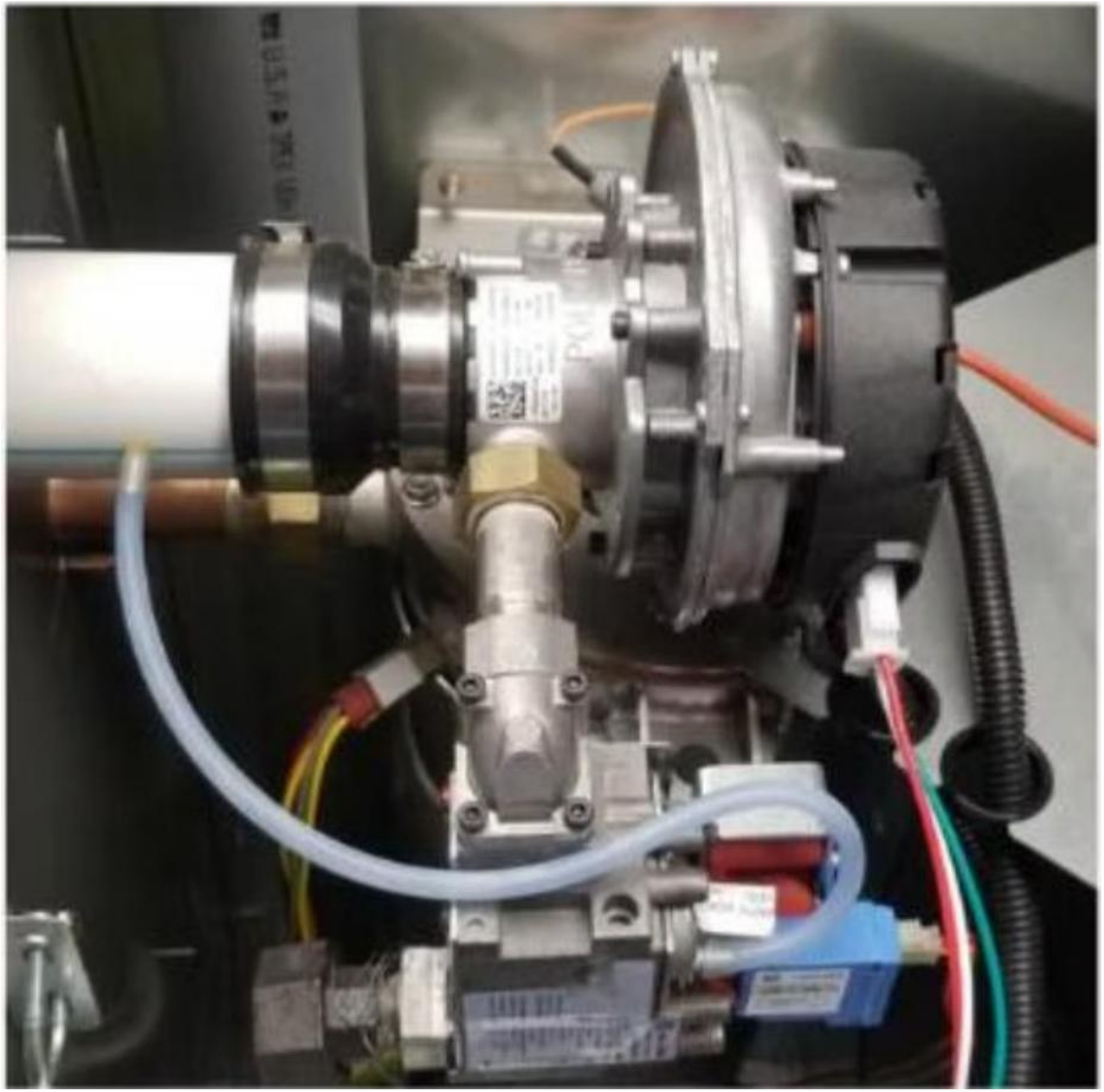
Air/Gas Proportioning Regulators

Figure 1-28
Air/gas ratio regulator on a nozzle mix burner

An air/gas proportioning regulator (often called a 1:1 pressure ratio regulator) is similar to a zero regulator, except that it delivers a pressure that matches the air pressure. Similar to the referenced pressure connection shown earlier, the air pressure is applied to the vent opening on the spring side of the diaphragm through a sensing line connected to an air supply line delivering combustion air to the nozzle mix burner (Figure 1-28). The outlet pressure from the ratio regulator changes automatically whenever changes are made to the air flow pressure.



Ratio Regulator in Combination Gas Valves



Although Figure 1-28 shows a ratio regulator arrangement normally used on industrial appliances, a gas/air ratio regulator can be incorporated into a combination gas valve for smaller input premix modulating burners, as shown for the boiler burner in Figure

Propane Regulator Systems

A big difference between natural gas systems and propane gas systems is that natural gas system pressures in service piping usually do not experience the same change in pressures that propane systems do.

Propane storage container pressures may vary from as low as 8 psig (55 kPa) in winter to as high as 220 psig (1500 kPa) in summer due to changes of temperature around the container.

The propane regulator system must compensate for this variation and deliver a steady pressure. The regulator must also be able to handle the problems that result from the intermittent use of the appliances attached to it.

Although single-stage regulator systems are still used on portable propane appliances or on older permanent installations, the Code has required all permanent installations use two-stage regulator systems since 1995.

Pressure Variation

Propane systems experience significant pressure changes due to temperature fluctuations.

Steady Pressure Delivery

Propane regulators must compensate for variations and deliver consistent pressure.

Intermittent Use Handling

Regulators must manage issues arising from intermittent appliance use.

Advantages of Two-Stage Regulator Systems

Two-stage regulator systems have a number of advantages over single-stage systems, including the following:

- They deliver a more uniform appliance pressure because the second-stage regulator receives a relatively uniform gas flow from the first-stage regulator.
- They reduce the possibility of internal freeze-ups caused when moisture in the gas is emitted as water and freezes as it drops in pressure (and therefore temperature) through the small orifice of a single-stage regulator. Two-stage regulator systems have larger orifices and lower pressure drops through each orifice compared to single-stage systems.
- There is an economy of installation since the line between the first- and second-stage regulators is much smaller than in single-stage systems.
- The allowance for future appliances is enhanced, as additional second-stage regulators may be added if the first-stage regulator still has additional capacity.

These systems should also be used in non-permanent installations to get full and proper use from the connected appliances.

Uniform Pressure

More consistent appliance pressure due to uniform gas flow from the first stage.

Reduced Freeze-ups

Larger orifices and lower pressure drops minimize internal freezing.

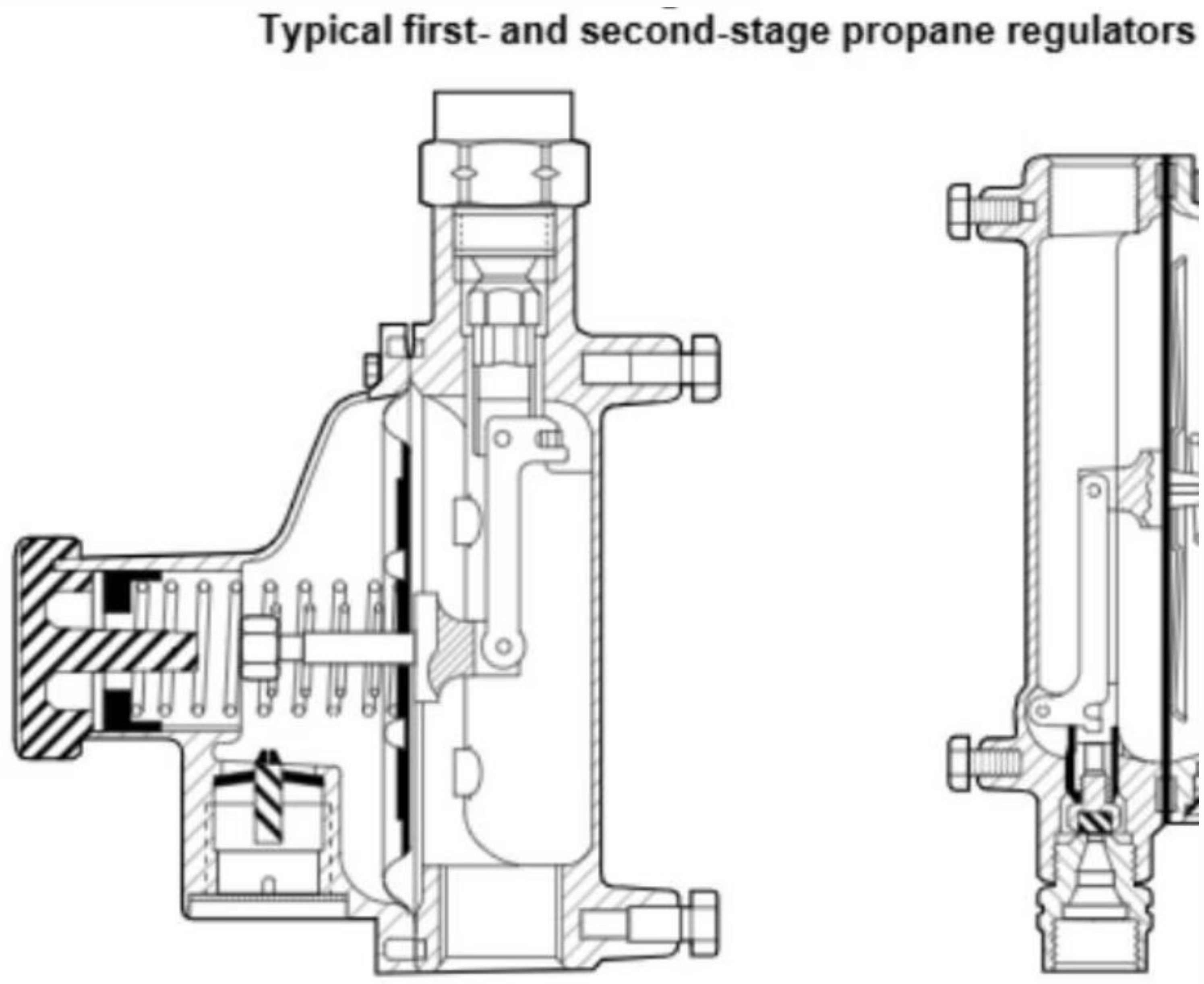
Installation Economy

Smaller line between stages reduces installation costs.

Future Appliance Allowance

Easier to add future appliances if first-stage regulator has capacity.

Two-Stage Pressure Regulation System Options

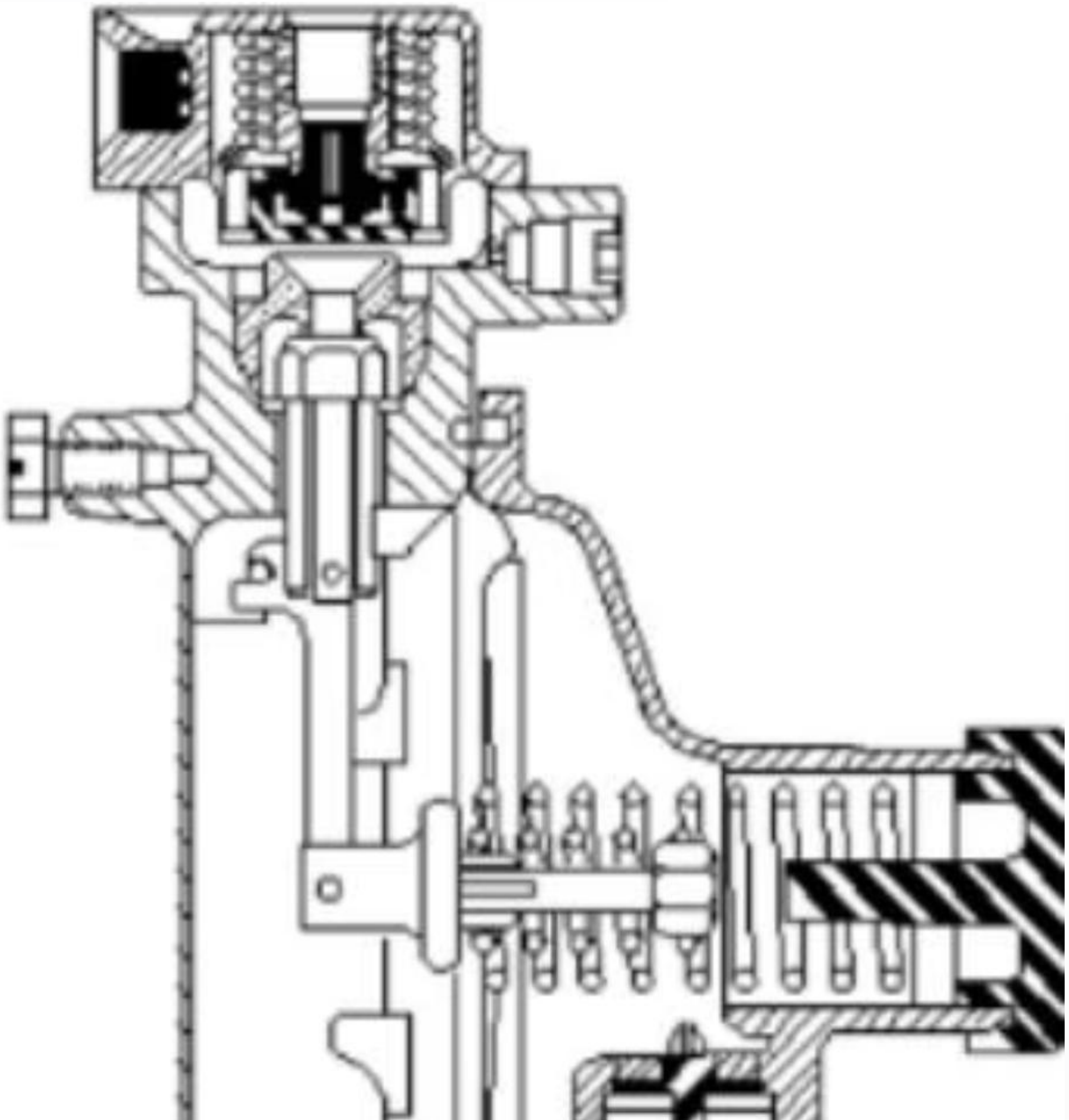


The following are two options for a two-stage pressure regulation system:

- A first-stage high pressure regulator [Figure 1-30(a)] with an inlet from the storage container and an outlet to a second-stage low pressure regulator [Figure 1-30(b)]. This second-stage regulator acts as a service regulator to the building.
- An integral twin-stage regulator that performs both of these functions internally. An example is shown in Figure 1-31. Use these when piping distances are 30 ft (9 m) or less. A big advantage is that the regulator is compact, allowing it to be used easily in mobile homes, onsite filling, and in average size domestic installations.

Figure 1-30

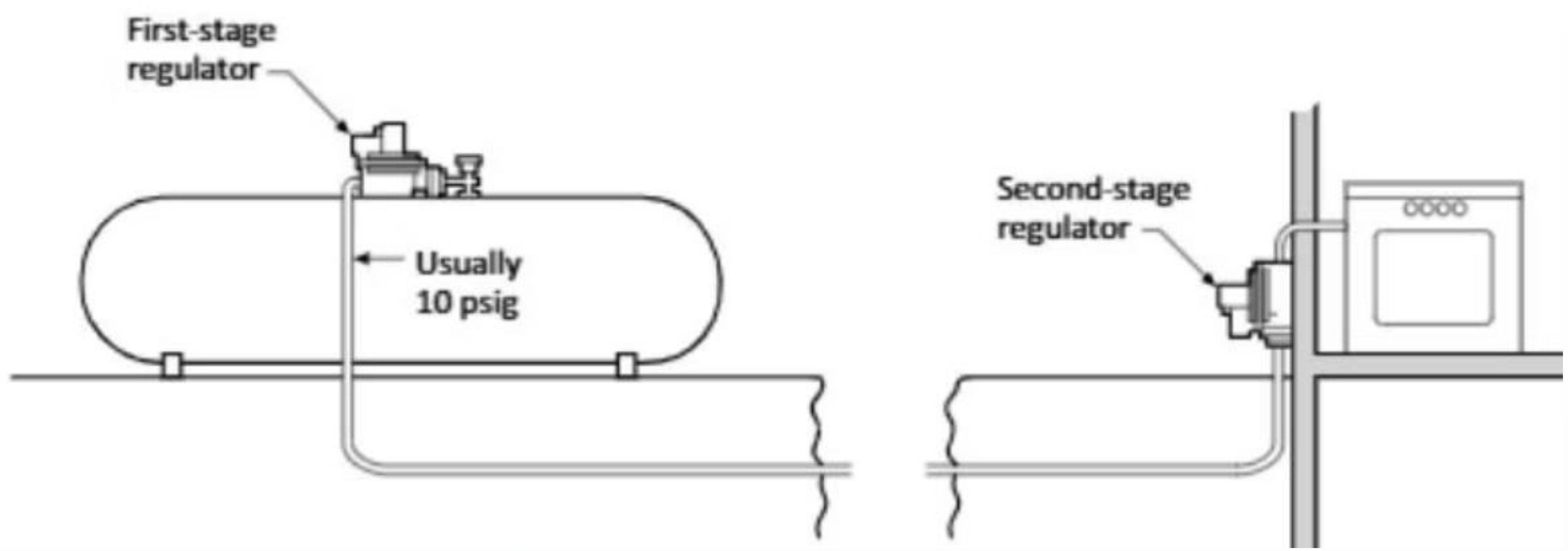
Integral Twin-Stage Propane Regulator



Typical Two-Stage Regulator System Installation

Figure 1-32
Two-stage regulator installation

Figure 1-32 shows a typical two-stage regulator installation. The first stage of the system supplies a nearly constant inlet pressure of 8 to 10 psig (55 to 70 kPa) to a second-stage regulator. This means that the second-stage regulator does not have to compensate for as much variance in inlet pressures. Any pressure loss through the pipe or tubing can be corrected by the secondstage regulator at the building being served. Smaller piping can be used between the first- and second-stage units because of the higher pressure.



Consistent Inlet Pressure

First stage provides 8-10 psig to the second stage, reducing pressure variance.

Pressure Loss Correction

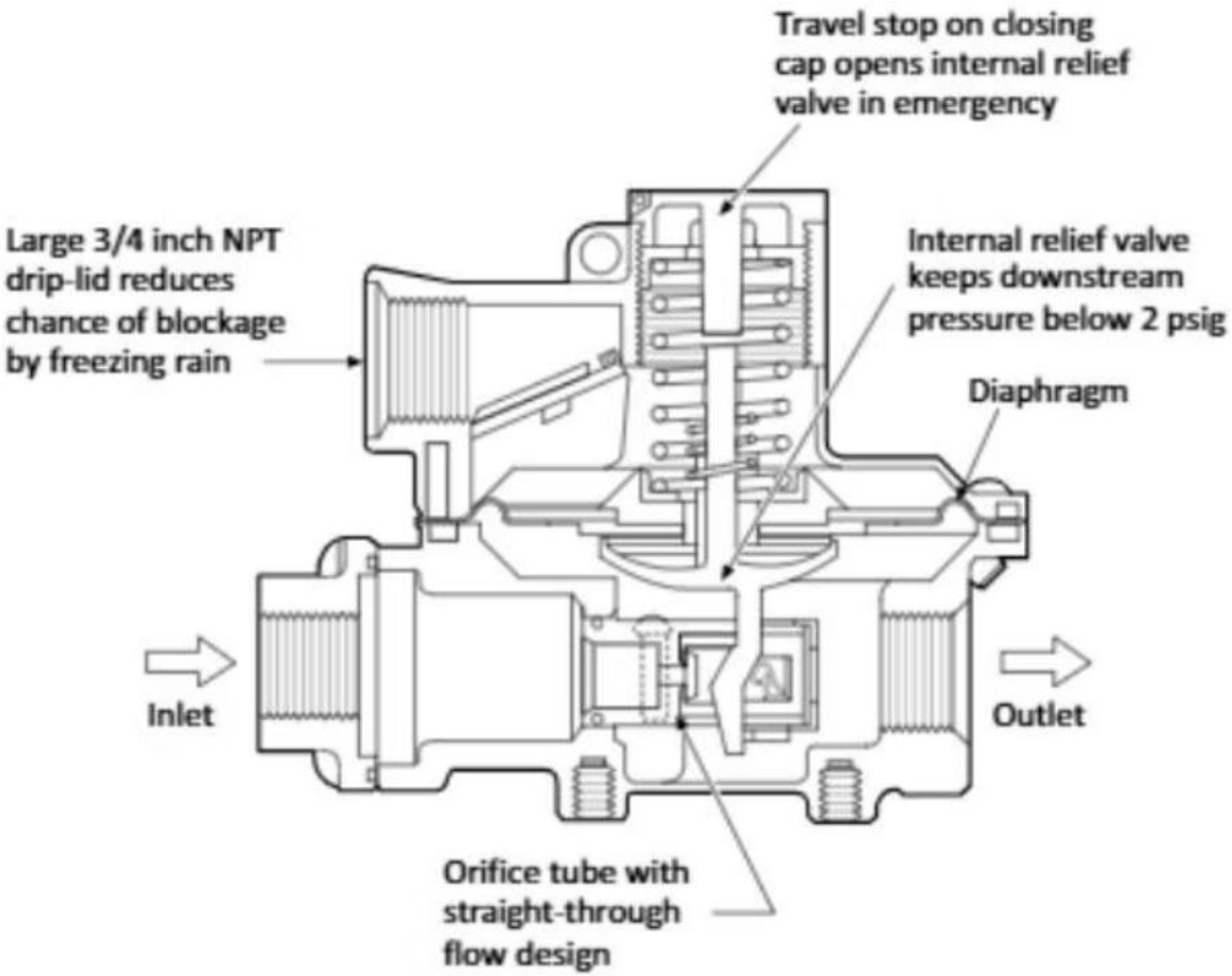
Second-stage regulator corrects any pressure loss in piping or tubing.

Smaller Piping

Higher pressure allows for smaller piping between first and second stages.

Single-Stage Regulator

Figure 1-33
Single-stage regulator



A single-stage regulator is used to reduce tank or cylinder pressures to appliance inlet pressure - usually 11 inches w.c. (2.7 kPa). A typical single-stage regulator is shown in Figure 1-33. As previously mentioned, the use of a single-stage regulator is only allowed on portable propane appliances.

Figure 1-34
Rego automatic changeover regulator
Courtesy of RegO Products

Regulator Selection Requirements

Selecting the correct gas regulator depends upon a number of factors. The main factors relate to the rate of flow, type of gas, maximum and minimum gas inlet pressures, outlet gas pressure, and pipe or tubing size. These factors need to be taken into account before choosing a regulator.

- Rate of flow
- Type of gas
- Maximum and minimum gas inlet pressures
- Outlet gas pressure
- Pipe or tubing size

Key Factors

Rate of flow, gas type, inlet pressures, outlet pressure, and pipe size are crucial.

Comprehensive Consideration

All factors must be considered for proper regulator selection.

Selection Factors: Rate of Flow

The rate of flow through the regulator is determined by the number of appliances connected to the downstream piping system. This flow rate is usually expressed in standard cubic feet per hour or standard cubic metres per hour.

Information	Description
Rate of flow	The rate of flow through the regulator is determined by the number of appliances connected to the downstream piping system. This flow rate is usually expressed in standard cubic feet per hour or standard cubic metres per hour.

Appliance Connection

Flow rate is determined by the number of connected appliances.

Measurement Units

Expressed in standard cubic feet per hour or standard cubic meters per hour.

Selection Factors: Type of Gas

Ensure that the regulator is designed for use with the intended fuel gas (natural gas or propane) as the flow rate is effected by the specific gravity of the gas.

Information	Description
The type of gas	Ensure that the regulator is designed for use with the intended fuel gas (natural gas or propane) as the flow rate is effected by the specific gravity of the gas.

Fuel Gas Compatibility

Regulator must be designed for either natural gas or propane.

Specific Gravity Impact

The specific gravity of the gas affects the flow rate.

Selection Factors: Inlet Gas Pressure

Regulators are manufactured with a maximum and minimum inlet pressure rating. Select the regulator that is designed to handle the possible range of inlet pressures. The maximum inlet pressure is a factor in determining overpressure protection requirements. The minimum available inlet pressure is an Important factor in determining the rate of flow (capacity) the regulator can deliver.

Information	Description
Inlet gas pressure	Regulators are manufactured with a maximum and minimum inlet pressure rating. Select the regulator that is designed to handle the possible range of inlet pressures. The maximum inlet pressure is a factor in determining overpressure protection requirements. The minimum available inlet pressure is an Important factor in determining the rate of flow (capacity) the regulator can deliver.

Pressure Range Compatibility

Choose a regulator that can handle the full range of possible inlet pressures.

Overpressure Protection

Maximum inlet pressure determines overpressure protection needs.

Flow Rate Determination

Minimum inlet pressure is crucial for determining the regulator's capacity.

Selection Factors: Outlet Gas Pressure

The outlet gas pressure is the downstream system-operating pressure. This pressure is usually adjustable within a small range and is necessary to select the proper spring. Outlet pressure is also a factor that effects the flow rate through the regulator, as the difference between it and the operating inlet pressure determine the allowable pressure drop through the regulator.

Information	Description
Outlet gas pressure (setpoint)	The outlet gas pressure is the downstream system-operating pressure. This pressure is usually adjustable within a small range and is necessary to select the proper spring. Outlet pressure is also a factor that effects the flow rate through the regulator, as the difference between it and the operating inlet pressure determine the allowable pressure drop through the regulator.

Downstream Operating Pressure

The outlet pressure is the system's operating pressure downstream of the regulator.

Adjustable Range

This pressure is typically adjustable within a small range, influencing spring selection.

Flow Rate Impact

The difference between outlet and inlet pressure affects the allowable pressure drop and flow rate.

Selection Factors: Piping or Tubing Size

The inlet and outlet pipe or tube size is a factor in determining how to select the regulator body size.

Information	Description
Piping or tubing size	The inlet and outlet pipe or tube size is a factor in determining how to select the regulator body size.

Inlet and Outlet Size

The size of the inlet and outlet pipes or tubes is a key factor.

Regulator Body Sizing

This factor directly influences the selection of the appropriate regulator body size.

Sizing Factors: Body Size

The regulator body size should never be larger than the pipe size. However, a properly sized regulator can be one or two sizes smaller than the pipe.

Information	Description
Body size	The regulator body size should never be larger than the pipe size. However, a properly sized regulator can be one or two sizes smaller than the pipe.

Maximum Size

Regulator body size should not exceed pipe size.

Optimal Sizing

A properly sized regulator can be one or two sizes smaller than the pipe.

Sizing Factors: Construction

The regulator should be constructed from materials compatible with the nature of the gas, the gas flow, and the temperature used. Also ensure that the regulator is available with the desired end connections.

Information	Description
Construction	The regulator should be constructed from materials compatible with the nature of the gas, the gas flow, and the temperature used. Also ensure that the regulator is available with the desired end connections.

Material Compatibility

Regulator materials must be compatible with gas type, flow, and temperature.

End Connections

Ensure the regulator has the required end connections.

Sizing Factors: Pressure Ratings

Pressure-reducing regulators are sized by using minimum inlet pressure to ensure that they can provide full capacity under all conditions. It is also very important to take note of the maximum inlet and outlet ratings. Downstream pressures significantly higher than the regulator pressure setting may damage soft seats and other internal regulator parts.

Information	Description
Pressure ratings	Pressure-reducing regulators are sized by using minimum inlet pressure to ensure that they can provide full capacity under all conditions. It is also very important to take note of the maximum inlet and outlet ratings. Downstream pressures significantly higher than the regulator pressure setting may damage soft seats and other internal regulator parts.

Minimum Inlet Pressure Sizing

Regulators are sized based on minimum inlet pressure for full capacity.

Maximum Ratings Awareness

Crucial to note maximum inlet and outlet pressure ratings.

Damage Prevention

High downstream pressures can damage internal regulator components.

Sizing Factors: Spring Pressure Range and Performance

If two or more springs have pressure ranges that include the desired pressure setting, use the spring with the lower range for more accuracy.

The full published range of a spring can generally be used without sacrificing performance or spring life.

Information	Description
Spring pressure range	If two or more springs have pressure ranges that include the desired pressure setting, use the spring with the lower range for more accuracy.
Spring performance	The full published range of a spring can generally be used without sacrificing performance or spring life.

Spring Selection for Accuracy

Choose the spring with the lower range for greater accuracy when multiple options exist.

Full Range Utilization

Springs can be used across their entire published range without compromising performance or lifespan.

Sizing Factors: Orifice Diameter

The recommended orifice size is the smallest diameter that handles the flow. This benefits operation by:

- avoiding instability and premature wear;
- allowing for smaller relief valves; and
- reducing lockup pressures.

Information	Description
Orifice diameter	The recommended orifice size is the smallest diameter that handles the flow. This benefits operation by:

Smallest Diameter

Recommended orifice size is the smallest that can handle the flow.

Operational Benefits

Prevents instability, reduces wear, allows smaller relief valves, and lowers lockup pressures.

Sizing Factors: Wide-Open Flow Rate

The capacity of a regulator when it has failed wide open is usually greater than the regulating capacity. Use the regulating capacities when sizing regulators and the wide-open flow rates only when sizing relief valves.

Information	Description
Wide-open flow rate	The capacity of a regulator when it has failed wide open is usually greater than the regulating capacity. Use the regulating capacities when sizing regulators and the wide-open flow rates only when sizing relief valves.

Regulating Capacity

Use regulating capacities for sizing regulators.

Relief Valve Sizing

Use wide-open flow rates only for sizing relief valves.

Sizing Factors: Accuracy

Evaluate the need for accuracy with each installed regulator. This is expressed as droop, which was discussed in the previous section.

Information	Description
Accuracy	Evaluate the need for accuracy with each installed regulator. This is expressed as droop, which was discussed in the previous section.

Accuracy Assessment

Assess the required accuracy for each regulator installation.

Droop as Metric

Accuracy is quantified by "droop," a concept previously explained.

Sizing Factors: Inlet Pressure Losses

The regulator inlet pressure used for sizing should be measured directly at the regulator inlet. Measurements at any distance upstream from the regulator are suspect because line loss can significantly reduce the actual inlet pressure to the regulator. During the design stage, this measurement is not available; therefore, the best practice is to select an operating inlet pressure based on the maximum allowable pressure loss criteria that was used for sizing the piping system. For example, a 5-psi system is sized based on a 2.5 psi pressure drop; therefore, the operating inlet pressure for the line pressure regulator would be 2.5 psi.

Information	Description
Inlet pressure losses	The regulator inlet pressure used for sizing should be measured directly at the regulator inlet. Measurements at any distance upstream from the regulator are suspect because line loss can significantly reduce the actual inlet pressure to the regulator. During the design stage, this measurement is not available; therefore, the best practice is to select an operating inlet pressure based on the maximum allowable pressure loss criteria that was used for sizing the piping system. For example, a 5-psi system is sized based on a 2.5 psi pressure drop; therefore, the operating inlet pressure for the line pressure regulator would be 2.5 psi.

Direct Measurement

Inlet pressure for sizing should be measured directly at the regulator inlet.

Line Loss Consideration

Upstream measurements are unreliable due to potential line loss.

Design Stage Practice

Select operating inlet pressure based on maximum allowable pressure loss criteria.

Sizing Factors: Turn-Down Ratio and Speed of Response

Within reasonable limits, most soft-seated regulators can maintain pressure down to zero flow. Therefore, a regulator sized for a high flow rate usually has a turn-down ratio sufficient to handle pilot-light loads during periods of low demand.

Direct-operated regulators generally have faster response to quick flow changes than pilot-operated regulators.

Information	Description
Turn-down ratio	Within reasonable limits, most soft-seated regulators can maintain pressure down to zero flow. Therefore, a regulator sized for a high flow rate usually has a turn-down ratio sufficient to handle pilot-light loads during periods of low demand.
Speed of response	Direct-operated regulators generally have faster response to quick flow changes than pilot-operated regulators.

Turn-Down Ratio

Soft-seated regulators can maintain pressure down to zero flow, handling pilot-light loads.

Speed of Response

Direct-operated regulators respond faster to flow changes than pilot-operated ones.

Sizing Factors: Overpressure Protection

Evaluations for overpressure protection should also be made at the time of regulator selection. As discussed previously, if the service or line pressure regulator has a system pressure of 2 psi or less and is equipped with a vent limiter, overpressure protection is not required. If the system pressure is greater than 2 psi then either; internal relief, line relief valve, or another approved method of overpressure protection (OPP) would be required.

Information	Description
Overpressure protection	Evaluations for overpressure protection should also be made at the time of regulator selection. As discussed previously, if the service or line pressure regulator has a system pressure of 2 psi or less and is equipped with a vent limiter, overpressure protection is not required. If the system pressure is greater than 2 psi then either; internal relief, line relief valve, or another approved method of overpressure protection (OPP) would be required.

Selection Time Evaluation

Overpressure protection needs to be evaluated during regulator selection.

System Pressure Criteria

Not required for systems 2 psi or less with a vent limiter.

Required Methods

For systems over 2 psi, internal relief, line relief valve, or other approved OPP is needed.

Regulator Selection Guidelines

Most regulator manufacturers offer a range of models to supply the required flow rate depending on inlet pressures and outlet pressures. Larger regulators may have the option of replaceable orifices and a range of springs that may be selected for each model of regulator depending on the particular application. When you are to make choices, always select the smallest orifice size that will provide the required flow rate, largest practical diaphragm, and the lightest spring rate. These guidelines will provide the best regulator performance.

- Always select the smallest orifice size that will provide the required flow rate.
- Choose the largest practical diaphragm.
- Select the lightest spring rate.

Model Variety

Manufacturers offer diverse models for various flow, inlet, and outlet pressures.

Optimal Performance

Smallest orifice, largest diaphragm, and lightest spring rate ensure best performance.

Selection Guides, Tables, and Online Programs

Regulator manufacturers offer a variety of models to accommodate the wide range of job applications. Although their sizing tables may have different formats between the various manufacturers, the required information needed to select an appropriate regulator and its components is the same for all manufacturers. An example of a typical model selection guide and some product catalogues are included in the appendix.

The selection process can seem very complexed if you were to try and look at all of the specifications for each model of regulator available. To streamline the process, the first step is to narrow the choices down to a few models by applying the selection factors related to your piping system. You can apply these factors to a Model Selection Guide or what is more commonly used today is an online sizing program. Figure 1-35 shows a snapshot of the computer screen in which the initial section factors have been inserted into the appropriate fields of the Itron online program.

Diverse Models

Manufacturers provide various models for different applications.

Consistent Information

Required selection information is uniform across manufacturers, despite varying table formats.

Streamlined Selection

Use model selection guides or online sizing programs to narrow choices.

Chapter 2
Overpressure protection

Overview

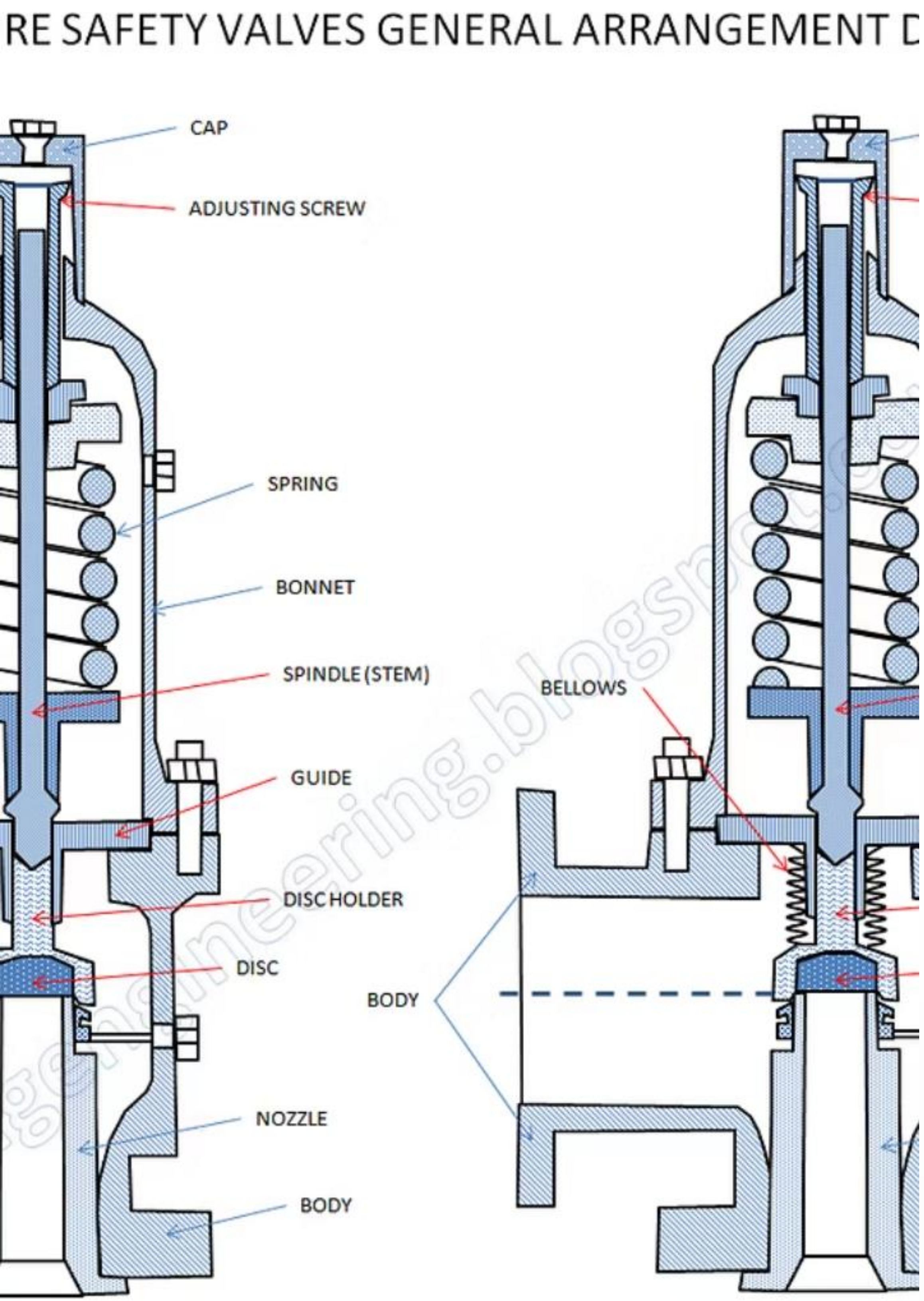
Purpose

An overpressure condition occurs when the pressure downstream of a regulator exceeds the maximum pressure rating of any downstream components. If the pressure requlator should happen to fail, components downstream that are not rated for the pressure upstream could be damaged. Due to the importance of protecting the system, overpressure protection should be a primary consideration in the design of any piping system.

Objectives

At the end of this chapter, you will be able to:

- describe overpressure protection;
- describe relief valves;
- describe the function and types of pressure limiting systems; and
- describe security shut-off systems.



Terminology

Term	Abbreviation Definition
Pressure buildup over setpoint (buildup)	For the relief valve to fully open, the pressure must build up to some level above the setpoint of the relief valve.

Introduction

Overpressure occurs when pressure downstream of a regulator exceeds the maximum pressure rating of any downstream component. It indicates a failure in the system that could result in a dangerous condition. Overpressure protection is a primary consideration in the design of any gas piping system.

The objective in providing overpressure protection is to maintain the pressure downstream of the regulator at a safe maximum value. This means identifying the weakest part in the pressure system, then limiting overpressure to that component's maximum pressure rating.

To identify the most vulnerable components, examine:

- the maximum pressure rating of downstream equipment;
- the low-pressure side rating of the main regulator; and
- the piping.

The lowest maximum pressure rating of any of these components is the maximum allowable pressure.

The worst-case conditions of regulator failure are those in which the regulator fails in either a fully closed or wide-open position.

Position	Description
A fully closed requlator	▪ Produces an underpressure condition. ▪ This is not damaging to equipment but may create dangerous conditions in the combustion chamber. ▪ This condition can be detected with pressure switches that will shut the equipment down until gas pressure is restored.
A fully open requiator	▪ Causes excessive pressure conditions that are damaging to equipment and create a potentially dangerous situation. ▪ These conditions can be controlled by using some form of overpressure protection.

Types of Overpressure Protection

Types of overpressure protection include:

- pressure relief using relief valves;
- pressure limiting; and
- automatic shut-off.

There are three selection criteria to evaluate the various methods of overpressure protection:

Selection criteria	Description
Continuity	How important is uninterrupted downstream flow?
Where the excess flow is directed	Is the excess flow directed to the atmosphere, or is it contained in the system?
System failure warning	How is it indicated that the system has failed and is operating on the safety system?

With this in mind, briefly examine the advantages and disadvantages of the three methods of overpressure protection as shown in Table 2-1.

able 2-1

Advantages and disadvantages of different methods of overpressure protection

Method	Relief valve	Pressure limiting	Automatic shut-off
Continuity	Provides continuity of service	Provides continuity of service as one requlator takes over when another fails	Does not provide continuity
Excess flow	Normally released to the atmosphere Depending on the nature of the gas and the location of the valve, this can be dangerous. It can also be noisy and create unpleasant odours.	No gas vented to the atmosphere	Any excess gas pressure contained in the system
Failure warning	Often given by the noise and odours as the gas vents to atmosphere This may go unnoticed in isolated areas.	Not very clear, as the backup regulator will maintain system pressure so no effects are sensed downstream Visual inspection and slightly higher pressure are indications.	Very clear since the system shuts down

Relief valves

Relief valves maintain the pressure downstream of a regulator at a safe maximum value using any device that vents fluid to a lower pressure system (often the atmosphere). They are considered to be one of the most reliable types of overpressure protection available and are popular for several reasons, including the following:

Unobstructed Flow

They do not block the normal flow through a line.

Capacity Preservation

They do not decrease the capacities of regulators they protect.

Audible/Olfactory Alarm

The noise and the odour act as an alarm if they vent to atmosphere.

Pressure buildup

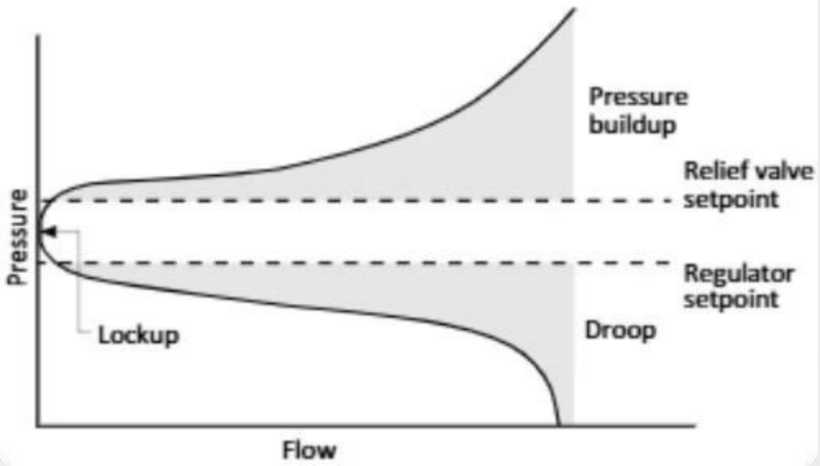
A relief valve has a setpoint at which it begins to open.

For the valve to fully open, the pressure must build up to some level above the setpoint of the relief valve. This is known as pressure buildup over setpoint, or more simply, buildup (Figure 2-1).

Relief valves are generally available in four types, namely:

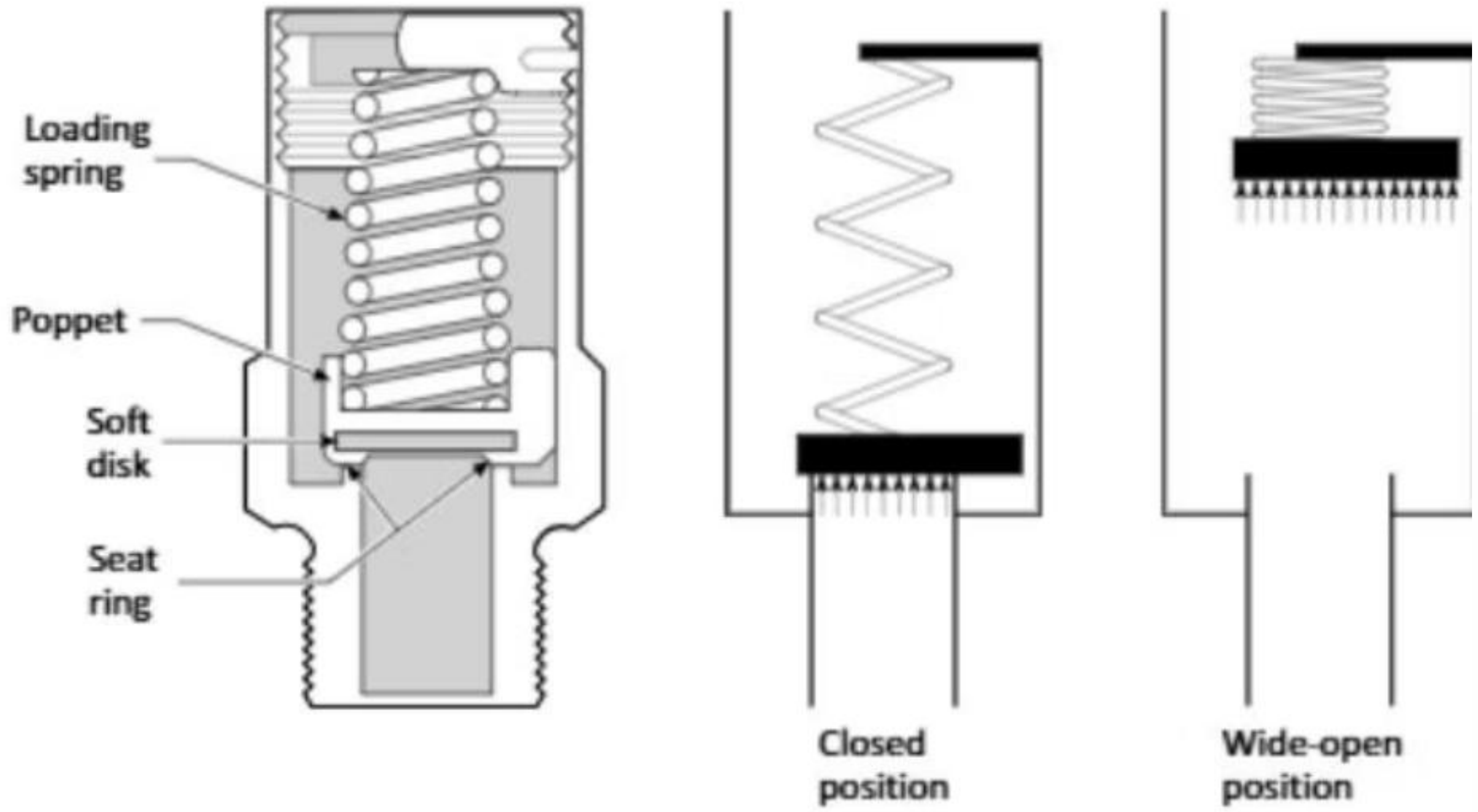
- Pop-type
- Direct operated
- Pilot operated
- Internal relief valves

Figure 2-1
Pressure buildup



Pop-type relief valves

Figure 2-2
Pop-type relief valve



Pop-type relief valves are essentially on-off devices. They generally operate in either the closed or wide-open position, as shown in Figure 2-2.

Operation

Pop-type designs register pressure directly on a spring opposed poppet, as shown in Figure 2-2. The poppet assembly includes a soft disk for tight shut-off against the seat ring.

When the inlet pressure increases above the relief valve's set pressure, the poppet assembly is pushed away from the metal seat. As the poppet rises, pressure registers against a greater surface area of the poppet. This dramatically increases the force on the poppet, so the poppet tends to travel to the fully open position until the overpressure condition is reduced.

This style of relief valve does not throttle the flow over a pressure range. Because of its on/off nature, it may create pressure surges in the downstream system.

If the relief valve capacity is significantly larger than the failed regulator's capacity, the relief valve may overcompensate each time it opens and closes, causing downstream pressure to become unstable.

Setpoint

Direct operated relief valves

Direct operated relief valves provide throttling action and require less pressure buildup to open the relief valve.

This relief valve looks like an ordinary direct operated regulator, except that it senses upstream pressure rather than downstream pressure. It also uses a spring close action and contains the same essential elements as a direct operated regulator (Figure 2-3):

Element	Description
Diaphragm	Measures the system pressure
Loading spring	Provides the initial load to the diaphragm and is used to establish relief setpoint
Restricting element	Throttles the flow

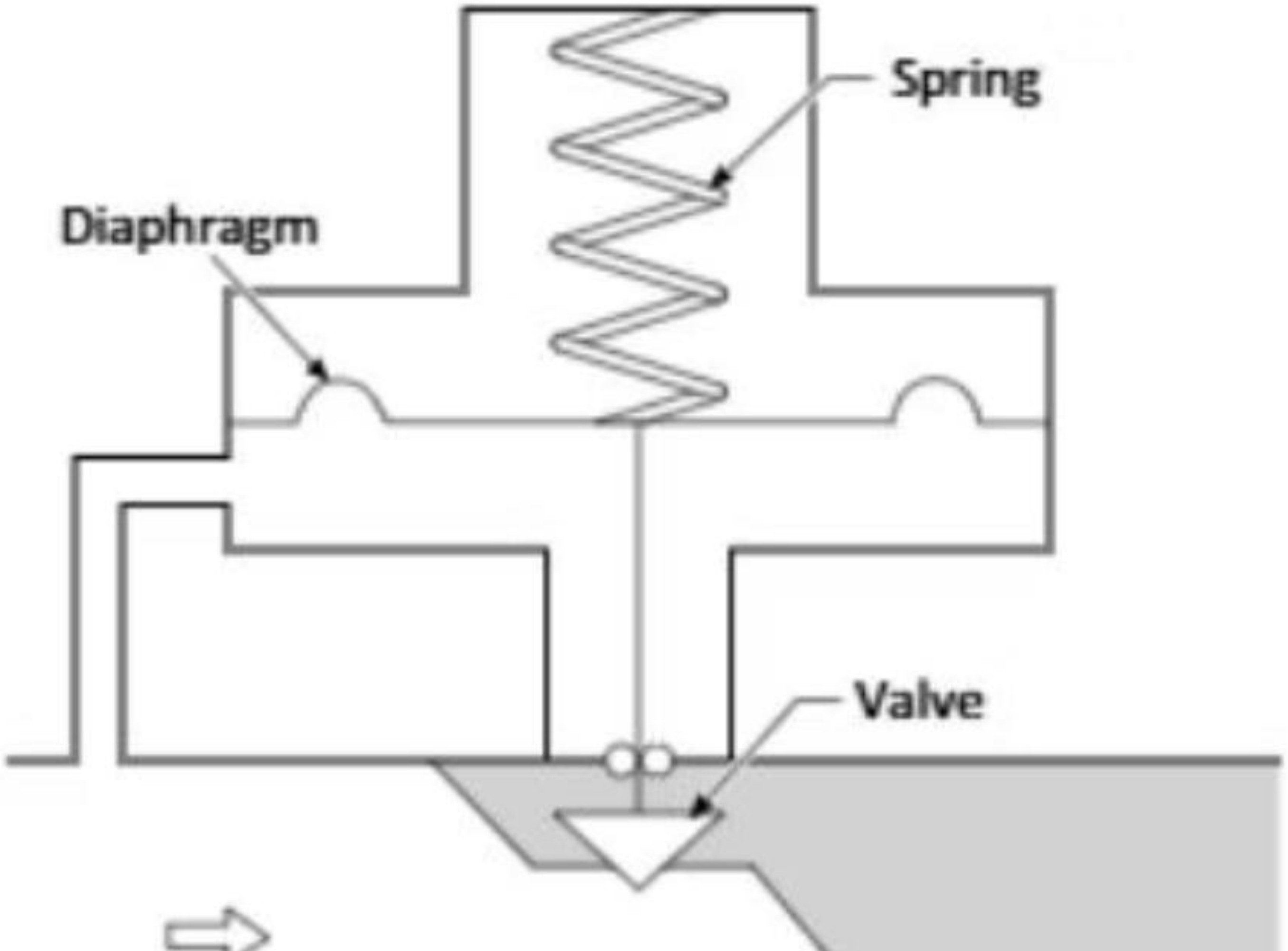
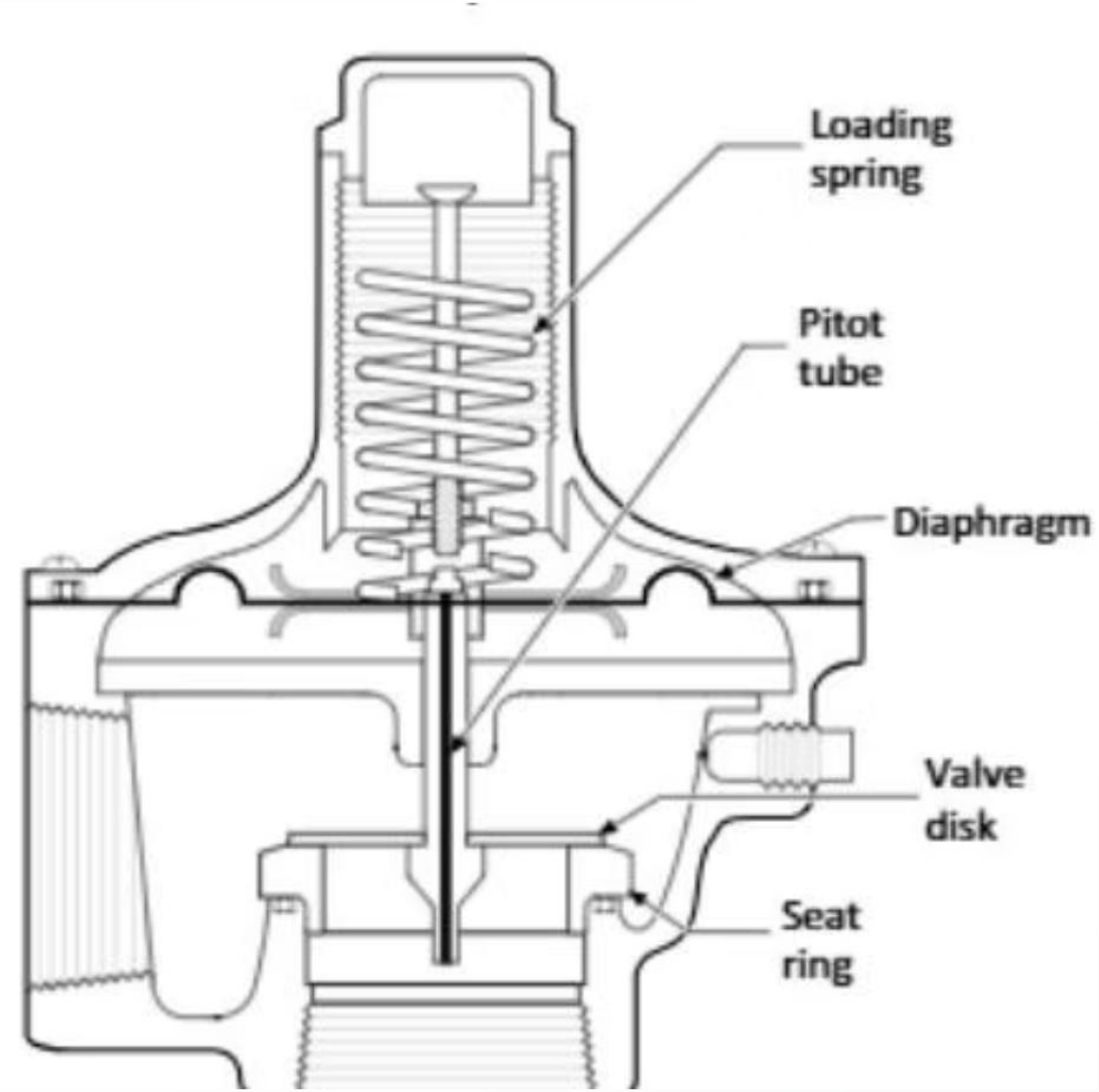


Figure 2-3
Direct operated relief valve

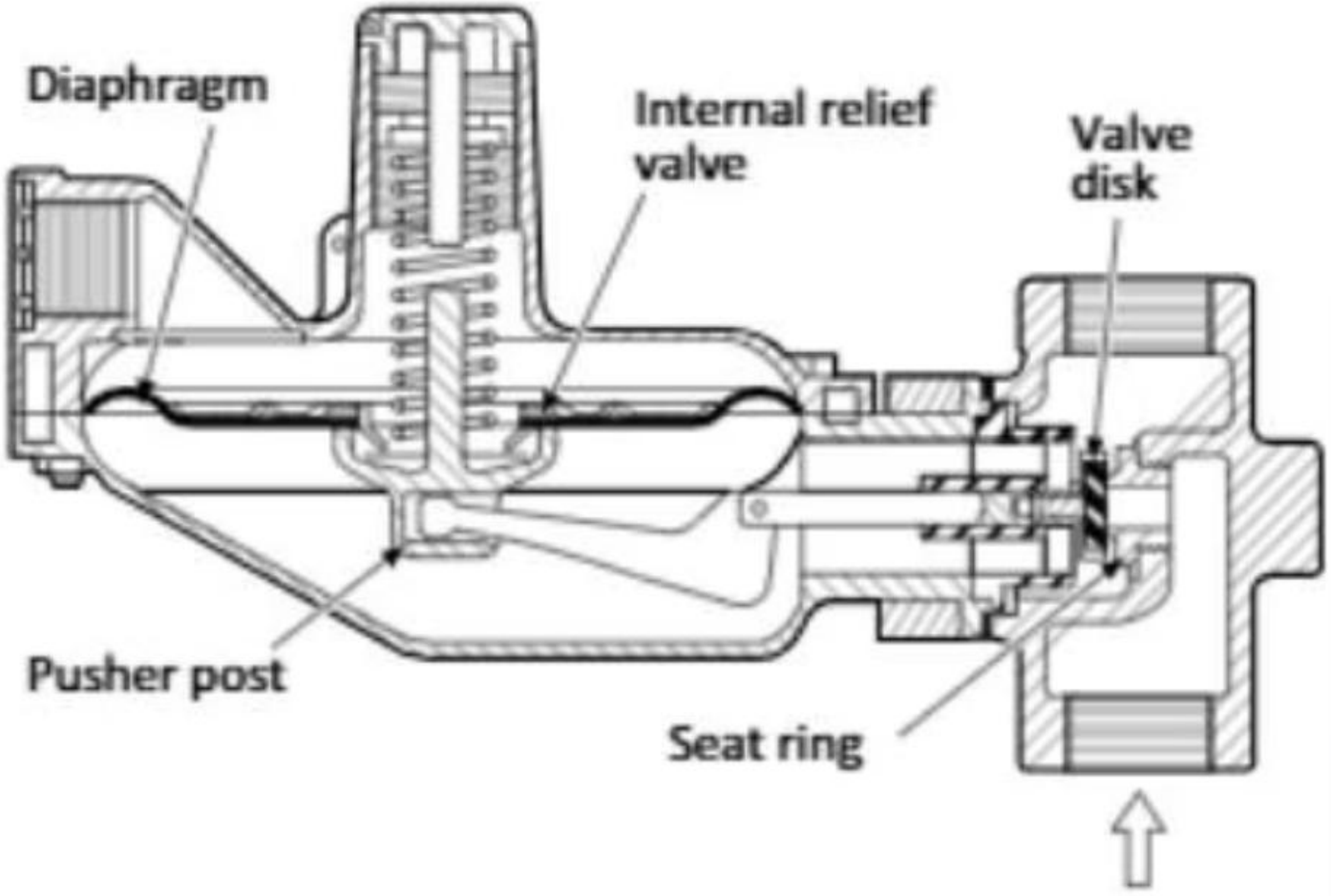
Pitot tube relief valve



While some direct operated relief valves require significant pressure buildup to achieve maximum capacity, others with the pitot tube can often pass high flow rates with minimum pressure buildup (Figure 2-4).

Internal relief valves

Figure 2-5
Internal relief valve



(a) With gas not flowing and downstream pressure normal

Sizing relief valves

The size of the relief valve depends on the system. Relief valves are made for different applications and operate in different ways. They also handle different pressure ranges.

Once the type of system and the pressure ranges that the system can safely handle are established, consult manufacturers' tables before choosing a relief valve.

Note: You should be able to set the pressure on a pressure relief valve at a higher value than the pressure on the regulator, but it should still be in the range of downstream pressure limitations.

Venting relief valves

Some aspects of venting gas pressure systems are discussed in Chapter 1. Pressure regulators.

Venting of relief valves is also covered extensively in CSA B149.1. Check for all the relevant regulations before planning a venting system for a pressure relief valve.

In particular, sizing relief valve vents are covered in Clause 5.5 of CSA B149.1. The manufacturer's rule of thumb for sizing relief valve vents is that it must be the size of the outlet if the termination point is less than 10 ft (3 m) away from the relief valve. For every additional 10 ft (3 m) farther away it is, the vent outlet must increase one size. A 90° elbow has an equivalent length of 3 ft (1 m). For long lengths, contact the manufacturer or the authority having jurisdiction.

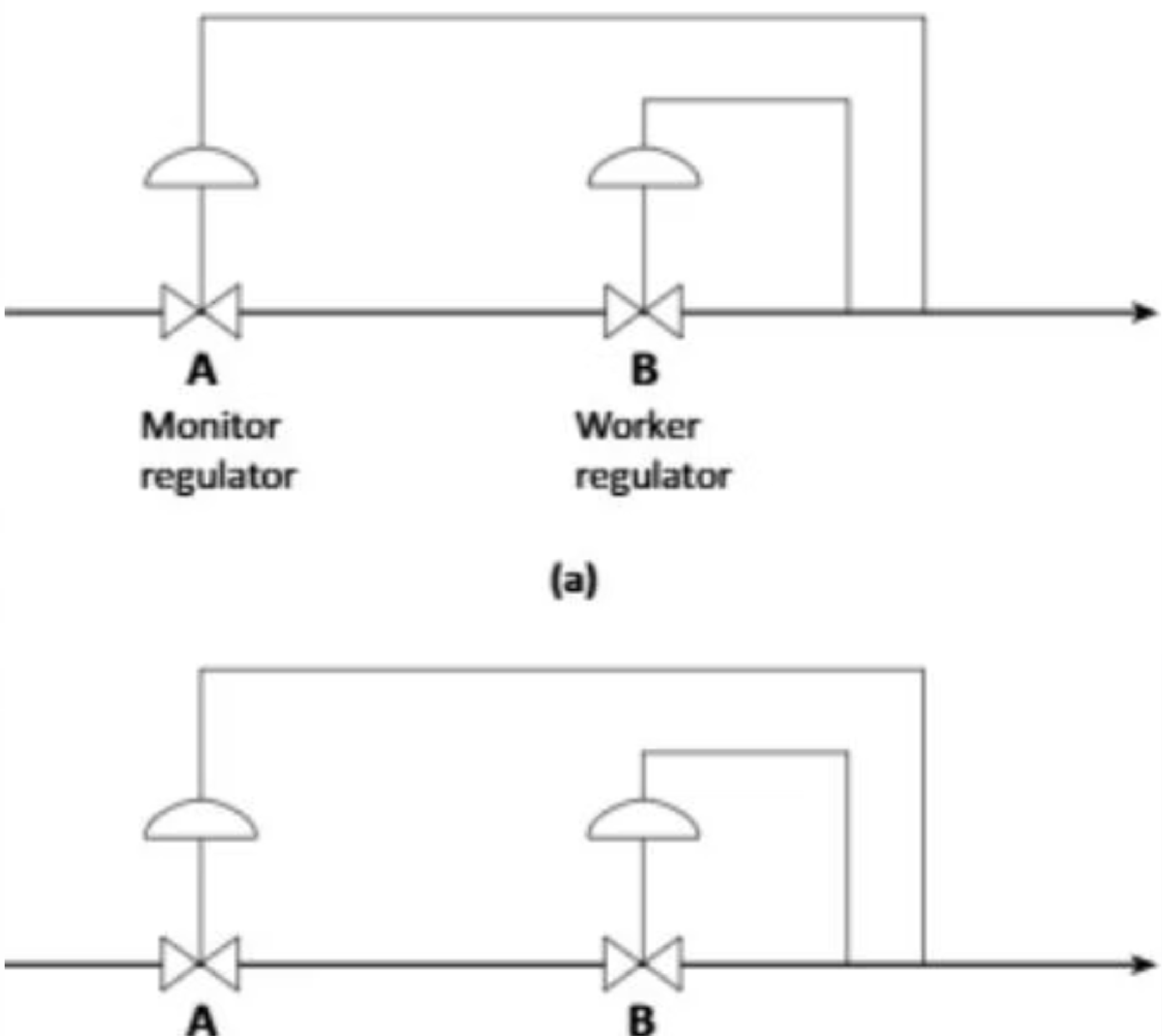
Pressure limiting regulator systems

Pressure limiting is overpressure control by containment. Pressure limiting regulators are listed as an acceptable overpressure protection device and are commonly used as preassembled units for 5 psi line pressure regulators (Figure 2-6). They are also used at service meters with the additional protection of a relief valve to ensure reliable protection (Figure 2-7).

Figure 2-6 Manufacture 5 psi line pressure regulator assembly Courtesy of Pietro Fiorentini S.p.a.

Wide-open monitors

Figure 2-8
Monitor regulator system



Series regulation

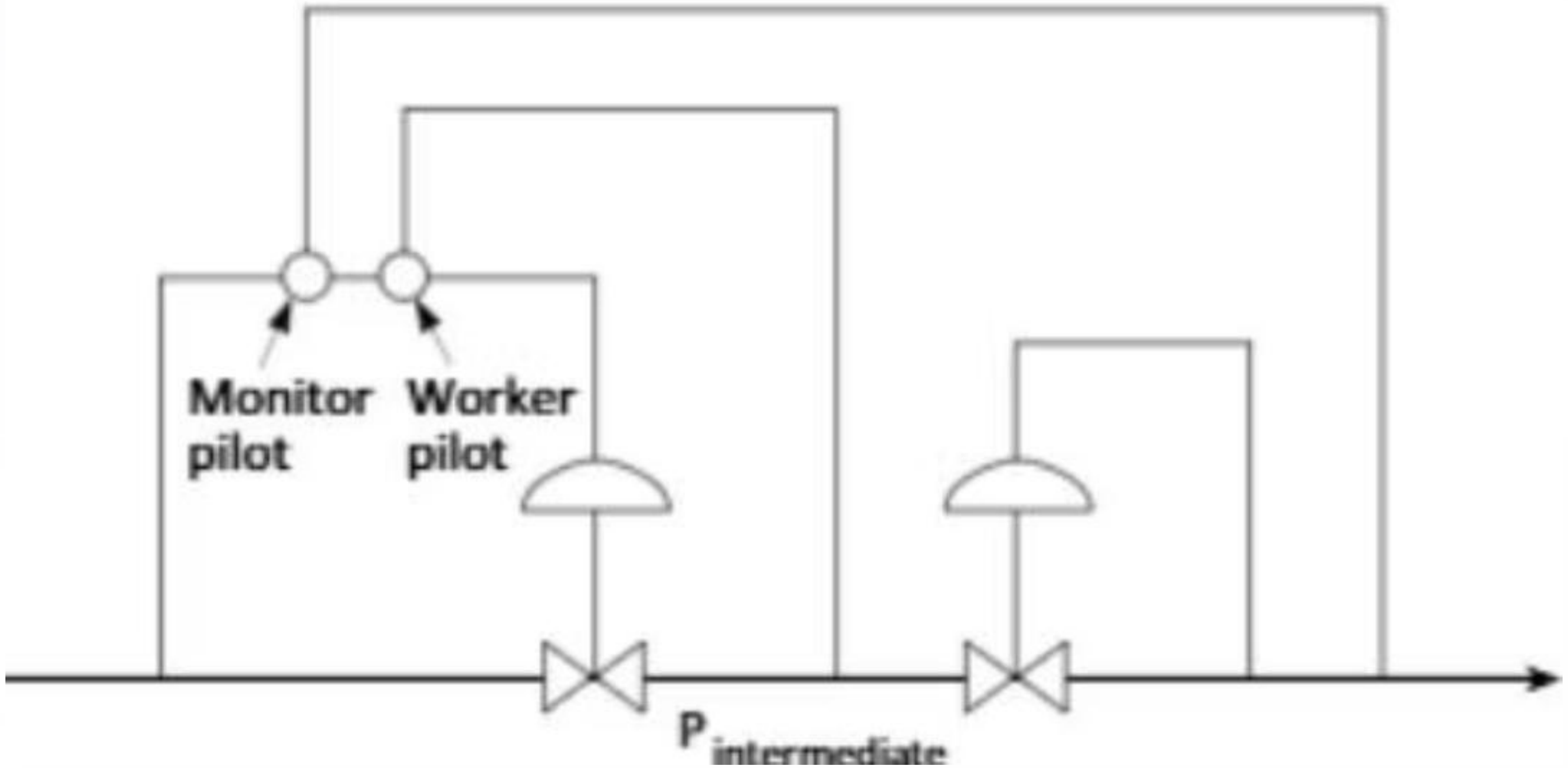
Series regulation is also known as two cut systems (Figure 2-10). Like the monitor system, they have two regulators set in the same pipeline and are available as preassembled units for 5 psi line pressure regulators (Figure 2-9).

Figure 2-9
Maxitrol 5 psi line pressure regulator assemble
Courtesy of Maxitrol Company

The first unit maintains an inlet pressure to the second valve that is within the maximum allowable operating pressure of the downstream system. Under this setup, if either regulator should fail, the resulting downstream pressure maintained by the other regulator would not exceed the safe maximum pressure

Figure 2-10
Series regulation system schematic

Working monitors



Working monitors use design elements from both series regulation and wide-open monitors. In a working monitor installation, the two regulators work continuously as series regulators to take two pressure cuts (Figure 2-11). Because both regulators are working, both are less likely to become clogged, sluggish, or stuck.

Figure 2-11 Working monitor

The worker pilot is connected as in series requlation and controls the intermediate pressure. Its setpoint is at some intermediate value that allows the system to take two pressure drops.

The monitor pilot is in series ahead of the worker pilot and is connected so that it senses downstream pressure. Its setpoint is set slightly higher than the required pressure.

When both regulators are performing properly, downstream pressure is below the setting of the monitor pilot, so it is fully open, trying to raise system pressure. Standing wide open, the monitor pilot allows the worker pilot to control the intermediate pressure. As demand changes, the downstream regulator adjusts flow and causes some change in the intermediate pressure. The worker pilot on the upstream requlator senses the change in the intermediate pressure and causes a repositioning of the upstream regulator. In this way, both regulators can work in response to changes in the pressure demand.

Automatic shut-off

Also known as overpressure shut-off (OPSO) or slam-shut (Figure 2-12), this device was previously introduced in the "Safety features" section of the previous chapter.

Chapter 3
Meters

A gas technician/fitter routinely measures gas flow rates to determine inputs. Calculating flow rates accurately requires a thorough knowledge of gas meter types, their operation, gas measurement standards, and correction factors.

Overview of Gas Meters

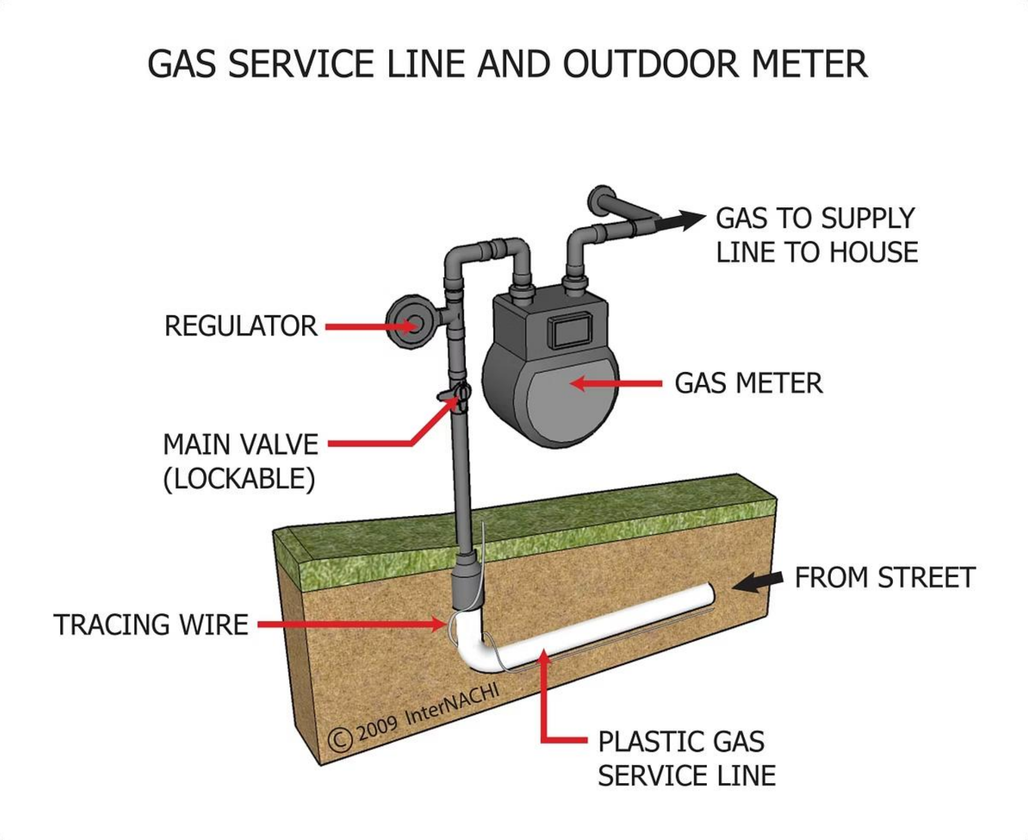
Purpose

A gas technician/fitter routinely measures gas flow rates to determine inputs. Calculating flow rates accurately requires a thorough knowledge of gas meter types, their operation, gas measurement standards, and correction factors.

Objectives

At the end of this chapter, you will be able to:

- describe types of meters; and
- determine gas flow rates.



Terminology

Term	Abbreviation (Symbol)	Definition
Burner input		See Firing rate (e.g., Btu/h, kW)
Clocking a meter		Using a meter to determine the input of a gas appliance
Firing rate		Amount of heat in the combustion chamber
Standard cubic foot	SCF	Quantity of gas contained in a cubic foot at the base temperature of 60°F and base pressure of 14.73 psia
Standard cubic metre	SCM	The quantity of gas contained in a cubic metre at the base temperature of 15°F and base pressure of 101.325 kPa
MBH		Thousands of BTUs per hour

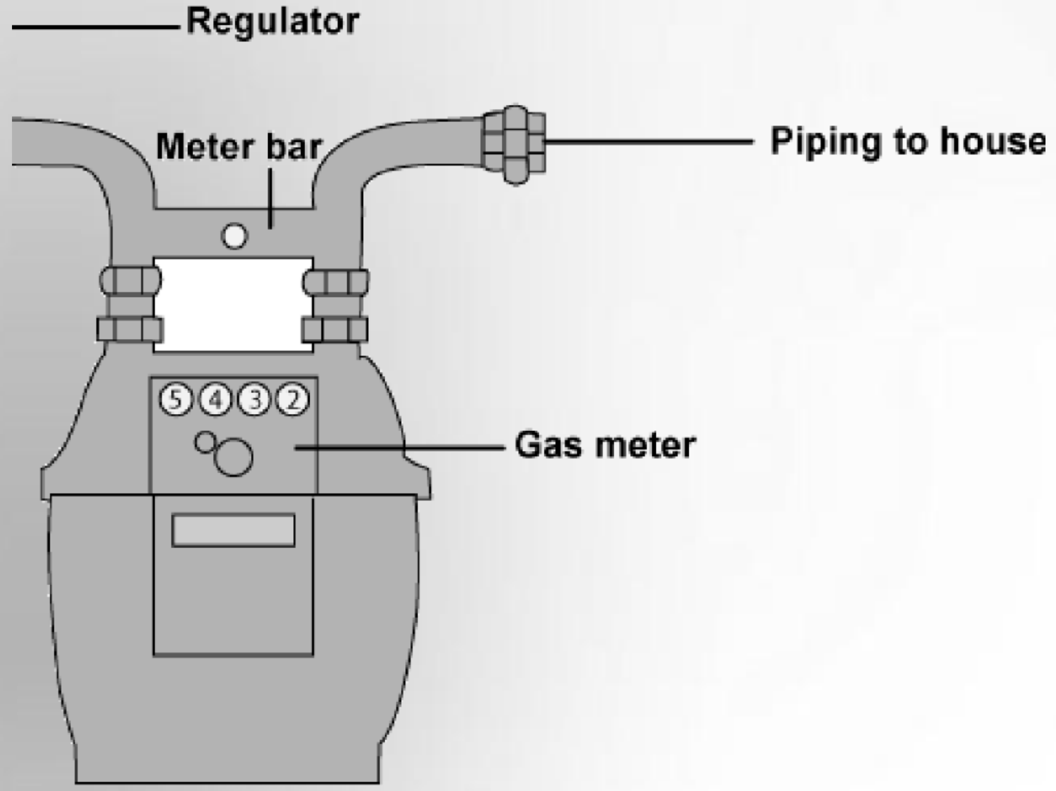
Types of Meters

Each piece of gas equipment is designed to produce a specific amount of heat in the combustion chamber. This amount of heat is called the firing rate or burner input.

Gas regulations require that the burner input be checked to ensure that it conforms to the equipment manufacturer's specifications. These are found on the rating plate attached to the appliance.

The common meters used in gas measurement may be grouped into two categories:

Meter	Description
Displacement meters	▪ Measure the total quantity, or volume, of gas that has passed through the meter at the time of the reading ▪ Can be adapted to provide rate of flow
Rate of flow meters	▪ Measure the instantaneous gas flow rate ▪ Can have totalizers to provide total volume flow



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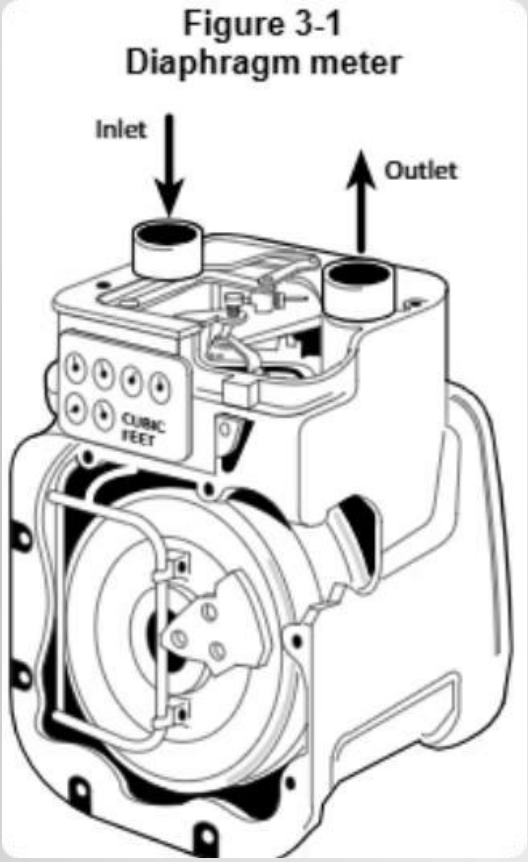
Displacement Meters

Displacement meters operate on the principle of positive volumetric displacement. A precise volume of gas passing through the meter is measured.

Two common types are used in the residential and commercial markets. These are:

- diaphragm (bellows) meter; and
- rotary (geared or lobed impeller) meter.

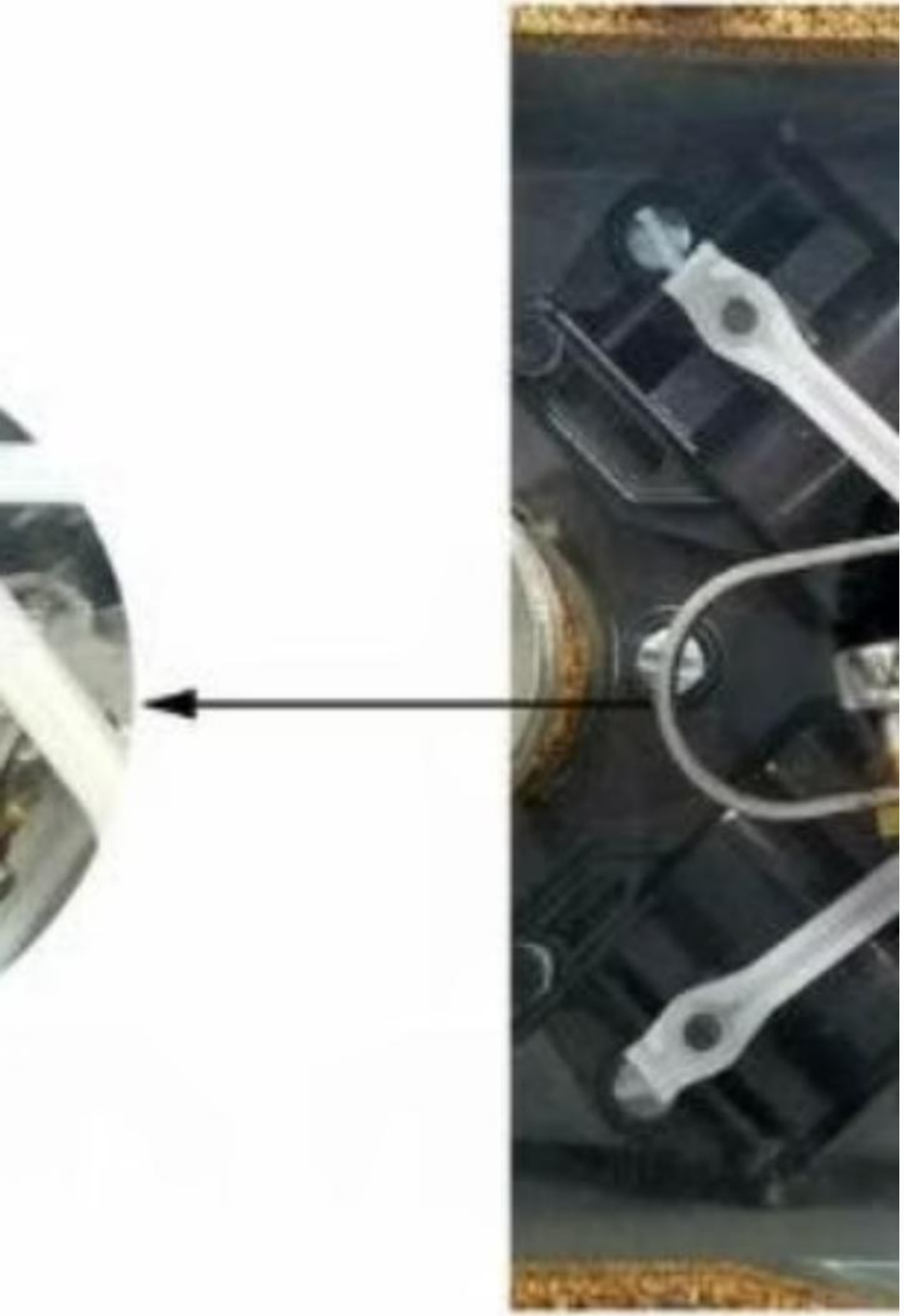


Diaphragm Gas Meter

The diaphragm gas meter (Figure 3-1) is the most frequently used gas meter at residential and light commercial installations. It provides highly accurate readings over most of its range.

Two bellows alternately fill and empty as the gas flows through the meter. The movement of the bellows is transferred through a series of linkages and gears that record the movement as a volume of gas on the display.

Diaphragm meters have capacities of up to 10 500 cu ft/h (300 m^3/h) when the piping system operates at less than 10 inches w.c. (2.5 kPa).

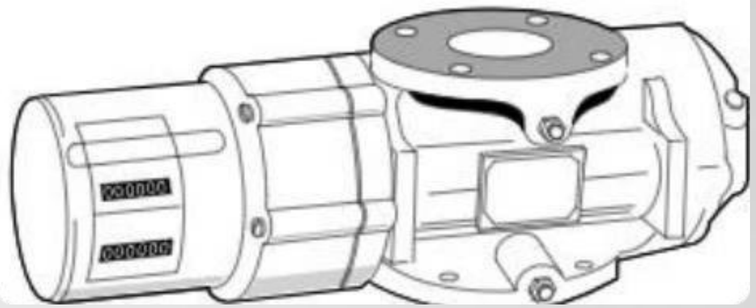


Temperature Correction Device

A temperature correction device (Figure 3-2) monitors the temperature of the gas flowing through the meter and causes the display dials to move slower in response to thinner hot gas or faster in response to denser cold gas, such that the end result is that the recorded gas volume is corrected to standard conditions of 1 ft3 at 60°F or 1 m3 at 15 °C.

Figure 3-2 Curved bimetallic temperature correction device Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

Figure 3-3
Rotary meter



Rotary Gas Meter

This displacement type of meter, shown in Figure 3-3, is mainly used by commercial or industrial customers. Rotary meters are available with pressure ratings of up to 1450 psig (10 000 kPa) and volume ratings of 175 to 105 000 cu ft/h (50 to 3000 m3/h).

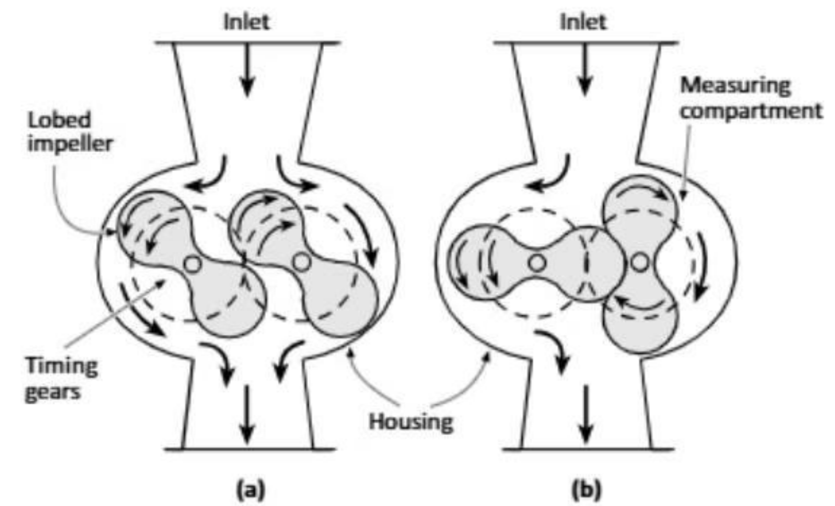


Figure 3-4
Cross-section of rotary meter shows two stages of impeller movement

Rotary Meter Cross-Section

Figure 3-4 shows the cross-section of a rotary meter at two stages of impeller movement. The two impellers are synchronized to rotate within a close-fitting housing. As the impellers turn, they displace a fixed volume of gas with each revolution, causing a slight differential pressure across the rotor. This allows a measured volume of gas to be discharged through the bottom of the meter.

A gear train transmits the number of rotations to a dial that displays the gas volume discharged.

Rotary Meter Maintenance

Rotary meters are oil filled, and the oil must be changed at least every two years.

Rate of Flow Meters

Rate of flow meters are referred to as "inferential" meters because the quantity of flow is determined by inference from interaction of the flowing stream and a primary element, such as an orifice plate, venture tube, ultrasonic device, turbine, or impeller inserted in the stream. They are non-positive displacement meters as such will have an accuracy flow range and cannot be used to sense very low flow such as leak testing or pilot flow. They are mostly used by utilities to measure how much gas is being generated or transferred at different stage of the distribution chain.

Orifice Meters

Orifice meters can be used for measuring air and gas flows on large commercial and industrial appliances. They simplify the combustion setup adjustments made on nozzle mixing burners.

The meter consists of the primary flow element and a differential flow transmitter. The primary element in these meters is an orifice plate in the pipe, which creates a differential pressure that varies in relation to the rate of flow (see Figure 3-5) as per Bernoulli's principle.

Figure 3-5
Orifice meter with differential pressure measured on a manometer

Orifice Flow Meter Components

A differential pressure flow transmitter converts the differential pressure across the ports into an electronic signal (Figure 3-6). To obtain an accurate reading, there should be a suitable straightening of the gas flow upstream of the orifice.

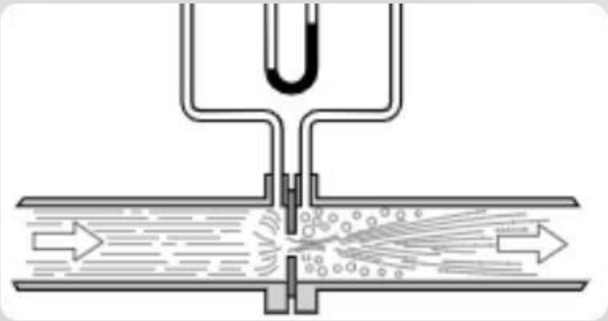
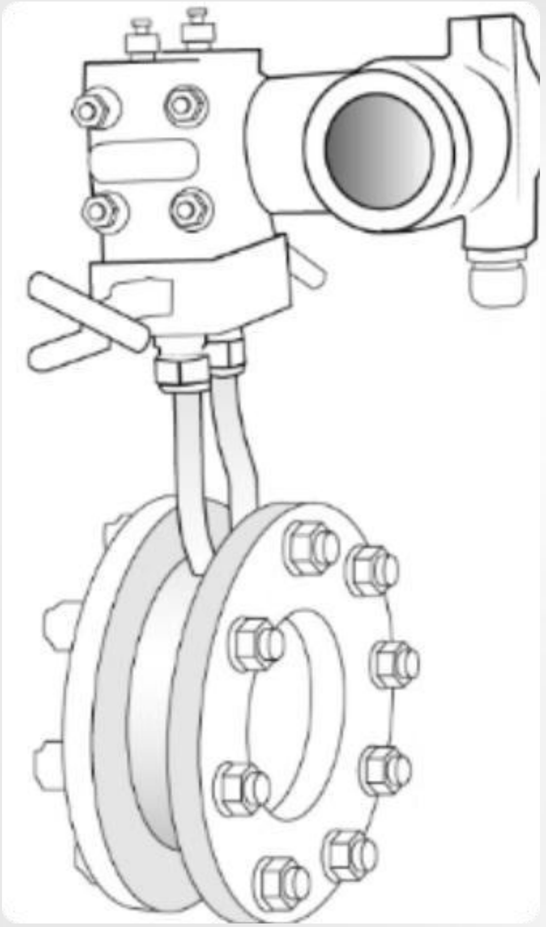


Figure 3-6 Orifice flow meter

Determining Flow Rates

Meters are used to determine flow rates, and so it is important to know how to read the meters in order to check the gas input. The Code requires that each piece of equipment be checked and adjusted to the correct firing rate. Inputs to gas appliances are based on standard temperature and pressure conditions. The measured volume of gas flowing through the meter may have to be corrected to standard conditions in order to determine the actual heat energy entering the combustion chamber.



	Imperial	Metric
Length	Inch, foot, yard, mile	Millimeter, centimeter meter, kilometer
Mass	Ounce, pound	Milligram, gram, kilogram
Capacity	Pint, gallon	Milliliter, centiliter, liter

Imperial Units	Metric Units
1 inch (in)	2.54 centimeters (cm)
1 inch (in)	25.4 millimeters (mm)
1 foot (ft)	30.48 centimeters (cm)
1 foot (ft)	0.30 meter (m)
1 yard (yd)	91.44 centimeters (cm)
1 yard (yd)	0.91 meter (m)
1 mile (mi)	1.61 kilometer (km)
1 ounce (oz)	28.34 grams (g)
1 ounce (oz)	29.57 milliliters (mL)
1 pound (lb)	453.59 grams (g)
1 pint (pt)	568.26 milliliters (mL)
1 gallon (gal)	4.55 liters (L)

Unit Conversion for Gas Meters

Gas meters are usually rated in metric or imperial units, and a gas technician/fitter should be able to convert between the two.

Being able to read and understand the reading on the meter gives the technician/fitter an indication as to whether the appliance is operating properly.

Calorific Value of Gas

To make accurate calculations of the quantity of heat in the combustion chamber, identify the calorific value of the gas in the piping system. If the calorific value is unknown, contact your local gas utility company.

The gas industry usually accepts the following calorific values for the three main fuel gases:

- natural gas 1000 Btu/cu ft or 10.35 kW/m3
- propane 2520 Btu/cu ft or 26 kW/m^3
- butane 3260 Btu/cu ft or 33.7 kW/m^3

Reading the Meter

There are two types of meter reading displays (Figure 3-7):

Display	Description
Dial-type	• The dial type meters are read according to the manufacturer's design of the display to determine the overall consumption of gas through the meter. • However, there are one or two additional test dials located on dial-type meters that a gas technician/fitter can use to check the piping system for leaks and check the input of individual appliances. • The latter procedure is often called "clocking the meter".
Direct reading-type	• Direct reading type of meters are easier to read than dial types because the actual reading is displayed as a number indicating cubic meters or cubic feet of gas. • However, like the dial-type meter, the diaphragm direct reading type of meter has one or two test dials on it that a gas technician/fitter can use to check the piping system for leaks and check the input of individual appliances.

Information on reading the meters is available from the local gas utility.

Figure 3-7 Gas meter displays Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

Electronic Rotary Meters

Modern rotary meters typically have an LED direct read display with multiple readout screens for different functions. Instead of test dials, the scroll pushbuttons are used to access the flow rate screen. Figure 3-8 shows the consumption screen on the left and the flow rate screen on the right.

Figure 3-8 Electronic rotary meters Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

Dial-Type Meter Dials

There are two types of dials on a dial-type gas meter:

Dial	Description
Consumption dials	Indicate the amount of gas that has been consumed and provides information to the gas utility for billing purposes
Test dials	Are used to determine the input to appliances and to indicate if there are any downstream leaks in the gas line

Reading a Dial-Type Gas Meter

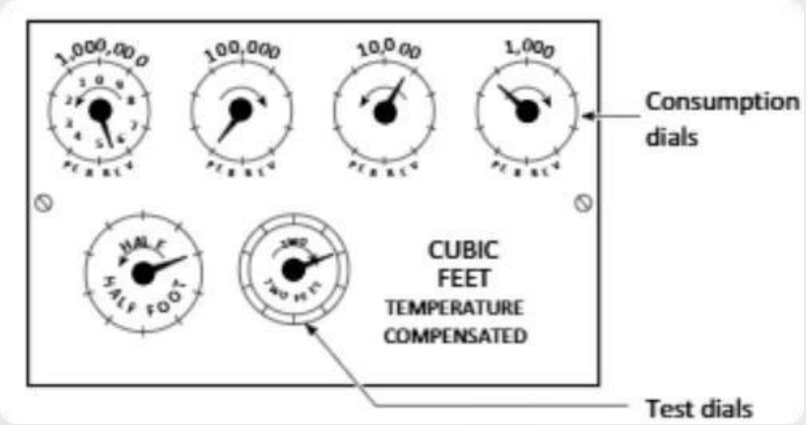


Figure 3-9 shows a typical dial-type gas meter and how the dials are read.

Note: Figure 3-9 shows a meter that measures in cubic feet. Meters may also measure in cubic meters.

Figure 3-9 A dial-type gas meter

Understanding Dial Readings

On the meter shown in Figure 3-9:

- every complete revolution that the test dial on the left makes represents half a cubic foot of das;
- the dial on the right measures two cubic feet of gas with every revolution; and
- check once again to see the units of measurement.

Calculating Flow Rates Through Meters

Using a meter to determine the input of a gas appliance is often called "clocking a meter". The following steps can be employed:

1. Make sure that the appliance being clocked is the only appliance in operation. If necessary, shut off the gas flow to all other appliances.
2. Make sure that the appliance is firing continuously throughout the clocking period. Avoid taking measurements immediately after start-up.
3. Take readings after about 5 minutes of continuous operation.
4. Record the time it takes for one complete revolution of the test dial that is moving at a reasonable speed (i.e., if the dial with the smallest scale is moving too fast to clock, use the dial with the larger scale.). Clock this two or three times and use the average.
5. Check the units of measurement of the meter.

Calculating Burner Input

6. Using the Imperial or metric formula given below, determine the volume of gas that would pass through the meter in one hour. Convert this volume to the amount of Btu/h that would be produced by that type of gas (i.e., multiply by 1000 Btu/ft3 for natural gas or 2500 Btu/ft3 for propane) and compare this to the input rating of the appliance given on the rating plate.

The measured input of an appliance should not exceed the rated input or be less than 90% of its rated input.

Unit	Measured input
Imperial	3600 seconds / nour x test dial size ft3 x # Btu / ft3 = Btu / h input
Metric	3600 seconds / how x test dial size m3 x # kw / m3 = Btu / h input

Example Calculation

For example, if the average time for one revolution of a 0.5 ft^3 natural gas meter dial was 30 seconds, the imperial formula is:

3600 seconds / hour x 0.5 ft^3 x 1000 Btu / ft^3 = 60,000 Btu / h input

1 meter	=	39.37008 inches	1 m	=	39.37008 in
1 meter	=	3.28084 feet	1 m	=	3.28084 ft
1 meter	=	1.09361 yards	1 m	=	1.09361 yd
1 kilometer	=	1093.6133 yards	1 km	=	1093.6133 yd
1 kilometer	=	0.62137 miles	1 km	=	0.62137 mi

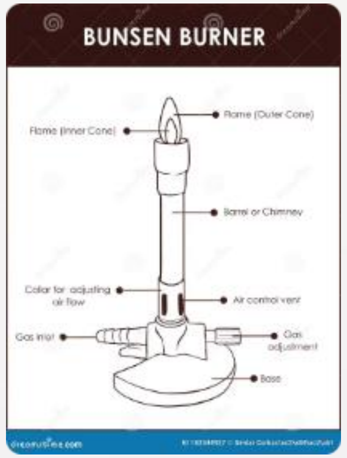
Imperial and Metric Conversions

Gas appliances are clocked in either Imperial or metric units. When both the meter and the appliance rating plates are expressed in the same measurement unit, calculations are straightforward.

At other times, an appliance rated in Btu may be connected to a meter showing its gas flow in cubic meters - or vice versa. In such cases, you use conversion factors to determine burner input in Imperial or metric values. Table 3-1 shows the Imperial and metric equivalences used in converting between the measurements.

Measurements	Imperial	Metric
For gas flow	35.31 cu ft	1 m3
For burner input	3412 Btu/h	1 kW

Table 3-1 Equivalences



Burner Input Conversion Factors

Based on natural gas having a calorific value of 1000 Btu per cu ft, Table 3-2 shows conversion factors used in calculating burner input.

	Btu/h	kW
1 cu ft/h	1.000	0.293
1 m3/h	35.310	10.35

Table 3-2 Burner input conversion factors

Flow Rates with Pressure (Volume) Compensation

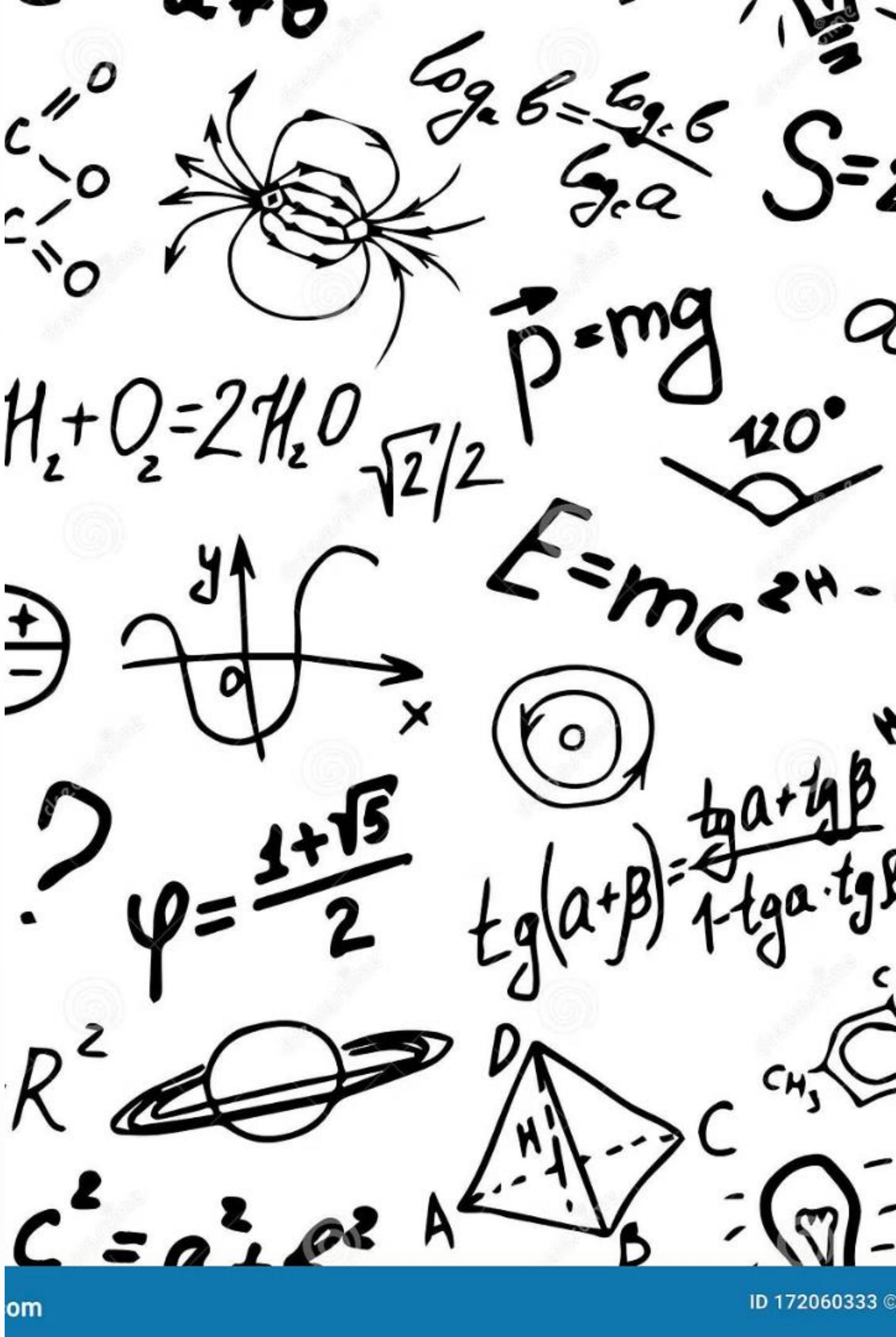
When gas pressures exceed 0.5 psig (3.5 kPa), the flow rates indicated by the meter's test dials may require correction for pressure to show the true flow rate. Use the following formula to calculate the flow rate as corrected for pressure:

$$Q = \left[\frac{3600 \times V}{t}\right]\left[\frac{\rho_g \quad \rho_w}{\rho_i}\right]$$

Formula Variables

Where

Description	
Q	Flow rate (cu ft/h or m3/h)
3600	Seconds per hour (constant)
V	Volume of test dial (cu ft or m3)
t	Time per revolution of test dial (in seconds)
Pa	Local atmospheric pressure (psia or kPa)
Pw	Working pressure of gas in meter (psia or kPa)
PS	Standard pressure (14.73 psia or 101.325 kPa)



Example Calculation: Pressure Compensation

The 2 cu ft test dial takes 18 seconds to complete one revolution.

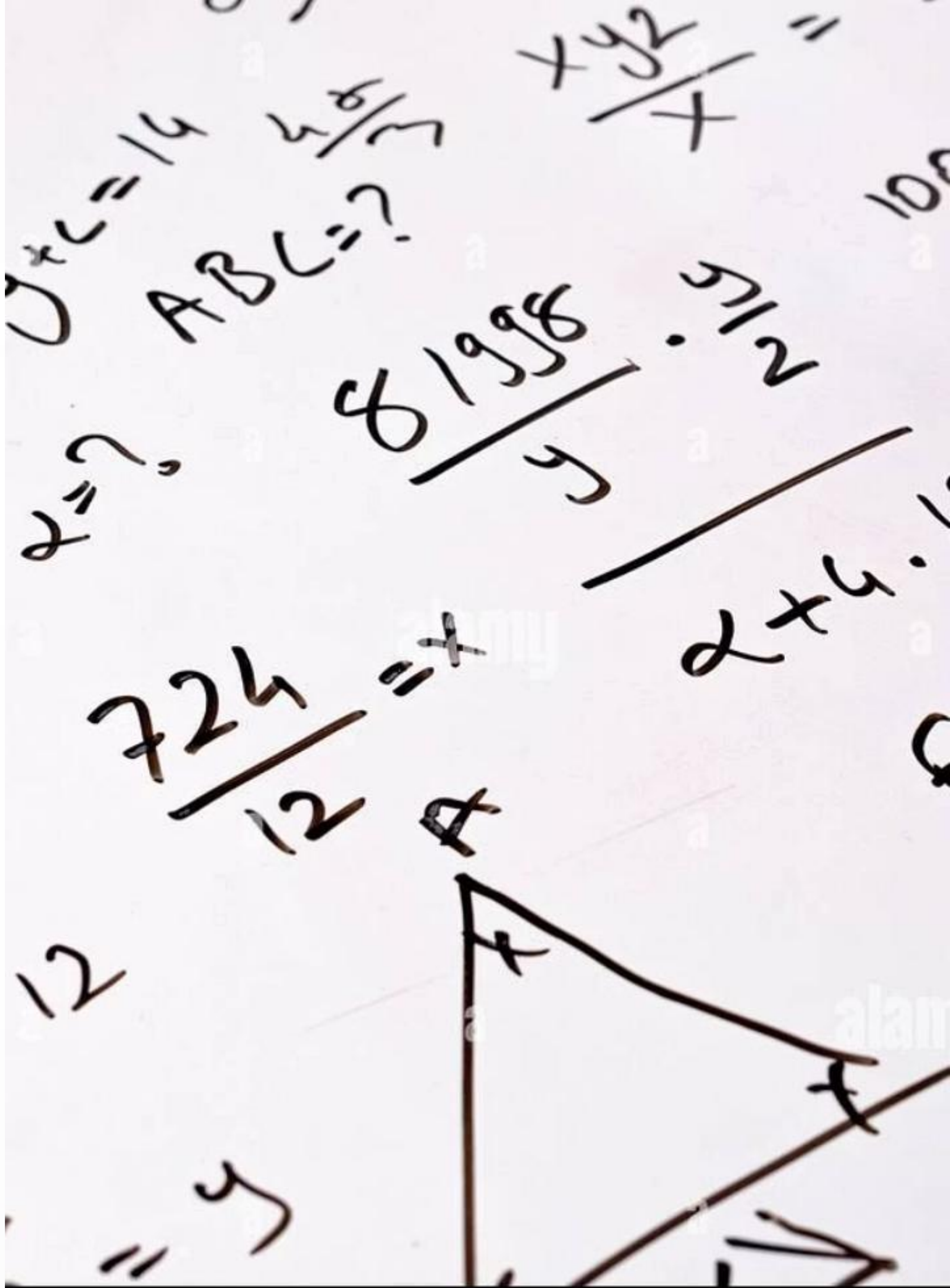
Calculate the flow rate to a burner in standard cubic feet if the working pressure in the meter is 5 psig and the local atmospheric pressure is 14.35 psia.

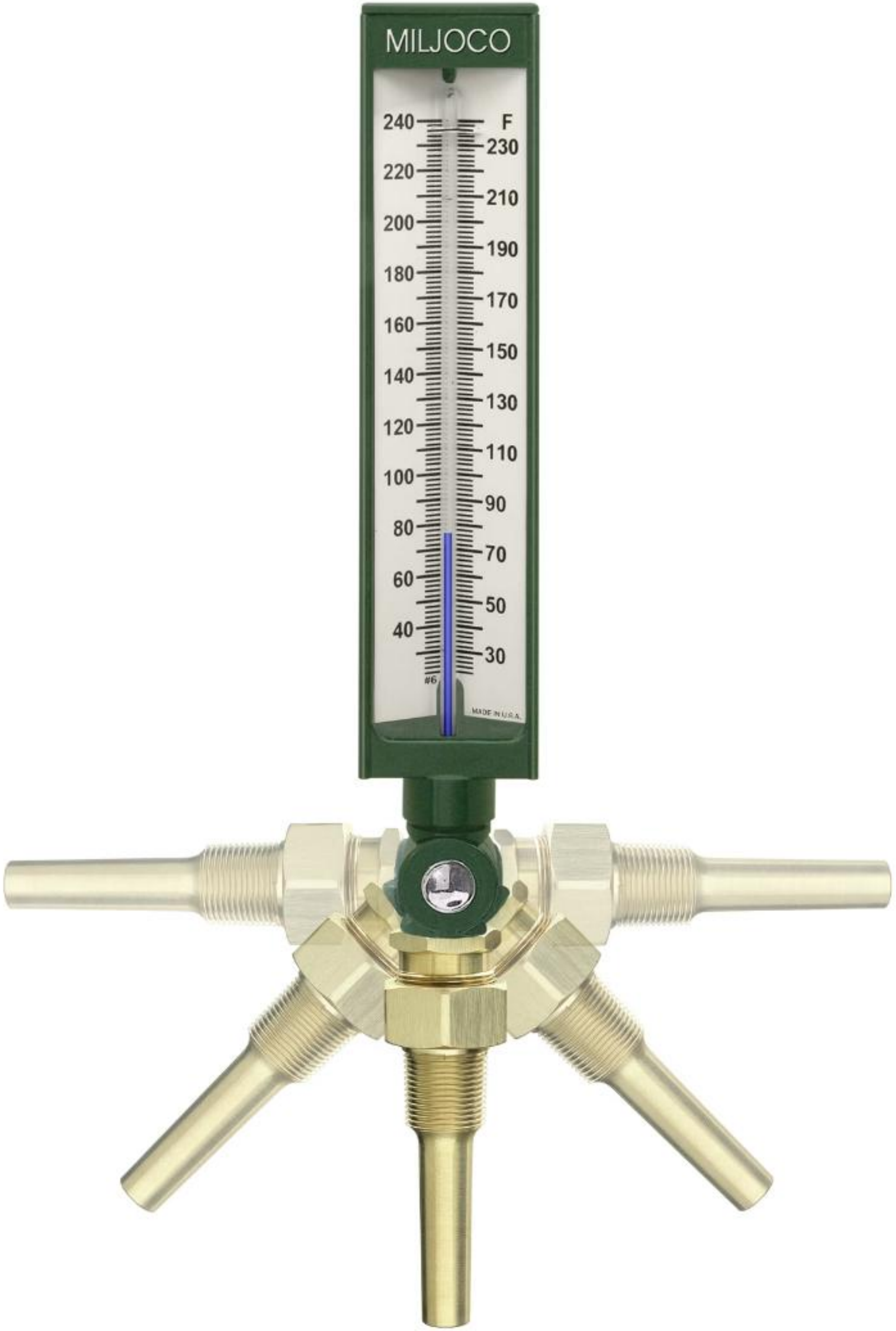
Solution: Pressure Compensation

Solution

Q = [3600 × 2 cu fi] [14.35 psia + 5 psig 14.73 psia + 18 sec = 400 cu fi/h x 1.313

= 525.44 cu ft/h





Flow Rates with Pressure (Volume) and Temperature Compensation

As the temperature of a gas increases, the volume of the gas increases, unless it is restricted in a container; in that case, the pressure in the container increases.

Most gas meters are equipped with temperature compensating devices to correct the actual volume of gas that passes through the meter to a standardized volume measurement at a standardized temperature (1 cubic foot at 60°F or 1 cubic metre at 15.4 °C).

When temperature is a factor in measuring flow rate with gas pressures over 0.5 psig, and the meter is not corrected, use the following formula to calculate the flow rate.

GAS LAW	FORMULA
Boyle's law	$P_1 V_1 = P_2 V_2$
Charles's law	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Gay-lussac's law	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$
Combined law	$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$
Ideal gas law	$PV = nRT$

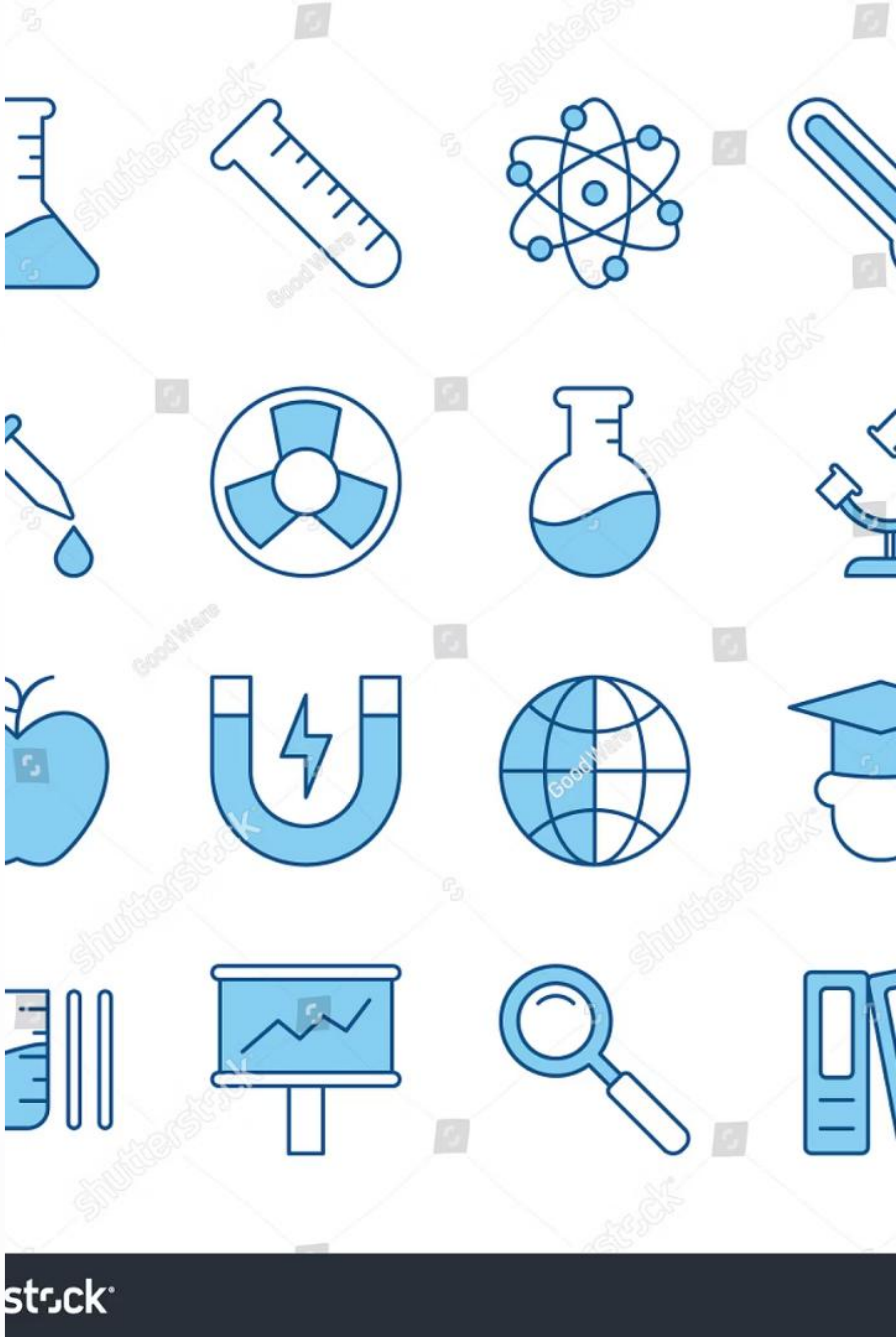
Temperature Compensation Formula

$$Q = \quad [3600 \times \frac{V}{t}]\,[\frac{P_a + P_w}{P_s}]\,[\frac{T_s}{T_a}]$$

Temperature Compensation Formula Variables

Where

Description	
Ts	Base temperature (60°F or 15 °C in absolute units)
Ta	Temperature of gas at meter in absolute units



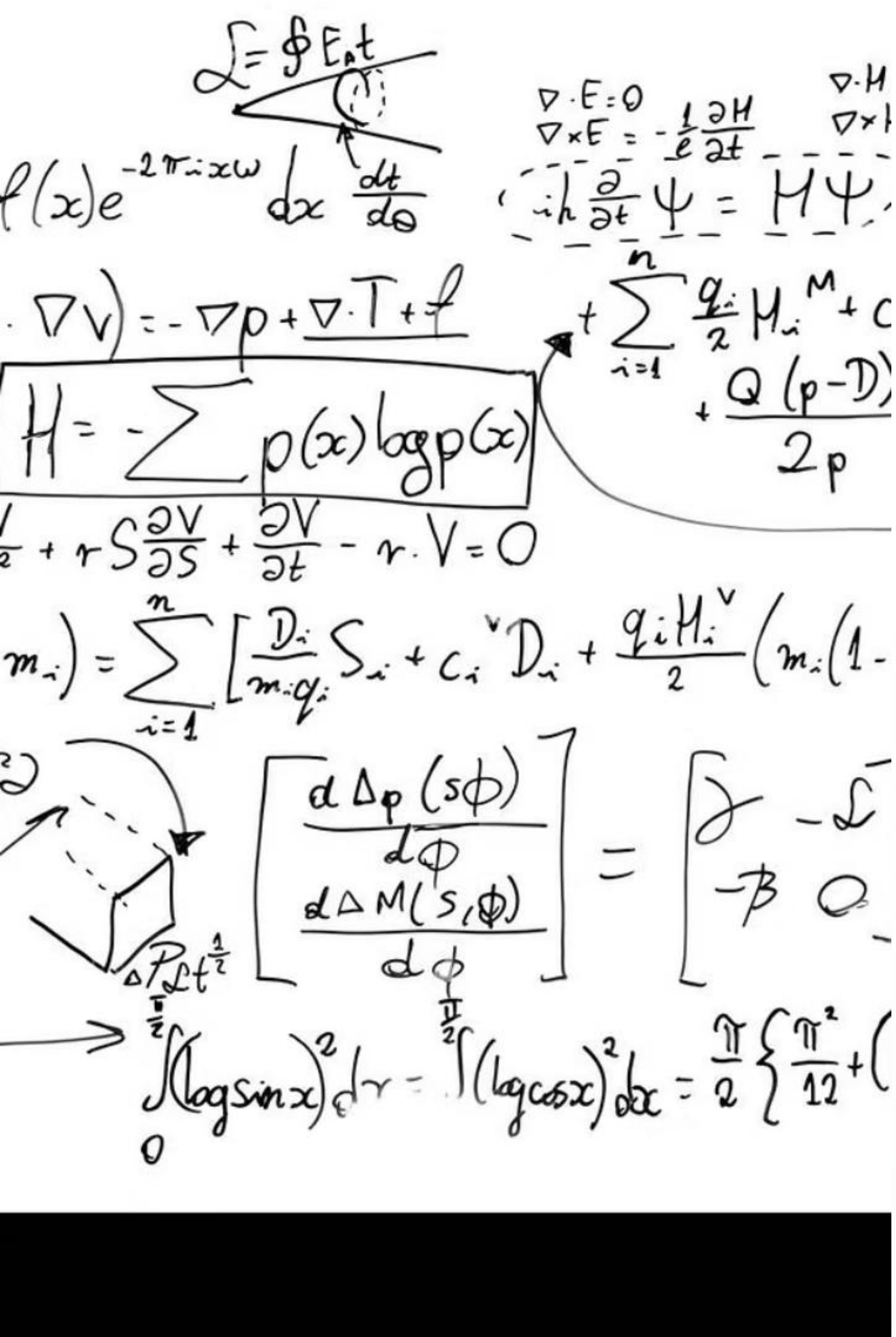
Example Calculation: Pressure and Temperature Compensation

A 5 cu ft test dial takes 20 seconds to complete one revolution.

The local atmospheric pressure is 14.55 psia and the pressure of the gas in the gas meter is 10 psig.

The temperature of the gas in the meter is 45°F.

Calculate the rate of flow to the burner in standard cubic feet.



Solution: Pressure and Temperature Compensation

Solution

Q = [3600 x 5 cu ft] [14.55 psia + 10 psig] [60° F + 460) ° R

= 900 cu fi/h x 1.66 × 1.02

= 1544.49 Std cu ft/h

Barometric Pressure Considerations

The local weather bureaus generally report barometric pressures that are corrected to sea level. In the above equation, the actual barometric pressure must be used. This can be obtained from the weather bureau.

Electronic Correctors

Electronic metering systems do all the things mechanical devices do (Figure 3-10), plus they have many more features such as continuous temperature, pressure, correction factor readouts, indications of gas flow conditions, and storage of load survey data. Some of this information can be accessed by the gas fitter using the scroll buttons, whereas more detailed information requires a computer connection with the appropriate software. The amount of information that can be accessed depends on the type and complexity of the device.

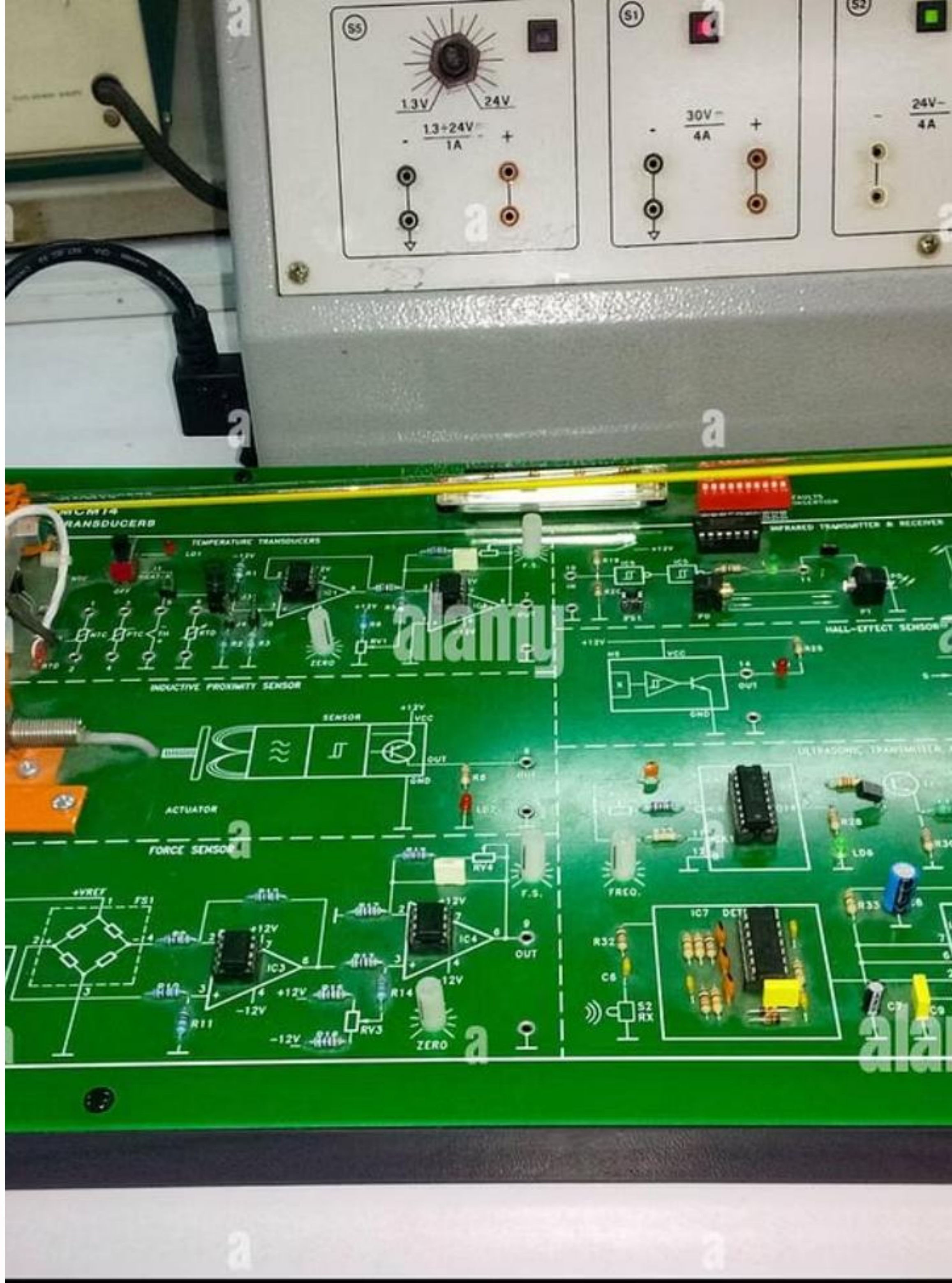
Figure 3-10 Electronic volume device for a gas rotary meter

Electronic Corrector Applications

Electronic metering devices are typically found on large commercial and industrial installations. Electronic correctors employ a magnetic sensing device to sense each rotation of the meter that represents the non-compensated (UNC-uncorrected) meter gas volume. The volumetric input pulses are also converted to base measurement conditions (COR-corrected).

Common Electronic Correcting Systems

- electronic temperature compensating index (TCI); and
- electronic volume corrector (EVC).



Electronic Temperature Compensating Index (TCI)

A TCI converts gas volume from operating conditions to reference temperature conditions. The temperature is measured by a temperature sensor located in the temperature well of the meter. A pressure transducer is also mounted inside the meter or as a separate piping connection.

Electronic Volume Corrector (EVC)

An EVC converts gas volume from operating conditions to reference pressure and temperature conditions. The temperature is measured by a temperature sensor located in the temperature of the meter. A pressure transducer is also mounted inside the meter or as a separate piping connection.

Correction Factor Calculation

The pressure and temperature correction factors are calculated by the same formulas previously mentioned. Depending on how the utility has set up the meter display, there are many parameters that could be viewed. Figure 3-11 shows the gas temperature and the calculated correction factor for a TCI. Because this meter is located indoors, the gas temperature is above the 15 ° C base conditions; therefore, the correction factor is less than one. Notice that the temperature correction factor is quite small unless the temperatures are very extreme.

TCI Temperature Displays

Figure 3-11 TCI temperature displays Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

Figure 3-12
EVC pressure factor display
Camosun College, Rodney Lidstone, licenced

EVC Unit Screens

In Figure 3-12, the two screens of an EVC unit show the absolute pressure on the left and the pressure correction factor on the right.

EVC Unit for Clocking Purposes

When using EVC unit for clocking purposes, the test dial display, also known as the live flow rate, may or may not be corrected depending on the parameter settings. You may have to contact the utility or meter manufacturer to verify which parameters are being displayed. The meter shown in

Live Corrected Flow Rate

Figure 3-13 is displaying the live corrected flow rate in cu ft/h for a 55 MBH appliance. This is useful for checking the appliance input, as there is no need to clock the meter or perform any correction factor calculations. You only need to multiply the flow rate by the appropriate CV of the gas for that area. Be aware that the utility could have the meter set up to display the live flow rate as cu ft/h or m3/h.

Figure 3-13 Live corrected flow rate in cu ft/h

Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

Using a Meter to Leak Test Piping Systems

A diaphragm or bellows meter can also be used for leak testing a piping system at working pressure. Rotary meters and orifice meters are not considered sufficiently accurate at measuring small volumes of gas to be reliably used for this purpose.

Steps for Leak Testing with a Diaphragm Meter

1. Turn off all gas consuming devices (appliances and pilots) as close to the appliance as possible.
2. Mark the position of both test dials on the meter display using a non-permanent marker. See Figure 3-9.
3. After waiting at least ten minutes, check to see if either dial has moved from the marked position.

Interpreting Leak Test Results

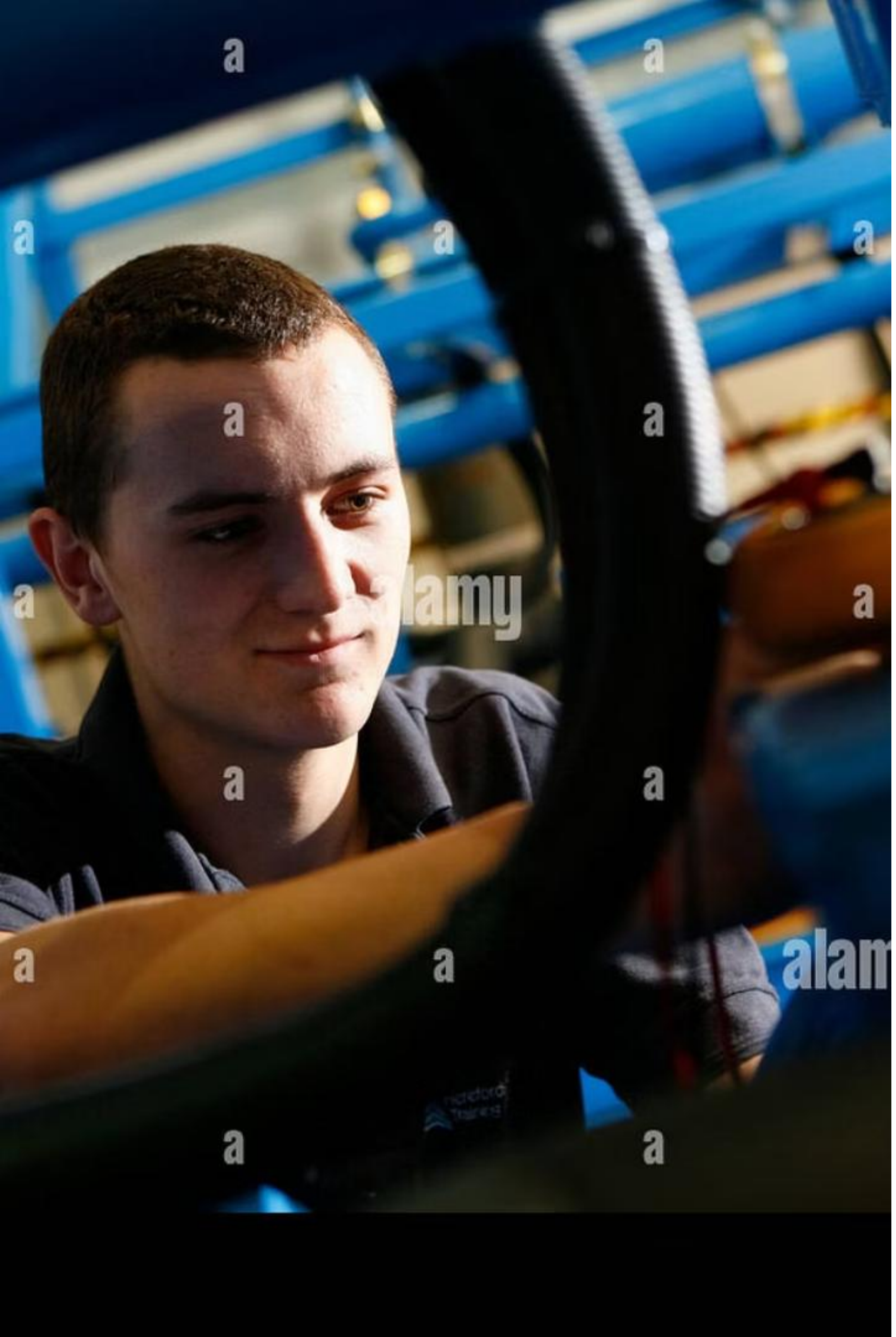
Movement of the test dials indicates that gas has passed through the meter and is leaking from the pipe (if all gas-consuming devices have been completely shut off). The source of the leak must be investigated and corrected.

Why Mark Both Test Dials?

Both test dials are marked during the meter leak test in case one dial moves back to its original position at the end of the test. Since the two dials are moving at different speeds, they are unlikely to both return to their original position.

Importance of Accurate Flow Rate Measurement

Accurate measurement of gas flow rates is crucial for ensuring the safe and efficient operation of gas appliances. It helps in verifying that the burner input conforms to manufacturer specifications and prevents potential hazards.



Role of Gas Technicians

Gas technicians and fitters play a vital role in maintaining gas systems. Their expertise in understanding different meter types, performing accurate calculations, and conducting leak tests is essential for public safety and optimal appliance performance.

Advancements in Metering Technology

The evolution from mechanical dial-type meters to advanced electronic correctors highlights the continuous improvement in gas measurement technology. These advancements provide more precise data and additional features for comprehensive monitoring and analysis of gas flow.

4

Ensuring Compliance and Safety

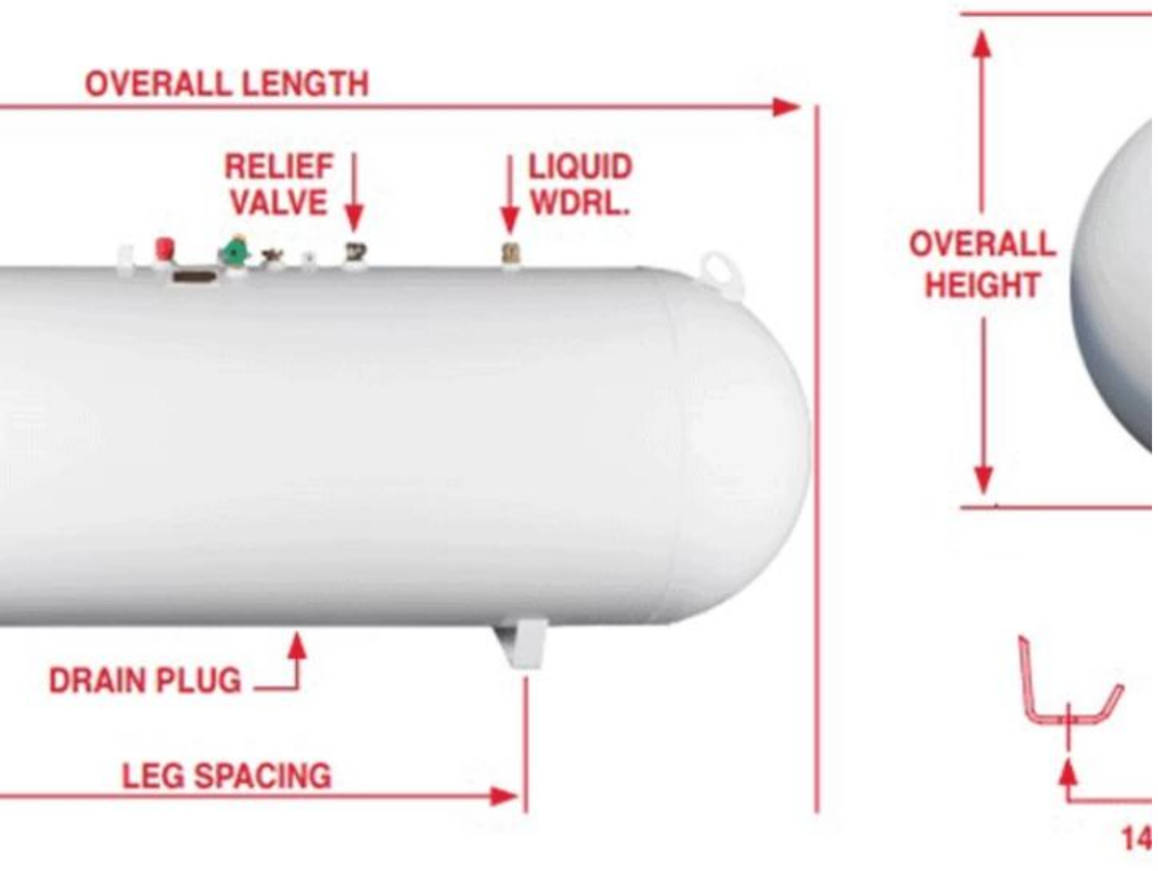
Adhering to gas regulations and standards is paramount. Regular checks of burner input and diligent leak testing procedures are critical steps in ensuring that gas equipment operates safely and efficiently, protecting both property and lives.

Continuous Learning in Gas Measurement

The field of gas measurement is dynamic, with ongoing developments in technology and best practices. Continuous learning and staying updated with the latest tools and techniques are important for gas technicians to excel in their profession and ensure high standards of service.

Chapter 4
Fuel Containers

Propane gas equipment is normally supplied from either a cylinder or a tank. To ensure a steady supply of gas, the container and accessories must be sized and installed to meet the appliance needs under all temperature and weather conditions.



XIMATE ABOVEGROUND VESSEL DIMENSIONS AND SPECIFICAT

HEAD TYPE	OVERALL LENGTH	OVERALL HEIGHT	LEG** WIDTH	LEG** SPACING	WEIGHT (lbs.)
Ellip.	5'-8"	2'-10"	1'-1 1/2"	2'-10 1/2" or 3'-11"	260
Hemi.	7'-10"	3'-6"	1'-5"	4'-11"	480
Hemi.	9'-7"	3'-6"	1'-5"	5'	620
Hemi.	10'	4'	1'-8"	5'	950
Hemi.	16'	4'-3"	1'-8"	10'-1"	1,800
Ellip.	17'-4"	4'-9"	1'-9"	11'-7"	2,650
Ellip.	23'-11"	4'-9"	1'-9"	16'	3,520

ns shown are approximate. Individual vessels may vary.

Objectives

1. **Describe Cylinders, Tanks, and Accessories**

   Understand the different types of propane storage and their components.

2. **Describe How to Size and Install Cylinders and Tanks**

   Learn the procedures for selecting and placing propane containers to meet demand.

Terminology

Term	Abbreviation (Symbol)	Definition
Prestolite threaded connection	POL	Fitting unique to vapour service that cannot accidentally be connected to a liquid line
Service connection		Outlet of the service valve
Wetted surface area		Specific area of the tank that comes in contact with the propane liquid

Cylinders, Tanks, and Accessories

Natural Gas Supply

Natural gas is normally supplied from a natural well. It travels from the well through a large pipeline to a city or town gate station operated by local utility. From here it is distributed to each building via service piping. It passes through a meter set before it reaches the consumer. A steady supply of natural gas is ensured if the piping and tubing systems, as well as the required pressure regulators, are operating correctly.

Propane Supply

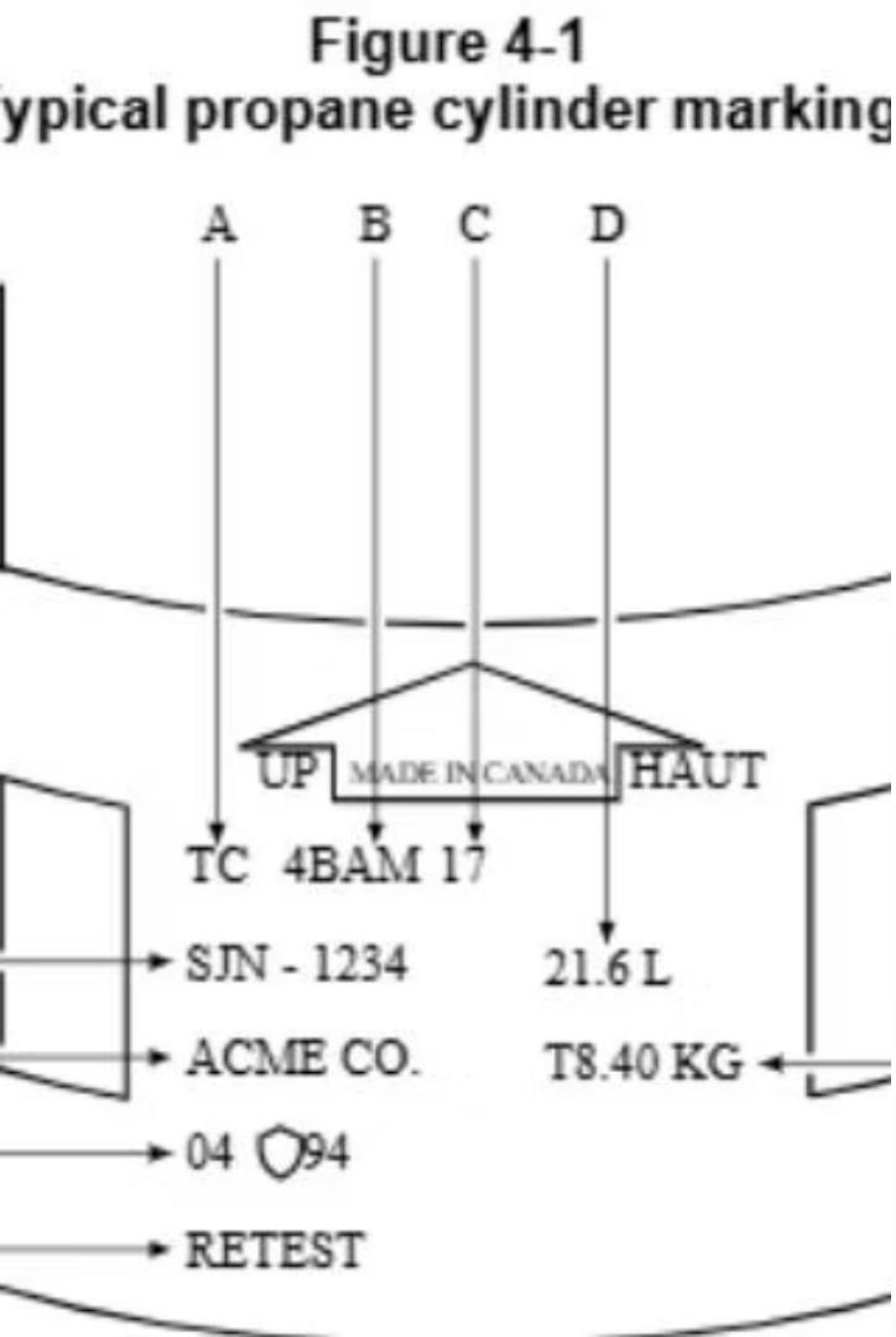
For propane, sufficient storage capacity is required to meet the total demand of installed appliances and equipment, especially during cold weather. It is thus extremely important to select the correct propane container.

Propane Container Services and Regulations

Propane companies normally lease propane tanks and cylinders to customers and then provide a filling service for the tank and an exchange service for the cylinder.

Propane cylinders are intended for transportation both empty and filled, and tanks are intended to remain stationary once they are placed in service and filled.

Due to the need for safety, a number of standards and regulations that govern the type, location, and size of propane storage containers are in place. Refer to CSA B149.2 for these requirements.



Cylinders

CSA B149.2 states that all cylinders must be fabricated, tested, inspected, and legibly marked in accordance with CSA B339 and the Transportation of Dangerous Goods Regulations from Transport Canada (www.tc.gc.ca).

Refillable cylinders will have the important information shown in Figure 4-1 stamped on their protective collar.

Cylinder Markings: Construction Standard

Additional information regarding these markings is provided below.

Construction Standard

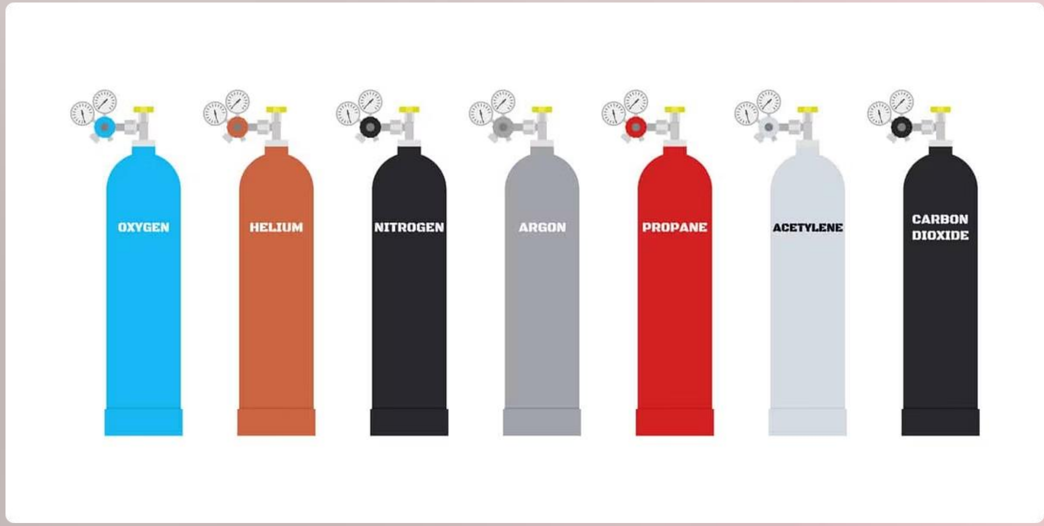
Only TC standards are currently acceptable in Canada. However, older cylinders may reference CTC or DOT (e.g., CTC/DOT 240 4BA). Note: "M" at the end indicates metric units.

Manufacturer's Name

Such as: Worthington, Manchester, etc.

Date of Manufacture

Such as: 12 10 or Dec 10



Cylinder Markings: Re-inspection and Capacity

Date of Re-inspection

Cylinders with a water capacity of 240 lb or less must be recertified within 10 years of the date of manufacture or date of re-inspection. The cylinder recertification facility must stamp the collar with the cylinder's identification number and date of recertification (e.g., AAO311096).

Note: Prior to June 1994, it was acceptable to simply stamp the date of re-inspection followed by an "E" meaning visual re-inspection.

Capacity

The volume of the cylinder is given in pounds or kilograms of water at 130°F (e.g., WC 240#). This is the capacity of the cylinder when filled with water. From this, you can quickly determine how much propane can be safely stored in the container by multiplying by .42 (since propane is .51 the weight of water and the cylinder must only be filled to the 80% capacity to allow for expansion). Therefore, a 240 lb w.c. cylinder can safely hold 100 lb of propane.

Note: The largest cylinder that is made has a capacity of 1000 lb of water (420 lb propane).

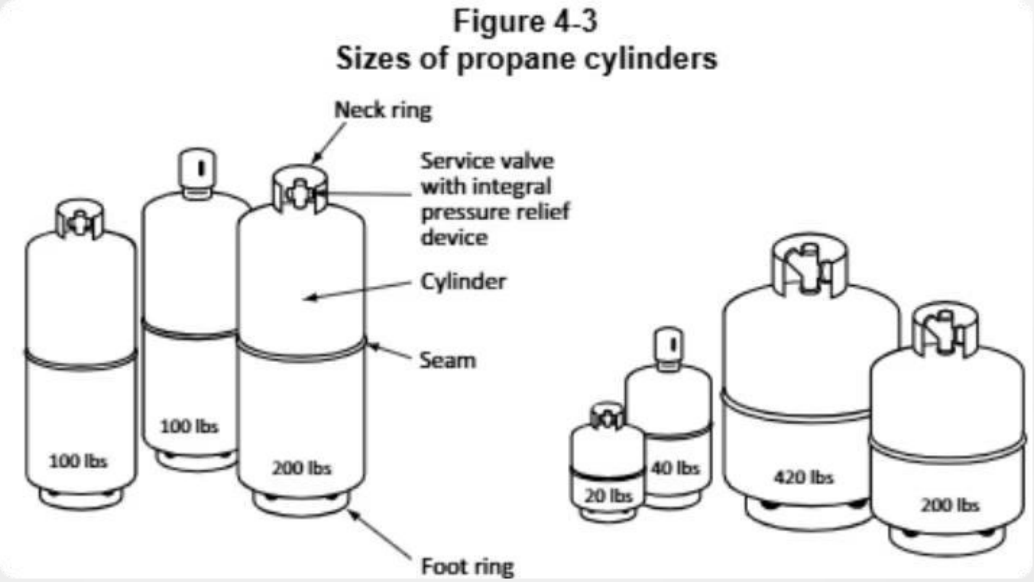
Cylinder Filling Methods and Overfill Prevention

Figure 4-2
Overfill prevention device (OPD)

When using a scale to fill, note that the weight of the cylinder and valves when empty is added to the weight of propane put into it.

Some cylinders have a "spit valve" for filling without a scale. The spit valve is a small orifice threaded valve equipped with a dip tube that extends down to the 80% level of the tank. When the spit valve is manually opened during filling operations, it will start to spit liquid propane when the liquid level reaches 80% at which time the filling operation must be stopped.

Cylinders manufactured after January 1, 2008, with a capacity of 40 lb (18.2 kg) or less were required to have an overfill prevention device (OPD) in compliance with UL 2227, Standard for Overfilling Prevention Devices. An OPD, as shown in Figure 4-2, prevents filling beyond the 80% capacity.



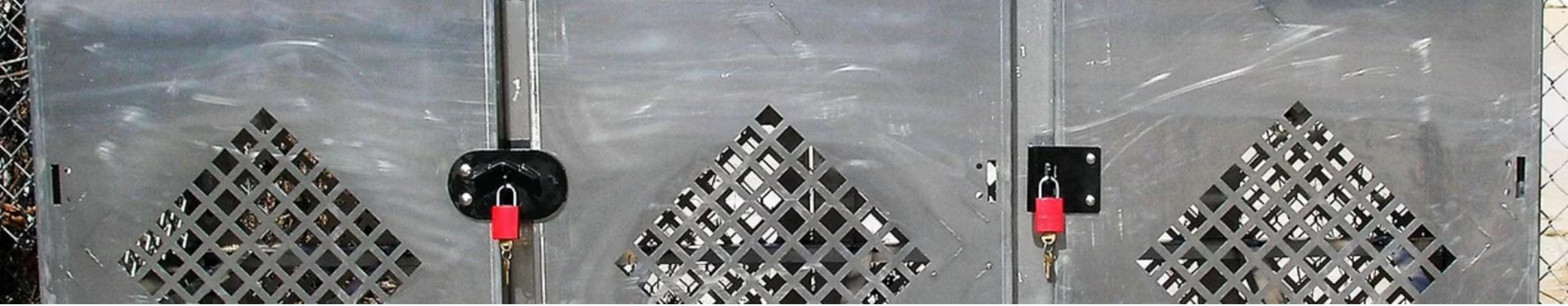
Working Pressure Rating and Cylinder Components

Working pressure rating is usually given as 375 psig (2586 kPa) since the relief set point of cylinder relief valves is 375 psig.

Cylinders come in a variety of sizes. Figure 4-3 shows the common sizes as well as components of a typical propane cylinder.

Common Propane Cylinders: Stationary Use

Type of service	Typical use	Propane capacity lb (kg)	US gal	Water capacity lb (liters)	Common DOT and TC* Codes
Stationary	Homes, business	420 (191)	100	1000 (454)	4B, 4BA, 4BW
Stationary	Homes, business	300 (136)	71	715 (324)	4B, 4BA, 4BW
Stationary	Homes, business	200 (91)	47	477 (216)	4B, 4BA, 4BW
Stationary	Homes, business	150 (68)	35	357 (162)	4B



Common Propane Cylinders: Exchange Use

Type of service	Typical use	Propane capacity lb (kg)	US gal	Water capacity lb (liters)	Common DOT and TC* Codes
Exchange	Homes, business	100 (45)	24	239 (108)	4B, 4BA, 4BW
Exchange	Homes, business	60 (27)	14	144 (65)	4B, 4BA, 4BW

Common Propane Cylinders: Motor Fuel Use

Type of service	Typical use	Propane capacity lb (kg)	US gal	Water capacity lb (liters)	Common DOT and TC* Codes
Motor fuel	Tractor	100 (45)	24	239 (108)	4B, 4BA, 4BW
Motor fuel	Tractor	60 (27)	14	144 (65)	4B, 4BA, 4BW
Motor fuel	Forklift	43.5 (19.7)	10	104 (47)	4B, 4BA, 4BW, 4E
Motor fuel	Forklift	33.5 (15.2)	8	80 (36)	4B, 4BA, 4BW, 4E
Motor fuel	Forklift	20 (9)	4.7	48 (22)	4B, 4BA, 4BW, 4E
Motor fuel	Forklift	14 (6.4)	3.3	34 (15.4)	4B, 4BA, 4BW, 4E

Common Propane Cylinders: Portable Use

Type of service	Typical use	Propane capacity lb (kg)	US gal	Water capacity lb (liters)	Common DOT and TC* Codes
Portable	Rec. vehicles	40 (18)	9.5	95 (43)	4B, 4BA, 4BW, 4E
Portable	Rec. vehicles	30 (13.6)	7.1	72 (32.7)	4B, 4BA, 4BW, 4E
Portable	Rec. vehicles	25 (11.3)	5.9	59.5 (27)	4B, 4BA, 4BW
Portable	Rec. vehicles	20 (9)	4.7	48 (22)	4B, 4BA, 4BW, 4E
Portable	Rec. vehicles	10 (4.5)	2.4	23.8 (10.8)	4B, 4BA, 4BW, 4E
Portable	Indoors, trailers	5 (2.3)	1.2	12 (5.4)	4B, 4BA, 4BW, 4E
Portable	Torches, camping	0.93 (0.42)	0.2	2.2 (1)	39 (disposable) 4B240 (refillable)

* TC codes include M to designate metric specifications.

Propane Storage Tanks

When a larger installation is planned, propane storage tanks are often required to deliver a sufficient flow of propane to meet the demand of connected appliances. Tanks may also be preferred when the number of cylinders required is inconvenient to handle or when the delivery schedule is not frequent enough to ensure a continuous supply.

As with propane cylinders, propane storage tanks have a label attached to them to identify their characteristics. A typical ASME propane storage tank nameplate is shown in Figure 4-4.

ASME Propane Storage Tank Nameplate

Figure 4-4 Typical ASME propane storage tank nameplate

CERTIFIED BACME INDUSTRIES, INC. ANYTOWN, ONTARIO, CANADA

MDMILL S/N CRN CRN OLLN.

START SIMP

°F AT

PSI STEAR

ABOVEGROUND SERVICE. THIS CONTAINER SHALL NOT

EXCESS OF

PSI

SH. THK. HD. THK. THK. D. RAD.

CONTAIN A PRODUCT HAVING A VAPOUR PRESSURE IN

AT A TEMPERATURE OF OF OF OUTSIDE AREA

Nameplate Information: MAWP and CAP

MAWP

- Gives the maximum allowable working pressure
- Minimum is 250 psig

CAP

- Gives the tank capacity in US water gallons

Nameplate Information: CRN and O.I.N.

CRN

- The Canadian registration number
- Indicates compliance with the Code and the regulations

O.I.N. (in Ontario)

- In Ontario, the O.I.N. indicates compliance with Ontario regulations for pressure vessels.

Nameplate Information: Service Type

The label will also state whether it is for above-ground or underground service.

The style of the nameplate varies among manufacturers and between the US and Canada.

All approved tanks will have a CRN on the label.

Common ASME Propane Storage Tanks: Domestic Service

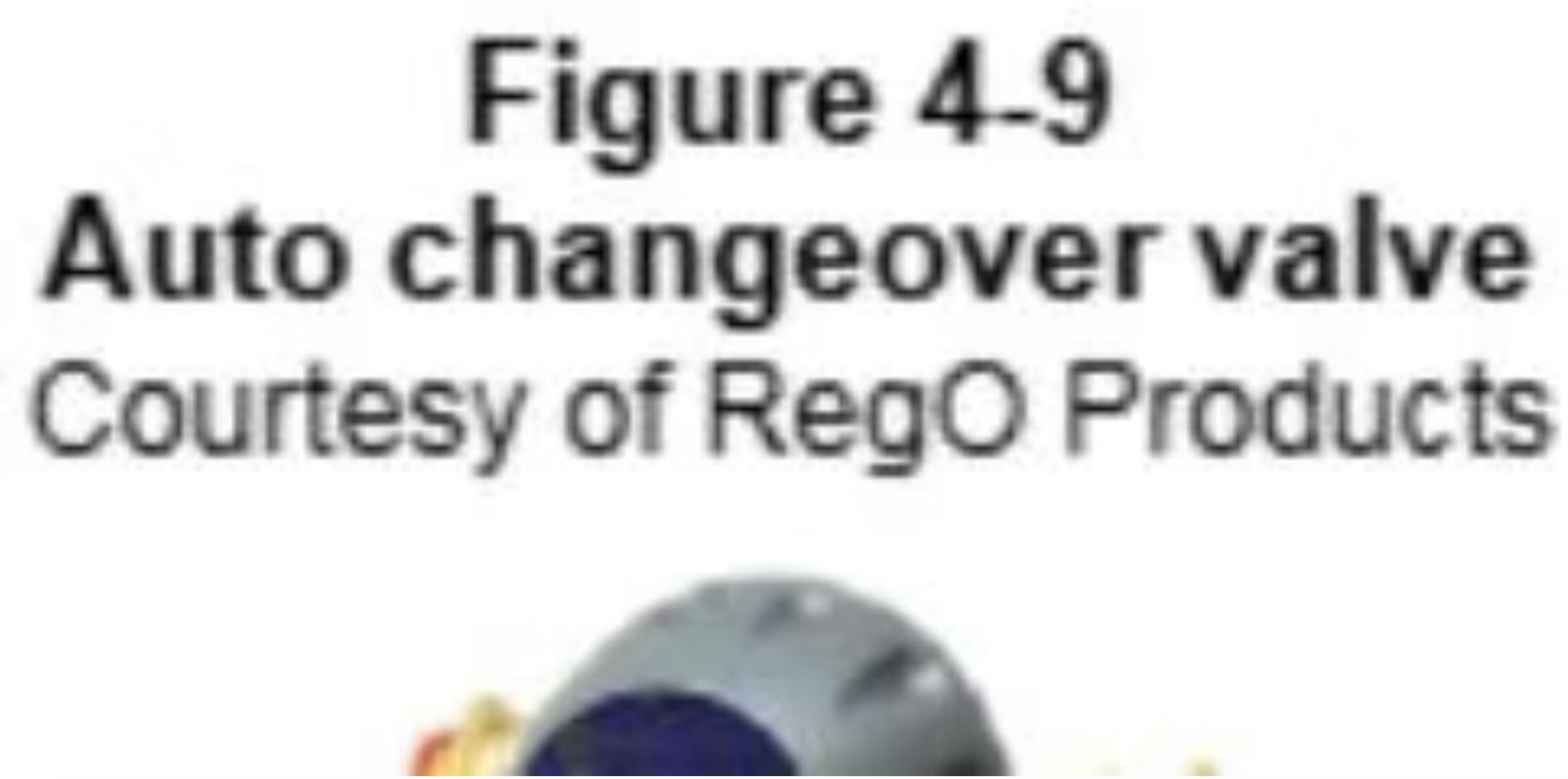
Type of service	Water capacity US gal (litres)	Propane capacity gal* (liters)	Propane capacity (lb)
Domestic	100 (379)	80 (301)	338
Domestic	125 (473)	100 (379)	423
Domestic	150 (268)	120 (454)	508
Domestic	250 (946)	200 (757)	848
Domestic	325 (1230)	260 (984)	
Domestic	500 (1893)	400 (1514)	
Domestic	1000 (3.8 m3)	800 (3 m3)	

Common ASME Propane Storage Tanks: Industrial and Bulk Service

Type of service	Water capacity US gal (litres)	Propane capacity gal* (liters)	Propane capacity (lb)
Industrial/agricultural	1000-5000 (3.8-19 m3)	800-4500 (3-17 m3)	
Service stations	1000-6500 (3.8-24.6 m3)	800-5850 (3-22 m3)	
Bulk plant or storage	12 000-18 000 (45.4-68 m3)	10 800-16 200 (41-61 m3)	
Bulk plant or storage	20 000-30 000 (76-114 m3)	18 000-27 000 (45.4-102 m3)	
Bulk plant or storage	30 000-60 000 (114-227 m3)	27 000-54 000 (102-204 m3)	
Bulk plant or storage	60 000-120 000 (227-454 m3)	48 000-96 000 (182-364 m3)	

* Based on propane specific gravity of 0.508 at 60°F (15.6 °C). Actual quantity depends on actual specific gravity.

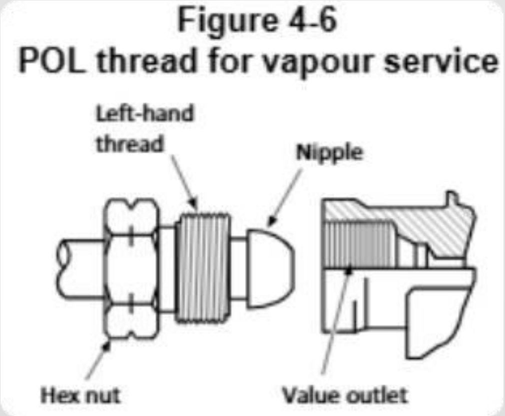
Valves and Accessories



The design of valves, controls, and accessories found on propane tanks and cylinders vary greatly with the design of the containers, manufacturers, and local code requirements. Stationary cylinders or tanks (Figure 4-5) must contain a:

- service valve;
- filler valve;
- safety pressure relief valve; and
- fixed liquid level gauge.

Portable cylinders have only one opening in the service end. A combination service valve is usually installed in this opening.



Service Valve Connections

An independent service valve controls the flow of gas out of the container. This type of valve is found on both a propane cylinder and a propane tank. The outlet of the service valve is called a service connection. There are two main types of vapour service connections on cylinders and tanks:

- Prestolite (POL); and
- quick closing coupling (QCC).

POL valves are the oldest standard for propane tank connections. They have a left-hand thread on the inside of the valve outlet (Figure 4-6). The POL fitting is unique to vapour service and cannot accidentally be connected to a liquid line.

QCC Connection for Acme Valves

QCC connection used for Acme valves (Figure 4-7) differs from POL valves in its size and use of external threads. Easier to use QCC connection can be tightened by hand. Acme propane valves are also compatible with appliances that have POL connections, as they also have the internal left-hand threads. A big advancement over the POL valve is the addition of a built-in safety device that allows gas to flow only when the tank is attached to a device, preventing accidental leakage while being stored.

Figure 4-7 Acme service valve Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY

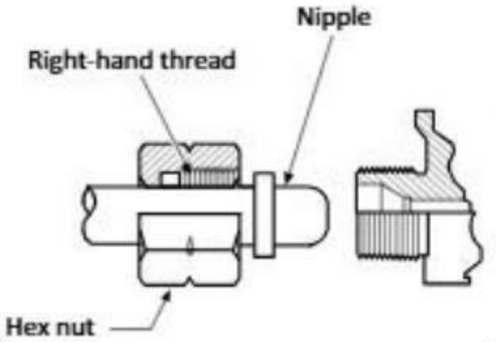
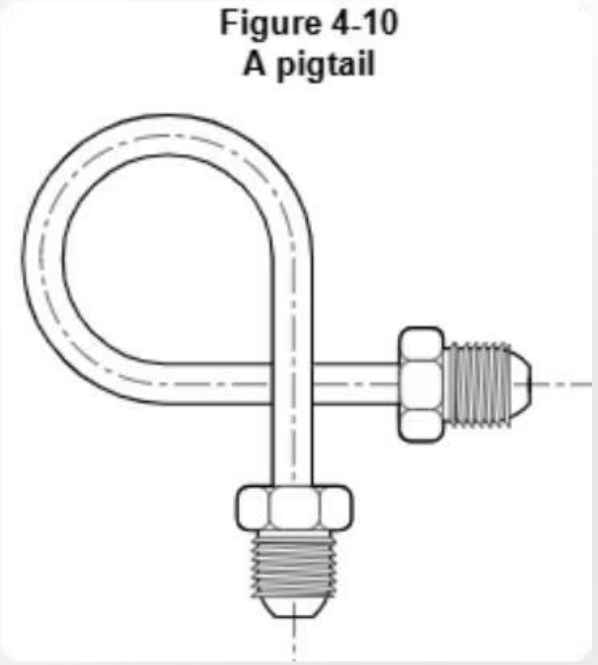


Figure 4-8
CGA thread for liquid service

Liquid Service Connections

Liquid service connections usually have a special thread (Figure 4-8) designed by the Compressed Gas Association (CGA). This unique fitting prevents the valve from being accidentally connected to a vapour service valve. Unlike the vapour withdrawal valve, the liquid withdrawal valve has a right-hand thread.

Changeover Manifold Assemblies



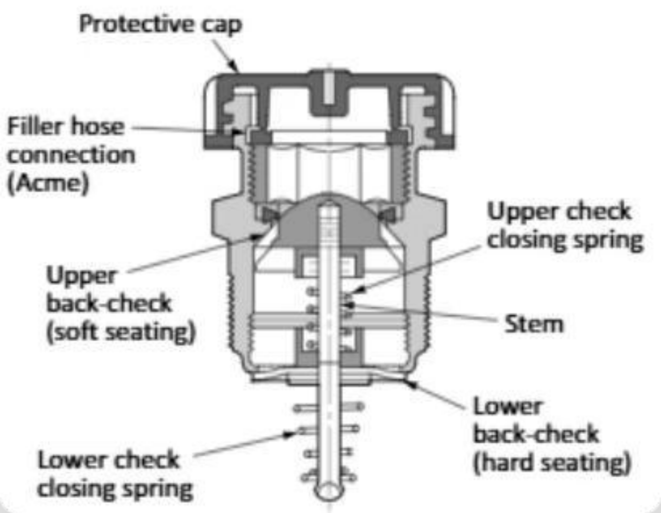
Connectors: Pigtail

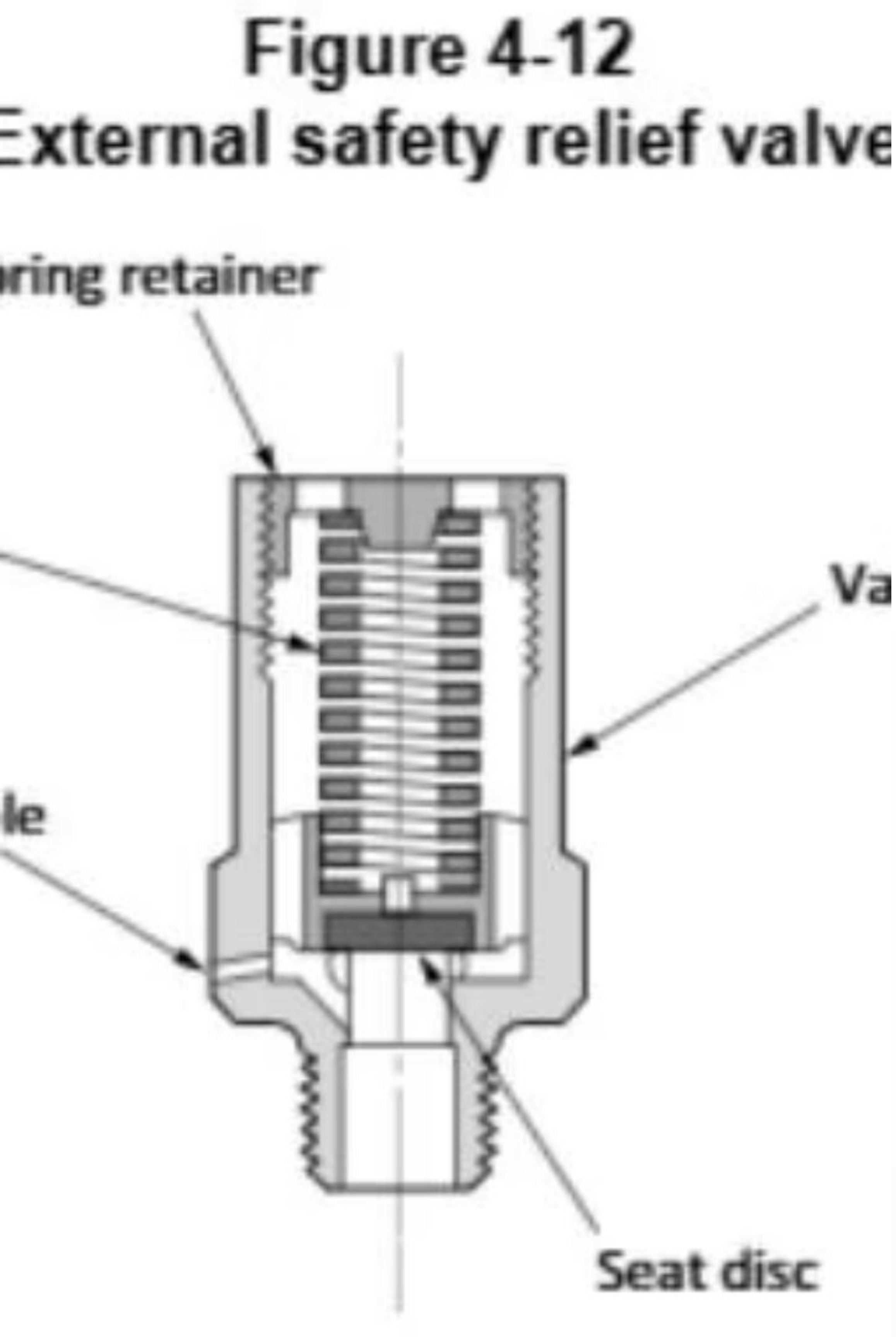
A common type of connection on propane tanks and cylinders is a pigtail (Figure 4-10). This type of copper tubing forms part of the vapour withdrawal system. It allows for flexibility in movement of the rest of the piping in the system.

Filler Valve

Stationary tanks and cylinders and tanks, rather than filling through the service valve, will have a separate filler valve to prevent interruption of service. The double check valve design allows fuel to enter the tank but prevents the propane from escaping when the fill hose is disconnected.

Figure 4-11
Double back-check filler valve





Safety Relief Valve

The safety relief valve is one of the most important valves installed in an LP-gas container. Also known as relief valves, pressure venting valves, and pop-off valves, their purpose is to automatically relieve excess pressure that can build up inside a cylinder or tank. For this reason, propane cylinders should always be stored outdoors in a well-ventilated area. The pressure relief valve setting for cylinders is 375 psig, and tanks are either 312 psig or 250 psig.

Liquid Level Indicators

It is important to know the level of the propane liquid in the tank to ensure the tank is not overfilled and to schedule refills when a stationary tank is running low.

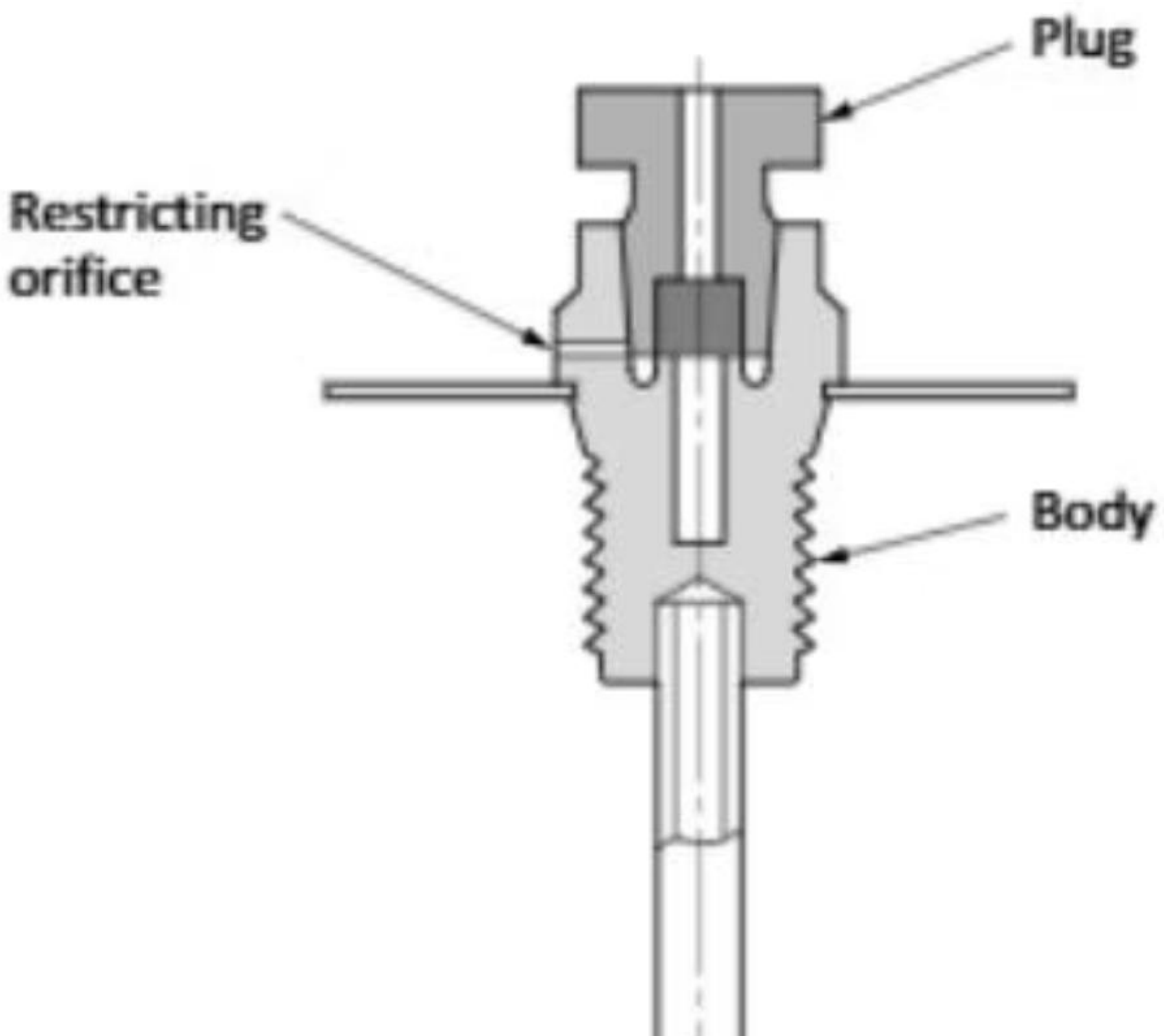
Float type (face) gauge

A float is located inside the tank and as the liquid level changes, the movement of the float raises or lowers indicating the liquid level in the tank or cylinder.

Figure 4-13 Float gauges Courtesy of Rotarex SGR

Fixed Tube Gauge

Figure 4-14
Fixed liquid level gauge



Excess Flow Valve

Excess flow valves are in-line valves intended to close upon excessive discharge of vapour or liquid resulting from a hose or piping break. If flow exceeds the valve setting, the valve will close, reducing the flow to a trickle until the pressure across it equalizes. They are available in a large variety of sizes and body configurations. For example, some propane service regulators will often have an excess follow valve incorporated into the tank connection.

Figure 4-15 Excess flow valve Courtesy of RegO Products

Combination Service Valves

These valves combine any number of the three basic valves:

- service;
- filler; and
- safety.

The most common combination is the service and safety relief valve.

The service and safety relief combination valve comes in two distinct forms: one for vapour service, the other for liquid service. Each combination valve is designed to be used solely with either vapour or liquid containers.

Vapour Service Combination Valve

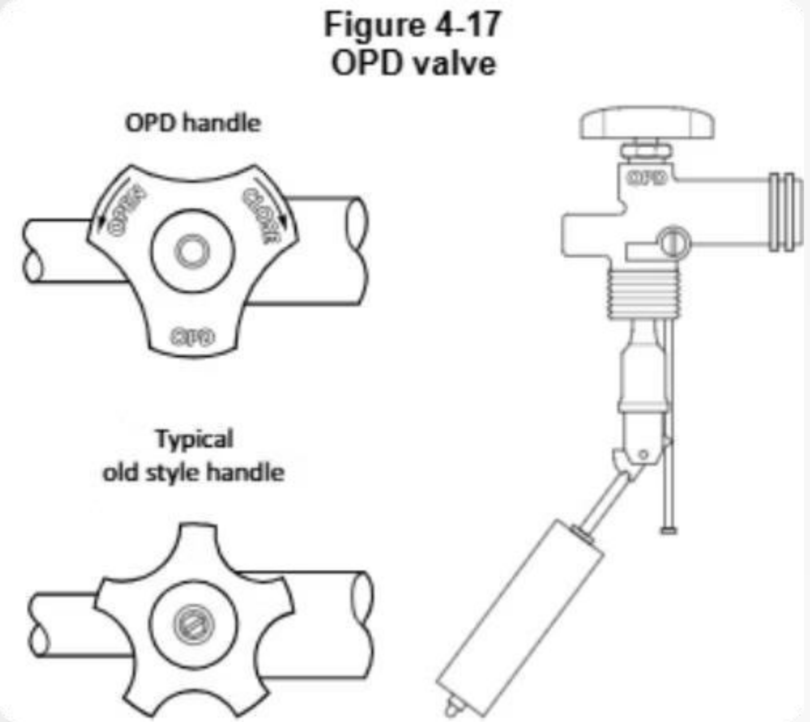
The combination valve shown in Figure 4-16 is designed for vapour service only. On portable cylinders, the outlet connection will be used for both service and filling. This combination valve is also equipped with a relief valve and a fixed liquid level gauge. The relief valve is only designed to relief gas; therefore, it is important that portable tanks with this type of valve be installed and transport in the upright position.

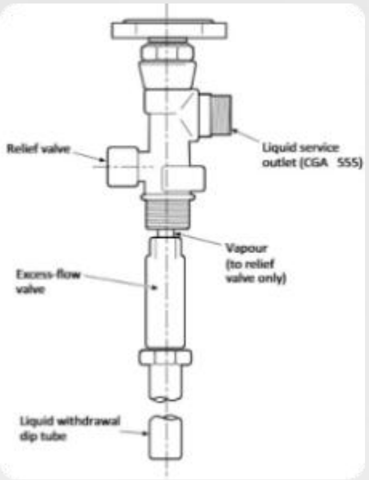
Figure 4-16 POL combination valve Courtesy of RegO Products

Overfill Protection Device (OPD)

The OPD valve is a backup system to prevent the overfilling of gas cylinders. OPD valves use a special float that rises during refilling to block the valve when the cylinder is 80% full.

All small capacity cylinders (4# to 40#) now come from the factory equipped with an OPD. A cylinder that comes with an OPD can be recognized by the unique triangular-shaped hand wheel (Figure 4-17) as well as by the letters OPD stamped on the valve and the valve handle.





Liquid Service Combination Valve

A combination valve used for liquid withdrawal is shown in Figure 4-18. It is designed for liquid service since it comes with a CGA 555 connection.

Figure 4-18 Combination valve for liquid service

The excess-flow valve protects the container against uncontrolled discharge of LP-gas in case the gas line breaks. The excess-flow valve is installed in the liquid dip tube. The dip tube completely isolates LP-gas liquid from the inlet to the relief valve. But vapour is free to flow around the dip tube to the inlet of the safety relief valve.

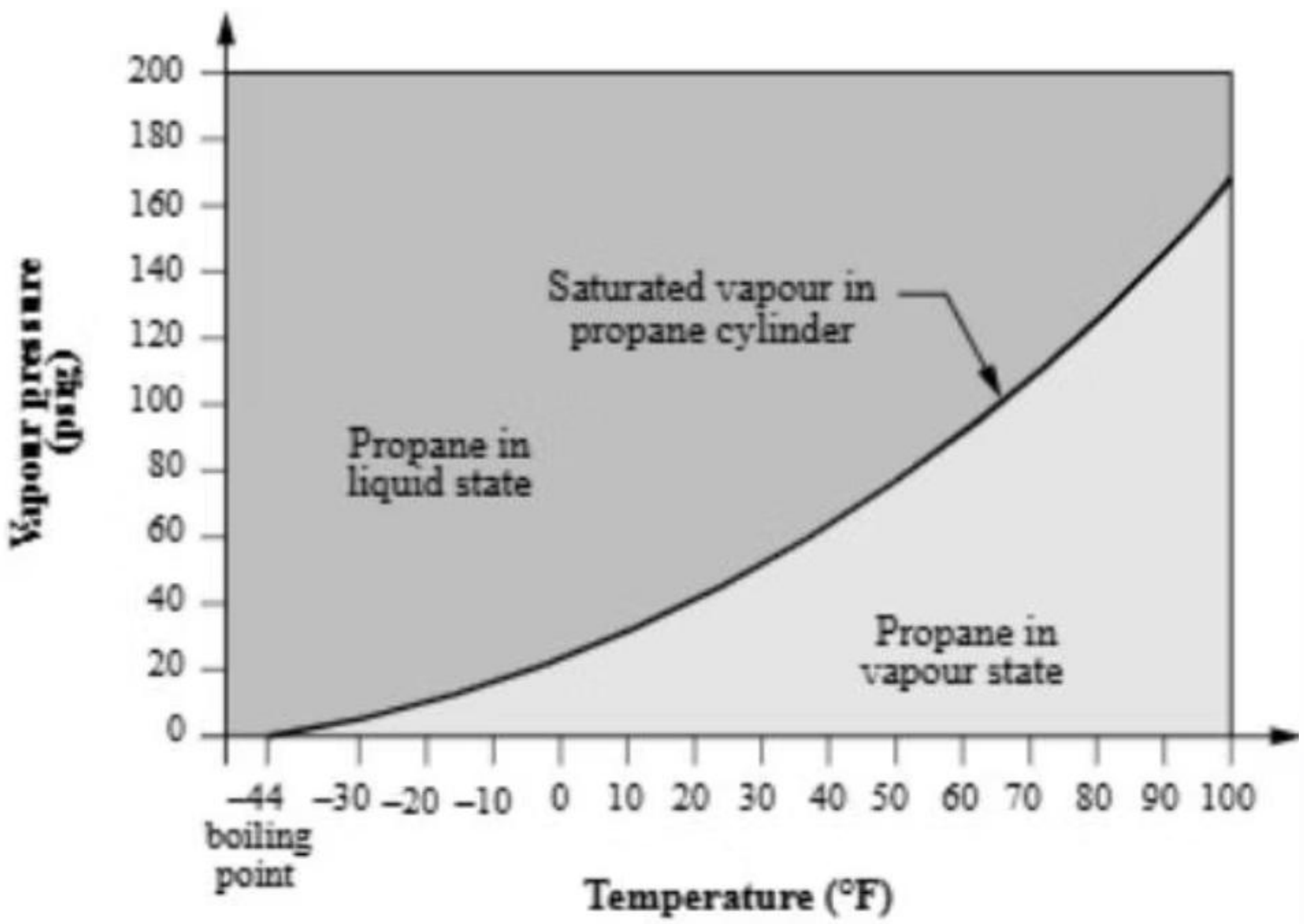
Sizing and Installing Cylinders and Tanks

When sizing a propane container, the most important consideration is the vapour or liquid withdrawal capacity of the container. The container must always have a propane withdrawal capacity that is high enough for the application. If the container's propane capacity is too low (having an undersized tank or cylinder), the appliances may not operate properly.

You will briefly review the propane vapourization process before discussing the procedures for sizing propane containers. Knowing how propane reacts under temperature and pressure changes will increase your understanding of the factors that influence container sizing.

Propane Vapourization

Figure 4-19
Propane vapourization point

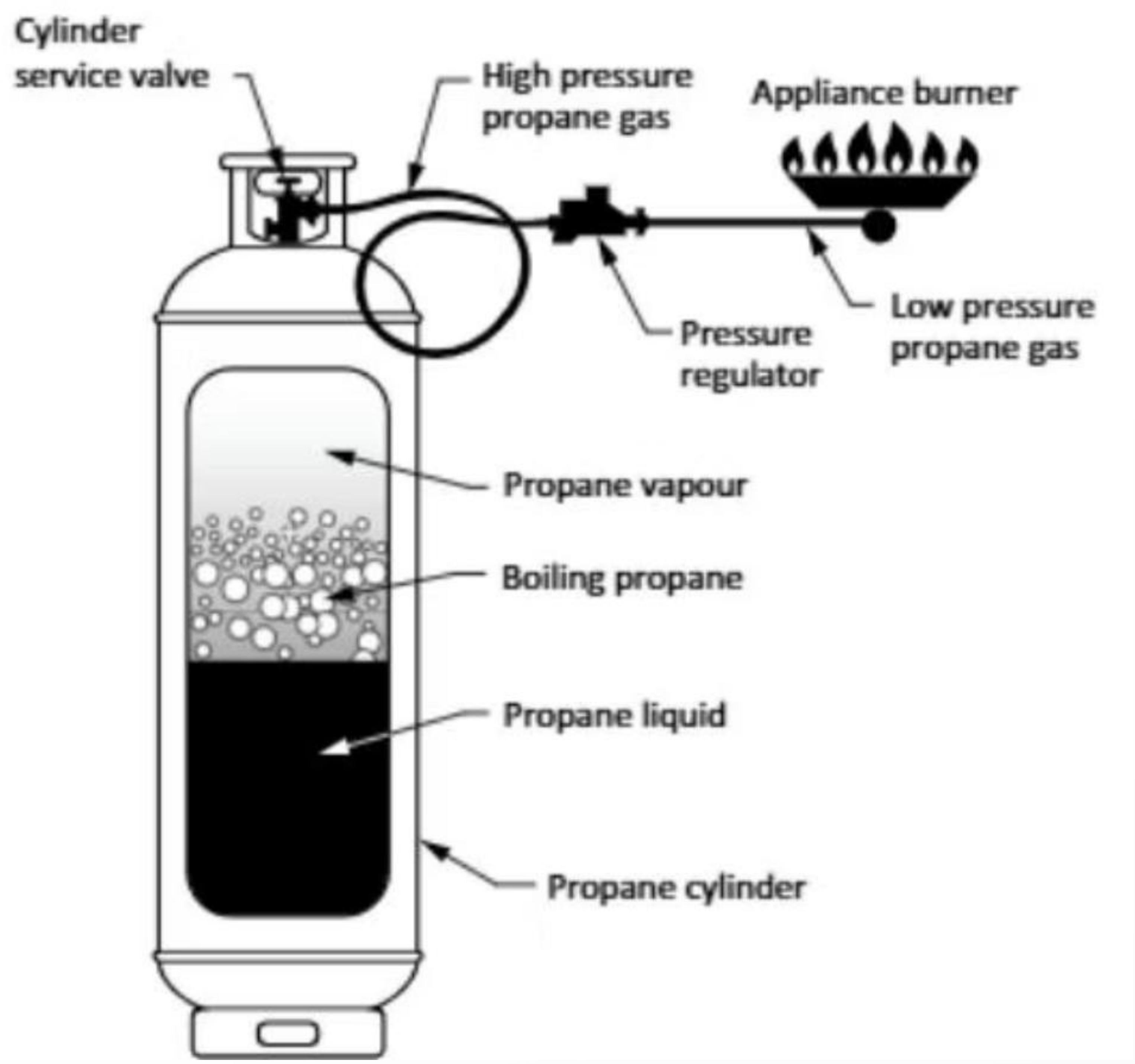


Propane is made up of hydrogen and carbon atoms. Under normal atmospheric pressure, propane is a vapour. To store propane, the vapour is pressurized and stored as a liquid. Although it is stored as a liquid, when filled to capacity, only 80% of the container is filled with liquid, the rest of the container is filled with vapourized gas. Overfilling the storage container reduces the volume available for vapourization and may result in liquid withdrawal or a hydrostatic pressure buildup.

The relationship between the propane liquid and vapour is constant unless the temperature of the propane changes or the pressure inside the container changes.

When the temperature of propane liquid inside a pressurized container increases, the liquid boils and vapourizes. This vapourization increases the pressure in the container. Since there is a relationship between temperature and pressure, this boiling continues until the temperature and pressure reach equilibrium at a new point (Figure 4-19).

Vapourization Rate



The vapourization rate of a container is the volume of propane that can be boiled off inside the container during a period of time. The vapourization rate is expressed in cubic feet or cubic meters of vapour per hour. When sizing a container for vapour service, always ensure that the container's vapourization rate is equal to, or greater than, the demand for propane. If it is smaller, the appliances will not operate at their rated inputs due to low pressure.

Factors Affecting Vapourization Rate: Surface Area and Ambient Temperature

Surface area of tank

Heat is transferred through the walls of the container. The specific area of the tank that comes in contact with the propane liquid is called the wetted surface area. In effect, the larger the wetted surface area, the higher the vapourization rate.

Ambient temperature

Temperature directly affects the vapourization rate. If the ambient temperature (temperature around the wetted surface area) is high, as in summertime, more heat is transferred to the liquid. When the outside temperature is high, the vapourization rate is high. In winter, when the outside temperatures are lower, the vapour pressure is reduced. When the vapour pressure is reduced, the vapourization rate is also reduced.

Factors Affecting Vapourization Rate: Liquid Temperature and Level

Temperature of gas

The temperature of the liquid in the container determines how much extra heat is needed for a specific vapourization rate. If the liquid temperature is low, more heat is required from the wetted surface area to bring the propane liquid to its boiling point.

Level of liquid

As propane vapour is withdrawn, the liquid level in the tank drops. This also means that the wetted surface area decreases. When the wetted surface area decreases, heat transfer to the liquid decreases, and the vapourization rate decreases.

Factors Affecting Vapourization Rate: Relative Humidity

As the demand for propane vapour increases, additional heat must be transferred to the liquid. In transferring heat to the liquid, the air surrounding the wetted surface may cool.

The resulting "frost line" on the wetted surface (in high humidity) acts as an insulator, drastically reducing the vapourization rate of the container.

If the air is very moist (high humidity), the cool air may reach its "dew point" temperature and condense on the wetted surface of the container. If a high demand for vapour continues after the moisture has condensed on the wetted surface area, the dew or moisture will continue to cool down rapidly. When the temperature reaches 32° F (0 °C), the moisture will freeze.

If the air is very dry (low humidity), the temperature surrounding the container can drop a great deal before any moisture or dew condenses.

Factors Affecting Vapourization Rate: Location

Containers can be installed above or underground. Containers that are installed above-ground benefit from high summer temperatures as well as direct sunlight.

The vapourization rate of an above-ground tank or cylinder in the winter drops because of the low outside temperatures. Underground containers usually have constant vapourization rates all year round due to the relatively constant temperatures underground.

Sizing a Container: Five Important Steps

- Determine the total demand of all present and future appliances.
- Determine the total effective load on the container.
- Determine the most severe weather conditions under which the container must operate.
- Determine the correct sizing table to use.
- Select the proper size and number of propane containers for the application.

Step 1 - Determine Total Demand

- Size the container so that it can handle the maximum possible load that will be placed on it.
- Check the demand of all existing appliances.
- Ask the customer if any appliances will be installed in the near future.
- Locate the data or rating plate on each appliance in the system.
- Record the input rating (Btu/h) of each appliance. Be sure to include the input ratings of appliances that may be installed later.

Step 1 - Determine Total Demand (Continued)

If the data plate is missing, get this information by:

- a) checking with the manufacturer or distributor of the appliance for the appliance's exact rating in Btu/h; or
- b) measuring the size of the burner orifices and determining the rating from an orifice sizing guide.

If you still cannot determine the input rating of the appliances, use Table 4-3 as a guide to various input ratings. This table shows common domestic, commercial, industrial, and agricultural appliances and their respective input ratings. However, try to determine the exact rating before referring to Table 4-3.

Average Appliance Input Ratings and Load Factors: Domestic

Appliance	Average input rating (Btu/h)	Average load factor
Domestic		
Range (with oven)	45 000 - 65 000	0.03
Dryer	20 000 - 25 000	0.15
Floor furnace	35 000 - 50 000	0.60
Recessed wall furnace	35 000 - 60 000	0.50
Central heating furnace	70 000 - 125 000	0.50
Radiant heater	20 000 - 25 000	0.40
Water heater	35 000 - 50 000	0.16

Average Appliance Input Ratings and Load Factors: Commercial

Appliance	Average input rating (Btu/h)	Average load factor
Commercial		
Water heater	100 000 - 500 000	0.50
Range (with oven)	45 000 - 65 000	0.30
Griddle	35 000 - 40 000	0.30
Oven	50 000 - 75 000	0.30
Fryer	100 000 - 150 000	0.50
Clothes dryer	30 000 - 105 000	0.60

Average Appliance Input Ratings and Load Factors: Industrial and Agricultural

Appliance	Average input rating (Btu/h)	Average load factor
Industrial		
Plumber's pot	16 000 - 25 000	1.00
Tar kettle	500 000 - 2 000 000	1.00
Construction heater	6000 - 50 000	1.00
Agricultural		
Grain/corn dryers	500 000 - 1 000 000	1.00
Peanut dryers	100 000 - 500 000	1.00
Tobacco curers	500 000 - 1 000 000	0.75
Poultry brooders	35 000 - 75 000	0.75
Livestock heaters	50 000 - 100 000	0.75

Step 2 - Determine Total Effective Load

The appliance input ratings shown in Table 4-3 are based on continuous operation for one full hour (Btulh). However, in many cases, an appliance burner is controlled by a thermostat. As a result, the burner does not operate for a full hour. Instead, it cycles on and off to satisfy the temperature setting on the thermostat.

For example, an 80 000 Btu furnace requires 32 cu ft of propane every hour to operate continuously. However, a properly sized furnace that is installed in a well insulated home will normally cycle on and off five or six times each hour. As a result, the main burner operates for approximately 30 minutes out of each hour.

This on and off cycling means that the supply withdrawn from the propane container is not continuous.

In order to properly size a container, you need to know what gas supply is actually required for.

Formula to Calculate Effective Load

To determine the effective (actual) load on a propane container, perform the following calculation:

Input rating × Load factor = Effective load

Where

Input rating Is that shown on the appliance rating plate

Load factor Is the actual amount of gas used, divided by the maximum amount of propane that the appliance would use if it operated continuously

Where

The right-hand column of Table 4-3 contains the average load factors for various appliances.

If the load factor for a particular application cannot be determined, use an average load factor for the relevant type of appliance or equipment. The following load factors are "safe" average load factors for individual appliances:

- domestic 0.5
- commercial 0.5
- industrial 0.75
- agricultural 1.0

In the 80 000 Btu/h furnace example, the propane container only boils off half (30 minutes) of the vapour that it requires to operate continuously. The load factor is therefore 0.5

Multiple Appliances: Calculating Total Effective Load

Since the propane container may be supplying gas to many appliances, all loads must be added together to find the effective load on the container. Use the following procedure:

1. Determine the input rating for each appliance or piece of equipment.
2. Multiply the input rating of each appliance by its proper load factor (Table 4-3).
3. Add the effective loads of each of the appliances together to determine the total effective load on the container.

For example, determine the total effective load of three domestic appliances, namely:

- domestic water heater (35 000 Btu/h);
- gas range (45 000 Btu/h); and
- central heating system (80 000 Btu/h).

Input rating × Load factor = Effective load

35 000 Btu / h × 0.16 = 5 600 Btu / h

45 000 Btu / h x 0.03 = 350 Btu / h

80 000 Btu / h × 0.50 = 40 000 Btu / h

= 46 950 Btu / h

Step 3 - Determine Weather Conditions

As stated earlier, several factors affect the vapourization rate inside the propane container. During vapour withdrawal, the two most important factors are:

- temperature; and
- humidity.

To properly size a container for vapour withdrawal, always size the container so that it provides propane under the most difficult weather conditions.

1. Determine the times when the container normally provides propane vapour to appliances (i.e., morning only, summer only).

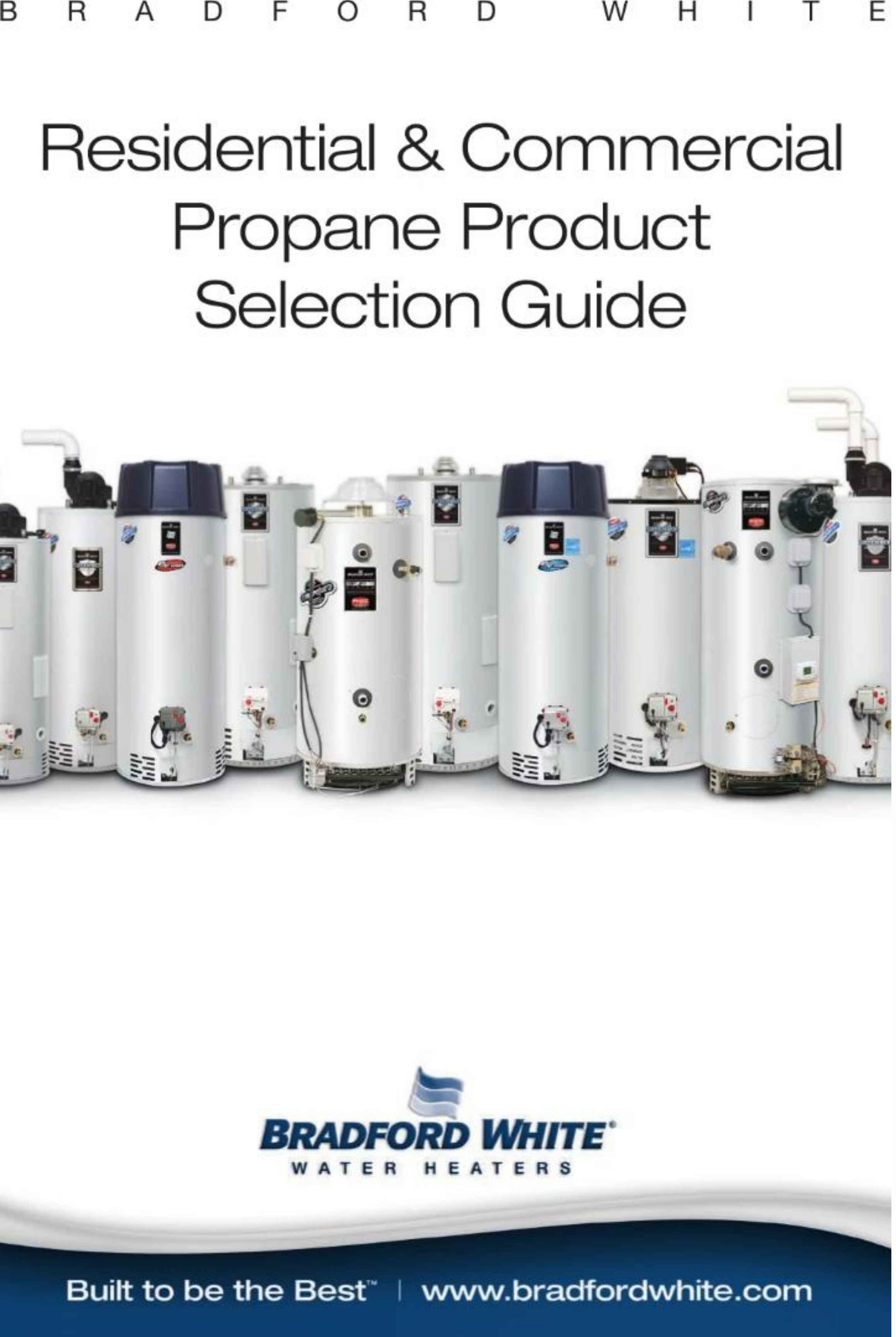
2. Determine the lowest outside temperature that occurs during a normal operating period.

Step 4 - Determine Sizing Table

The tables for sizing containers are organized according to the type and size of container (ASME tanks, stationary DOT/TC cylinders, portable DOT/TC cylinders, etc.). For this reason, first determine the type of container to be used before selecting one of the tables.

There are three tables for sizing containers, all located in Appendix A:

Use	For
Table 4A-1	ASME aboveground tanks
Table 4A-2	ASME underground tanks
Table 4A-3	DOT/TC portable cylinders, exchange cylinders, and stationary cylinders



Step 5 - Select Propane Gas Containers

1. Now that the effective load, operating conditions, and sizing table have been determined, select the proper size and number of container(s) from the tables.

- To make the tables easier to use, the vapourization rates are not expressed in cubic feet per hour; instead, the ratings have been converted to Btu per hour (Btu/h).
- Additionally, the ratings indicate the vapourization rate when the container is ready to be refilled. As a consequence, all ratings in the tables are based on a container that is a quarter full (25% of the container's water capacity). As long as the container is at least 25% full, an adequate supply of gas is ensured.

Sizing Aboveground ASME Tanks

To properly size an aboveground ASME tank, follow the steps using Table 4A-1 in Appendix A of this workbook.

1. Based on the relative humidity in the area, select the applicable table:

Use	For
Table 4A-1a	50-60% humidity
Table 4A-1b	60-70% humidity
Table 4A-1c	70-80% humidity

1. Based on the lowest temperature for the operating season of the tank, select the appropriate temperature column in the table.

2. Read down the temperature column until you locate a Btu rating that is equal to, or greater than, the effective load of the application.
3. Read across to the Tank capacity (gallons w.c.) column to locate the required tank size.

Sizing Underground ASME Tanks

Table 4A-2 in Appendix A of this workbook, lists the vapourization rate of various ASME tanks when they are installed underground.

Note: The temperature column only lists 50 °F. Regardless of the time of year, the earth surrounding an underground tank usually remains around 50 °F. Note: The moisture content of the soil has been averaged out.

1. To select the proper size of an underground tank, read down the 50 °F column until you find a rating that is equal to, or greater than, the effective load of the application.
2. Read across to the left to determine the proper size tank capacity (gallons w.c.).

If the tank is undersized, a frost line could develop on the tank and the vapourization rate will drop off to zero. If this occurs, the tank must be dug up and a larger tank set in, resulting in a waste of time and money.

Note: Never undersize an underground tank.

Sizing DOT/TC Cylinders

Table 4A-3 in Appendix A of this workbook lists the capacities of common DOT/TC cylinders.

This table is different from the others because each cylinder has four different vapourization rates:

- two ratings for winter; and
- two ratings for summer.

Further, the summer and winter ratings are divided into low and high humidity:

Average	S
High humidity	70%
Low humidity	30%

Because of the low capacities of cylinders, a 10% difference in humidity or temperature does not greatly change the vapourization rate of the cylinder.

To select a DOT/TC cylinder for an application, use the following procedure:

1. Select the column in Table 4A-3 that represents the most severe weather conditions for the area (winter and high humidity, summer and low humidity, etc.)
2. Determine the type of cylinder needed (portable, replaceable, or stationary).
3. Read down the column until you locate a Btu rating that is equal to, or greater than, the effective load of the application.
4. Read straight across to the extreme left column, Cylinder Capacity, and select the cylinder required.

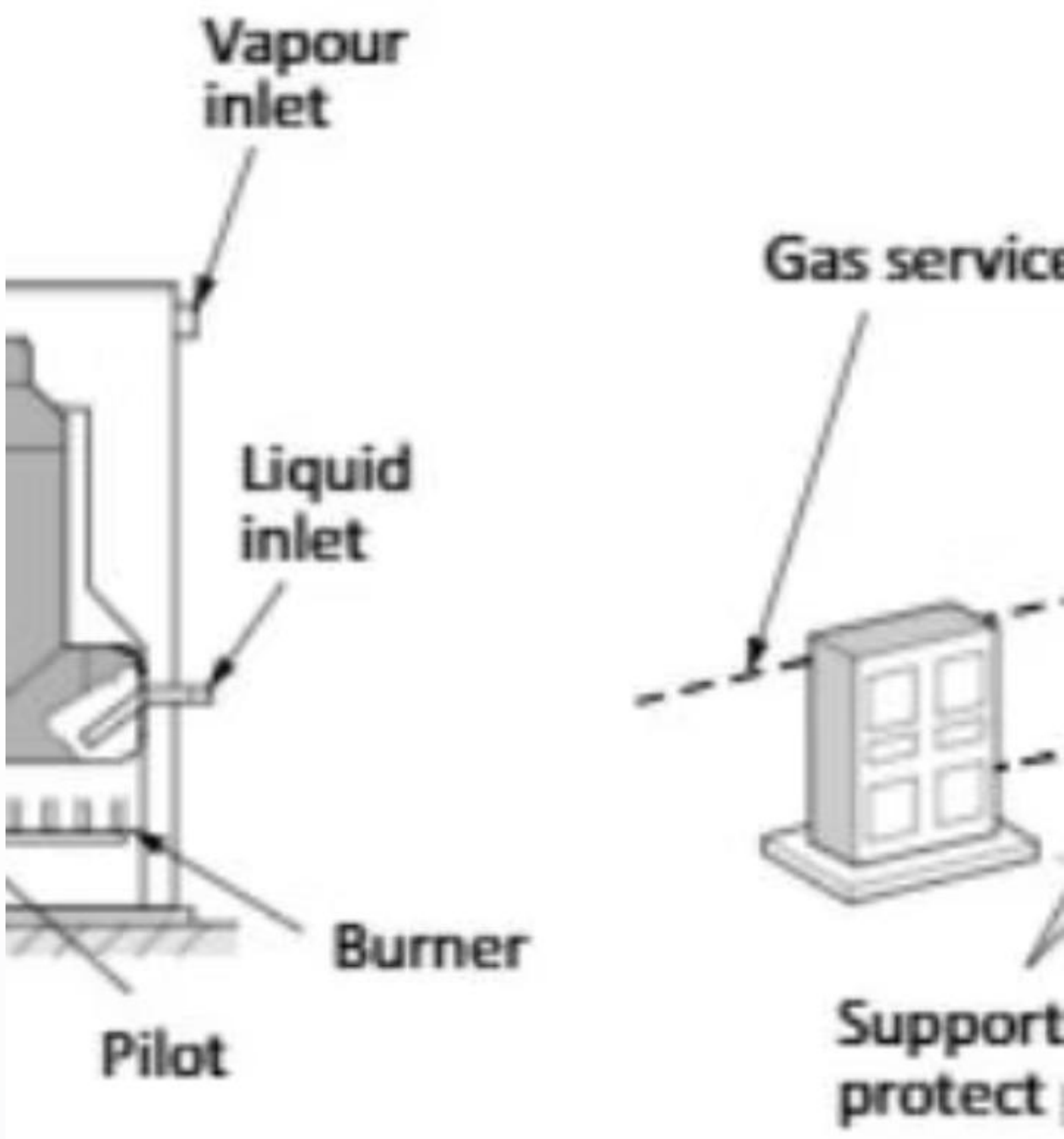
Propane Vapourizers

Propane vapourizers can be used when equipment or appliance demand exceeds the natural vapourizing capacity of the tank and placing a much larger tank, with higher vapourization capacity would not be practical.

Direct fired propane vapourizer shown in Figure 4-21, uses a flame that directly heats the liquid propane which turns it to gas for use in downstream, high vapour demand equipment. Liquid propane is piped from the tank to the vapourizer where it is then heated and in turn, the propane gas vapourization is accelerated. The vapourizer is essentially a boiler that does not build pressure.

Figure 4-21

ropane direct fire vapourize



Container Sizing for Liquid Withdrawal

Sizing LP-gas containers for vapourizers, liquid burner applications, and stationary engines is a simple procedure. Basically, the size of the container is based on two considerations:

- liquid withdrawal rate each day; and
- minimizing the number of gas deliveries to the customer.

In order to properly size containers for these applications, determine the daily withdrawal rate for the application. Stationary engines are rated in the number of US gallons (litres) that they use in one continuous hour of operation (gal/hr, l/hr). To size the container, determine the expected number of hours that the engine must operate under normal conditions.

If there are additional loads in Btu/h convert:

- effective load Btu/h divided by 91,500 = gal/hr; and
- effective load Btu/h divided by 24,174 = l/hr.