Block A: Medical Gas Systems

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Plumbing Apprenticeship Program Level 4

SkilledTradesBC

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Competency A1: Install Medical Gas Systems

Medical gases are used every day by millions of people in thousands of different locations. These gases perform a critical role in healthcare delivery in such locations as hospitals, homes, ambulances, dental offices, and more. This module will provide an overview of medical gases, helping you better identify what they are, their uses, and safety considerations when they are in use. Apprentices will also gain insight into the governing Standard, Z7396.1-12, Medical Gas Pipeline Systems which is the foundation for installation of medical gas systems within Healthcare Facilities.

Learning Objectives

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

- Describe medical gas systems,
- Lay out a medical gas piping system
- Install piping for medical gas systems,
- Install equipment for medical gas systems

Definitions

- **Control equipment** — components necessary to maintain the medical gas pipeline system within the specified operating parameters.
- **DISS —** Diameter Index Safety System is a threaded gas-specific type of medical gas outlet connection
- **Gas-specific connector** — a connector with dimensional characteristics that prevent connections between different gas services.
- **Line pressure regulator** — a pressure regulator intended to supply the nominal distribution pressure to the terminal units.
- **Nominal distribution pressure** — the pressure that the medical gas pipeline system is intended to deliver to the terminal units.
- **Pipeline distribution system** — the portion of a medical gas, vacuum, medical support gas, or AGSS located from and including the main supply shut off valve to (and including all terminal units), junction points, or demarcation points.
- **Pressure relief device (PRD)** — a fitting installed on pressure equipment designed to provide primary protection from overpressurization. PRDs include both reclosing devices (e.g., safety valves, relief valves, safety relief valves) and non-reclosing devices (including rupture discs and fusible plugs).
- **Primary source** — the portion of a supply system that is the first to be drawn on to supply the pipeline distribution system.
- **Reserve source** — the portion of the supply system that supplies the complete pipeline distribution system, or a portion of it, in the event of failure or exhaustion of both the primary and secondary sources of supply.
- **Secondary source** — the portion of the supply system that supplies the pipeline distribution system in the event of failure or exhaustion of the primary source of supply.

Learning Task 1

Describe Medical Gas Systems

Medical gases are used for patient care in health-care facilities, dental suites and laboratories. Gases manufactured for medical use may be identified by the acronym “USP,” which represents that their purity levels adhere to the United States Pharmacopeia standards. In Canada, medical gas piping systems are installed and commissioned to the CSA Z7396.1 Standard.

Advantages of pipe systems versus individual cylinders

There are a number of advantages to using medical gas pipelines rather than individual supply cylinders at the patient locations.

Advantages for patients:

- no distressing sight of oxygen cylinders at the bedside
- elimination of irritating noise from movement of cylinders
- protection from contamination during movement of cylinders
- uninterrupted and clean supply at desired location

Advantages for hospital staff:

- instant availability of gas at the terminal unit
- clean, safe and reliable delivery of gases
- continuous flow of gases when and where required
- minimal risk of accidents due to mishandling of cylinders

Advantages for hospital administrators:

- easy purchase of gases in bulk quantities
- more cost effective than purchasing and storing cylinders
- fewer breakages
- minimal damage to building due to handling of cylinders

Responsibilities

Patient safety is paramount in the design, installation, commissioning and operation of medical gas pipeline systems. The basic principles of safety are achieved by a team of professionals working

together to provide a safe, convenient and cost-effective system. While these individuals strive toward a common goal, their responsibilities are quite different.

Owner

The owner of a medical gas system bears ultimate responsibility for the safe operation of a medical gas pipeline system. The owner and his design engineer must employ a trained installation contractor and a certified inspection company to perform and attest to final verification of the systems. The owner is also responsible to ensure that facility staff is properly trained. Facility personnel need to be aware of the nature of the systems in order to understand the purpose of warning and alarm systems and to participate in the safe operation of the systems. The owner should be familiar with the systems and be able to isolate these systems in the event of an emergency.

Installer

A medical gas installer is responsible for the proper installation, brazing and testing of medical gas and vacuum systems and pipeline distribution systems. They must possess the certification necessary to ensure that they have met the requirements of the CSA Z7396.1 Standard and are technically competent and experienced in the field of medical gas systems installation.

Third-party inspectors

A medical gas inspection agency is a certified company that is proficient and experienced in the installation, inspection, and verification of medical gas and vacuum systems. The inspector is responsible for: inspecting and testing all new piped medical gas systems, additions, renovations, temporary installations or repaired systems to ensure, by a documented procedure, that all applicable provisions of CSA Z7396.1 have been adhered to and system integrity has been achieved or maintained. Medical gas inspectors are required to maintain a logbook that contains records of site observations and test results. Test and inspection reports are also required as the project progresses. The inspector must personally witness the various tests and record and verify the results of any tests performed by the installer. The collected information then is assembled into a document for approval by the authority having jurisdiction.

Types of medical gases

The following supply gases and removal systems are frequently used in the health-care industries:

- oxygen
- nitrous oxide
- nitrogen
- medical air

Removal systems:

- medical vacuum
- anaesthetic gas scavenging systems

Some hospitals may have other gas piping systems, depending on the type of medical treatment the facility specializes in. Some of these gases are:

- carbon dioxide
- helium
- ethylene oxide

Uses and purpose:

- **Oxygen (O_2)** is for patients requiring supplemental oxygen via a mask. This is accomplished by a large storage system of cryogenic liquid oxygen at the hospital, which is evaporated into a concentrated oxygen supply. Distribution pressures are usually around 380 kPa (55 psi). In small medical centres with a low patient capacity, oxygen is supplied by multiple standard cylinders or by mobile single cylinders.
- **Nitrous oxide (N_2O)** is supplied to various surgical suites for anaesthetic functions during pre-operative procedures. Delivered to the hospital in standard tanks and supplied through the medical gas system. System pressures are around 380 kPa (55 psi).
- **Nitrogen (N_2)** is typically used to power surgical tools such as bone saws and drills during various procedures. Pressures range around 1.2 MPa (175 psi) to the various locations within the facility and may be stored cryogenically. Nitrogen and instrument air are also referred to as medical support gases.
- **Medical air (MedAir)** is supplied by a special air compressor to patient-care areas using clean outside air. Pressures are maintained at around 380 kPa (55 psi). Medical air is only used for the application of human respiration and calibration of medical devices. Medial air is not to be used for nonpatient functions or to power pneumatic tools.
- **Medical vacuum or suction (MedVac)** is used, or piped, to virtually every patient location in a healthcare facility. The main application for suction is to assist in removing fluids or material from the patient. The fluid or material is collected at the “point of use” in vacuum vessel which prevents any substances from entering the pipeline. The system vacuum is usually supplied by various vacuum pump systems exhausting to the atmosphere. Continuous vacuum is maintained around 75 kPa (22 inches of mercury).
- **Anaesthetic gas scavenging system (AGSS)** is used to remove anaesthetic gas after it is exhaled from the patient. In operating rooms, it prevents the anaesthetic from leaking away from the patient or anaesthesia system and flooding the operating room.
- **Carbon dioxide (CO_2)** is typically used to inflate or suspend tissues during surgery, and also used in laser surgeries. System pressures are maintained at about 380 kPa (55 psi).
- **Helium (He)** is used in MRI scanners that use magnetic fields and radio waves to form images of the body. Liquid helium (cryogenic) is used to cool down the superconductive magnet coils in MRI scanners to a temperature below –263°C (10 Kelvin).
- **Ethylene oxide (CH_2CH_2O)** is a highly flammable gas used to sterilize surgical instruments

and other supplies.

Sources of medical gas

Medical gases are piped throughout the faculty from a central supply system. These systems must be designed to ensure there is no disruption of the medial gas supply. Depending on the volume and type of gas central supply systems can consist off:

- Bulk storage
- Cylinder manifolds
- Oxygen concentrators
- Compressors

Bulk sources of supply

Bulk supply systems are used where there is a high demand for medical gases within the facility. The advantage of bulk systems is that they allow convenient storage of large gas volumes within a small footprint on the property. Bulk storage can occur as a cryogenic liquid or a non-cryogenic high-pressure gas. Oxygen, nitrogen, nitrous oxide and carbon dioxide can be stored in bulk as gas, while cryogenic bulk vessels are restricted to oxygen and nitrogen due to the ability of these elements to liquefy.

Cryogenic bulk systems containing liquid oxygen and liquid nitrogen are very cost effective and convenient supply options for large installations. The bulk system equipment would include (Figure 1):

- storage tanks
- vaporizers
- control/monitoring panels
- pressure relief valves
- pressure regulating valves

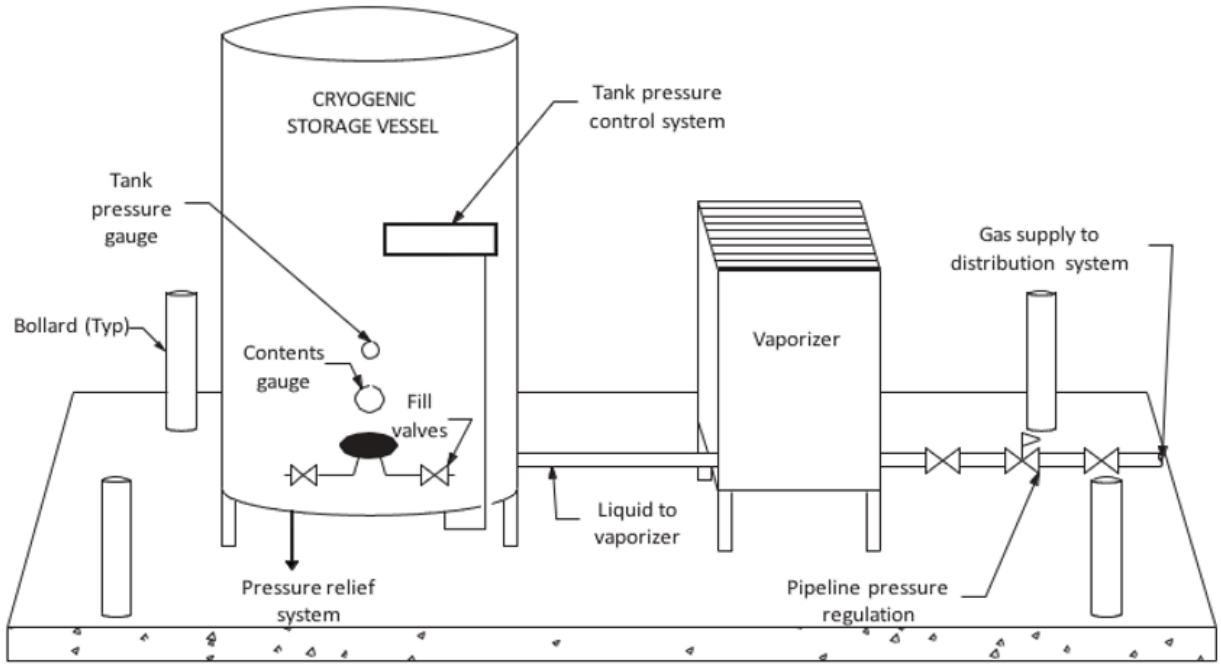

Figure 1. Overview of a cryogenic bulk supply system

The liquid is converted to a gas with the use of vaporisers located near the storage tank. When a supply of gas is required in the facility, the liquid is drawn off and passed through a vaporizer to convert it into a gas, which is then piped to individual wards. It is very common to see these vaporisers covered in frost regardless of whether it is winter or summer. This condition is due to the heat required to facilitate the change of state (vaporization) before the gas enters the piping distribution system.

Bulk systems are usually located on a concrete pad in a fenced compound outside the building (Figure 2). The tanks are replenished by supply tanker trucks when required. Most regulating authorities require a professional engineer (P. Eng.) to assist in the design of the bulk storage facilities.

Figure 2. Bulk oxygen storage system

Bulk reserve systems

The typical bulk reserve system for the medical gas system provides a secondary source of product when the primary source is not functioning. The reserve system is designed to operate automatically when the main system fails. In larger facilities, the reserve system is a smaller liquid tank with its own vaporizers that provides gas flow to the system when the main tank runs empty or malfunctions. When the reserve system is activated, maintenance personnel are alerted that the primary supply is off-line. This is usually accomplished with audible and visible alarms.

Quite often a facility using a bulk supply system may have a cylinder bank acting as the reserve. Medical gas cylinders should be kept in a purpose-built cylinder storage.

Cylinder supply

When a medical facility does not consume enough gas to warrant the use of a bulk system, the gas piping systems are usually supplied by banks of gas cylinders connected to a supply manifold. Cylinder manifolds can also work to provide backup for bulk and mini-bulk installations. Medical gases are available in high pressure gas cylinders or liquid cryogenic cylinders. Liquid containers have limits in their rate of delivery based on the vaporization rate limitations of the cylinder. Manifolds can be set up in three possible configurations: cylinder by cylinder; liquid by liquid by cylinder; or liquid by cylinder by cylinder. Manifolds are typically configured as either auto changeover or simplex, depending on the complexity of the system.

A simplex manifold is a low-complexity system for connecting one bank of cylinders, typically as a reserve system for bulk supply systems to ensure a reliable supply.

A changeover manifold (Figure 3) has two separate banks each with an average day's supply of cylinders. One bank is designated as a primary source of gas while the other bank stands in reserve as a secondary. The pipeline will draw from the primary side until the volume available no longer meets the minimum requirement. When the primary bank has been sufficiently depleted, a switchover will occur and the reserve bank will now begin supplying the pipeline. This system creates an uninterrupted availability of medical gas for patients and allows time for the facility staff to replenish the exhausted bank with new cylinders. When this occurs, the reserve bank is now operating as the primary and the replenished bank is now acting as the reserve. This process will continue back and forth as the medical gas is consumed by the patients.

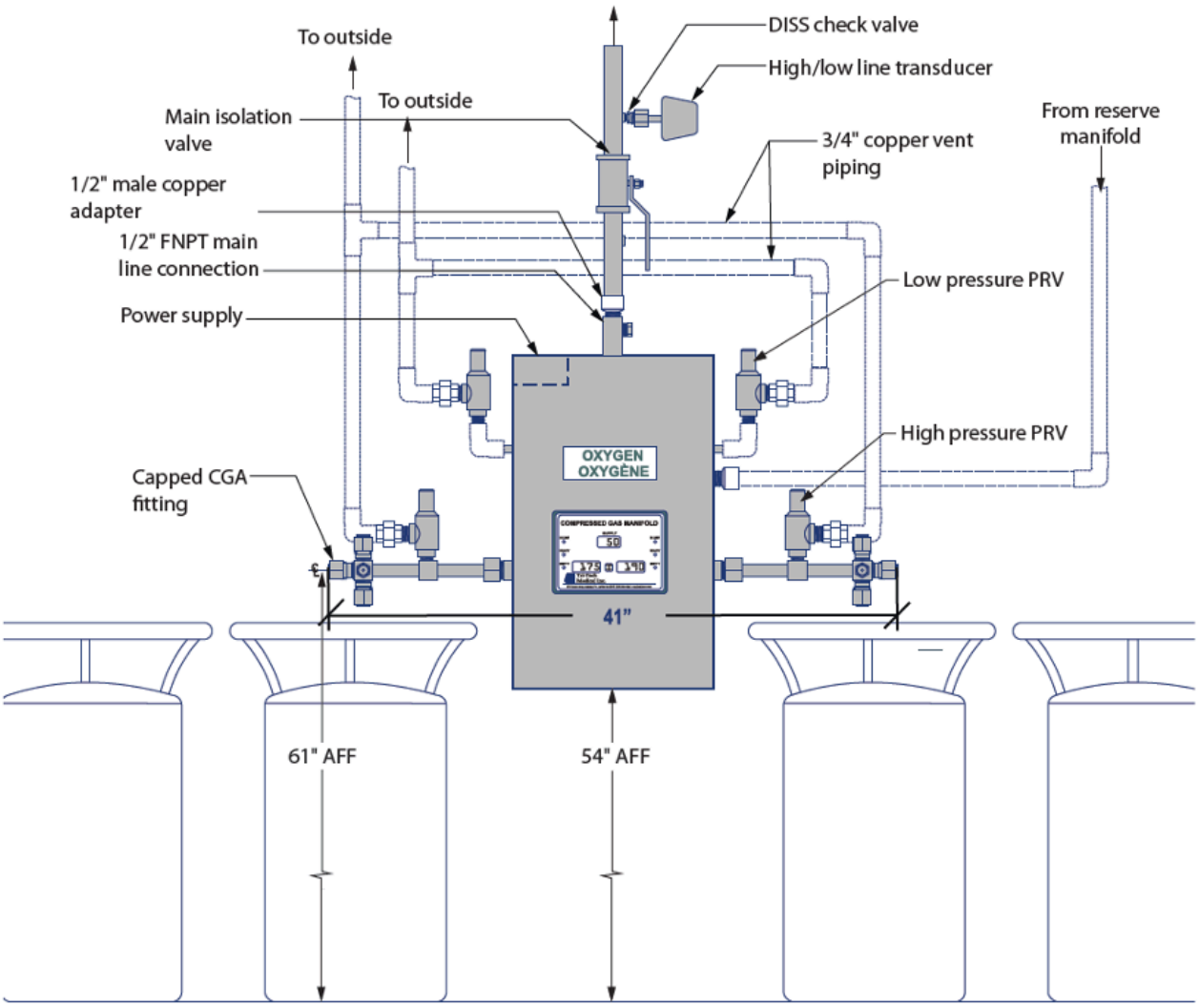

Figure 3. Liquid oxygen cylinders connected to automatic changeover manifold [Image Description]

Medical gas cylinders contain two distinct parts:

- **Storage vessel**. Medical gas suppliers provide steel or aluminum cylinders in different sizes to suit the end users' needs. These sizes are typically designated by a letter or number that identifies dimensions and storage volume.
- **Cylinder valve**. The valve outlet on each cylinder incorporates a thread pattern designed

especially for use with a specific gas. The Compressed Gas Association (CGA) uses a number system to assign specific thread configurations for each specific gas valve profile. This assures the industry that all medical gases used in Canada will have exactly the same threaded connection for that specific gas. This requirement eliminates the potential for cross-connection when attaching equipment to a cylinder valve. The CGA thread patterns must match or the connection cannot be made. Figure 4 lists medical gases and their designated CGA connection numbers.

Figure 4. CGA gas connection designations

Gas	**CGA #**
Oxygen	540
Air	346
Nitrogen	580
Carbon dioxide	320
Nitrous oxide	326

Medical gas cylinders should be kept in a purpose-built cylinder storage room, so that the cylinders can be kept dry and in a clean condition. The medical gas cylinder storage room should:

- Allow cylinders to be stored under cover, preferably enclosed and not subjected to extremes of temperature.
- Have racks, chains, or other fastenings to secure all cylinders from falling, whether connected, unconnected, full, or empty.
- Be kept dry, clean and well ventilated (both top and bottom).
- Have good access for delivery vehicles and reasonably level floor areas.
- Be large enough to allow for segregation of full and empty cylinders and permit separation of different medical gases.
- Be totally separate from any non-medical cylinder storage areas.
- Be situated away from storage areas containing highly flammable liquids and other combustible materials and any sources of heat or ignition.
- Have warning notices posted prohibiting smoking within the vicinity of the storage room.
- Be secure enough to prevent theft and misuse.

Oxygen concentrators

An oxygen concentrator unit (Figure 5) is an engineered assembly of components that operate to produce oxygen from ambient air by extraction of nitrogen. Normal air is 20.9% oxygen and 79% nitrogen. The concentration process passes air through a molecular sieve which captures the nitrogen and outputs 93 percent USP oxygen. Much like a sponge the sieve bed can only hold so much nitrogen

so it is necessary to regenerate the sieve bed by venting or pulling the nitrogen off the sieve. The air source is typically a compressor or blower, which pushes the air into the sieve. A vent ,blower, or pump is used to remove nitrogen and recycle the sieve.

Besides direct supply to the hospital supply line, an on-site oxygen system can be designed to include the capacity to fill cylinders to provide backup, peak, and remote oxygen requirements.

Figure 5. Deployable Oxygen Concentration

An oxygen concentrator-based supply system must have at least three sources of supply (Figure 6). At least one of which must be an oxygen concentrator source of supply; and at least one shall be a portable cylinder source of supply (high pressure and/or liquid). The system must be able to deliver the total design flow with any two sources of supply out of service.

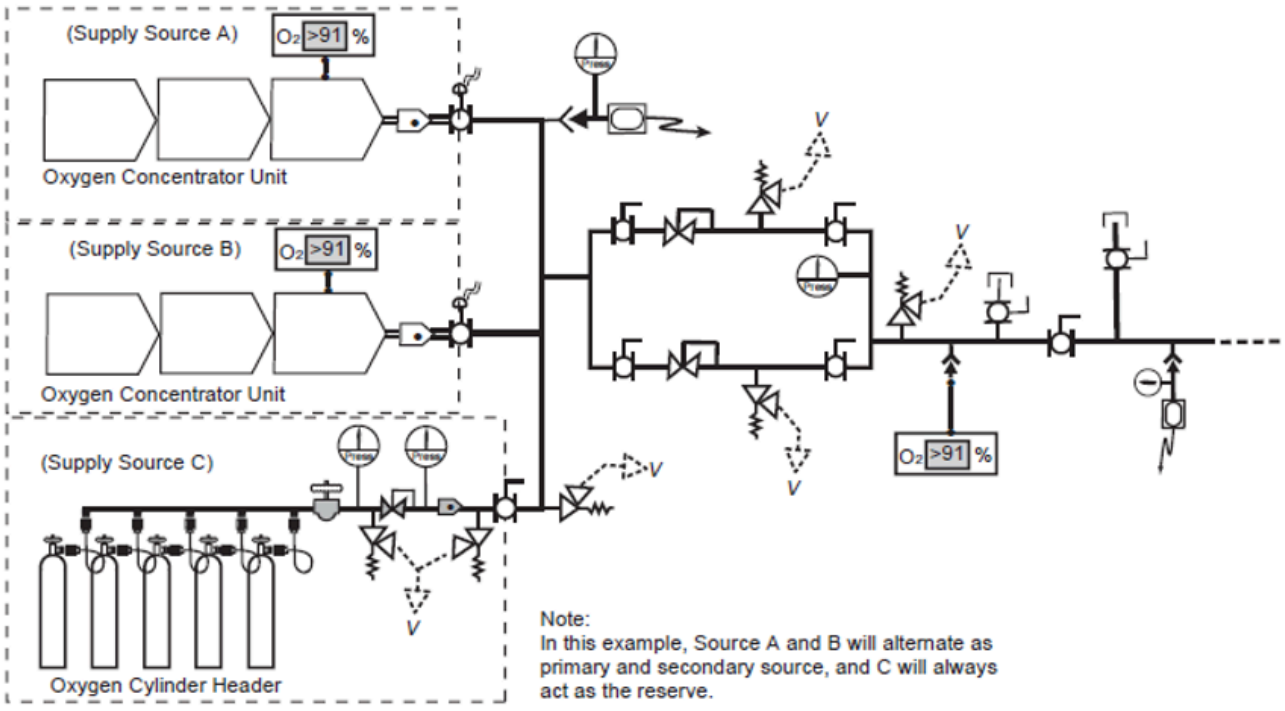

Figure 6. Oxygen concentrator central supply source with three sources [Image Description]

Each oxygen concentrator source of supply shall include two oxygen analyzers and controls so that each concentrator source of supply is automatically isolated if the oxygen concentration of the produced gas falls outside the 93 percent USP specification. 93% USP is defined as no less than 90% but no more then 96%.

Medical air compressors

Medical air is sometimes supplied in high-pressure cylinders, but due to the large volume of air that hospitals consume, on-site production is usually the most practical and economical method of supply. Medical air is manufactured on-site with sophisticated air compressor systems.

A medical compressed air system is made up of four major sections:

- compressors
- control systems and panel
- receiver
- purification

Compressor types

The definition of a medical air compressor is a compressor that is designed to exclude oil from the air stream and compression chamber and that does not, under normal operating conditions or due to any single fault, add toxic or flammable contaminants to the compressed air.

The CSA Z7396.1 Standard states that:

> A compressor-based supply system for medical air shall consist of at least three sources of supply, at least one of which shall be a compressor source of supply and at least one of which shall be a cylinder source that acts as a reserve source. The supply system shall be such that the system design flow can be supplied with any two sources of supply out of service.

For the purposes of medical air production in Canada, acceptable technologies must use an oil-less or oil-free method of compression that contain no oil or grease in the compression chamber. This requirement limits the type of units that can be used, as oil is a very common way to reduce friction within a number of different compressor types. An oil less compressor contains no oil or grease within the machine. Oil-free compressors may contain oil in the running gear but are designed to prevent oil from reaching the compression chamber using a physical break such as a distance piece and vent.

Typical types of compressors used for medical air include (Figure 7) oil-free reciprocating, oil-less reciprocating, oil-less scroll, oil-free dry claw (tooth), oil-free screw, and liquid ring compressors. Some are direct driven and torque is transmitted from the motor to the pump through a shaft coupling, whereas others use a v-belt to connect the pump and motor pulleys.

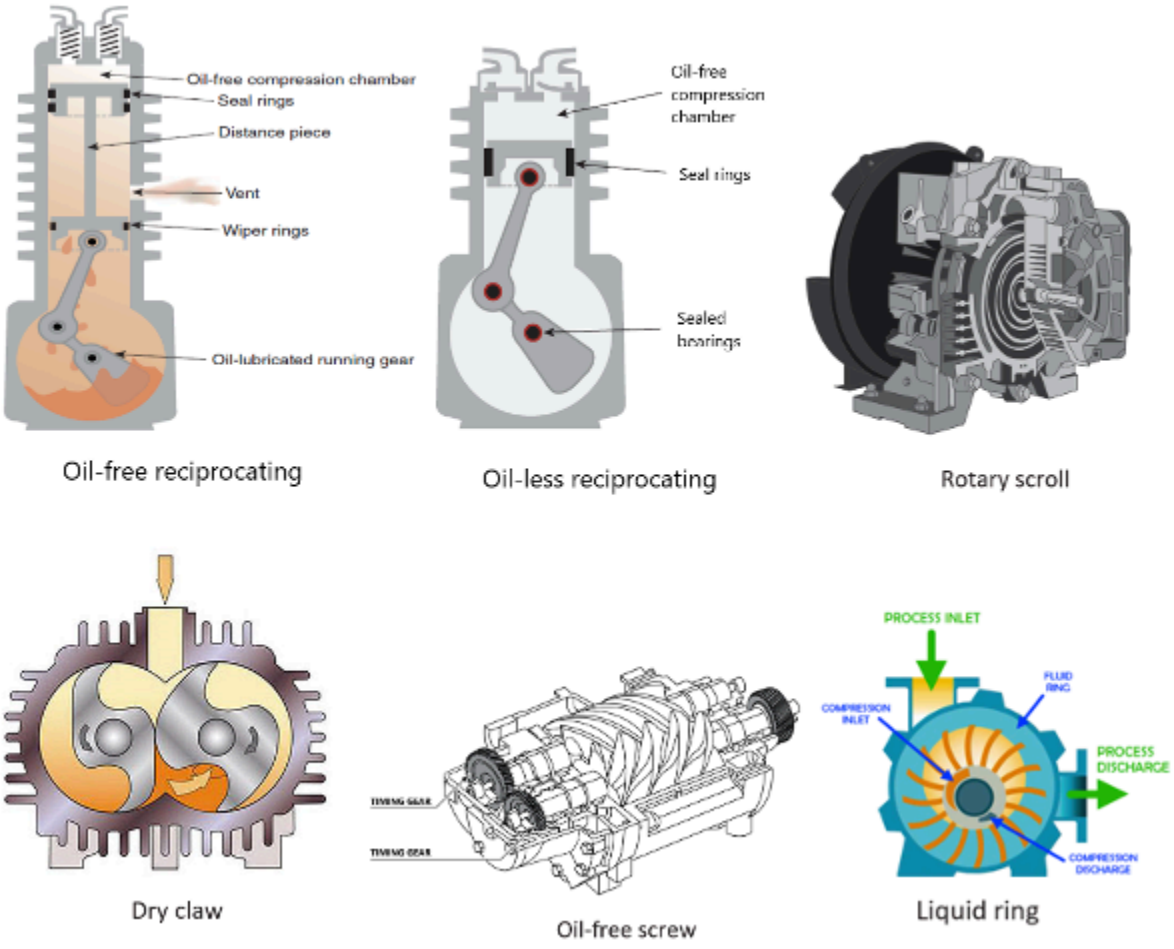

Figure 7. Types of medical air compressors

There are pros and cons for each type of compressor and the designers will consult with the

manufacture to determine which type is ideal for their facility. Some selection factors include: capacity, cost, efficiency, physical size, additional accessories, noise, maintenance.

As each type has different working principles it is important to consult the manufacture literature for the proper installation, operating and maintenance requirements.

Control systems and panels

Control panels manage the operation and protection of the system's electrical components. These control panels contain all of the regular components used in industrial electric motor applications as well as a circuit of alarms. Latching relays and timers are used to control the sequence of operation. Many manufacturers are using more advanced control circuits that include solid-state circuit boards or PLCs (programmable logic controllers).

Receivers

Once the air has been compressed and leaves the chamber, it needs to be stored until it is required by the pipeline. This is accomplished by a receiver which, in essence, is a bulk steel storage tank that allows air to enter or exit under pressure. The receiver tanks vary in size and configuration and must be lined with a coating to prevent corrosion. These coatings are generally epoxy linings or galvanized coatings. Most medical air compressors produce a certain volume at approximately 100 to 125 psi (700 to 875 kPa) pressure (much less than what is stored in a high-pressure cylinder). The output is stored in the receiver.

Purification

Medical facilities rely on clean, dry compressed air for the medical air supply produced on-site. Air that has been compressed and stored is not considered medical grade until it has been dried and filtered. Since the intake for compressors is simply ambient air taken from outdoors, it could contain a high moisture content and carbon monoxide (CO). These impurities are transferred through the compression cycle and stored in the receiver. A dryer and filters are located downstream of the receiver to ensure that air being delivered to the pipeline does not contain a high dew point or CO. Although there are different technologies used in compressed medical air drying, Canada has moved almost exclusively to twin tower regenerating desiccant units.

The CSA Standard requires the installation of two identical banks of air treatment equipment piped in parallel and provided with valves to bypass either filter set for element replacement, maintenance and repair work while still treating medical compressed air through the other set.

Figure 8 is a two-bank desiccant dryer package each bank consists of three stages within each bank:

- The 1st stage is a prime efficiency coalescing pre-filter rated for 0.01 microns, with filtered differential pressure gauge (element change indicator) and an electric solenoid auto drain valve controlled by the main control system. The pre-filter is the first line of defense against water contaminants and removes water aerosols before the gas enters the dryer. Liquids collected by the assembly's filter cartridge(s) fall to the housing sump and are drained by a float drain.

- The 2nd stage is the heatless desiccant dryer towers. Each bank has two towers filled with desiccant that adsorbs moisture from the compressed airstream down to a dewpoint of -400C. One desiccant tower is always on-line in a drying cycle throughout normal dryer operation. The off-line tower is in a regeneration cycle for removal of the previously adsorbed moisture content.
- The 3rd stage are the after filters. The after-filter removes particulate matter such as desiccant fines that are carried over. To further remove any contaminants, the air passes through an optional activated carbon filter and an optional medical grade sterile filter.

Figure 8. Medical air dryer package

Dew point and CO sensors

Quality monitoring for medical air revolves around measuring the dew point level and the amount of carbon monoxide (CO) present. While air drying and filtration are required, these two elements will not be completely removed and therefore need to be monitored to prevent them from going beyond the USP allowable amounts.

High levels of water vapour present in medical gases create two possible problems:

1. The higher the concentration of water vapour, the more likely condensation will occur within the system. This could either interfere with sensitive instruments and apparatuses or cause corrosion within the system.
2. High levels of water vapour, coupled with the warm conditions in hospitals, encourage the growth of bacteria, which could be harmful when inhaled by the patient.

Both dew point and CO are monitored by passing the medical air through sensors that relay the current levels to a visual display. The system initiates an alarm if the dew point or the CO are above the

maximum level allowed under the USP requirement for medical air. Base mounted package units will typically include factory mounted, piped, and wired, sensors which will include remote alarm contacts.

Summary medical air supply system design:

There are basically four essentials to building a medical air system:

- The intake air location must never be contaminated by placing the medical compressed air systems in a poorly ventilated area
- The medical air must be available at all times, including in the event of a single fault failure.
- The air must be dry enough to ensure no liquid water can develop under any normal operating conditions
- Any contamination that the system can produce within itself under any operating conditions (e.g. particulates) must be removed (e.g. by filtration) before it reaches the patient.

Complete manufacture pre-engineered medical air packages (Figure 9) provide all of the required safety devices for each machine type as well as all of the crucial elements of good compressed air systems design such as aftercoolers, drains and traps, dryers, and vibration isolation.

Figure 9. Medical air package unit

Vacuum (Suction) systems

Like medical air systems that are administered directly to patients, medical-surgical vacuum systems are also considered a life-support system and as such has specific requirements under CSA. All the system components shall be designed for full redundancy with the ability to provide continuous service in the event of a single source component failure and include additional provisions.

The CSA Z7396.1 Standard required that a supply system for vacuum shall consist of a minimum of three interconnected vacuum pumps and that the system shall be capable of supplying the design flow of the pipeline distribution system with any two sources of supply out of service.

A medical vacuum source system is a mechanical unit that through “on-site production” produces a negative pressure and takes air away from the patient. The fluid or material is collected at the “point of use” in a vacuum vessel which prevents any substances from entering the pipeline. The pipeline itself is not meant to capture or transport any fluids or solids. This service is used for a wide number of applications in a hospital and personal will often refer to it as suction.

While pressures in other medical piping systems are measured in psi or kPa, vacuum is commonly measured in inches mercury (in Hg) or millimeters mercury (mm Hg).

The diagram in Figure 10 shows the components of a vacuum system which include:

- pumps/compressors
- filters
- receivers
- controls

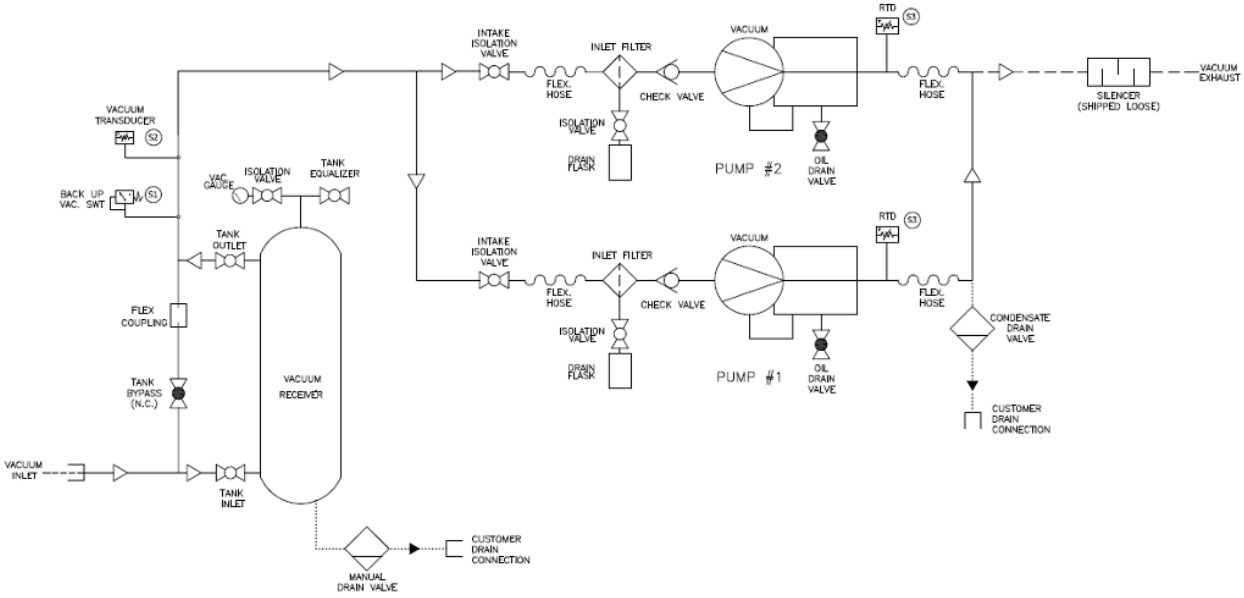

Figure 10. Vacuum system components [Image Description]

Vacuum pumps/compressors

A package medical vacuum system (Figure 11) does not look much different than a medical air system. Just like medical air the compressor is at the heart of the vacuum system. As the air flow is in the opposite direction, the unit is referred to as a pump rather than a compressor.

Figure 11. Packaged medical vacuum pump and receiver system

Just like medical air systems, different types of pumps can be used including rotary vane, reciprocating, liquid ring, rotary screw, rotary claw type, and multi-stage regenerative blowers. The choice of a specific type of vacuum pump depends on factors such as the required level of vacuum, the nature of medical procedures, and considerations for contamination prevention.

Medical vacuum pipeline systems are not intended to convey liquids, so the system must have a means to monitor or control the unintended entry of liquids into the piping. Any liquid drawn into the vacuum pump could cause a catastrophic failure.

Vacuum receiver

As vacuum can be stored as readily as compressed air, a receiver is connected to the suction of the vacuum pump. The primary function of the receiver is to act as a vacuum reservoir to accommodate sudden or unusually high system demands. Receivers used with vacuum pumps are similar to ones used with air, but they must be able to withstand the negative pressure rating to prevent the tank from collapsing. The receiver for a vacuum system is also used as a safeguard to protect the pumps from being exposed to liquids or solids that may be transported by the vacuum pipeline system.

Vacuum Filtration

The vacuum stream poses risks of biohazard exposure to healthcare staff, maintenance personnel, and the broader community if contaminants are released through the vacuum system exhaust. The healthcare facility is encouraged to make an assessment and determine if they consider the medical vacuum stream to be a biohazard and if bacteria filtration is necessary. To mitigate this risk, vacuum system suppliers may supply a HEPA filter with a minimum efficiency of 99.97% at the inlet of the vacuum pump. This measure helps limit the contamination of the vacuum equipment. Safety takes precedence during the maintenance of vacuum pump filters, as they should be regarded as biohazards. When changing these filters, it is imperative to use appropriate personal protective equipment (PPE)

and adhere to proper handling precautions to ensure the well-being of those involved in the maintenance process.

Vacuum system controls

A minimum of three pumps are required by the CSA Standard, so the necessary controls for each pump will be centralized on one control panel. Most control panels will at minimum include the following:

- incoming power disconnects
- indicating lights for operation or alarm functions
- a pressure display
- individual control switches for each of the pumps in the system

The use of programmable logic controllers (PLC) and microprocessors is now relatively standard in newer systems, with the benefits largely revolving around the amount of information that can be shared with the maintenance staff.

Supply system pressure controls and safeties

The pressure in the pipeline between the supply source and patient must very accurately controlled to ensure that the medical gas and vacuum systems remain safe for patient use.

Table in Figure 12 shows the following nominal distribution pressures as listed in the CSA standard:

Figure 12. Medical Gas nominal distribution pressures

Medical Gas	**Nominal Pressure/vacuum**
Oxygen	345 kPa (50 psi)
Medical air	345 kPa (50 psi)
Nitrous oxide	345 kPa (50 psi)
Nitrogen/instrument air	1100 kPa (160 psi)
Carbon dioxide	500 kPa (70 psi)
Vacuum	-68 kPa (-20 in Hg)
AGAA	-40 kPa (-12 in Hg)

Pressure regulators

The gas pressure from each supply system, other than medical vacuum or AGSS, must be must be regulated before they can be used in a medical procedure. Regulation is accomplished by at least two line pressure regulators, installed in parallel to control the distribution pipeline pressure. Regulators are designed to control pressure; they do not measure or control flow unless they are equipped with devices such as a flowmeter specifically designed for such purposes.

The parallel assembly (Figure 13) enables for maintenance, repair, and replacement of any components on one arm without service interruption. The assembly provides single fault protection, automatic backup, overpressure protection, and appropriate regulator adjustments.

A dual-arm assembly includes the following in each arm:

- an inlet isolation valve;
- a line pressure regulator;
- a pressure indicator downstream of the line pressure regulator;
- a bleed valve downstream of the line pressure regulator;
- a pressure relief device installed downstream of the pressure regulator, with no valve intervening; and
- an outlet isolation valve.

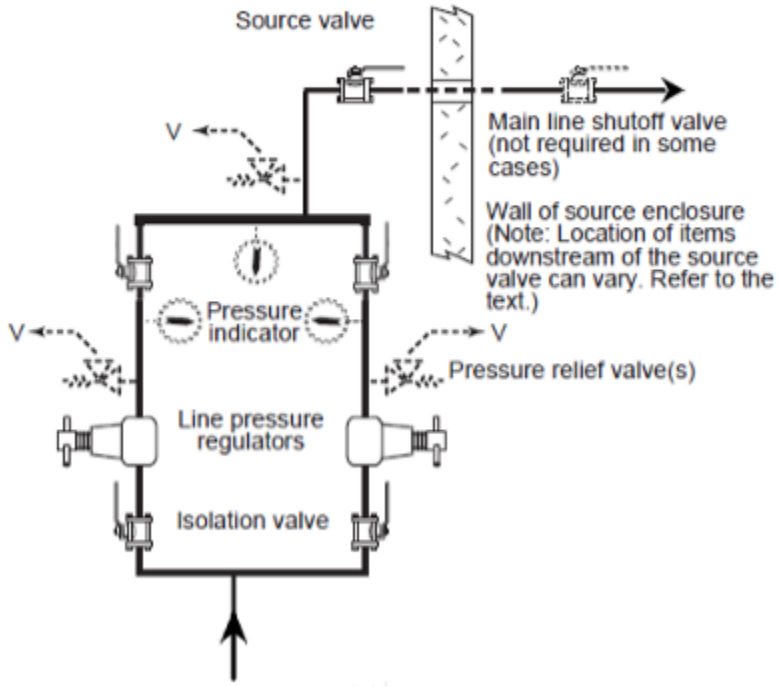

Figure 13. Parallel line pressure regulators

A dome loaded regulator (Figure 14) uses gas pressure to load the top of the sensing element rather than a spring. Dome loaded regulator are commonly used on change over manifolds to activate the appropriate cylinder bank header.

Figure 14. Dome loaded regulator

Pressure relief valve

Pressure relief valves (Figure 15) are installed downstream of pressure regulators. They are used to prevent system overpressure due to regulator failure and cannot be isolated (by a shut-off valve) from pipeline or the pressure regulator to which they serve. They are set approximately 50% above nominal pipeline pressure but not exceeding 1360 kPa (200 psi). Pressure relief valves shall not discharge into locations that would create potential hazards. Therefore, for the most part, all relief valves are vented to outdoors and the vent discharge line can not be smaller than the relief valve outlet.

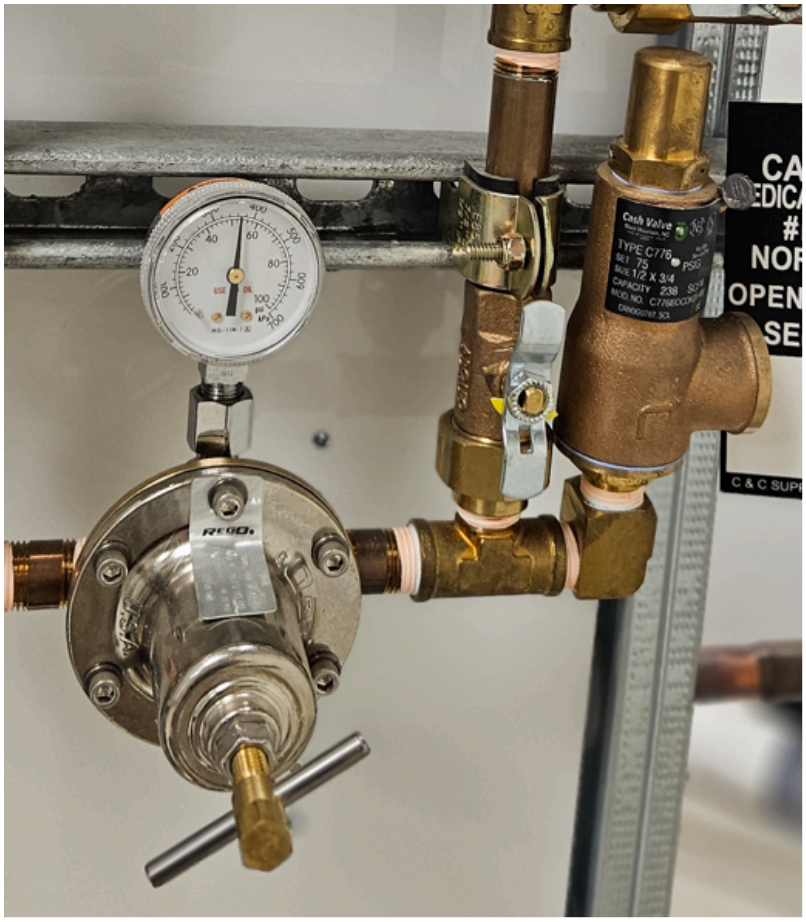

Figure 15. Pressure relief valve monitoring a line pressure regulator

Medical gas cylinder manifolds

A gas cylinder changeover manifold assembly will have multiple regulators and relief valves built into it. The assembly will have additional regulators to first reduce the high cylinder pressure down to an intermediate pressure before going through the line pressure regulator.

Both changeover and simplex supply manifolds contain the following components:

- cylinder pigtails
- high-pressure header bar
- high pressure cylinder bank regulators(with gauges)
- pressure relief valve

A changeover manifold (Figure 16) will also include the following:

- changeover mechanism
- parallel line pressure regulators
- line pressure gauges/display

- method to identify that changeover has occurred

Figure 16. Pressure relief valve monitoring a line pressure regulator

Medical Gas pipeline distribution system

The piped distribution system starts at, and includes, the source valves, warning systems, interconnecting piping and all other components up to and including the station terminal units.

Shut-off valves

Shut-off valves installed in a medical gas pipeline serve two purposes: They control flow during maintenance procedures, and they are used to stop the flow of gas during an emergency. With the exception of vacuum systems which may use butterfly valves, all other medical piping systems must use quarter-turn ball valves. The shut-off valve is a three-piece design with a removable body for servicing without cutting or disassembling of lines. Valves are manufactured with copper extensions (pigtails)to facilitate brazing to the pipeline or with corrugated medical tubing (CMT) fittings. Valves can come with single (Figure 16) or double ¼” NPT-threaded ports cw installed plugs. The code does not specify whether single-port or double-port valve must be used; either can be used at the convenience of the facility. The ports are used to connect line pressure gauges and or sensors. During construction the ports can be used to purge the pipeline with nitrogen.

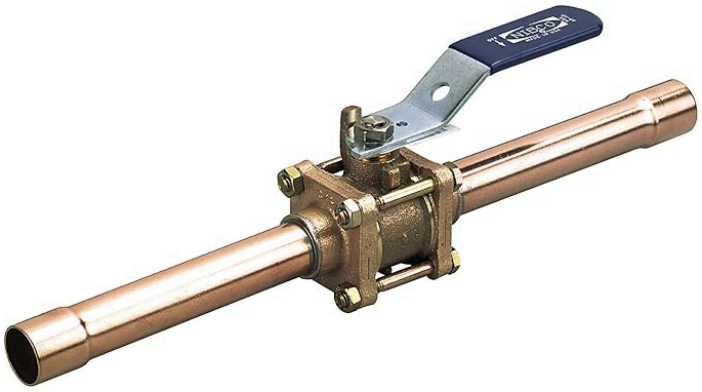

Figure 17. Three-piece ball valve (single port)

The CSA Z7396.1 Standard outlines where shut-off valves are required in the medical gas distribution network. They are identified by their pipeline location such as; source, main, riser, branch and zone valves. Each valve type corresponds to a different level of access and security to maintain the integrity of the systems.

The first valve of the system, called the *main isolation valve*, is located in-view directly at each source supply. When a source system is located remotely away from the building being served, CSA requires a main line valve also be installed in addition to the source valves. The closing of either the source and/or the main line valves will completely shut off the system from the entire building.

The piping system contains numerous lockout type service isolation valves that are required to isolate each riser and branch line from the distribution mains. They are typically installed in “out–of-view” locations known only by maintenance personnel. For this reason, they are only used for isolation purposes and are not for use in an emergency. The isolation valves located throughout the facility must be locked in the open position during normal operation to prevent the valve from accidentally being closed.

The next set of shut-off valves is located within individual zones or departments of the facility. Each type of medical gas that is piped to a specific area will have a zone valve that allows patient care personnel and first responders to isolate a specific gas in the event of an emergency or for authorized maintenance within a zone. There shall be a zone valve between any gas outlets and the upstream branch isolation valve that controls them. Zone valves shall not be installed in series. These zone valves are located in a flush-mounted box or enclosure. This enclosure, known as a zone valve box assembly, or ZVBA (Figure 18), is visible and accessible by department medical personnel. In an emergency the Plexiglas window on the front of the enclosure can be quickly removed by a hard pull of the ring in the center of the window, and the valve(s) can then be closed. The frame edge must be removed in order to replace the window.

Figure 18. Zone valve box

By way of the valve handle orientation, the valves can only be closed if the window is removed. This feature deters inadvertent valve closure, which could have serious consequences for patients relying on the gases.

Zone valve enclosures can contain up to seven valves, depending on the installation requirements. Some valve enclosures have an opening that exposes the chrome-plated portion of the valve, giving an aesthetically pleasing look. The connection with the pipeline is actually concealed behind the drywall so only the valve body and a portion of the connecting pipe are exposed.

The valves in the enclosure must **not** be equipped with a locking feature, and they must have labels identifying the direction flow, type of medical gas, and the locations it serves. There will also be a gauge indicating what the pressure is on the outlet side of the valve.

Medical gas terminal units

Industry professionals may refer to these as either the wall outlets or medical gas outlets. The NFPA standard uses the terms station outlets, or inlets for vacuum. The formal title used in the CSA Z7396.1 Standard is *terminal units*.

The terminal units (Figure 19) are provided at patient locations and allows the gas to be administered to the patient. The connections and faceplates are gas-specific, colour- identified and labelled with the name of the gas they supply. These identifiers are very important in preventing health-care staff from giving the wrong gas to a patient when attaching a device such as a flowmeter or a mask.

Figure 19. Nitrous Oxide terminal unit

A complete terminal unit consists of two separate modules: the rough in assembly and the latch valve assembly (Figure 20). The latch valve assembly is pin indexed to the corresponding rough in assembly to avoid accidental cross connection.

Figure 20. Rough-in body with check valve disassembled (left), bayonet styled (PISS) latch valve and trim plate installed (right)

The terminal unit must contain two safety mechanisms (check valves) that will only allow the flow of gas if the proper conditions exist. These safety mechanisms are known as the primary and secondary check valves. The primary is located in the latch valve assembly and stops the flow of gas or allows gas

to be delivered, depending on whether a gas-specific hose fitting is attached. The secondary is located in the rough-in section and will not allow the flow of gas if the primary section has been removed.

These assemblies include the following components:

- Rough-in assembly:
    - the body that includes the secondary, spring loaded check and latch valve seals, which permits removal of the latch valve assembly for service without requiring the pipeline to shut down.
    - A colour code labeled ½" [12.7 mm] OD copper tube is silver brazed into the body for external pipeline connection.
- Indexed latch valve assembly:
    - the gas specific outlet connector with O-ring seal and internal primary check valve.
    - the color-coded block, complete with body indexing pin
    - gas specific faceplate

Flowmeters

To measure and adjust flow, a special device called a *flowmeter* (Figure 21) is used in conjunction with a pressure regulator to deliver the necessary flow rate of gas for the prescribed treatment.

Figure 21. Oxygen flowmeter

Alarms and sensors

Sensing/alarm systems provide a means to continuously monitor the medical gas source equipment and the operating pressures in the pipeline distribution system as well as in the critical-care areas of the facility.

To accomplish this, two main types of alarm warning systems are utilized for medical gas and vacuum systems:

- master alarm systems
- area alarm systems

Master alarm systems

These systems monitor each medical gas and vacuum source system and the mainline operating pressures at the source of supply. Two master alarm warning panels (Figure 22) are required: one located in an area where it is continuously supervised during all operating hours of the health-care facility, and the other located in the department responsible for maintaining the medical gas and vacuum systems (e.g., facility management, engineering, maintenance shop, etc.).

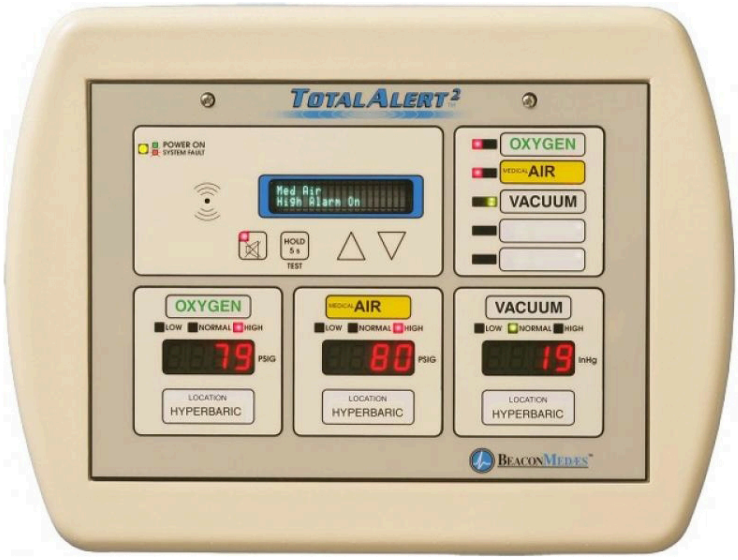

Figure 22. Master alarm panel

Area alarm systems

Area alarm systems (Figure 23) monitor the operating pressures in the pipeline distribution system for specific areas of the health-care facility. They are required for all life-support, critical- care and anaesthetizing locations. These alarm systems provide the medical staff with important information regarding the operation of the medical gas and vacuum pipeline to ensure they remain safe for patient use. Alarm panels are required to monitor pipeline pressure downstream of the zone valve box and must be located where they can be supervised by staff in the area they serve. The area alarm panels are NOT required to be monitored at the master alarm panels.

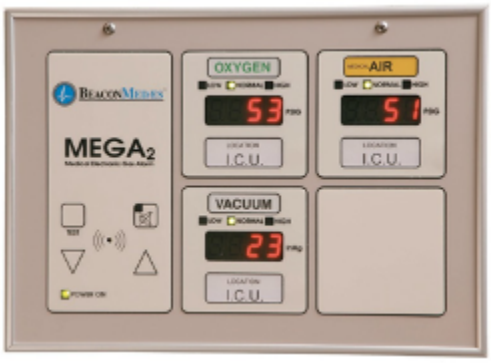

Figure 23. Area alarm panel

Pressure switches

Pressure in the pipelines is sensed by pressure switches or pressure transducers (Figure 24).

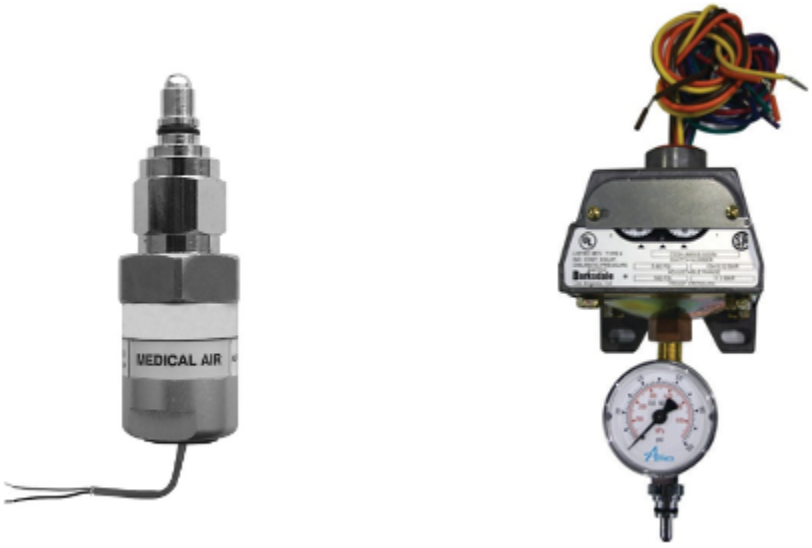

Figure 24. Pressure sensors; Pressure Transducer (left), Pressure Switch with gauge (right)

These pressure sensors connect to the distribution pipeline at critical alarm points and are wired back to the appropriate alarm panel (Figure 25). If the pressure in the pipeline exceeds or drops below a set value it will be annunciated at the alarm panel. The CSA Z7396.1 Standard provides a complete breakdown of all the required alarm points, but the facility operator may add their own extra points. It is important to note that there must not be any valves installed between the pipeline and the pressure sensor to prevent inaccurate reading due to accidental valve closure.

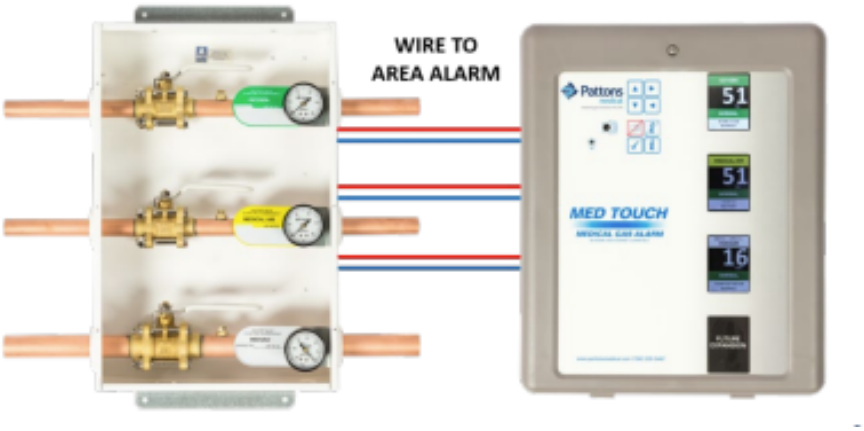

Figure 25. Zone valve transducers wired to area alarm

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://opentextbc.ca/plumbing4a/?p=28#h5p-2

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Image Descriptions

Figure 3. "Liquid oxygen cylinders connected to automatic changeover manifold" image description: A labeled diagram illustrating the main components of an automatic medical oxygen changeover system, including oxygen tanks, changeover control box, distribution piping, and operating and safety controls.

- Oxygen Tanks: An oxygen tank is connected via piping to each side of the Changeover Control Box. Additional oxygen tanks are also available.
- Changeover Control Box: This control unit monitors the system and indicates when a changeover from the primary to the secondary oxygen bank has occurred. It typically features status lights to signal the switch, and many units also include an audible alarm to alert operators. Some changeover boxes may also have a manual reset function.
- Distribution Piping: The system includes supply piping for the oxygen and vent piping for safely venting gas from the pressure relief devices to the atmosphere. All distribution piping is required to be ASTM B819 approved.
- Operating and Safety Controls:
    - High and Low Pressure Relief Valves (PRVs): These valves protect the system by maintaining safe pressure levels within the oxygen supply.
    - High/Low Line Transducer: This device continuously monitors and adjusts the system the desired pressure.

- Standards and Safety Codes:
    - DISS (Diameter Index Safety System): This system ensures that only compatible medical gas equipment is connected, preventing the risk of improper connections.
    - CGA (Compressed Gas Association): The system follows CGA standards to ensure safety and compliance with industry regulations related to compressed gas use. *[Return to Figure 3]*

Figure 6. “Oxygen concentrator central supply source with three sources” image description: A labeled diagram of an oxygen concentrator-based supply system, featuring three sources of supply, distribution piping, and key operating and safety controls.

- Sources of Supply:
    - The system is supported by two oxygen concentrator units and one bank of cylinders for continuous supply.
- Isolation and Monitoring:
    - Isolation Valves are strategically placed throughout the system to allow for isolation of supply lines when necessary for maintenance or emergency procedures.
    - Pressure Gauges are installed at key points to monitor and display the pressure levels within the system.
- Safety Features:
    - Vented Pressure Relief Devices are integrated into the system to protect against overpressure conditions. These devices safely vent excess oxygen to the outdoors, preventing potential system failure or hazardous conditions.

DISS ports will be installed along the piping for collection of samples. *[Return to Figure 6]*

Figure 10. “Vacuum system components” image description: A labeled diagram illustrating the components of the vacuum system, including pumps/compressors, filter locations, a receiver, and key controls.

In this example, two vacuum pumps operate in parallel to maintain the required vacuum pressure within the medical vacuum piping, ensuring continuous and reliable operation.

- Filters are strategically located upstream of each pump’s inlet, establishing that only clean, filtered air enters the pumps, preventing contamination and maintaining desired system performance.
- The vacuum receiver serves as a storage unit, temporarily holding air extracted from the facility until a vacuum demand arises, helping to stabilize the system’s pressure during intermittent usage.
- Essential control components include:
    - Isolation valves, which enable safe and efficient maintenance.
    - Flexible connectors, which protect the piping from stresses caused by movement or

vibrations.

- Drain valves, which allow for easy removal of any accumulated condensate or debris. *[Return to Figure 10]*

Learning Task 2

Lay Out a Medical Gas Piping System

The medical gas pipelines lead to many areas of the hospital, with the most vital area being surgery. Surgery and patient rooms are equipped with outlets that act as quick connections for attaching equipment and medical devices. Different configurations for the piping distribution system exist to link the source equipment to the terminal units. The chosen configuration should consider the acuity level of patients in different departments and the demand for medical gas from those patients.

Service requirements for different areas

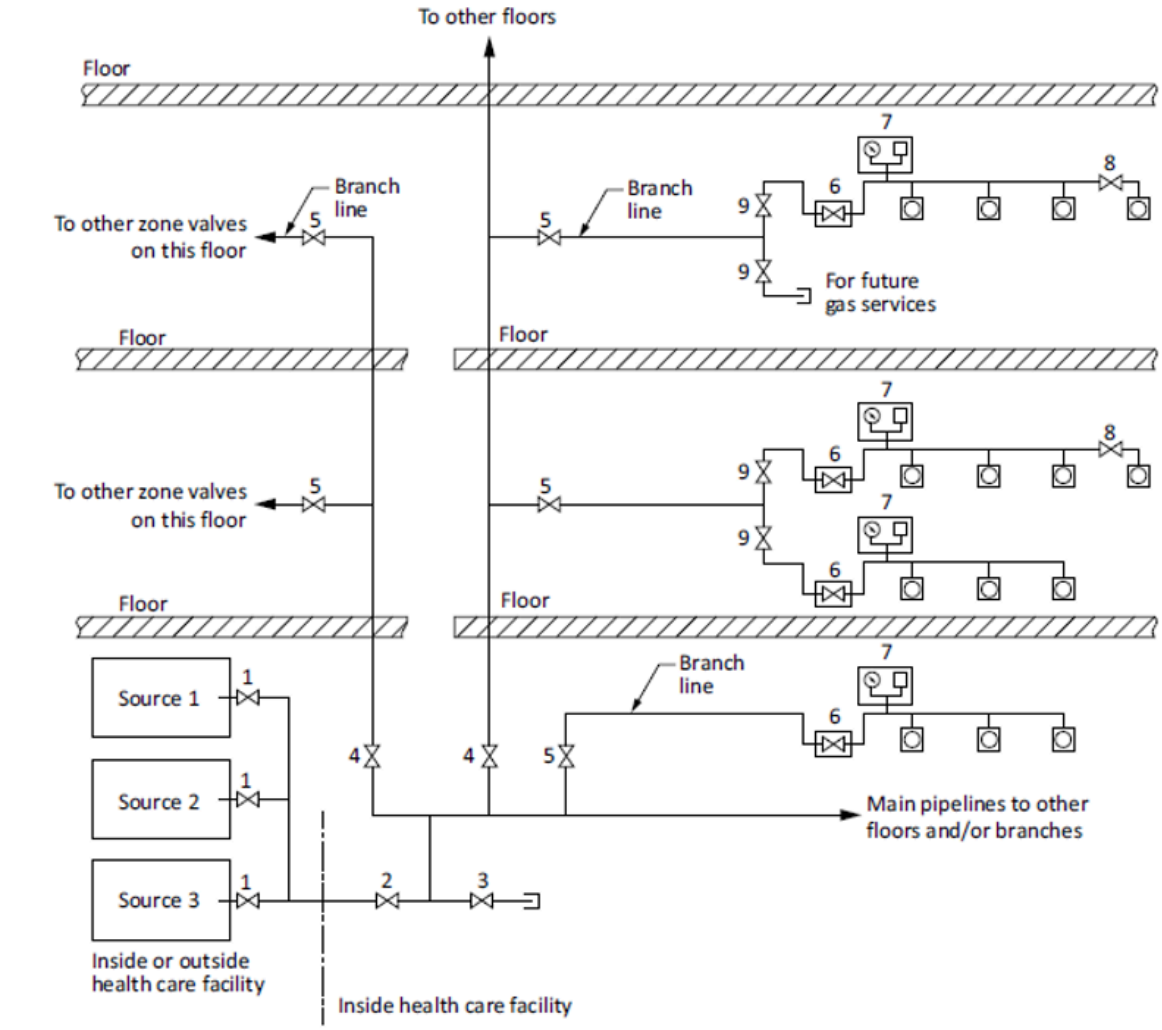
The type of care given in different areas of a facility will dictate the specific gases and services that are required. The CSA 7396.1 Standard gives a suggested distribution guide used to direct the design professional in laying out the piping network (Figure 26).

Figure 26. Piping network distribution guide

Area	Oxygen	Nitrous Oxide	Medical Air	Medical Vacuum	Nitrogen	Carbon Dioxide	AGSS
Anaesthetics	X	X	X	X	X	X	X
Autopsy				X	X		
Clinical areas	X	X	X	X			X
Critical care	X		X	X			
Emergency	X		X	X			
Surgery	X	X	X	X	X		X

Route piping

Figure 27 shows the terminology used for medical gas pipelines and shut-off valves. In general, outlets route to branch lines, branch lines will route to zone valves, zone valves must route via the branch to service valves at the main or riser, risers will route to riser valves, riser valves will route to the mains and the mains will connect to the main line valves. Records shall be made listing the location of each service isolation valve and the rooms or areas controlled by each service isolation valve. These records shall be stored in a secure manner and be accessible for reference by service and repair personnel.



Legend:

1 = Source shut-off valve
2 = Main shut-off valve
3 = Auxiliary inlet connection
4 = Riser shut-off valve
5 = Branch shut-off valve
6 = Zone valve
7 = Zone alarm
8 = Optional service isolation valve
9 = Service isolation valve

Figure 27. Medical gas pipelines and shut-off valves [Image Description]

A few general routing guidelines include:

- Piping should be configured to make the route as short as practically possible with a minimum number of fittings and turns (in particular medical vacuum).
    - The more fittings and bends that are present in the pipeline, the greater the head loss for the medical gas. This means that the pressure drop in the line will be

greater, ultimately affecting the end flow or suction the patient will be receiving.

- Wherever possible, route piping down hallways instead of through walls. If a wall only serves as a partition and does not reach the deck above, the piping can be run over the walls. Running lines through firewalls is not advised, as that will reduce the fire-stopping capability of that wall.
- For vacuum piping, avoid creating low spots or “U” traps in the route. The ideal vacuum layout would be sloped towards the pump inlet, to allow for any liquid to run off before reaching the pump. Of course, this is just an idealization and very difficult to implement practically. However, fluid drainage is definitely a consideration to keep in mind while creating pipe routes.
- It is standard practice for zone valves to run from the source into the left side and to the outlets/inlets from the right side. There are few circumstances where this orientation can be reversed and problems later on will not occur.
- Zone valves are to never be connected in series, so that shutting down one zone valve will force the shutdown of another. Each zone valve must separately run to a service valve. However, multiple zone valves may be feed from a single service valve.

Section 8 of the CSA Z7396.1 Standard lists the requirements for service isolation and zone valves. The following are some of the requirements that relate to the routing and location of these valves:

- All shut-off valves shall be accessible for servicing.
- There shall be an isolation shut-off valve between each supply system and the distribution system, located as close as possible to the supply.
- These valves shall be accessible to facility personnel.
- When the supply source is located outside the facility in an enclosure, a service isolation valve is required within the enclosure. This valve must be secured in the open position.
- Each riser connected to the distribution main and each branch connected to the riser shall have a service isolation valve installed. These valves shall be accessible to authorized persons only.
- There shall be at least one service isolation valve between the pipeline distribution system and any zone valve. The first service isolation valve upstream of the zone valve must be on the same floor as the zone valve.
- All service isolation valves shall be accessible to authorized personnel only.
- A zone valve shall be installed to control all of the terminal units in a specified zone.
- There shall be a zone valve between any terminal unit or group of terminal units and the upstream service isolation valve that controls them.
- A zone valve shall be on the same floor as the terminal unit(s) it controls.
- Zone valves shall not be installed in series.
- Zone valves shall be placed in locations where they can be seen and accessed
- Zone valves shall not be located in closets or locked rooms.

- Zone valves shall be installed immediately outside each anaesthetizing location.
- Zone valves shall not be installed closer than 2 m (6.5 ft.) to any fixed terminal unit.
- Zone valves shall be enclosed in zone valve boxes.
- Zone valve boxes shall be accessible at all times.

Areas not permitted

Generally, medical gas pipelines should be kept away from areas where an unsafe condition may exist. Specific areas where their installation is prohibited include the following:

- Kitchens or elevator shafts.
- A tunnel where contact with oil could occur.
- Exposed areas subject to damage unless protected.
- A service trench or tunnel, unless it is well ventilated.
- Underground, unless protected adequately against frost, corrosion and physical damage. Copper tubes may experience severe corrosion if buried in direct contact with certain aggressive environments.
- For buried pipe, a continuous warning system, such as warning tape, should be placed at one-half the depth of the burial.

Pipe sizing

Sizing of the pipeline distribution system should be carried out after the piping distribution system

routing through the building has been determined. The CSA Z7396.1 Standard states within Section 7.2 on pipe size design:

- *Pipelines and fittings, including line pressure regulators, connecting assemblies, and low-pressure flexible hose assemblies, shall be capable of passing the maximum design flow of the pipeline distribution system at a nominal distribution pressure within the ranges given in Table 2. The pressure change shall remain within the limits given in Table 2. See* Annex E for general guidelines for pipe sizes, flows, and pressure drops.
- *The health care facility shall determine its medical gas flow requirements in consultation with technical and clinical staff, consulting engineers, and equipment suppliers.*

The quoted Annex E of the CSA standard is supplied as a Medical gas pipe sizing guideline but ultimately the entire piping system must engineered for a minimum amount of pressure loss to ensure it meets the flow requirements for all of anticipated respiratory, anesthesia, and other diagnostic and therapeutic applications.

Pressure drop in the risers and main pipes should be kept below 2.3 Pa per linear metre (0.01 psi per 100 linear feet) of piping). This allows the risers and main pipes to act as reservoirs to accommodate the sudden spikes in demand in the piping system. The total pressure drop across the pipeline

distribution system, excluding the terminal unit and its inlet connector, shall not exceed 35 kPa (5 psi) for compressed gases, except for nitrogen, which shall not exceed 85 kPa (12 psi). The pressure drop for vacuum shall not exceed 17 kPa (5 in Hg).

As a final precaution the pressure drop will be tested at each terminal unit when the system is commissioned.

Location of compressor systems

The area should have an average ambient temperature of 70oF (21°C) with a minimum ambient temperature of 40°F (4.4°C) and a maximum ambient temperature of 104°F (40°C). (Note: At temperatures below 32°F the bare compressor will not be adversely affected, but freezing of the condensate can occur which could affect operation.)

The systems should be located as close as possible to the point of usage to prevent excessive loss of operating pressure/vacuum due to friction pressure drop. Sound levels should be considered when locating the systems.

The compressor packaged systems should be placed to ensure easy access to perform maintenance and high visibility of indicators and gauges. It is recommended that a minimum space of 24” be allowed on all sides of the compressor systems for ventilation and maintenance. A minimum space of 36″ in front of the control panel is required by the electrical code. A vertical distance of 36” is required above the units for ventilation and maintenance.

Locations and limitations of cylinder and bulk supplies

There are particular requirements for storing medical gas cylinders and for bulk tank storage in health-care facilities.

Medical gas cylinders should be stored in a specifically built cylinder storage room or enclosure that allows the cylinders to be kept dry and in a clean condition. The storage room:

- Must be built of materials having a fire rating of at least one hour.
- Must have doors that open outwards and are lockable and accessible by authorized personnel only.
- Must be heated by low-temperature indirect means if required.
- Must provide electrical protection for electrical devices.
- Must be climate controlled so that the ambient temperature does not exceed 40°C (104°F) for any gas and is not be less than 15°C (60°F) for nitrous oxide and carbon dioxide.
- Must be well ventilated, with the vents located near the floor.
- Should have a means of separating empty and filled cylinders and labelling them as such, and have physical supports for the cylinders to avoid the risk of them tipping over.

- Should have good access for delivery vehicles and reasonably level floor areas.

Medical gas bulk storage systems must be located above ground if outdoors, or must be installed in a building or enclosure of non-combustible construction that is adequately vented and used for that purpose exclusively. Delivery truck access and signage are important considerations for these storage areas, as the tanks must be labelled in a very specific manner to warn building occupants of the safety hazards within.

Now complete Self-Test 2 and check your answers.

Self-Test 2

Self-Test 2

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Media Attributions

- Figure 27. “Medical gas pipelines and shut-off valves” – The source for this image is unknown. It is being used for non-commercial, educational purposes. To receive credit for this image, please reach out to the publisher.

Image Descriptions

Figure 27. “Medical gas pipelines and shut-off valves” image description: A labeled diagram illustrating the use of shut-off valves in medical gas distribution piping, highlighting the isolation points and key component locations through the different levels of a building.

- First Level:
    - Tank Storage (1): External tanks are equipped with individual shut-off valves, allowing for the isolation of each tank.
    - Main Supply Shut-off (2): Located immediately inside the building, this valve

isolates the entire supply source(s) from the distribution system.

- Auxiliary Supply Shut-off (3): Positioned to isolate a backup gas supply, for uninterrupted service in case of primary supply failure.
- Riser Shut-off Valves (4): Each vertical riser has a dedicated shut-off valve to isolate specific sections of the system.
- Branch Shut-off (5): Any branch extending from a riser is fitted with a shut-off valve to allow for localized isolation.
- Redundant Zone Valve Shut-off (6): Installed to isolate a bank of terminal units, providing additional redundancy for enhanced safety.
- Zone Alarm (7): Positioned upstream of each zone, these alarms monitor the system to alert operators to any issues.

- Second Level:
  - Service Isolation Shut-off (9): Positioned upstream of the zone shut-off, this valve allows for isolation of service lines feeding into the zone.
  - Optional Service Shut-off (8): Installed downstream of multiple terminal units, this valve provides isolation for another group of terminal units, offering flexibility in maintaining the system. *[Return to Figure 27]*

Learning Task 3

Install Piping for Medical Gas Systems

The medial gas system supplies clean, contaminant-free gasses through hundreds, if not thousands, of feet of pipe and tube that has been cleaned and installed per requirements of the CSA standard.

Certification requirements

The Z7396.1 Standard states in clauses 11.4.1.1 and 11.4.1.2 that:

An installer shall meet the requirements of the CSA Medical Gas Piping & Systems Installation Personnel Certification Program or equivalent.

And that:

Prior to any installation, with the exception of stationary liquid supply systems, installers shall submit evidence of qualification to install medical gas systems to the health care facility for inclusion in its permanent records.

Note: In Canada, evidence of qualification to install medical gas systems consists of a valid medical gas licence meeting the requirements of the CSA Medical Gas Piping & Systems Installation Personnel Certification Program or equivalent.

To meet the certification needs of industry, the CSA Group has formed a training partnership with the United Association Canada (UA) and the National Association of Union Schools and Colleges (NAUSC). The UA Med G.A.S. program prepares journeyperson and apprentice pipe trades workers with the skills and abilities to complete medical gas piping installations safely and securely in all forms of construction and maintenance operations in the hospital construction industry. Once certified the installer will possess the necessary knowledge of the following:

- CSA-Z396-1 Standard requirements
- medical gas tools and equipment
- principles of medical gas pipeline systems
- brazing and purging theory
- certification requirements
- hospital shutdowns
- practical brazing and purging
- installation tests

To apply to take the Medical Gas Piping and Systems Installer exam for certification, candidates must satisfy the following prerequisites and submit documentation:

1. Certificate of Qualification (C of Q) Plumber or Steamfitter/Pipefitter; and
2. Documented completion of a recognized medical gas training program that includes:
3. 32 hours classroom training, and
4. 4-hour practical/hands-on training (brazing / purging procedures); and
5. Valid provincial brazing test (acceptable to the AHJ in province of residence).

The Standard also states:

If applicable, prior to any installation, installers shall submit evidence of qualification (e.g., a valid brazing licence, as issued by an authority having jurisdiction in accordance with CSA B51) to the health care facility for inclusion in its permanent records. Currently, the Technical Safety of BC – Boiler and Pressure Vessel Safety Program has been designated to perform the oversight functions cited in Clause 4.5 of CSA B51.

In addition to meeting the requirements of the CSA Medical Gas Piping & Systems Installation Personnel Certification Program, installers of Corrugated Medical Tubing (CMT) shall complete and pass the manufacturer's training course.

Codes and regulations

The installation, use and verification of medical gas pipeline systems are governed by the CSA Z7396.1 Standard. The current version is not a legislated document that is mandatory in all areas of Canada. It is a voluntary standard that is available for use or reference by those involved with medical gas piping systems. In order for the standard to become mandatory, it must be listed within the National Building Code (NBC), which sets out construction and building standards for Canada.

The Standard provides a detailed list of supporting standards that are referenced to be used in conjunction with the CSA Z7396.1. These other standards are primarily from Canada, the United States or the European Union and cover areas such as pressure vessels/piping (CSA B51), performance requirements for piping material (ASTM) and electrical requirements (CSA Z22.1), to name a few. The rationale for using these other standards is that they deal with very specific topics that have a direct relationship with medical gases or pipeline systems.

Besides the various sections that list the system requirements, there are also diagrams, tables and annexes, which offer both mandatory and normative references. These are intended to further assist in understanding various concepts, give examples of specific situations or provide much more detail of particular requirements.

Location

The positions of pipes, supports, fixings and terminals are determined from plans and specifications or

site requirements, so as not to cause damage or interference to surrounding structures. The CSA Z7396.1 Standard states the installation requirements for pipelines in the following clauses:

- 11.2.1: Pipelines and electrical services shall either be run in separated compartments or, if in the same compartment, separated by at least 50 mm (2 in.) or by conduit.
- 11.2.2: Pipelines in corridors and other exposed locations shall be protected from physical damage (e.g., from the movement of portable equipment, such as trolleys, stretchers, and trucks).
- 11.2.3: Unprotected pipelines shall not be installed in hazardous areas (e.g., in areas where flammable materials are stored). Where installation of pipelines in such a location is unavoidable, the pipeline shall be protected by an enclosure that will prevent the release of medical gas within the room if leaks occur.
- 11.2.4: Pipelines shall not be installed in elevator shafts.
- 11.2.5: Terminal units shall be located or protected so as to avoid physical damage to the terminal unit and attached auxiliary or control equipment. Risk analysis shall be in accordance with CAN/CSA-Z1002
- 11.2.6: Where medical gas pipelines are installed in pipe shafts with other services, they shall be suitably protected against physical damage and excessive temperatures.
  If pipelines are placed in the same tunnel, trench, or duct with fuel pipelines, steam lines, or other services, they shall be a minimum of 50 mm (2 in) apart.
  Ducts in which pipelines are installed shall be ventilated.
- 11.2.7: Buried pipelines shall be placed below the frost line in free-draining, non-corrosive backfill. Measures (i.e., permanent signage, physical barriers, or both) shall be taken to protect the pipeline from accidental digging or other damage. A medical gas pipeline shall not be placed in a tunnel, trench, or duct where it can be exposed to oil. Corrugated medical tubing shall be routed in a watertight, non-metallic conduit when installed underground or when encased in concrete.
- 11.2.8: A continuous tape or marker placed at half-depth above the pipeline shall clearly identify the pipeline by name

Pipe types

Copper has antibacterial properties which make it ideal for use in medical gas installations. The pipelines shall be either:

- Seamless copper tubing that complies with the ASTM B 819 standard. Type K or L hard temper copper tube is used for all locations except underground, where soft temper is preferred in order to reduce the number of inaccessible joints. Type K must be used where operating pressures are above 1275 kPa (185 psi) and the pipe size is larger than NPS 3 inch.
- Listed corrugated medical tubing (CMT) and fitting system fabricated from copper alloy No. 51000 strip meeting ASTM B103/B103M and is certified to UL 1365 (Figure 28). The CMT is externally coated with a non-metallic sheath which has the proper flame and smoke rating.

The CMT has a minimum pressure rating of 1100kPa (160 psi) and cannot be used for vacuum piping.

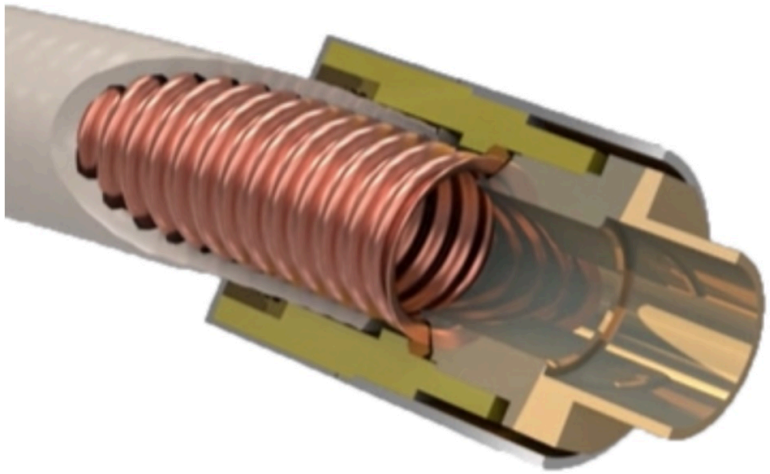

Figure 28. Corrugated copper alloy tube and permanent fitting system

The only exception to these two pipeline materials requirements are approved flexible connection assemblies which are used for vibration isolation and expansion control.

Hangers and supports

Hangers and supports are installed to comply with plans, specifications, standards, authorities' requirements and manufacturer recommendations. Installation requires added care for the protection of pipes from physical harm. Medical gas pipe is hung independently from other piping, and the hangers must be of a type, style and strength that will prevent accidental pipe movement. Figure 29 lists the maximum spacing of piping supports.

Figure 29. Spacing of piping supports

NPS (mm)	Spacing of support ft. (m) Horizontal	Spacing of support ft. (m) Vertical
½” (12)	6 (1.8)	6 (1.8)
¾” (18)	8 (2.4)	6 (1.8)
1” (25)	8 (2.4)	8 (2.4)
1¼” (32)	10 (3.0)	8 (2.4)
1½” (40)	10 (3.0)	8 (2.4)
2” (50) and larger	10 (3.0)	10 (3.0)

Joining methods

Medical gas piping may be joined using two distinct types of joints:

- Silver Brazed
- Axially swaged, elastic strain preload fittings
- Threaded

Brazed fittings shall be constructed from wrought copper, brass, or bronze complying with ASME B16.50 or ASME B16.22. They must be rated for the maximum pipeline pressure that could be encountered in the installation, testing, and service of the system.

Approved axially swaged, elastic strain preload fittings are used on CMT and create a permanent and non-separable connection. These fittings must be installed by qualified persons in accordance with the manufacture’s instructions.

Threaded joints ½” or less are used on main line gauges, zone valve gauges, alarm sensors, gas specific check valves and relief valves. Central supply source equipment and manifolds also use threaded connections. Joints shall be made up with approved Teflon tape or joint compounds rated for medical use that must not contain oil if used on oxygen systems. Joint sealant is applied to the male threads only, keeping the first three threads bare to prevent any compound from squeezing into the pipe. This type of joining method is only used in accessible locations for testing/ inspection and only to connect devices that cannot be brazed. The use of threaded joints should be minimized as they are more susceptible to leaking.

Cleaning and storing methods

The contractor who installs medical gas piping must take care to use only clean pipe. Since copper is used for many other applications, pipe that is cleaned specifically for medical purposes will be stamped accordingly. Each length of copper tubing or CMT shall be delivered plugged or capped by the manufacturer. On-site cleaning of medical gas piping shall not be permitted (Figure 30).

Special cleanliness requirements are called for because oxygen under pressure may cause the spontaneous combustion of some organic oils (the residual of lubricating oil used during manufacture) and for the safety of patients receiving medical gases. It is the responsibility of the installer to ensure they are using the proper type of piping material and that it meets with the cleaning requirements of the CSA Z7396.1 Standard.

Care must be taken when storing and handling piping material. The contractor should establish “clean areas” on the job site for storage. Material for use in a medical gas system should be stored separately from pipe and fittings use for water distribution and must be capped or plugged to prevent recontamination before final assembly. Immediately before final assembly, the material must be examined internally for contamination.

Figure 30. ACR med nitrogen-filled degreased medical gas tubing

Degreasing

Copper tube used in medical gas systems typically arrives at the site degreased, capped and holding a nitrogen purge. Fittings used in the installation are also available cleaned and degreased from some manufacturers. Alternatively, on-site cleaning of fittings and hand tools can be accomplished by washing them in a hot solution of trisodium phosphate (TSP) or sodium carbonate. This solution is mixed at a rate of 40 g of cleaning material per litre of hot water.

The fittings or tools are scrubbed if necessary and rinsed in clean hot water. After cleaning, fittings and components are carefully stored or packaged to prevent recontamination until final installation is completed.

Capping

Medical gas copper tubing is available from the manufacturer degreased, oil-free and nitrogen purged. The manufacturer installs caps in the tube ends that fit snug to the tube's ID surface and do not require any special tools to remove. The reason for the nitrogen purge is to prevent copper oxide from forming inside the tubing. Once the caps are removed and the tube is cut for installation, the nitrogen protection is lost. Oxygen in the air combines with copper to form cupric oxide.

This substance is often visible on the surface of the copper tube as a light to dark brown discoloration, even when in storage.

Cutting, fitting and brazing methods

All tools used for assembly of medical gas piping systems must be free of grease and oil before they are used. Reamers and cutters may be cleaned (degreased) on-site by washing them in a hot solution of trisodium phosphate (TSP) or sodium carbonate.

When fitting the piping system before joining, accurately measure the length of each tube segment required for the installation. Cut the tubing using a tube cutter and remove all inside and outside burrs with a reamer. If the joint is to be silver brazed, remove all oxides and surface soil from the tube ends and fitting hub using a nonshedding abrasive pad for a distance slightly more than the depth of the fitting hub. Clean the fitting hubs by the same method or use a properly sized stainless or brass fitting brush. The removal of oxides is crucial for the proper flow of brazing alloy into the joint to provide strength. If the joint is to be threaded, it must be made up with Teflon tape or other thread sealants suitable for oxygen service. Sealants shall be applied to the male threads only.

Medical gas systems require that during brazing, the system shall be continuously purged with oil-free dry nitrogen. The purge gas displaces oxygen from the interior of the tubing while it is being subjected to the high temperatures of brazing and therefore eliminates the possibility of oxide formation (oxidation) on the interior surface of the tube. The purge shall be maintained until the joint is cool to the touch.

When brazing onto the pigtails of valves and terminal units take care not to heat up the valve body. It is recommended to wrap the pigtails with a wet rag or heat block putty next to the valve to prevent overheating and possible damage to the valve seals.

The outside of all tubes, joints and fittings should be cleaned by washing with hot water after the brazing process to provide a clear visual inspection of brazed connections. The inspection body will inspect the entire system before validation. If the inspection body deems it necessary, they may randomly choose fittings to cut out and inspect the joints for interior oxidation and depth of penetration of the brazing alloy.

Purging requirements and procedures

All medical gas piping must be purged with dry nitrogen while brazing. At high brazing temperature a heavy black oxide scale forms (cupric oxide). On cooling, this oxide scale flakes off. While on the

exterior of the tube this is mostly cosmetic, on the inside the oxide flakes are carried by the gases through the system. To prevent oxidation, establish a flow of dry nitrogen through the tube during brazing. Nitrogen is inert (non-reactive) and will displace the oxygen to prevent scale formation.

Nitrogen is typically introduced into the system through a hose adapter/fitting at the manifold location or other system opening such as a valve port. Connect a hose or tube from the fitting to the regulator or flow control valve on the nitrogen cylinder. There is no universal requirement for the delivery pressure setting, but the goal is to use low volume/ pressure to displace the oxygen. A suggested starting point is 10–15 CFH. Some users set pressure until they feel a slight flow at the exit point on the back of their hand. It's good practice to initiate nitrogen flow before heating and to continue the flow until the joints have cooled.

Avoid an excessive flow rate that builds pressure inside the tube. A high flow rate will tend to cool the tube, reducing brazing heat efficiency. Excess nitrogen pressure can build up inside the tube and reduce braze alloy penetration. A small hole in a cap at the end of the line will allow the nitrogen to escape. Some installers prick a hole in a balloon and attach it to the open end of the pipe. The balloon inflates enough to show a visible pressure as nitrogen escapes through the now-enlarged pinhole.

Brazing material requirements and characteristics

All brazed joints in the piping must be made up using brazing filler metals that bond with the base metals being brazed and that comply with Specification for Brazing Filler Metal, ANSI/AWS A5.8, which states:

- Copper-to-copper joints shall be made using a copper-phosphorus brazing filler metal (BCuP series) without flux. The phosphorous within the BCuP brazing rod acts as the flux on all copper connections.
- Dissimilar metals such as copper and brass shall be joined using an appropriate flux with either a copper-phosphorus (BCuP series) or a silver (BAg series) brazing filler metal. Apply flux sparingly to the clean tube only and in a manner to avoid leaving any excess inside of completed joints.

Tools and equipment

During disassembly and reassembly of any equipment, procedures shall be followed to ensure tools and parts are kept clean and free of contamination in the form of dust, dirt, grease or oil. Always keep medical vacuum parts and positive pressure parts separated from each other. You as the installer should exercise great care in the storage and handling of tools used in cutting and reaming to prevent oil, grease or other contaminants from being introduced into tubing during assembly. Ladders, scaffolds and personal protective equipment must be selected and checked for serviceability in accordance with WorkSafeBC guidelines.

Coordination with other trades

Coordination and communication early on with other trades is key to the success of any project to assure timely installations and to avoid conflicts and interference. Due to the complexity of medical facility installations, there are always space limitations in the ceiling that affect the ventilation, electrical and sprinkler systems. The installer must be able to coordinate work with other trades to accommodate actual architectural, structural and site conditions. Some of the typical coordination requirements are as follows:

- Coordinate with the metal stud partition installer and/or mason to ensure anchors, sleeves and similar items are provided in sufficient time to avoid delays. Ensure that chases and openings are properly sized and prepared.
- Coordinate with the owner to ensure medical gas outlets, whether owner supplied or contractor supplied, in walls, ceilings and all equipment are provided by the same medical gas equipment manufacturer (MGEM) and are satisfactory to the owner.
- Coordinate with the bulk cryogenic gas supplier for installation, connection and verification of bulk gas supply systems.
- Coordinate with the medical gas verifier (or inspector) to deliver a complete, tested medical gas installation ready for the owner’s use.

Pipe and component labelling

Medical gas piping, including all intakes, exhausts and vents, must be clearly identified using non-removable stickers that are colour coded to specify the gas it conveys. Colours are standardized according to the CSA Z7396.1 Standard (Figure 31).

Figure 31. CSA Z7396.1 Standard – Marking and Colour Coding

Gas or gas mixture	**Symbol**	**Background colours**	**Lettering**
Medical air	MedAir	Half black – half white	Half black – half white
Carbon dioxide	CO_2	Grey	White or black
Helium	He	Brown	White
Nitrogen	N_2	Black	White
Oxygen	O_2	White	Green
Nitrous oxide	N_2O	Blue	White
Medical – surgical	MedVac	Yellow	Black
Anaesthetic gas scavenging system	AGSS	Magenta	White

Labels (Figure 32) must be spaced along the pipe no more than 6 m (20 ft.) apart and also at:

- every valve
- each access door
- each terminal unit
- immediately before and after barriers
- inlet and outlet points

The label must:

- be lettered and coloured in accordance with Table 5 in the CSA Z7396.1 Standard
- have lettering at least 9 mm (3/8″) high
- have arrows indicating direction of flow
- be applied with the lettering parallel to the axis of the pipe
- be of sufficient width to overlap itself when applied

Figure 32. Medical gas pipe labels

When a large medical gas system is being installed, several different gases may be piped into an area, all running beside each other. This installation will have numerous branch lines connected to the main pipe. These branches will then split and go to various rooms or departments, which will involve using tees, elbows, etc. It is sometimes confusing which line is intended for which gas, especially since they may not be labelled for a short period of time at the location where the work is being done. It is critical that installers use good piping practices to recognize and eliminate cross-connections before the system is tested. Sentence 10.3 of the CSA Z7396.1 Standard states: “Labels shall be placed on the piping, including all intakes, exhausts and vents, **as each is installed**.”

Dangers associated with cross-connection

The installation, use and verification of medical gas pipeline systems are governed by the CSA Z7396.1 Standard. The driver behind the development of the Standard was to address a fatality that occurred when a patient was being treated for a non-life-threatening condition. It was discovered that a cross-connection between the oxygen and nitrous oxide pipelines supplied the patient with 100% nitrous oxide, which does not sustain human respiration.

CSA Z7396.1 Standard contains significant steps to ensure that a dedicated pipeline is not conveying the wrong gas due to a cross-connection. The Standard prescribes different procedures that must be followed to validate gas-specificity of the pipeline and certify that no two pipelines of different medical gases have been mistakenly cross-connected. These tests and verifications must be completed following any repair, maintenance or modification of a medical gas system.

Now complete Self-Test 3 and check your answers.

Self-Test 3

Self-Test 3

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Learning Task 4

Install Equipment for Medical Gas Systems

Medical gas systems require specialized equipment for the supply of different types of gases such as: Medical air, Vacuum, Oxygen, Nitrogen, CO_2, and Nitrous oxide.

Regardless of whether a building is being newly constructed or a renovation is planned, it is important to be familiar with all documents, which specify the minimum system requirements and the minimum training standards required for medical gas installers, inspectors and verifiers. When all of these resources are utilized, there is a much greater likelihood that facilities will be constructed and maintained for the greatest patient safety.

Codes and regulations

Medical gas installers should be familiar with the standards that define the proper installation of medical gas equipment. The following are important industry trade groups that have helped to establish and support the codes that are necessary to design and construct safe medical gas pipeline systems:

- CSA Group
- National Fire Protection Association
- American Society of Plumbing Engineers
- Medical Gas Professional Healthcare Organization

Each of these groups has contributed to the development of formalized guidelines for the construction and maintenance of medical gas piping systems and medical gas testing and certification. When dealing with medical gas systems and equipment manufacturers, CSA Z7396.1 and NFPA 99 are the most important documents to reference.

Jurisdictional requirements

Although CSA Z7396.1 and NFPA 99 are the codes of reference for medical gas installations in North America, the local authority having jurisdiction (AHJ) may have established certain requirements that must be complied with while installing systems in their area. These requirements are published to enforce the construction of medical gas systems to higher performance thresholds than the code's minimum requirements. As an installer, it is your responsibility to be aware of these jurisdictional requirements and to exercise them in your project.

Tools and equipment

A medical gas installer will require certain specialized tools and equipment when installing and testing the system. Such tools and equipment may include:

- copper fittings, cleaned for oxygen service as per the CSA Standard
- pipe thread compound approved for use with oxygen
- brazing rod
- tubing cutters
- deburring tool
- non-shedding abrasive cleaning pads
- oxygen analyzer (can be used by installers as well as verifiers)
- low-pressure nitrogen purge alarm with regulator
- nitrogen flowmeters
- oxygen-safe leak detector solution
- spray bottle (for leak detector)
- pipe labels
- valve tags
- fittings and adapters for outlets/inlets from different manufacturers

Source supply equipment installation

Many of the installation criteria for mechanical supply package units (compressors, vacuum pump, oxygen concentrators) are similar:

- The condition of the system should be carefully inspected upon delivery. Any indication of damage by the carrier should be noted on the delivery receipt, especially if the system will not be immediately uncrated and installed.
- Modules may remain in their shipping containers until ready to be installed. If any of the modules are to be stored prior to installation, they must be protected from the elements to prevent rust and deterioration.
- DO NOT REMOVE the protective covers from the inlet and discharge connection ports of the modules until they are ready for connecting to the facility’s pipeline distribution system
- Keep all packing in place around the dew point sensor and CO sensor during installation to minimize damage.
- For service accessibility it is recommended that there is a minimum of 60 cm (2 ft) clearance around the system and 90 cm (3 ft) of clearance in front of the control panel. As well as a vertical distance of 36” above the unit for ventilation and maintenance.

- Ensure that the site where the system will be installed has a source of electrical power and that power is of the correct electrical specification as per the design of the system.
- The system should be leveled and placed on a concrete pad that is suitable to sustain the weight of the system. If a raised concrete pad is used, the base must not overhang the concrete pad.
- The unit base must be securely bolted using all mounting holes provided in the base.
- The unit may have shipping spacers under the compressor/motor base which will need to be removed after the unit is secured.
- A method to drain away moisture is necessary. If a gravity drain is not available, a connection to a drain is necessary.
- Install in a well-ventilated and clean location with ample drainage
- Vibration during shipment can loosen electrical terminals, fuse inserts and mechanical connections. Tighten as necessary.

Supply equipment piping

The CSA Z7396.1 Standard states that the intake, exhaust and system piping for each medical air compressor, medical vacuum pump or other vibrating equipment must be isolated from vibration.

Isolation from vibration is achieved by the proper selection of resilient devices to be placed between the pump base and the building structure. Isolation is further accomplished by placing isolators between the compressor and the floor, flexible connections on all piping from the compressor and spring-type hangers on the piping around the compressor for a distance of about 6 m (20 ft.). Base mounted package units will usually have the compressor and motor isolators, and flex piping connectors as part of the package design. This enables the package frame base to be directly mounted to the floor and the piping connected directly to the supplied flex connectors. Seismic isolation may also be an option to order with the unit or engineered on site.

There shall be an auxiliary supply connection for each supply system of adequately sized to allow an auxiliary supply system to be connected to the pipeline. The auxiliary supply connection isolation valve shall be secured in the closed position when not in use, with a threaded inlet fitting capped or plugged for cleanliness.

The compressor air intake and vacuum exhaust pipelines must be sized as per the manufacture to account for length and fittings to ensure that no restriction of air flow that could cause compressor starvation.

The medial air compressor intake termination must be placed in an area free of toxic or hazardous contaminates. Unless an indoor source can be continuously monitored the air is taken from outside and the intake shall be located:

- at least 3 m (10 ft) from any door or operable window, and
- 15 m (50 ft) from any exhaust, such as vacuum pump discharge or sanitary vent exhaust, and
- at least 3 m (10 ft) above grade, turned down and screened to prevent contamination, and

- in a location where it will not draw in contamination from exhaust systems (e.g., contamination from furnaces, gasoline or diesel engines, vacuum systems, or scavenging systems)

Discharge piping from the medical air compressor source of supply shall be routed in such a way that it is not normally subjected to a temperature lower than 10°C above the produced medical air dew point.

The vacuum exhaust line is piped away from the vacuum pump discharge to the outside atmosphere. The exhaust outlet is typically located:

- at least 10 m (30 ft) from any door or operable window, and
- 15 m (50 ft) from any mechanical air intake, and
- a minimum of 3 m (10 ft) above grade with the end of the exhaust typically turned downward and screened.

Supply Manifolds

Medical gas manifolds are designed to supply the pipeline system with a sufficient quantity of gas by any combination of cylinders and/or tanks. The typical manifold for medical gases (oxygen, nitrogen, CO_2 or medical air) usually consists of a two-sided supply with automatic changeover between the empty and full side, and an additional third source for emergency supply.

If cylinder storage is used as either the primary or secondary source, the cylinders are located in the same enclosure and connect to the manifold using two main components (Figure 33):

- cylinder pigtails
- header bar

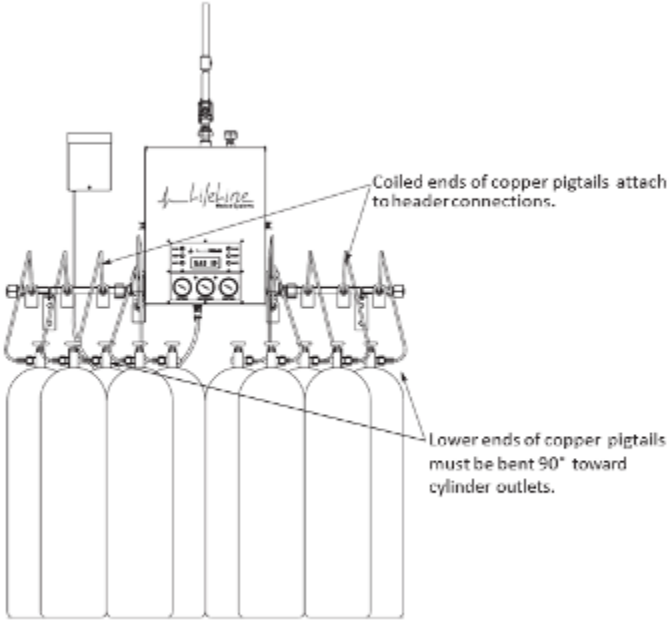

Figure 33. Medical gas pigtail and header bar configuration

A cylinder pigtail connects a high-pressure cylinder to a header bar. This attachment device will have a CGA gas-specific nut and stem assembly at both ends to protect against cross-connection. The typical pigtail will be constructed of flexible copper or flexible braided stainless steel, depending on the type of gas and pressure. The cylinder end of the pigtail will include a check valve that will prohibit gas from other connected cylinders from escaping while it is disconnected from the cylinder. Also, if the cylinders on the bank do not have exactly the same pressure, the check valve will stop gas from transferring between the different cylinders.

The header bar assembly provides the means to connect multiple cylinders to a single regulator assembly located in the manifold enclosure. Each station will have a gas-specific CGA valve that matches the medical gas and the pigtail.

Section 5.3 of the CSA Z7396.1 Standard lists the requirements for the manifolds used for cylinder supply systems. The following is an overview of these requirements:

- Each cylinder bank, whether it is used as a primary or reserve source, shall be connected to a manifold that is equipped with a manifold pressure regulator, pressure indicator, pressure relief valve and shut-off valve.
- A non-return valve shall be installed at the manifold inlet or the manifold connection fitting of each flexible connector between the cylinder and the manifold.
- The flexible connector from each cylinder to the manifold shall be gas-specific for the intended purpose.

Manifold cabinet

The header bar and pigtail assemblies with the appropriate number of connections will be supplied separate from the manifold assembly cabinet. In addition to the change over mechanism the manifold assembly will contain master source valves, pressure regulators, and pressure relief devices (PRD):

Medical gas manifold assemblies (Figure 34) provide two-stage pressure regulation by using two distinct single-stage regulators piped in series:

- Bank pressure regulator; The header bar assembly will be connected to a high pressure bank regulator that is responsible for reducing the cylinder pressure down to a predetermined intermediate level. There is a bank regulator provided for each bank of cylinders.
- Line pressure regulator; A single-stage, diaphragm-type regulator is used to reduce the manifold’s intermediate pressure to normal hospital line pressure. Two line regulators are provided, piped in parallel, to allow for isolation and service of one while the other is in use.

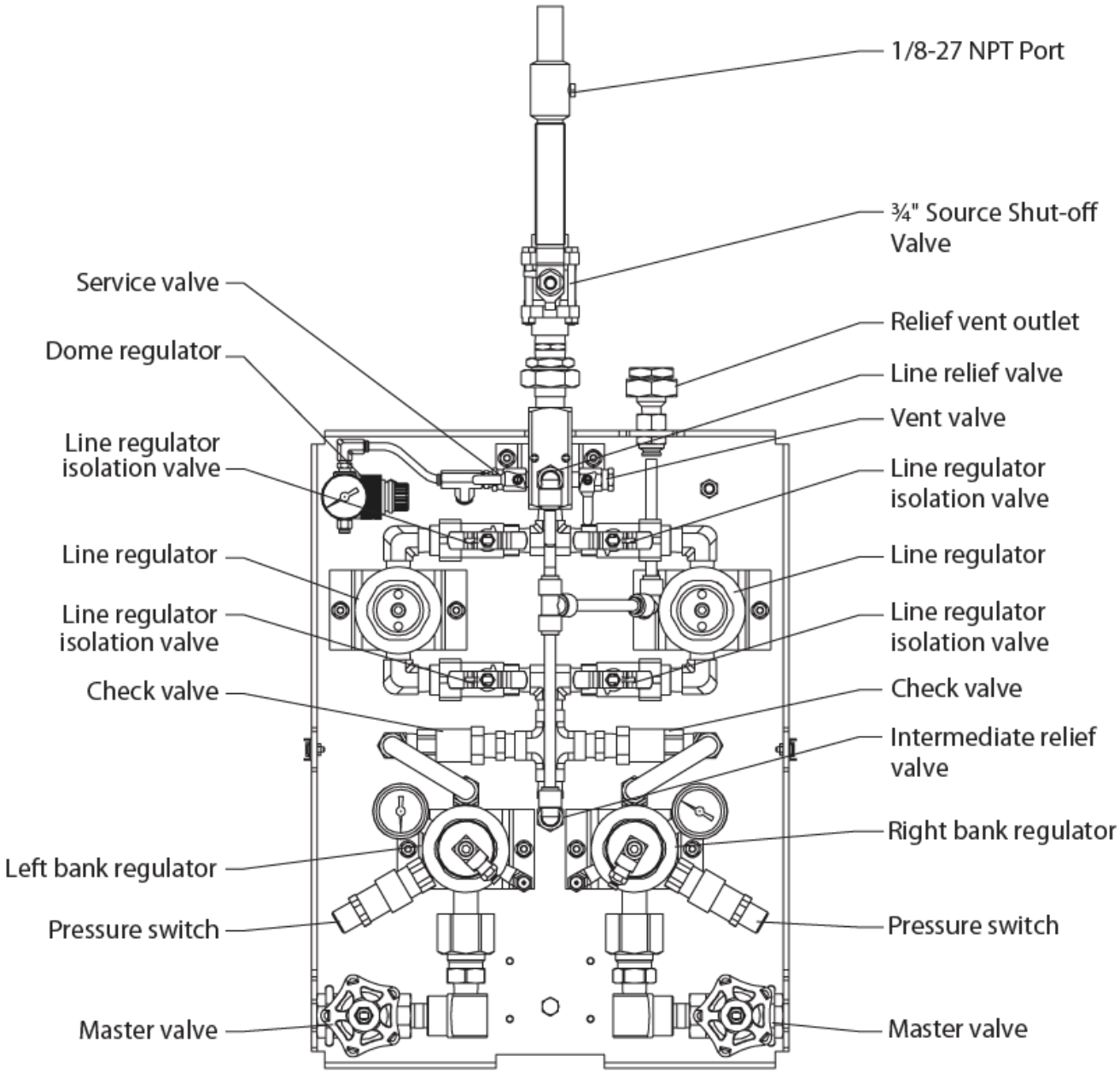

Figure 34. Inside of Medical gas manifold assembly cabinet [Image Description]

Relief valves are provided to prevent over-pressurization of the hospital piping system if a line regulator fails. These valves are set to relieve at a predetermined pressure that is higher than the intended delivery pressure but lower than the maximum rating of the pipeline. They operate using a spring and diaphragm assembly that has been calibrated to the proper level. Figure 35 is a schematic of the previously shown manifold assembly; notice the outlets of the relief valves are piped to a common relief valve port on top of the manifold. In this diagram the change over solenoid valve is also shown, which supplies gas pressure from the dome/pilot regulator to activate the appropriate bank regulator.

Note the parallel line pressure regulator arrangement. One regulator will be designated as the primary regulator with its pressure adjusted at normal distribution pressure. The secondary regulator shall be set

at a pressure that is below the pipeline low-pressure alarm setting but not less than 241 kPa (35 psi).If the primary regulator fails to meet the flow and maintain pressure, the pipeline low pressure alarm will alert the qualified person. The secondary regulator will continue to deliver flow and maintain a pressure that supports medical equipment. During normal operation the secondary regulator will be held in the closed position therefore every six months the two line pressure regulator settings must be alternated to ensure both regulators are functioning.

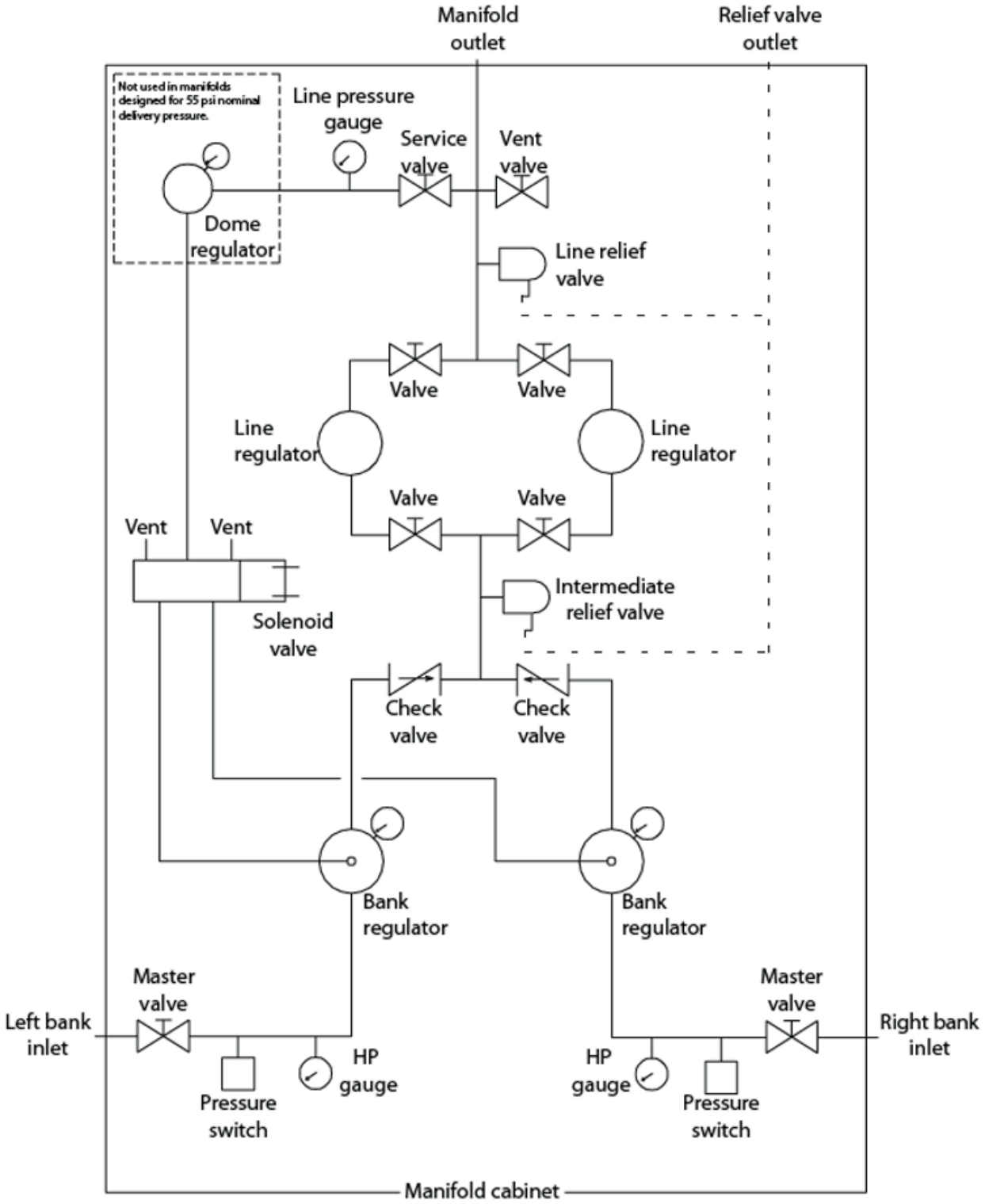

Figure 35. Medical gas manifold piping diagram

Manifold installation

The manifold system will be shipped in multiple boxes containing; manifold cabinet, cabinet mounting

bracket, header bar extensions, header support, and pigtails. The manufacture will provide detailed installation instructions for the manifold system that will cover:

- Cabinet wall mounting
- Connecting master valves and headers bars extensions to manifold cabinet
- Header support installation
- Securing cylinders
- Installing pigtails to the header bar connections and cylinders
- Outlet valve connection (The manifold system is often supplied with a separate source valve that will require installation to the manifold outlet.)
- Relief valve connection
- Power supply connection
- Remote alarm contact connections

The relief valve vent piping must be installed with appropriate materials and joining methods for the type of medical gas being vented. The relief valve outlet will typically be located on top of the manifold cabinet. Although the connection size will ½" NPT, the vent pipes must be sized in such a way that the vent line back pressure plus relief valve overpressure does not exceed 10% of setpoint.

For all compressed medical gases, except medical air and instrument air, the relief valve vent shall terminate outside of the building, away from flammable materials, and the vents shall be turned down and protected from the ingress of insects and debris. They shall be at least 3 m (10 ft) from any door, operable window, or ventilation intake and located so that discharges will not endanger passersby. When vents outlets locations are being planned, consideration should be given to the potential effects of prevailing winds or accumulated snow.

Shut-off valves

Section 8 of the CSA Z7396.1 Standard lists the requirements for shut-off valves. The following are the requirements related to the valve installations:

- All shut-off valves shall be quarter-turn ball valves.
- All shut-off valves shall be accessible for servicing.
- Service isolation valves shall be secured in the open position when a pipeline distribution system is in operation. During an extension, modification or maintenance of a pipeline system, the appropriate service isolation valves may be shut. When they are shut they shall be secured in the closed position.
- All service isolation valves shall be accessible to authorized personnel only.
- All service isolation valves shall be identified with the full gas service name and colour code.
- All service isolation valves shall be identified as to their purpose, area or section that they serve.

- All service isolation valves shall be identified whether the valve is normally open or normally closed and the identification label shall be secured to the valve or pipe and be readily visible.
- Zone valves shall not be installed in series.
- Zone valves shall not be installed closer than 2 m (6.5 ft.) to any fixed terminal unit.
- Zone valves shall be installed at a height where they can be operated by a person standing on the floor.
- Zone valve assemblies shall have a pressure indicator on the terminal unit side of the valve and be marked with a direction-of-flow arrow.
- Zone valves shall be enclosed in zone valve boxes.
- Zone valve boxes shall have covers or doors that can be secured in the closed position but that will allow quick access in case of emergency.
- Zone valve boxes shall be designed to prevent accumulation of gas and be permanently labelled as to the gases they control and the area they serve.
- Zone valve boxes shall be designed so that the shut-off valve handle prevents the closure of the box door or replacement of the cover when the valve is in the off position.
- In zone valve boxes with multiple shut-off valves, the valves shall be arranged in such a way that operation of one valve will not interfere with the proper operation of any other valves installed in the same service box.
- Zone valve boxes must be permanently labelled with a control label identifying the area of control, either on the box or the wall adjacent to the box (Figure 36).

Figure 36. Labels for zone valve control box

Valve box assemblies are shipped in packages that contain the; valve box recessed rough-in, valves, gauges, window, and frame assembly. Additional manufactures installation instructions may state:

- Allow sufficient space to accommodate the zone valve box. The rough-in of the zone valve box comes with a cardboard shield covering it’s front. The card-board shield will need to be removed to install the box but needs to be repositioned to protect the valves while the walls

are being finished.

- Anchor the valve box to the structural frame supports so that it is level and the front edge will be flush with the finished wall. Box mounting height is suggested at 1.7 m (5.5 ft) from floor to top of finished box. Location should allow a clear view of gas readouts and access to valves during an emergency situation.
- Set valves into the valve box and slide plastic grommets as close to the center of the Zone Valve Box before brazing to avoid heat damage. Move grommets back to original location after piping has cooled. The Shutoff Valve handles should be installed to point downstream for pressurized gases.
- Wrap wet rags around the tube extensions next to the valves to prevent overheating and possible damage to the valve seals. Connect copper tubing to the valve extensions (outside the valve box) using brazing methods and materials in accordance with CSA Z7396.1. Once valve extensions are cool, remove rags.
- Alarm style zone valve will require completion of the wiring rough-in before the wall finishing.
- Install the correct gas identification label to the label holders in box. Mark location serviced by each valve in the space below the gas label.
- Test each system per CSA standard. After pressure test is finished replace cardboard shield until wall is finished to keep dust and debris out of box. ***Do not install gauges and sensors before the leak test as excessive pressure can damage them.***
- After wall is finished remove cardboard shield (keep screws). Install Gauges and alarm sensors using Teflon tape or oxygen compatible pipe sealant.
- Pull ring to remove window from frame. Secure aluminum frame to box using screws from cardboard shield. Replace window into frame. Clean Window with soap and water, do not use strong solvents that will damage the window.

Alarms

Medical gas alarm systems monitor the status of the medical gas equipment and distribution systems. To properly evaluate the system, certain alarm-causing conditions (alarm points) must be monitored continuously by alarm sensors. The information is transmitted to an alarm panel, which provides audible and visual indicators to facility staff. Section 6 of the CSA Z7396.1 Standard lists the requirements for the monitoring of alarm systems. All master, area and local alarm warning systems used for medical gas and vacuum systems must include the following:

- Visual indicators that remain in alarm mode until the situation that has caused the alarm is resolved.
- A cancellable audible indication of each alarm condition that produces a sound with a minimum level of 70 dBA at 2 m (6.5 ft.).
- Re-initiation of the audible signal if another alarm condition occurs while the audible alarm is silenced.

- Labelling of each alarm panel stating its area of surveillance.
- Separate visual indicators for each condition being monitored.
- Labelling of each indicator indicating the condition monitored.
- Power for the master and area alarms is drawn from the life-safety branch of the emergency electrical system.

Location of alarm points

The CSA Z7396.1 Standard lists the required alarm points for both cylinder-based supply systems and mechanical-based supply systems. These are minimum requirements, and certain AHJs and design engineers could possibly require more. The following is a summary of some of the more common alarm points found in health-care facilities.

- Oxygen liquid supply:
    - oxygen primary liquid level low
    - oxygen secondary liquid supply in use
    - oxygen secondary liquid low head pressure
    - oxygen secondary liquid level low
    - oxygen emergency reserve cylinders in use
    - oxygen emergency reserve cylinders low
    - oxygen line pressure low
    - oxygen line pressure high
- Oxygen cylinder supply:
    - oxygen reserve cylinders in use
    - oxygen line pressure low
    - oxygen line pressure high
- Nitrogen cylinder supply:
    - nitrogen reserve cylinders in use
    - nitrogen line pressure low
    - nitrogen line pressure high
- Nitrous oxide cylinder supply:
    - nitrous oxide reserve cylinders in use
    - nitrous oxide line pressure low
    - nitrous oxide line pressure high
- Medical air compressor:
    - medical air lag compressor in use

    - medical air high water level in receiver
    - medical air receiver flooded
    - medical air compressor low water shutdown
    - medical air reserve cylinders in use
    - medical air reserve cylinders low
    - medical air high dew point
    - medical air line pressure low
    - medical air line pressure high
- Medical air dryer (desiccant):
    - desiccant dryer switching failure
    - desiccant dryer low outlet pressure
- Medical air dryer (refrigerated):
    - refrigerated dryer high temperature
    - refrigerated dryer power failure
- Medical vacuum system:
    - vacuum pumps low oil shutdown
    - vacuum pumps high temperature shutdown
    - vacuum pumps maintenance required
    - vacuum lag pump in use
    - vacuum low

Alarm sensor installation

Every sensor is distinctly marked and color-coded based on the gas or vacuum it is monitoring. The sensor module incorporates a gas-specific Diameter Index Safety System (DISS) fitting, ensuring correct connection of the sensor to the corresponding gas. Each sensor undergoes factory calibration by a computer, aligning it precisely with the gas indicated on the sensor housing. In the event of incorrect connection to the designated gas display module, an error message will be promptly displayed.

Gauge and sensor will need to be installed into the appropriate pipeline ¼” NPT ports (Figure 37) after the pressure tests have been completed.

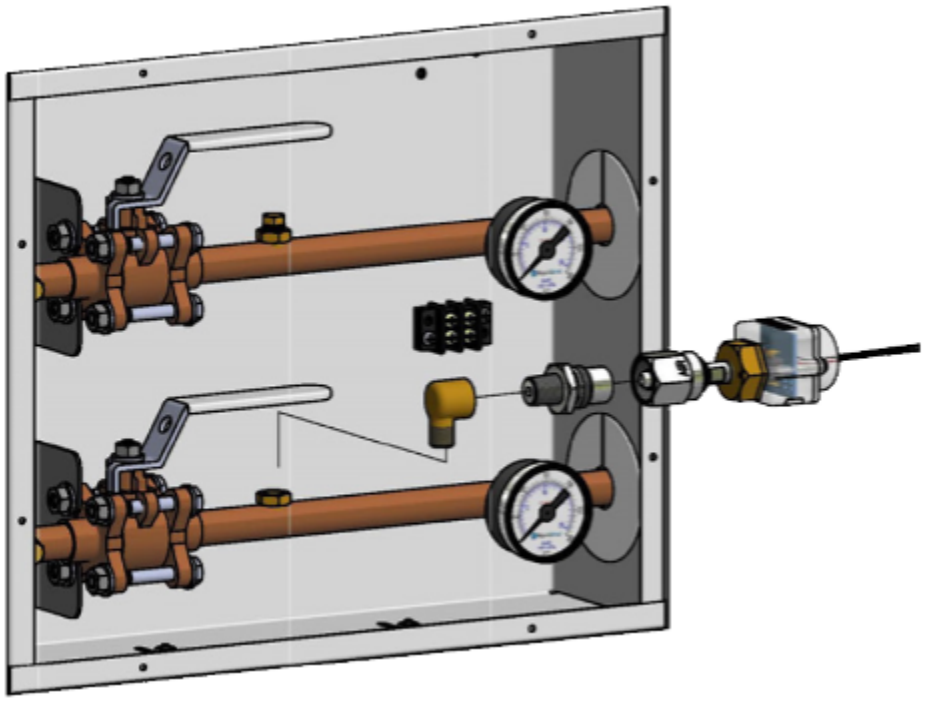

Figure 37. Sensor installation

Check the manufacture manual for detailed instructions. Here are some general guidelines for the installation of sensors into an alarm zone valve box:

1. Do not install gauges and sensors assembly before the leak test. Excessive pressure can damage the gauge and sensor.
2. Remove sensor modules from shipping carton and locate the gas specific sensor module to be installed.
3. Wrap threaded end of 90° elbow with teflon tape and insert into port. Tighten 90° elbow until opening faces away from valve for handle clearance.
4. Verify the gas label on the valve piping is the same as the gas identification found on the DISS check valve.
5. Install Check Valve into 90° elbow.
6. Connect sensor with DISS fitting to the appropriate DISS check. Verify Gas ID labels match between the sensor and piping to ensure no cross connections occur.

Repeat this process for all sensors within alarm panel.

Terminal units

The CSA standard provides a distribution chart of suggested terminal unit locations; however, the health care facility can select the number and type of terminal units required based on their clinical practices.

Station outlets/inlets should be located at an appropriate height above the floor to prevent physical damage to connected equipment

Styles of connections

Terminal units are available with either Quick-connect or DISS outlets/inlets (Figure 38). Both methods are designed to ensure gas-specificity and can only accept compatible fittings. The main difference between these two options is that DISS is a threaded connection and quick connect adapters are a "push–and- lock" type of design. For either system once the connection is made, the primary valve within the terminal unit is opened, permitting gas to flow.

There are three different types of quick connect systems; Ohmeda Diamond, Puritan-Bennett or Chemetron. Only the matching system and corresponding gas type of adapters can be used with the Quick-Connect outlets

The DISS type of connections, comply with Compressed Gas Association Standard V-5 for medical gases at 200 psig (1400 kPa) or less. They a have a unique diameter of threaded connector for each type of gas.

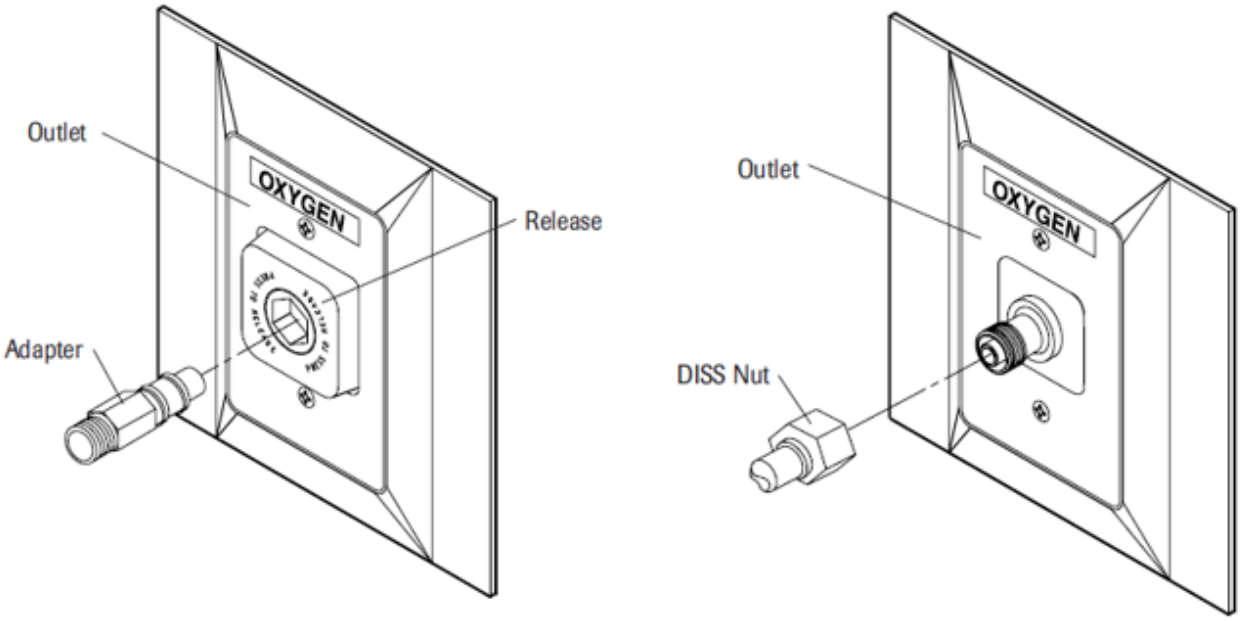

Figure 38. Medical gas terminal units Quick-Connect type (left) and DISS type (right)

Terminal unit installation

A complete terminal unit is made up to two separate components, the "Rough-in Assembly" and the "Latch-Valve Assembly". The rough-in assembly (AKA Back-Body Assembly) has a specific pin indexing arrangement (Figure 39) to prevent the wrong latch valve assembly from being plugged into the rough-in assembly.

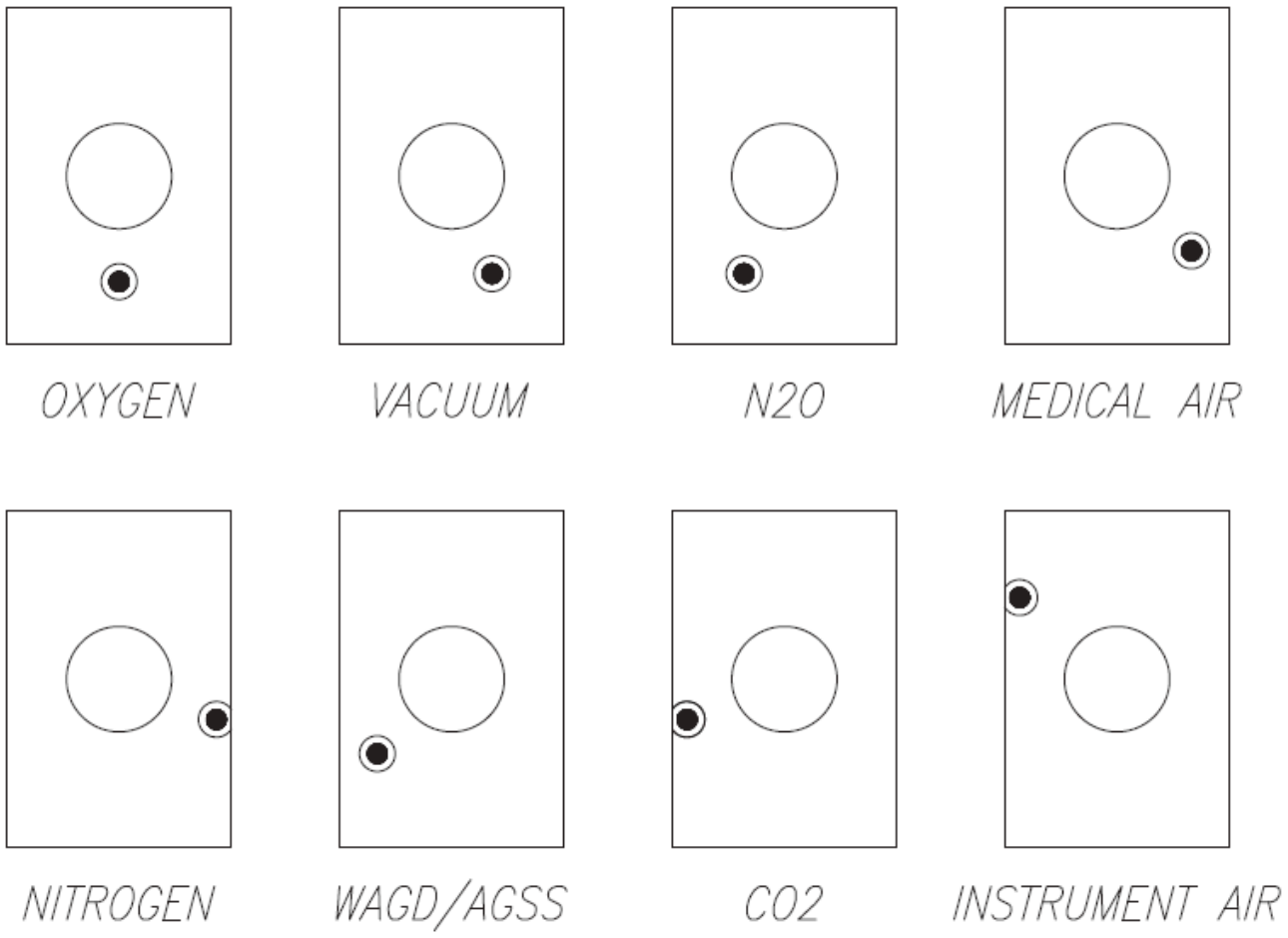

Figure 39. Example of a rough-in assembly pin index system [Image Description]

The installation is completed in two stages of the building construction, rough-in and finishing. The following is an example of installation instructions for wall outlets, be sure to check the actual manufactures instructions:

Rough-in stage:

- Provide rigid mounting for rough-in assemblies (Figure 40) appropriate for wall construction. Rough-in assemblies must be mounted to a structural member (3). It is suggested that rough-in assemblies be installed with the outlet centerline approximately 1.5 m (5 ft) above the finished floor or as specified by the building plans. Position the front edge of the rough-in assembly (1) at the depth that will be flush with the finished wall surface.
- Connect the extension tube (pigtail) (2) to the piping system, making certain that piping is for the same service as labeled on the extension tube and mounting plate. The extension tube can be rotated a full 360 degrees for ease of connection to the facility gas piping. When brazing the pipe connection take extreme care not to apply heat to the check unit body.
- Ensure that the clear plastic dust cover over the rough-in assembly is securely in place until the latch-valve assembly can be installed, to protect the outlet from drywall compound or other contaminants.

- Perform standing pressure and cross connection tests per applicable standards. Inspect all joints for leaks.

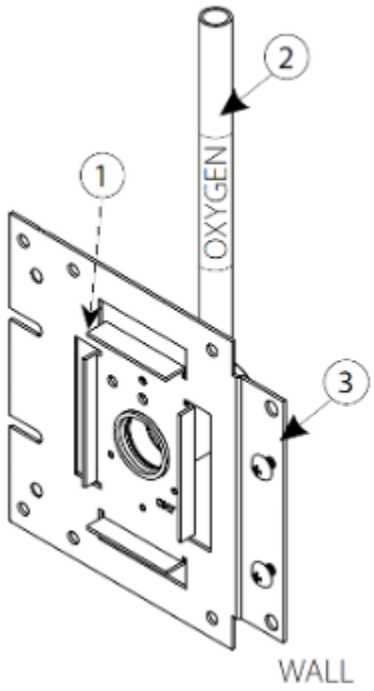

Figure 40. Terminal unit wall mounted rough-in assembly

Finishing stage:

- Select the service indexed and labeled latch valve assembly to match the correspondingly indexed and labeled concealed outlet rough-in assembly already installed.
- When installing the latch-valve assembly, remove the protective dust cover from the rough-in assembly and inspect for dirt or debris in the outlet body. Carefully clean out any contaminants.
- Align the indexing pin on the latch-valve assembly with the indexing hole in the rough-in assembly (Figure 41). The latch-valve mechanism should slide smoothly into the rough-in assembly. If it does not, inspect to verify that there has been no damage to the indexing pins. If the indexing pins are bent or damaged the gas specific characteristics of the outlet may be compromised. In this instance the entire latch-valve assembly should be replaced.
- The cover plate should be flush against the finished wall. The latch-valve assembly is secured with plated steel screws, alternately tighten the mounting screws until the cover plate is held snug against the finished wall. Do not overtighten the mounting screws, doing so may distort the valve assembly.

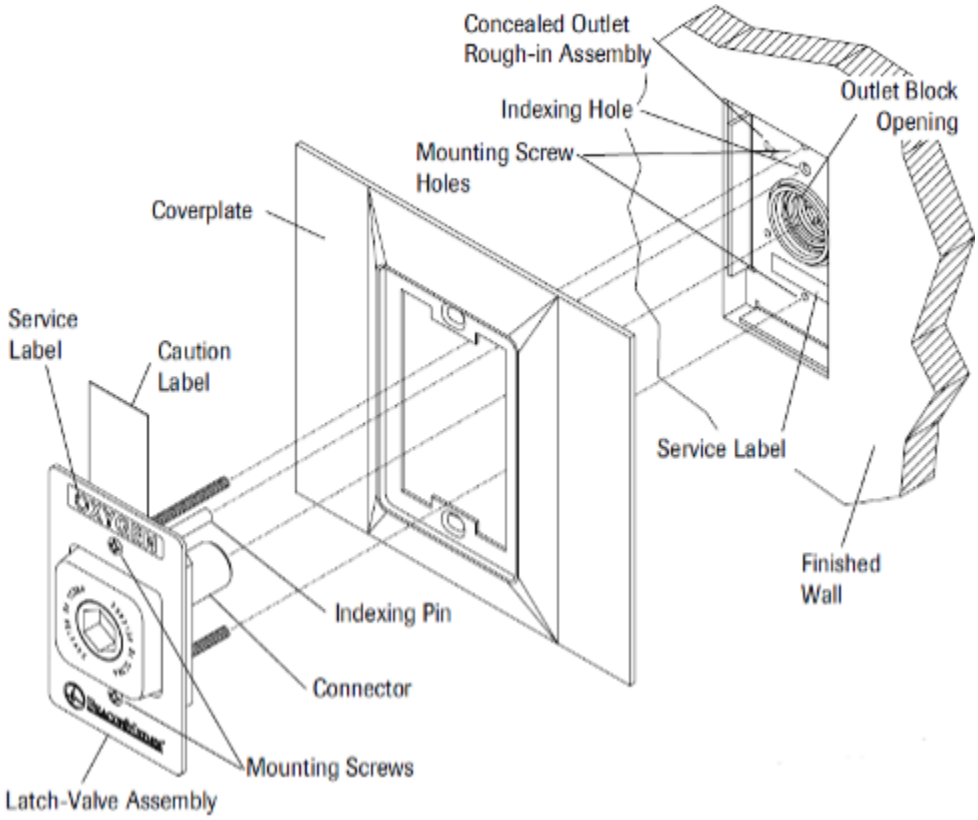

Figure 41. Latch-valve assembly installation

Pressure testing

The CSA Z7396.1 Standard requires installers to conduct two pressure tests for the detection of leaks when installing medical gas pipeline systems:

- A standing pressure test confirms for the installer's own purposes that the work is of the required quality.
- A documented final leak test provides a record that the installation of the system meets the requirements of the CSA Standard.

In order to perform these tests, the installer should have the following equipment on-site:

- 0–100 psi (0–700 kPa) gauge (calibrated)
- 0–300 psi (0–2100 kPa) gauge (calibrated)
- 0–30″ Hg vacuum gauge (calibrated)
- a source of oil-free dry air or oil-free dry nitrogen
- gas-specific connection hoses

The full testing procedures are outlined in A-2, "Test and Commission Medical Gas Systems."

Now complete Self-Test 4 and check your answers.

Self-Test 4

Self-Test 4

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://opentextbc.ca/plumbing4a/?p=81#h5p-5

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Image Descriptions

Figure 34. “Inside of Medical gas manifold assembly cabinet” image description: A labeled diagram of a medical gas manifold system, showing various components involved in gas flow control and pressure regulation. Key features of the diagram include:

- Service valve and ¾” source shut-off valve for controlling gas input.
- Dome regulator and line regulators that help manage gas pressure.
- Isolation valves for shutting off different sections of the system.
- Check valves to prevent backflow.
- Intermediate relief valve and line relief valve for pressure relief.
- Pressure switches for monitoring system conditions.
- Master valves at the bottom for primary control.
- Left bank and right bank regulators, for dual gas supply banks. *[Return to Figure 34]*

Figure 39. “Example of a rough-in assembly pin index system” image description: A diagram showing a rough-in assembly pin index system. For each example, there is one large circle in the centre representing the connector and one smaller circle representing the pin.

- Oxygen: the pin is directly below the connector
- Vacuum: the pin is about 15 degrees to the lower right of the connector
- N2O: the pin is about 15 degrees lower left of the connector
- Medical air: the pin is about 30 degrees to the lower right of the connector
- Nitrogen: the pin is about 50 degrees to the lower right of the connector
- WAGD/AGSS: the pin is about 30 degrees to the lower left of the connector
- CO2: the pin is about 50 degrees to the lower left of the connector
- Instrument air: the pin is about 30 degrees to the upper left of the connector *[Return to Figure 39]*

Competency A2: Test and Commission Medical Gas Systems

Specialized system commissioning is the process of assuring that all components of piping system are designed, installed, tested, operated, and maintained according to the operational requirements of authoritative codes, designers and owners alike. This module provides an overview of the testing and commissioning procedures for Medical gas systems.

Learning Objectives

After completing this competency, you will be able to describe the testing and commissioning of medical gas systems, including:

- Approved testing agencies
- Medical Gas Piping Installer Certification
- Pre commission system installation tests
- Leak (pressure) testing
- Cross-connection testing
- Particulate filter test
- System commissioning inspections and tests
- Alarm testing

Definitions

Commissioning — the proof of function to verify that the agreed system specification is met and is accepted by the user or the user’s representative

Inspection body — an organization accredited and qualified to inspect and test medical gas systems.

System design flow — the flow calculated from the maximum flow requirement of the health care facility and corrected by the diversity factor(s).

Learning Task 1

Describe the Testing and Commissioning of Medical Gas Systems

In practice, the commissioning process comprises of a set procedure to check, inspect and test every operational component of the system. Few installations that a tradesperson will be involved with have more ability to cause immediate loss of life than a medical gas system that has been incorrectly installed. The need to strictly test various aspects of medical gas piping installations is imperative.

The system must pass alarm notification, piping pressure, cross-connection, gas concentration, particulate contaminant and terminal unit flow tests. The requirements for each of these tests are very specific, and systems must pass all of the tests before receiving approval for operation. Under certain circumstances the authority having jurisdiction may require additional testing.

System testing involves a series of procedures before systems can receive final approval. Some of these tests are performed by the installer as described in Appendix B of the CSA Z7396.1 Standard, and some by the inspection body as described in Appendix D. Some of the tests are the same or similar for both parties to ensure consistent results.

Before using a new or modified supply system or pipeline distribution system or an addition or

renovation to an existing system, the health care facility shall obtain documented evidence from an approved testing agency that the system complies with the CSA Standard.

Approved testing agencies

The CSA Standard Z7396.1-12 states that medical gas pipeline systems shall be commissioned after installation and then be subjected to a certification inspection. This inspection must be completed by an approved testing agency. In order for a company to become an approved testing agency, it must first be recognized as an inspection body by the Standards Council of Canada for the inspection of non-flammable medical gas piping systems for compliance with the CSA Standard.

Medical gas testing services include:

- testing and certification of newly installed or renovated medical gas systems
- annual maintenance assessment and gas purity testing

Verification of installer qualification

In order to certify the system, the testing agency is required to verify the qualifications of the installer. The installer will be required to produce:

- Evidence of qualification meeting the requirements of the CSA Medical Gas Piping &

Systems Installation Personnel Certification Program or equivalent

- A valid brazing license issued by an authority having jurisdiction
- A current copy of relevant standards

Installer testing

The medical gas system installer and the designer shall be jointly responsible for the performance of the tests. The installer shall provide documentation to the inspection body that all tests have been performed.

Clause 11.4.3.2 of the CSA Z7396.1 Standard lists the tests to be performed by the installer after the connection of the terminal units, these include:

- a 24-hr. standing pressure test,
- a final leak test,
- purge the terminal units,
- a particulate filter test, and
- cross-connection tests

If the system fails any of these tests, the failure condition shall be investigated and corrected, and the system shall then be retested.

Annex B of the CSA Z7396.1 Standard describes the installer test procedures.

To perform the tests you will need to have a terminal unit testing assembly similar to Figure 1.

A. Terminal unit
B. Manufacturer’s gas-specific connector
C. 0–690 kPa (0–100 psi) oxygen cleaned pressure gauge with a resolution of at least ± 7 kPa (± 1 psi) for compressed gases or 0–101 kPa (0–30 in Hg) with a resolution of ± 3.4 kPa (1 in Hg) for vacuum and AGSSs
D. ¼” NPT tee
E. ¼” NPS non-restrictive shut-off valve
F. ¼” NPT cap centre drilled to create a clean 1.98 mm (5/64 in) orifice

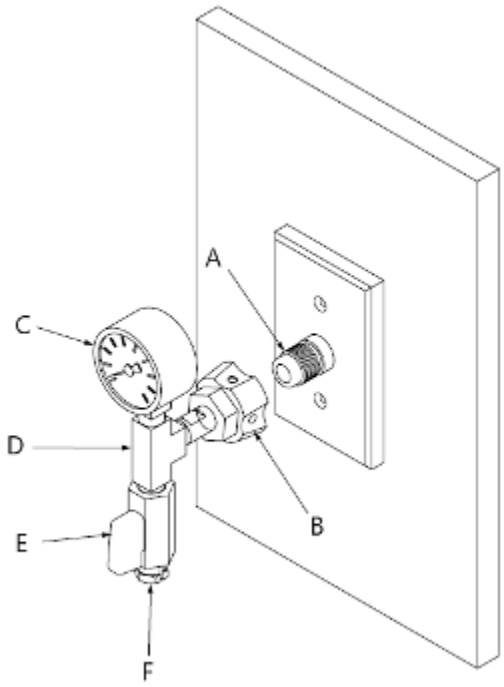


Figure 1. Typical terminal unit test assembly

You will need to change the gas specific connector (DISS shown) on the assembly for each type of gas or have multiple assemblies. The drill cap will only be installed for tests that require a controlled flow rate

Leak (pressure) testing

Before system components are attached, each section of the piping system must be subjected to a pressure test with oil-free, dry nitrogen. When pressure testing a medical gas installation, it is very important that the test pressure reading on the gauge is accurate. The test dial should be larger than 38 mm (1 ½ in.) in diameter to allow a more accurate reading. Most pressure gauges have their highest accuracy in the middle third of the gauge; therefore, the selected gauge should have a range of about twice the required test pressure.

Two pressure tests for the detection of leaks shall be performed:

1. The standing pressure test to confirm the work is of the required quality
2. The final leak test to provide a record that the installation of the system meets code requirements

The standing pressure test shall include the following:

- All joints are subject to a 24-hour standing pressure test.
- The test gas shall be oil-free dry air or oil-free nitrogen and all piping shall be pressurized to

1030 kPa (150 psi) or 1 ½ times the operating pressure, whichever is greater.

- Vacuum lines are tested to a maximum of 415 kPa (60 psi).
- The only allowable change in pressure during the 24-hour test is due to ambient temperature changes in the areas around the piping tested.

Upon completion of the 24-hour test and the installation of the final components (alarm components and outlet covers), the final leak test at system working pressure shall be performed.

Purge terminal units

After completion of the pressure tests, the terminal units must be purged a sufficient number of times to clear them of particulate matter. Using appropriate adapters (or the test assembly without the orificed cap), each outlet should be purged with an intermittent high-volume flow of test gas until the purge produces no discoloration in a clean white cloth loosely held over the adapter (Figure 2).

Start at a point closest to the source of supply and move outward to the end of the pipeline. Rapidly interrupting the flow several times (pulse purging) has been found to effectively break up materials in the pipeline such as cupric oxide scale.

Figure 2. Piping purge being performed at a terminal unit

The outflow from each gas terminal unit must also be observed to confirm the absence of visible moisture (i.e., droplets or mist).

Particulate filter test

After the entire piping system has been purged the installer shall perform a visual test of all compressed pipelines for particulate contamination. This test is very similar to final step of the purge procedure; were a clean white cloth or a white 0.3 micron particulate filter is placed over the end of the terminal unit test assembly. The significant difference is that a flow regulation orifice is installed in the test assembly to ensure a minimum flow of 120 L/min (4 SCFM) for at least 15 seconds. The filter shall be

free from particulate matter when viewed by the naked eye in good light. At least one terminal unit for each compressed gas in each zone shall be tested.

Cross-connection testing

Cross-connections are the main cause of deaths and injuries with medical gas systems, therefore the initial cross-connection test should be considered the most important installer performed tests. The installer ensures that there are no cross-connections in the installed systems and then the inspection body will also perform cross-connection tests to validate the installers results. The CSA Z7396.1 Standard describes two methods of conducting a cross-connection test. Depending on the number of gas services provided the installer will complete a cross-connection test using one of the methods described in the CSA Z7396.1 Standard.

During the initial cross-connection test, it is vital to confirm that the labelling and identification of the terminal units match the correct pipeline being checked.

Method 1 (Individual Pressurization method can be used when there are one or more services)

- Involves the pressurization of a particular medical gas piping system with oil-free air or oil-free nitrogen to 345 kPa (50 psi). All other pipelines shall be reduced to atmospheric pressure.
- A gauge is then attached to each terminal unit to ensure that only the proper outlets for the medical gas system being tested is pressurized. Disconnect the test gas from the system that was just tested and reduce the pressure in the system to atmospheric.
- This test must be carried out for each medical piping system and all terminal units are checked each time to ensure no pressure is registered at any terminals that are not part of the gas service being tested.
- Each terminal unit shall be inspected to ensure that it is properly identified by name and colour.

Method 2 (Pressure differential method can be used when there are pipelines for more than two gases in addition to vacuum)

- Involves the pressurization of all medical gas piping systems at different pressures with oil-free air or oil-free nitrogen. The pressure in one system shall be raised to at least 140 kPa (20 psi) and the pressure in the other pipelines shall be adjusted to a level that has a clearly recognizable pressure difference of no less than 70 kPa (10 psi) between each gas.
- If medical vacuum or AGSS are to be tested, they shall be set to a level of 0 kPa (0 psi). If both are used, they shall be set at a level of 0 kPa (0 psi) and 70 kPa (10 psi) respectively.
- After the different system pressures have been set every terminal unit must be measured using a pressure gauge attached to the specific adapter for that terminal unit. The pressures must be monitored to ensure the differentials are maintained.
- Each terminal unit shall be inspected to ensure that it is properly identified by name and colour.

The pressure differential method (Method 2) is only meant as an option when there are pipelines for more than two gases in addition to vacuum . The individual pressurization method (Method 1) can be used for all sizes of systems as it provides for less chance of both mechanical and human error in identifying a cross connection.

Commissioning and Certification

After completion of the installer testing and prior to commencement of the compliance testing, the installer and a representative of the system designer shall review the installation and provide written and signed attestation to the health care facility that:

a. every terminal unit in an occupied area under test is labelled to indicate that the system is under test and that it shall not be used
b. all safety interlocks are functional (e.g. terminal unit disconnects)
c. the system as installed is as designed and
d. the pipeline installation test report has been submitted.

When all of the installer tests are satisfied the inspection body can be called to certify the system. The inspection body will conduct the final testing prior to use to demonstrate that the supply system or pipeline system, or both, complies with this Standard. The system shall not be used until it complies and the inspection body has provided a written certification report to the health care facility and the installer.

The following inspections/tests are performed by the inspection body in the presence of the installer.

Supply system inspection/testing

Each source within a supply system shall be functionally tested according to the requirements of the CSA Standard and the manufacturer’s manuals and specifications. Annex C of the CSA Z7396.1 Standard provides a detailed list of all of the visual inspections, functional tests, and alarm simulations that must be performed on each supply system and its control equipment. To prepare for this compliance testing of the supply systems all alarm wiring must be completed. The main isolation valve for each source will remain closed and locked out until the source commissioning and inspection is completed. At least two bottles of each type of pressurized gas will need to be connected to verify each supply manifold operation.

Supply manifolds

Once all of the components of the portable cylinder supply systems have been visually inspected the function of the manifold automatic changeover will need to be tested. The following are an example of the typical steps for commissioning and operational testing of a medical gas manifold. On the job it is important to follow the actual manufactures instructions.

1. Remove the manifold control panel cover.

2. Verify the following:
    - Both master valves located on both header bars are turned fully counter clockwise (open)
    - All four line regulator isolation valves are open
    - Power supply has been connected
    - Both red “Empty” indicators on the front of the manifold are illuminated
    - If connected to a master alarm panel, “Secondary Supply” alarm is activated
    - ¾” source shut-off valve is closed and locked out
3. Slowly open one cylinder on the right side of the manifold.
4. Verify the following:
    - Right bank red “Empty” LED goes out
    - Right bank green “In Use” LED illuminates
    - Right bank cylinder contents gauge reads cylinder pressure
5. Slowly open one cylinder on the left side of the manifold.
6. Verify the following:
    - Left bank red “Empty” LED goes out
    - Left bank yellow “Ready” LED illuminates
    - Left bank cylinder contents gauge reads cylinder pressure
    - If connected to a master alarm panel, “Secondary Supply” alarm is not activated
7. Close right bank cylinder. Slightly open vent/bleed valve. Verify the following:
    - Right bank cylinder contents gauge drops slowly
    - As the right cylinder contents gauge is nearly depleted, the manifold changes over to the left bank
    - After changeover, the right bank green “In Use” LED goes out and the red “Empty” LED illuminates
    - After changeover, the left bank yellow “Ready” LED goes out and the green “In Use” LED illuminates
8. Verify the line pressure gauge reading is acceptable.
9. Slowly open one cylinder on the right side of the manifold.
10. Verify the following:
    - Right bank red “Empty” LED goes out
    - Right bank yellow “Ready” LED illuminates

- Right bank cylinder contents gauge reads cylinder pressure

11. Close the left bank cylinder. Depress the valve located on the side of the line regulator. Verify the following:
    - Left bank cylinder contents gauge drops slowly
    - As left cylinder contents gauge is nearly depleted, the manifold changes over to the right bank
    - After changeover, the left bank green “In Use” LED goes out and red “Empty” LED illuminates
    - After changeover, the right bank yellow “Ready” LED goes out and green “In Use” LED illuminates
12. Slowly open one cylinder on the left side of the manifold.
13. Verify the following:
    - Left bank red “Empty” LED goes out
    - Left bank yellow “Ready” LED illuminates
    - Left bank cylinder contents gauge reads cylinder pressure
    - If connected to a master alarm panel, “Secondary Supply” alarm is not activated
14. Close the left and right-side cylinders.
15. Record the pressure readings of the left and right bank cylinder contents gauges.
16. Wait 15 minutes.
17. Compare current readings of the left and right bank cylinder contents gauges to those recorded in step 15. If there is a noticeable pressure change on either gauge, perform leak testing.
18. Reinstall manifold control panel cover.
19. When the piping system is ready to receive gas slowly open the locked-out source shut-off valve.

Supply plants

Vacuum pumps, medical air compressors, and oxygen concentrators are to be started by factory rep and running for at least 24 hours. Failure to have an authorized manufacture technician start-up the system can void the manufacturer’s warranties.

New compressors often produce odours. At initial start-up the air produced by the compressor should be diverted from the system upstream of the dryers (and the receivers, if possible) and vented to waste, preferably outside the facility then the compressor can be operated until there is no detectable odour in the discharge air. This will ensure the downstream piping and equipment does not become contaminated with odour-causing materials.

A sample of the compressor discharge air will be taken by the inspection body at a point downstream of the dryers and upstream of the supply shut-off valve. A gas sample will be taken at each source to verify the gas conforms to the USP formulary. Samples must be analyzed by a laboratory meeting the requirements of ISO/IEC 17025 for the testing of medical gases. The source samples will also be used later as a comparison to an end point sample to ensure the pipeline distribution system is not adding contaminants to the source gas.

The supply plant tests detailed in Annex C shall be performed in the presence of the manufacturer's representative as well as the inspection body, so that the test or simulation can be conducted without compromising the integrity of the equipment or voiding a warranty.

Pipeline distribution system inspection/testing

Annex D of the CSA Z7396.1 Standard provides a detailed list of all of the visual inspections, functional tests, and alarm simulations that must be performed on each pipeline, valve and zone alarm. The installer shall make the working as-constructed drawings available to the inspection body at the time of the inspection.

System pipeline purge

During this procedure, each gas-specific pipeline shall be filled and emptied a sufficient number of times to displace the test gas used in the testing performed by the installer. Each terminal unit shall be opened in turn to ensure that no sections of pipeline remain filled with test gas.

Inspection of outlets, junction points and valves

This inspection confirms that:

- Each outlet of a pipeline distribution system has a terminal unit that is brazed to the pipeline with no flexible hose intervening or a medical supply unit junction point.
- Each junction point for a medical supply unit is readily accessible for service and either permanently connected to the medical supply unit (e.g., by brazing or welding) or fitted with a gas-specific DISS connector.
- Each supply system shall have a shut-off valve located as close as possible to the supply system outlet.
- Each supply system located outside the facility shall have a service isolation valve, secured in the open position, within the supply system enclosure.
- Each pipeline and service isolation valve is installed as outlined in the CSA Z7396.1 Standard.
- All labelling is installed as stated in the CSA Z7396.1 Standard.
- All pipeline installations shall be checked for compliance with the CSA Z7396.1 Standard.
- The installation tests haves been performed by the installer.
- Each zone valve shall be checked for correct identification and operation.

- Each zone valve shall be checked to verify that they control only those terminal units intended by the system design.

Particulate filter test

The approved testing agency shall test all pipelines for compressed medical gases for particulate contamination. This procedure is identical to the earlier test performed by the installer.

Gas identity and cross-connection

This test is performed after the source of test gas shall be disconnected and the proper gas source of supply is connected to each system.

- Each system is purged a sufficient number of times to remove the test gas.
- The line pressure regulator controlling each piped gas must be adjusted to maintain a clearly recognizable pressure difference of no less than 35 kPa (5 psi).
- The medical vacuum system shall be in operation, and the cut-in and cut-out settings of the vacuum pump controller are to be measured and recorded.
- After all of the different system pressures are adjusted and recorded, every terminal unit must be checked with a pressure gauge attached to the specific adapter for that terminal unit. The pressure at the terminal units is recorded while there is a flow of 15 to 25 L/min (0.5 to 1 SCFM). The recorded flow pressure must be the same as the previously recorded static pressure for the system.
- The outflow gas concentration from each gas terminal must be tested using the appropriate gas analyzer. Gas concentrations should measure at least 99% for oxygen, nitrous oxide, carbon dioxide, helium, and nitrogen and 19.5 to 23.5% oxygen for medical and instrument air.

Check of terminal units

Each terminal unit is checked to ensure that gas is released only when the correct gas-specific connection device is inserted into the terminal unit.

Contaminant testing

Tests for contaminants in a medical gas piping system are taken from a terminal unit after the gas has been allowed to travel the maximum length of the medical gas piping system. The gas samples are then sent to an independent laboratory for analysis. The terminal unit samples are compared to the previous taken system supply samples, to ensure there are no pipeline contaminants being added to the supplied gas.

Flow testing

Each terminal unit shall be tested for flow resistance. The flow test measures the pressure drop across the terminal unit and its inlet connector. The terminal unit test assembly complete with a 1.98 mm (5/64

in) flow regulation orifice is used to measure both static then flow pressure at each terminal unit. When testing, the pressure drop shall not exceed 70 kPa (10 psi) for nitrogen, 30 kPa (4 psi) for all other medical gases and 13 kPa (4″ Hg) for medical vacuum.

Alarm testing

The CSA Z7396.1 Standard lists the testing protocols for alarm testing in Table D.3. The table lists the different alarm system components, the characteristic or function being checked, and the type of tests performed. The approved testing agency would complete the entire list of prescribed tests before system certification.

A typical functional test of a positive pressure alarm would be the following:

- Close the applicable service (shutoff) valve to the area
- Increase the line pressure in the piping system to the high-pressure alarm set point.
- Check the applicable alarm panel to ensure that the properly labelled warning signal is activated
- Check a test gauge in the area to ensure that the pressure reading is the same as the reading on the alarm panel.
- Silence the audible signal. The visible signal should remain activated.
- Reduce the line pressure in the piping system to the normal operating pressure and check the applicable alarm has deactivated and the pressure readings are back to normal.
- Reduce the line pressure in the piping system to the low-pressure alarm set point.
- Check the applicable alarm panel to ensure that the properly labelled warning signal is activated.
- Check a test gauge in the area to ensure that the pressure reading is the same as the reading on the alarm panel.
- Silence the audible signal. The visible signal should remain activated.
- Open the service (shutoff) valve to the area
- Check the applicable alarm has deactivated and the pressure readings are back to normal.
- Disconnect the low voltage alarm wiring from the pressure switch or transducer.
- Check the applicable alarm panel to ensure that the properly labelled warning signal is activated.
- Reconnect the low-voltage alarm wiring to the pressure sensor.
- Check the applicable alarm has deactivated
- Document the test results.

Final Approval

Medical gas supply and or pipeline distribution systems can not be used until the health care facility has obtained written confirmation from the inspection body that the installation conform to the requirements of the CSA Standard. When the results of the inspections meet the Standard, the inspection body must issue a certification report to the health care facility. The inspection body shall also confirm that working as-built drawings and evidence of installer qualifications have been provided to the health care facility. The health care facility shall retain the certification report, working as-built drawings, as well as copies of individual brazing licences (if applicable) for inclusion in their permanent records.

Either the installer or manufacture shall also provide the health care facility with all of the necessary operating and service manuals for the newly commissioned equipment as well as the recommend maintenance schedules.

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://opentextbc.ca/plumbing4a/?p=106#h5p-6

Media Attributions

- Figure 1. “Typical terminal unit test assembly” – The source for this image is unknown. It is being used for non-commercial, educational purposes. To receive credit for this image, please reach out to the publisher.
- Figure 2. “Piping purge being performed at a terminal unit” – The source for this image is unknown. It is being used for non-commercial, educational purposes. To receive credit for this image, please reach out to the publisher.

Competency A3: Maintain Medical Gas Systems

Like all electro-mechanical equipment, medical gas systems require periodic maintenance to operate at peak efficiency and minimize unscheduled downtime. Manufacturers provide inspection, maintenance, and service schedules that must be strictly followed. The CSA standard also specifies the minimum ongoing auditing and inspections that must be performed as part of the preventative maintenance program.

Problems can arise when different departments of the health care facility each assume that the other is looking after a particular system. Among the tasks involved in planning an maintenance program are to determine where the divisions are and then to document who is responsible for the different elements of the system. The health care facility shall maintain in its permanent records the results of the maintenance program. It shall contain all relevant details pertaining to ongoing verification results and repairs, as well as identify any observed deficiencies or concerns requiring the operators' attention.

Learning Objectives

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

- Describe the required periodic system inspections and audits as specified in the CSA Z7396.1 standard
- Service medical gas pipeline systems according to manufacturers' instructions
- Repair or replace defective components in a manner that will ensure the health and safety of the facility occupants is maintained.

Definitions

Commissioning — the proof of function to verify that the agreed system specification is met and is accepted by the user or the user's representative

Creep (pressure regulator) — the rise in the outlet pressure above the original set-point without a significant change in the inlet pressure.

Droop (pressure regulator) — the drop in the outlet pressure, below the original set-point, as flow increases.

Maintenance — actions performed to preserve the as-built functionality of the medical gas pipeline system as required in the original manufacturer's manual.

Medical gas pipeline system — a complete system that comprises a supply system, a monitoring and alarm system, and a distribution system with terminal units at the points where medical gases, medical support gases, medical vacuum, or anaesthetic gas scavenging is required.

Medical supply unit — prefabricated equipment that supplies medical gases, either singly or in combination with other services, at the point of patient care.

Modification — an alteration made to an existing medical gas pipeline system or its components

Qualified operator — a competent person who, through professional training and education, is responsible for the safe operation and maintenance of medical gas systems for their given health care facility

Qualified service technician — a competent person who, through professional training and education, is qualified to service a medical gas system.

Repair — an action to restore a medical gas pipeline, or part thereof, to its former operational Condition

Learning Task 1

Ongoing Verification of Medical Gas Pipeline Systems

An important part of the preventative maintenance program includes regular inspections of the components of the medical gas pipeline system to verify their proper operation. The administrator of the health care facility shall designate one or more qualified operators to manage the security, testing, monitoring, operating, inspecting, maintaining, and recording of the condition and performance of medical gas systems. Maintenance and ongoing verification shall only be performed and recorded by persons qualified for the process. An audit or verification of the health care facility maintenance program must be completed every three years.

The CSA standard identifies specific minimum operating verifications that must be performed.

Scheduled inspections and audits

The frequency of verifications for all sections of the system shall be consistent, and as specified in the CSA Z7396.1 standard.

Daily inspections:

- Each pipeline pressure shall be observed and recorded at least once per day. If the pressure deviation is observed to be greater than ±5% from normal, the system shall be investigated.

6 month inspections:

- Supply systems and control equipment shall be checked at least every six months to determine the following:
    - Smooth transfer between primary, secondary and reserve sources.
    - Pressure regulators shall be observed and tested for droop as well as for creep.
    - The pressure setting of the parallel line pressure regulators shall be alternated and an operating record shall be kept.
    - Pigtails for high-pressure cylinder connections shall be inspected for flexibility, fatigue, damage, and gas compatibility. Non-return (check) valves shall be tested for closure.
    - Manifold valves shall be inspected for external leaks and closurability.
    - Cylinders, including spares and empties, shall be inspected to ensure that they are properly secured.
    - Gauges and displays shall be inspected for accuracy and legibility.
    - Indicator lights shall be inspected and replaced as needed.

    - Pressure relief devices shall be inspected for damage, leakage, and broken seals.
- Zone alarm panels shall be verified and documented for compliance with the audible, visual, and marking requirements, and verified for integrity. Documentation shall include observed defects, and/or where alarm panels are deemed noncompliant.
- Supply system alarm panels shall be verified and documented every six months to ensure that they continue to meet as-installed operating specifications.
- Medical air produced by a compressor-based system shall be analyzed for purity compliance.

12 month inspections:

- Zone alarm panels shall be verified and documented annually applying low-pressure and low vacuum alarm simulations to verify sensor functionality and ensure alarm calibrations.
- Instrument air produced by a compressor-based system shall be analyzed for purity compliance.
- Oxygen produced by a concentrator shall be analyzed for purity compliance.
- The supply systems environment shall be inspected annually to ensure it continues to conform to the installation requirements.
- Terminal units shall be tested for function, wear, mechanical performance, and flow resistance.
- Zone valves shall be leak tested and verified and documented to remain in compliance with the original installation requirements. Additionally, every 5 years zone valves must be checked for internal leakage by using a controlled standing pressure test to confirm tightness of shutoff.

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://opentextbc.ca/plumbing4a/?p=114#h5p-7

Learning Task 2

Service Medical Gas Pipeline System

Medical gas systems require periodic maintenance to operate at peak efficiency and minimize unscheduled downtime. Inadequate maintenance can have a significant impact on energy consumption due to lower compression efficiency, gas leakage or pressure variability. It can also lead to high operating temperatures, poor moisture control and excessive contamination. Most problems are minor and can be corrected by simple adjustments, cleaning, replacing parts or eliminating adverse conditions.

All defective components must be replaced or repaired and operational defects immediately corrected upon observation, including flow obstructions and leaks. Repairs shall minimally conform to as-installed specifications. If circumstances prevent the repair or replacement from being performed immediately, and the defect has the potential to pose a health and/or safety risk, a risk assessment shall be made.

To protect the lives of patients, always notify the appropriate medical facility staff before performing any maintenance or service procedures. Display prominent notices indicating that maintenance is being carried out. If the repair or replacement of a defective component cannot be performed immediately, the component shall be tagged or labelled with at least the following information noted:

- the date;
- the problem;
- “Do Not Use” or limitations on use; and
- the name or signature of a qualified person.

The tag or label shall be removed by a qualified person or designate only on resolution of the defect.

Conducting routine preventive maintenance on a schedule is a useful way to perform necessary inspections and maintenance in a way that will minimize disruption to facility operations.

Maintain comprehensive records of maintenance activities, inspections, and any repairs performed on the medical gas systems. Accurate documentation aids in tracking the system’s performance and compliance with regulations.

Central cylinder supply systems

Regular and thorough maintenance of medical gas cylinder supply systems is essential to prevent disruptions in the delivery of medical gases, promote patient safety, and comply with regulatory requirements. It is advisable to follow manufacturer recommendations and industry standards for maintenance practices. Conduct routine visual inspections of the entire medical gas cylinder supply

system. Connecting lines, or “pigtails”, from the gas cylinders to the manifold should be inspected and leak tested every six months. Since the cylinders containing the various gases run out and are replaced on a regular basis, these fittings and hoses get worn.

The manifold room typically has various cylinders of different kinds of gas lined up against the walls. Each kind of gas will come in color-coded cylinders, plainly labeled with their contents name, and have unique connectors to ensure no cross-connection of gases. All cylinders must be supported (usually chained) in a vertical position. Only gas cylinders and their accessories can be stored in rooms containing central supply systems or gas cylinders. Doors exiting from cylinder rooms shall have unobstructed, direct exit from supply system rooms via doors opening outward. The cylinder room must be temperature controlled, with adequately ventilation and an oxygen deficiency alarm.

Cylinder replacement

The exchanging of cylinders on an automatic changeover manifold is the most common interface that maintenance staff have with the medical gas supply system. When one of the banks of cylinders is depleted the manifold will automatically switched to the secondary bank of cylinders. An alarm is triggered and the empty cylinders must be replaced as soon as possible

Even though cylinders and manifold pigtails are fitted with gas specific connectors it is still important to confirm that the cylinder labels are in place and match gas required. being replaced. Labels shall not be defaced, altered, or removed, and connecting fittings must not be modified.

To replace empty cylinders:

- Enter cylinder storage room with caution, open door and air out the room.
- Identify which cylinders bank, left or right side, is empty.
- Close the cylinder valves on the empty cylinders.
- Using an appropriate wrench to loosen pigtail from empty cylinders releasing any residual pressure, then disconnect pigtails from the cylinder valve outlets.
  Oxidizing gasses will have copper tubing pigtails which will be move difficult to remove
- Install protective valve caps onto empty cylinders.
- Tag/identify empty cylinders.
- Use a cylinder cart to replace empty cylinders with full ones.

All cylinders both in use and stored (including empties) must be restrained

- When positioning and restraining new cylinders double check the gas identification labels.
- Remove the cylinder protective covers and store them were they can be easily located.
- Using a clean (lint free) cloth, wipe each cylinder valve outlet clean. Do not use your fingers.
- Standing to one side, “crack” each cylinder valve by briefly opening and closing to blow out any dust. Make sure they are pointing away from you and other personnel.
- Check the condition of the pigtail and replace any damaged ones.

- Connect the pigtails to the cylinder valve outlets and tighten the nut with an appropriate wrench
- When all of the cylinders are connected, very slowly open one cylinder valve and observe the bank pressure gauge, when the manifold is pressurized then all cylinder valves can be slowly opened fully.
- Leak test the pigtail connections
- Observe the manifold status indicators to confirm the empty bank is now indicating full cylinders on standby.
- Record the cylinder change out into the log

Mechanical supply systems

Compressor-based systems for medical air and instrument air as well as drying and filtration units, oxygen concentrators, medical vacuum systems, and AGSSs shall be inspected, maintained, and documented according to the manufacturer's instructions at the recommended intervals. In many cases, it makes sense from efficiency and economic standpoints to maintain equipment more frequently than at the intervals recommended by manufacturers, which are primarily designed to protect equipment. Operators should review the equipment information and keep it handy for future reference.

Compressed air is dangerous and safety precautions must be observed in the use, service, and maintenance of compressed air and compressed air equipment. Lock-out and tag-out protocols should be followed. Completely vent the internal air pressure to the atmosphere before disassembling any subassemblies or components and before doing any work on compressed air equipment. To vent internal air pressure, follow the maintenance shutdown instructions. Never perform any maintenance functions while the unit is in operation. Before starting any maintenances procedures, disconnect and lockout all power to the package unit.

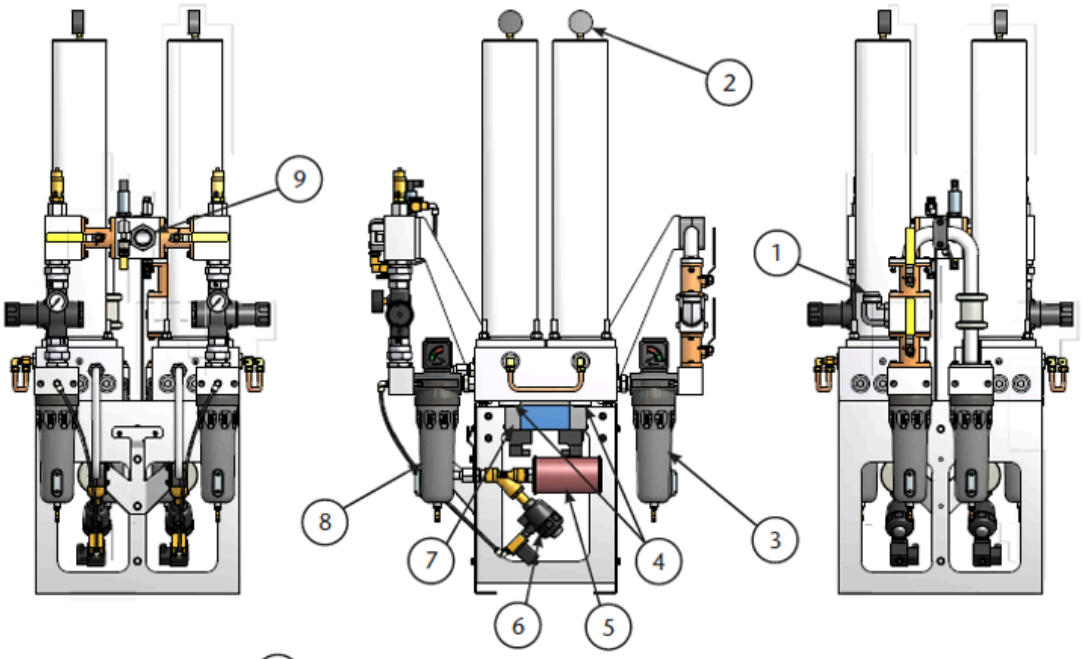
The following are suggested service schedules for typical medical air, instrument air, and medical vacuum compressor systems:

- Daily:
    - check condensate in the receiver tank
    - check the automatic drain on receivers
    - check the oil level(s) and
    - check the exhaust drain drip leg for presence of moisture/water
- Weekly:
    - check the frequency of starts and the duration of the run period and compare with previous records and
    - check the cut-in and cut-out pressure
    - check operation of safety valve
- Monthly:

    - check outdoor vacuum exhaust vents for obstruction (ice or debris on the screen)
    - check belts and tension
    - check flow through orifice of dew point sensor
    - check outdoor medical air intake for obstruction
- Every 6 months:
    - test all system functions and
    - calibrate carbon monoxide transmitter
    - replace intake and other system filters, if necessary
- Every 12 months:
    - check dew point sensor accuracy
    - change inlet filters
    - change oil filters (oil lubricated pumps)
    - change oil separator elements (oil lubricated pumps)
    - change v-belts
    - check inlet and discharge check valve operations
    - check flex lines for wear or leaks
    - check control panel contactors for wear
    - check motor to pump coupler bushings and
    - check and document vane wear (composite rotary vane-type pumps)
- Following manufacturer's instructions:
    - replace dew point and carbon monoxide transmitters
    - change oil with specified type and grade
    - lubricate the pump, motor, and bearings and
    - replace piston rings.

Dryers

A compressed air dryer (Figure 1) should give long and trouble-free operation if the recommended preventative maintenance program is carried out. Ensure that the dryer and associated pre-filter(s) and after filter(s) are valve isolated and fully depressurized before attempting to remove or disassemble any subassemblies or components.



Item Number	Description
1	Dryer Inlet
2	Tower Pressure Gauge
3	Dryer Pre-Filter
4	Check Valve (2)
5	Purge Muffler
6	Poppit Purge Valve
7	441® Switching Valve
8	Dryer After-Filter
9	Air System Outlet
10	Canister O-Ring
11	Tower O-Ring

Figure 1. Desiccant dryer components [Image Description]

The following are suggested service schedules for typical drying and filtration units:

- daily checking of operation of the dryers and their filters for continued compliance with the manufacturer's operating instructions;
- every 3 months;
    - Clean the auto drain in the coalescing filter.
    - Monitor the backpressure on the purging tower. If the gauge reads more than 0 psig (when purging), check the purge muffler for blockage and replace if necessary.
- every 6 months:
    - test all system functions and
    - clean the pre-filter strainer ball valve

- every 12 months:
    - check or change all filters cartridges as per manufacturer's instructions
    - check or change exhaust mufflers/silencers as per manufacturer's instructions
    - check the automatic drain function in the coalescing filter as per manufacturer's instructions
    - check for air leakage of the outlet and purge check valves
    - check for leakage at the inlet/exhaust control valve solenoids and
    - check the inlet and exhaust valves/solenoids for wear.
- every 36 months:
    - Change all annual parts.
    - Change desiccant, check valves, shuttle valve(s), and purge valve(s).

Condensate drains

Condensate drains are possibly the least glamorous and most ignored component of a compressed air system. Nevertheless, there are very few things that can cause more trouble than having condensation accumulates in the supply unit. Condensate receiver tanks will usually have both a manual drain with sight glass and an electronic automatic drain. The condensate in the receiver tank must be checked daily to verify free flow and proper operation of the automatic drains. Electronic drains are usually either of the timer or demand type.

Timer drains use a timer to activates a valve to dump the condensation (Figure 2).

- You can adjust the drain cycles by setting the number of cycles per hour and the length of time the valve will stay open during each cycle. The theory is to set the timer for a long enough period to completely drain the condensation without setting it long enough to waste compressed air.
- The problem is that the amount of condensation will vary according to changes in the temperatures and relative humidity of the ambient environment. This means that the settings will have to be adjusted to compensate for climate and seasonal changes.
- Take the time to change the settings on your timer drains to match the changes in the ambient temperature and humidity.
- Avoid the temptation of using settings that will keep the valve open longer than necessary. This approach may get the condensation out of the system, but it sets up an automatic leak point for compressed air.

Figure 2. Timed electric drain assembly

Electronic demand drains have electronic sensors that monitor the level of condensation within a reservoir (Figure 3). One sensor opens the outlet valve to dump the condensation when the housing registers as being full. Another sensor closes the outlet valve before completely draining the condensate to avoid wasting air.

Figure 3. Selection of electronic demand drains

Maintaining electronic demand drains:

- Clean inlet filters
- Clean the sensors and the housing of an electronic drain regularly.

Compressor V-Belts

Check the belt tension monthly. Lock-out the main power and remove the belt guard. As shown in Figure 4, deflect each V-belt at the center of the drive span (position F) with a spring balance or tension meter at the manufactures tension force. Then check that the average deflections (position D) at the proper tension force are correct (usually approximately ¼ “).

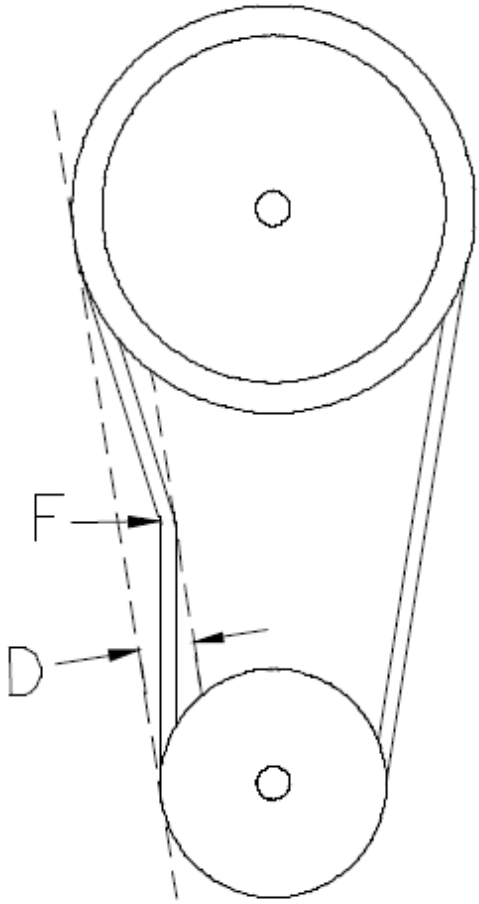


Figure 4. Belt tension

V-belts should be changed yearly under normal operating conditions. If any damage is found, V-belts should be replaced at once. To change the V-belts call the nearest distributor or follow this procedure:

1. Remove the old belts:
    a. Remove the belt guard.
    b. Loosen the locking bolts securing the motor base.
    c. Adjust the belt tensioning adjustment rods on the motor base to loosen tension on belts.
    d. Remove the old belt(s).
2. Check and clean:
    a. Check and clean all of the grooves of both the motor and compressor sheaves.
    b. Check the tightness of bolts on the sheave bushings.
3. Installation of new belts:
    a. Confirm the belt type and length.
    b. Place the belt(s) into the grooves of both sheaves.

c. Adjust the belt tensioning adjusting rods on the motor base until the proper tension and alignment is obtained. To check for correct alignment, place a straight edge on the faces of the two sheaves (Figure 5). Proper alignment is obtained when all the gaps between the straight edge and the sheaves are minimized and less than 1/8”.

d. Replace the belt guards **before** operating the machine.

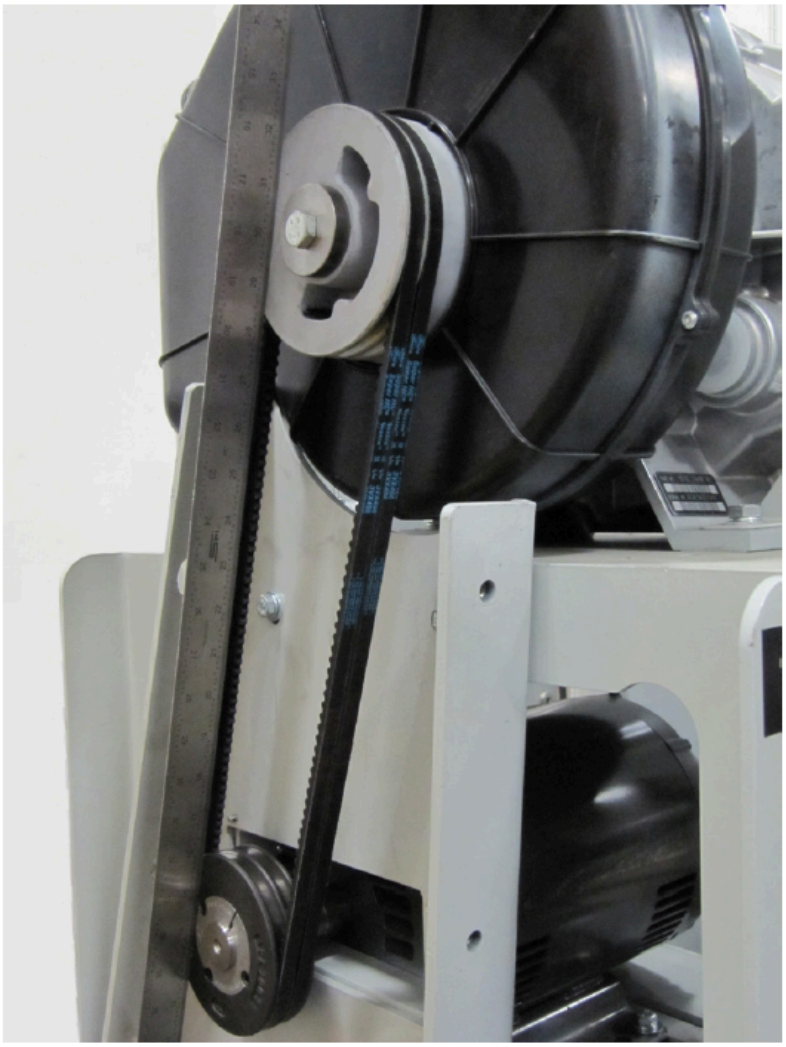


Figure 5. Checking belt alignment

Line pressure regulators

As previously discussed, on parallel line pressure regulator arrangements one regulator is designated as the primary regulator with its pressure adjusted at normal distribution pressure. The secondary regulator is set at a pressure that is below the pipeline low-pressure alarm setting. During normal operation the assembly outlet pressure gauge will indicate pressure of the line regulator with the highest set-point and the secondary regulator will be in the closed position. As part of the required maintenance, the line regulator pressure settings must be alternated every six months and an operating record shall be kept. Below is an example of a manufacture’s instructions for the line pressure regulator

adjustment on a cylinder changeover manifold. The manifold changeover, regulator droop and creep tests could also be tested at the same time.

Line pressure regulator adjustment:

1. Open the right-side Line Regulator Isolation Valve and close the left-side Line Regulator Valve.
2. Slightly open vent valve (less than ¼ turn) to create a small flow of gas through manifold.
3. Using a wrench, loosen the right Line Regulator locknut.
4. Turn the Right Line Regulator Adjusting Screw to achieve an appropriate output pressure gauge reading.
5. Tighten the Right Line Regulator Lock Nut.
6. Open left-side Line Regulator Isolation Valve and close the right-side Line Regulator Isolation Valve
7. Using a wrench, loosen Line Regulator Locknut.
8. Turn left-side Line Regulator Adjusting Screw to achieve an appropriate output pressure gauge reading.
9. Tighten the left Line Regulator Lock Nut.
10. Close Vent Valve.
11. Open right-side Line Regulator Isolation Valve.
12. Verify manifold operation.

Pipeline distribution system maintenance

If any part of the distribution system is breeched they must be tested and inspected as per the code installation standards. A system is breeched at point of pipeline intrusion by physical separation or by system component removal, replacement, or addition.

WARNING: To protect the lives of patients, always notify the appropriate medical facility staff before shutting off the supply of medical gas or vacuum through a shutoff valve. Do not close shutoff valves except in cases of emergency or maintenance

Shut-off valves

All shut-off valves should be tested annually for external leakage using oxygen compatible leak detector solution and/or suitable electronic leak detection equipment. Opportunities to test the main supply shut off valve or downstream isolating valves for tightness of shut-off are infrequent as it is impossible to shut-off valves while systems are in use. If the opportunity arises main supply shut-off valves, riser valves, branch valves, and any other service isolation valves should be operated to be checked, as seals can stick or leak.

Every 5 years zone valves must be checked for internal leakage by using a controlled standing pressure test to confirm tightness of shutoff. The standing pressure test entails; closing a valve and lowering the downstream pressure of the zone 20% of its normal value then observing any change in pressure.

The three-piece design of the shut-off valves makes changing the internal components of the ball valve easy. The valve bodies can be accessed by loosening all bolts and nuts and removing only one bolt, at this point the valve body can be swung out for servicing

Terminal units

Each terminal unit shall be tested annually for function, wear, mechanical performance, and flow resistance. During the performance test, a downward weight load similar to secondary equipment loads, and not in excess of the manufacturer's recommended limit, shall be applied to the terminal unit to determine if the strain causes leakage.

If repairs are needed the "Latch Valve Assembly" can be removed without interrupting the service, but when servicing the "Rough-in Assembly" the supply pressure has to be shut off.

Zone alarm panels

Annually the functionality of pressure sensors must be checked by applying low-pressure and low vacuum alarm simulations (Figure 6) to ensure alarm calibrations.

Figure 6. Zone alarm pressure display

If an LED gas pressure readings is not accurate the sensor module should be checked (Figure 7). Ensure that the sensor module is properly connected to the DISS demand check-valve. Trace and check the wiring from the sensor module to the display module. If the sensor is faulty it can be removed at the DISS fitting from the check valve without shutting of the gas.

Figure 7. Gas specific pressure sensor assembly

Now complete Self-Test 2 and check your answers.

Self-Test 2

Self-Test 2

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://opentextbc.ca/plumbing4a/?p=173#h5p-8

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Figure 1. “Desiccant dryer components” image description: A labeled diagram displaying four different views of a desiccant dryer, highlighting its key components.

- Top Left: Shows the air system outlet (9), where dried air is delivered.
- Top Middle: Displays the tower pressure gauge (2), a visual indicator of tower pressure. The pre-filter (3) and after-filter (8) remove debris from incoming and outgoing air. Check valves (4) ensure unidirectional airflow. The purge muffler (5) reduces exhaust noise and filters out particulates like desiccant dust, while the poppet purge valve (6) controls the release of purge air. The 441 switching valve (7) toggles between the two filtered air lines.
- Top Right: Highlights the dryer inlet, where new air enters the system.
- Bottom Left: Shows the canister (10) and tower (11) o-rings, essential for maintaining an airtight seal. *[Return to Figure 1]*

Versioning History

This page provides a record of edits and changes made to this book since its initial publication. Whenever edits or updates are made in the text, we provide a record and description of those changes here. If the change is minor, the version number increases by 0.01. If the edits involve substantial updates, the version number increases to the next full number.
The files posted by this book always reflect the most recent version. If you find an error in this book, please fill out the Report an Error form.

Version	Date	Change	Details
1.00	May 6, 2025	Book published.	