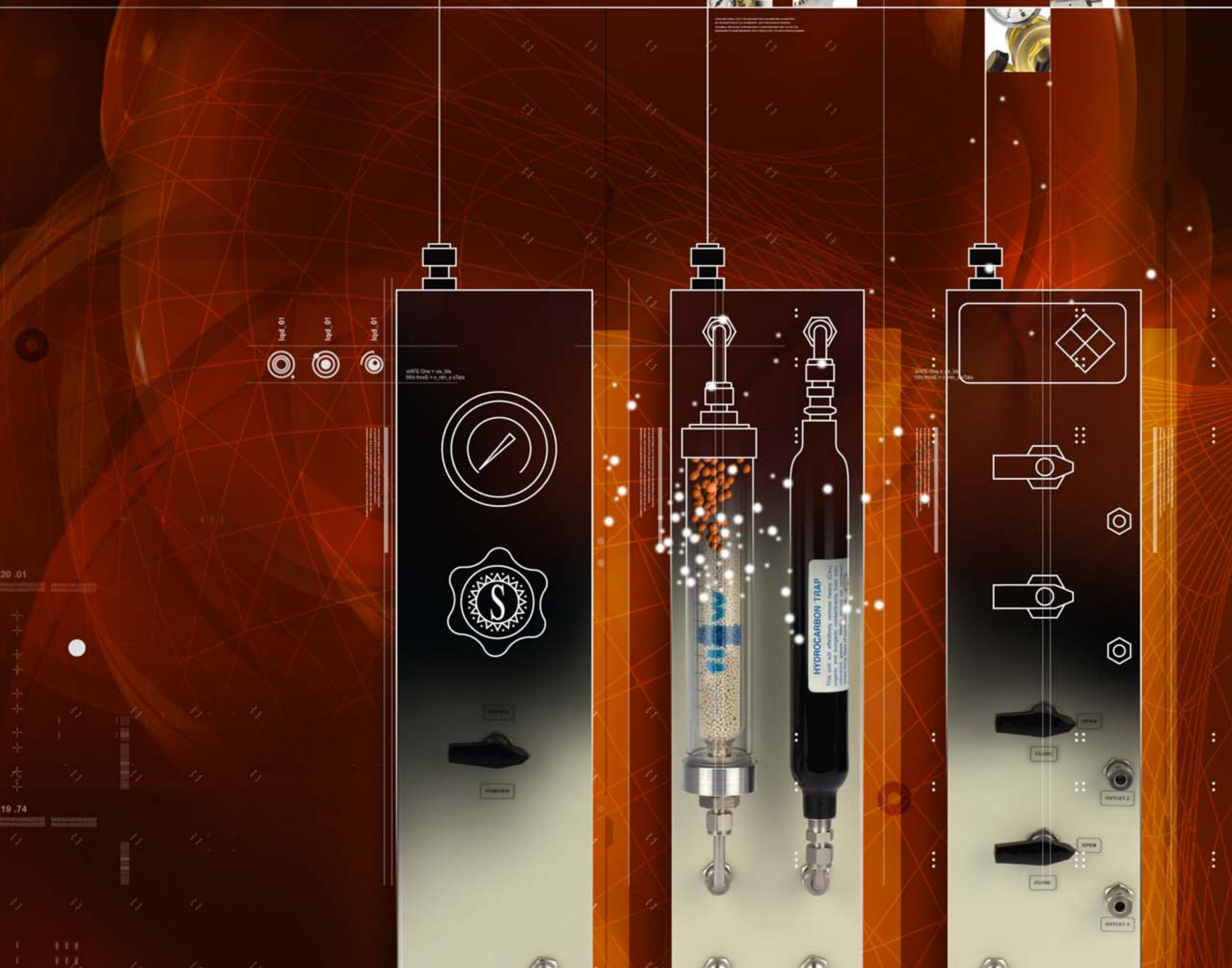
Scott Specialty Gases

design AND safety handbook

FOR SPECIALTY GAS DELIVERY SYSTEMS

updated 4th edition



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This handbook is a compendium of the knowledge and experience gathered over many years by Scott's Research and Development Department, production staff, equipment specialists, field representatives and customers. We gratefully acknowledge their contributions.

Industrial processes must move at ever faster speeds in order to remain competitive in today's global economy. It is increasingly more important to improve quality and reduce the cost of the end product. At the same time, many industries are faced with meeting tougher regulations governing process emissions. To prosper in such an environment, reliable testing methods are essential, both to ensure regulation compliance and to result in a quality end product that is cost-effective to produce. Modern analytical instrumentation is certainly up to this challenge—yet today's instruments are only as reliable as the specialty gases used to calibrate them and the equipment used to deliver those gases.

Quality and performance of specialty gas delivery equipment are essential. This handbook will aid in the design and safe operation of custom specialty gas delivery systems. Our goal is to help you acquire (or design) an efficient, safe and reliable system that will provide the correct gas to the point where it is needed—at the specified purity level, pressure and flow rate.

As one of the world's largest suppliers of specialty gas products and technology, Scott has a long history of working with agencies such as the U.S. Environmental Protection Agency (EPA), the National Institute for Standards and Technology (NIST) and the Netherlands Measurement Institute (NMi), helping to develop many protocols and certified reference materials. Our products include high-purity gases and gas mixtures for industrial, scientific, laboratory, electronic, medical, environmental, chemical and petrochemical applications, as well as high-performance gas handling equipment. Scott provides expert design and construction services of custom gas delivery systems for any application as well as individual components for existing systems.

Compressed Gas: Safety

All cylinders containing gases must be labeled, packaged and shipped according to local and national requirements, as well as industry standards. Transportation label diamonds, regardless of color, indicate hazardous materials. Personnel handling any compressed gas should be familiar with the potential hazards before using the gas. In addition to the chemical hazards of compressed gases, hazards accompanying high pressure or low temperature may also be present due to the physical state of the gas (i.e. liquefied or nonliquefied).

It is also recommended that personnel who handle compressed gases engage in pre-job discussion with their supervisor or another knowledgeable coworker before beginning any task. Outline the job step by step. Address potential emergencies and the safe and proper measures necessary to avoid these emergencies. Identify several scenarios that could result in gas leaks or other emergencies to be totally prepared to respond adequately. If there is doubt regarding proper safety procedures, consult your Scott Representative. Further information concerning the safe handling, storage and use of compressed gases, in addition to the information presented in this handbook, is available from Scott Specialty Gases and at scottgas.com.

Gas Categories

Corrosive – Gases that corrode material or tissue with which they come in contact, or do so in the presence of water, are classified as corrosive. They can also be reactive and toxic and/or flammable or an oxidizer. Most are hazardous in low concentrations over long periods of time. It is essential that equipment used for handling corrosive gases be constructed of proper materials. Use check valves and traps in a system where there is a possibility that water or other inorganic materials can be sucked back into the cylinder. Due to the probability of irritation and damage to the lungs, mucus membranes and eye tissues from contact, the threshold limit values of the gas should be rigidly observed. Proper protective clothing and equipment must be used to minimize exposure to corrosive materials. A full body shower and eye wash station should be in the area. Personnel must be familiar with the work area. Aisles should always be clear and unobstructed in the event that the gas makes contact with the eyes and vision is disrupted.

Flammable – Gases that, when mixed with air at atmospheric temperature and pressure, form a flammable mixture at 13% or less by volume, or have a flammable range in air of greater than 12% by volume regardless of the lower flammable limit, are classified as flammable. They can be high-pressure, toxic, reactive and displace oxygen in air. A change in temperature, pressure or oxidant concentration may vary the flammability range considerably. All possible sources of ignition must be eliminated through proper design of facilities and the restriction of smoking and open flames. Use a vent line made of stainless steel, purge with an inert gas and use a flash arrester. It is important to have (and know how to use) a fire extinguisher in the area where flammable gases are used and stored, as well as a hand-held flammable gas detector to determine if flammable gases are building up. This gas detector can also be used as a leak detector on the lines of the equipment being used. Always remember that the source of flammable gas must be closed or shut-off before attempting to put out a fire involving flammable gases.

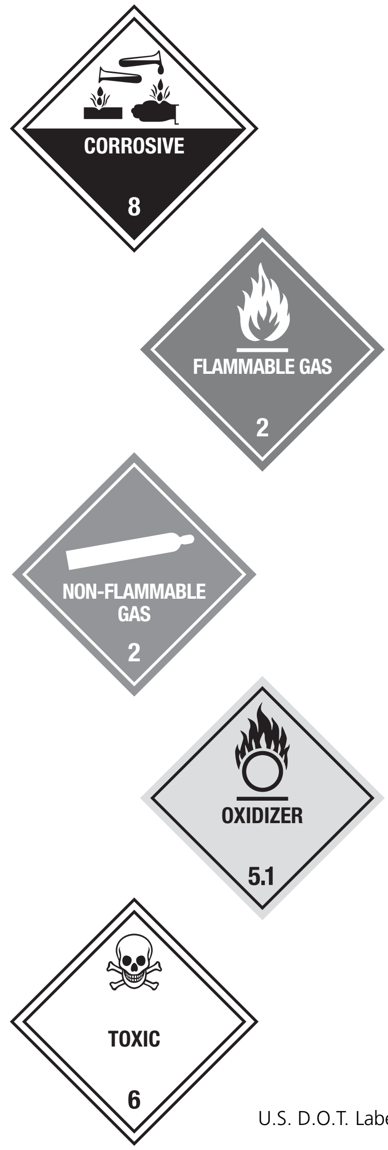
Inert – Gases that do not react with other materials at ordinary temperature and pressure are classified as inert. They are colorless and odorless, as well as nonflammable and nontoxic. The primary hazard of these gases is pressure. These gases are often stored at pressures exceeding 2,000 psi (138 bar). Also, they can displace the amount of oxygen necessary to support life when released in a confined place. Use of adequate ventilation and monitoring of the oxygen content in confined places will minimize the danger of asphyxiation. Always wear safety glasses and safety gloves when working with the lines to avoid absorption of the gas through the skin.

Oxidant – Gases that do not burn but will support combustion are classified as oxidants. They can be high-pressure, toxic and reactive, and can displace breathing oxygen from air (except O_2 itself). All possible sources of ignition must be eliminated when handling oxygen and other oxidants as they react rapidly and violently. Do not store combustible materials with oxidants. Do not allow oil, grease or other readily combustible materials to come in contact with the cylinder or equipment used for oxidant services. Use only equipment that is intended for this type of service. Use only a regulator that has been clearly prepared for use with this type of service—this regulator should be labeled "Cleaned for O_2 Services."

Cryogenic – Gases with a boiling point below -130°F (-90°C) at atmospheric temperature are considered cryogenic gases. They are extremely cold and can produce intense burns (similar to heat burns) and tissue necrosis may be even more severe. They can be nonflammable, flammable or oxidizing. Cryogenic liquids can build up intense pressures. At cryogenic temperatures, system components may become brittle and crack. Never block a line filled with cryogenic liquid as a slight increase in temperature can cause tremendous and dangerous buildup of pressure and cause the line to burst. The system should also be designed with a safety relief valve and, depending upon the gas, a vent line. To protect from injury, always wear gauntlet gloves to cover hands and arms, and a cryogenic apron to protect the front of the body. Wear pants over the shoes to prevent liquids from getting trapped inside your shoes. Wear safety glasses and a face shield as cryogenic liquids tend to bounce upward when spilled.

Toxic or Poison – Gases that may produce lethal or other harmful effects on humans are classified as toxic or poison. They can be high pressure, reactive, nonflammable or flammable, and/or oxidizing in addition to their toxicity. The degree of toxicity and the effects will vary depending on the gas; however, death will occur when breathed in sufficient quantities. The permissible exposure levels must be strictly adhered to (please refer to the PELs listed in the Scott Specialty Gases' Reference Guide or at scottgas.com). Read your MSDS thoroughly before use and consult with your Scott Representative or a more knowledgeable coworker who has handled the gas before. Never work alone with toxic gases — a backup safety person is essential! Inspect the entire assembly or system that will contain the gas and thoroughly test it for leaks with an inert gas before use. Purge all lines with an inert gas before opening the cylinder valve or breaking connections. Contact your Scott Representative for proper purge procedures.

Use toxic gases in a well-ventilated area. For safety purposes and to minimize exposure, it is important to have gas detectors. It is preferable that the breathing apparatus be stored in a safe area immediately adjacent to the work area, so that in the event of an emergency, a person can go directly into the area and close the door and safely put on the apparatus. Full body showers, eye washes, fire alarms and firefighting equipment should be in the area of use and readily accessible. Refer to your local building code for storage and use requirements for toxic gases. Keep your inventory of toxic or poison gases to a minimum. When a project is completed, return leftover cylinders to Scott. They should never be stored for possible future use. This might result in accidental removal of cylinder labeling, making it an unnecessary hazard and greatly increasing the cost of proper disposal.



U.S. D.O.T. Labels

Definitions

Compressed – Nonflammable material or mixture that is contained under pressure exceeding 41 psia (3 bar) at 70°F (21°C) or any flammable or poisonous material that is a gas at 70°F (21°C) and 14.7 psia (1 bar) or greater. Most compressed gases will not exceed 2,000 to 2,640 psig (138 to 182 bar) though some go up to 6,000 psig (414 bar).

Nonliquefied Compressed – Chemical or material other than gas in solution that under the charged pressure is entirely gaseous at a temperature of 70°F (21°C).

Liquefied Compressed – Chemical or material that under the charged pressure is partially liquid at a temperature of 70°F (21°C).

Compressed Gas in Solution – Nonliquefied compressed gas that is dissolved in a solvent.

Cylinder: Storage and Use

Cylinder Rack – Model 55-84CS stores cylinders safely

Safety glasses, gloves and shoes should be worn at all times when handling cylinders.

Appropriate firefighting, personnel safety and first aid equipment should be available in case of emergencies. Ensure adequate personnel are trained in the use of this equipment.

Follow all federal, state and local regulations concerning the storage of compressed gas cylinders. Refer to the Compressed Gas Association (CGA) Pamphlet P-1 in the U.S. for further information or consult EIGA (European Industrial Gas Association), CPR-15 or CIMAH in Europe.

Storage

Storage Area – Store gas cylinders in a ventilated and well-lit area away from combustible materials. Separate gases by type and store in assigned locations that can be readily identified. Store cylinders containing flammable gases separated from oxygen cylinders and other oxidants, by a fire-resistant wall (having a fire-resistance rating of at least a half-hour) or locate them at least 20 feet (6.1 meters) apart from each other. Poison, cryogenic and inert gases should be stored separately. Labels, decals or other cylinder content identification should not be obscured or removed from the gas cylinder. Cylinders should also be stored where they can be protected from tampering by unauthorized personnel.

Storage Area Conditions – Storage areas should be located away from sources of excess heat, open flame or ignition, and not located in closed or subsurface areas. The area should be dry, cool and well-ventilated. Use of a vent hood does not provide for a safe storage area except for when a cylinder is actually in use. Outdoor storage should be above grade, dry and protected from the weather.

Securing Cylinders in Storage – The risk of a cylinder falling over and possibly shearing off its valve demands that a cylinder always be held in place with a chain or another type of fastener such as a bench or wall clamp. While in storage, cylinder valve protection caps MUST be firmly in place.

Cylinder Temperature Exposure – Cylinder temperature should not be permitted to exceed 125°F (52°C). Steel cylinders are typically used for more corrosive products. Though they are more durable than aluminum cylinders, they should not be stored near steam pipelines or exposed to direct sunlight. Aluminum cylinders are used for increased stability of mixtures containing certain components and they can be damaged by exposure to temperatures in excess of 350°F (177°C). These extremes weaken the cylinder walls and may result in a rupture. Do not apply any heating device that will heat any part of the cylinder above 125°F (52°C).

Empty Cylinders – Arrange the cylinder storage area so that old stock is used first. Empty cylinders should be stored separately and clearly identified. Return empty cylinders promptly. Some pressure should be left in a depleted cylinder to prevent air backflow that would allow moisture and contaminants to enter the cylinder.

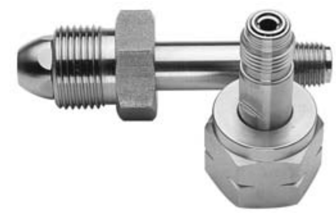
Usage

Labeling – If a cylinder's content is not clearly identified by proper labels, it should not be accepted for use.

Securing Cylinders Before Use – When a cylinder is in use, it must be secured with a fastener. Floor or wall brackets are ideal when a cylinder will not be moved. Portable bench brackets are recommended when a cylinder must be moved around. Stands are available for small cylinders as well as for lecture bottles. Your Scott Representative can assist you in determining which type of cylinder fastener best meets your needs.

Initiating Service of Cylinder – Secure the cylinder before removing the valve protection cap. Inspect the cylinder valve for damaged threads, dirt, oil or grease. Remove any dust or dirt with a clean cloth. If oil or grease is present on the valve of a cylinder that contains oxygen or another oxidant, do NOT attempt to use it. Such combustible substances in contact with an oxidant are explosive. Notify the nearest Scott facility of this condition and identify the cylinder to prevent usage.

Valve Outlet Connections and Fittings – Be sure all fittings and connection threads meet properly – never force. Dedicate your regulator to a single valve connection even if it is designed for different gases. NEVER cross-thread or use adapters between nonmating equipment and cylinders. Most cylinder valve outlet connections are designed with metal-to-metal seals; use washers only where indicated. Do not use Teflon® tape on the valve threads to help prevent leaking, it may become powdered and get caught on the regulator poppet causing full pressure downstream. Never use pipe dope on pipe threads. Also, never turn the threads the wrong way. This could produce brass particles that might get caught in the poppet.



Know your connections and fittings! If you are using a CGA and its middle digit is an even number, then it is right-handed and the threads should be turned clockwise to tighten the fitting. If the middle digit is an odd number, it is left-handed and the threads should be turned counterclockwise to tighten the fitting.

Gas Cabinets – When hazardous specialty gases are used in an enclosed location, it is wise to provide an extra degree of protection for personnel. A gas cabinet can contain and vent leaking gas. A gas cabinet also accommodates manifolds and gas handling systems, providing an efficient and cost-effective means to safely organize specialty gas distribution equipment.

Properly Designed Gas Systems

- Contain hazardous gas in the event of leakage
- Maintain gas integrity
- Automatic shutoff of gas in the event of catastrophic failure
- Effective control of residual gas during cylinder changeout

Cylinder storage problems are simplified because the cabinet/manifold system concept encourages separation of gases according to their classification. For example, corrosives, oxidizers, flammables and toxics can be separated and grouped into separate cabinets. This satisfies both national and local fire and building codes.

In order to provide containment of potentially dangerous gases, cabinet exhaust systems should be designed with the capability to allow 150 to 200 linear feet (45.7 to 61 linear meters) per minute of air to pass through the cabinet with the access window open. This is equivalent to 13 air changes per minute. As an extra measure of fire protection, gas cabinets used to store flammables should be equipped with an integral sprinkler system. While exact requirements may vary with the specific application, a typical sprinkler would have a fuse rated at about 135°F (57°C) and a flow capability of approximately 40 GPM (2.524 L/s).

Gas Cabinet with Model 8404 ChangeOver

Consideration should be given to materials of construction when selecting a gas cabinet. For example, use of 11-gauge steel or better for the cabinet and door will ensure sturdiness and also provide a half-hour or more of fire protection. Horizontally and vertically adjustable cylinder brackets should also be specified to ensure that cylinders are properly secured. If poisonous gases are to be kept in the cabinet, an access window should be provided so the cylinder valves can be closed and leaks detected without opening the cabinet door and compromising the exhaust system. For cabinets used to store inert gases, a fixed window to allow visual inspection is an acceptable and economical alternative.

Terminating Service of Cylinder – Disconnect equipment from the cylinder when not in use for long periods and return the cylinder valve protection cap to the cylinder.

Transporting Cylinders – Always move cylinders by hand trucks or carts that are designed for this purpose. During transportation, cylinders should be properly secured to prevent them from falling or striking each other. Always use a cylinder cart equipped with a chain restraint. Do not move a cylinder with a regulator connected to it. Never transport a gas cylinder without its valve protection cap firmly in place. Keep both hands on the cylinder cart during transport. A cylinder cart or hand truck is not a suitable place for storage of a cylinder.

Pressure Regulators: Selection / Operation

The safest means to reduce cylinder pressure to a workable level for operating equipment and instruments is through a pressure reduction regulator. Application determines which regulator to use.

Scott offers over 40 regulator series with more than 120 different pressure ranges. All are intended for specific applications. Information for gases listed in the Scott Specialty Gases reference guide includes recommended pressure regulators for best service.

Single-Stage vs Two-Stage – There are two basic types of regulators. Duration of gas usage helps to identify whether a single-stage or two-stage regulator provides the best service. A single-stage regulator is a good performer for short duration gas usage. It reduces the cylinder pressure to the delivery or outlet pressure in one step. This type of regulator is recommended when precise control of the delivery pressure is not required because delivery pressure variations will occur with decreasing cylinder pressure.

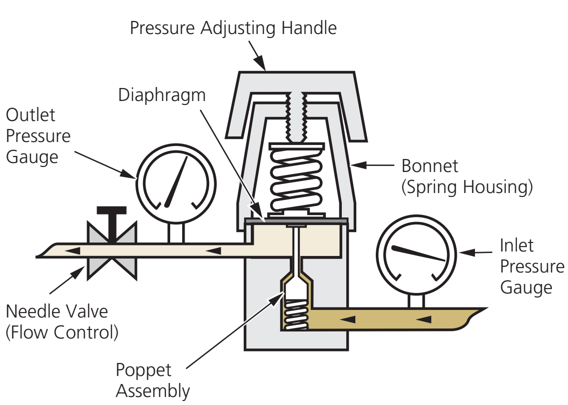
A two-stage regulator provides better performance for long duration gas usage. It reduces the cylinder pressure to a working level in two steps. The cylinder pressure is reduced by the first stage to a preset intermediate level, which is then fed to the inlet of the second stage. Since the inlet pressure to the second stage is so regulated, the delivery pressure (manually set by means of the adjusting handle) is unaffected by changes in the cylinder pressure. Thus, the two-stage pressure regulators provide precise control of the gas being consumed. A two-stage regulator performs best when it is attached to the cylinder and adjusted to the desired reduced pressure, and then remains in service until the cylinder is ready for changeout.

Materials of Construction – A regulator must be constructed with materials compatible with the intended gas service and application. When selecting your regulator, you should first consider the wetted materials (those that will come in contact with the gas). Typical materials used for regulator construction are:

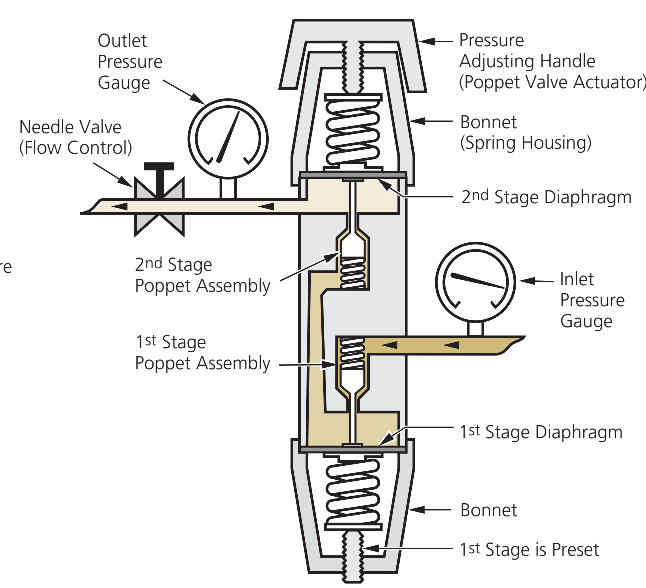
Noncorrosive:	Aluminum, Brass, Stainless Steel, Buna-N, PCTFE, Neoprene, Teflon®, Viton®, Nylon.
Corrosive:	Aluminum, Stainless Steel, Monel®, Nickel, PCTFE, Teflon

The ideal construction for high-purity gas service is a regulator that has a stainless steel diaphragm. They are noncontaminating and assure satisfactory use for all applications of noncorrosive and mildly corrosive gases.

Single-Stage Regulator



Two-Stage Regulator



For general use, brass regulators with Buna-N or Neoprene diaphragms will give good service in noncorrosive applications where slight contamination or diffusion from an elastomeric diaphragm is not important. Both Buna-N or Neoprene are permeable to oxygen. Therefore, regulators with these types of diaphragms are not suitable for GC analysis that can be affected by the diffusion of atmospheric oxygen through the elastomer diaphragm, or the outgassing of monomers and dimers from the elastomer. In fact, labs that perform temperature programmed analysis are faced with excessive baseline drift and large unresolved peaks due to this diffusion and outgassing.

Brass regulators with stainless steel diaphragms have several advantages over the elastomeric type. Firstly, they prevent air diffusion and adsorption of gases on the diaphragm. This is important with low concentration mixtures of hydrocarbons where the trace components may be adsorbed on the elastomeric diaphragm. Secondly, these regulators do not outgas organic materials and prevent the diffusion of atmospheric oxygen in the carrier gas. The chemical potential of oxygen between the carrier gas and the atmosphere provides sufficient driving force for oxygen to intrude the carrier gas through a permeable diaphragm. Stainless steel diaphragms prevent this scenario from happening.

Two-Stage Stainless Steel Regulator
Model 215 – Corrosive gas use

Single-Stage Brass Regulator
Model 202 – Noncorrosive gas use

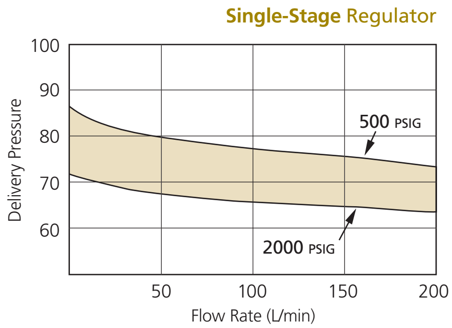
Performance Characteristics

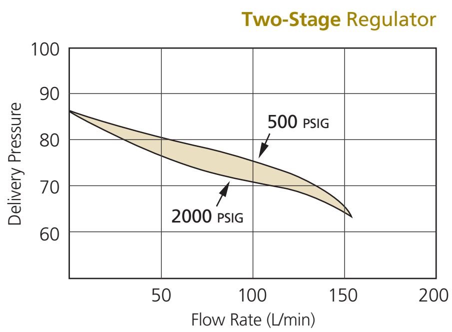
Droop	Regulator performance is characterized by droop; the change in delivery pressure as flow is initiated and increased through the regulator.
Supply Pressure Effect	Supply pressure effect is the change in delivery pressure as the inlet pressure changes. For most regulators, a decrease in inlet pressure causes the delivery pressure to increase.
Repeatability	Repeatability refers to the change in delivery pressure after pressure has been set by turning gas flow on and off using an external valve.
Delivery Pressure Creep	There are two types of creep. The first type is normal as a result of internal spring forces equalizing when the flow stops. The second type of creep is a result of contamination that, when left unchecked, can lead to regulator and/or supply line failure.

Droop – The two most important parameters to consider during regulator selection and operation are droop and supply pressure effect. Droop is the difference in delivery pressure between zero flow conditions and the regulator's maximum flow capacity. Supply pressure effect is the variation in delivery pressure as supply pressure decreases while the cylinder empties. Single-stage and two-stage regulators have different droop characteristics and respond differently to changing supply pressure. The single-stage regulator shows little droop with varying flow rates but a relatively large supply pressure effect. Conversely, the two-stage regulator shows a steeper slope in droop but only small supply pressure effects.

The effect of these differences on performance can be illustrated with some examples. For instance, when a centralized gas delivery system is supplying a number of different chromatographs, flow rates are apt to be fairly constant. Supply pressure variations, however, may be abrupt, especially when automatic changeover manifolds are used. In this scenario, a two-stage regulator with a narrow accuracy envelope (supply pressure effect) and a relatively steep droop should be used to avoid a baseline shift on the chromatographs. On the other hand, if gas is being used for a short-duration instrument calibration, a single-stage regulator with a wide accuracy envelope (supply pressure effect) but a comparatively flat droop should be chosen. This will eliminate the need to allow the gas to flow at a constant rate before the calibration can be done.

Selection / Operation continued





Accuracy envelopes for single and two-stage regulators at two supply pressures

The envelopes are bounded by inlet pressure curves of 2000 psig (138 bar) and 500 psig (35 bar). Each regulator was set to the shown delivery pressure with 2000 psig (138 bar) inlet pressure and zero flow. Once set, this delivery pressure was not manually changed during the evaluation. The curves generated are the result of increasing flow through the regulator to its capacity, decreasing the flow rate through the regulator to zero.

Delivery Pressure Range – Determining an appropriate delivery pressure range for a regulator can be confusing but can be accomplished by following these steps:

1. Determine the gas pressure needed.
2. Determine the maximum pressure the system might require (this pressure and the gas pressure are often the same).
3. Select a delivery pressure range so that the required pressures are in the 25% to 90% range of the regulator's delivery pressure (a regulator's performance is at its best within this range).

Relieving/Non-Relieving – A relieving regulator has a hole in the center of the diaphragm. As long as the diaphragm is in contact with the poppet, the regulator does not relieve. When the pressure under the diaphragm increases as a result of back pressure from downstream, the diaphragm will rise, allowing the pressure to relieve through the opening in the diaphragm. While the internal gas is relieving through this opening, the surrounding atmosphere (i.e. air) is diffusing into the gas stream. Oxygen (a component of air) is a harmful contaminant, especially when a gas stream is intended to be oxygen-free. It is well documented that oxygen affects gas chromatographic results. Relieving regulators should not be used in specialty gas applications.

Linked Poppet/Tied Diaphragm – The poppet and diaphragm are mechanically linked. An increase in pressure in the cavity below the diaphragm will cause the diaphragm to move upward, pulling the poppet to improve its seal against the seat. A tied diaphragm regulator is effective in corrosive gas service, especially in the event that corrosive particles form under the poppet or on the seat. Tied diaphragm or linked poppet are terms used by manufacturers to describe this regulator feature.

Gauges – Generally single and two-stage regulators are equipped with two gauges – a cylinder or inlet pressure gauge and a delivery or outlet pressure gauge. The cylinder pressure gauge has the higher pressure range and is located adjacent to the inlet port. The delivery pressure gauge of the lower pressure range is located adjacent to the outlet port.

The actual pressure gauge range is usually greater than the pressure range for which the regulator is rated. For example, a regulator that has a delivery pressure range of 1–50 psig (0.1–3 bar) will typically be supplied with a 0–60 psig (0–4 bar) delivery pressure gauge. This ensures that the rise in delivery pressure as a result of the regulator's supply pressure effect will not exceed the gauge pressure range.

Not all cylinder regulators have two gauges. A line regulator is typically provided with a single gauge that monitors the outlet pressure or reduced pressure. This gauge is usually situated in the 12 o'clock position. Regulators designed for liquefied gases may not have a cylinder pressure gauge because the cylinder pressure varies only with temperature as long as liquid is present in the cylinder.

Regulator Placement – Specialty gas regulator applications are divided into two types. The first is when the regulator is fastened to a gas cylinder using a CGA, DIN or BS fitting. The second application is when a regulator is located in a gas line, providing a means to further reduce the line pressure. A line regulator is identified by having the inlet and outlet opposite of each other and by a single gauge as discussed above.

Gas Compatibility

The compatibility data shown on the following pages has been compiled to assist in evaluating the appropriate materials to use in handling various gases. Prepared for use with dry (anhydrous) gases at normal operating temperature of 70°F (21°C), information may vary if different operating conditions exist.

It is extremely important that all gas control equipment be compatible with the gas being passed through it. The use of a device that is not compatible with the service gas may damage the unit and cause a leak that could result in property damage or personal injury. To reduce potentially dangerous situations, always check for compatibility of materials before using any gases in your gas control equipment. Systems and equipment used in oxidizer gas service (i.e. oxygen or nitrous oxide) must be cleaned for oxidizer service. Since combinations of gases are virtually unlimited, mixtures (except for Ethylene Oxide/Halocarbon and Ethylene Oxide/CO_2 sterilizing gas mixtures) are not listed in the Compatibility Chart. Before using a gas mixture or any gas not listed in the chart, please refer to the Scott Reference Guide or contact your Scott Representative for more information.

Directions

Locate the gas you are using in the first column.

Compare the materials of construction for the equipment you intend to use with the materials of construction shown in the Compatibility Chart. Then use the Key to Materials Compatibility to determine compatibility.

Key to Materials Compatibility

- **•** Satisfactory for use with the intended gas.
- **U** Unsatisfactory for use with the intended gas.
- **?** Insufficient data available to determine compatibility with the intended gas.
- **C1** Satisfactory with brass having a low (65–70% maximum) copper content. Brass with higher copper content is unacceptable.
- **C2** Satisfactory with acetylene, however, cylinder is packaged dissolved in a solvent (generally acetone) which may be incompatible with these elastomers.
- **C3** Compatibility varies depending on specific Kalrez® compound used. Consult E.I. DuPont for information on specific applications.
- **C4** Satisfactory with brass, except where acetylene or acetylides are present.
- **C5** Generally unsatisfactory, except where specific use conditions have proven acceptable.
- **C6** Satisfactory below 1000 psig (68.9 bar).
- **C7** Satisfactory below 3000 psig (206.9 bar) where gas velocities do not exceed 30 ft./sec.
- **C8** Compatibility depends on condition of use.

Compatibility Guide		**Materials of Construction**																	
		Metals							Plastics						Elastomers				
Common Name	**Chemical Formula**	Brass	303 SS	316 SS	Aluminum	Zinc	Copper	Monel®	PCTFE	Teflon®	Tefzel®	Kynar®	PVC	Polycarbonate	Kalrez®	Viton®	Buna-N	Neoprene	Polyurethane
Acetylene	C_2H_2	C1	•	•	?	U	U	•	•	•	•	•	?	C2	•	C2	C2	C2	C2
Air	—	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Allene	C_3H_4	•	•	•	•	?	U	•	•	•	•	•	?	?	•	•	•	•	?
Ammonia	NH_3	U	•	•	•	U	U	•	•	•	•	U	•	U	C3	U	•	•	U
Argon	Ar	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Arsine	AsH_3	•	•	•	C5	?	•	•	•	•	•	•	•	?	•	•	•	•	U
Boron Trichloride	BCl_3	U	•	•	U	?	•	•	•	•	•	?	•	?	C3	?	?	?	?
Boron Trifluoride	BF_3	•	•	•	•	?	•	•	•	•	•	?	•	?	C3	?	?	?	?
1,3-Butadiene	C_4H_6	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	U	•	U
Butane	C_4H_{10}	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	•	•	•
1-Butene	C_4H_8	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	•	•	•
cis-2-Butene	C_4H_8	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	•	•	•
trans-2-Butene	C_4H_8	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	•	•	•
Carbon Dioxide	CO_2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	U
Carbon Monoxide	CO	•	•	•	•	•	•	•	•	•	•	•	•	•	•	?	•	•	•
Carbonyl Sulfide	COS	•	•	•	•	?	•	•	•	•	•	•	•	?	?	•	?	?	?

Gas Compatibility continued

Compatibility Guide		Materials of Construction																	
		Metals							Plastics						Elastomers				
Common Name	**Chemical Formula**	Brass	303 SS	316 SS	Aluminum	Zinc	Copper	Monel®	PCTFE	Teflon®	Tefzel®	Kynar®	PVC	Polycarbonate	Kalrez®	Viton®	Buna-N	Neoprene	Polyurethane
Chlorine	Cl_2	U	•	•	U	U	U	•	•	•	•	•	U	U	•	•	U	U	U
Deuterium	D_2	•	•	•	•	•	•	•	•	•	•	•	•	?	•	•	•	•	•
Diborane	B_2H_6	•	•	•	U	?	•	•	•	•	•	?	?	?	•	?	?	?	?
Dichlorosilane	H_2SiCl_2	?	•	•	?	?	?	•	•	•	•	•	?	?	•	?	?	?	?
Dimethyl Ether	C_2H_6O	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	•	•	?
Ethane	C_2H_6	•	•	•	•	•	•	•	•	•	•	•	•	?	•	•	•	•	•
Ethyl Acetylene	C_4H_6	?	•	•	•	?	U	•	•	•	?	•	?	?	•	•	?	•	?
Ethyl Chloride	C_2H_5Cl	•	•	•	U	?	•	•	•	•	•	•	U	U	•	•	•	•	U
Ethylene	C_2H_4	•	•	•	•	•	•	•	•	•	•	•	?	?	•	•	•	•	?
Ethylene Oxide*	C_2H_4O	C4	•	•	C5	?	U	?	•	•	?	?	U	U	C3	U	U	U	U
Ethylene Oxide/Carbon Dioxide Mixtures*		C4	•	•	?	?	U	?	•	•	?	?	U	U	C3	U	U	U	U
Ethylene Oxide/Halocarbon Mixtures*		C4	•	•	?	?	U	?	•	•	?	?	U	U	C3	U	U	U	U
Ethylene Oxide/HCFC-124		C4	•	•	?	?	U	?	•	•	?	?	U	U	C3	U	U	U	U
Halocarbon 11	CCl_3F	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	•	•	U	U
Halocarbon 12	CCl_2F_2	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	•	•	•	•
Halocarbon 13	$CClF_3$	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	•	•	•	•
Halocarbon 13B1	CBF_3	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	•	•	•	•
Halocarbon 14	CF_4	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	•	•	•	•
Halocarbon 21	$CHCl_2F$	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	U	U	•	•
Halocarbon 22	$CHClF_2$	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	U	U	•	U
Halocarbon 23	CHF_3	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	?	?	?	•
Halocarbon 113	CCl_2FCClF_2	•	•	•	C5	U	•	•	•	•	•	•	U	U	C3	•	•	•	•
Halocarbon 114	$C_2Cl_2F_4$	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	•	•	•	•
Halocarbon 115	C_2ClF_5	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	•	•	•	•
Halocarbon 116	C_2F_6	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	?	?	?	•
Halocarbon 142B	$C_2H_3ClF_2$	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	U	•	•	•
Halocarbon 152A	$C_2H_4F_2$	•	•	•	C5	?	•	•	•	•	•	•	U	U	C3	U	•	•	•
Halocarbon C-318	C_4F_8	•	•	•	C5	?	?	•	•	•	•	•	U	U	C3	•	•	•	•
Halocarbon 502	$CHClF_2/CClF_2\text{-}CF_3$	?	•	•	C5	?	?	•	•	•	?	•	U	U	C3	•	•	•	•
Halocarbon 1132A	$C_2H_2F_2$	•	•	•	C5	?	•	•	?	•	•	•	U	U	C3	?	?	?	•
Helium	He	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Hydrogen	H_2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Hydrogen Chloride	HCl	U	•	•	U	U	U	•	•	•	•	•	•	U	•	•	U	U	U
Hydrogen Sulfide	H_2S	U	•	•	•	?	?	•	•	•	•	•	•	•	•	U	•	•	•

* Satisfactory for use with EPR (Ethylene Propylene Rubber) and EPDM.See key on page 9 for more information.

Compatibility Guide

		Materials of Construction																	
		Metals							Plastics						Elastomers				
Common Name	**Chemical Formula**	Brass	303 SS	316 SS	Aluminum	Zinc	Copper	Monel®	PCTFE	Teflon®	Tefzel®	Kynar®	PVC	Polycarbonate	Kalrez®	Viton®	Buna-N	Neoprene	Polyurethane
Isobutane	C_4H_{10}	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	•	•	•
Isobutylene	C_4H_8	•	•	•	•	?	•	•	•	•	•	•	•	?	•	•	•	•	?
Isopentane	C_5H_{12}	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	•	•	•
Krypton	Kr	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Methane	CH_4	•	•	•	•	•	•	•	•	•	•	•	•	?	•	•	•	•	•
Methyl Chloride	CH_3Cl	•	•	•	U	U	•	•	•	•	•	•	?	?	•	•	U	U	U
Methyl Mercaptan	CH_3SH	•	•	•	U	?	U	U	•	•	•	?	?	?	•	?	?	•	?
Neon	Ne	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Nitric Oxide	NO	U	•	•	•	?	•	•	•	•	•	?	•	?	•	?	?	•	?
Nitrogen	N_2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Nitrogen Dioxide	NO_2	?	•	•	•	?	?	•	•	•	•	?	U	?	•	U	U	U	U
Nitrous Oxide	N_2O	•	•	•	•	•	•	•	•	•	•	•	•	?	C3	•	•	•	•
Oxygen	O_2	•	C7	C7	C5	•	•	•	•	•	•	•	•	•	C3	C8	C8	C8	•
Perfluoropropane	C_3F_8	•	•	•	•	?	•	•	•	•	•	?	?	?	?	?	•	•	?
Phosphine	PH_3	?	•	•	•	?	?	•	•	•	•	?	?	?	•	?	?	?	?
Phosphorous Pentafluoride	PF_5	?	•	•	?	?	?	•	•	•	•	?	?	?	?	?	?	?	?
Propane	C_3H_8	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	•	•	•
Propylene	C_3H_6	•	•	•	•	•	•	•	•	•	•	•	•	U	•	•	U	U	U
Propylene Oxide	C_3H_6O	?	•	•	?	?	?	?	•	•	•	?	U	•	C3	U	U	U	U
Refrigerant Gases	—	See Halocarbons																	
Silane	SiH_4	•	•	•	•	?	•	•	•	•	•	•	•	?	•	•	•	•	•
Silicon Tetrachloride	$SiCl_4$	?	•	•	U	?	?	•	•	•	?	?	U	?	C3	?	?	?	?
Silicon Tetrafluoride	SiF_4	•	•	•	•	?	•	•	•	•	•	•	•	?	C3	•	•	•	•
Sulfur Dioxide	SO_2	U	•	•	•	U	U	•	•	•	•	•	•	U	•	•	U	U	•
Sulfur Hexafluoride	SF_6	•	•	•	•	?	•	•	•	•	•	•	•	?	C3	•	•	•	•
Trichlorosilane	$HSiCl_3$	?	•	•	U	?	?	•	•	•	?	?	U	?	C3	?	?	?	?
Vinyl Methyl Ether	C_3H_6O	•	•	•	•	?	U	•	•	•	•	?	?	U	C3	?	?	?	?
Xenon	Xe	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

See key on page 9 for more information.

Pressure Regulators: Maintenance

How to Perform Dilution Purging

The most effective means of purging regulators and connecting lines is the dilution purging method.

STEP 1

Attach the regulator to the specialty gas cylinder. A tee with a valve on the side branch should then be located in the line between the regulator and the instrument(s). This branch should be connected to a safety vent while the main trunk runs to the instrument(s). The tee should be located close to the instrument so that the connecting line between the regulator and instrument is also purged.

STEP 2

Adjust the regulator to the fully closed position. Then, close the safety vent valve and the valve at the instrument and open the valve on the outlet side of the regulator.

STEP 3

Open and quickly close the cylinder valve to pressurize the inlet side of the regulator to cylinder pressure. It is necessary to quickly close the cylinder valve after each cycle to keep downstream contaminants from entering the cylinder until the regulator is fully purged. Mounting the regulator on a single-station manifold that incorporates a check valve in the pigtail will eliminate this problem.

STEP 4

Adjust the regulator to establish an appropriate delivery pressure and open the vent valve to bleed off the regulator pressure.

Steps 2–4 represent one purge cycle. This cycle should be repeated three to five times to ensure that the regulator and connecting line are both properly purged.

Regulator maintenance is an important part of maximizing your system's performance and extending the service life of system components. A maintenance schedule is the frequency at which recommended maintenance operations should be performed. Adherence to a maintenance schedule should result in minimizing downtime due to regulator failure as well as enhancing safety in the work area. Regulator service defines the gas service in which the regulator is installed in terms of its corrosive nature. There are three categories: noncorrosive, mildly corrosive and corrosive. Establishing the category a regulator fits into can be difficult. Consult your Scott Representative.

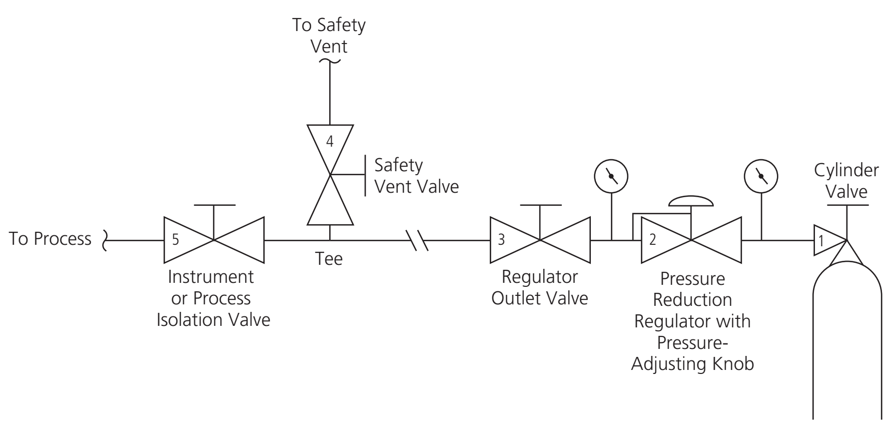
Recommended Schedule – This schedule should be used as a general guide. Be sure to follow the manufacturer instructions supplied with your regulator.

Service	Leak Check	Creep Test	Inert Purge	Overhaul	Replace[1]*
Noncorrosive	Monthly	Annually	NA	5 years	10 years
Mildly corrosive	2x month	6 months	at shutdown	2 years**	4 years**
Corrosive†	2x month	3 months	at shutdown	1–2 years**	3–4 years**

1 More frequent overhaul or replacement may be required for regulators installed in a corrosive ambient environment.
* If diaphragms are neoprene or another elastomer, they may dry out and require more frequent replacement.
** If regulators are not properly installed and used, or if a poor grade of gas is used, or if purging is not properly done, overhaul and/or replacement may be required more frequently than indicated.
† For regulators used in toxic or corrosive gas applications, care should be taken to ensure proper precautions are followed, as recommended by Scott.
NA Not applicable

Leak Check – With a regulator under pressure (both high and low pressure side) check all connections for leaks using a gas leak detector (Scott Model 46-B Series) or Snoop®. If a leak is detected, shut down the gas source, reduce pressure to atmospheric, and tighten or redo the leaking connection. Retest. If leak persists, contact Scott.

Warning: If the connection must be redone (i.e. to replace a compression fitting), regulators used on toxic or corrosive gases must first be purged with an inert gas such as nitrogen. Consult Scott or the regulator manufacturer for specific purging instructions.



Recommended configuration for proper dilution purging.

Creep Test – Regulator creep is a phenomenon in which delivery pressure rises above a set point. Creep can occur in two ways. The first is due to changes in the motion of the regulator springs when gas flow is stopped. When flow has stopped, the springs must move to a new position of equilibrium, causing a slight increase in delivery pressure. This type of creep may be thought of as the opposite of droop.

The second and more insidious type of regulator creep is caused by foreign material being lodged between the poppet and seat, thus preventing tight shut-off. The result is that inlet and delivery pressure can equalize across the regulator, exposing all tubing and instrumentation to the inlet pressure. Regulator creep as a result of seat failure due to foreign material is the single most common cause of regulator failure. In order to prevent costly damage to the gas delivery system and the instrumentation it serves, care must be taken to ensure that regulator connections are capped to protect against ingress of dirt or foreign material. Tubing should also be flushed or blown clean to remove any foreign matter. A pressure relief valve should be installed downstream of the regulator as additional protection against creep.

To creep test, isolate the downstream side of the regulator by closing the regulator outlet valve, instrument valve or process isolation valve. Close the regulator by turning the adjustment knob counterclockwise until it reaches stop or rotates freely. Slowly turn on the gas supply. When the regulator inlet gauge registers full cylinder delivery pressure, shut off the gas supply. Turn the regulator adjusting knob clockwise until delivery pressure gauge reads approximately half of scale (i.e. 50 psi (3 bar) on a 100 psi (7 bar) gauge). Close the regulator by turning the adjustment knob counterclockwise until it rotates freely or reaches the stop. Note the reading on delivery pressure gauge. Wait 15 minutes and recheck the setting on delivery pressure gauge. If any rise in delivery pressure is detected during this time, the regulator is defective. Remove and replace.

Regulator Purging – Regulator purging is not always given the attention it deserves in the use of both high-purity gases and calibration gases. It is easy to understand that special precautions are necessary when using pyrophoric, toxic, corrosive, flammable or oxidizing gases. These gases require special safety precautions or special gas handling equipment. The results obtained from the use of nonreactive gases and mixtures, however, can also depend upon how the gas delivery system is prepared.

In order to maintain cylinder integrity and obtain the best results possible, the end user should purge all regulators. The connecting lines and the purging procedure influence the quality of the end gas. Purging of regulators is often either not done at all, or is done by simply allowing an arbitrary amount of gas to flow through the regulator. But, there is a shortcoming to this method. In virtually all regulators, there are internal dead pockets that tend to hold contaminants. These pockets tend to be unaffected by the flow of purge gas. Better results will be achieved by alternately pressurizing and depressurizing the regulator with the purge gas. This is called dilution purging.

Overhaul – All regulators should be removed from service periodically and returned to the manufacturer for inspection/overhaul as appropriate (see Regulator Maintenance Schedule, page 12).

Replacement – Regulator failure that warrants regulator replacement will vary considerably based on conditions of use. However, once the life expectancy of a regulator has been exceeded, it should be replaced to prevent failure. Contact your Scott Representative to determine the life expectancy of your particular regulator model.

Single-Station Manifold with Bracket

The Scott 8100 Series is ideal for applications where gas consumption does not warrant multi-cylinder operation. It provides a safe, cost-effective means of connecting and changing-out cylinders by eliminating the need to repeatedly handle the regulator. Available in a variety of materials with options to suit any application, an 8100 series manifold is compatible with all Scott regulators and ensures safe, economical, contaminant-free gas delivery. Scott manifolds are available in single-cylinder or double-cylinder configurations.

Pressure Regulators: Accessories

Stainless Steel Relief Valve

Model 64 Check Valve

Flow Limit Safety Shut-Off Valve – Shuts off gas flow when exceeding factory preset level

Relief Valves – A relief valve (such as the Scott Model 65 series) is a safety device to prevent overpressurization in the line to which it is attached. A relief valve located downstream from a regulator prevents overpressurization by releasing excessive pressure in the event of creep or failure that causes downstream pressure to increase beyond its rating. An appropriately set and sized relief valve will protect personnel, instrumentation and the system. The outlet of the relief valve should always be connected to a vent line to protect personnel from toxic and flammable gases or asphyxiation by inert gases.

When selecting a relief valve, the pressure at which it is to open must be decided. The selected cracking pressure should be below the rating of downstream equipment but should be set high enough above normal delivery pressure so minor fluctuations do not cause it to open. The relief valve should have a capacity that equals or exceeds the capacity of the pressure regulator. In some high-capacity applications, it may be necessary to install more than one relief valve.

Check Valves – In virtually all applications, it is important that the specialty gas not be allowed to escape into the atmosphere where it could present a safety hazard. Equally, it is undesirable to allow atmospheric contaminants to enter the distribution system and interfere with instrument performance or cause corrosion. Both of these potential problems can be avoided through the proper use of check valves.

Check valves (such as the Scott Model 64) are designed to permit gas flow in one direction only. Commonly used at the regulator inlet to prevent escape of gas into the atmosphere and on vent lines to prevent ingress of the atmosphere into the system, they are quick-opening and bubble-tight against back pressure. A resilient O-ring at the valve seat ensures quick and efficient sealing.

Flow Limit Shut-Off Valve – Despite the proper installation of check valves and relief valves, substantial gas leaks can still occur. These leaks can be caused by a break in the line or by the inadvertent opening of a purge or vent valve. Particularly when the gas involved is toxic or flammable, a means should be provided to prevent or limit the leak. A flow limit safety shut-off valve (such as the Scott Model 1) is ideally installed between the cylinder outlet and the inlet of the pressure regulator. It automatically shuts off all flow when flow exceeds a preset level. On relatively low-flow systems that only serve one or two users, a single shut-off valve installed between the cylinder outlet and the inlet of the pressure regulator is sufficient. For larger systems, additional shut-off valves with lower preset limits should be installed on branch lines.

The flow limit safety shut-off valve senses flow as a pressure drop across the preset internal orifice. When the preset differential pressure limit is reached, the valve closes with a snap action for a leaktight seal. To further ensure safe operation, manual reset is required in order to resume flow. Reset is also required at startup, opening of the cylinder valve, during purging, and after correction of any process flow problem or excess flow demand. It is advisable to select a setting that will provide shut-off at 6 to 10 times the anticipated actual process flow rate to allow normal gas usage as the cylinder pressure decreases.

Inlet Connection – Cylinder regulators require an inlet cylinder valve fitting (either CGA, DIN or BS) that must be compatible with the mating fitting on the cylinder valve. Do not force connections. Never use pipe dope or Teflon® tape with the cylinder valve connections. A leaking cylinder valve fitting must be replaced. Adapters from one fitting to another fitting should not be used to connect equipment to a high-pressure cylinder.

Line regulators are installed in a gas line to provide a means to further reduce the gas line pressure prior to its end-use point. The inlet connection supplied with a line regulator is typically a compression fitting, but also could be a male or female pipe fitting.

Outlet Valve Connection – Cylinder regulators are often supplied with an outlet valve that provides a means to isolate the regulator and cylinder from downstream equipment. A needle valve or a diaphragm packless valve may be used. Select the control valve type to fit the specific application. The outlet connection supplied with either a cylinder or line regulator is a tube compression fitting or a pipe fitting that is typically a female 1⁄4 inch National Pipe Thread (NPT).

Annunciator – The hazardous condition monitor output should be wired to an annunciator or other type of alarm system to alert operating personnel. In larger plants, such as refineries or chemical plants, the connection can be made directly to the distribution control system. Where available, plant managers can use the information provided to minimize downtime and improve overall productivity.

4-Point Annunciator

Indicating Pressure Switch – An indicating pressure switch (such as Scott's Model 69 series) provides both local pressure indication and a remote system pressure switch. A switch closure is provided for remote activation of either a visual alarm and/or an audible alarm. This alerts the operator of a change in pressure conditions in the system. The pressure indicating switch is activated when it reaches a preset pressure that is user-adjustable. A pressure indicating transmitter provides continuous voltage or current output that is linear to the applied pressure.

Pressure Switch Gauge

Purge Assemblies – Purge assemblies provide a convenient means to purge a regulator with an inert gas, both prior to and after use. The Scott Model P74 series purge assemblies are commonly used when controlling a toxic or corrosive gas. They are designed to be used with stainless steel regulators. The cross purge and the tee purge are typically located between the cylinder and the regulator. The straight purge is designed to connect directly to a regulator that has a purge port. A check valve such as the Model 64 should be supplied with each assembly to minimize possible backflow of cylinder gas into the inert purge gas source.

Flash Arrester – When fuel gas or oxygen is used, a potential of flashback to the cylinder exists in the event of a fire. To protect against flashback, a flash arrester should be installed. The flash arrester is a simple in-line mechanical device that provides three-way protection against flashback of fuel gas and oxygen:

Checks reverse flow – a built-in check valve stops gas backflow.

Extinguishes flashbacks – the flash check diverts the flashback flame into three feet of tubing where it is extinguished. This prevents explosions in the regulators, pipelines and cylinders.

Stops gas flow – The shockwave preceding the flashback flame closes and locks the flash-check shut-off valve. This eliminates feeding gas to any residual sparks or fire.

Flash Arrester – Provides protection of flashback of fuel gas and oxygen

Manifold Systems – When an application warrants the use of many of the preceding accessories, a logic-controlled manifold system, an automatic changeover system or a single-station manifold is suggested. Scott offers a wide variety of gas delivery systems (see pages 16–27). Consult your Scott Representative to discuss your system requirements in further detail.

Delivery Systems: Safety

Safety must always be a primary goal when handling potentially dangerous compressed gases. Storing and handling cylinders safely is addressed on pages 2–5. This section discusses safety considerations in the design of gas delivery systems.

Safety in gas delivery systems is often regulated by codes and standards. While it is beyond the scope of this handbook to list or interpret the various codes, the prudent system designer will be alert to their impact on the design. A few agencies with established codes are listed on the following page, however, it is important to note that local codes may also apply that can be more stringent than any of the national or industry standards.

The primary hazards associated with handling cylinder gases are high-pressure, toxicity, reactivity and instability, corrosivity, flammability, extreme low temperatures and asphyxiability. Most compressed gases will not exceed 2,000 to 2,640 psig (138 to 182 bar), however, some can go up to 6,000 psig (414 bar). If cylinders are damaged mechanically or by fire or corrosion, they can rupture. The same is true when high-pressure gas is injected into components, vessels or piping not suited for high pressures. Remember: the system's weakest component determines the overall pressure limit.

Many gases produce acute effects on lungs, eyes and skin. Others such as phosgene and ammonia may make their toxic effects felt only hours or days after exposure. A key responsibility of anyone whose staff works with gases is to make sure an industrial hygienist is frequently consulted and that laboratory workers know particular symptoms of poisoning and appropriate first aid.

Strong oxidizing or reducing agents can sensitize materials, generate heat or release large amounts of gaseous products. Example: liquid oxygen spilled on wood or asphalt makes it explosive under shock. Fluorine will ignite violently with many substances; silane can explode on contact with air; and ammonia will decompose thermally into twice its volume. Thermodynamically unstable substances present special hazards—acetylene gas with a partial pressure of more than 15 psig (1 bar) can detonate, and copper used with acetylene can result in the formation of copper acetylides that are explosive.

Corrosion takes many forms. The most obvious is its attack on metals by halogens, halogen acids, sulfur compounds, ammonia or aliphatic amines. Less obvious but just as significant are: embrittlement of carbon steel by hydrogen; ozone's attack on many rubbers; and the action of hydrogen chloride on polymethyl methacrylate under stress. All of these reactions can weaken or destroy structural members of a gas-containing system– sometimes imperceptibly, sometimes dangerously. Laboratory workers should have at least an elementary knowledge of material compatibilities.

When a container or vessel containing a compressed gas bursts, that bursting is rapid and violent. Consequently, the integrity of the cylinder is of crucial concern to the user. The flash points of compressed flammable gases are extremely low and always below room temperature. Explosive mixtures with air are rapidly formed. Ignition of even a small leak may cause other materials to ignite. Ignition of a large leak can cause a violent explosion. But it is imperative to remember that ease of combustion depends not only on flash points and upper and lower flammable limits of gases, but on concentration of oxygen or other oxidant gas too. Hydrogen is a particularly dangerous material for two reasons. First, it burns with a practically invisible flame. Secondly, it can form unsuspected pockets at a ceiling (heavy gases will pool at the floor).

Supercooled gases or cryogenic liquids have become common in the modern laboratory environment. These gases all have one important characteristic – they are extremely cold. Nitrogen, which is frequently used to produce low temperature, boils at -320°F (-196°C). It can produce intense burns similar to heat burns. In many cases tissue necrosis may be even more severe. Cryogenic liquid spills can cause particular injury when the liquid becomes trapped inside the shoe.

Probably as many deaths are caused by physical suffocation (insufficient oxygen) as are caused by poisoning. Innocuous gases such as nitrogen, helium or carbon dioxide can suffocate, sometimes with almost unbelievable rapidity. Carbon dioxide exposure increases both respiration and heart rates. Carbon dioxide suffocation induces reflex gasping that decreases the oxygen in the blood very quickly leading to almost immediate unconsciousness. Whenever the danger of suffocation exists, or wherever ventilation is poor, sensor alarm systems should be used to monitor oxygen concentration. Anything below 19.5% should be considered dangerous. An important point, too, is not to work alone in continuing an experiment after hours or over the weekend.

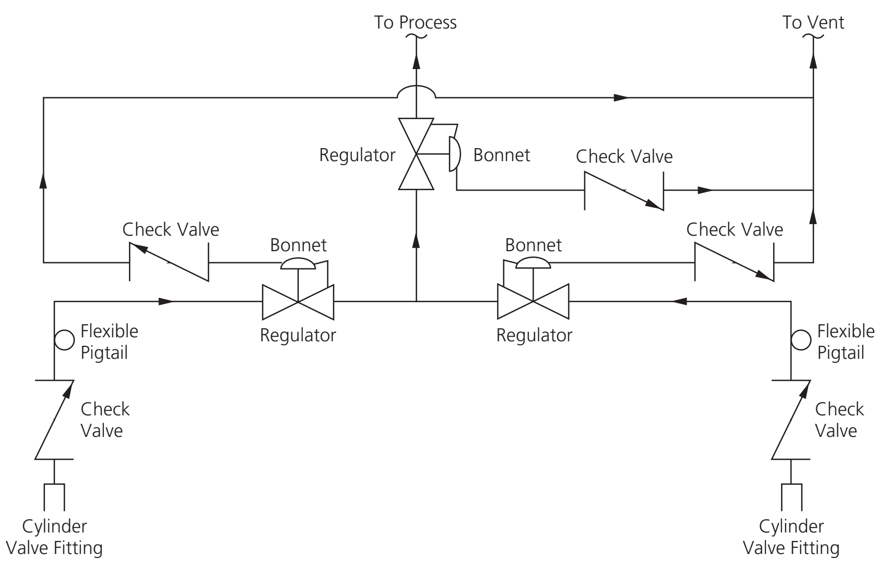
Remote Shutdown – Some applications require the ability to shut down the entire distribution system whenever certain hazardous conditions are detected. The capability of remote emergency shutdown may also be required. These requirements usually arise when particularly toxic or flammable gases are being distributed, especially in larger systems with multiple users. When this type of system shutdown is required, a logic-controlled manifold should be specified.

With the digital electronic capabilities of the logic-controlled manifold, virtually any shut-off mode requirement can be accommodated. For example, flame or smoke detectors can be used to signal the logic-controlled manifold to shut the system down. A manual kill switch can also be included to allow the operator to stop gas flow. Various other hazardous condition monitors can be used in this way. See page 23 for more information regarding logic-controlled manifolds.

Capturing and Venting

Although ruptures of regulator diaphragms are quite rare, where such rupture and subsequent gas leak could endanger personnel it is prudent to capture and vent the regulator bonnet (see diagram below).

Capturing and venting regulator bonnets is a fairly common requirement when automatic changeover manifolds are used. Regulator bonnets can be vented to a common line, and a check valve should be fitted between each bonnet and the vent line. The check valve prevents gas from a failed regulator from pressurizing the bonnet of a good one, causing it to open fully and overpressurize the system.



Proper capture and venting of regulator bonnets.

Some of the safety codes that should be consulted are established by:

- National Fire Prevention Agency (NFPA)
- Compressed Gas Association (CGA)
- European Industrial Gas Association (EIGA)
- Uniform Fire Code (UFC)
- Uniform Building Code (UBC)
- The BOCA National Building Code
- The BOCA National Fire Protection Code
- OSHA/ARBO/COSHH
- Seveso II Directive
- IEC 79-10, BS5345 and NEN 3410 (Electrical Equipment in Explosive Atmospheres)
- Semiconductor Equipment and Materials Institute (SEMI)

Delivery Systems: Sizing Lines

Table 1 Specific Gravity of Gases

Gas	Specific Gravity
Air	1.0
Argon	1.38
Carbon Dioxide	1.52
Carbon Monoxide	0.97
Helium	0.14
Hydrogen	0.07
Nitrogen	0.97
Oxygen	1.11

Table 2 Capacity Correction for Gases Other than Air

Specific Gravity (g)	Factor ($\sqrt{1/g}$)
0.10	3.16
0.25	2.00
0.50	1.41
0.75	1.15
1.00	1.00
1.25	0.89
1.50	0.82
1.75	0.76
2.00	0.71
2.25	0.67
2.50	0.63

Selecting the correct size of tubing for gas distribution is important. An undersized line will result in high pressure drops, making it difficult or impossible to consistently supply the required gas pressure to the instrument. An oversized line, by contrast, will ensure adequate pressure but will be unnecessarily expensive to install.

The relative suitability of copper and stainless steel tubing must also be taken into account. There are a number of considerations in this regard. First, in terms of maintaining gas purity, stainless steel is preferred since oxygen and water do not adsorb onto it as much as onto copper. Further, the option of having stainless steel degreased and passivated is available. This process removes all traces of oil, grease and dirt and ensures optimal performance. Also, the installed costs of stainless steel and copper tubing are approximately the same.

Maximum Service Pressure Ratings

Tube Material	Tube Size Outside Diameter	Wall Thickness	Maximum Service Pressure
Copper	1/8" (0.31 cm) 1/4" (0.64 cm) 3/8" (1 cm)	0.030" (0.08 cm) 0.049" (0.12 cm) 0.065" (0.17 cm)	2500 psig (172 bar) 2200 psig (152 bar) 2412 psig (166 bar)
Stainless Steel	1/8" (0.31 cm) 1/4" (0.64 cm) 3/8" (1 cm)	0.028" (0.07 cm) 0.028" (0.07 cm) 0.035" (0.09 cm)	8200 psig (565 bar) 3900 psig (269 bar) 3220 psig (222 bar)

To calculate capacities for gases other than air, multiply the figures in Table 3 by the correction factor shown in Table 2.

Example – Calculate distribution line size for helium flow of 1,000 SCFH (472 L/min) at inlet pressure of 100 psig (7 bar) and maximum allowable pressure drop of 5 psig (0.3 bar) per 100 feet (30.5 m).

1. Find specific gravity of helium from Table 1 .... 0.14
2. Calculate correction factor from Table 2 .... 2.67
3. Divide required flow rate by correction factor .... 375 SCFH (177 L/min)
4. Enter Table 3 at Point A for inlet pressure of 100 psig (7 bar) and pressure drop of 5 psi (0.3 bar) per 100 ft (30.5 m).
   Go to Point B for capacity greater than or equal to corrected flow of 375 SCFH (177 L/min).
   Follow to Point C for required line size.. 1/4"

To calculate capacities at temperatures other than 60°F (16°C), multiply capacity from the table by the ratio:

$$\frac{[460+T]}{520} \quad \left[\frac{[273.15+T]}{288.71}\right]$$

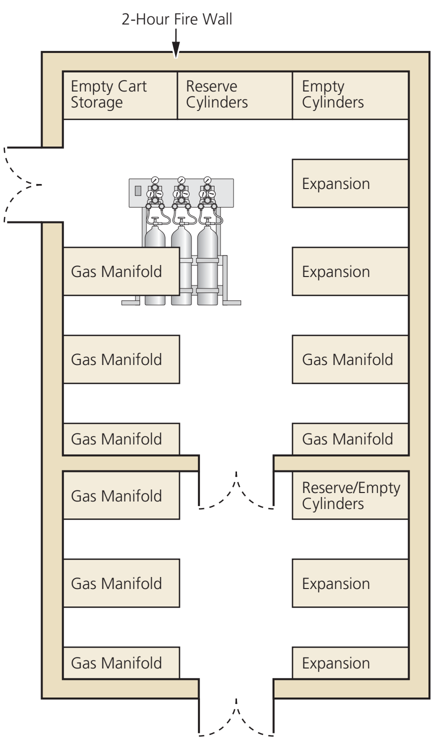
Where: "T" is the temperature in degrees Fahrenheit (Celsius) under consideration.

Table 3 Capacity of Distribution Lines in SCFH (NL/m) of Air @ 60°F (16°C)

Inlet Pressure psig (bar)	**Pressure Drop per 100' (30.4 m)** psig (bar)	**Line Size**					
		1/8"	1/4"	3/8"	1/2"	3/4"	1"
50 (3)	1 (0.07)	20 (9)	180 (84)	405 (191)	760 (358)	1,610 (759)	3,040 (1,433)
	5 (0.3)	49 (24)	400 (188)	910 (429)	1,700 (801)	3,600 (1,687)	6,800 (3,206)
	10 (0.7)	70 (33)	580 (273)	1,300 (613)	2,410 (1,136)	5,100 (2,404)	9,720 (4,582)
100 (7)	1 (0.07)	28 (13)	245 (116)	550 (259)	1,020 (481)	2,160 (1,018)	4,070 (1,919)
	5 (0.3)	65 (31)	545 (257)	1,230 (580)	2,280 (1,075)	4,820 (2,272)	9,100 (4,290)
	10 (0.7)	90 (42)	775 (365)	1,750 (825)	3,240 (1,527)	6,820 (3,215)	12,970 (6,114)
150 (10)	1 (0.07)	32 (15)	290 (137)	660 (311)	1,220 (575)	2,580 (1,216)	4,870 (2,296)
	5 (0.3)	75 (34)	650 (306)	1,470 (693)	2,730 (1,287)	5,775 (2,722)	10,900 (5,138)
	10 (0.7)	110 (52)	930 (438)	2,100 (990)	3,880 (1,829)	8,170 (3,852)	15,540 (7,326)
200 (14)	5 (0.3)	85 (41)	745 (351)	1,680 (792)	3,120 (1,471)	6,590 (3,107)	12,450 (5,869)
	10 (0.7)	125 (59)	1,060 (500)	2,390 (1,127)	4,430 (2,088)	9,330 (4,392)	17,750 (8,368)
300 (21)	5 (0.3)	105 (50)	900 (424)	2,040 (962)	3,780 (1,782)	7,980 (3,762)	15,070 (7,104)
	10 (0.7)	150 (71)	1,280 (605)	2,900 (1,367)	5,370 (2,532)	11,300 (5,327)	21,480 (10,126)
400 (28)	5 (0.3)	125 (59)	1,040 (490)	2,340 (1,103)	4,340 (2,046)	9,160 (4,318)	17,300 (8,156)
	10 (0.7)	175 (83)	1,470 (693)	3,330 (1,570)	6,160 (2,904)	12,970 (6,114)	24,660 (11,625)
500 (35)	5 (0.3)	130 (61)	1,180 (556)	2,660 (1,254)	4,940 (2,329)	10,440 (4,922)	19,700 (9,287)
	10 (0.7)	190 (87)	1,680 (792)	3,790 (1,787)	7,020 (3,309)	14,770 (6,963)	28,100 (13,247)
1,000 (69)	5 (0.3)	190 (90)	2,030 (957)	3,920 (1,848)	7,270 (3,427)	15,360 (7,241)	29,000 (13,671)
	10 (0.7)	270 (127)	2,470 (1,164)	5,580 (2,630)	10,330 (4,870)	21,740 (10,249)	41,300 (19,470)
1,500 (103)	5 (0.3)	230 (108)	2,030 (957)	4,570 (2,154)	8,470 (3,993)	17,900 (8,438)	33,800 (15,934)
	10 (0.7)	330 (156)	2,880 (1,357)	6,500 (3,064)	12,040 (5,676)	25,350 (11,951)	48,200 (22,723)
2,000 (138)	5 (0.3)	265 (125)	2,340 (1,103)	5,270 (2,489)	9,770 (4,606)	20,650 (9,735)	39,000 (18,380)
	10 (0.7)	380 (179)	3,320 (1,565)	7,500 (3,536)	13,890 (6,548)	29,200 (13,766)	55,600 (26,211)
2,500 (172)	5 (0.3)	300 (142)	2,610 (1,230)	5,890 (2,777)	10,920 (5,148)	23,100 (10,890)	43,550 (20,531)
	10 (0.7)	427 (201)	3,710 (1,749)	8,380 (3,950)	15,510 (7,312)	32,650 (15,392)	62,100 (29,276)

Delivery Systems: Design

In most gas distribution systems, cylinder pressure is reduced at or near the cylinder storage area to an intermediate distribution pressure. The purpose of this pressure reduction is to avoid piping gases in excess of 2,000 psig (138 bar) to areas where people are working. This reduction may be accomplished with either a simple regulator or with a more sophisticated manifold. In either case, the potential for failure of the pressure-reducing element must be taken into account.



Typical Cylinder Storage Area

When specialty gases are used in significant volumes, a centralized gas delivery system is a practical necessity. A well-conceived delivery system will reduce operating costs, increase productivity and enhance safety. A centralized system will allow the consolidation of all cylinders into one storage location. With all the cylinders in one place, inventory control will be streamlined and cylinder handling will be simplified and improved. Gases can be separated by type to enhance safety. A typical cylinder storage area is shown in the diagram.

Maintaining gas purity is also simplified with a centralized system. Selection of materials of construction should be consistent throughout (please see the Gas Compatibility Guide on pages 9–11). For example, if a research grade gas is being distributed, all stainless steel construction and diaphragm packless valves should be used.

The frequency of cylinder changeouts required is reduced in a centralized system. This is achieved by connecting multiple cylinders to manifolds in banks in such a way that one bank can be safely vented, replenished and purged while a second bank provides continuous gas service. Such a manifold system can supply gas to multiple instruments and even entire laboratories, eliminating the need for separate cylinders and regulators for each instrument.

Since cylinder switchover is accomplished automatically by the manifold, cylinders in a bank will be uniformly exhausted, resulting in improved gas utilization and lower costs. Further, the integrity of the delivery system will be better protected since cylinder changeouts will be done in a controlled environment. The gas manifolds used in these systems should be equipped with check valves to prevent gas backflow and purge assemblies to eliminate contaminants from the system during changeout. Thus, system and gas purity will be maintained.

Single-Station Systems – In some applications, specialty gas is used only to calibrate the instrumentation. For example, a continuous emissions monitoring system (CEMS) may only require calibration gases to flow for a few minutes each day. Such an application clearly does not require a large-scale automatic changeover manifold. However, the delivery system should be designed to protect against contamination of the calibration gas and to minimize costs associated with cylinder changeouts.

A single-station manifold with bracket is an ideal solution for this type of application. It provides a safe and cost-effective means of connecting and changing out cylinders by eliminating the need to struggle with the regulator. When the calibration gas includes corrosive components such as hydrogen chloride or NOx, a purge assembly should be incorporated into the manifold to allow the regulator to be purged with an inert gas (usually nitrogen) to protect it from corrosion.

The single-station manifold can also be equipped with a second pigtail and isolation valves. This arrangement allows an additional cylinder to be connected and held in reserve. Switchover is accomplished manually. This is usually desirable with calibration gases since the precise mix of components generally varies somewhat from cylinder to cylinder, and a cylinder change may require resetting the instrument.

Multiple-Cylinder Systems – Many applications require a flowrate of gas beyond what can reasonably be supplied by a single-station manifold but are not of such a critical nature that they cannot tolerate occasional shutdown for cylinder changeout. A header manifold is generally a wise choice in this situation.

The header manifold offers a cost-effective means to connect two or more cylinders to the same line for continuous gas supply. Each cylinder connection point, or station, is fitted with a valve to permit individual cylinders to be isolated for changeout. In order to preserve system purity, these valves should be the diaphragm packless type to eliminate oxygen, nitrogen, water vapor or other contaminants from intruding.

Header manifolds may be used in both single-row and double-row configurations, allowing virtually any number of cylinders to be connected to the delivery system. Header manifolds are also used in conjunction with switchover manifolds, providing a means to connect more than one cylinder to each bank of the switchover manifold.

ChangeOver Methods

Many users require a constant, uninterrupted supply of gas. Any pause in the gas supply results in lost or ruined experiments, a loss of productivity and even downtime for an entire laboratory. Manifolds that provide the capability to switch from a primary to a reserve bank without interrupting the gas supply can minimize or eliminate such costly downtime. The selection of the correct manifold for a given application depends on a number of factors.

There are a number of different methods used to effect cylinder bank changeover. These methods vary substantially in their level of sophistication. As would be expected, cost usually increases with sophistication. Selecting the correct manifold, then, depends on the application since the additional features in the more sophisticated versions can justify their expense in critical applications.

Differential Type – The simplest manifolds are designed to changeover on a sensed drop in pressure of one cylinder bank relative to the other. Such a manifold is called a differential type. For example and to operate, the regulator on Bank #1 is set for a delivery pressure of 250 psig (17 bar). The regulator on Bank #2 is set at 200 psig (14 bar).

As long as there is sufficient gas in Bank #1 to maintain the 250 psig (17 bar) delivery pressure, the Bank #2 regulator stays closed. When Bank #1 is exhausted, delivery pressure drops until the Bank #2 regulator opens at about 200 psig (14 bar). The regulator pressure gauges must be visually monitored to determine when changeover has occurred.

When Bank #1 has been replenished, the regulator settings should be reversed so that Bank #1 is at 200 psig (14 bar) and Bank #2 is at 250 psig (17 bar). If this is not done, replenishing Bank #1 will cause the Bank #2 regulator to close. Bank #2 will then be gradually drained each time Bank #1 is replaced until there is not enough gas in Bank #2 to effect changeover. Resetting the regulators alternates which bank is primary and which is reserve to prevent this possibility.

Differential manifolds require regulator monitoring and resetting, and are generally selected for applications where cylinder bank changeover is relatively infrequent and where a drop in delivery pressure at changeover will not cause a problem.

The level of gas purity required at the end-use point is extremely important in designing a gas delivery system. In general, three levels of purity are sufficient to describe nearly any application.

LEVEL 1

Usually described as a multi-purpose application, this has the least stringent purity requirement. Typical applications are AA, ICP and general gas chromatography. Manifolds for multi-purpose applications are economically designed for safety and convenience. Acceptable materials of construction include brass, copper, Teflon®, Tefzel® and Viton®. Packed valves such as needle valves and ball valves are often used for flow shutoff.

LEVEL 2

Called high-purity, this requires a higher level of protection against contamination. Applications include gas chromatography where capillary columns are used and system integrity is important. Materials of construction are similar to multi-purpose manifolds except flow shut-off valves are diaphragm packless to prevent diffusion of contaminants into the specialty gas.

LEVEL 3

Referred to as ultra-high purity, this needs the highest level of purity. Trace measurement in gas chromatography is an example of an ultra-high purity application. Wetted materials for manifolds at this level must be selected to minimize trace component adsorption. These materials include 316 series Stainless Steel, Teflon®, Tefzel® and Viton®. All tubing should be 316 ELC cleaned and passivated. Flow shut-off valves must be diaphragm packless.

Consulting the Scott Reference Guide is helpful in determining which level of gas purity is required. It is particularly important to recognize that components that are suitable for multi-purpose applications may adversely affect results in high or ultra-high purity applications. For example, outgassing from neoprene diaphragms in regulators can cause excessive baseline drift and unresolved peaks.

Design continued

Automatic ChangeOver Manifold
Model 58ACS

Automatic ChangeOver Manifold
Model 58RCS

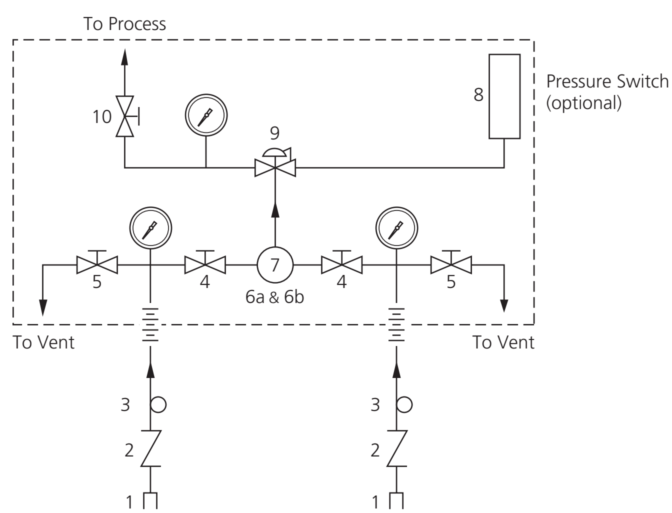
Automatic ChangeOver System
Model 8404

Automatic Changeover – A change or drop in delivery pressure can, in some instances, result in an adverse effect on instrument performance. To avoid this problem, an automatic manifold may be selected. The operation of this type of manifold is also based on differential pressure, but delivery pressure is held virtually constant during cylinder bank changeover. The automatic manifold regulates pressure in two (or three) stages to keep delivery pressure steady, even during changeover. The diagram below illustrates the principle of operation of a typical automatic manifold.

Gas flows from CGA fittings (1) through optional check valves (2) and pigtails (3) to isolation valves (4). Purge valves (5) can be used at startup or after cylinder change-out to eliminate contaminants from the gas stream. Gas flows to the primary regulators (6a & 6b) from the isolation valves. Outlet pressure settings of the primary regulators are factory preset with a nominal pressure differential (contact your Scott Representative for changeover ranges available). The primary bank selector (7) determines which bank is primary and which is secondary (or reserve). The outlets of regulators 6a & 6b are connected to the outlet regulator (9) then to the process isolation valve (10). The outlet regulator can be set to maintain the desired delivery pressure even during changeover.

When bank #1 (primary bank) is depleted, outlet pressure from regulator 6a begins to drop from its set point until it reaches the set point of regulator 6b. Gas then begins to flow from regulator 6b. Simultaneously, optional pressure switch (8) causes annunciator or alarm (optional and not shown) to alert the operator that changeover has occurred. The process isolation valve (10) may need to be rotated to reset the optional pressure switch (8). After bank #1 has been replenished, the primary bank selector (7) is rotated so that bank #2 becomes primary and bank #1 is the reserve. Thus, the flow of gas to the process is uninterrupted and delivery pressure is maintained at a constant setting.

When used in conjunction with a pressure switch and annunciator to provide remote indication of changeover, the automatic manifold need not be monitored. Since resetting of regulators is not required, the potential for operator error and draining of the reserve bank is minimized. Automatic manifolds are used in applications where changeover is relatively frequent and variations in delivery pressure cannot be tolerated.



Principle of operation of a typical automatic changeover manifold.

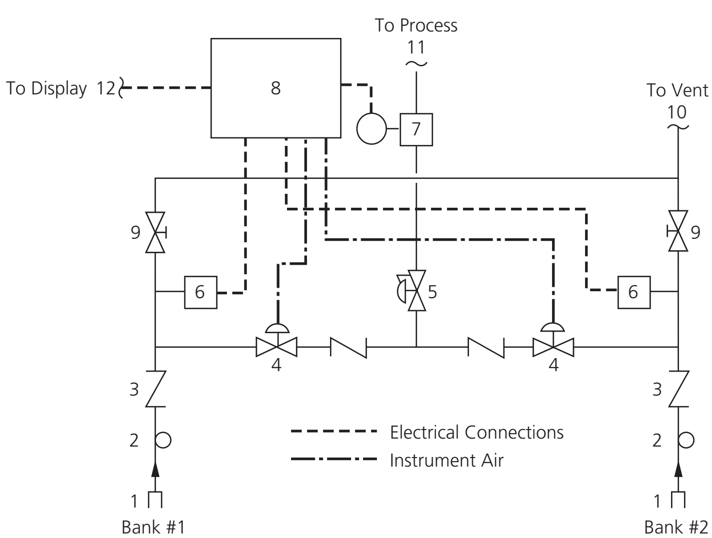
Logic-Controlled Manifold – In some critical manufacturing and laboratory processes, an uninterrupted gas supply is an absolute necessity. Failure of the gas supply in these cases could result in loss of an entire lab's in-process experiments or even shutdown of a production line. The potential cost of either of these events is so high that the installation of a gas delivery system designed to provide an uninterrupted gas supply is clearly justified. A logic-controlled manifold is generally selected for these applications.

The logic-controlled manifold is designed to sense the cylinder bank pressures and to automatically switch to a full bank of cylinders with no disruption in delivery pressure or flow rate when one cylinder bank is depleted. As shown in the diagram below, this is accomplished electronically using pressure switches. In addition, the manifolds are designed with the capability of interfacing with scales having analog outputs. By using pressure transducers or a scale, the logic-controlled manifold can provide the user with the ability to constantly monitor the pressure or weight in their supply from a remote location. It can also indicate which side of the manifold is currently in use.

Cylinders are connected to the CGA fittings (1) and gas through the pigtails (2) and check valves (3) to pneumatically activated changeover valves (4) and the purge valves (9), which are used to purge and vent (10) system at start-up. Pressure transducers (6) monitor bank pressure and send status to the controller (8), which opens one changeover valve as the primary supply. Gas flows to the delivery regulator (5), which is user adjustable from 0-250 psig. An excess flow sensor (7) signals the controller to shut-down the system in the event of a leak downstream.

When the controller (8) detects a depleted cylinder bank, it signals the second changeover valve (4) to open. After a built-in delay of approximately 7 seconds to avoid fluctuation of delivery pressure, it signals the changeover valve (4) on the depleted side to close. At the same time, the controller (8) signals the remote display (not shown) to sound an alarm and cause the depleted side light to flash. The display automatically indicates status of the full side. The automatic nature of this operation ensures continuous gas flow at constant pressure while alerting the operator that action must be taken.

The logic-controlled manifold eliminates the danger of inadvertently draining the reserve bank since there is no reliance on the operator to switch a changeover valve or reset regulators. Fail-safe operation is assured by using normally closed pneumatic valves on each cylinder bank. In the event that either electrical power or the instrument air supply should fail, these valves will automatically close and shut down the entire system. The inclusion of this provision may be critical when toxic or flammable gases are being distributed.



Electronic switches on a logic-controlled manifold sense pressure from a bank of cylinders.

Delivery Systems: Semiconductor

A properly designed electronic grade gas delivery system will incorporate each of the following attributes:

- Cleanroom Assembly
- Welded and Face-Seal Fitting Construction
- 316L Stainless Steel Material
- Superior Surface Finishes
- Electropolishing Treatments
- Helium Leak Checking Procedures

The fabrication of semiconductor integrated circuits (chips) is an exacting series of process steps that require extremely pure gases and gas handling systems to transmit the gas. Semiconductors are sensitive to unwanted contamination, even from amounts as small as several parts per million. Microscopic dirt particles many times smaller than the diameter of a human hair lead to defects and low fabrication yields. The presence of contaminant gases or hydrocarbons will cause unwanted reactions or will change the rate of reaction. Trace amounts of H_2O will cause the growth of SiO_2, which can block diffusion or cause uneven growth. Contaminant metal ions will be electrically active in the semiconductor wafer and cause undesired effects. Finally, microscopic particulate contamination can be swept through the gas delivery system and embedded in the wafer.

Cleanroom Assembly – A cleanroom is an area supplied with specially filtered air that will keep minutely sized particles from entering a gas delivery system during assembly. Cleanroom personnel wear special cleanroom garments and operate under a set of guidelines that will keep particles off the product. Federal Standard 209D is the U.S. government specification that provides a qualified and standardized method for measuring how clean the air is in a cleanroom. Federal Standard 209D has designated six classes of cleanliness for cleanrooms:

Class 100,000	Class 1,000	Class 10
Class 10,000	Class 100	Class 1

The class numbers refer to the maximum number of particles bigger than half a micron in size that would be allowed in one cubic foot of cleanroom air. A micron is a millionth of a meter and is many times smaller than the diameters of a human hair. The lower the cleanroom class number – the cleaner the cleanroom. A Class 100 cleanroom has a maximum of 100 particles per cubic foot whereas a Class 10 has a maximum of 10 particles per cubic foot.

Face-Seal Fittings – The purpose of a face-seal fitting is to provide a leak-tight, high-purity connection as a means of joining components. A face-seal fitting is made when a metal gasket is deformed by two highly polished heads located on the connection glands and bodies. A face-seal fitting offers the high purity of a metal-to-metal seal while providing leak-free service, from critical vacuum to positive pressure. Component removal of a face-seal system typically requires no axial clearance. A face-seal fitting requires replacement of the metal gasket at each connection fitup.

A face-seal fitting is superior to threaded connections such as National Pipe Thread (NPT) and compression connections.

Face-Seal Fitting Benefits

- Dead space and entrapment zones are significantly reduced.
- A better degree of leak integrity is achieved.
- Particle generation is minimized.
- Venturi aspiration of outside contaminants is virtually eliminated.

316L Material – 316L is a special stainless steel alloy with an extremely low carbon content. It contains a maximum of 0.035% carbon to reduce the tendency toward carbide precipitation during welding. The reduction in carbon content further reduces the opportunity for particulates to be generated during welding and construction.

Surface Finish – Surface finish is the most focused-upon aspect of a gas delivery system's interior surface texture. It is a quantification of how rough the surface of a component is as measured in micro inches or micrometers. Common surface roughness measurement terms are Ra, RMS or Rmax. Each is a slightly different means of measuring a surface roughness. Superior surface finishes of 7 Ra, 10 Ra, 15–30 Ra micro inches are desired to minimize entrapment zones and to reduce outgassing effects. The principle method used to achieve these levels of surface finish is electropolishing.

Electropolishing, a treatment performed on stainless steel, is an electrochemical method of removing metal ions from the surface of metal parts by making the metal part anodic. It is usually done in a tank filled with acid electrolyte. The tank has metal cathodes on the sides and an anode bar where the metal parts are connected. When the proper current is applied, electropolish takes place.

Electropolish Advantages

- Surface Refinement – reduces microfinish
- Hydrogen Removal – no hydrogen embrittlement
- Passivation – corrosion resistance
- Deburring
- Stress Relieving

Helium Leak Checking – Helium leak checking is performed to verify that gas delivery systems will not leak. Some of the gases used in semiconductor processes are toxic or highly toxic, and others are corrosive. A helium leak checking instrument uses a mass spectrometer analysis cell tuned for the mass of a helium molecule to detect for the presence of helium. Helium is a "skinny" molecule having 2 protons, 2 neutrons and 2 electrons. It readily fits through small holes and cracks, as compared to a gas such as argon, which has 18 protons, 22 neutrons, etc. Helium is also readily available and is not regulated or toxic.

Leak rates are commonly specified as 1 x 10^9 atmospheres/standard cubic centimeter/second (sccs).

The table below provides a real world comparison. The table is based on the amount of bubbles that would be observed if a pressurized gas delivery system were immersed in water and the number of escaping bubbles were counted.

Leak Rate	Bubble Count
10^{-1}	Steady stream
10^{-2}	10 Bubbles per second
10^{-3}	1 Bubble per second
10^{-4}	1 Bubble in 10 seconds
10^{-5}	Too infrequent to count
10^{-6}	Too infrequent to count
10^{-7}	Too infrequent to count
10^{-8}	Too infrequent to count
10^{-9}	Too infrequent to count
10^{-10}	Technology limit

Delivery Systems: Accessories

Point-of-Use Panels

Most modern laboratories have multiple instruments that use the same specialty gas but may require different delivery pressures, flow rates or purity levels. Unfortunately, even when a centralized gas distribution system is in place, these varying needs of the instruments are often accommodated by a maze of tubing, line regulators and traps that are scattered behind laboratory equipment.

Such disorganization can result in a number of serious problems. First, since regulators and tubing can be bunched together, it is easy to connect the wrong gas to the instrument, resulting in lost or degraded experiments or even damage to the instrument. Second, safety may be compromised since tubing, regulators and traps will not be adequately protected or marked. Third, operating and maintenance costs will increase as the difficulty of identifying and correcting the causes of problems increases.

A more practical arrangement to eliminate or minimize these problems is to install point-of-use panels designed for dedicated gas service. A typical panel provides a means to control both delivery pressure and flow rate for a gas supplied to an instrument at the point of use. When required, traps can be included on panels as well. Where one instrument requires several gases, a panel can be designed to conveniently regulate the gases. The Model 57P shown in the sidebar allows control of three separate gases.

Point-of-Use Panels
Model 57P

Scott point-of-use panels provide well-organized and safe gas delivery in the lab.

Modular Gas Panels
Model 57MGP

These panels make it easier than ever to control specialty gases at point-of-use when the gas source is located remotely. Gas pressure, purity, filtration and distribution can all be controlled conveniently in a single unit with preassembled, snap-in panels. Any combination of pressure regulators, purifiers, moisture traps and outlet valves can be configured to meet virtually any laboratory requirements.

Traps

Traps remove unwanted contaminants from specialty gases before they reach the instrument. They also indicate gas contamination. Traps are typically used to remove oxygen, moisture and hydrocarbons, and they may be indicating or nonindicating.

Nonindicating traps are usually high-capacity replaceable traps used in conjunction with indicating traps. For instance, a cartridge-type oxygen trap is used with argon-methane mixtures commonly used with electron capture gas chromatographs. It will remove 99% of the oxygen present in a 300 cubic foot (91 cm) gas cylinder (15 ppm O_2 level) before replacement of the cartridge is required. A cartridge-type trap should be fitted with check valves to prevent contamination of gas lines with atmospheric oxygen during cartridge replacement.

Indicating traps contain an extremely active reagent that changes color from a pale green to a deep brown as the catalyst becomes saturated. When used downstream of a cartridge-type trap, an indicating trap serves to prevent premature replacement of high-capacity cartridges and to provide a means to indicate the oxygen status of carrier gases.

Oxygen Traps – Oxygen traps can treat inert gases such as nitrogen, helium, argon and krypton, as well as hydrogen, alkanes and alkenes, aliphatic hydrocarbon gases, low-boiling aromatics such as benzene and toluene, carbon dioxide and carbon monoxide.

Moisture Traps – For gas chromatographic carrier gas applications that require low moisture concentrations, a molecular sieve adsorbent is used. With its high affinity for carbon dioxide and its ability to adsorb as much as 20% of its weight in water, the molecular sieve is the preferred adsorbent for general gas drying. The indicating sieve is blue when installed and turns a buff color at 20% relative humidity.

Silica gel, used in general purpose gas carrier applications, is the highest moisture capacity adsorbent available. Silica gel, which can adsorb as much as 40% of its weight in water, reduces moisture content of the gas to approximately 5 ppm. The indicating gel turns from a deep blue to pale pink at 40% relative humidity and has a high affinity for hydrocarbons.

Indicating Traps – Indicating moisture traps are designed to remove water, oil and organics from gases commonly employed in, but not limited to, gas chromatography. Moisture traps generally use one of two adsorbent fills, depending on the application.

Some applications, such as electron capture GCs or Hall® electrolytic conductivity detectors, require glass indicating moisture traps. The glass body eliminates outgassing typical of reactive plastic bodied traps that can contribute to unacceptable background levels for extremely sensitive detectors. These traps are used with carrier gases such as methane/argon, hydrogen/argon, nitrous oxide/nitrogen, nitrogen, argon, helium and hydrogen.

Hydrocarbon Traps – Hydrocarbon traps are designed for use in vapor phase applications such as gas chromatography. A typical trap contains very highly active, fine pore structure, high-density, high-volume activity, coconut shell-based activated carbon which is prepurged prior to packaging to remove any traces of moisture. All metal construction is used to eliminate organic contaminants which often bleed from traps constructed from plastics. Materials adsorbed include alcohols, ethers, esters, chlorinated hydrocarbon, ketones and aromatics.

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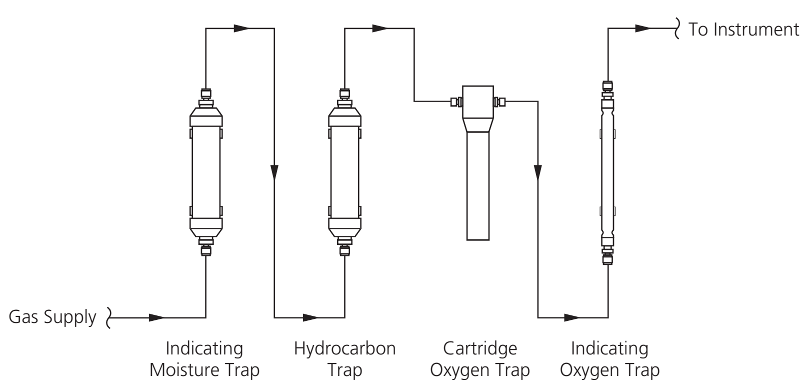


An indicating oxygen trap should be installed between the primary oxygen trap or moisture trap and the instrument. When a hydrocarbon trap is used, it should be installed between the moisture trap and the oxygen trap.

Manifold Specification Worksheet

General	1	Tag No.				
	2	Service				
	3	Lab				
Cylinder Connections	4	CGA / DIN / BS / NEN				
	5	No. of Pigtails				
	6	Type of Pigtails				
	7	Check Valve(s)				
	8	Purge-Process / Inert				
Manifold Type	9	Manual / Automatic				
	10	Tubing & Fitting Material				
	11	Valve Type/Material				
	12	Regulator Material				
	13	Outlet Connection				
Gas Data	14	Gas (Liquid)				
	15	Cylinder Pressure				
	16	Delivery Pressure				
	17	Maximum Flow Rate				
	18	Normal Flow Rate				
	19	Grade/Purity				
Options	20	Flow Limit Shut-Off Valve				
	21	Flash Arrester				
	22	Pressure Switch				
	23	Alarm-Annunciator				
	24	Pressure-Relief Valve(s)				
	25	Enclosure Type				
	26	Intrinsically Safe				
	27	Hazardous Shutdown				
	28	Manufacturer				
	29	Model Number				

Spec. No	
Revision	
Req. P.O.	
Date	
Job	

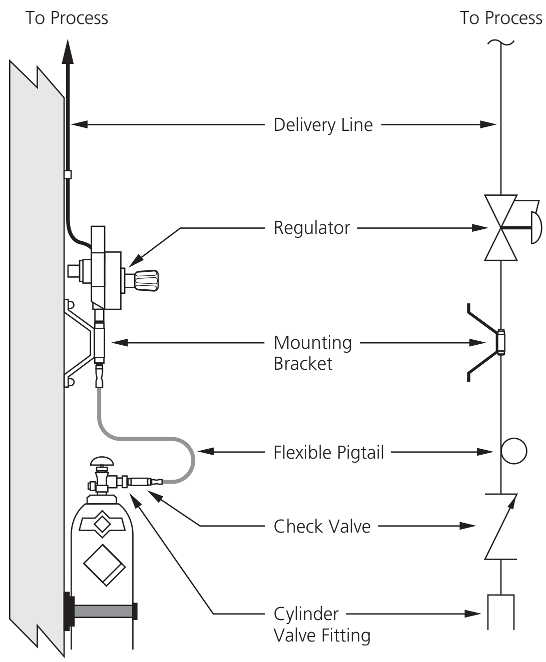
Directions

1–3	Used for identification
4	Specify CGA, DIN, BS or NEN connection required (i.e. CGA 580 for nitrogen, see page 37 for cylinder valve outlets and connections by gas).
5–6	Specify number and type of pigtails required
7	Indicate if check valves are required on pigtails
8	State whether purge assembly is required and indicate type
9	State type required
10	Brass or stainless steel
11	Ball valve or diaphragm packless valve/brass or stainless steel
12	Brass, stainless steel, other
13	State size and type of connection (i.e. 1/4" or 0.64 mm NPT M)
14	State type of gas or liquid to be distributed
15–18	Self-explanatory
19	Indicate purity or grade of gas (i.e. helium 99.9999% pure)
20–27	Specify type if required
28–29	Self-explanatory

Application Connections

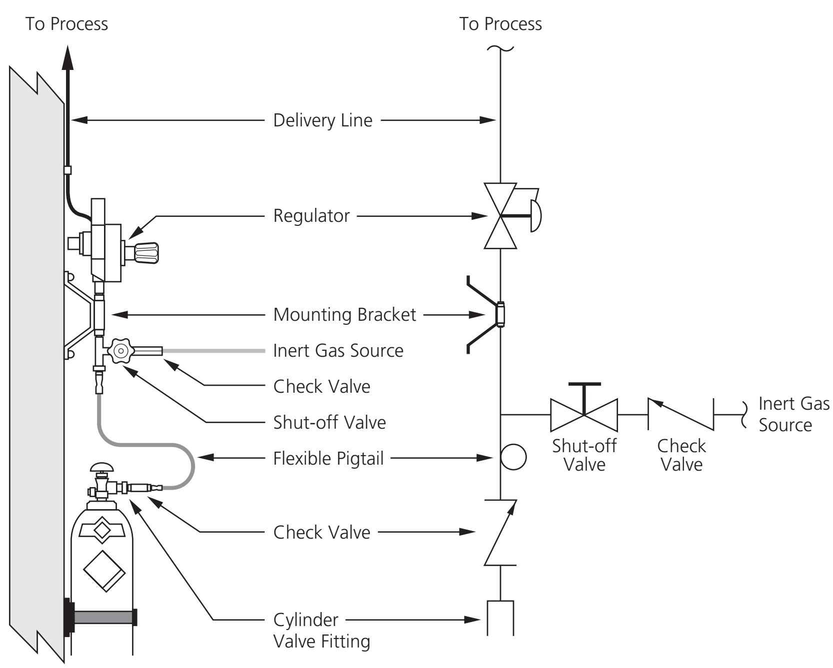
Typical Connection of a Single Cylinder to a Regulator

A single-station manifold with bracket provides a safe, cost-effective means of connecting and changing out cylinders by eliminating the need to handle the regulator. It should be fitted with the correct CGA, BS, DIN or NEN for the application and should include a check valve to prevent back-flow of gas from the delivery system.



Single-Cylinder Connection with Tee Purge

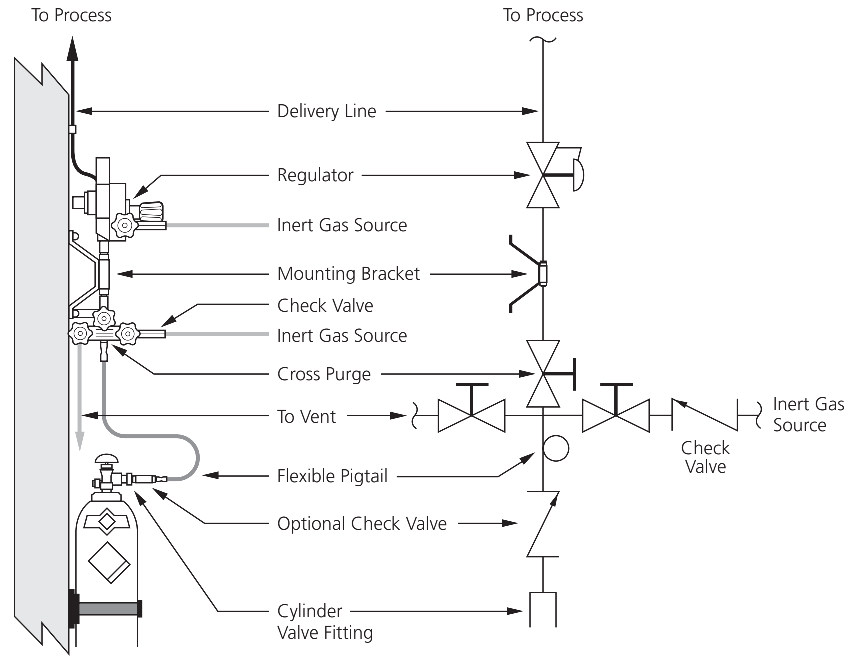
The inclusion of a tee purge in a cylinder-to-regulator connection provides the capability of dilution purging as a means to purge the regulator and connecting lines. Used with nonreactive gases and mixtures, this purging procedure removes unwanted oxygen and moisture from the system. It eliminates the wasteful practice of allowing large volumes of gas to flow through the system to remove contaminants.



Application Connections continued

Single-Cylinder Connection with Cross Purge for Purging with Inert Gas

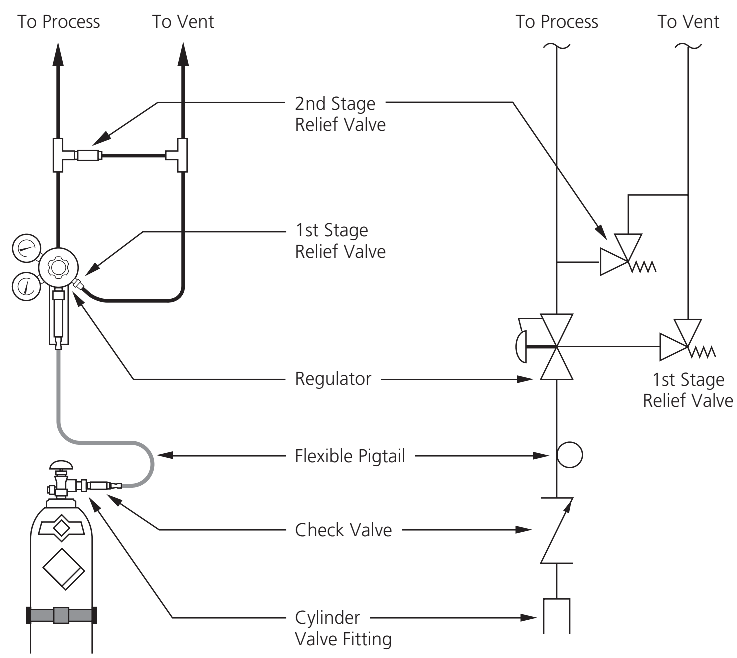
Cross-purge assemblies allow the use of an inert gas for dilution purging of delivery systems for corrosive, toxic or pyrophoric gases that can extend the life of the delivery system equipment and protect personnel from exposure to these gases.



Regulator with Vented 1st- and 2nd-Stage Relief Valves

When two-stage regulators are used, a preset 1st-stage (or interstage) relief valve is sometimes required to protect the 2nd stage from overpressure. Additionally, it is good practice to install an adjustable relief valve on the 2nd stage to protect the system and instruments from damage from excessive pressure.

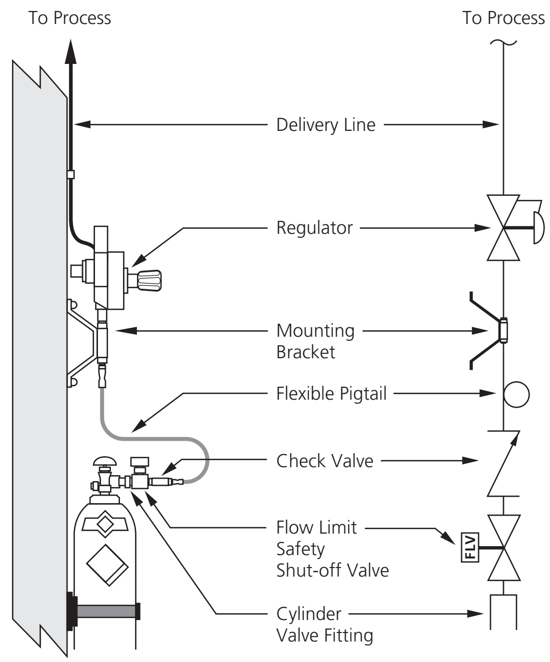
For outdoor installations involving inert gases, the relief valves can exhaust directly to the atmosphere. For indoor installations, or any installations involving toxic or flammable gases, the relief valve exhaust should be captured and vented to a safe location as shown.



Flow Limit Safety Shut-off Valve for Single-Cylinder Connection

A flow limit safety shut-off valve stops potentially dangerous and expensive leaks by automatically shutting off all flow from the cylinder when flow exceeds a preset level. The flow limit valve should be installed between the cylinder outlet and the pressure regulator inlet. It senses flow as a pressure drop and closes the valve with a "snap action" for a leaktight seal when the preset differential pressure limit is reached.

To allow normal gas usage as the cylinder pressure decreases, the flow limit setting should be set to provide shutoff at six to ten times the anticipated actual process flow rate.

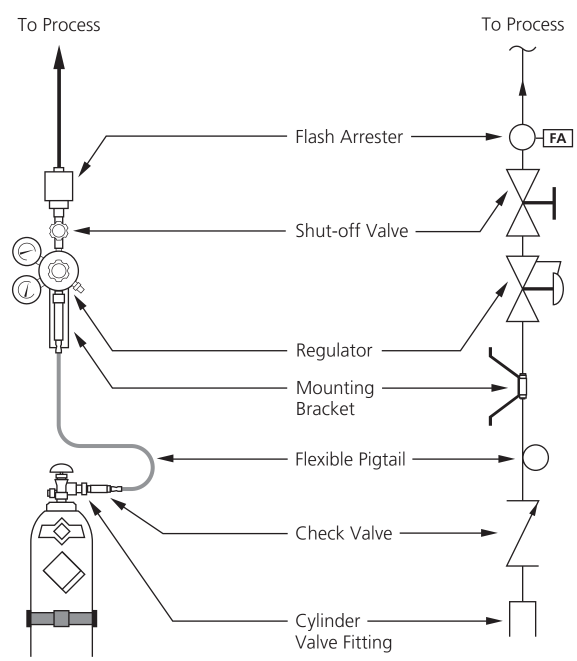


Flash Arrester on Single Cylinder

To prevent a flame from reaching the cylinder, a flash arrester should be installed on the downstream side of the regulator. The flash arrester should be designed to:

1. Check reverse flow
2. Extinguish flashbacks to prevent explosions in the regulator, pipeline or cylinder
3. Stop gas flow to eliminate feeding gas to any residual sparks or fire

Flash arresters are recommended for oxygen and fuel gas service.

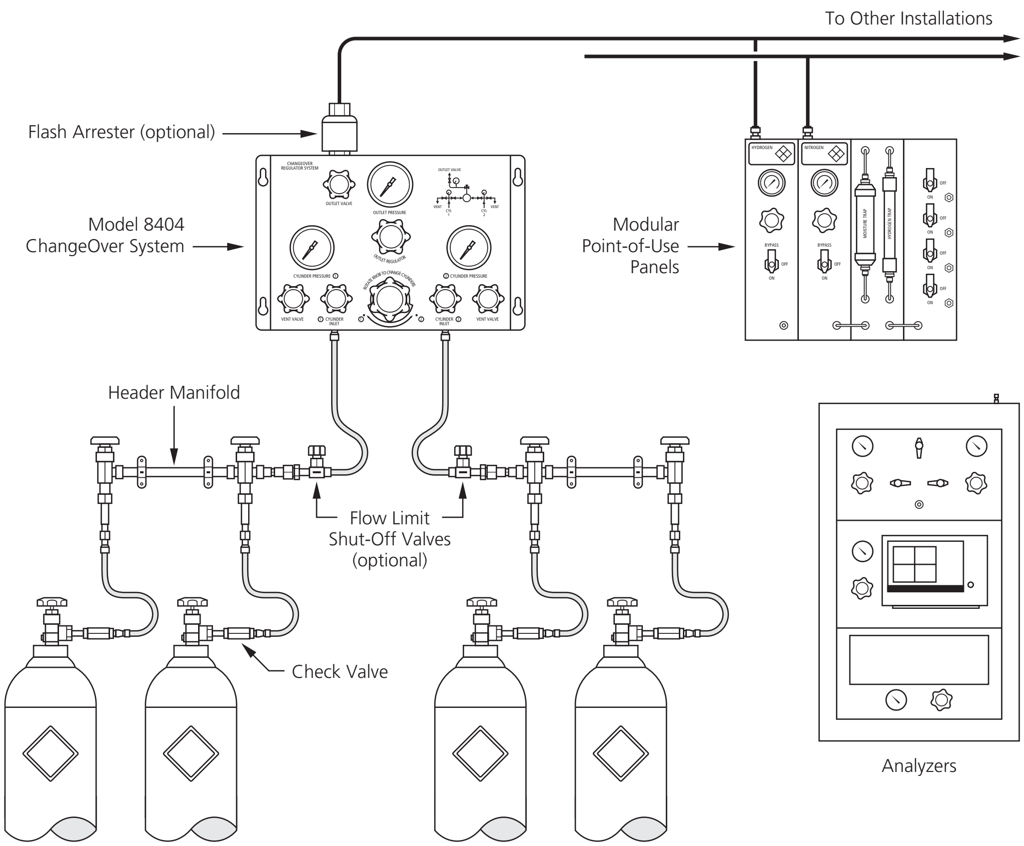


Application Connections continued

Supplying an Automatic Changeover Manifold from Header Manifolds

Centralized gas delivery systems serving multiple instruments or laboratories must supply high volumes of gas. In order to reduce the cost of frequent cylinder changeouts, it is more economical to connect several cylinders into a bank using header manifolds. These banks are then connected to an automatic changeover manifold to provide an uninterrupted flow of gas with fewer cylinder changeouts.

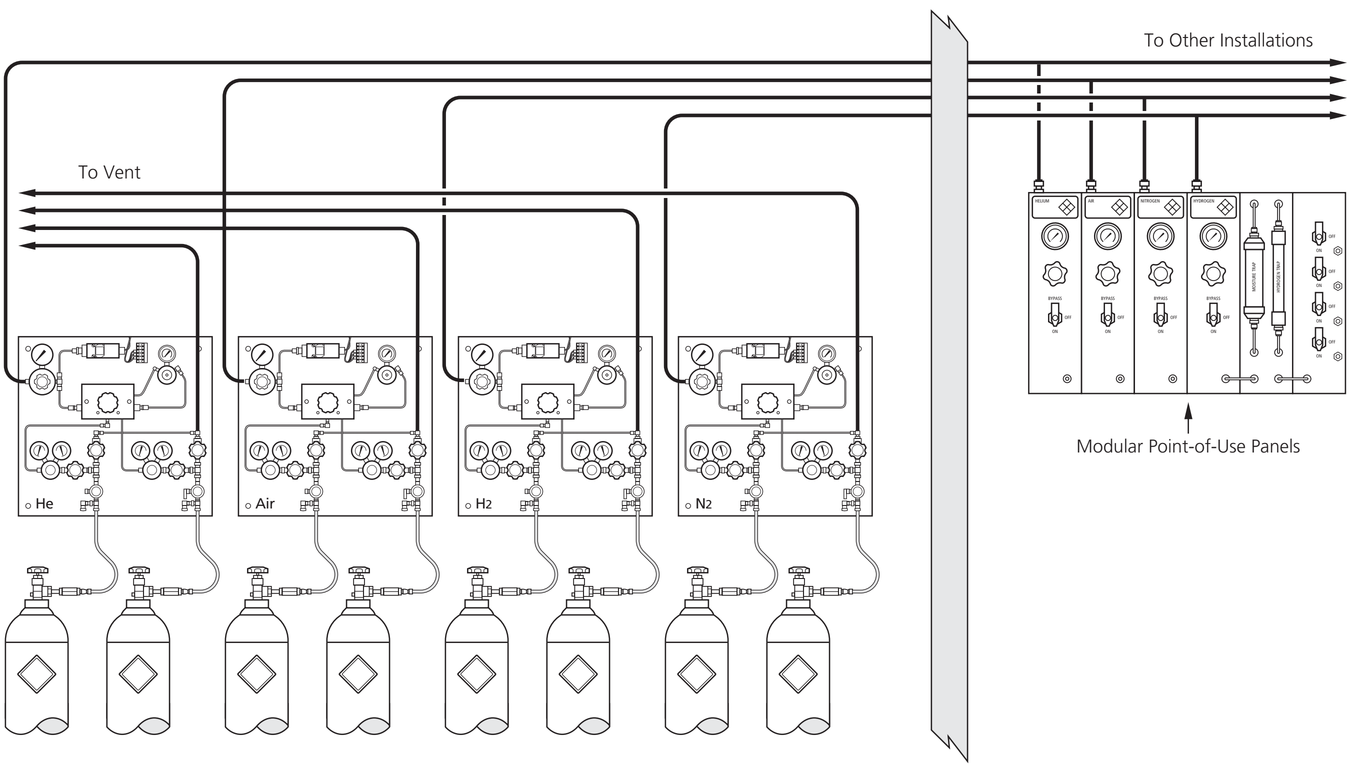
Where even larger volumes are needed, cylinders can be preconnected into banks on movable carts, sometimes called six packs. Since only one connection need be made, changeout labor costs are further reduced.



Centralized Gas Delivery from Gas Pod to Lab(s)

Below is an illustration of automatic changeover manifolds providing uninterrupted supply of four gases at constant delivery pressure.

This centralized delivery system can supply multiple labs economically. It allows consolidation of cylinders into one location, enhancing safety. Operating costs are reduced since downtime due to interrupted gas flow is eliminated and labor for cylinder changeouts is minimized.



Characteristics of Specialty Gases

Gas	NonLiquefied Compressed Gas	Liquefied Gas	Flammable Limits in Air (Vol. %) (1)	Oxidant	Inert	Corrosive	Toxic
Acetylene	(2)		2.5–100				
Air	X			X			
Allene		X	2.2–N.A.				
Ammonia		X	15–28			X	
Argon		X			X		
Arsine		X	5.1–78				(4)
Boron Trichloride		X				X	X
Boron Trifluoride	X			X		X	(4)
1,3-Butadiene		(5)	2.0–11.5				
Butane		X	1.8–8.4				
Butenes		X	1.6–10				
Carbon Dioxide		X			X		
Carbon Monoxide	X		12.5–74				X
Carbonyl Sulfide		X	11.9–28.5			(3)	X
Chlorine		X		X		(3)	(4)
Cyanogen		X	6.6–32				(4)
Cyclopropane		X	2.4–10.4				
Deuterium	X		4.9–75				
Diborane	X		0.8–98				(4)
Dimethylamine		X	2.8–14.4			X	
Dimethyl Ether		X	3.4–27				
Ethane		X	3.0–12.4				
Ethyl Acetylene		X	(7)				
Ethyl Chloride		X	3.8–15.4				
Ethylene	X		2.7–36				
Ethylene Oxide		(6)	3.6–100				X
Fluorine	X			X			(4)
Germane	X		(7)				(4)
Helium	X				X		
Hydrogen	X		4.0–75				
Hydrogen Bromide		X				(3)	(4)
Hydrogen Chloride		X				(3)	(4)
Hydrogen Fluoride		X				X	(4)

(1) Flammable limits are at normal atmospheric pressure and temperature. The flammable limits in air for some components vary in Europe – please refer to Chemiekaarten for specified limitations of each gas.
(2) Dissolved in solvent under pressure. Gas may be unstable and explosive above 15 psig (1 bar).
(3) Corrosive in presence of moisture.
(4) Toxic. It is recommended that the user be thoroughly familiar with the toxicity and other properties of this gas.
(5) Cancer suspect agent.
(6) Recognized human carcinogen.
(7) Flammable. However, limits are not known.

Characteristics of Specialty Gases **Gas**	NonLiquefied Compressed Gas	Liquefied Gas	Flammable Limits in Air (Vol. %) (1)	Oxidant	Inert	Corrosive	Toxic
Hydrogen Sulfide		X	4–44			(3)	(4)
Iso-Butane		X	1.8–9.6				
Iso-Butylene		X	1.8–9.6				
Krypton	X				X		
Methane	X		5.0–15.0				
Methyl Chloride		X	10.7–17.4				
Methyl Mercaptan		X	3.9–22				(4)
Monoethylamine		X	3.5–14			X	
Monomethylamine		X	4.9–20.7			X	
Neon	X				X		
Nitric Oxide	X			X		(3)	(4)
Nitrogen	X				X		
Nitrogen Dioxide		X		X		(3)	(4)
Nitrogen Trioxide		X		X		(3)	(4)
Nitrosyl Chloride		X		X		(3)	(4)
Nitrous Oxide		X		X			
Oxygen	X			X			
Phosgene		X					(4)
Phosphine		X	1.6–99				(4)
Propane		X	2.1–9.5				
Propylene		X	2.0–11				
Halocarbon-12 (Dichlorodifluoromethane)		X			X		
Halocarbon-13 (Chlorotrifluoromethane)		X			X		
Halocarbon-14 (Tetrafluoromethane)	X				X		
Halocarbon-22 (Chlorodifluoromethane)		X			X		
Silane	X		1.5–98				
Sulfur Dioxide		X				(3)	(4)
Sulfur Hexafluoride		X			X		
Sulfur Tetrafluoride		X				X	(4)
Trimethylamine		X	2.0–12.0			X	
Vinyl Bromide		X	9–15				
Vinyl Chloride		(5)	3.6–33				
Xenon	X				X		

(1) Flammable limits are at normal atmospheric pressure and temperature. The flammable limits in air for some components vary in Europe – please refer to Chemiekaarten for specified limitations of each gas.
(2) Dissolved in solvent under pressure. Gas may be unstable and explosive above 15 psig (1 bar).
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(5) Cancer suspect agent.
(6) Recognized human carcinogen.
(7) Flammable. However, limits are not known.

Physical Properties of Gases

Gas	Chemical Formula	Molecular Weight	Vapor Pressure (psia (bar) 21°C)	Specific Volume (L/g)	Boiling Point (°C)	Freezing Point (°C)	Heat of Fusion (Cal/g mole)	Vaporization Heat (Cal/g mole)	Heat Capacity (Cp Cal/g mole °C)	Heat Capacity (Cv Cal/g mole °C)
Air		28.96		0.83	-194.3				6.96	4.97
Ammonia	NH_3	17.03	128.8 (9)	1.41	-33.4	-77.7	1351	5577	8.83	6.75
Argon	Ar	39.95		0.61	-185.9	-189.2	280	1558	4.98	2.98
1,3-Butadiene	C_4H_6	54.09	36.1 (2)	0.43	-4.4	108.9	1908	5398	19.62	17.63
n-Butane	C_4H_{10}	58.12	31.0 (2)	0.41	-0.5	-138.3	1114	5349	23.97	21.99
i-Butane	C_4H_{10}	58.12	45.4 (4)	0.41	-11.7	-159.6	1086	5087	22.49	20.50
1-Butene	C_4H_8	56.11	38.2 (3)	0.42	-6.3	-185.3	920	5235	20.86	18.90
cis-2 Butene	C_4H_8	56.11	27.7 (2)	0.42	3.7	-138.9	1747	5577	21.64	19.68
trans-2-Butene	C_4H_8	56.11	29.7 (2)	0.42	0.9	-105.6	2332	5437	19.51	17.49
Carbon Dioxide	CO_2	44.01	853.4 (59)	0.54	-78.5†		1900	6030	8.97	6.82
Carbon Monoxide	CO	28.01		0.86	-191.1	-207.0	200	1443	6.98	4.97
Chlorine	Cl_2	70.91	100.2 (7)	0.34	-34.1	-101.0	1623	4878	8.44	6.45
Deuterium	D_2	4.03		6.00	-249.6		47	300	6.98	4.99
Ethane	C_2H_6	30.07	558.7 (39)	0.80	-88.7	-183.3	683	3509	12.74	10.69
Ethylene	C_2H_4	28.05		0.85	-103.8	-169.2	800	3237	10.37	8.34
Halocarbon-12	CCl_2F_2	120.93	84.9 (6)	0.20	-29.8	-158.0		4773	17.79	15.81
Halocarbon-13	$CClF_3$	104.46	473.4 (33)	0.23	-81.4	-181.0		3742	16.16	14.17
Halocarbon-14	CF_4	88.01		0.27	-128.0	-186.8	167	2864	14.63	12.65
Halocarbon-22	$CHClF_2$	86.47	137.7 (9)	0.27	-40.7	-157.4	985	4830	13.74	11.73
Helium	He	4.00		6.03	-268.9	-272.1	0.08	20	5.01	3.07
Hydrogen	H_2	2.02		11.98	-252.8	-259.3	28	216	6.89	4.90
Hydrogen Chloride	HCl	36.46	626.7 (43)	0.66	-84.9	-113.9	478	3859	7.06	5.01
Hydrogen Selenide	H_2Se	80.98	139.6 (10)	0.30	41.2	-65.9		4761	8.30	
Hydrogen Sulfide	H_2S	34.08	267.7 (18)	0.70	-59.7	-82.9	568	4463	8.17	6.16
Krypton	Kr	83.80		0.29	-153.3	-157.4	392	2158	5.02	3.01
Methane	CH_4	16.04		1.50	-161.4	-182.5	225	1954	8.58	6.58
Neon	Ne	20.18		1.20	-245.9	-248.5	77	440	4.96	3.02
Nitric Oxide	NO	30.01		0.80	-151.7	-163.6	550	3307	6.98	4.99
Nitrogen	N_2	28.01		0.86	-195.8	-210.0	172	1336	6.92	4.99
Nitrogen Dioxide	NO_2	46.01	14.7 (1)	0.29	21.2	-11.3	1751	4555	8.83	
Nitrous Oxide	N_2O	44.01	774.7 (53)	0.54	-88.4	-90.8	1563	3950	9.23	7.08
Oxygen	O_2	32.00		0.75	-182.9	-218.4	106	1629	7.02	4.97
Propane	C_3H_8	44.10	124.3 (9)	0.54	-42.1	-187.7	842	4487	17.68	15.48
Propylene	C_3H_6	42.08	151.9 (10)	0.58	-47.7	-185.3	717	4403	14.89	12.91
Silane	SiH_4	32.11		0.75	-112.0	-185.0		2960	10.24	
Sulfur Dioxide	SO_2	64.06	49.1 (3)	0.37	-10.1	-75.5	1769	5960	9.53	7.39
Sulfur Hexafluoride	SF_6	146.06	320.0 (22)	0.16	-63.9†		1199	5600	23.21	
Xenon	Xe	131.30		0.18	-108.3	-111.5	740	3110	5.02	3.02

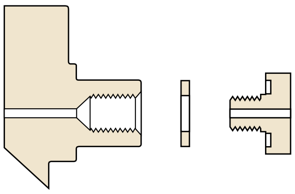
† Sublimation Point

Cylinder Valve Outlets and Connections

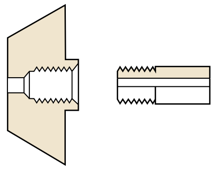
Scott supplies gases in cylinders with valves having BS, CGA, DIN and NEN standard outlet connections. In some cases, alternate connections may be used, and upon customer's request, will be supplied instead of the standards shown below.

Gas	BS	CGA	DIN	NEN	**Gas**	BS	CGA	DIN	NEN
Acetylene	2	510	–	Li2	Hydrogen Bromide	–	330	8	
Air	3	590	6		Hydrogen Chloride	6	330	8	
Allene	–	510	1		Hydrogen Sulfide	15	330	5	
Ammonia, Anhydrous	10	240, 660	8		Iso-Butane	4	510	1	
Argon	3	580	10		Iso-Butylene	4	510	1	
Arsine	4	350	5		Krypton	3	580	10	
1,3-Butadiene	4	510	1		Methane	4	350	1	
Butane	4	510	1		Methyl Chloride	7	660	5	
Butenes	4	510	1		Methyl Mercaptan	–	330	5	
Carbon Dioxide	8	320	6		Monoethylamine	11	240	5	
Carbon Monoxide	4	350	5		Monomethylamine	11	240	5	
Carbonyl Fluoride	–	660	8		Natural Gas	4	350	1	
Carbonyl Sulfide	–	330	5		Neon	3	580	10	
Chlorine	6	660	8		Nitric Oxide	14	660	8	
Cyanogen	–	660	8		Nitrogen	3	580	10	
Deuterium	4	350	1		Nitrogen Dioxide	14	660	8	
Dimethylamine	11	240	5		Nitrous Oxide	13	326	6	
Dimethyl Ether	–	510	1		Oxygen	3	540	–	Ri2
Ethane	4	350	1		Phosgene	6	660	8	
Ethyl Acetylene	–	510	1		Phosphine	4	350	5	
Ethyl Chloride	7	510	1		Propane	4	510	1	
Ethylene	4	350	1		Propylene	4	510	1	
Ethylene Oxide	7	510	1		Silane	–	350	5	
Halocarbon-14					Silicon Tetrafluoride	–	330	8	
(Tetrafluoromethane)	6	580	6		Sulfur Dioxide	12	660	8	
Halocarbon-22					Sulfur Hexafluoride	6	590	6	
(Chlorodifluoromethane)	6	660	6		Trimethylamine	11	240	5	
Helium	3	580	10		Vinyl Chloride	7	510	5	
Hydrogen	4	350	1		Xenon	3	580	10	

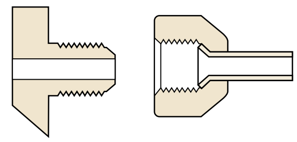
CGA U.S. Standards Cylinder Valve Outlets and Connections



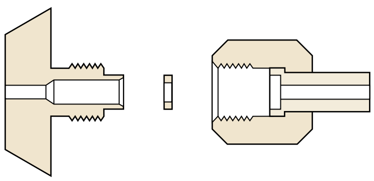
Connection 110 5/16" – 32 RH INT., with Gasket



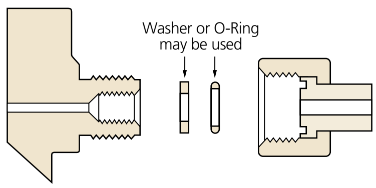
Connection 160 1/8" – 27 NGT RH INT.



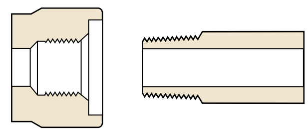
Connection 165 0.4375" – 20 UNF 2A RH EXT.



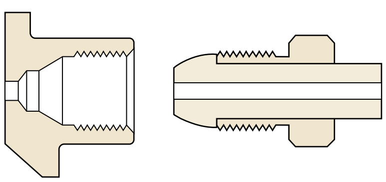
Connection 170 9/16" – 18 RH EXT. and 5/16" – 32 RH INT., with Gasket



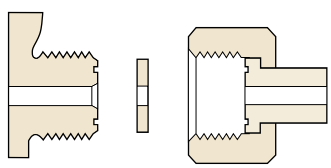
Connection 180 0.625" – 18 UNF 2A RH EXT., with Gasket



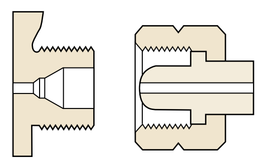
Connection 240 3/8" – 18 NGT – RH INT.



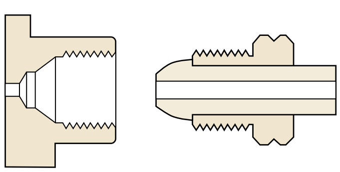
Connection 296 0.803" – 14 RH INT.



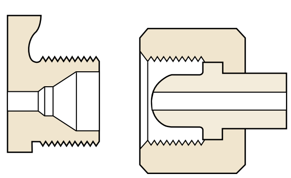
Connection 320 0.825" – 14 RH EXT., with Gasket
Connection 330 0.825" – 14 LH EXT., with Gasket



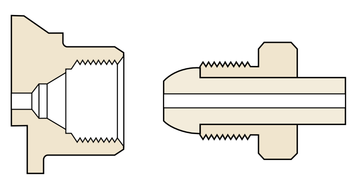
Connection 326 0.825" – 14 RH EXT.
Connection 350 0.825" – 14 LH EXT.



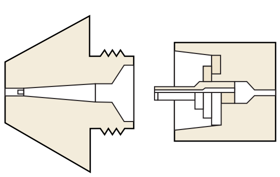
Connection 510 0.885" – 14 LH INT.



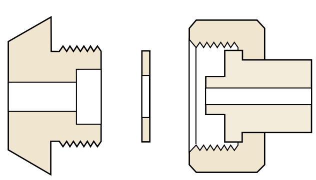
Connection 540 0.903" – 14 RH EXT.



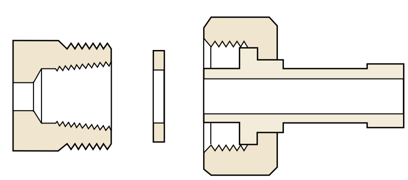
Connection 580 0.965" – 14 RH INT.
Connection 590 0.965" – 14 LH INT.



Connection 600 1.000" – 20 UNEF RH EXT., with Gasket

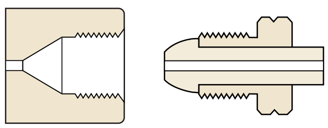


Connection 660 1.030" – 14 RH EXT., with Gasket

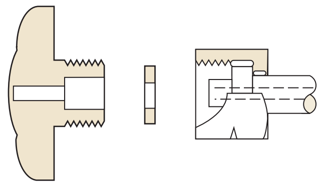


Connection 705 1.125" – 14 UNS 2A RH EXT., with Gasket

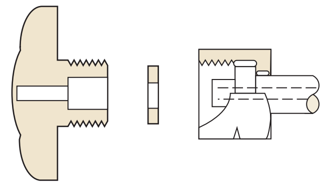
BS341 British Standards Cylinder Valve Outlets and Connections



BS No 3 5/8" BSP RH INT.
BS No 4 5/8" BSP LH INT.

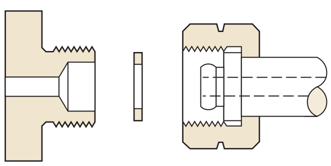


BS No 6 5/8" BSP RH EXT.
Flat Seal with Gasket
BS No 8 0.860 BSW RH EXT.
Flat Seal with Gasket

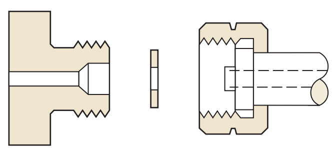


BS No 14 3/8" BSP RH EXT.
Flat Seal with Gasket
BS No 15 3/8" BSP LH EXT.
Flat Seal with Gasket

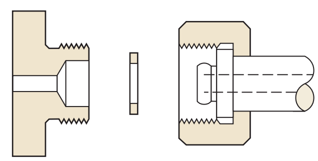
DIN 477 German Cylinder Valve Outlets and Connections



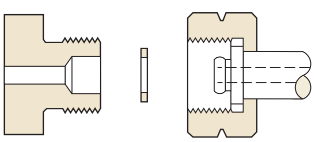
DIN 1 21,80 mm x 1/14" – LH EXT.
Flat Seal with Gasket
DIN 6 21,80 mm x 1/14" – RH EXT.
Flat Seal with Gasket



DIN 5 1" – LH EXT.
Flat Seal with Gasket
DIN 8 1" – RH EXT.
Flat Seal with Gasket

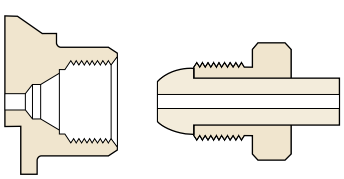


DIN 10 24,32 mm x 1/14" – RH EXT.
Flat Seal with Gasket



DIN 14 M 19 x 1,5 mm – LH EXT.
Flat Seal with Gasket

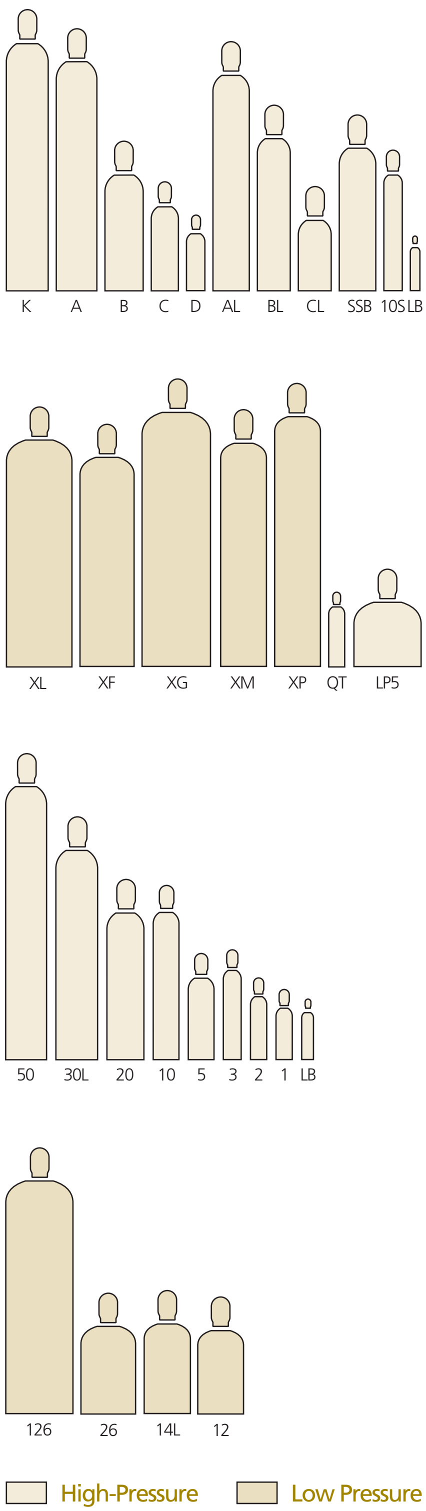
NEN 3268 Nederlandse Norm Cylinder Valve Outlets and Connections



Ri2 G 5/8" – RH INT.

Cylinder Specifications

Cylinder Sizes



U.S. DOT Cylinder Size	Nominal* Size Dia x Height (inches)	Nominal* Tare Weight (lbs.)	Water Capacity (lbs.)	Internal Volume @21°C, 1 ATM		DOT Specs
				liters	cu. ft.	
K	9.25 x 60	135	110	49.9	1.76	3AA2400
A	9 x 56	115	96	43.8	1.55	3AA2015
B	8.5 x 31	60	37.9	17.2	0.61	3AA2015
C	6 x 24	27	15.2	6.88	0.24	3AA2015
D	4 x 18	12	4.9	2.24	0.08	3AA2015
AL	8 x 53	52	64.8	29.5	1.04	3AL2015
BL	7.25 x 39	33	34.6	15.7	0.55	3AL2216
CL	6.9 x 21	19	13	5.9	0.21	3AL2216
SSB	8 x 37	95	41.6	18.9	0.67	3A1800
10S	4 x 31	21	8.3	3.8	0.13	3A1800
LB	2 x 15	4	1	0.44	0.016	3E1800
XL	14.5 x 50	75	238	108	3.83	4BA240
XF	12 x 46	180	—	60.9	2.15	8AL
XG	15 x 56	149	278	126.3	4.46	4AA480
XM	10 x 49	90	120	54.3	1.92	3A480
XP	10 x 55	55	124	55.7	1.98	4BA30
QT	3 x 14**	2.5	2.0	0.900	0.0318	4B-240ET
LP5	12.25 x 18.25	18.5	47.7	21.68	0.76	4BW240

* Includes 5.5" (140 mm) or 4.5 lbs. (2 kg) for valve and cap.
** Includes 4.5" (114 mm) or 1.5 lbs. (0.68 kg) for valve.

EEC Cylinder Size	Water Capacity (liters)	Outside Diameter (mm)	Height Excluding Cap and Valve (mm)	Weight Excluding Cap and Valve (kg)
50	50	229	1530	66
20	20	204	820	25.5
10	10	140	825	13.4
5	5	140	455	5.9
3	3	100	500	4.8
2	2	90	352	3.88
1	1	90	287	3.16
50L	50	250	1510	56.7
30L	31.5	236	1170	36.6
20L	20	191	1060	23.6
10L	10	176	660	12.8
5L	5	152	465	7.2
3L	3	118	458	4.20
2L	2	117	330	3.0
1L	1	102	240	1.7
50H	50	229	1530	66
20H	20	204	820	25.5
10H	10	140	825	13.4
5H	5	102	455	5.9
LB	0.47	61	265	1.4
126	126	381	1300	48
26	26	305	490	12.4
14L	14.3	261	500	4.8
12	12	255	465	7.3

Piston Cylinder Size	Nominal*† Size Dia x Height (inches)	Nominal* Tare Weight (lbs.)	Water Capacity (lbs.)	**Internal Volume** @21°C, 1 ATM		DOT Specs
				liters	cu. ft.	
Vortex						
P1K	56.5 x 5.25	18.75	2.20	1.0	0.0353	E7657
P4K	60 x 8.5	77	8.80	4.0	0.1412	E7657
PC3	25 x 5.25	11.5	0.066	0.3	0.0105	E7657
PC5	33 x 5.25	13.5	1.10	0.5	0.0176	E7657
PC8	Inquire	Inquire	1.76	0.8	0.0282	E7657
Gravity						
PC3	18.5 x 5.25	11.25	0.66	0.3	0.0105	E7657
PC5	23.5 x 5.25	12.75	1.10	0.5	0.0176	E7657
PC8	Inquire	Inquire	1.76	0.8	0.0282	E7657
P1K	35 x 5.25	18.25	2.20	1.0	0.0353	E7657

* Approximate measurements.
† Diameter includes the maximum measurement of the cylinder with a mounted gauge.
Length includes the cylinder with a mounted valve.
Carrying cases are not included.
Please note: Due to DOT regulations, these cylinders can only be filled to 80% of their respective capacities.

Cylinder Markings

U.S. DOT Cylinder Marking Information

1. Cylinder Specifications

- DOT — U.S. Dept. of Transportation. (Regulatory body that governs use of cylinders)
- 3AA — Type and material of construction.
- 2015 — Service pressure in pounds per square inch gauge.

2. A-13016 — Serial number (Scott).

3. SRL — Identifying symbol, registered with DOT.

4. Manufacturing Data

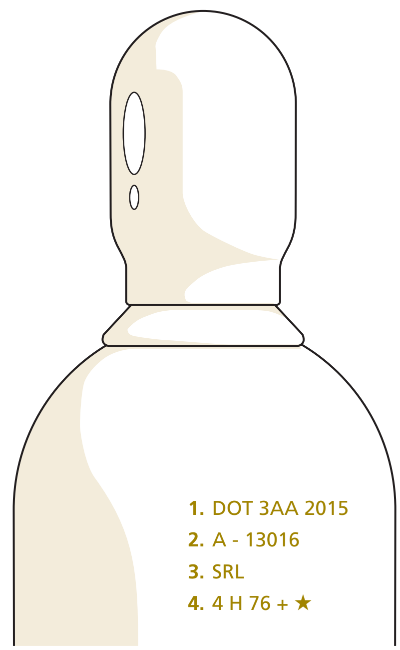
- 4-76 — Date of manufacture and original test date.
- H — Inspectors official mark.
- \+ — Cylinder qualifies for 10% overfill.
- ★ — Cylinder qualifies for 10 year retest interval.

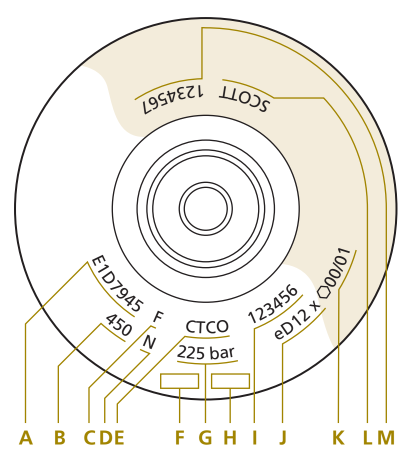
EEC Cylinder Marking Information

Cylinder Imprints (required by EEC)

A. EEC type approval
B. Value R in N/mm2
C. Country of origin
D. Type of heat treatment (steel cylinders only)
E. Manufacturer or cylinder owner
F. Weight of empty cylinder
G. Test pressure (maximum allowed)
H. Water contents of cylinder in liters
I. Manufacturing number
J. Inspector's official mark
K. Date of hydrostatic testing (year/month)

In general, you will also find an expiration date for HST, the name of the pure gas or gas mixture, and the Scott cylinder number (on bar code label).





General Definitions and Terminology

Absolute Pressure – A quantity of pressure measured with respect to total vacuum. Equal to the sum of a pressure gauge reading and atmospheric pressure (14.69 psia or 1.01 bar at sea level).

Absorption – The soaking up of gas, liquid or dissolved substances into a solid material.

Acid – A chemical compound that dissociates in aqueous solution to form hydrogen ions; a proton donor that reacts with a base to form a salt.

Adsorption – The condensation of gas, liquids or dissolved substances on the surface of solids.

Aerobic Gas Mixture – Gas mixture containing oxygen; used for incubation of microorganisms that require oxygen for life.

Air – The mixture of gases that surrounds the earth. The composition of air is 78.08% nitrogen, 20.95% oxygen, 0.03% carbon dioxide, and 0.93% argon. Standard air has a density of 0.075 lb/ft^3 (1.2 kg/m^3) measured dry at 70°F (21°C) and 760 mm Hg pressure, M.W. 28.3.

Anaerobic Gas Mixture – A gas mixture containing no oxygen, used for incubation of microorganisms that do not require free oxygen for life.

Anhydrous – A descriptive term meaning without water.

Auto Ignition Temperature – The minimum temperature at which a substance will ignite in the air when there is no ignition source. For liquids, it is defined as the lowest temperature at which a drop of solvent will ignite spontaneously.

Balance Gas – A gas used to top off a gas mixture after individual component gases at specified concentrations are added.

Base – A chemical compound that can react with an acid to form a salt.

Boiling Point – The temperature at which the vapor pressure of a liquid equals the atmospheric pressure (usually given at 760 mm Hg).

BS – British Standard. A standard from the British Standards Institution. BS 341 recommends cylinder valve outlet connections for specific gas services based upon safety considerations.

Calibration Gas – A gas of accurately known concentration that is used as a comparative standard in analytical instrumentation.

Carrier Gas – Pure gases or gas mixtures used to move a sample to be analyzed through the gas analysis system at an even rate and provide a zero reference (baseline) when a sample is not being detected.

Caution – A term used in precautionary labeling to denote a lower degree of hazard than the terms Danger or Warning.

CGA – Compressed Gas Association. An association that recommends cylinder valve outlet connections for specific gas services based on safety considerations.

Compressed Gas – Any material or mixture having in the container either an absolute pressure exceeding 40 psia (3 bar) at 70°F (21°C) or an absolute pressure exceeding 104 psia (7 bar) at 130°F (54°C).

Compressed Gas in Solution – A nonliquefied compressed gas that is dissolved in a solvent.

Corrosive – Gases that corrode material or tissue with which they come in contact, or do so in the presence of water, are classified as corrosive. It is essential that equipment used for handling corrosive gases be constructed of proper materials. Proper protective clothing and equipment must be used to minimize exposure to corrosive materials.

Critical Pressure – The pressure required to liquefy a gas at the critical temperature.

Critical Temperature – The temperature above which a gas cannot be liquefied by pressure alone.

Cylinder – A pressure vessel designed for pressure higher than 40 psia (3 bar) and having a circular cross-section.

Danger – A term denoting the highest degree of hazard.

Desorption – The leaching out of gas, liquids or dissolved substances from solid material.

DIN – Deutsche Norm. A standard from the Deutsches Institut fur Normung. DIN 477 recommends cylinder valve outlet connections for specific gas services based upon safety considerations.

Explosion Proof – An enclosure for an electrical apparatus designed that an explosion of flammable gas or vapor inside the enclosure will not ignite flammable gas or vapor outside.

FID – Flame ionization detector.

FID Fuels – Hydrogen-nitrogen and hydrogen-helium mixtures burned as a source of heat and power in FIDs.

Flammable – A substance that will ignite easily and burn rapidly in the presence of an oxidizer.

Flashback – The phenomenon characterized by vapor ignition and flame travel back to the vapor source.

GC – Gas chromatograph.

Impurity – Amount of foreign material or contaminants found in a pure material.

Inert – Gases that do not react with other materials under normal temperature and pressure.

Liquefied Compressed Gas – A gas that is partially liquid at its charging pressure and a temperature of 70°F (21°C).

Mole – Mass numerically equal to its molecular weight. A gram mole is the weight in grams equal to the molecular weight.

Molecular Weight – The sum of the atomic weights of all the constituent atoms in a molecule.

NEN – Nederlandse Norm. A standard from the Dutch Normalisation Institute. NEN 3268 recommends cylinder valve outlet connections for specific gas services based upon safety considerations.

Nonliquefied Compressed Gas – A nonliquefied compressed gas is a gas, other than gas in solution, that under the charged pressure is entirely gaseous at a temperature of 70°F (21°C).

NTP – Normal temperature and pressure, 20°C and 760 torr.

Off-Gassing – The removal of gas, liquids or dissolved substances from the surface of solids.

Oxidant – A gas that does not burn but will support combustion.

Partial Pressure – In any gas mixture, the total pressure is equal to the sum of the pressures (partial) that each gas would exert were it alone in the volume occupied by the mixture.

PPB – Parts per billion.

PPM – Parts per million.

PPT – Parts per trillion.

Pyrophoric – Materials that spontaneously ignite on contact with air at normal conditions.

Specific Gravity – The ratio of the weight of any volume to the weight of an equal volume of another substance taken as a standard. For solids or liquids, the standard is usually water and for gases, the standard is air.

Specific Heat – The amount of heat required to raise the unit weight of a substance one degree of temperature at constant pressure.

Specific Volume – The volume of a unit weight of a substance at a given temperature.

STP – Standard temperature and pressure, 0°C and 760 torr.

Sublimation – The process of passing from a solid state directly to a gaseous state.

TLV – Threshold Limit Value. The time-weighted average concentration of an airborne substance that represents the condition under which it is believed nearly all workers may be exposed in a normal eight-hour day, five-day work week without suffering adverse effect.

Toxic Gas – Gases that may chemically produce injurious or lethal effects to humans.

Vapor Pressure – The pressure exerted when a solid or a liquid is in equilibrium with its own vapor at a particular temperature.

Warning – A term indicating an intermediate degree of hazard in precautionary labeling between Danger and Caution.

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