UPDATED 5TH EDITION

DESIGN

AND SAFETY HANDBOOK

FOR SPECIALTY GAS DELIVERY SYSTEMS

AIR LIQUIDE™
SPECIALTY GASES

Contents

Compressed Gas Safety
- Gas Categories ... 2
- Physical Properties ... 6
- Storage and Use ... 8

Pressure Regulators
- Selection and Operation ... 10
- Gas Compatibility ... 13
- Selection Guide ... 16
- Maintenance ... 18
- Accessories ... 20

Delivery Systems
- Safety ... 22
- Sizing Lines ... 24
- Design ... 26
- Semiconductor ... 30
- Accessories ... 31
- Manifold Specification Worksheet ... 33

Application Connections ... 34

Compressed Gas Cylinders
- Valve Outlets and Connections ... 39
- Selecting Outlets and Connections ... 40
- Specifications ... 44

Definitions and Terminology ... 48

Table Index

Gas Categories ... 4
Physical Properties ... 6
Gas Compatibility Guide ... 13
Regulator Selection Guide ... 16
Maximum Service Pressure Ratings ... 24
Specific Gravity of Gases ... 24
Capacity Correction for Gases other than Air ... 24
Capacity of Distribution Lines in SCFH (NL/m) @ 60°F (16°C) ... 25
Valve and Outlet Connections ... 40

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

Remaining competitive in today's global economy requires industrial processes to move at speeds never before imagined. Moreover, industries have learned they must continually seek new ways to improve end-product quality and performance, while reducing the cost of production.

Many industries are also faced with meeting tougher regulations governing process emissions that harm our environment. In order to survive, let alone prosper in such a climate, reliable testing methods are essential to ensure regulation compliance and to achieve a quality end product that is cost-effective to produce. While we have the analytical instruments needed to meet this challenge, they are only as reliable as the gases used to calibrate them, as well as the equipment that delivers those gases.

Use of quality gas distribution equipment is critical. It not only protects the purity and integrity of the specialty gases in use, but also protects the health and welfare of the user. This handbook is intended to aid in the safe design and operation of nearly any type of specialty gas delivery system. Our goal is to help you acquire and maintain an efficient, safe and reliable system that will deliver the specialty gas to your point-of-use—at the specified purity level, pressure and flowrate.

As a world leader in the supply of gases for industry, health and the environment, Air Liquide has a 100+ year history developing innovative specialty gas technology. This also includes helping to develop protocols and certified reference materials through partnerships with agencies such as:

- U.S. Environmental Protection Agency (EPA)
- National Institute for Standards and Technology (NIST)
- Van Swinden Laboratorium BV (VSL)

Our products include high-purity and mixed gases for nearly any application imaginable, as well as high-performance Scott™ brand equipment to safely and efficiently handle these gases.

Compressed Gas Safety:

Gas Categories

All gas cylinders 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 compressed gas should be familiar with the potential hazards before using the gas. In addition to chemical hazards, hazards accompanying high pressure or low temperature may also be present due to the physical state of the gas (i.e. liquefied or nonliquefied).

Definitions

Compressed Gas

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 a pressure of 14.7 psia (1 bar) or greater. Most compressed gases will not exceed 2,000–2,640 psig (138–182 bar), though some go up to 6,000 psig (414 bar).

Nonliquefied Compressed Gas

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 Gas

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.

Asphyxiant Gases

These are gases that are non or minimally toxic but can dilute the oxygen in air, leading to death by asphyxiation if breathed long enough. Toxic gases in large enough concentrations can also cause asphyxiation and lead to death by other mechanisms such as interaction with the respiratory system by competing with oxygen (such as carbon monoxide) or causing direct damage (such as phosgene). Because asphyxiant gases are relatively inert, their presence in large quantities may not be noticed until the effects of elevated blood carbon dioxide are recognized by the body. Notable examples of asphyxiant gases are nitrogen, argon and helium.

Corrosive Gases

These are gases that corrode material or tissue on contact, or in the presence of water. They are reactive and can also be 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, mucous 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.

Cryogenic Gases

These are gases with a boiling point of -130°F (-90°C) at atmospheric pressure. They are extremely cold and can produce intense burns. They can be nonflammable, flammable or oxidizing. Cryogenic liquids can build up intense pressures. At cryogenic temperatures, system components can 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. 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 up when they are spilled.

Flammable Gases

These are 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. A change in temperature, pressure or oxidant concentration may vary the flammable range considerably. All possible sources of ignition must be eliminated. Use a vent line made of stainless steel, purge with an inert gas and use a flash arrester. It is important to have a fire extinguisher where flammable gases are used and stored. A hand-held gas detector is also recommended to guard against gas buildup and to detect leaks in gas lines. Remember that the source of gas must be eliminated before attempting to put out a fire involving flammable gases.

Inert Gases

These are gases that do not react with other materials at ordinary temperature and pressure. They are colorless and odorless, as well as nonflammable and nontoxic. Inert gases 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.

Oxidant Gases

These are gases that do not burn but will support combustion, and they can displace oxygen in air (with the exception of O_2 itself). It is essential that all possible sources of ignition 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 a cylinder or equipment used for oxidant services. Use only equipment that is intended for this type of service. Use only a regulator that is designated and labeled "cleaned for O_2 service."

Pyrophoric Gases

Gases such as silane, phosphine, diborane and arsine are commonly used in the semiconductor industry and are extremely dangerous to handle because they do not require a source of ignition to explode or catch fire. Pyrophoric gases will ignite spontaneously in air at or below 130°F (54°C). Specific gases may not ignite in all circumstances or may explosively decompose. Under certain conditions, some gases can undergo polymerization with release of large amounts of energy in the form of heat.

Toxic or Poison Gases

These are gases that may chemically produce lethal or other health effects. They can be high-pressure, reactive, flammable or nonflammable, and/or oxidizing in addition to their toxicity. The degree of toxicity and the effects will vary depending on the gas. Permissible exposure levels must be strictly adhered to (please refer to OSHA PEL's listed in our specialty gas catalog or at ALspecialtygases.com). Read the MSDS thoroughly before use. Never work alone with toxic gases—inspect the 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.

Use toxic gases in a well-ventilated area. It is important to have gas detectors, self-contained breathing apparatus and protective clothing on hand. The breathing apparatus must 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, close the door and safely put on the apparatus. Full body showers, eye washes, fire alarms and firefighting equipment should be readily accessible.

Refer to your local building code for storage and use requirements for toxic gases. Keep your inventory of toxic or poison gases at a minimum. When a project is completed, return leftover cylinders to Air Liquide. 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.

WARNING

Many specialty gases have flammable, toxic, corrosive, oxidizing, pyrophoric and other hazardous properties. These gases can cause serious injury or death, as well as property damage, if proper safety precautions are not followed.

Compressed Gas Safety:

Gas Categories continued

Gas mixtures assume the categories of all components of the mixture with the predominant component determining the final classification of the mixture. The exception is when a component is toxic to a degree sufficient enough to influence the final classification. The information offered in this listing is assumed to be reliable and is for use by technically qualified personnel at their discretion and risk. Air Liquide does not warranty the data contained herein.

Specialty Gas	Nonliquefied Compressed	Liquefied	Flammable Limits in Air Vol.%(1)	Oxidant	Inert	Corrosive	Toxic
Acetylene	(2)		2.5 – 80				
Air	X			X			
Allene		X	2.1 – 13				
Ammonia		X	15 – 25			X	
Argon	X				X		
Arsine		X	5.1 – 78				(4)
Boron Trichloride		X				X	X
Boron Trifluoride	X					X	(4)
1,3-Butadiene		(5)	2 – 11.5				
Butane		X	1.9 – 8.5				
Butenes		X	1.6 – 9.3				
Carbon Dioxide		X			X		
Carbon Monoxide	X		12.5 – 74				X
Carbonyl Sulfide		X	12 – 28.5			(3)	X
Chlorine		X		X		(3)	(4)
Cyanogen		X	6.6 – 32				(4)
Cyclopropane		X	2.4 – 10.4				
Deuterium	X		5 – 75				
Diborane	X		0.8 – 98				(4)
Dimethylamine		X	2.8 – 14.4			X	
Dimethyl Ether		X	3.4 – 18				
Ethane		X	3 – 12.4				
Ethyl Acetylene		X	1.1 – 6.6(7)				
Ethyl Chloride		X	3.8 – 15.4				
Ethylene	X		3 – 34				
Ethylene Oxide		(6)	3.6 – 100				X
Fluorine	X			X			(4)
Germane	X		2 – 98(7)				(4)
Halocarbon-12 (Dichlorodifluoromethane)		X			X		
Halocarbon-13 (Chlorotrifluoromethane)		X			X		
Halocarbon-14 (Tetrafluoromethane)	X				X		
Halocarbon-22 (Chlorodifluoromethane)		X			X		

(1) Flammable limits are at normal atmospheric pressure and temperature. Other conditions will change the limits.
(2) Dissolved in solvent under pressure. Gas may be unstable and explosive above 15 psig (1 bar).
(3) Corrosive in the 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 estimated.

Specialty Gas	Nonliquefied Compressed	Liquefied	Flammable Limits in Air Vol.%[1]	Oxidant	Inert	Corrosive	Toxic
Helium	X				X		
Hydrogen	X		4 – 75				
Hydrogen Bromide		X				(3)	(4)
Hydrogen Chloride		X				(3)	(4)
Hydrogen Fluoride		X				X	(4)
Hydrogen Sulfide		X	4.3 – 46		(3)	(3)	(4)
Isobutane		X	1.8 – 8.4				
Isobutylene		X	1.8 – 9.6				
Krypton	X				X		
Methane	X		5 – 15				
Methyl Chloride		X	8.1 – 17.4				
Methyl Mercaptan		X	3.9 – 21.8				(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 – 98				(4)
Propane		X	2.1 – 9.5				
Propylene		X	2 – 11.1				
Silane	X		1.5 – 98				
Sulfur Dioxide		X				(3)	(4)
Sulfur Hexafluoride		X			X		
Sulfur Tetrafluoride		X				X	(4)
Trimethylamine		X	2 – 11.6			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. Other conditions will change the limits.
(2) Dissolved in solvent under pressure. Gas may be unstable and explosive above 15 psig (1 bar).
(3) Corrosive in the 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.

Compressed Gas Safety:

Physical Properties of Gases

Pure Gases		Molecular Weight	Vapor Pressure psia 21°C	Specific Gravity air=1	Specific Volume		Boiling Point °C
Common Name	Chemical Formula				CF/lb	m³/kg	
Acetylene	C_2H_2	26.038	43.2	0.91	14.7	0.91	-85
Air	–	28.96		1	13.33	0.82	-194.3
Allene	C_3H_4	40.065	107	1.411	9.6	0.6	-34.4
Ammonia	NH_3	17.031	128.8	0.597	22.6	1.4	-33.4
Argon	Ar	39.95		1.38	9.7	0.6	-185.9
Arsine	AsH_3	77.95	1100**	2.695	5	0.31	-62
Boron Trichloride	BCl_3	117.17	4.4	4.05	3.3	0.2	12.5
Boron 11 Trifluoride	BF_3	67.81		2.37	5.6	0.16	-100.3
Boron Trifluoride	BF_3	67.81		2.37	5.6	0.16	-100.4
Bromine Trifluoride	BrF_3	136.9	19.1	4.727			-128
1,3 Butadiene	C_4H_6	54.092	36.1	1.898	6.9	0.43	-4.4
n-Butane	C_4H_{10}	58.124	31	2.076	6.4	0.4	-0.5
1-Butene	C_4H_8	56.11	38.2	1.998	6.7	0.42	-6.3
cis-2-Butene	C_4H_8	56.11	27.7	1.997	6.7	0.42	3.7
trans-2-Butene	C_4H_8	56.11	29.7	1.997	6.7	0.42	0.9
Carbon Dioxide	CO_2	44.01	853.4	1.521	8.76	0.55	-78.5††
Carbon Monoxide	CO	28.01		0.968	13.8	0.86	-191.1
Carbonyl Sulfide	COS	60.075	9412**	2.1	6.5	0.4	-50
Chlorine	Cl_2	70.906	100.2	2.49	5.4	0.33	-34.1
Chlorine Trifluoride	ClF_3	92.46	< 760**	3.14	4.2	0.262	11.8
Cyanogen	CNCN	52.036	69.6	1.806	7.4	0.46	-21.2
Cyanogen Chloride	CNCl	61.47	133.33†	1.98	6.3	0.393	13
Cyclopropane	C_3H_6	42.08	75	1.45	9.2	0.574	-34
Deuterium	D_2	4.032		0.139	95.9	5.95	-249.6
Diborane	B_2H_6	27.67		0.95	13.98	0.88	-92.8
Dichlorosilane	SiH_2Cl_2	101.01	1230**	3.48	3.83	0.24	8
Dimethylamine	$(CH_3)_2NH$	45.08	1292**	1.55	8.5	0.53	7
Dimethyl Ether	$(CH_3)_2O$	46.07	77	1.59	8.4	0.52	-24.8
2,2-Dimethylpropane	C_5H_{12}	72.15	1100**	2.622	5.3	0.331	9.5
Disilane	Si_2H_6	62.22	46				-14.15
Ethane	C_2H_6	30.07	558.7	1.047	12.8	0.79	-88.7
Ethyl Acetylene	C_4H_6	54.09	8.5	1.966	7.2	0.45	8.1
Ethyl Chloride	C_2H_5Cl	64.52	1000**	2.22	6	0.37	12.3
Ethylene	C_2H_4	28.054		0.974	13.8	0.86	-103.8
Fluorine	Fl_2	37.997		1.696	10.2	0.64	-187
Germane	GeF_4	76.62	638	3.43	5.05	0.315	-88.4
Halocarbon 11	CCl_3F	137.7	796**	5.04	2.993	0.186	23.8
Halocarbon 12	CCl_2F_2	120.91	84.9	4.2	3.1	0.19	-29.8
Halocarbon 13	$CClF_3$	104.46	473.4	3.8	3.5	0.22	-81.4
Halocarbon 13 B_1	$CBrF_3$	178.91	206	5.3	2.6	0.16	-58
Halocarbon 14	CF_4	88.01		3.038	4.4	0.27	-128
Halocarbon 21	$CHCl_2F$	102.92	1195**	3.82	3.5	0.22	8.9
Halocarbon 22	$CHClF_2$	86.47	137.7	3.08	4.4	0.27	-40.7
Halocarbon 23	CHF_3	70.01	635.3	2.43	5.5	0.34	-82.1
Halocarbon 113	$CCl_2F\text{-}ClF_2$	187.38	5.4	2.39			47.7
Halocarbon 114	$C_2Cl_2F_4$	170.93	26.1	5.93	2.3	0.14	3.6
Halocarbon 115	C_2ClF_6	154.45	117.7	5.569	2.4	0.15	-39
Halocarbon 116	C_2F_6	138.01	398.9	4.773	2.8	0.17	-78.2
Halocarbon 142B	CH_3CClF_2	100.5	42.1	3.63	3.6	0.22	-9.6
Halocarbon 152A	$C_2H_4F_2$	66.05	87	2.36	5.85	0.365	-25

** mmHg
† kPa
†† Sublimation point

Pure Gases		Molecular Weight	Vapor Pressure psia 21°C	Specific Gravity air=1	Specific Volume		Boiling Point °C
Common Name	Chemical Formula				CF/lb	m3/kg	
Halocarbon C-318	C_4H_8	200.03	25	7.33	1.9	0.12	-6
Halocarbon 1132A	$C_2H_2F_2$	64.04		2.2	6	0.37	
Helium	He	4.003		0.138	96.7	6	-268.9
Hexafluoropropylene	C_3F_6	150.03		1.583	2.58	0.156	-29
Hydrogen	H_2	2.016		0.0696	192	11.9	-252.8
Hydrogen Bromide	HBr	80.92	22.77†	2.7	4.8	0.3	-67
Hydrogen Chloride	HCl	36.46	626.7	1.268	10.9	0.68	-84.9
Hydrogen Fluoride	HF	20.01	110**	1.27	17	1.05	19.4†
Hydrogen Selenide	H_2Se	80.976	139.6	2	4.8	0.3	41.2
Hydrogen Sulfide	H_2S	34.08	267.7	1.189	11.2	0.69	-59.7
Iodine Pentafluoride	IF_6	221.9		3.189 (liq.)	1.7	0.11	
Isobutane	C_4H_{10}	58.124	45.4	2	6.5	0.4	-11.7
Isobutylene	C_4H_8	56.11	39	1.997	6.7	0.42	-6.9
Krypton	Kr	83.8		2.889	4.6	0.29	-153.3
Methane	CH_4	16.043		0.55	23.7	1.47	-161.4
Methyl Acetylene	C_3H_4	40.065	60	1.411	9.7	0.605	-23.2
Methyl Bromide	CH_3Br	94.94	2.4†	3.3	4.1	0.25	3.6
3-Methylbutene-1	C_5H_{10}	70.135		2.549	5.5	0.343	
Methyl Chloride	CH_3Cl	50.49	3796**	1.74	7.6	0.47	-24.2
Methyl Fluoride	CH_3F	34.03	538	1.195	11.36	0.709	-78.4
Methyl Mercaptan	CH_3SH	48.11	1535**	1.66	7.5	0.47	6.8
Monoethylamine	$C_2H_5NH_2$	45.08		1.56	7.9	0.49	
Monomethylamine	CH_3NH_2	31.058	1.08	1.07	12.1	0.755	-6.3
Neon	Ne	20.183		0.696	19.2	1.19	-245.9
Nitric Oxide	NO	30.006		1.04	12.9	0.8	-151.7
Nitrogen	N_2	28.1		0.967	13.8	0.86	-195.8
Nitrogen Dioxide*	NO_2	46.005	14.7	1.58	4.7	0.29	21.2
Nitrogen Trifluoride	NF_3	71		2.48	5.44	0.034	-129
Nitrogen Trioxide	N_2O_3	76.01			5.1	0.31	
Nitrous Oxide	N_2O	44.013	774.7	1.53	8.7	0.54	-88.4
Oxygen	O_2	32		1.105	12.1	0.755	-182.9
Perfluoropropane	C_3F_8	188.02	116	6.683	2	0.12	-36.7
Phosgene	$COCl_2$	98.92	10.17	3.4	3.9	0.24	7.55
Phosphine	PH_3	34		1.184	11.4	0.71	-87.7
Propane	C_3H_8	44.1	124.3	1.55	8.7	1.54	-42.1
Propylene	C_3H_6	42.08	151.9	1.476	9.1	0.58	-47.7
Silane	SiH_4	32.13		1.114	12.1	0.75	-112
Silicon Tetrafluoride	SiF_4	104.08		3.7	3.7	0.23	-95.1
Sulfur Dioxide	SO_2	64.063	49.1	2.262	5.9	0.37	-10.1
Sulfur Hexafluoride	SF_6	146.054	320	5.114	2.5	0.16	-63.9††
Sulfur Tetrafluoride	SF_4	108.06		3.53	3.7	0.23	-40.4
Tetrafluoroethylene	C_2F_4	100.016	441.3	3.53	3.8	0.24	-78.4
Trimethylamine	$(CH_3)_3N$	59.11	1.9†	2.087	6	0.37	3
Tungsten Hexafluoride	WF_6	297.84		10.29	1.3	0.09	
Vinyl Chloride	C_2H_3Cl	62.5	2530**	2.15	6.2	0.387	-13.9
Xenon	Xe	131.3		4.553	2.9	0.18	-108.3

* Or nitrogen tetroxide (N_2O_4)
** mmHg
† atm
†† Sublimation point

Compressed Gas Safety:

Storage and Usage

Wear safety glasses, gloves and shoes at all times when handling cylinders.

Appropriate firefighting, personnel safety and first aid equipment should be available in case of emergencies. Follow all federal, state and local regulations concerning the storage of compressed gas cylinders. Refer to the Compressed Gas Association (CGA) Pamphlet P-1 for further information.

Gas Cabinet with Scott™ Model 8404 ChangeOver

Scott Gas Safety Cabinets can be used to contain toxic, flammable or corrosive gases.

Storage

Storage Area – Store gas cylinders in a ventilated and well illuminated area away from combustible materials. Separate gases by type and store them in assigned locations that can be readily identified. OSHA requires that cylinders containing flammable gases be stored at least 20 feet (6.1 meters) from cylinders containing oxygen and other oxidants, or separated by a fire-resistant wall with a rating of at least 30 minutes. 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 to increase 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 Air Liquide 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 Air Liquide 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 PTFE 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. Refer to page 39 for additional information.

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
- Automatically shutoff gas in the event of catastrophic failure
- Effectively control 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 contain 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. 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).

Consideration should be given to materials of construction when selecting a gas cabinet. For example, using 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.

SMARTOP™ valve with open cylinder cap

Safety innovations that protect personnel and improve ease-of-use

Some high-pressure gas cylinders, such as those offered by Air Liquide, feature a nonremoveable, ergonomic cap. This innovative design replaces traditional screw-on type caps that can be difficult to remove and accidentally misplaced. It also provides added safety during transport and service, permits easier cylinder handling, and minimizes insect nesting when a cylinder is stored outside.

Most pure gases from Air Liquide feature SMARTOP equipped with a lever-activated valve for fast gas shutoff in case of emergency. A built-in pressure gauge shows cylinder contents without the need for a regulator and auto flow restriction provides protection against pressure breach in the event of an accident.

Pressure Regulators:

Selection and Operation

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

Air Liquide offers more than 50 regulator series with more than 120 different pressure ranges. All are intended for specific applications. Information for gases listed in our specialty gas catalog includes recommended pressure regulators for best service.

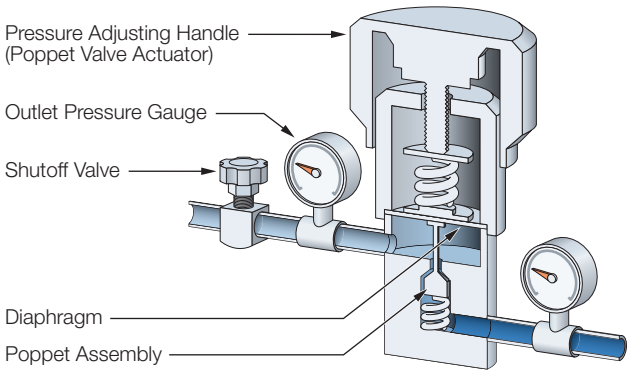
Single-Stage vs Two-Stage – There are two basic types of regulators. Duration of gas usage helps to identify whether a single-stage or two-stage regulator provides the best service. A single-stage regulator is a good performer for short duration gas usage. It reduces the cylinder pressure to the delivery 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, adjusted to the desired reduced pressure, and then remains in service until the cylinder is ready for changeout.

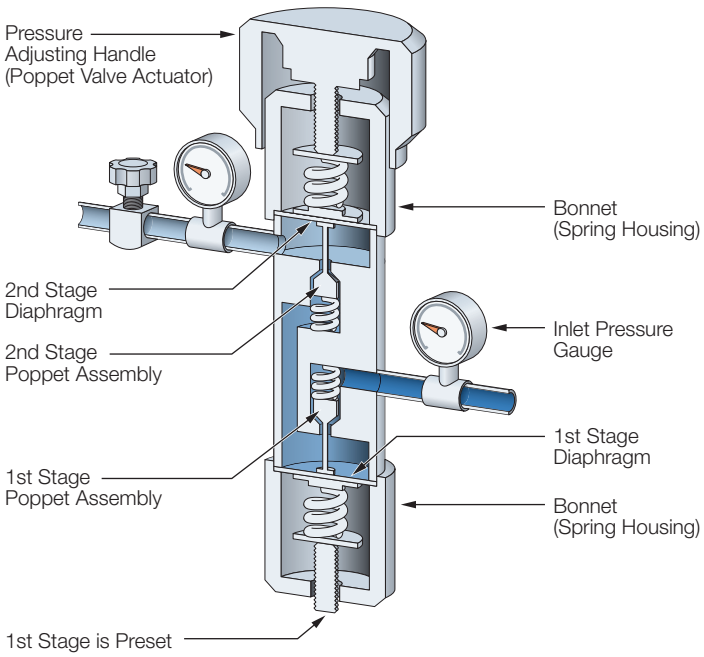
Materials of Construction – A regulator must be constructed with materials compatible with the intended gas service and application. When selecting your regulator, you should first consider the wetted materials (those that will come in contact with the gas). Typical materials used for regulator construction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

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

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. Buna-N and 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. First, 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. Second, 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.

Scott™ Single-Stage Ultra-High-Purity Regulator
Model 213 – Stainless Steel, Corrosive Service

Scott Two-Stage Ultra-High-Purity Regulator
Model 318 – Brass, Noncorrosive Service

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.

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 flowrates but a relatively large supply pressure effect. Conversely, the two-stage regulator shows a steeper slope in droop but only small supply pressure effects.

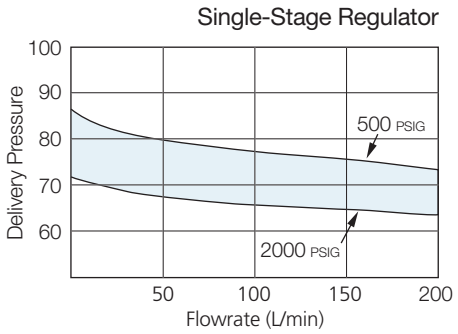
The effect of these differences on performance can be illustrated with some examples. For instance, when a centralized gas delivery system is supplying a number of different chromatographs, flowrates are apt to be fairly constant. Supply pressure variations, however, may be abrupt, especially when automatic 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.

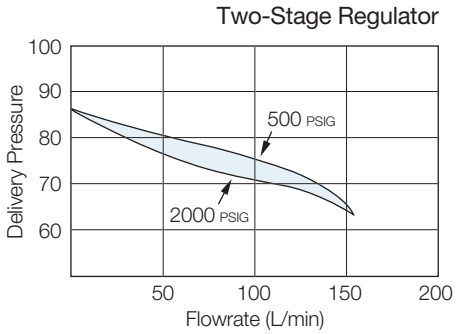
Pressure Regulators:

Selection and Operation continued

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

The envelopes are bound by inlet pressure curves of 2000 psig (138 bar) and 500 psig (35 bar). Each regulator was set to the indicated 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 flowrate 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 to 50 psig (0.1 to 3 bar) will typically be supplied with a 0 to 60 psig (0 to 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 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, DISS, 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.

Pressure Regulators:

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 a 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 Air Liquide Specialty Gas Catalog or contact your Air Liquide 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.
- 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 DuPont Performance Plastics 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 (69 bar).
- C7 Satisfactory below 3000 psig (207 bar) where gas velocities do not exceed 30 ft./sec.
- C8 Compatibility depends on condition of use.

Gas Encyclopedia

First published in 1976, this reference book quickly became a must-have in the gas industry. Over 1,000 pages includes information such as thermodynamics, safety, tables of physical and biological properties, and much more.

Available in print or at www.airliquide.com. Contact your Air Liquide representative for more information.

Pressure Regulators:

Gas Compatibility continued

Pure Gases		Materials of Construction																	
		Metals							Plastics						Elastomers				
Common Name	Chemical Formula	Brass	303 SS	316 SS	Aluminum	Zinc	Copper	Monel®	PCTFE	PTFE	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	•	•	•	•	?	•	•	•	•	•	•	•	?	?	•	?	?	?
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	•	•	•

* Satisfactory for use with EPR (Ethylene Propylene Rubber) and EPDM. See key on page 13 for more information.

Pure Gases		Materials of Construction																	
		Metals							Plastics						Elastomers				
Common Name	Chemical Formula	Brass	303 SS	316 SS	Aluminum	Zinc	Copper	Monel®	PCTFE	PTFE	Tefzel®	Kynar®	PVC	Polycarbonate	Kalrez®	Viton®	Buna-N	Neoprene	Polyurethane
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	•	•	•
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
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 13 for more information.

Pressure Regulators:

Regulator Selection Guide

Regulator Model Series	Gas Service										Materials						Inlet Pressure					
	Type			Properties							Body				Diaphragm		Maximum Inlet Range					
	General Purpose	High-Purity	Ultra-High-Purity	Inert	Flammable	Oxidant	Toxic	Noncorrosive	Corrosive	Reactive	Brass	Stainless Steel	Aluminum	Other	Stainless Steel	Elastomer/Plastic	0 – 6000 psig	0 – 3000 psig	0 – 1000 psig	0 – 500 psig	0 – 400 psig	0 – 250 psig
14		•		•	•	•		•			•				•			•				
14A-165		•		•	•	•		•			•				•							•
14DFR	•			•	•	•		•			•					•						
19VOC			•	•	•	•	•	•	•	•		•			•			•				
20B	•			•	•	•		•			•					•		•				
23A	•			•	•			•					•			•						•
23S	•			•	•			•				•				•						•
24	•			•	•	•		•			•					•					•	
27	•			•	•			•			•								•			
38	•			•	•			•	•			•							•			
202	•			•	•	•		•			•					•		•				
202-510A	•			•	•						•					•				•		
205		•		•	•	•		•			•				•			•				
206B		•		•	•	•		•			•				•			•				
206S		•		•	•	•		•	•			•			•			•				
208B		•		•	•	•		•			•							•				
208S		•		•	•	•	•	•	•	•		•						•				
209	•			•	•	•		•			•					•		•				
211		•		•	•	•		•			•				•			•				
213			•	•	•	•		•	•			•			•			•				
215			•	•	•	•		•	•			•			•			•				
216B		•		•	•	•		•			•				•			•				
216S		•		•	•	•	•	•	•	•		•			•			•				
217			•	•	•	•	•	•	•	•		•			•			•				
220S		•		•	•	•		•	•			•			•			•				
226		•		•	•	•		•	•				•		•					•		
228B		•		•	•	•		•			•				•			•				
228S		•		•	•	•	•	•	•	•		•			•			•				
229B	•			•	•	•		•			•							•				
242	•			•	•	•		•			•					•					•	
247A80	•			•	•			•					•					•				
261	•			•	•	•		•					•			•						•
262	•			•	•	•		•			•					•						•
318			•	•	•	•		•			•				•			•				
500	•			•	•	•		•			•							•				
720	•			•	•	•		•						•		•						•
730	•			•	•	•		•						•		•		•				
750B		•		•	•	•		•			•				•			•				
750S		•		•	•			•	•			•			•			•				
2172			•	•	•	•	•	•	•	•		•			•			•				
2700B/10B			•	•	•	•		•			•				•			•				
2700S/10S			•	•	•	•		•	•			•			•			•				
2800B		•		•	•	•		•			•				•							•
2800S		•		•	•	•		•	•			•			•							•
2900B		•		•	•	•		•			•						•					
2900S		•		•	•	•	•	•	•	•		•					•					
3300			•	•	•	•		•			•				•			•				

Most regulators offered are approved for oxygen service as per CGA 4.1 “Cleaning Equipment for Oxygen Service.”

Regulator Model Series	Delivery Pressure: Maximum Outlet Range							Pressure Reduction Design						Regulator Type					Gauges		
	0 – 30 psig	31 – 75 psig	76 – 150 psig	151 – 250 psig	251 – 500 psig	501 – 1000 psig	1001+ psig	Diaphragm	Piston	Preset	Adjustable	Single-Stage	Two-Stage	Cylinder	In-Line	Back-Pressure	Lecture Bottle	SCOTTY™	Inlet	Outlet	Outlet Valve
14	•	•	•					•	•		•		•	•			•		•	•	○
14A-165	•							•	•		•		•					•	•	•	○
14DFR								•	•	•			•	•	•			•	•		
19VOC		•						•			•	•		•					•		
20B	•	•	•					•			•	•					•		•	•	•
23A	•	•	•	•				•			•	•			•				○	○	
23S	•	•	•	•				•			•	•			•				○	○	
24	•	•						•			•	•		•	•			•	•		○
27		•							•	•		•		•				•	•		▲
38		•							•	•		•		•				•	•		▲
202	•	•	•	•				•			•	•		•	•				•	•	•
202-510A	•							•			•	•		•					•	•	•
205	•	•	•	•				•			•	•		•	•				•	•	•
206B	•	•	•					•			•	•		•	•				•	•	○
206S	•	•	•					•			•	•		•	•				•	•	○
208B			•	•	•	•	•		•		•	•		•	•				•	•	•
208S			•	•	•	•	•		•		•	•		•	•				•	•	•
209	•	•	•	•				•			•		•	•					•	•	•
211	•	•	•	•				•			•		•	•					•	•	•
213	•	•	•	•	•			•			•	•		•	•				•	•	•
215	•	•	•	•	•			•			•		•	•					•	•	•
216B	•	•	•					•			•		•	•	•		•		•	•	○
216S	•	•	•					•			•		•	•	•		•		•	•	○
217	•	•	•					•			•	•		•	•				•	•	•
220S	•	•	•					•			•	•					•		•	•	○
226	•	•	•					•			•	•		•	•			•	▲	▲	
228B	•	•	•	•				•			•	•		•	•				•	•	
228S	•	•	•	•				•			•	•		•	•				•	•	
229			•	•	•	•	•		•		•	•		•	•				•	•	
242	•							•		•		•		•					•		
247A80	•								•	•		•		•				•	•		
261		•						•			•	•		•				•	•		
262	•							•			•	•		•				•			
318	•	•	•	•	•			•			•	•		•	•				•	•	•
500				•	•				•		•	•			•					•	
720	•							•			•	•			•					•	•
730	•							•			•	•			•					•	•
750B	•							•			•		•	•					•	•	○
750S	•							•			•		•	•					•	•	○
2172	•	•	•					•			•		•	•					•	•	•
2700B/10B	•	•	•	•	•			•			•	•			•					•	
2700S/10S	•	•	•	•	•			•			•	•			•					•	
2800B	•	•	•	•				•			•	•				•					
2800S	•	•	•	•				•			•	•				•					
2900B					•	•	•		•		•	•		•	•				•	•	•
2900S					•	•	•		•		•	•		•	•				•	•	•
3300	•	•	•	•	•			•			•		•	•	•				•	•	•

○ Optional feature ▲ Comes with or without

Pressure Regulators:

Maintenance

Scott™ Tee Purge Assembly
Model P5

Scott Cross Purge Assembly
Model P74

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 Air Liquide 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	Replace1*
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 a poor grade of gas is used, or 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, ensure proper precautions are followed as recommended by Air Liquide.
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 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 Air Liquide.

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 Air Liquide or the regulator manufacturer for specific purging instructions.

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 shutoff. 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. Due to their hazardous and/or reactive nature, it's easy to understand the importance of effective purging when using pyrophoric, toxic, corrosive, flammable and oxidizing gases. However, it is also important to understand that process and analytical results can be adversely affected if proper purging techniques are not used, even when nonreactive gases are being used.

Purging is important whenever a new gas supply or a new piece of distribution equipment is introduced. This includes all gas distribution lines within a particular system, but is especially important for regulators. Unfortunately, purging of regulators is often either omitted entirely or is accomplished by allowing an arbitrary amount of gas to flow through the regulator. While this method of purging is better than nothing, there is a shortcoming to this method that many people fail to consider. Inside nearly all regulators, there are dead pockets in which contaminants can collect. These pockets tend to be unaffected by the flow of purge gas. Therefore, better purging results can be achieved by alternately pressurizing and depressurizing the regulator with an inert gas such as nitrogen. This method is known as dilution purging.

Overhaul – All regulators should be removed from service periodically and returned to the manufacturer for inspection and overhaul as appropriate (see Regulator Maintenance Schedule, page 18).

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 Air Liquide representative to determine the life expectancy of your particular regulator model.

Purging

Purging is an important procedure that is often overlooked in many gas processes. Before initial and subsequent system start-ups, the system should be purged in order to remove contaminants such as air and water vapor. Purging should also be done before changing out cylinders to remove residual corrosive or toxic gases for health and safety reasons.

Oxygen and moisture can adversely affect many applications where specialty gases are used. Other gases such as hydrogen chloride or chlorine will react with moisture to form highly corrosive acids. These acids attack most metals, including stainless steel, and will reduce the service life of pressure regulators and other system components. Proper purging can avoid these and other related problems.

Purging is often accomplished by simply flowing the service gas through the system and venting until the system has been cleansed. However, when the service gas is toxic, corrosive or otherwise hazardous, purging by this method is not practical. In these cases purging can be accomplished using an inert gas such as dry nitrogen.

Purge assemblies provide a convenient way to introduce purge gas into a system after the service gas supply has been connected. They are commonly available in tee or cross configurations as shown on page 18.

Pressure Regulators:

Accessories

Scott™ Stainless Steel Relief Valve
Model 65

Scott Flow Limit Safety Shutoff Valve
Model 1

Scott Stainless Steel Check Valve
Model 64

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 Shutoff 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 shutoff 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 shutoff valve installed between the cylinder outlet and the inlet of the pressure regulator is sufficient. For larger systems, additional shutoff valves with lower preset limits should be installed on branch lines.

The flow limit safety shutoff 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 shutoff at 6 to 10 times the anticipated actual process flowrate to allow normal gas usage as the cylinder pressure decreases.

Inlet Connection – Cylinder regulators require an inlet cylinder valve fitting (either CGA, DISS, etc.) that must be compatible with the mating fitting on the cylinder valve. Do not force connections. Never use pipe dope or PTFE 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.

Indicating Pressure Switch – An indicating pressure switch (like the Scott Model 69) 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.

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 shutoff valve. This eliminates feeding gas to any residual sparks or fire.

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. Air Liquide offers a wide variety of gas delivery systems (see pages 26–29). Consult your Air Liquide representative to discuss your system requirements in further detail.

Scott™ Annunciator
Model 8AE

Scott Pressure Switch Gauge
Model 69M

Scott Flash Arrester
Model 85

Delivery Systems:

Safety

Design in accordance with safety codes and standards

While it is beyond the scope of this handbook to list and fully discuss all appropriate safety codes, a specialty gas delivery system must be designed with these in mind. Federal, state and local, as well as industry standards, often apply. 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)

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. For 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 also 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 still significant forms include 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 or 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 also on the concentration of oxygen or other oxidant gases too. Hydrogen is a particularly dangerous material for two reasons. First, it burns with a nearly invisible flame. Secondly, it can collect undetected in pockets against 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 severe 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. Remember – don't work alone to continue an experiment after hours or over the weekend.

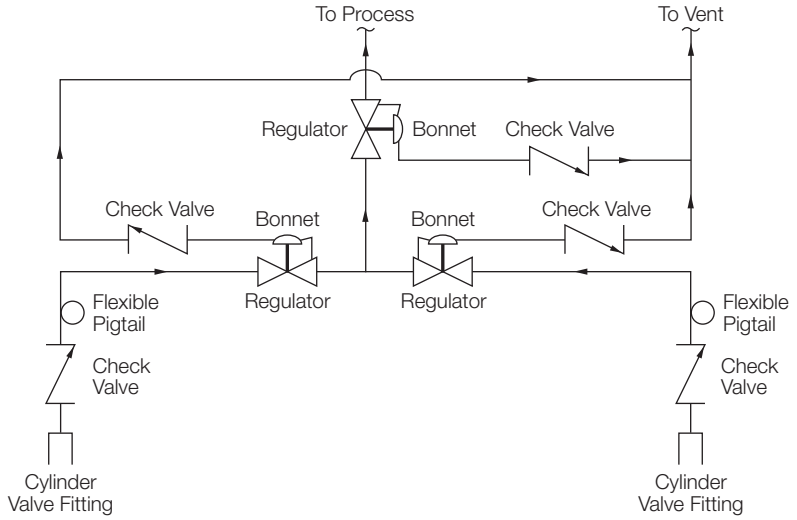
Remote Shutdown – Some applications require the ability to shut down the entire distribution system whenever certain hazardous conditions are detected. The capability of remote emergency shutdown may also be required. These requirements usually arise when particularly toxic or flammable gases are being 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 29 for more information regarding logic-controlled manifolds.

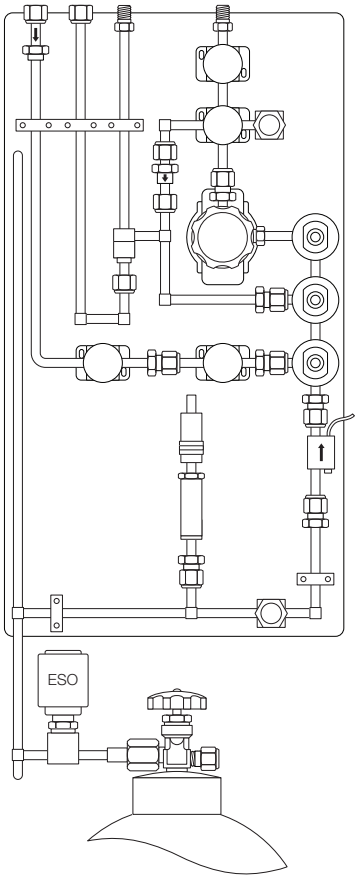
Capturing and Venting

Although ruptures of regulator diaphragms are quite rare, such ruptures and subsequent gas leaks could endanger personnel. Therefore 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.



Automatic Gas Panels
Model A-108

These systems are designed for hazardous applications that require fully automated vacuum assisted purging, They are available in a modular face-seal (VCR type) design, which minimizes total internal volume while maximizing leak integrity. A swept internal process gas volume eliminates the use of bourdon tube pressure gauges and minimizes all dead space volumes. These panels require the use of a MICROPURGE™ M series fully automatic control system to provide shutdown control and the automatic sequence of the alternating vacuum and nitrogen pressure purge process steps. This automatic procedure ensures complete removal of the process gas from the panel to eliminate the risk of exposure to the operator and contamination of the distribution system.

Delivery Systems:

Sizing Lines

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. Furthermore, the option of having stainless steel degreased and passivated is available. This process removes all traces of oil, grease and dirt to ensure optimal performance. Also, the installed costs of stainless steel and copper tubing are approximately the same.

Tube Material	Tube Size (Outside Diameter)	Wall Thickness	Service Pressure (Maximum)
Copper	1/8" (0.31 cm)	0.028" (0.07 cm)	2700 psig (186 bar)
	1/8" (0.31 cm)	0.035" (0.09 cm)	3600 psig (248 bar)
	1/4" (0.64 cm)	0.065" (0.17 cm)	3500 psig (241 bar)
	3/8" (1 cm)	0.065" (0.17 cm)	2200 psig (152 bar)
Stainless Steel	1/8" (0.31 cm)	0.028" (0.07 cm)	8500 psig (586 bar)
	1/4" (0.64 cm)	0.028" (0.07 cm)	4000 psig (276 bar)
	1/4" (0.64 cm)	0.035" (0.09 cm)	5100 psig (352 bar)
	1/4" (0.64 cm)	0.049" (0.12 cm)	7500 psig (517 bar)
	3/8" (1 cm)	0.035" (0.09 cm)	3300 psig (228 bar)
	1/2" (1.27 cm)	0.049" (0.12 cm)	3700 psig (255 bar)

Table 1 Specific Gravity of Gases

Gas	Specific Gravity
Air	1.00
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

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

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"	C 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)
A	10 (0.7)	90 (42)	B 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

Horizontal Manifold
Scott™ RM Series

Vertical Manifold
Scott 8100 Series

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.

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 13–15). 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.

Scott 8100 and RM Series single-station manifolds with brackets are 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.

Dual-cylinder manifolds include two pigtails and built-in 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.

Scott™ Model 8200 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 are the diaphragm packless-type designed 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 changeover manifolds, providing a means to connect more than one cylinder to each bank of the changeover 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 affect 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 (Semi-Automatic) Changeover – 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 150 psig (10 bar). The regulator on Bank #2 is set at 100 psig (7 bar).

As long as there is sufficient gas in Bank #1 to maintain the 150 psig (10 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 100 psig (7 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 100 psig (7 bar) and Bank #2 is at 150 psig (10 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 a drop in delivery pressure at changeover will not cause a problem. A line regulator should be installed downstream to eliminate pressure variations caused by differential-type manifolds.

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 (ARCAL™, ALIGAL™)

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, PTFE, Tefzel® and Viton®. Packed valves such as needle valves and ball valves are often used for flow shutoff.

Level 2 (ALPHAGAZ™ 1)

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 shutoff valves are diaphragm packless to prevent diffusion of contaminants into the specialty gas.

Level 3 (ALPHAGAZ™ 2)

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 Type 316 Stainless Steel, PTFE, Tefzel® and Viton®. Flow shutoff valves must be diaphragm packless.

Consulting the Air Liquide catalog 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.

Delivery Systems:
Design continued

Scott™ High-Purity Primary ChangeOver
Model 8ACS

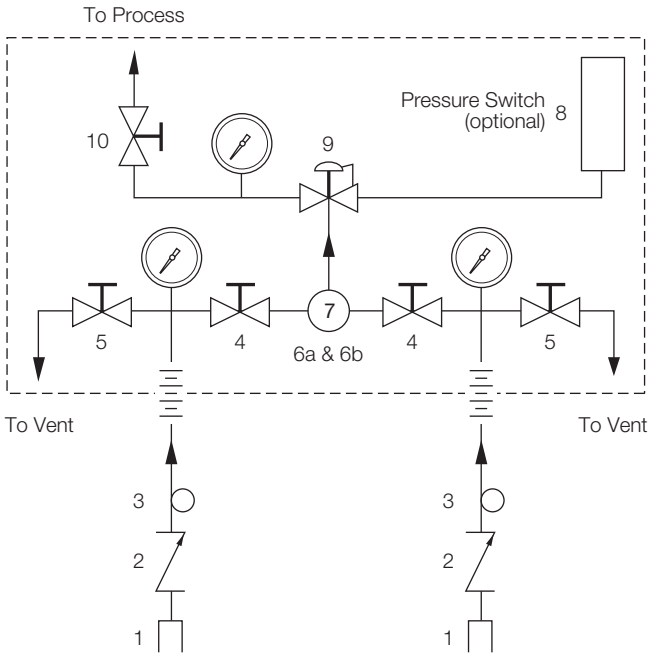
Scott High-Purity Automatic ChangeOver
Model 8RCS

Scott High-Flow Automatic Primary ChangeOver
Model 8AS

Automatic ChangeOver – A change or drop in delivery pressure can adversely affect instrument performance in some instances. To avoid this problem, an automatic changeover 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). Optional purge valves (5) can be used at startup or after cylinder changeout 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 Air Liquide 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 the annunciator or alarm (optional and not shown) to alert the operator that changeover has occurred. The primary bank selector (7) will 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.

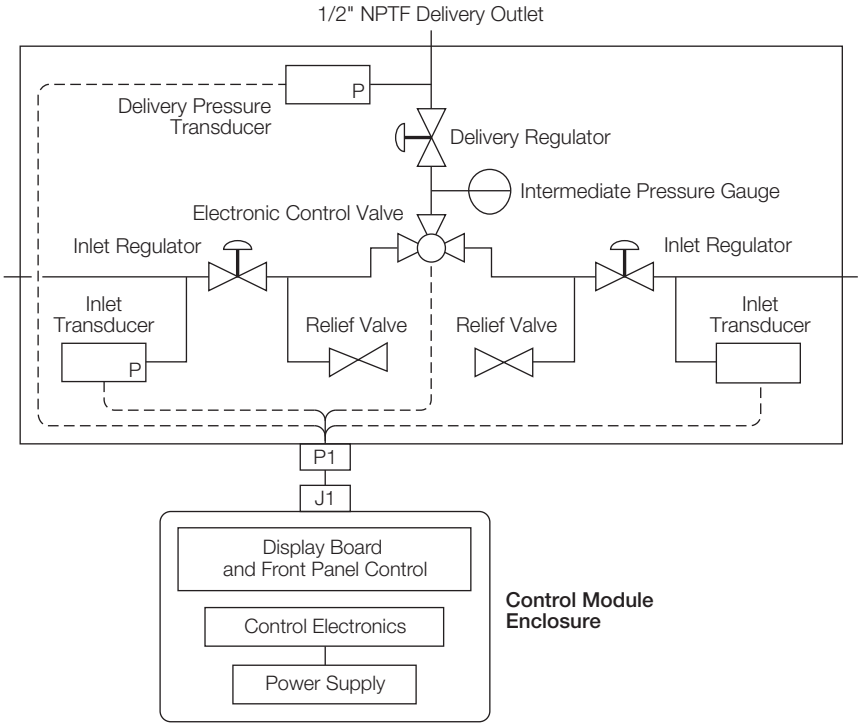


Principle of operation of a Model 8404 automatic changeover manifold.

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.

Auto Logic Controlled ChangeOver – 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 changeover is generally selected for these applications.

The Model 8404E is a fully automatic changeover manifold that controls gas delivery from two independent banks of cylinders. An integrated circuit board monitors and displays cylinder bank pressure and delivery pressure electronically. Changeovers occur automatically, eliminating the need to manually reset levers or valves. The Model 8404E includes separate mechanical and control enclosures with interface cable. Also included is a telemetry contact for use in interfacing with certain third party devices that will provide information for remote monitoring of the gas supply status.



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

Scott™ Electronic ChangeOver Systems
Model 8404E

DATAL™ with Scott Model 8404 ChangeOver Manifold
Remotely manages your gas inventory 24/7, alerting you when gas levels become low and then automatically reorders your supply.

Delivery Systems:

Semiconductor

Face-Seal Fitting Benefits

- Significantly reduces dead space and entrapment zones
- Achieves better degree of leak integrity
- Minimizes particle generation
- Eliminates venturi aspiration of outside contaminants

Electropolish Advantages

- Refines surfaces and reduces microfinish
- Removes hydrogen (no embrittlement)
- Passivates and resists corrosion
- Deburring
- Stress relieving

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

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

Leak Rate	Bubble Count
10^{-1}	4 per second
10^{-2}	25 per minute
10^{-3}	2 per minute
10^{-4}	1 in 5 minutes
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

Fabrication of semiconductors is an exacting series of process steps requiring high-purity gases and contaminant-free gas delivery systems. Semiconductors are highly sensitive to contamination, even in concentrations as small as a few parts per million. Microscopic dirt particles, many times smaller than the diameter of a human hair, lead to defects and low fabrication yields while presence of contaminant gases or hydrocarbons can cause either unwanted reactions or will change rates of process reaction. Trace amounts of H_2O will cause 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 a gas delivery system and embedded in the wafer.

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

Cleanroom Assembly – An area supplied with filtered air that keeps minute particles from entering a gas delivery system during assembly. Personnel wear special cleanroom garments and operate using protocols that keep products particle-free. Federal Standard 209D provides a qualified and standardized method for measuring how clean the air is in a cleanroom and designates six classes: 100,000, 10,000, 1,000, 100, 10, 1. Class numbers refer to the maximum allowable number of particles bigger than half a micron in size in one cubic foot of cleanroom air. A micron is a millionth of a meter. The lower the cleanroom class number, the cleaner the cleanroom.

Face-Seal Fittings – Provide a leak-tight, high-purity connection between components. This fitting is made when a metal gasket is deformed by two highly polished heads located on the connection glands and bodies. It 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 fit-up. These fittings are superior to threaded connections such as National Pipe Thread (NPT) and compression connections.

Type 316L Stainless Steel – A special 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 – An important aspect of a gas delivery system's interior surface texture is a quantification expressed in micro inches or micrometers. Common surface roughness measurement terms are Ra, RMS or Rmax. Each represents a slightly different means of measurement. Superior surface finishes of 7 Ra, 10 Ra, 15–30 Ra micro inches are desired to minimize entrapment zones and reduce outgassing effects. The principle method used to achieve these levels of surface finish is electropolishing.

Helium Leak Checking – Verifies that a gas delivery system is leak-free since semiconductor gases can be highly toxic and/or 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 that fits through small openings that other gases can not.

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, flowrates 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 flowrate 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 7P (shown to the right) allows control of three separate gases.

Scott™ Point-of-Use Panels
Model 7P
Point-of-use panels provide a practical way to regulate and control specialty gases in the lab.

Traps

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

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.

Nonindicating traps are usually high-capacity replaceable traps used in conjunction with indicating traps. For instance, an oxygen trap used with argon-methane mixtures is commonly used with electron capture gas chromatographs. Oxygen levels can be effectively reduced to less than 2 ppb when starting levels are 10 ppm or less. System design should incorporate check valves to prevent contamination of gas lines with atmospheric oxygen during trap replacement.

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

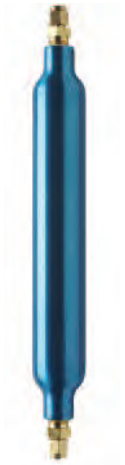
Scott Modular Gas Panels
Model 7MGP
These customized panels provide unlimited flexibility and can be configured to meet any existing or future lab requirements. Gas pressure, purity, filtration and distribution can be controlled conveniently in a single unit with preassembled, snap-in panels. All panels are tested and cleaned before shipping to assure purity.

Delivery Systems:

Accessories continued

Scott™ Indicating Moisture Trap
Model 44R

Scott Hydrocarbon Trap
Model 44H



Scott Disposable Oxygen Trap
Model 43L

Scott Indicating Oxygen Trap
Model 43T

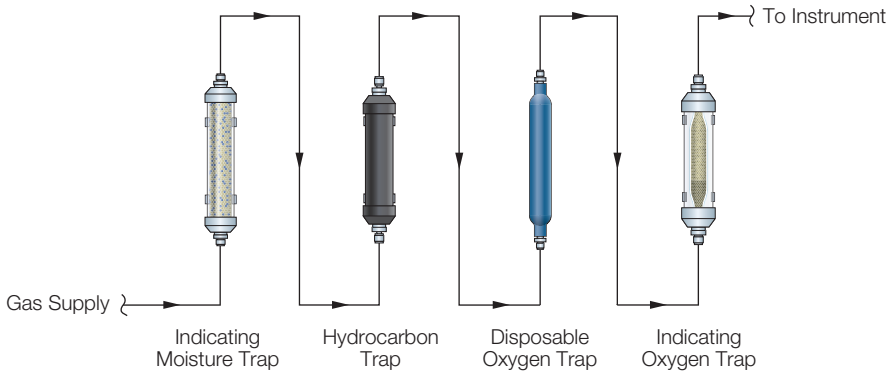
Moisture Traps – For gas chromatographic carrier gas applications that require low moisture concentrations, a molecular sieve adsorbent is used. With its high affinity for carbon dioxide and its ability to adsorb as much as 20% of its weight in water, the molecular sieve is the preferred adsorbent for 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 Moisture 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 and a 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.



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

Delivery Systems:

Manifold Specification Worksheet

General	1	Tag No.				
	2	Service				
	3	Lab				
Cylinder Connections	4	CGA, DISS, 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 Flowrate				
	18	Normal Flowrate				
	19	Grade/Purity				
Options	20	Flow Limit Shutoff 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				

Directions

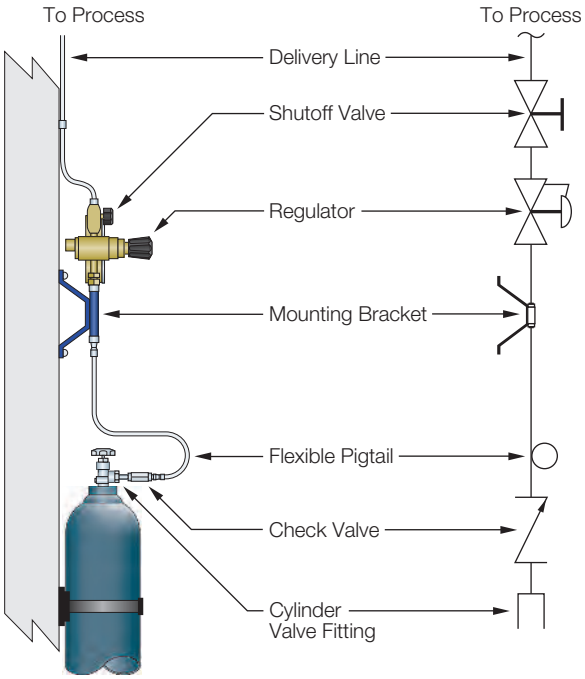
1–3	Used for identification
4	Specify CGA, DISS, DIN, BS or NEN connection required (i.e. CGA 580 for nitrogen, see page 39 for cylinder valve outlets and connections by gas).
5–6	Specify number and type of pigtails required
7	Indicate if check valves are required on pigtails
8	State whether purge assembly 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" NPT Male)
14	State type of gas or liquid to be distributed
15–18	Self-explanatory
19	Indicate purity or grade of gas (i.e. helium 99.9998% pure)
20–27	Specify type if required
28–29	Self-explanatory

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

Application Connections

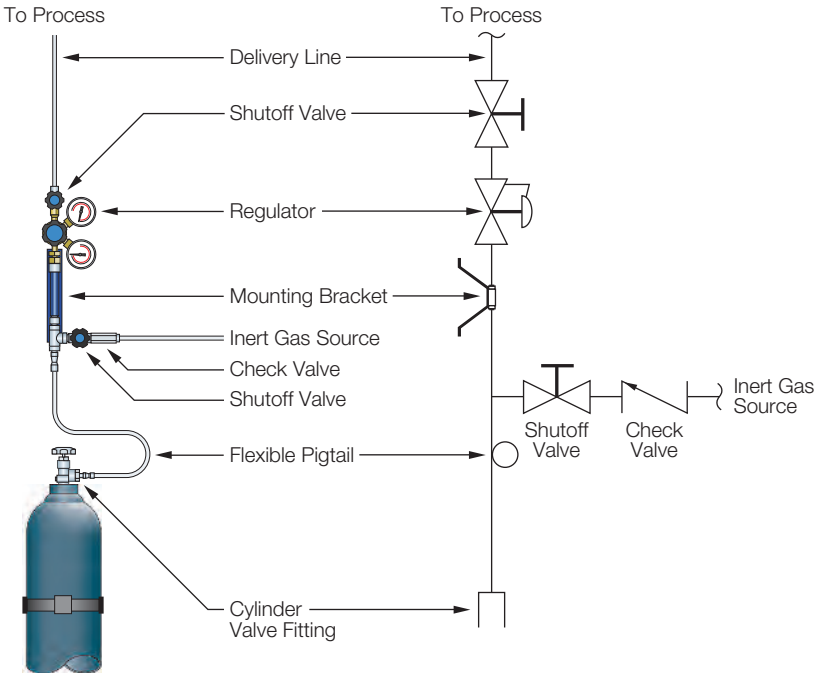
Typical Connection of a Single Cylinder to a Regulator

A Scott™ Model 8100 Series single-cylinder 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, DISS, BS, DIN or NEN for the application and should include a check valve to prevent back-flow of gas from the delivery system.



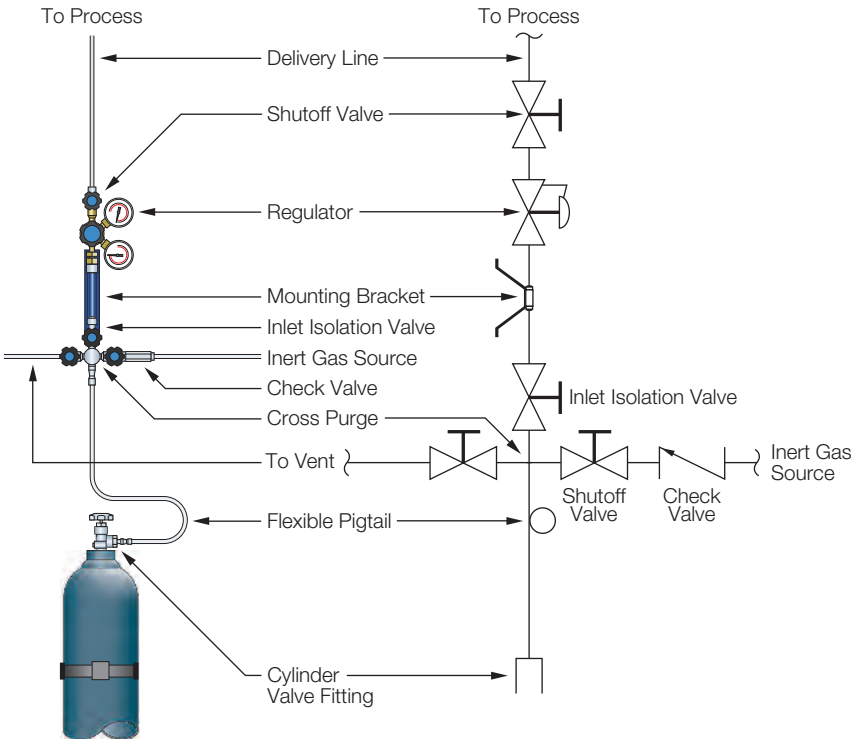
Single Cylinder Connection with Tee Purge for Purging with Inert Gas

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.



Single Cylinder Connection with Cross Purge for Purging with Inert Gas

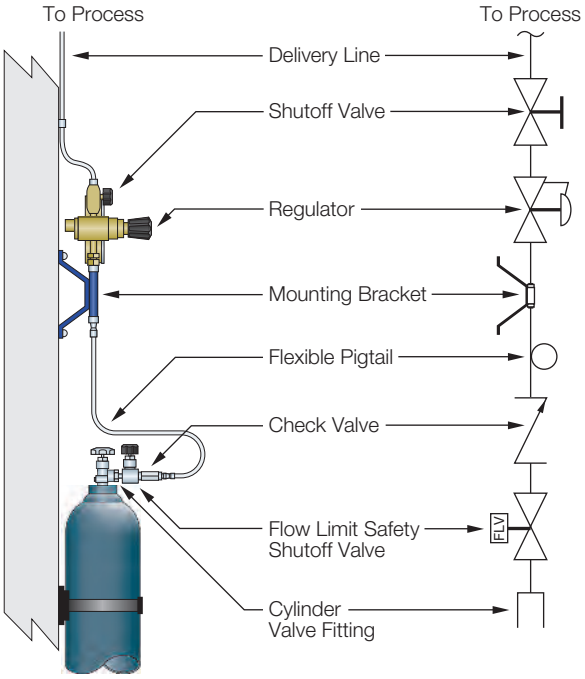
Cross purge assemblies allow the use of an inert gas for dilution purging of delivery systems for corrosive, toxic or pyrophoric gases that can extend the life of the delivery system equipment and protect personnel from exposure to these gases.



Flow Limit Safety Shutoff Valve for Single-Cylinder Connection

A flow limit safety shutoff 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 flowrate.



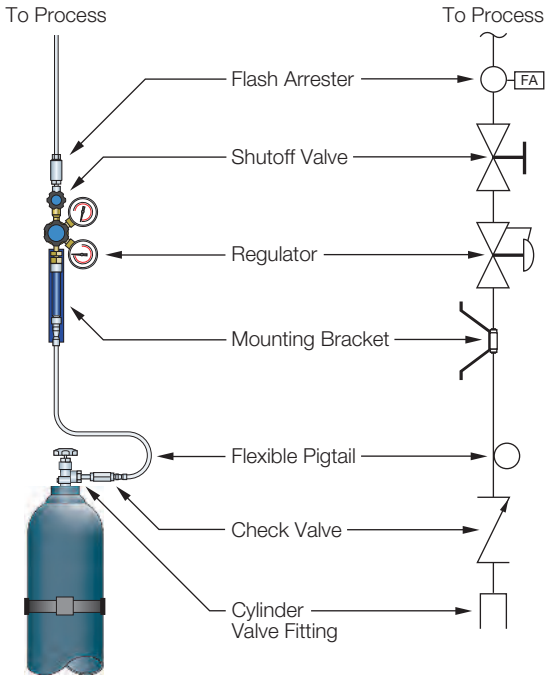
Application Connections continued

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

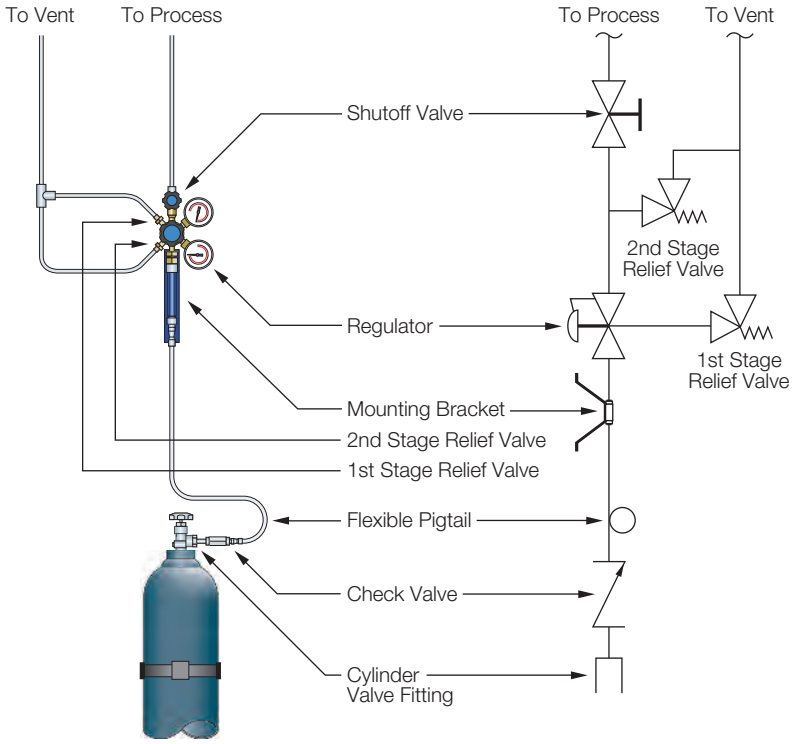
Flash arresters are recommended for oxygen and fuel gas service.



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.

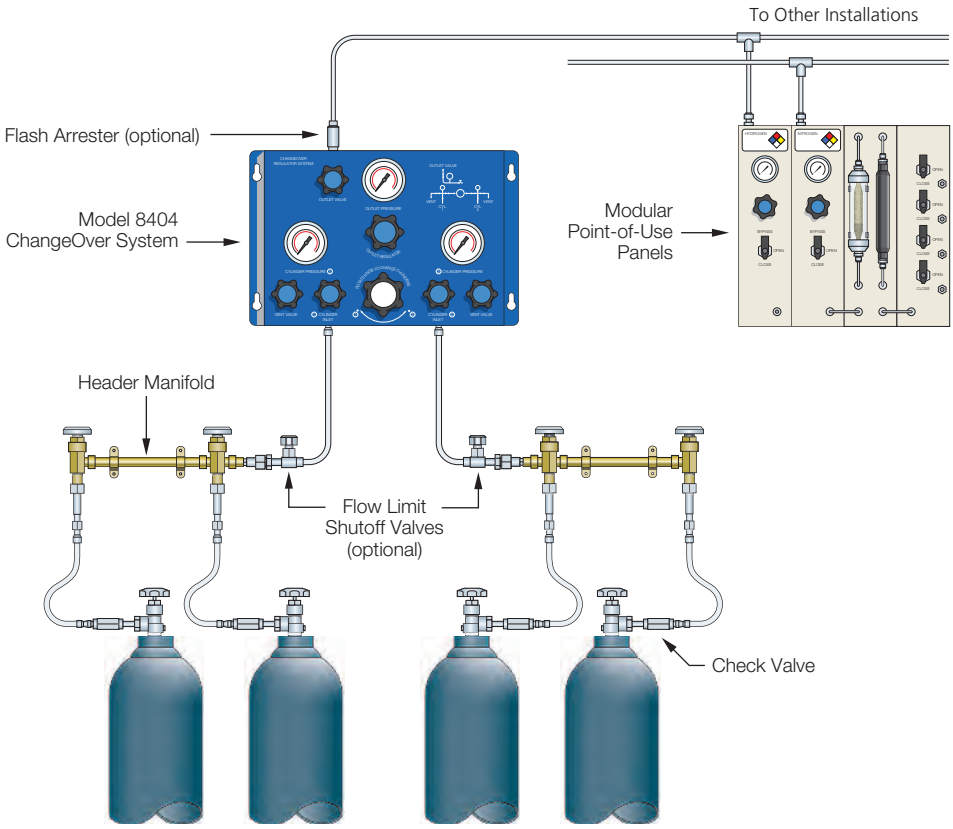
For outdoor installations involving inert gases, the relief valves can exhaust directly to the atmosphere. For indoor installations, or any installations involving toxic or flammable gases, the relief valve exhaust should be captured and vented to a safe location as shown.



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.

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

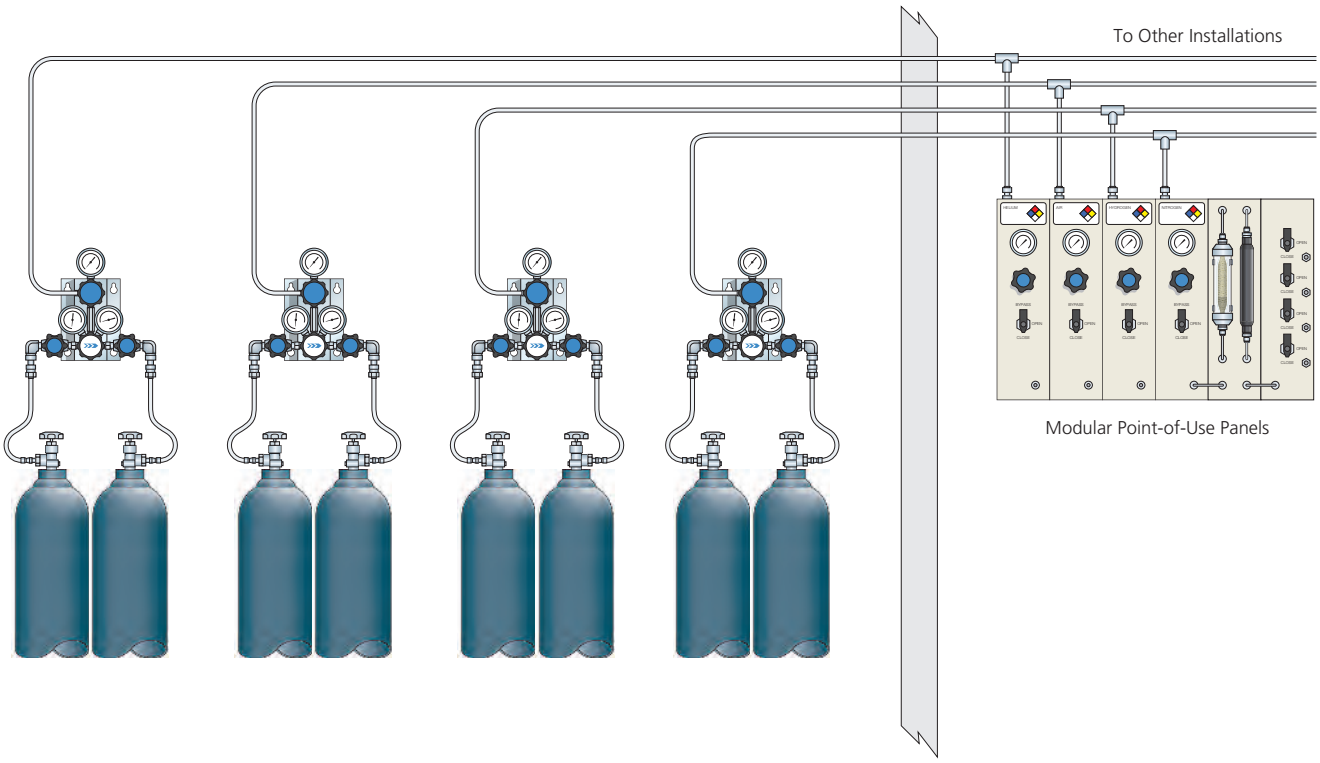


Application Connections continued

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, to enhance safety. Operating costs are reduced since downtime due to interrupted gas flow is eliminated and labor for cylinder changeouts is minimized.



Compressed Gas Cylinders:

Valve Outlets and Connections

The Compressed Gas Association (CGA) assigns standard valve outlet connectors for specific gases, as well as specific dimensions for the manufacture of these connectors. Thus, continuity is achieved within the gas industry and the opportunity for accidental interconnection of incompatible gases is minimized. Connectors are typically assigned a three-digit number, so that the accepted connector for nitrogen, for example, is CGA 580. Often, especially with gas mixtures, more than one CGA is specified. For example, hydrogen calls for either CGA 660 (in air) or CGA 330 (in methane or nitrogen) depending on the balance gas being used.

CGA connections have three or four parts depending on the type of connect. A bullet-nose type includes three parts: valve outlet, nut and nipple. The nut encompasses the nipple and engages the threads on the valve outlet, drawing the nipple against the sealing surface of the valve outlet. The threads themselves do not provide any sealing. The actual seal takes place only where the metal of the nipple contacts the metal of the valve outlet. A gasketed connection includes four parts: valve outlet, nipple, nut and gasket. The nut engages the threads on the valve outlet, drawing the nipple against the valve and achieving a gas-tight seal by compressing the gasket between the two surfaces.

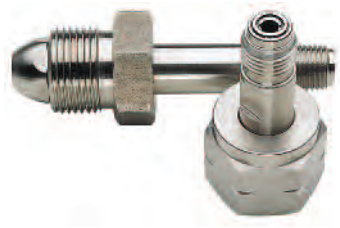
Washers – The CGA connections listed below come equipped with PTFE washers. Use this washer until your cylinder is empty. For best results, install a new washer with every cylinder change. Replacement washers are available from Air Liquide – contact your representative.

110	320	670
170	330	705
180	660	

Torque Guidelines

The question often arises: “How much torque must be applied to a connector to achieve a gas-tight seal without damaging the connector itself?” The answer, unfortunately, depends on several factors. Age, prior care and cleanliness of the connectors are all factors to consider. So is the material of construction. Generally, the harder the material, the more force is necessary to achieve a gas-tight metal-to-metal seal. Thus, brass, being softer and more malleable than stainless steel, is generally easier to seal. Dissimilar metals and washer materials may influence the torque requirement.

A table indicating suggested torque values (CGA TB-14-2004) is available, based on results of tests conducted by the Compressed Gas Association. Contact CGA directly to purchase a copy of their study results.



Standard CGA connections reduce the chance of mixing incompatible gases as well as connecting low-pressure equipment to a high-pressure gas source. CGA connections use several design features to prevent cross connections.

- **Different Threads –** Left-hand threads are used almost exclusively on flammable gas connections and are identified by the V-shaped notch in the hexagon nut.
- **Different Nipple Geometries** – Nipples may vary in diameter, length and overall shape.
- **Pin Indexing** – Medical products in small cylinders utilize a pin-indexing system requiring the gas connection to be equipped with pins that mate with holes in the valves.

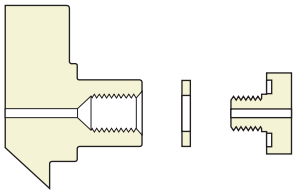
Compressed Gas Cylinders:

Selecting Outlets and Connections

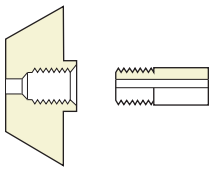
Air Liquide supplies gases in cylinders with valves having CGA (Compressed Gas Association) and DISS (Diameter Index Safety Systems) standard outlet connections. In some cases, alternate CGA connections may be used, and upon customer's request, will be supplied instead of the standards shown below. BS, DIN or NEN outlet connections may also be available—contact your Air Liquide representative.

Gas	CGA	DISS	Gas	CGA	DISS
Acetylene	410*, 510		Hydrogen Bromide	330	634
Air	590		Hydrogen Chloride	330	634
Allene	510		Hydrogen Fluoride	670	638
Ammonia, Anhydrous	240, 660, 705	720	Hydrogen Sulfide	330	722
Argon	580	718	Isobutane	510	
Arsine	350	632	Isobutylene	510	
Boron Trichloride	660	634	Krypton	580	718
Boron Trifluoride	330	642	Methane	350	724
1,3-Butadiene	510		Methyl Chloride	510, 660	
Butane	510		Methyl Mercaptan	330	
Butenes	510		Monoethylamine	705	
Carbon Dioxide	320	716	Monomethylamine	705	
Carbon Monoxide	350	724	Natural Gas	350	
Carbonyl Fluoride	660		Neon	580	718
Carbonyl Sulfide	330		Nitric Oxide	660	728
Chlorine	660	728	Nitrogen	580	718
Chlorine Trifluoride	670	728	Nitrogen Dioxide	660	
Cyanogen	660		Nitrogen Trifluoride	330	640
Deuterium	350		Nitrous Oxide	326	712
Dichlorosilane	678	636	Oxygen	540	714
Dimethylamine	705		Phosgene	660	
Dimethyl Ether	510		Phosphine	350	632
Disilane	350	632	Propane	510	
Ethane	350	724	Propylene	510	
Ethyl Acetylene	510		Silane	350	632
Ethyl Chloride	300		Silicon Tetrafluoride	330	642
Ethylene	350	724	Sulfur Dioxide	660	
Ethylene Oxide	510		Sulfur Hexafluoride	590	716
Germane	350	632	Trimethylamine	705	
Halocarbon-14			Trisilane	350	632
(Tetrafluoromethane)	320	716	Tungsten Hexafluoride	670	638
Helium	580	718	Vinyl Chloride	510	
Hydrogen	350	724	Xenon	580	718

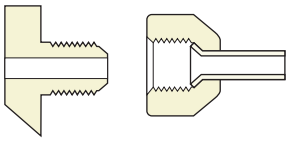
* Canada only.



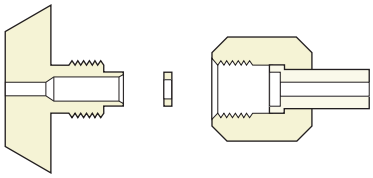
Connection 110 5/16" – 32 RH INT., with Gasket



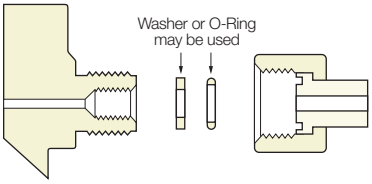
Connection 160 1/8" – 27 NGT RH INT.



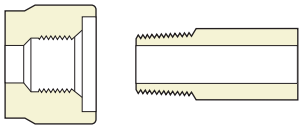
Connection 165 0.4375" – 20 UNF 2A RH EXT.



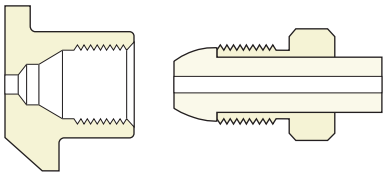
Connection 170 9/16" – 18 RH EXT. and 5/16" – 32 RH INT., with Gasket



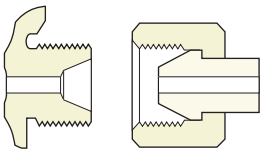
Connection 180 0.625" – 18 UNF 2A RH EXT., with Gasket



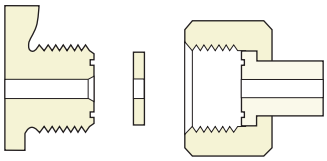
Connection 240 3/8" – 18 NGT – RH INT.



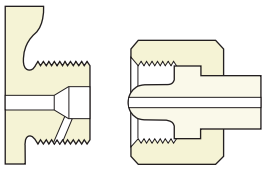
Connection 296 0.803" – 14 RH INT.



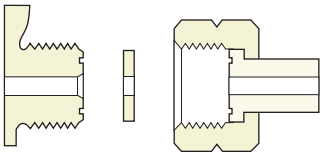
Connection 300 0.825" – 14 NGO RH EXT.



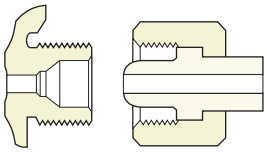
Connection 320 0.825" – 14 RH EXT., with Gasket



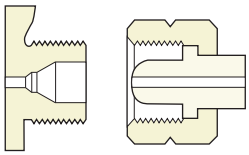
Connection 326 0.825" – 14 RH EXT.



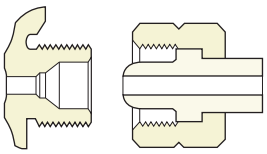
Connection 330 0.825" – 14 LH EXT., with Gasket



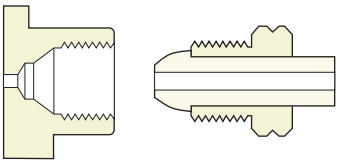
Connection 346 0.825" – 14 NGO RH EXT.



Connection 350 0.825" – 14 LH EXT.



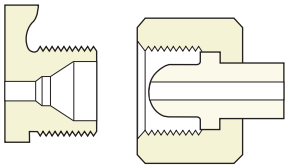
Connection 410 0.85" – 14NGO LH EXT.



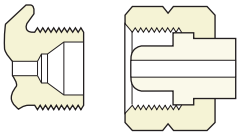
Connection 510 0.885" – 14 LH INT.

Compressed Gas Cylinders:

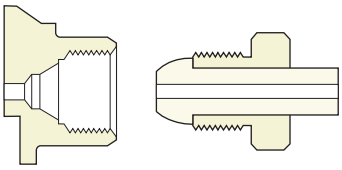
Selecting Outlets and Connections continued



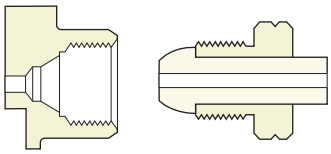
Connection 540 0.903" – 14 RH EXT.



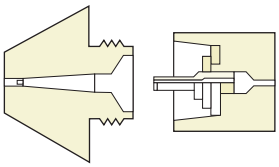
Connection 555 0.903" – 14NGO LH EXT.



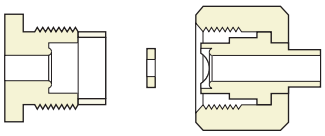
Connection 580 0.965" – 14 RH INT.



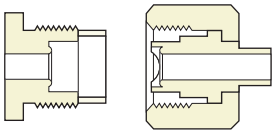
Connection 590 0.965" – 14NGO LH INT.



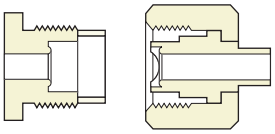
Connection 600 1" – 20 UNEF RH EXT., with Gasket



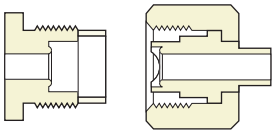
Connection 630 1.03" – 14NGO RH EXT.



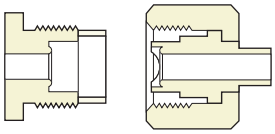
Connection 632 1.03" – 14NGO RH EXT.



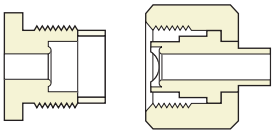
Connection 634 1.03" – 14NGO RH EXT.



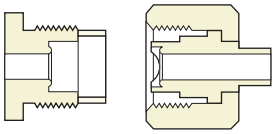
Connection 636 1.03" – 14NGO RH EXT.



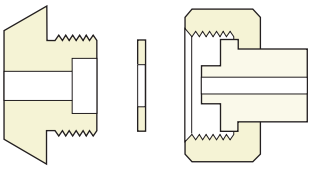
Connection 638 1.03" – 14NGO RH EXT.



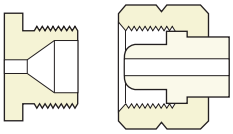
Connection 640 1.03" – 14NGO RH EXT.



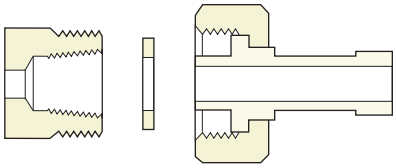
Connection 642 1.03" – 14NGO RH EXT.



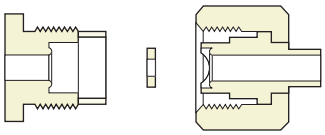
Connection 660 1.03" – 14 RH EXT., with Gasket



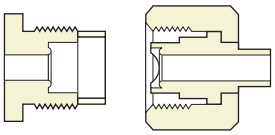
Connection 677 1.03" – 14NGO LH EXT.



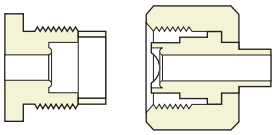
Connection 705 1.125" – 14 UNS 2A RH EXT., with Gasket



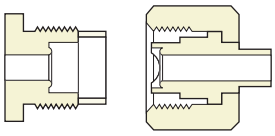
Connection 710 1.125" – 14NGO RH EXT.



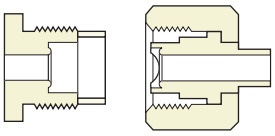
Connection 712 1.125" – 14NGO RH EXT.



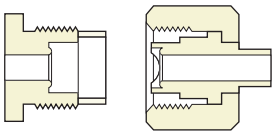
Connection 714 1.125" – 14NGO RH EXT.



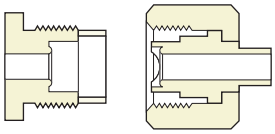
Connection 716 1.125" – 14NGO RH EXT.



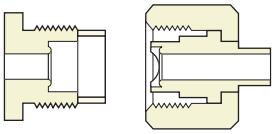
Connection 718 1.125" – 14NGO RH EXT.



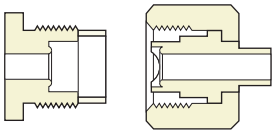
Connection 720 1.125" – 14NGO RH EXT.



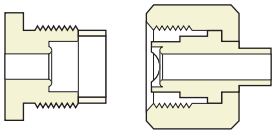
Connection 722 1.125" – 14NGO RH EXT.



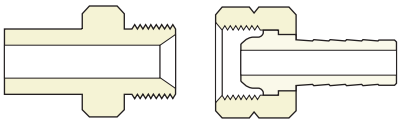
Connection 724 1.125" – 14NGO RH EXT.



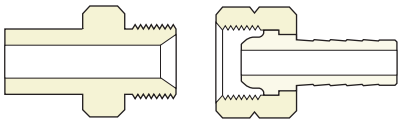
Connection 726 1.125" – 14NGO RH EXT.



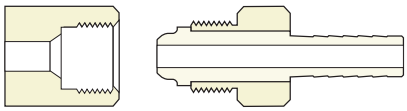
Connection 728 1.125" – 14NGO RH EXT.



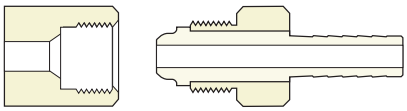
Connection 024 0.875" – 14UNF RH EXT.



Connection 025 0.875" – 14UNF LH EXT.



Connection 034 0.875" – 14UNF RH EXT.



Connection 035 0.875" – 14UNF LH EXT.

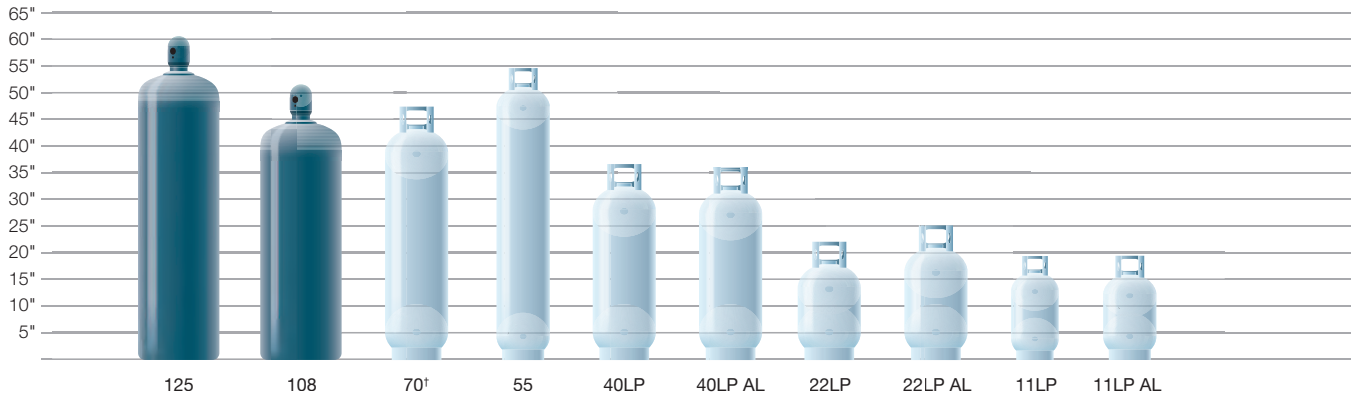
Compressed Gas Cylinders:

Specifications

The following pages describe the many different cylinder options available for packaging Air Liquide products. While most of our cylinders remain the property of Air Liquide, we also fill customer-owned cylinders provided they meet all appropriate safety requirements.

Low-Pressure Cylinder Size	DOT Specification	Service Pressure	Approximate Capacity Gas at STP		Outside Diameter	Height*	Tare Weight**	Internal Water Volume††	
		psig	cu. ft.	liters	inches	inches	lbs.	cu. in.	liters
125 (formerly LG)	4AA	480	144	4076	15	54.5	159	7628	125
108 (formerly 110)	4BA	260	70	1982	15	45	73	6712	110
70†	8AL	250	419	11865	12	42	182	4271	70
55	4BA	300	40	1121	10	51	56	3356	55
40LP(RS)	4BA	240	28	786	12	32.5	34	2868	47
40LP AL(RS)	4E	240	26	722	12	32	21	2624	43
22LP(RS)	4BA	240	13	368	12	18	22	1342	22
22LP AL(RS)	4E	240	13	368	12	21	14	1342	22
11LP(RS)	4BA	240	7	200	9	17	16	732	12
11LP AL(RS)	4E	240	7	200	10	16	11	732	12

* Without valve.
** With valve, nominal.
† Acetylene cylinder with acetone.
†† Nominal.
(RS) Resale cylinder only.

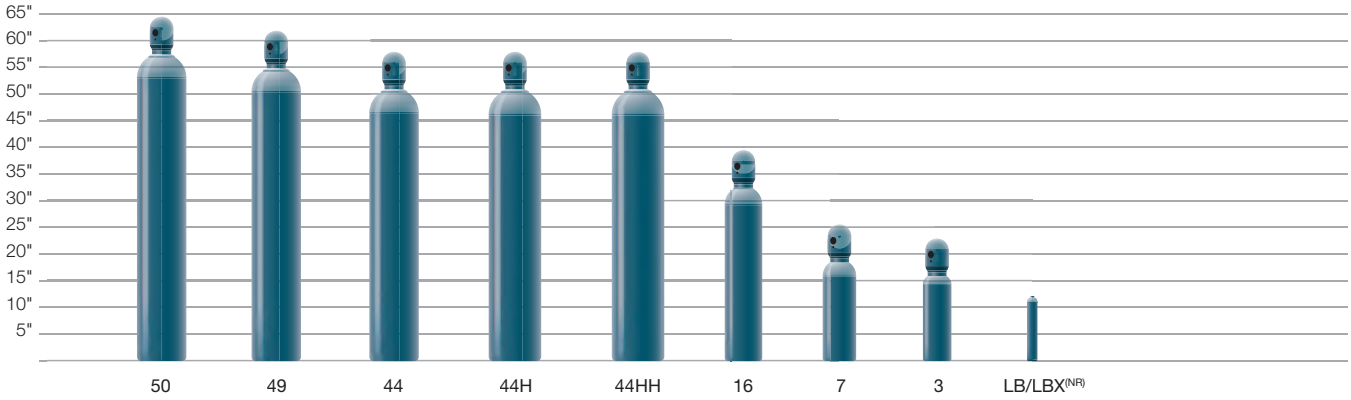


Cylinder Comparison Chart

Air Liquide	Scott	Airgas	Linde	Matheson	Praxair
125	XG	400	126	1K	FS
108	XL	350	350	1F	FX
70	XF	380	110	1B	A8
40LP	–	–	L60	–	–
40LP AL	–	–	–	–	–
22LP	5LP	25	L20	–	–
22LP AL	5LP AL	–	–	–	–
11LP	2.5LP	–	–	–	–
11LP AL	2.5LP AL	–	–	–	–

HP Steel Cylinder Size	DOT Specification	Service Pressure	Approximate Capacity†		Outside Diameter	Height*	Tare Weight**	Internal Water Volume††	
		psig	cu. ft.	liters	inches	inches	lbs.	cu. in.	liters
50	9809-1***	2900	335	9373	9	58.2	130	3051	50
49	3AA	2400	277	7844	9.25	55	143	2990	49
44	3AA	2265	232	6570	9	51	133	2685	44
44H	3AA	3500	338	9571	10	51	189	2607	44
44HH	3AA	6000	433	12261	10	51	303	2383	43
16	3AA	2015	76	2152	7	32.5	63	976	16
7	3AA	2015	33	934.6	6.25	18.5	28	427	7
3	3AA	2015	14	396.5	4.25	16.75	11	183	3
LB/LBX (NR)	3E	1800	2	53.8	2	12	3.5	27	0.4

* Without valve.
** With valve, nominal.
*** UN/ISO specification.
† For N_2 at 70°F 1 atm.
†† Nominal.
(NR) Nonreturnable cylinder. Price of cylinder included in the price of gas.
Note: LBX is an LB cylinder with a CGA valve other than 170 or 180.



Cylinder Comparison Chart

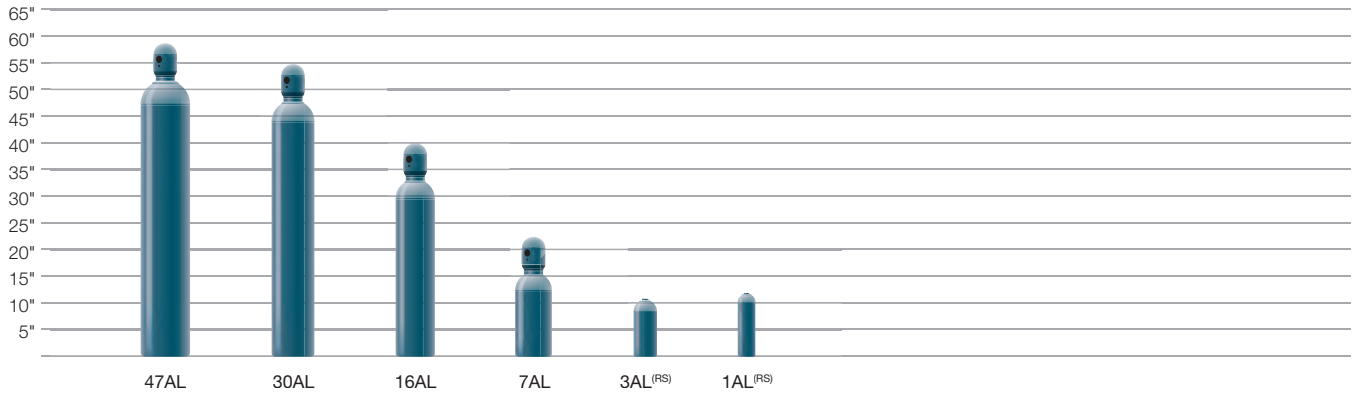
Air Liquide	Scott	Airgas	Linde	Matheson	Praxair
49	K	300	049 (T)	1L	T/UT
44	A	200	044 (K)	1A	K/UK
44H	–	–	–	1H	3K
44HH	–	3HP	485	1U	6K
16	B	80	016 (Q)	2	Q/UQ
7	C	35	007 (G)	3	G/UG
3	–	–	3	4	F
LB	LB	LB	LBR (LB)	LB	LB/RB
LBX	–	LX	–	7X	EB

Compressed Gas Cylinders:

Specifications continued

HP Aluminum Cylinder Size	DOT Specification	Service Pressure	Approximate Capacity†		Outside Diameter	Height*	Tare Weight**	Internal Water Volume††	
		psig	cu. ft.	liters	inches	inches	lbs.	cu. in.	liters
47AL	3AL	2216	244	6909	9.8	51.9	90	2831	46.4
30AL	3AL	2015	141	3993	8	47.9	48	1800	29.5
16AL	3AL	2216	83	2350	7.25	33	30	958	15.7
7AL	3AL	2216	31	878	6.9	15.6	15	360	5.9
3AL (RS)	3AL	2015	8	227	4.4	10.5	3.5	103	1.7
1AL (RS)	3AL	2216	5	142	3.2	11.7	2.3	61	1

* Without valve.
** With valve, nominal.
† For N_2 at 70°F 1 atm.
†† Nominal.
(RS) Resale cylinder only.



Cylinder Comparison Chart

Air Liquide	Scott	Airgas	Linde	Matheson	Praxair
47AL	KAL	–	–	–	AT
30AL	AL	150A	A31	1R	AS
16AL	BL	80A	A16	2R	AQ
7AL	CL	33A	A07	3R	AG
3AL	–	–	–	–	A3
1AL	–	–	–	–	–

Cryogenic Cylinder Size	DOT Specification	Service Pressure†	Approximate Capacity††		Outside Diameter	Height	Tare Weight	Internal Water Volume	
		psig	cu. ft.	liters	inches	inches	lbs.	cu. in.	liters
230-VGL	4L	230	5921	167665	26	57	324	14646	240
180-VGL	4L	230	4835	136913	20	64	260	11961	196
160-VGL	4L	230	4486	127030	20	60	250	10740	176

† Additional delivery pressures are available.
†† Approximate gas volume for oxygen for VGLs.

Helium Dewars	DOT	Service Pressure	Approximate Capacity, Liquid		Outside Diameter	Height	Tare Weight*	Internal Water Volume*	
Dewar Size	Specification	psig	cu. ft.	liters	inches	inches	lbs.	cu. in.	liters
500	N/A	12	18	500	42	71	480	33563	550
250	N/A	12	9	250	32	67	348	17392	275
100	N/A	12	4	100	24	59	212	6957	110
60	N/A	12	2	60	24	50	184	4028	66

* Nominal.

Packs	DOT	Service Pressure	Approximate Capacity		Width x Depth x Height	Tare Weight*	Internal Water Volume*	
Number of Cylinders	Specification	psig	cu. ft.	liters	inches	lbs.	cu. in.	liters
16	3AA	2400	4432	125501	41 x 41 x 79	2650	47843	784
6	3AA	2265	1392	39417	31 x 20 x 73	870	16110	264

* Nominal.

Piston	DOT	Service Pressure	Approximate Capacity		Outside Diameter	Width	Length	Internal Water Volume*	
Cylinder Size	Specification	psig	cu. in.	liters	inches	inches	inches	cu. in.	liters
300	E-7657	1800	18.3	0.3	3	12.8	18	18.3	0.3
500	E-7657	1800	30.5	0.5	3	17.2	22.4	30.5	0.5
1000	E-7657	1800	61	1	3	30.7	35.9	61	1

* Nominal.

Tube Trailers	Tube Trailer Length	Tube Outside Diameter	Air	Argon	Helium	Hydrogen	Nitrogen	Oxygen
Number of Tubes	feet	inches	SCF	SCF	SCF	SCF	SCF	SCF
30	21	9-5/8	46,361	45,330	43,670	43,038	45,623	43,322
34	21	9-5/8	51,438	50,294	48,453	47,751	50,619	48,066
38	21	9-5/8	57,270	55,996	53,947	53,165	56,359	53,516
49	21	9-5/8	74,486	72,830	70,164	69,147	73,302	69,604
55	34	9-5/8	136,852	133,808	128,910	127,043	134,675	127,881
10	34	22	–	133,894	128,993	127,124	134,761	127,881
7	40	22	116,122	112,539	109,383	–	114,275	108,510
9	40	22	149,149	145,832	140,494	–	146,776	139,372

Definitions and Terminology

Absolute Pressure – A measurement of pressure which sets a total vacuum as having a value of zero, abbreviated as psia or bar. Absolute pressure is equal to the sum of a pressure gauge reading and atmospheric pressure (14.69 psia or 1 bar at sea level).

Anaerobic – Gases that do not contain oxygen and are used for biological culture growth.

Anhydrous – A term meaning without water or dry. It is often used with gases that are particularly corrosive in the presence of moisture such as ammonia.

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

Boiling Point (BP) – The temperature of a liquid at which the vapor pressure is equal to the pressure of the atmosphere above it.

British Standard (BS) – 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 with an accurately known concentration that is used as a comparative standard in analytical instrumentation.

Carrier Gas – The gas that flows through a separation column of a gas chromatograph and propels a sample to a detector.

Compressed Gas – Any material or mixture having one of the following: an absolute pressure exceeding 40 psia (2.72 bar) at 70°F (21°C); an absolute pressure exceeding 104 psia (7.07 bar) at 130°F (54°C); a flammable liquid having a vapor pressure exceeding 40 psia (2.8 bar) at 100°F (38°C) as determined by ASTM D323-72.

Compressed Gas Association (CGA) – A nonprofit trade organization for the gas industry that develops and promotes industry standards for safe handling, transport and storage of compressed gases. Also recommends cylinder valve outlet connections for specific gas services based on safety considerations.

Corrosive – Any gas that chemically attacks materials with which it comes in contact (i.e. metals, skin) and capable of irreversible damage.

Critical Pressure – The pressure exerted by a material at the critical temperature.

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

Cylinder – A container designed to safely hold compressed gases. Air Liquide's cylinders are designed and tested to meet government specified standards of construction.

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

Diameter Index Safety System (DISS) – Type of valve designed with metal-to-metal seals for high leak integrity and generally used for high-purity, corrosive or toxic gases.

Flame Ionization Detector (FID) – One of the most commonly used detectors for measuring organic compounds in a gas stream. Organic species are decomposed by a hydrogen flame and measured by electrodes near the flame.

Flammable – DOT definition of any gas that will either form a flammable mixture with air at concentrations of 13% or less by volume, or has a flammable range wider than 12% regardless of the lower explosive limit (LEL).

Impurity – An additional or extra component of a pure gas or mixture. Impurities are most commonly encountered in pure material used as the raw material source for a component of a gas mixture. An impurity may be removed by purification. Alternatively, the impurity may be measured and accounted for during blending, thereby preventing it from becoming a contaminant.

Inert – A component with no uncontrolled chemical incompatibility with other components or with the container materials of construction, such as nitrogen, helium, carbon dioxide and methane.

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

Mole – For a given molecule, one mole is the mass numerically equal to its molecular weight. A gram mole is the mass in grams equal to the molecular weight. A pound mole is the weight in pounds equal to the molecular weight.

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

Nederlandse Norm (NEN) – 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).

Normal Temperature and Pressure (NTP) – 68°F and 1 atm (20°C and 760 torr)

Oxidant – A substance that supports or causes combustion of other materials.

Partial Pressure – The vapor pressure exerted by one component of a gas mixture. In any gas mixture, the total pressure is equal to the sum of the partial pressures that each gas would exert were it alone in the volume occupied by the gas mixture.

Pyrophoric – A substance that can spontaneously ignite when exposed to air at temperatures of 130°F (54°C) or below.

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. For gases, specific volume is greatly affected by temperature and pressure.

Standard Temperature and Pressure (STP) – 32°F and 1 atm (0°C and 760 torr).

Sublimation – The direct passage of some substances from the solid state to the gaseous state without going through the liquid state first.

Threshold Limit Valve (TLV) – Set by ACGIH, the time-weighted average concentration of an airborne substance that nearly all workers may be exposed in a normal 8-hour day, 5-day work week, without suffering adverse effect.

Toxic Gas – A substance that has the ability to produce injurious or lethal effects through its chemical interaction with the human body.

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

MOLECULES that matter™

As the world's leading supplier of specialty and industrial gases, Air Liquide is all about "molecules that matter."

Our technologies are carefully engineered to provide customers with meticulously analyzed measures of certain molecules in the form of pure or mixed gases and liquids. These molecules are in turn used as raw materials or end products in themselves, as is often the case in healthcare or food and beverage processing. Other times the molecules we provide are used to measure or test for the presence of other molecules, as is the case in monitoring air pollution.

Our focus however, goes beyond the refining and selling of molecules. It includes providing value that can be measured at the bottom line. Air Liquide products and services help our many customers keep pace with a challenging global economy—by empowering them to improve efficiencies without sacrificing end product quality or analytical accuracy.

Our commitment to safety, technology and innovation has kept Air Liquide at the forefront of our industry for more than 100 years. Our presence of over 43,000 employees in nearly 80 countries enables us to leverage the resources of a global enterprise with personalized service from our localized, customer-focused teams. Combined with products such as ALPHAGAZ™ pure gases, Scott™ gas mixtures and Scott gas handling equipment, this is a winning formula that transforms "molecules that matter" into greater customer satisfaction, efficiency and success—plus a safer and cleaner environment for us all.

AIR LIQUIDE™

Trademarks

ALPHAGAZ, ARCAL, ALIGAL, DATAL, MICROPURGE, Molecules that Matter, Scott, SCOTTY and SMARTOP are trademarks of the Air Liquide Group.

Hall is a trademark of Thermo Fischer Scientific Incorporated.
Kalrez and Viton are trademarks of DuPont Performance Plastics.
Kynar is a trademark of Arkema Incorporated.
Monel is a trademark of Special Metals Corporation.
Snoop is a trademark of Swagelok Company.
Tefzel is a trademark of E.I. du Pont de Nemours and Company.

Founded in 1902, Air Liquide is the world leader in industrial and medical specialty gases and related services, providing innovative solutions for the manufacture of everyday products and for the protection of life.

NOTE: This brochure is intended for general information purposes only and is not intended as a representation or warranty of any kind, or as a statement of any terms or condition of sale. The information herein is believed to be correct, but is not warranted for correctness or completeness or for applicability to any particular customer or situation.

©2013 Air Liquide America Specialty Gases LLC. All Rights Reserved 11/13-MSD-7.5M 3001.5
Reproduction of this handbook either in whole or in part without written permission from Air Liquide is prohibited.

Air Liquide America Specialty Gases LLC
6141 Easton Road, Box 310
Plumsteadville, PA 18949
Phone: 800.654.2737 Fax: 732.271.1630
Email: ALASG.Equipment@airliquide.com
www.ALspecialtygases.com

AIR LIQUIDE™
SPECIALTY GASES

3001.5