The Pipeliner

Design Guidelines for High Purity Gas Delivery Systems

BeaconMedæs®

INTRODUCTION

A high purity gas delivery system that is over-designed requires state-of-the-art components, meticulous installation and always ends up to be costly. On the other end, selecting inadequate components and using un-experienced installers are sure ways to contaminate the gas stream. Therefore, a good gas delivery system is about installing the right equipment adequately while making sure all safety aspects are covered. It is easier said than done.

Gases are chemicals with different properties and their inherent safe handling requirements. High purity gas delivery system design is also a matter of dealing with impurities that acceptable for a given application. Then comes the financial aspect of the project.

We are all busy and we understand the need to go straight to the point. That's why we are using a lot of images, graphics, schematics and tables in this design guide. This Pipeliner is intended to be used by plumbing engineers, piping installers and users of high purity gases. It is a unique design guide book in a way that it covers pretty much all topics a high purity gas delivery system design without going too deep in each topic. Consider this document to be a tool to quickly understand the vast worlds of high purity piping, analytical equipment and compressed gases.

The best way to fully understand the content of the design guide is to attend one of the seminar about the Pipeliner. On top of going through this design guide, the experienced instructor provides real-life examples and explanations that are easy to understand.

The Pipeliner is a compendium of the knowledge, experience, technical expertise and education of scientists, piping installers, engineers and sales people. We all hope you will find this document useful and relevant.

Thank You!

Denis Hache
Global Product Marketing Manager
Laboratory and Non-Medical Applications
BeaconMedaes

Periodic Table Of Elements

Natural Form

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	271 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	1 Ir	1 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Ra
87 Fr	88 Ra	89-103															

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Solid · Liquid · Gas

Source
http//chemistry.about.com

About Chemistry

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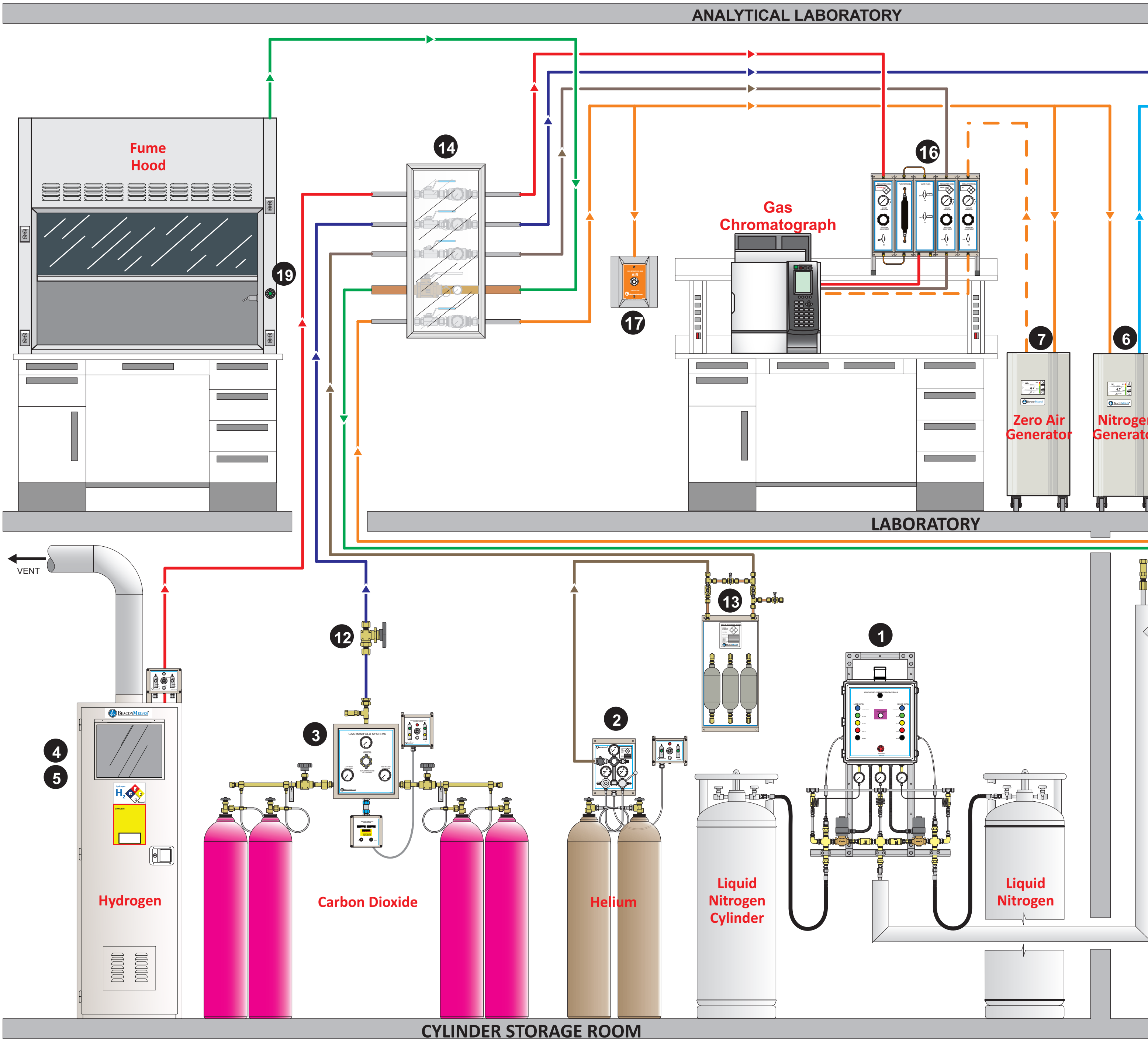
Ideal Solutions: From Design To Completion To S



CYLINDER DISCHARGING EQUIPMENT

1. CFAM-TX - Manifold, Fully Auto, Cryogenic
2. PDC3000 - Manifold, Pressure Differential, Ultra High Purity
3. AFAM1500 - Manifold, Fully Auto, High Purity

CYLINDER CONTAINMENT

4. DP3000 - Delivery Panel, 5-Valve, Stain. Steel
5. IGC-2 - Gas Cabinet, Double Cylinder

GAS GENERATORS

6. NITRO STATION 50LC - Nitrogen Generator for LC/MS
7. AERO STATION 50LC - Air Generator for LC/MS

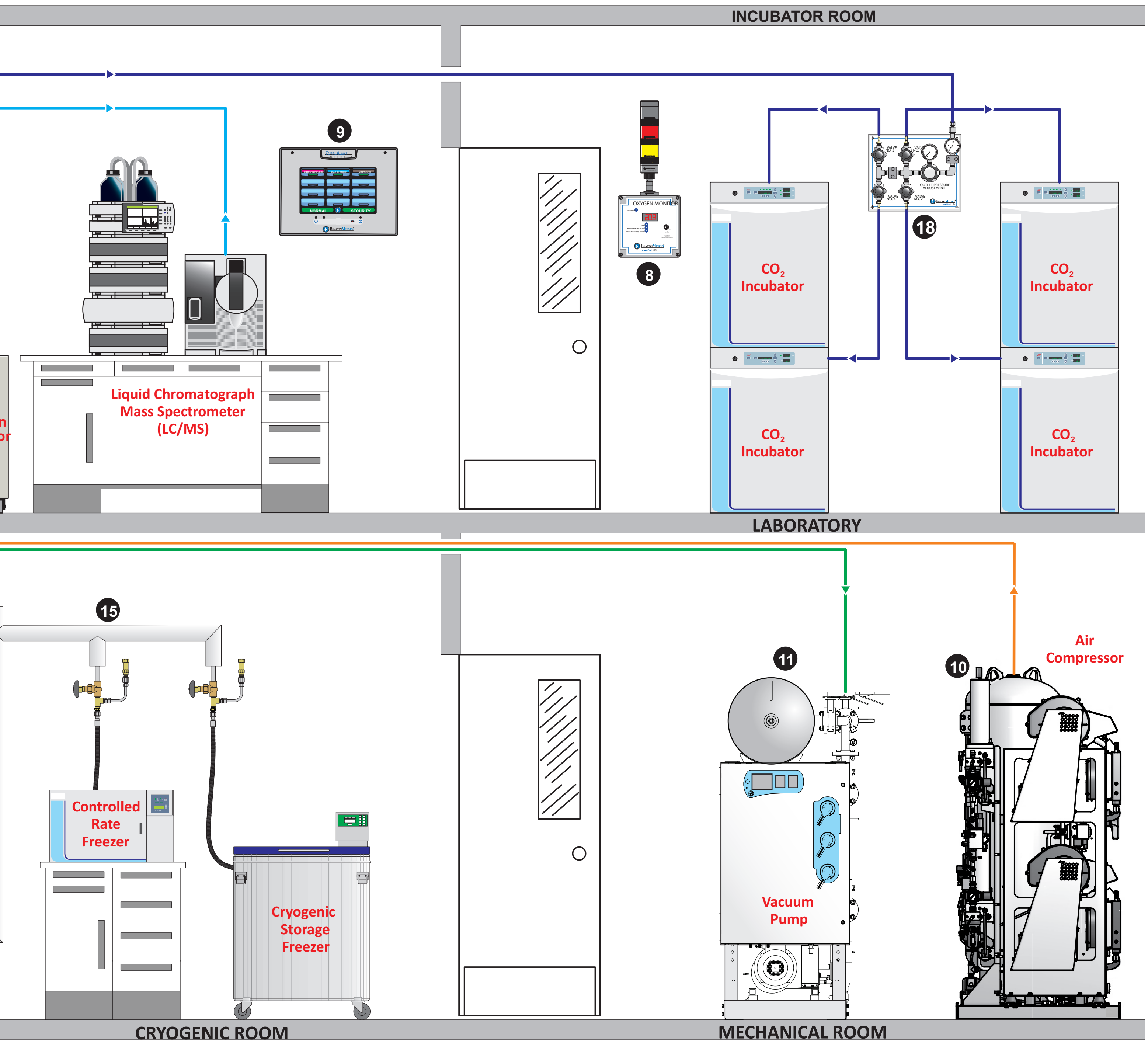
SOURCE EQUIPMENT

10. 2HP Duplex Scroll Air Compr
11. 3HP Claw Vacuum Pump

ALARMS & CONTROLS

8. FGM - Gas Monitor, Oxygen
Stackable Flashing Beacon w
9. TOTAL ALERT INFINITY Serie

Start-Up • From Gas Source To The Point-Of-Use



ressor

s

Depletion w/Optional
with Horn

s - Master Alarm Box

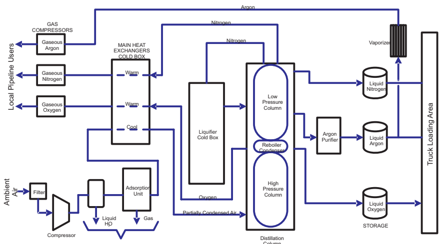
PIPELINE EQUIPMENT

- 12 HBV3000 - Ball Valve, Instrument, High Purity
- 13 MP250 - Multi-Purifier Panel - H_2O, THC, O_2
- 14 ZVBL - Zone Valve Box - 5 Valves, High Purity
- 15 Vacuum Jacketed Pipe, Bayonnet-Style

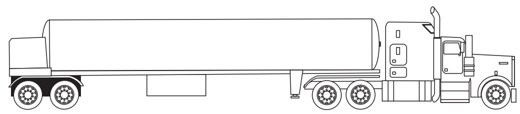
POINT-OF-USE

- 16 MP - Modular Panels - Regulator, Filter, Valve
- 17 WOA - Wall Outlet for High Purity Applications
- 18 PCP - Pressure Control Panel for Incubators
- 19 LGT - Laboratory Gas Turrets

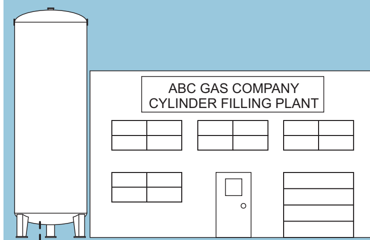
The Specialty Gas Cylinder Journey



AIR SEPARATION PLANT OR CHEMICAL PLANT

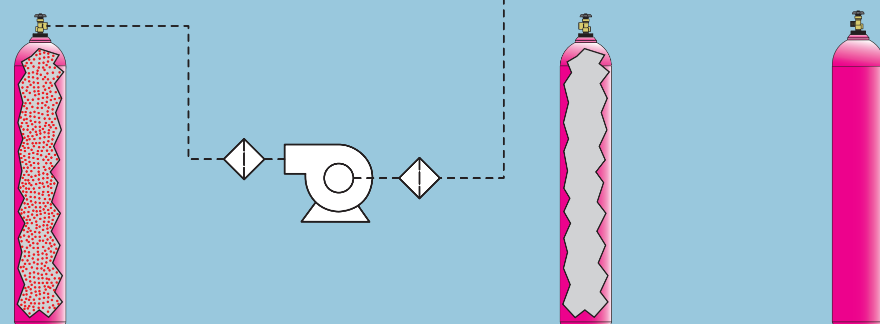


LIQUID TANKER OR BULK SUPPLY EQUIPMENT



SPECIALTY GAS CYLINDER FILLING FACILITY

Specialty gas cylinder filling plants are specialized and dedicated to that purpose.



CHOICE OF CYLINDER

Once a cylinder is put in a specific gas service. It generally remains in that gas service.

CYLINDER PREPARATION

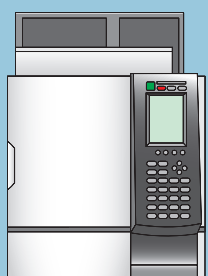
Impurities are removed from gas cylinder walls via several steps: cleaning, baking, pickling vacuuming and purging

MOLECULE FILTRATION & COMPRESSION

During that very important stage, the molecules are also being filtered and compressed.

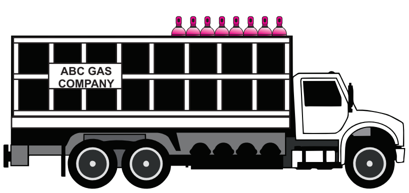
CYLINDER *FILLING (PUMPING)*

The cylinder is filled with the proper gas.



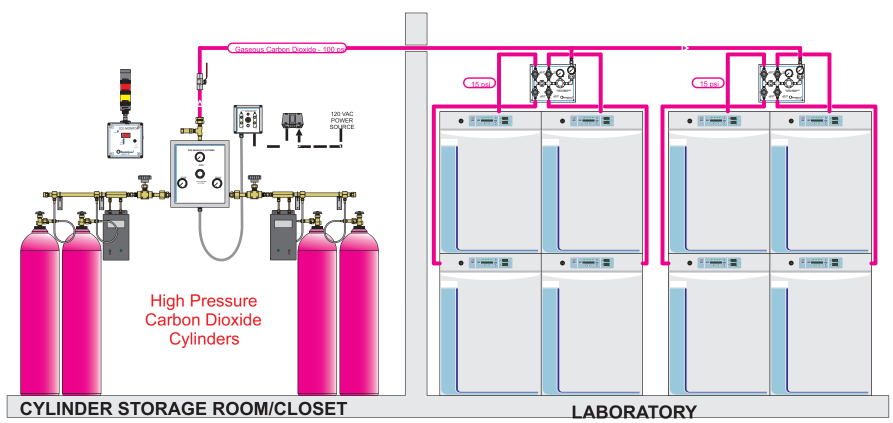
QUALITY CONTROL

Cylinders are either tested individually or one per batch of cylinders. Cylinders have to match a certain set of specifications for purity and impurities.



GAS CYLINDER DELIVERY

Most gas companies have branches (aka distributors) serving a multitude of different gas users including specialty gas users.



END USER

End users expect to receive gas cylinders that meet their requirements and specifications.

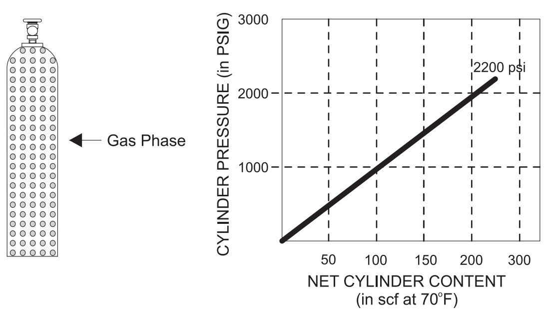
Common Cylinder Size Comparison Between Gas Manufacturers

Approx. Dimensions (inches)	Air Products	AGA	Airgas	BOC	Air Liquide	Praxair	Matheson	MG	Linde	Scott Specialty Gases
High Pressure Steel Cylinders										
24 x 90	Y	-	-	-	-	TO	-	-	-	-
9 x 55	A	049	300	300	49	T	1L	300	049	K
9 x 51	B	044	200	200	44	K	1A	200	044	A
7 x 33	C	016	80	80	16	Q	2	80	016	B
7 x 19	D-1	007	35	30	7	G	3	35	007	C
4 x 17	D	003	7	12	3	F	4	10	-	D
2 x 12	L.B.	LBR	L.B.	L.B.	L.B.	L.B.	L.B.	L.B.	LBS/LBR	L.B.
4 x 26	E	005	E	E	MEDE	ANE	3L	E	-	ER
10 x 51	BX	485	3HP	500	44H	6K	1U	3HP	046	-
9 x 51	BY	-	-	-	44H	3K	1H	2HP	-	-
High Pressure Aluminum Cylinders										
10 x 52	A (Al)	-	-	-	AT	-	-	-	-	-
8 x 48	B (Al)	A31	150A	150A	30AL	AS	1R	150AL	A31	AL
7 x 33	C (Al)	A16	80A	80A	22AL	AQ	2R	80AL	A16	BL
7 x 16	D-1 (Al)	A07	33A	30A	7AL	AG	3R	33AL	A07	CL

Typical Cylinder Content

Gas Phase Only Cylinders

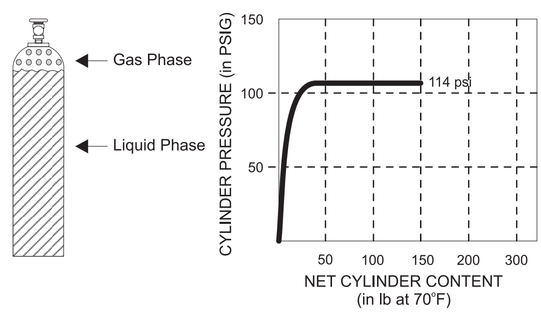
Gases with extremely low boiling temperatures have a gas phase only in high pressure cylinders. The main characteristic of this type of gas cylinder is the direct correlation between the net content and its pressure. In other words, the cylinder pressure decreases as the content depletes. Most of these gases can be found in gas form in nature.



Molecule	Cylinder Content		Cylinder Pressure	
	ft³	m³	psig	barg
High Pressure Steel Cylinders (K- size, 44-size, 200-size)				
Air	227	6.31	2200	151.7
Argon	243	6.77	2200	151.7
Carbon Monoxide	173	4.79	1650	113.8
Helium	214	5.93	2200	151.7
Hydrogen	192	5.32	2000	137.9
Methane	256	7.09	2000	137.9
Nitrogen	224	6.20	2200	151.7
Oxygen	244	6.76	2200	151.7

Gas & Liquid Phases Cylinders

Gases with high boiling temperatures have both a gas phase and a liquid phase in the cylinders. The cylinder pressure decreases mainly when the liquid phase inside the cylinder is depleted. Those gases are called process gases as they are the results of industrial processes such as refineries.



Molecule	Cylinder Content		Cylinder Pressure	
	lbs	kg	psig	barg
High Pressure Steel Cylinders (K- size, 44-size, 200-size)				
1, 3-Butadiene	45	20.41	21.4	1.5
Carbon Dioxide	57	25.85	830	57.2
Ethylene	30	13.60	1250	4.79
Hydrogen Chloride	55	24.95	613	86.2
Nitrous Oxide	60	27.22	745	51.4
Propane	25	15.88	109	7.5
Propylene	100	45.36	136	9.4
Sulfur Hexafluoride	115	52.16	320	22.2

Typical Analytical Equipment Using Gases

Gas Chromatography (GC)

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Thermo Scientific™ TRACE™ 1310 GC Analyzers

Typical Gas Used

Helium
Hydrogen
Air
Nitrogen

Definitions & Applications

Separation of individual species in a sample is taking place in a column using a mobile gas phase and a stationary solid phase.

Liquid Chromatography (HPLC, LCMS)

Used by permission from Thermo Fisher Scientific, the copyright owner

Thermo Scientific™ UltiMate™ 3000 Standard HPLC System

Typical Gas Used

Air
Nitrogen

Definitions & Applications

Separation of individual species in a sample is taking place in a column using a mobile liquid phase and a stationary solid phase.

Inductively Coupled Plasma (ICP)

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Thermo Scientific™ iCAP™ 7600 ICP-OES

Typical Gas Used

Argon
Nitrogen

Definitions & Applications

Spectroscopy trace analysis of chemical elements. Popular technique used to detect the presence of metals in different types of samples.

Atomic Absorption (AA)

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Thermo Scientific™ iCE™ 3300 AA Spectrometer

Typical Gas Used

Acetylene
Nitrous Oxide

Definitions & Applications

Spectroscopy analysis of chemical elements. Popular technique used to detect the presence of metals in given samples.

Incubators

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Typical Gas Used

Carbon Dioxide
Oxygen
Nitrogen
Gas Mixture

Definitions & Applications

An incubator is a device used to grow and maintain microbiological cultures or cell cultures. Incubators maintains optimal conditions (humidity, temperature, CO_2 and Oxygen) for the cultures to grow.

Spectrometry

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Thermo Scientific™ Nicolet iS50 FTIR Spectrometers

Typical Gas Used

Air
Nitrogen

Definitions & Applications

Spectroscopy is the study of the interaction between matter and electromagnetic radiation (such as light). Different families of spectrometers are ICP, ICP-MS, AA, FT-IR and RMN.

Impurities - What Are They?

Where Do They Come From?

The Importance of Maintaining Gas Purity

Below is a list of common detectors used in gas chromatography. The impurities/contaminants (called enemies) and their impacts on the analytical equipment performance.

DISCHARGE IONIZATION DETECTOR (DID)
Enemies: Trace levels of oxygen, moisture and hydrocarbons
Impact: Reduce detector response and affect baseline stability

ELECTRON CAPTURE DETECTOR (ECD)
Enemies: Moisture, oxygen and trace of halocarbons
Impact: Reduce detector response, cause baseline shift and create negative peaks

FLAME IONIZATION DETECTOR (FID)
Enemies: Hydrocarbons, oxygen, moisture
I*mpact:* Decrease detector sensitivity and damage chromatographic columns

FOURIER TRANSFORM INFRARED DETECTOR (FTIR)
Enemies: Impurities absorbing in the same waveband of species, moisture and oxygen
Impact: Inaccurate response and interfere with infrared spectroscopy

HELIUM IONIZATION DETECTOR (HID)
Enemies: Trace of hydrocarbons, oxygen and moisture
Impact: Affect detector stability

MASS SPECTROSCOPY DETECTOR (MSD)
Enemies: Traces of impurities with equivalent mass of the species
Impact: Inaccurate response

PULSE DISCHARGE ELECTRON CAPTURE DETECTOR (PDECD)
Enemies: Moisture, oxygen and trace of halocarbons
Impact: Reduce detector response, cause baseline shift and create negative peaks

PULSE DISCHARGE HELIUM IONIZATION DETECTOR
Enemies: Trace levels of oxygen, moisture and hydrocarbons
Impact: Reduce detector response and affect baseline stability

PULSE DISCHARGE PHOTO IONIZATION DETECTOR
Enemies: Trace levels of oxygen, moisture and hydrocarbons. Oxidizer and contaminants in fuel gas
Impact: Reduce detector response and affect baseline stability. Interfere with detector response

THERMAL CONDUCTIVITY DETECTOR (TCD)
Enemies: Trace levels of oxygen and hydrocarbons
Impact: Reduce detector sensitivity and corrode filament of detector

The Multiple Sources of Impurities in a Gas Distribution System

We have just seen that hydrocarbons, moisture, oxygen and halocarbons (to a lesser extent) are the main gas stream contaminants. These contaminants can find their way into the piping system in many ways. The list below is certainly not exhaustive.

GAS CYLINDERS
Unless the purity (aka grade) of the gas selected is inadequate for the intended purpose - like using industrial grade helium for a GC-MS, it is very unlikely that the source of contaminants is the gas cylinders. Gas companies are analyzing gas purity either in cylinder batches or individually. But, because mistakes can happen, contaminants have been found in gas cylinders.

PIPELINE INSTALLER
Pipeline installers are not all made equal. While several installers have competent and experienced personnel, the lack of knowledge of the not so fortunate installers can lead to fairly disastrous installs (even with the best intentions in mind). The sources of contamination by a poor pipeline installation are countless: leaky joints, oily tools and hands, bad purges (if any), poor inerting (if any) while brazing/welding , wrong materials installed, etc...

PIPING AND TUBING
It is better to have a clean medical grade copper pipe than a dirty stainless steel pipe. Nowadays, several stainless steel tubes and pipes are imported from overseas in ship containers. Humidity is gradually building up causing accumulation of lime for dust to stick better inside the tubes and pipes. Wholesalers are often keeping those tubes/pipes on their big pipe racks uncapped and therefore open to atmosphere where dust and debris gradually build up.

GAS EQUIPMENT
The poor selection of gas equipment can lead to serious gas contamination. Off gassing of rubber materials such as Neoprene diaphragm regulators will inevitably be visible to most detectors. That's why it is not recommended to use regulators designed for welding or for medical applications in high purity applications. Airborne contaminants (moisture, oxygen and carbon dioxide) find their way into gas streams from several locations; valves with packing (ball valves and needle valves) and forged body regulators, to name a few. Even good three-piece medical ball valves are not suitable for high purity applications. Although the cost could be prohibitive, the best type of valve is definitely the packless diaphragm valve. A good quality instrumentation needle valve or ball valve (Swagelok type) will greatly limit the damages compared to medical ball valves for example, should a ball valves or needle valves be needed for high purity applications,.

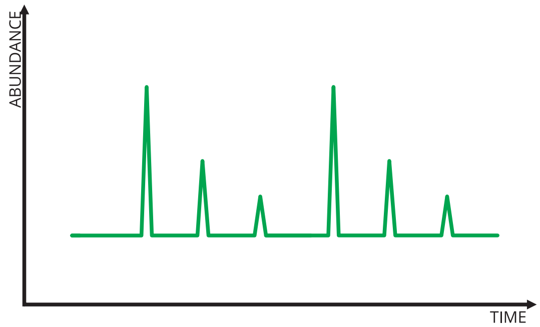
END USER
Chemists / scientists and lab technicians have not been trained to properly handle high purity gas equipment. Many times gas cylinder regulators have changed gas service by simply changing the inlet connection. Worse yet is when end users are inadequately connecting a series of gas chromatographs with old and worn out fittings.

Impurities Impact On Analytical Results

Normal Base Line

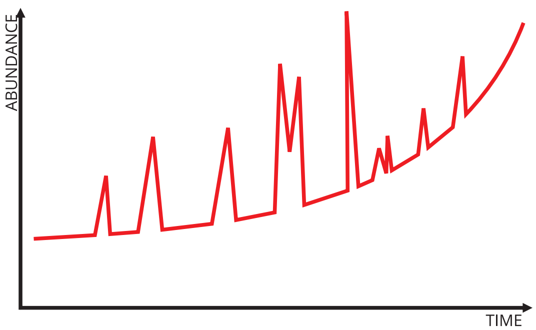
A normal baseline is flat, without peak and no drifts.

Desired Chromatogram



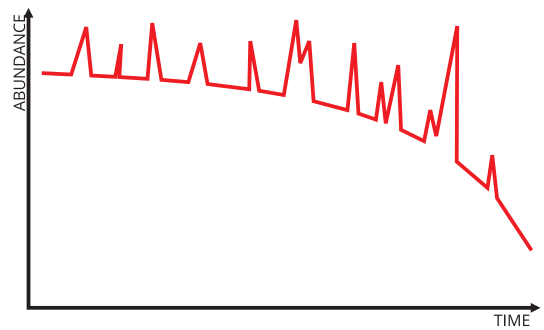
A normal chromatogram has a stable baseline with well separated and well separated peaks

Upward (Positive) Drift



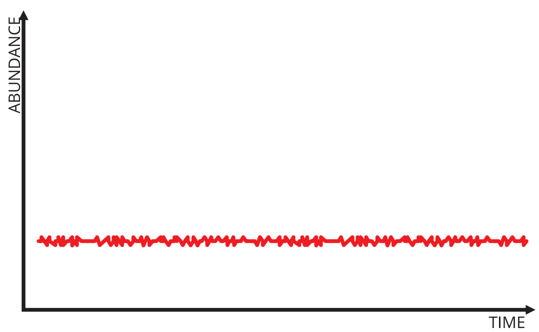
Cause: Damage to the stationary phase of the GC column

Downward (Negative) Drift



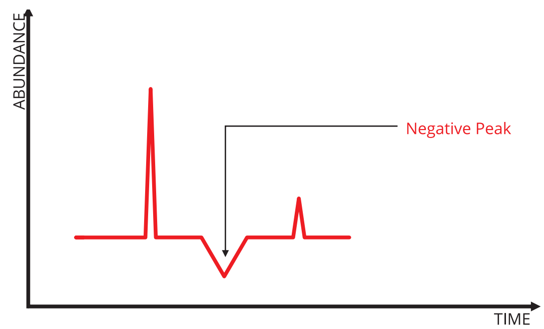
Cause: Back out of contaminants from the detector

Baseline Noise



Cause: Contaminated column and/or air leak

Negative Peaks



Cause: Dirty detector

Other Chromatogram Problems	Cause
Offset peaks	**Contaminated column and/or contaminated detector, unstable carrier gas flow**
Wander peaks	**Contaminated carrier gas**
Irreproducible peak heights or areas	**Baseline disturbance**
No peaks at all	**Problem with carrier gas flow**
Selective sensitivity loss	**Contamination of the column**
Retention time shift	**Contaminated column**
Rapid column performance degradation	**Exposure to oxygen, particularly at elevated temperature**
Tailing peaks	**Debris in the liner or column**

Quick Reference Application Guide

Application	Gas Requirement	Purity	Flow Capacity	BeaconMedaes Recommendations	
				Single Gas Generator	Combined Gases Generator
Products for Gas Chromatography					
GC-FID	Hydrogen (H) for fuel Gas	99.999% [5.0]	30-50	HYDRO50	IDSTATION ; GCSTATION; H2-N2STATION
	Zero air for flame gas	HC Free	300-500	AERO40	FIDSTATION ; GCSTATION ; PIDSTATION
	H_2 for capillary carrier gas	99.99995% [7.5]	Up to 10 cc	HYDRO65	FIDSTATION ULTRA ; GCSTATION ULTRA ; H2-N2STATION ULTRA
	N_2 for packed carrier gas	99.999% [5.0]	20-50	NITROSTATION ULTRA	FIDSTATION ULTRA ; GCSTATION ULTRA ; PIDSTATION ULTRA
	N_2 for make-up gas	99.999% [5.0]	30-50	NITRO50	GCSTATION ; PIDSTATION ; H2-N2STATION
GC FPD	Hydrogen (H_2) for fuel Gas	99.999% [5.0]	60-90	HYDRO50	FIDSTATION ; GCSTATION; H2-N2STATION
	Zero air for flame gas	HC Free	90-120	AERO40	FIDSTATION ; GCSTATION ; PIDSTATION
GC NPD	H_2 for capillary carrier gas	99.99995% [6.5]	up to 50 cc	HYDRO65	FIDSTATION ULTRA ; GCSTATION ULTRA ; H2-N2STATION ULTRA
	N_2 for make-up gas	99.999% [5.0]	up to 30 cc	NITRO50	GCSTATION ; PIDSTATION ; H2-N2STATION
GC ECD	N_2 for carrier gas	UHP-Zero Grade	up to 60 cc	NITROSTATION ULTRA	FIDSTATION ULTRA ; GCSTATION ULTRA ; PIDSTATION ULTRA
	N_2 for make-up gas	99.999% [5.0]	up to 100 cc	NITRO50	GCSTATION ; PIDSTATION ; H2-N2STATION
GC TCD	H_2 as carrier gas	99.99995% [7.5]	up to 50 cc	HYDRO65	FIDSTATION ULTRA ; GCSTATION ULTRA ; H2-N2STATION ULTRA
GC ATD	Air for purge	Dry Air	< 2L/Min	AERO50	FIDSTATION ; GCSTATION ; PIDSTATION
GC AED	N_2 for carrier gas	Ultra-Zero Grade	< 1L/Min	NITROSTATION ULTRA	FIDSTATION ULTRA ; GCSTATION ULTRA ; PIDSTATION ULTRA
GC ELSD, HALL	Hydrogen (H_2) as reaction gas	99.999% [5.0]	70-200	HYDRO50	FIDSTATION ; GCSTATION ; PIDSTATION
Products for Liquid Chromatography					
LCMS API/LCMS	Air for nebulizer gas	Dry air	18L/Min	AERO50	DUO18LCMS
APCI Electrospray	Nitrogen (N_2) for curtain	HC free 99.5%	5-35L/min	NITRO20	-
LCMS/MS, TOF	Sheath shield gas	99% [2.0]	20,35,60L/min	NITRO18LCMS	NITRO20LCMS ; DUO18LCMS; TRIO18LCMS
Products for Spectroscopy					
FT-IR	Purge gas for sample compartment, optics, air bearing and microscope	CO_2 free air	14-85 L/min	AERO50 FTIR	-
NMR	Air for lifting spinning and ejecting	Dry air	up to 300L/min	AERO20	-
ICP	Nitrogen (N_2) for purge gas	99.995% [4.5+]	up to 9L/min	NITRO40 ICP	-
AA	Air for oxidant gas	Dry Air	28L to 200L/min	AERO50	-
Products for Analyzers					
TOC	Air	Dry air, CO free	100-500 cc	AERO50 TOC	-
	Nitrogen (N_2) for carrier gas or combustion gas	99.999% [5.0]	50-700 cc N_2	NITRO50	GCSTATION ; PIDSTATION ; H2-N2STATION
THA	Zero air for FID	HC free	50-500 cc	AERO40	FIDSTATION ; GCSTATION ; PIDSTATION
	Hydrogen (H_2) for fuel gas	99.999% [5.0]	5-50 cc	HYDRO50	FIDSTATION ; GCSTATION; H2-N2STATION
DSC	Air for shield	Dry air	100 cc	AERO50	FIDSTATION ; GCSTATION ; PIDSTATION
TGA	Air as furnace gas	Dry air	100 cc	AERO50	FIDSTATION ; GCSTATION ; PIDSTATION
	Nitrogen (N_2)	UHP-Zero Grade	100 cc	NITROSTATION ULTRA	FIDSTATION ULTRA ; GCSTATION ULTRA ; PIDSTATION ULTRA
TOD	Nitrogen (N_2) for carrier gas	UHP-Zero Grade	300 cc	NITROSTATION ULTRA	FIDSTATION ULTRA ; GCSTATION ULTRA ; PIDSTATION ULTRA
CO_2 Analyzer	Air for calibration	CO_2 & HC	550-1000 cc	AERO60	-

Quick Reference Application Guide

Application	Gas Requirement	Purity	Flow Capacity	BeaconMedaes Recommendations	
				Single Gas Generator	Combined Gases Generator
Other Applications					
Sample Preparation	Nitrogen (N_2) for solvent preparation	95-99%	up to 130 L/min	NITRO15LS	NITRO20LCMS ; DUO -18LCMS ; TRIO18LCMS
Auto Sample	Air for pneumatic controls	Dry air	28 L/min	AERO50	_
	Nitrogen (N_2) for sample injector	99.999% [5.0]	550 cc	NITRO50	GCSTATION ; PIDSTATION ; H2-N2STATION
Circular Dichroism	Nitrogen (N_2)	99.999% [5.0]	-	NITRO50	GCSTATION ; PIDSTATION ; H2-N2STATION
ELSD Detector	Nitrogen (N_2)	98% [1.8]	2 - 8 L/min	NITRO15	_
Particle sizing by laser difraction	Air for nebulizing	Dry air	-	AERO5	-
Inorganic Spectroscopy	Oxygen (O_2)	99.995% [4.5]	3 -6 L/min	OXY40	-
Organic Spectroscopy	Oxygen (O_2)	99.995% [4.5]	7 L/min	OXY40	-
MOCVD	Hydrogen (H_2)	99.99995% [6.5]	250 ml/min - 2L/min	HYDRO70	_
Optical Protection	Air for protection gas	Ultra Zero air, CO_2 free, HC free	1 -1.5 L/.min	AERO60	_

Glossary

AA - Atomic Absorption

AED - Atomic Emission Detector

ATD - Automated Thermal Desorption

APCI - Atmospheric Pressure Chemical Ionization

CVD - Chemical Vapor Deposition

DID - Discharge Ionization Detector

DSC - Differential Scanning Calorimetric

DTA - Differential Thermal Analysis

ECD - Electron Capture Detector

ELSD - Evaporative Light Scattering Detector

FID - Flame Ionization Detector

FPD - Flame Photometric Detector

FTIR - Fourier Transform Infrared Detector

GC - Gas Chromatography

HID - Helium Ionization Detector

HPLC - High Performance Liquid Chromatography

ICP - Indictively Coupled Plasma

LC - Liquid Chromatography

MP-AES - Microwave Plasma - Atomic Emission Spectrometer

MOCVD - Metal Organic Chemical Vapor Deposition

MS - Mass Spectrometer

NMR - Nuclear Magnetic Resonance

NPD - Nitrogen Phosphorous Detector

PDECD - Pulse Discharge Electron Capture Detector

PID - Photoionization Detector

SFE - Super-critical Fluid Extraction

SFC - Super-critical Fluid Chromatography

TCD - Thermal Conductivity Detector

TGA - Thermal Gravimetric Analysis

TOC - Total Organic Carbon

TOD - Total Oxygen Demand

TOF - Time of Flight

Table Of Gas Properties & Material Compatibilities

Gas	Primary Hazards					Metals					Plastics				Elastomers			Explosive Levels		Toxicity Levels		Physical Properties		
	Asphyxiant	Toxic	Flammable	Corrosive	Oxidizer	Aluminum	Brass	Copper	Monel	Stainless Steel	Kel-F	Teflon	Tefzel	Kynar	Viton	Buna-N	Neoprene	LEL (% in Air)	UEL (% in Air)	TLV-TWA (ppm in Air)	TLV-STEL (ppm in Air)	Specific Volume (ft³/lb)	Boiling Point @ 1 atm (°F)	Specific Gravity (Air=1)
ACETYLENE	X		X			S	S	U	S	S	S	S	S	S	S	S	S	2.5	100	-	-	14.77	-119.6	0.899
AIR					X	S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	12.55	-317.8	1.000
AMMONIA		X	X	X		S	U	U	S	S	S	S	S	U	U	S	S	15.0	28.0	25	35	22.49	-28.3	0.588
ARGON	X					S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	9.68	-302.5	1.379
ARSINE		X	X			-	S	S	S	S	S	S	S	S	S	S	S	-	-	.05	-	4.91	-79.9	2.691
BORON TRICHLORIDE		X		X		U	D	D	S	S	S	S	S	-	-	-	-	-	-	-	-	3.18	55.1	4.045
BORON TRIFLUORIDE		X		X	X	-	D	D	S	S	S	S	S	-	-	-	-	-	-	1C	-	5.68	-147.5	2.341
BROMINE TRIFLUORIDE		X		X		D	D	D	S	S	D	D	S	U	U	U	U	-	-	-	-	415.1	258.2	4.727
1.3-BUTADIENE		X	X			S	S	S	S	S	S	S	S	S	S	S	S	2.0	12.0	2	-	6.98	23.7	1.868
n-BUTANE	X		X			S	S	S	S	S	S	S	S	S	S	S	S	1.8	8.4	800	-	6.45	31.0	2.007
1-BUTENE			X			S	S	S	S	S	S	S	S	S	S	S	S	1.6	10.0	-	-	6.70	21.1	1.937
cis-2-BUTENE			X			S	S	S	S	S	S	S	S	S	S	S	S	1.7	9.7	-	-	6.61	53.1	1.937
trans-2-BUTENE			X			S	S	S	S	S	S	S	S	S	S	S	S	1.7	9.7	-	-	6.62	47.3	1.937
CARBON DIOXIDE	X					S	S	S	S	S	S	S	S	S	S	D	D	-	-	5000	3000	8.74	-126.5	1.519
CARBON MONOXIDE		X	X			S	S	S	S	S	S	S	S	S	S	S	S	12.5	74.0	25	-	13.80	-312.7	0.967
CHLORINE		X		X	X	U	U	U	S	S	S	S	S	S	S	U	U	-	-	.5	1	5.39	-28.8	2.448
CHLORINE TRIFLUORIDE		X		X		U	-	-	S	S	D	D	S	U	U	U	U	-	-	-	-	4.09	53.1	3.192
DEUTERIUM	X		X			S	S	S	S	S	S	S	S	S	S	S	S	4.9	75.0	-	-	96.0	-417.0	0.139
DICHLOROSLANE		X	X	X		U	-	-	S	S	S	S	S	S	-	-	-	4.1	98.8	-	-	3.72	46.7	3.487
DI-, MONO-, AND TRIMETHYLAMINESS		X	X	X		U	U	U	S	S	S	S	S	S	U	U	-	-	-	-	-	-	-	-
DISILANE			X			S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	6.01	6.7	2.148
ETHANE	X		X			S	S	S	S	S	S	S	S	S	S	S	S	3.0	12.4	-	-	12.76	-127.5	1.038
ETHYL CHLORIDE			X			S	S	S	S	S	S	S	S	S	S	S	S	3.8	15.4	100	-	5.82	54.0	2.227
ETHYLENE	X		X			S	S	S	S	S	S	S	S	S	S	S	S	2.7	36.0	-	-	13.71	-154.8	0.969
FLUORINE		X		X	X	D	D	D	S	S	D	D	D	D	U	U	U	-	-	1	2	10.18	-306.8	1.312
HALOCARBON-14						S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	-	-	-
HALOCARBON-23	X					S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	5.48	-115.9	2.917
HALOCARBON-116	X					S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	2.77	-108.7	4.765
HELIUM	X					S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	96.67	-452.0	0.138
HYDROGEN	X		X			S	S	S	S	S	S	S	S	S	S	S	S	4.0	75.0	-	-	191.95	-423.2	0.070
HYDROGEN BROMIDE		X		X		U	U	U	S	S	S	S	S	S	S	U	U	-	-	3C	-	4.74	-88.0	2.794
HYDROGEN CHLORIDE		X		X		U	U	U	S	S	S	S	S	S	S	U	U	-	-	5C	-	10.55	-120.8	1.259
HYDROGEN FLUORIDE		X		X		U	U	U	S	S	S	S	S	S	U	U	U	-	-	3C	-	5.65	-108.7	4.765
HYDROGEN SULFIDE		X	X	X		S	S	-	S	S	S	S	S	S	U	S	S	4.0	44.0	10	15	11.26	-74.9	1.176
ISOBUTANE	X		X			S	S	S	S	S	S	S	S	S	S	S	S	1.8	8.4	-	-	-	-	-
ISOBUTYLENE	X		X			S	S	S	S	S	S	S	S	S	S	S	S	1.8	9.8	-	-	-	-	-
KRYPTON	X					S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	4.61	-244.1	2.893
METHANE	X		X			S	S	S	S	S	S	S	S	S	S	S	S	5.0	15.0	-	-	24.06	-258.7	0.554
METHYL CHLORIDE		X	X			U	S	S	S	S	S	S	S	S	S	U	U	7.0	17.4	50	100	4.83	-11.2	1.740
METHYL FLUORIDE		X	X			S	S	S	S	S	S	S	S	S	-	-	-	-	-	-	-	11.23	-109.0	0.170
NEON	X					S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	19.18	-410.9	0.697
NITROGEN	X					S	S	S	S	S	S	S	S	S	-	-	-	-	-	-	-	13.80	-320.4	0.967
NITROGEN DIOXIDE		X		X	X	S	U	U	U	S	S	S	-	-	U	U	U	-	-	3	5	-	-	-
NITROGEN TRIFLUORIDE		X			X	-	S	S	S	S	S	S	S	S	S	-	-	-	-	10	-	5.43	-200.2	2.451
NITROUS OXIDE					X	S	S	S	S	S	S	S	S	S	S	S	S	-	-	50		8.74	-128.3	1.520
OCTAFLUOROCYCLOBUTANE	X					S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	1.87	21.2	6.906
OCTAFLUOROPROPANE	X					S	S	S	S	S	S	S	S	-	-	S	S	-	-	-	-	2.01	-34.3	6.491
OXYGEN					X	D	S	S	S	D	S	S	S	S	D	U	D	-	-	-	-	12.08	-297.4	1.105
PHOSPHINE		X	X			S	-	-	S	S	S	S	S	-	-	-	-	-	-	.03	1	11.30	-126	1.174
PROPANE	X		X			S	S	S	S	S	S	S	S	S	S	S	S	2.1	9.5	-	-	8.62	-43.7	1.522
PROPYLENE	X		X			S	S	S	S	S	S	S	S	S	S	S	U	2.4	11.0	-	-	9.06	-53.8	1.453
SILANE			X			S	S	S	S	S	S	S	S	S	S	S	S	-	-	5	-	11.98	-170.4	1.109
SILICON TETRACHLORIDE		X		X		U	U	U	S	S	S	S	S	S	U	U	U	-	-	-	-	8.25	136.6	5.866
SILICON TETRAFLUORIDE		X		X		U	U	U	S	S	S	S	S	S	U	U	U	-	-	-	-	3.69	-148.3	3.593
SULFUR DIOXIDE		X		X		S	U	S	S	S	S	S	S	S	S	U	U	-	-	2	5	5.95	13.8	2.212
SULFUR HEXAFLUORIDE	X					S	S	S	S	S	S	S	S	S	S	S	S	-	-	1000	-	2.62	-90.8	5.042
SULFUR TETRAFLUORIDE		X		X		U	U	U	S	S	S	S	S	S	U	U	U	-	-	-	-	3.53	-53.5	3.731
TUNGSTEN HEXAFLUORIDE		X		X		U	U	U	S	S	S	S	S	S	U	U	U	-	-	-	-	1.26	63.0	10.283
XENON	X					S	S	S	S	S	S	S	S	S	S	S	S	-	-	-	-	2.93	-162.6	4.533

S = Satisfactory   - = Insufficient Data or Not Applicable   U = Unsatisfactory   D = Suitability depends on condition of use
C = Ceiling Value   X = Indicates primary hazard

NFPA 704 -HMIS

Hazardous Materials Identification System

HEALTH HAZARD

4 EXTREME
Highly Toxic
May be fatal on short-term exposure.

3 SERIOUS
Toxic
Full protective suit and breathing apparatus must be worn.

2 MODERATE
Breathing apparatus and face mask should be worn.

1 SLIGHT
Breathing apparatus may be worn.

0 MINIMAL
No precautions necessary

FLAMMABILITY HAZARD

4 EXTREME
Extremely flammable gas or liquid.
Flash Point: below 73° F

3 SERIOUS
Flammable.
Flash Point: 73° F to 100° F

2 MODERATE
Combustible. Requires heating to ignite.
Flash Point: below 200° F

1 SLIGHT
Slightly combustible.
Requires strong heating to ignite.

0 MINIMAL
Will not burn under normal conditions.

SPECIFIC HAZARD

OX	OXYGEN
OXY	OXDIZER
ACID	ACID
ALK	ALKALI
COR	CORROSIVE
W	Use NO WATER

INSTABILITY HAZARD

4 EXTREME
Explosive at room temperature.

3 SERIOUS
May detonate if shocked or heated under confinement or mixed with water.

2 MODERATE
Unstable.
May react with water.

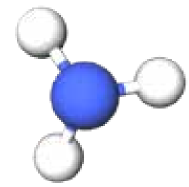
1 SLIGHT
May react if heated or mixed with water.

0 MINIMAL
Normally stable.
Does not react with water.

Gas Data Sheet

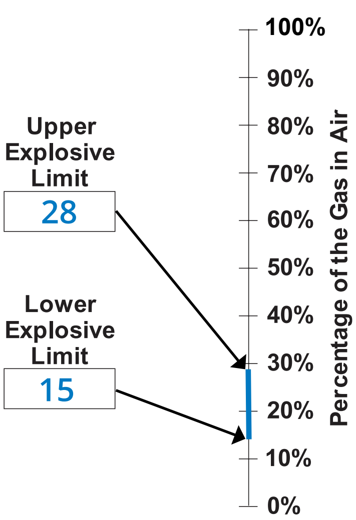
Example

Ammonia (NH_3)

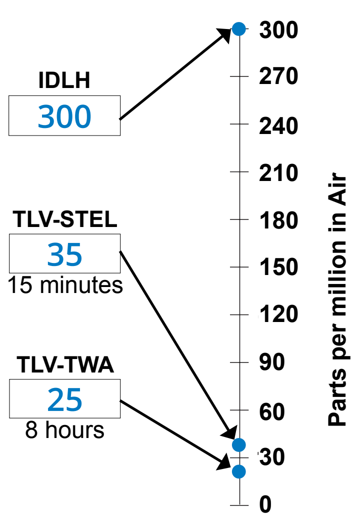


CAS #: 7664-41-7
UN #: 1005
General Description: A colorless, toxic, alkaline, flammable, liquefied gas with a pungent odor, irritating to eyes, skin and mucous membranes in high concentrations.
Trade Names: Anhydrous ammonia

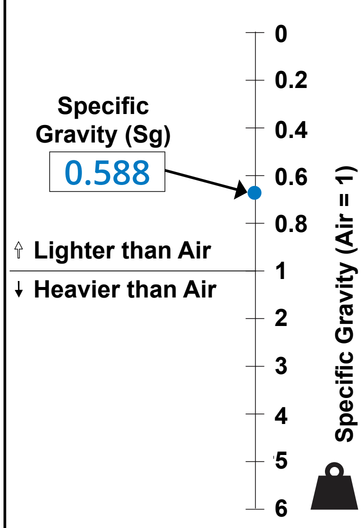
Hazards



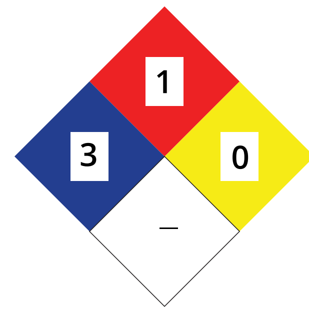
Flammability Range (%)



Toxicity Level (ppm)



Gas Density (Compared to Air)



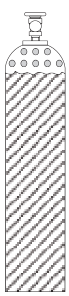
Primary Hazard
Poison, Toxic, Corrosive

Secondary
Fire & Explosion

Safety (NFPA) Placard

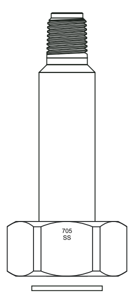
Gas Cylinder Data

Liquid/Gas



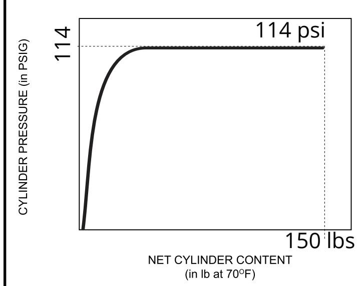
Molecule Distribution

CGA 705
DISS 720



N. American Gas Cylinder Connection

DOT Label



Cylinder Pressure

Material Compatibility

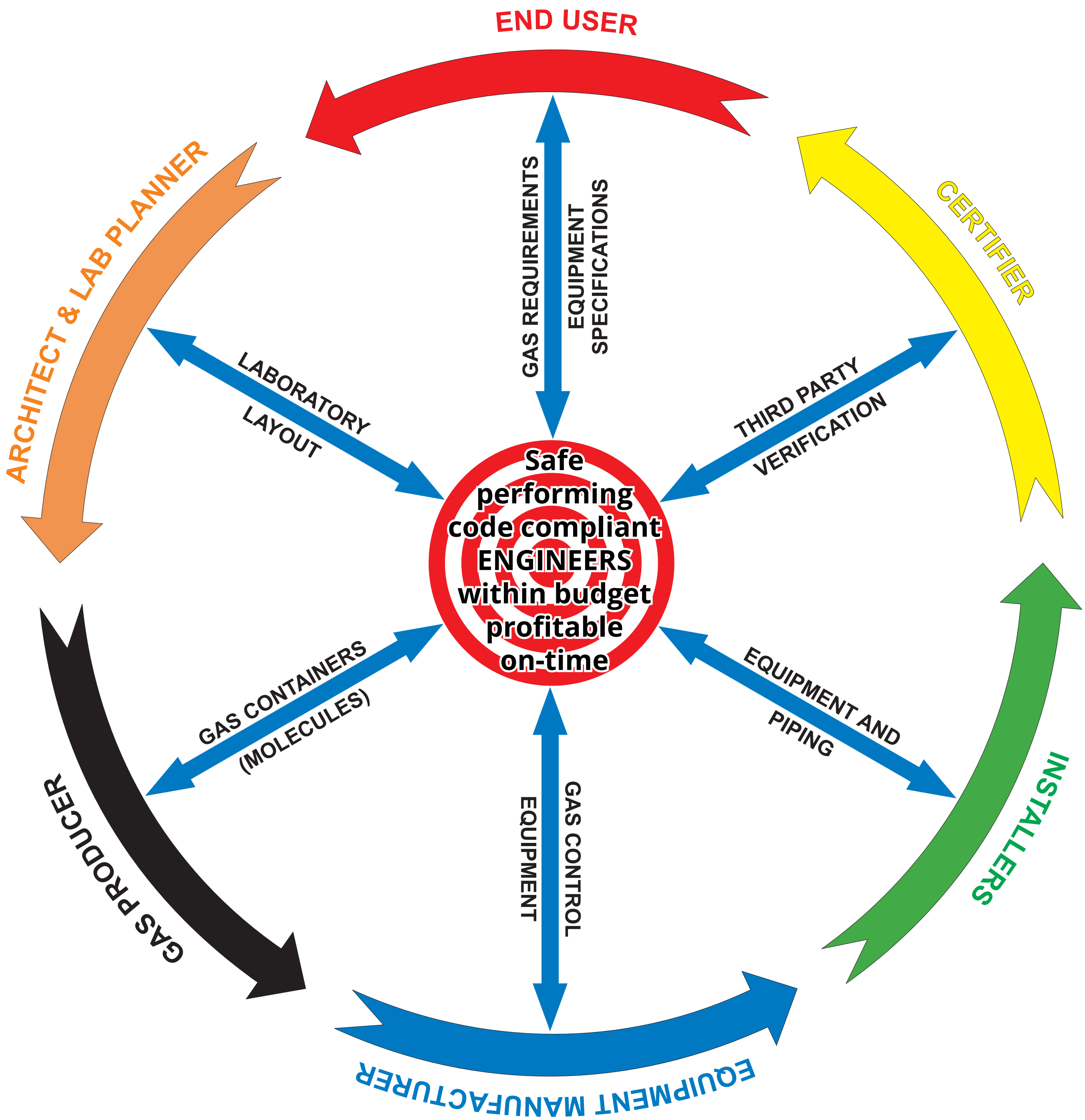
Metals					Plastics					Elastomers (Synthetic Rubbers)			
Aluminum	Brass	Copper	Monel	Stainless Steel	Teflon (PTFE)	Nylon (PVC)	Tefzel	Kymar	Kel-F (PCTFE)	Buna-N	EPDM	Neoprene	Viton
B	B	B	G	G	G	B	G	B	G	G	B	G	B

B Bad
G Good

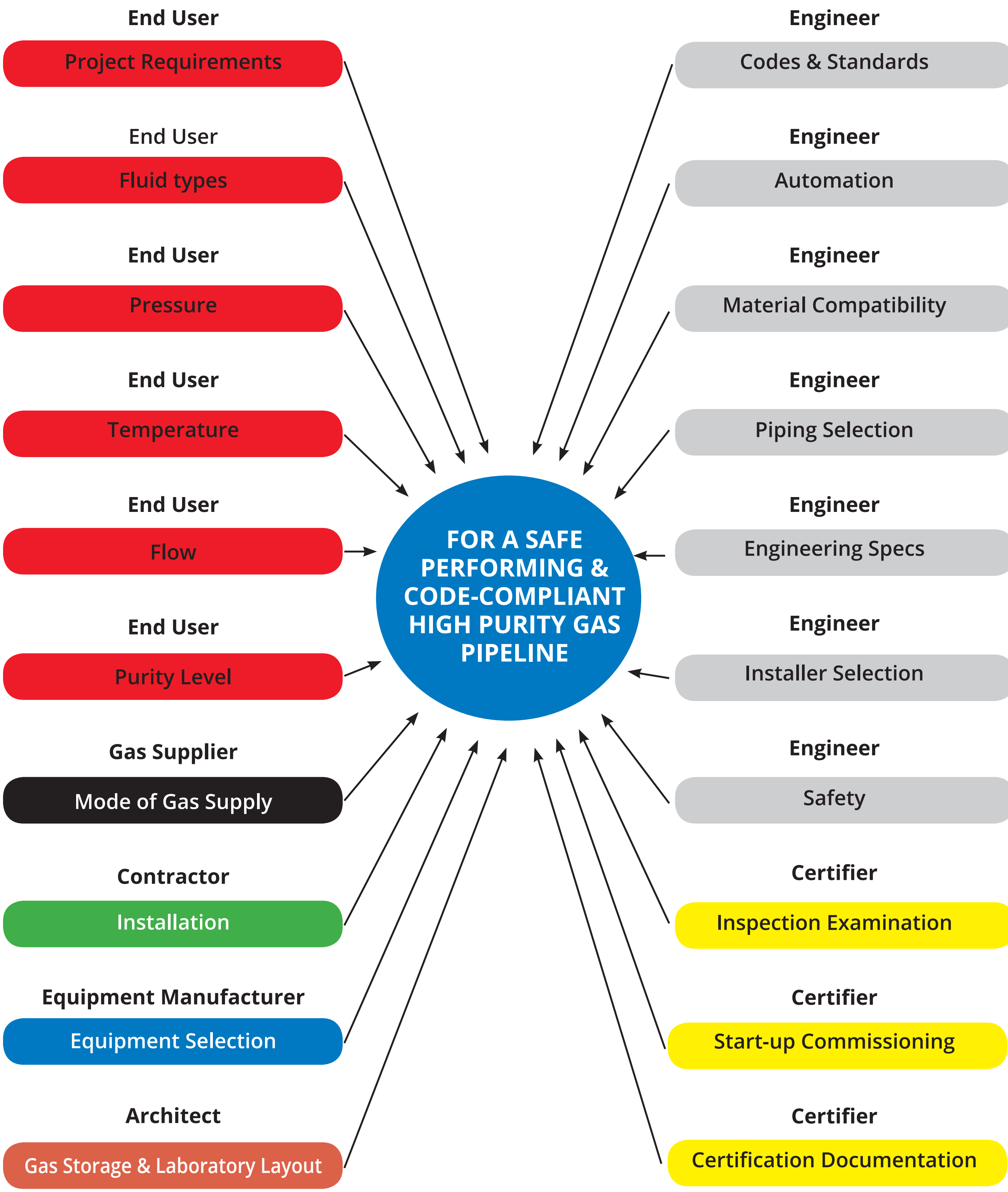
For more gas data reference sheets, please visit our online reference library at bmgasdata.com

Design & Construction Cycle

Who's Involved?



Pipeline Design Criteria



Pipeline Design

Key Steps

STEP 1	STEP 2	STEP 3	STEP 4
GAS SUPPLY MODE	**CYLINDER STORAGE**	**GAS CYLINDER CONTROL EQUIPMENT**	**PIPELINE TYPE**
Determine the flow pattern: *-Max flow rate* *-Steady flow rate* *-Monthly usage* **Establish the purity required delivered to each point of use** **List the pressure for each gas at each point of use** **What is the best storage cylinder type?** *- High pressure cylinders* *-Liquid cylinders* *-Gas generators*	**Cylinder storage:** *- Inside laboratory* *-Cylinder room/closet* *-Loading dock* *-Gas cabinet* **Sprinkers available?** *You can store twice as much gas in a room equipped with sprinklers* **Is the gas toxic, flammable, inert, or oxidizer?** *Gas segregation storage is required* **How many gas cylinders?** *Meet Maximum Allowable Quantity as per NFPA 55* **Explosion control requirements** **Space planned for full and empty cylinders?** **Are you using elevators to transport cryogens?**	**Is gas supply interruption allowed?** *-Switchover manifold* *-Simple regulators* **Desired pipeline pressure per gas?** **Flow requirement per gas** *-Equipment Cv* *-How many cylinders?* **Purity level required per gas:** *Ultra high purity: >99.9995* *High Purity = 99.999* *Commercial: < 99.99* *-Brass* *-Stainless steel* *-Hoses* *-Regulators* *-Valves* **Cylinder supply status?** *-Alarm box* *-Automatic shutdown*	**Material compatibility:** *-Stainless steel* *-Copper* *-Teflon* *-Vacuum jacketed piping* **Purity level requirements:** *-Cleanliness* *-Desorption* *-Off gassing* *-Leak integrity* *-Installer qualification* **Flow requirements per gas:** *-Pipe diameter* **Pipeline pressure per gas:** *-Wall thickness* **Pipe or tube?** **Joints:** *-Silver brazed* *-Soldered* *-Compression fittings* *-Flared fittings* *-Threaded (NPT, ISO, BSP)* *-Welded (orbital or TIG)* **Can you pipe away all the relief valves to a common pipe?**
Optimized gas supply mode will require one delivery of cylinders per week	**The design shall meet applicable standards, codes, and regulations**	**Select the proper BeaconMedaes manifold for each gas to meet application needs**	**Select the proper pipeline construction for each gas to meet application needs**

Pipeline Design
Key Steps

STEP 5	STEP 6	STEP 7	STEP 8
PIPELINE EQUIPMENT	PIPELINE FILTRATION	POINT-OF-USE CONTROL	SAFETY & AUTOMATION
Supply isolation valve *(aka source valve)* **Emergency tie-in valve** *-Back up feed* *-Sampling point* *-Test port* *-Vent valve* **Pipeline pressure relief valve** *-Equipment PRV are there to protect the equipment* **Pipeline pressure gauge** **High/low pressure switches** **Pressure transmitters** **Zone valve box for high purity gases** **Master gas valve boxes**	**Removal of:** *-Particles* *-Oxygen* *-Moisture* *-Hydrocarbons* *-Carbon dioxide* *-Virus* *-Mold* *-Bacteria* **Trap and filter change out valves:** *-Inlet isolation* *-Service isolation* *-Vent* *-By-pass*	**Pressure reducing and control** **Flow measurement and control** **Final filtration** *-Particles* *-Oxygen* *-Moisture* *-Hydrocarbons* *-Carbon dioxide* *-Virus* *-Mold* *-Bacteria* **Multiple delivery point valves** **Gas turrets** **Wall outlets for high purity gases** **Location of each point-of-use:** *-On a bench* *-In a fume hood* *-On a wall* *-Hanging from the ceiling*	**Gas detection** *-Room monitoring* *-Gas cabinet* *-Point-of-use* **Voice dialer** *-Emergency situation* *-Need fresh cylinders* **Excess flow** *-Excess flow switch* *-Excess flow valve* **Automatic shut-off controller** *-Key to reset* *-Fail safe automatic shutoff valve* **Signage & Audio/Visual Alarm** *-Buzzer and/or beacon* **External signal** *-BMS/DDC* *-Fire alarm system* *-Dry contact or 4-20 mA* **Remote shutdown actuation** *-Emergency stop*
Provide pipeline protection, adaptability and serviceability	**Maintain integrity of the pipeline** **Allow easy and contamination-free filter change-outs**	**Provide ease of gas control at each point-of-use**	**Provide notification to key personnel and/or system of present or potential hazardous conditions**

Questionnaire

Point-Of-Use Requirements

PURPOSE OF THIS QUESTIONNAIRE
We are currently in the design stage of a high purity gas delivery system. The purpose of this questionnaire is to gather information on the gas requirements of the analytical process or experiment. The goal is to make sure to supply each application with gas at the appropriate quality, flow and pressure. Would you please complete this questionnaire to the best of your knowledge and return to: john.doe@xyzengineering.com
Please use one questionnaire per analytical equipment, process or experiment.

IDENTIFICATION	
Questionnaire completed by	Date
Denis Hache	01-18-2017
Telephone number	
803-817-5600	
E-mail address	
denis.hache@beaconmedaes.com	
Laboratory name, department, section	
Analytical Instruments Lab	
Building name or number	Room number
J. Armand Bombardier	2700

DESCRIPTION OF YOUR APPLICATION		
Analytical equipment, description of experiment or process (please provide: tag number, name, type of detector, brand of equipment, model number)		
Gas Chromatograph, Flame Ionization Detector + Thermal Conductivity, Shimandzu, GC-2014		
Is it an existing or new requirement?	Is it a temporary or permanent requirement?	If temporary, for how long?
New	Permanent	N/A

DESCRIPTION OF YOUR APPLICATION			
GAS 1	**GAS 2**	**GAS 3**	**GAS 4**
Gas name	Gas name	Gas name	Gas name
Helium	Hydrogen	Air	
Minimum purity (gas grade or 9s)	Minimum purity (gas grade or 9s)	Minimum purity (gas grade or 9s)	Minimum purity (gas grade or 9s)
99.995%	99.995%	Dry air	
Impurities to avoid	Impurities to avoid	Impurities to avoid	Impurities to avoid
Moisture + organic comp.	Moisture + organic comp.	Moisture + organic comp.	
Temperature	Temperature	Temperature	Temperature
Not applicable	Not applicable	Not applicable	
Purpose	Purpose	Purpose	Purpose
Carrier gas + make up gas	Flame fuel to FID	Air supply to FID	
Supply pressure	Supply pressure	Supply pressure	Supply pressure
Inlet 980 KPa	Inlet 500 KPa	500 KPa	
Flow (peak ***and*** per week)	Flow (peak ***and*** per week)	Flow (peak ***and*** per week)	Flow (peak ***and*** per week)
30 ml/min	40 ml/min	400 ml/min	
SPECIAL REQUIREMENTS OR ADDITIONAL INFORMATION			
I work in both split and splitless mode.			
Please note any additional information or special requirements. If required, please attach another sheet to this document			

BeaconMedæs®	Project Name: XYZ Laboratory Fit Out	Revision:
	Location: Anywhere, ST	Date:

Item	Room	Panel	Description	CO_2 (gas)		CO_2 (liquid)	Air		Air X.P. (H.P.)		Nitrogen (gas)		Nitrogen (liquid)	Nitrogen X.P. (H.P.)		Argon		Helium		Hydrogen		Oxygen		Propane
				PSI	ml/min		PSI	ml/min	PSI	ml/min	PSI	ml/min		PSI	ml/min	PSI	ml/min	PSI	ml/min	PSI	ml/min	PSI	ml/min	PSI
6	123	D-19	ICP - atom scan 25 - metal analyzer													60	20000							
61	123	D-18	Wickbold																	14.5		29		
14	122	D-17	Isotherm oven								20	25												
4	119	D-22	Antek & computer - nitrogen													40	200					40	650	
5	119	D-21	Antek 9000 & computer - sulfurs													40	200					40	650	
9	119	D-14	GC DHAX HP/AC HP 6890 & computer				75	600					22					75	640	200	660			
9	119	D-15	SIMDIS HP/AC, HP 6890 & computer				75	300										75	25	75	30			
11	119	D-25	Titrometer Mettler DL37								10	25												
21	119	D-23	LECO/C-200 computer & printer																			40	3000	
22	119	D-26	Isotherm oven								20	25												
77	119	D-24	JFTOT											500	1500									
35	119	—	Dry ice Presto			X																		
50	119	D-16	Black room								15													
28	113	D-7	GC Sivers, HP 6890, Sivers 355				40	25										60	25	40	25			
29	113	113	GC Wason gas analyzer				60	25			90	25						90	25	40	25			
20	113	D-5	Caral Hewlett Packard 5890 & printer				40	25										50	25	20	25			
30	113	D-6	GC AC gas analyzer				90	25			90	25						90	25	90	25			
N/A	109	D-2	H-109 fume hood								100													
37	111	D-3	PAV PG-59 C-622, Prentex-1997						305															
38	111	D-3	PAV PG-59 C-748, Prentex-1998						305															
74	111	D-28	C3 (propane)																					15
75	111	D-4	Oven																					X
7	119	—	ISL	100	35																			
9	119	—	ISL	100	35																			
72	119	—	Distillation ISL no. 1 AD 96 5G ISL	100	35																			
12	119	—	ISL	100	35																			
14	119	D-9	MCRT								20	25												
20	119	D-27	Titrometer								10	25												
56	119	D-13	COC flash point																					40 mbar
64	119	D-11	PSA-70								20													
70	119	D-12	Gum bath				5	36000																
76	119	D-10	Induction oven (not on drawing)																			100		
91	112	Future	Potsill								30	2[1]												
96	112	Future	DHA				75	350										75	40	75	35			
97	112	Future	LT SIMDIS															75	350[2]	75	200[3]	75	100[4]	
93	112	Future	HT SIMDIS															75	350[2]	75	200[3]	75	100[4]	
92	112	Future	Flowloop											300	100-200[5]									

Gas Service	CO_2 (gas)	CO_2 (liquid)	Air	Air X.P. (H.P.)	Nitrogen (gas)	Nitrogen (liquid)	Nitrogen X.P. (H.P.)	Argon	Helium	Hydrogen	Oxygen	Propane
Location of gas/liquid cylinders	Lab	Lab	Cyl. room	Cyl. room	Cyl. room	Lab	Cyl. room	Cyl. room	Cyl. room	Cyl. room	Cyl. room	Cyl. room
Main pipeline pressure in psig	100	40	150	305	150	40	500	100	150	225	150	25
Flow in ml/min. [scfh]	140 [0.296]	-	36,450 [77.233]	-	177 [0.375]	-	1700 [3.602]	20,400 [43.225]	1,505 [3.189]	1,225 [2.596]	4,500 [9.535]	-

(1) Average of 2 ml/min., maximum of 100 ml/min.
(2) Average of 350 ml/min., maximum of 2000 ml/min. minimum purity of 99.995%
(3) Average of 200 ml/min., maximum of 500 ml/min. minimum purity of 99.995%
(4) Average of 100 ml/min., maximum of 200 ml/min. minimum purity of 99.75%
(5) Upon start-up, flow can go up to 1000-2000 ml/min for 1 minute

Gas Supply Modes

Cryogenics

Cryogenic Plants (Air Separation)

Used by permission from Air Liquide, the copyright owner

Characteristics

Manufacturers	Primarily major gas companies
Products	Mainly N_2, O_2, Ar, He, H_2, CO_2
Capacity	Several tons per day
Location	Independent site near major user
Pressure	In general below 200 psig
Purity	Commercial grade (can be purified)
Purpose	Merchant plant
Typ. Industry	All industries

Cryogenic Liquid Tankers

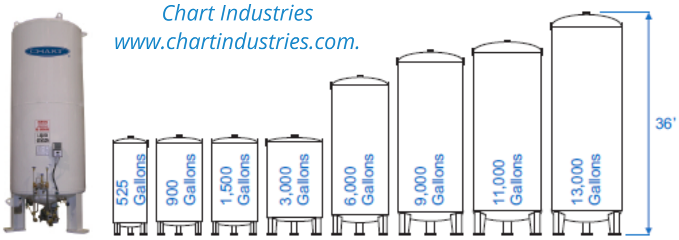
Used by permission from Air Liquide, the copyright owner

Characteristics

Manufacturers	Original Equipment Manufacturers (OEM)
Products	Mainly N_2, O_2, Ar, He, H_2, CO_2
Capacity	Generally around 15,000 gallons
Location	Road tankers and ISO containers
Pressure	Cryo: up to 60 psig - CO_2 is diff.
Purity	Commercial grade (can be purified)
Purpose	Hauling product from ASP to tanks
Typ. Industry	All industries

Cryogenic Storage Vessels

Image courtesy of Chart Industries www.chartindustries.com.



Characteristics

Manufacturers	Chart, Taylor Wharton, Tomco
Products	Mainly N_2, O_2, He, Ar, H_2, CO_2
Capacity	From 525 to 20,000 gallons
Location	End user sites
Pressure	Cryo: up to 500 psig - CO_2 : 350 psig
Purity	Commercial grade or better
Purpose	Product storage in liquid state
Typ. Industry	All industries

Micro-Bulks

Images courtesy of Chart Industries www.chartindustries.com.

Characteristics

Manufacturers	Chart
Products	Mainly N_2, O_2, Ar, CO_2
Capacity	Up to 2,000 liters (liquid content)
Location	End user sites
Pressure	Cryo: up to 500 psig - CO_2 : 350 psig
Purity	Commercial grade or better
Purpose	Product storage in liquid state
Typ. Industry	Welding, restaurants, laboratories

Portable Liquid Cylinders

Image courtesy of Chart Industries www.chartindustries.com.

Characteristics

Manufacturers	Chart, Taylor Wharton
Products	Mainly N_2, O_2, Ar, CO_2
Capacity	Up to 230 liters
Location	End user sites
Pressure	Cryo: up to 500 psig - CO_2 : 350 psig
Purity	Commercial grade or better
Purpose	Product storage in liquid state
Typ. Industry	All industries

Gas Supply Modes

On-Site Generation

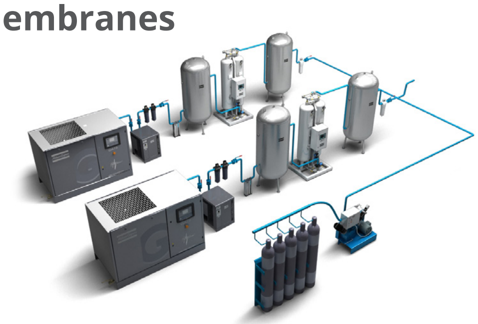
Large Size On-Sites: APSA & VPSA

Used by permission from Air Liquide, the copyright owner

Characteristics

Manufacturers	Primarily major gas companies
Products	Mainly N_2, O_2, H_2
Capacity	Several tons per day
Location	Mostly at customers' sites
Pressure	In general below 200 psig
Purity	Commercial grade (can be purified)
Purpose	Supply gas for one application
Typ. Industry	O_2 for pulp & paper, N_2 for electronics

Medium Size On-Sites: PSA - Membranes



Characteristics

Manufacturers	Majors, AirSep, Dow, Parker
Products	Mainly N_2, O_2, H_2
Capacity	Vary greatly (low to mid tons per day)
Location	Mostly at customers' sites
Pressure	In general below 200 psig
Purity	Commercial grade (can be purified)
Purpose	Supply gas for one application
Typ. Industry	Food packaging, bright annealing

Small Gas Generators

Table Top Hydrogen Generator

Nitrogen Generator

Characteristics

Manufacturers	BeaconMedaes, Parker, Peak & more
Products	Laboratory grade N_2, Air, H_2, O_2
Capacity	Very low (from lpm to 100 scfh)
Location	End user sites
Pressure	In general below 200 psig
Purity	Both laboratory & commercial grade
Purpose	Chromatography, Spectrometry
Typ. Industry	Pharmaceutical, universities

Gas Supply Modes
High Pressure Containers

Tube Trailers

Used by permission from FIBA Technologies, the copyright owner

Characteristics

Manufacturers	FIBA
Products	Mainly Air, He, N_2, O_2, Ar, H_2
Capacity	Up to 150,000 scfh
Location	Hauling products from plants to cust.
Pressure	Rarely above 2400 psig
Purity	Any purity
Purpose	Temporary supply or cascading
Typ. Industry	All industries

Hydril Tubes

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Characteristics

Manufacturers	FIBA
Products	Mainly Air, He, N_2, O_2, Ar, H_2
Capacity	Could be limitless
Location	Point of use sites
Pressure	Rarely above 2,400 psig
Purity	Any purity
Purpose	High pressure gas storage (medium)
Typ. Industry	All industries

High Pressure Cylinders

Characteristics

Manufacturers	Norris, Taylor Wharton, Catalina
Products	All
Capacity	Vary greatly upon size and gas
Location	Point of use sites
Pressure	Up to 6000 psig
Purity	Any purity
Purpose	Individual or small applications
Typ. Industry	All industries

Consult the "Common Cylinder Size Comparison Between Gas Manufacturers" table on page 7 of this document.

Codes, Standards & Regulation

ASME B31.3

Process Piping

Design of chemical and petroleum plants and refineries processing chemicals and hydrocarbons, water and steam. This Code contains rules for piping typically found in petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants; and related processing plants and terminals. This Code prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping. This Code applies to piping for all fluids including: (1) raw, intermediate, and finished chemicals; (2) petroleum products; (3) gas, steam, air and water; (4) fluidized solids; (5) refrigerants; and (6) cryogenic fluids. Also included is piping which interconnects pieces or stages within a packaged equipment assembly.

Toxic Gas Ordinance Data Book

In 1988 the Santa Clara County Fire Chief's Association drafted a "Model Ordinance for Toxic Gas Regulation" in conjunction with the Santa Clara County City Manager's Association, the Santa Clara County Manufacturing Group and the Silicon Valley Toxics Coalition. This model ordinance was subsequently adopted into municipal code and county ordinance by the various jurisdictions within Santa Clara County as well as various other regulatory agencies as the "Toxic Gas Ordinance" or TGO. The TGO has been subsequently used as the base model for the 1994 Uniform Fire Code (UFC) amendments for Toxic and Highly-Toxic gases through the current Fire Code adoption.

Compressed Gas Association

Publications

CGA develops and publishes the broadest distribution of technical information, standards, and recommendations for safe and environmentally responsible practices in the manufacture, storage, transportation, distribution, and use of industrial gases.

NFPA 55

Standard for the Storage, Use and Handling of Compressed Gases and Cryogenic Fluids in Portable Stationary Containers, Cylinders, and Tanks

The most comprehensive industrial and medical gas storage and use document in the National Fire Codes®, NFPA 55 is essential for users, producers, distributors, and anyone who is involved with the storage, use, or handling of compressed gases or cryogenic fluids.
This edition expands coverage and incorporates three NFPA® Standards as individual chapters:

- *NFPA 50: Bulk Oxygen Systems at Consumer Sites*
- *NFPA 50A: Gaseous Hydrogen Systems at Consumer Sites*
- *NFPA 50B: Liquefied Hydrogen Systems at Consumer Sites*

Additionally, the 2005 edition of NFPA 55 includes provisions for underground hydrogen storage and the use of hydrogen generating devices. The allowable storage requirements are coordinated for consistency with the requirements in NFPA 5000®. (54 pages, 2005)

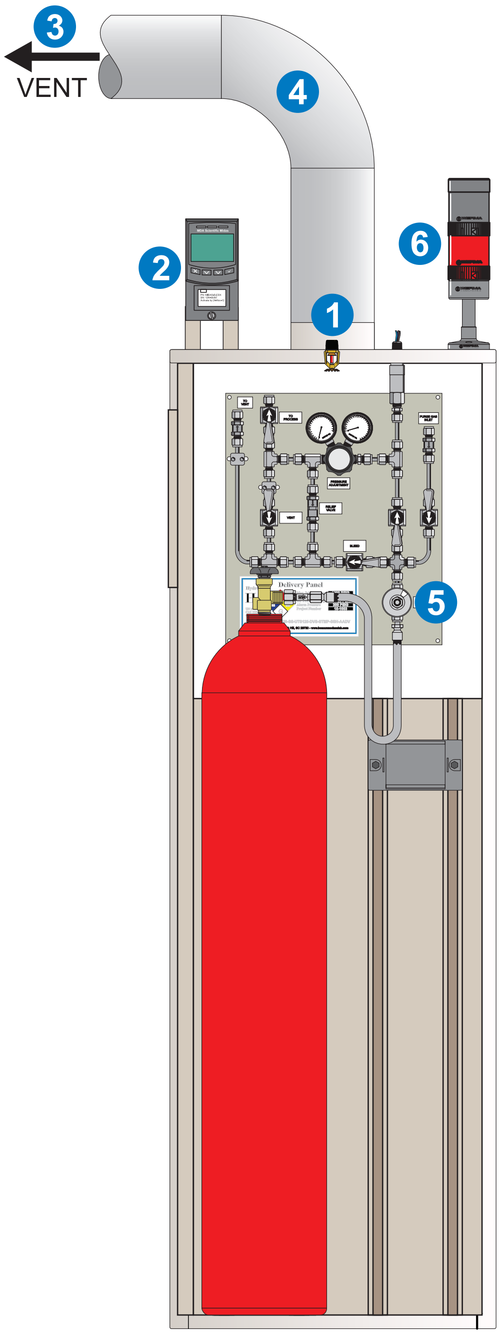
General Safety Requirements as per the Toxic Gas Ordinance (TGO)

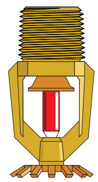
GENERAL REQUIREMENTS	CLASS I HIGHLY TOXIC	CLASS II TOXIC	CLASS III MODERATELY TOXIC	MINIMUM THRESHOLD QUNATITIES	PYROPHORIC	FUEL GAS
General Obligation for Storage & Use	X	X	X	X	X	X
Permit - Operations, Storage & Use	X	X	X	X	X	X
Permit - Install, Alter, Modify or Repair	X	X	X	-	X	X
Permit - Close, Decommission or Demolition	X	X	X	-	X	X
Compliance Plan	X	X	X	X	X	X
Emergency Response Plan	X	X	X	X	X	X
Protective Plugs & Caps in Place for Safety	X	X	X	X	X	X
Flow Limiting Orifice & Devices	X	-	-	-	X	-
Inert Gas Purge System	X	X	X	-	X	-
Automatic Fire Sprinkler	X	X	X	-	X	X
Emergency Control Station	X				X	
PIPING SYSTEMS						
Installed and Leak Tested per ASME B31.3	X	X	X	-	X	X
Labeled per ASME A13/1	X	X	X	X	X	X
ESO Located at the Source and Point of Use	X	X	X	-	X	X
Excess Flow Control	X	X	X	-	X	-[2]
Seismic Protection - Importance Factor	I = 1.5	I = 1.25	I = 1.0	-	I = 1.5	I = 1.0
Welding Piping or Ventilated Enclosure	X	X	-[1]	-	X	-[3]
Double Walled Secondarily Containment Piping	X	-	-	-	-	-
TESTING & MAINTENANCE (Annually, or in accordance with approved manufacturer's requirements)						
Gas Detection and Leak Monitoring Systems	X	X	-[1]	-	X	-[2]
Limiting Controls: Level, Temperature, Pressure or Flow	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]
Manual and Automatic ESO Controls	X	X	-[1]	-	X	-[2]
Alarms and Alarm Functions	X	X	-[1]	-	X	-[2]
EXHAUST VENTILATION SYSTEM						
Gas Room	X	X	-	-	X	-
Gas Cabinet, VMB's and Exhausted Enclosures	X	X	-[1]	-[3]	X	-[3]
Treatment to 1/2 IDLH at Point of Discharge	X	X	-	-	-[3]	-
EMERGENCY ALARM MONITORING & CONTROLS						
Gas Detection	X	X	X	-	X	
Optical Flame Detection	-	-	-	-	X	-
Smoke Detection	X	-	-	-	-[3]	-
Seismic Detection	X	X	X	-	-	-
Exhaust Flow	X	X	X	-	X	-
Manual or Remotely Actuated Automatic ESO	X	X	X	-	X	-
EMERGENCY SHUTOFF						
for Gas Detection	X	X	-[1]	-	X	
for Optical Flame Detection	-	-	-	-	X	-
for Smoke Detection	X	-	-	-	-[3]	-
for Seismic Sensor	X	X	-	-	-	-
for Exhaust Flow	X	X	-	-	X	-
for Manual or Remotely Actuated Automatic ESO	X	X	-[1]	-	X	X
for Activation of Automatic Fire Alarm System	X					
EMERGENCY POWER						
for Gas Detection	X	X	-[1]	-	X	
for Optical Flame Detection	-	-	-	-	X	-
for Smoke Detection	X	-	-	-	-[3]	-
for Seismic Sensor	X	X	-	-	-	-
for Exhaust Flow	X	X	-	-	X	-
for Manual or Remotely Actuated Automatic ESO	X	X	-[1]	-	X	X
for Temperature Control	X	X	-	-	-	-

X = Required per code.
1. May be required per Fire Code for materials having a NFPA hazard ranking of 3 or 4.
2. Required when provided, or as an alternate to other control requirements.
3. May be provided to mitigate other code requirements.

Gas Requirements

Minimum Requirements as per NFPA 55

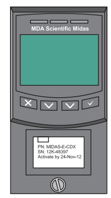




1

Water Supply For The Sprinkler

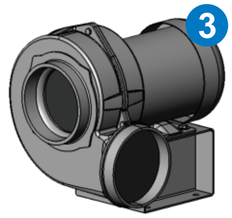
NFPA 55 - 6.16.3 Fire Protection - "Gas cabinets used to contain toxic, highly toxic, or pyrophoric gases shall be internally sprinklered."



2

Gas Detector (By BeaconMedaes … Strongly Recommend)

NFPA 55 - 7.9.3.2.1.2 - Gas Detection - "The gas detection system shall monitor the exhaust system at the point of discharge from the gas cabinet, exhausted enclosure, or gas room."



3

Exhaust Fan (By Installing Contractor)

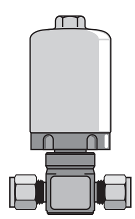
Indoor gas cabinets require ventilation. Hereunder are NFPA 55's exhaust fan requirements:

- *Air velocity: 200 ft/min with access window open 150 ft/min (no less) at any single point.*
- *Explosion-proof classification might be required.*
- *Material compatibility of exhaust fan components with gas service to be verified.*

4

Duct Work (By Installing Contractor)

Compatibility: The duct materials used must be compatible with the gas being vented.
Duct work must be installed to prevent any leaks to the atmosphere.



5

Fail-Safe Automatic Closing Valve (By BeaconMedaes)

NFPA 55 - 7.9.3.2.2 - Fail-Safe Automatic Closing Valve - "An approved automatic-closing fail-safe valve shall be located immediately adjacent to and downstream of active container, cylinder, or tank valves."

6

Warning Device (By BeaconMedaes or By Others)

NFPA 55 - 7.9.3.2.2 - Fail-Safe Automatic Closing Valve - "An approved automatic-closing fail-safe valve shall be located immediately adjacent to and downstream of active container, cylinder, or tank valves."

Treatment Systems (By Others)

NFPA 55 - 7.9.3 - Treatment System - "Except as provided in 7.9.3.1 and 7.9.3.2, gas cabinets, exhausted enclosures, and gas containing toxic or highly toxic gases shall be provided with exhaust ventilation, with all exhaust directed to a system designed to process accidental release of gas."
NFPA 55 - 7.9.3.2 - Use of Toxic Gases - "Treatment systems shall not be required for toxic gases in use where containers, cylinders and tanks are provided with controls specified in 7.9.3.2.1 (Gas Detector) and 7.9.3.2.2 (Fail-Safe Automatic Closing Valve)."

Purity Levels & Choice Of Materials

General Purpose Applications

Level 4
(99.99% +)

Recommended Materials & Equipment	
Pipe or Tube	Copper, stainless steel, any soft
Joints	Threaded, silver brazed, compression
Manifolds	Cabinet-style, general purpose, hi-flow
Soft Materials	All plastics & all polymers are good
Valves	All types of valves
Regulators	All types of regulators
Hoses	All types of hoses

Contamination Protection

- This has the least stringent purity requirements

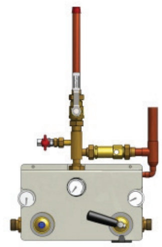
Applications

- Atomic Absorption (AA)
- Inductively Coupled Plasma (ICP)
- General Gas Chromatography (GC)

Examples of Components

Medical Grade Copper Pipes

Silver Brazed Joints



General Purpose Switchover Manifolds

General Purpose Regulators

Medical Ball Valves

High Purity Applications

Level 5
(99.999%)

Recommended Materials & Equipment	
Pipe or Tube	Copper, stainless steel (no soft tubing)
Joints	Threaded, silver brazed, compression
Manifolds	Cabinet-style, high purity, hi-flow
Soft Materials	Preferences for plastics like Teflon
Valves	All types of valves as long as CFOS
Regulators	Forged body with SS diaphragm
Hoses	All types of hoses (cleaning is critical)

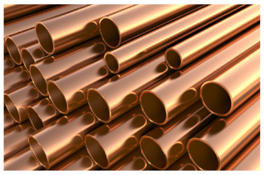
Contamination Protection

- Requires a higher level of protection against contamination

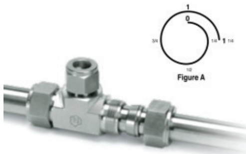
Applications

- Gas chromatography where capillary columns are used and system integrity is important

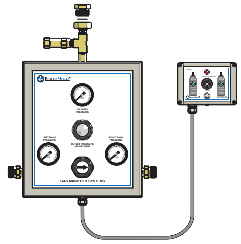
Examples of Components



Nitrogenated Grade Copper Tubes



Brass Precision Compression Fittings



High Purity Switchover Manifolds

Forged Body Chrome-Plated Brass Regulators

High Purity Two-Piece Ball Valves

Purity Levels & Choice Of Materials

Critical Purity

Level 5.5 (99.9995%)

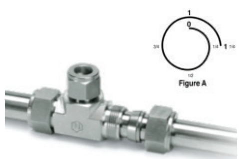
Contamination Protection
- Specific contamination control (one or two impurities)

Applications
- Electron Capture Detector
- ICP-MS

Recommended Materials & Equipment	
Pipe or Tube	Stainless steel tube
Joints	Orbitally welded or compression
Manifolds	UHP PDC stations (brass or SS)
Soft Materials	Teflon (minimize quantity of soft mat'l)
Valves	Brass diaphragm valve
Regulators	Brass barstock body w/ SS diaphragm
Hoses	Stainless steel hose

Examples of Components


Clean Stainless Steel Tubing


Stainless Steel Precision Compression Fittings


Ultra High Purity Changeover Stations


Brass Barstock Regulators


Diaphragm Valves With Compression End Fittings

Ultra High Purity Applications

Level 6 (99.9999%)

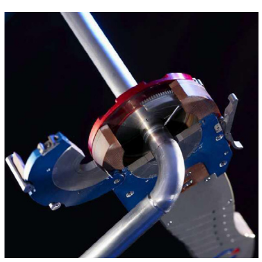
Contamination Protection
- This needs the highest level of purity

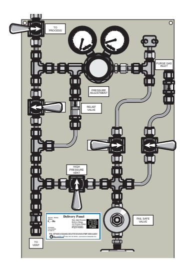
Applications
- Trace measurement in gas chromatography

Recommended Materials & Equipment	
Pipe or Tube	Electropolished stainless steel tube
Joints	Orbitally welded, VCR fittings
Manifolds	Delivery panels or UHP PDC stations
Soft Materials	Teflon or PCTFE (minimize soft mat'l)
Valves	Stainless steel diaphragm valve
Regulators	SS barstock body w/ SS diaphragm
Hoses	Stainless steel rigid pigtail

Examples of Components


Electroplated Stainless Steel Tubing


Orbital Welded Joints


Ultra High Purity Delivery Panels


Stainless Steel Barstock Regulators


Ultra Clean VCR Fittings Diaphragm Valves

Important Design Considerations Related To Gas Piping Installations

What do we want to achieve as designers of laboratory gas delivery systems?

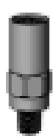
The goal is to safely and efficiently transport and control a gas from its source to the points of use at the right:

Pressure,
Purity, and
Flow
at the right cost without introducing contaminants in the gas stream.

This is much easier said than done because, in order to achieve that goal, you have to know all the options available.

Connecting All Relief Valves & Vent Valves To A Common Vents
Yes it is possible to do that as long as the following rules are respected:
- *The gases must be compatible with each other and be compatible with the vent pipe materials;*
- *The pipes must be sized so that there is no flow restriction throughout the entire vent network;*
- *The vent pipe must discharge to a safe location and away from building air intakes.*

Pipe Unions
All mechanical equipment fail or will require maintenance one day. All pipes/tubes connected to any manifold should be mounted with a pipe union. Not all pipe union is not made equal. We recommend pipe unions mounted with an o-ring seal as manufactured by Hart Industries and Superior Products.

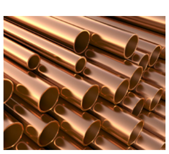


Pressure Relief Valves
Gas equipment pressure relief valves are there to protect the gas equipment from over-pressure. The gas delivery system designer is responsible to provide a PRV adequate for any specific applications.

Zone Isolation Valves
Ceilings are NOT the best place to isolate a zone in case of an emergency. A better way of isolating area, rooms or floors is to use zone valve boxes specially made for high purity gases. We recommend to install in corridors adjacent to the zone to be isolated.

Emergency Tie-In
Tie-in kits are ideal for installation right after any cabinet-style manifolds. They allow to perform a variety of tasks:
- *Emergency supply tie-in point*
- *Pipeline venting*
- *Gas Sampling*
- *Purge gas inlet*
- *Isolation of the main gas supply manifold for repair*
- *Connection assembly for pipeline pressure relief valve*

Dimensions & Length
Short distances between the gas source and the points of use reduce the risk of contamination. This also applies to proper pipe dimension. Keep in mind that the vast majority of laboratory analytical instruments use very small amounts of gases.



Can You Clean The Interior Of A Pipe/Tube Once Installed?
In 99% of the cases, the answer is NO. It is very difficult to clean piping when their diameters is either small, long and not designed for field cleaning in mind. Field cleaning in mind means regular drip valves, proper slopes and liquid traps avoided.

Tubing/Piping Electropolishing

Description
Surface metal is dissolved, removing all embedded contaminants, creating a smooth, mirror finish.

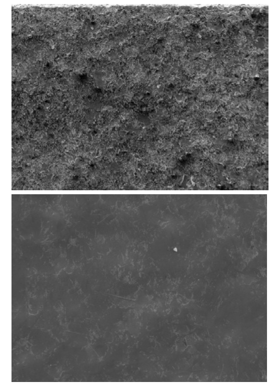
Applications
Used as gas distribution pipeline finish for the semi-conductor industry to prevent bacterial and impurity attachment to the inner conduit wall.

Cleanliness
Highest grade of passive surface available, can be subjected to long term exposure to aggressive molecules and caustic wash down.

Finish (Roughness Average = RA)
Depending on material, electropolishing can result in up to 50% increased smoothness measured in RA.

Untreated Stainless Steel surface (Magnified 150X)

Electropolished Stainless Steel surface (Magnified 500X)



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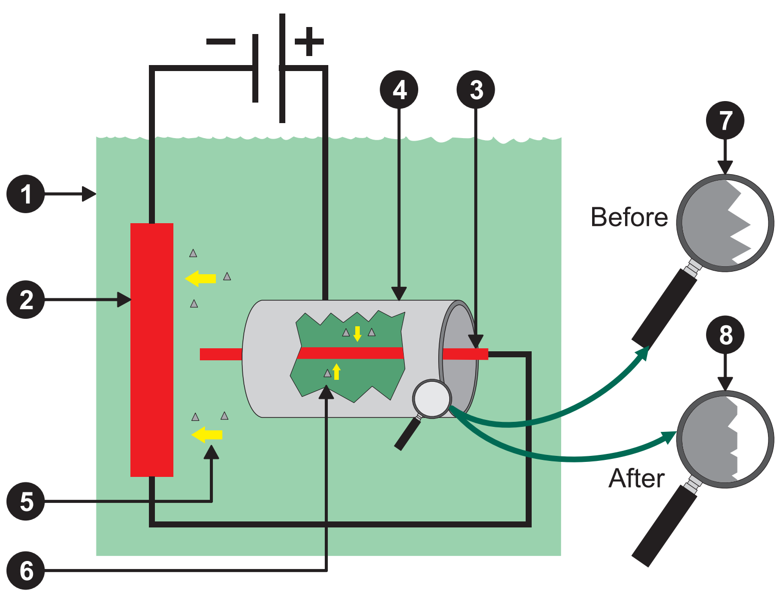
ELECTROPOLISHING = REVERSE ELECTROPLATING

Surface particles are pulled off the surface when DC current is applied leaving a very smooth surface.



ELECTROPOLISHING PRINCIPLE

1. Solution of electrolytes
2. Cathode for pipe ext. wall
3. Cathode for pipe int. wall
4. Pipe/Tube (Anode)
5. Particles traveling from the Pipe/Tube **ext.** to the cathode
6. Particles traveling from the Pipe/Tube **int.** to the cathode
7. Surface BEFORE elecropolishing
8. Surface AFTER elecropolishing

Why Packless Diaphragm Valves Are So Much Better?

To Leak or Not to Leak - That is the question

Gas leaks in general - and particularly leaky valves - have always been a great source of safety hazards, cost increment and gas purity decay.

Safety Hazards - Let's put it this way. Who would like to be exposed to toxic gases escaping from a leaky valve? Would you feel safe to install above a drop ceiling a potentially leaky valve in hydrogen service? Asking the questions is providing the answers at the same time.

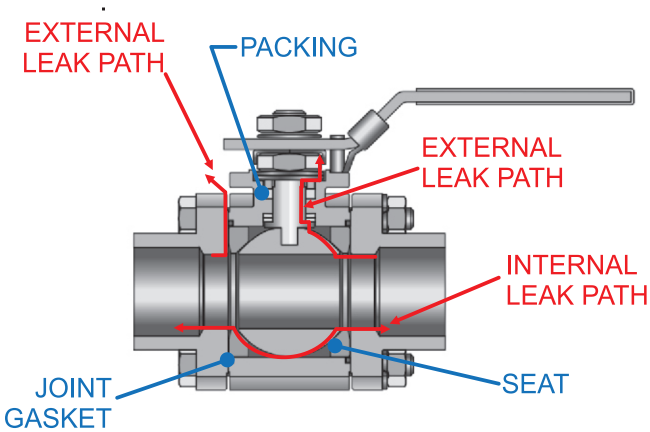
Cost Increment - Did you know that a large cylinder of Research Grade Helium is several hundreds of dollars? An Helium leak is not hazardous but it's certainly a costly situation.

Purity Decay - Contrary to popular belief, a pressurized pipeline can let ambient air (and related impurities) inside the gas stream. How? By three (3) simple phenomena:
- *Venturi*
- *Rapid Decompression*
- *Diffusion*

Ball Valves

Ball valves (and particularly three-piece ball valves such as medical ball valves) are prone to leak. There are three (3) leak paths:
- *Internal leak through the seat*
- *External leaks through the packing*
- *External leaks through the joint gasket*

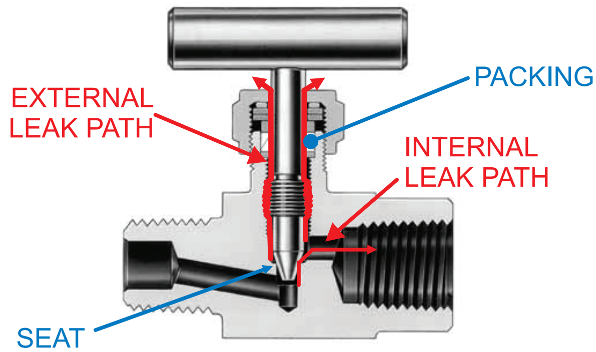
Although high quality instrumentation ball valves offer relatively good leak integrity when the valve is new. Wear and tear due to friction (high duty cycles) make this type of valve prone to critical leakage. Large variations in service pressure is a sure way to get the valve to leak internally.



BALL VALVE WITH PACKING

Needle Valves

Needle valves provide both flow control and shut-off service. There are two (2) leak paths: one (1) internal and one (1) external. The external leak path follows the stem from the wetted internal portion up to packing nut. Leaks are particularly noticeable when the stem is rotating (ie opening or closing the valve) due to vibration and mechanical friction. The internal leak takes place where the stem sits on the valve body. This is particularly true when the stem tip is bare metal (metal-to-metal seal are prone to leak).

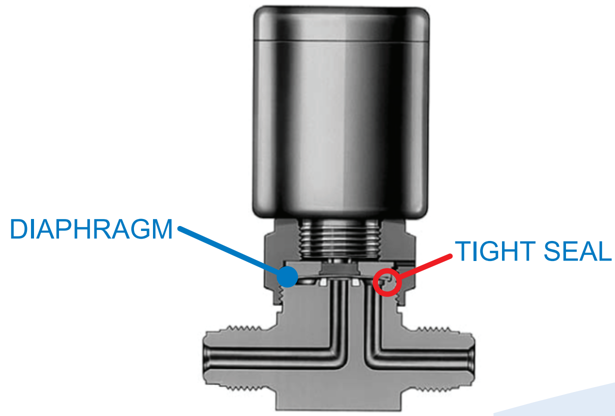


NEEDLE VALVE WITH PACKING

Packless Diaphragm Valves

Diaphragm valves are the best choice for high purity applications for three (3) main reasons:
- *There is no direct path between the handle mechanism and the wetted components (separated by the diaphragm);*
- *There is no friction between the seats and the closing mechanism (diaphragm).*
- *Pressure has no impact on the leak integrity.*

Diaphragm valves are also specifically cleaned to handle high purity gases and prepared for aggressive molecules such as acids and oxidizers.



PACKLESS DIAPHRAGM VALVE

Carbon Dioxide & Regulator Freeze Up

Under certain conditions, users of carbon dioxide gas (from high pressure cylinders) experience “freeze up” problems on valves, regulators and other compressed gas equipment. The term “freeze up” refers to a pressure regulator becoming clogged with dry ice, snow or crystals which restrict the flow of gas through the regulator or other pressure control valve. The following explains this phenomenon in an effort to help users avoid problems in CO_2 distribution systems.

Why does a regulator freeze up?

When high pressure CO_2 gas expands through a regulator seat or other flow control orifice, it can be seen downstream of the orifice on the low pressure side of the regulator as a mixture of gas with solid (snow) or liquid CO_2. If the downstream pressure is below 60 PSIG, the mixture is gas and snow, above 60 PSIG, the mixture is gas and liquid.

The amount of solid (snow) or liquid can vary from <1%, at inlet pressures under 800 PSIG when the cylinder is cool, to more than 20% under severe freeze up condition when the pressure is above 1100 PSIG resulting from a warm cylinder. Contrary to what one might expect, the most severe freeze-up conditions with CO_2 exists on warm days when a full cylinder is at 90F or higher and the cylinder pressure is at least 1100 PSIG. At normal room temperature, and full cylinder pressure of 700-900 PSIG, the problem exists, but not as severe as under the conditions above.

CO_2 cannot form at pressures above 60 PSIG. It occurs when the gas undergoes the pressure drop at the regulator valve from inlet pressure to a delivery pressure below 60 PSIG, emerging as a mixture of gaseous and solid CO_2 at a temperature in the range of -70F at 60 PSIG to -100F at the lower pressures. Under the most severe freeze-up conditions, a significant percentage of the mixture can be solid, requiring about 200 watts of heat /100 scfh of CO_2 to vaporize the solid and raise to room temperature.

Why use a heated regulator?

Unheated regulators, operating at delivery pressures below 60 PSIG, are subject to classic freeze up with solid CO_2. The CO_2 snow and dry ice particles may pass through a regulator of the outlet is wide open. If an orifice or flow control valve used, a filter is needed to prevent the solid CO_2 particles from clogging the orifice. This can result in a regulator of the outlet is wide open. This can result in the low pressure chamber of the regulator becoming completely filled with solid CO_2. The severity of the problem depends upon the flowrate of CO_2, the inlet conditions, the duty cycle (percentage of time that the gas is flowing) and the physical size of the regulator.

Unheated regulators, even if they avoid the classic problem of freeze up, cannot avoid the refrigerant effect of CO_2. When the pressure drops at the regulator valve, the CO_2 temperature drops sharply to the levels stated above, and at normal flow rates, frost can cover the entire regulator and extend to the downstream system. This frost is a result of the moisture in the air freezing and accumulating on the exterior surface. It is not related to the CO_2 effects described here and typically have no effect on the performance of the valve.

The solution

Heated regulators can relieve or eliminate freeze-up problems. The BeaconMedaes CTS Series has 200 watts of heat to provide a continuous 100 scfh of CO_2 under the most severe freeze-up conditions and higher flow rates under normal (intermittent) conditions. The regulators are two-stage, to include the advantages of the two-stage regulators discussed above. The first stage cavity serves as a boiler to vaporize CO_2 liquid and eliminate or minimize any CO_2 solids in the second stage. The second stage is then available to heat the CO_2 vapor before it reaches the outlet.

Manifold Selection Questionnaire

Gas Service		
Molecule		*That determines all kinds of things such as CGA fitting and materials.*
Delivery Pressure		*To cover all applications needs.*
Maximum flow rate		*Flows are generally unknown except when they are exceptionally high.*
Normal flow rate		*Most high purity applications are steady low flow.*
Grade / Purity/ Level		*For UHP applications, opt for small equipment like stations.*
Gaseous or cryogenic liquid service		*Self explanatory*
Environment		
Indoor or outdoor installation?		*Outdoor equipment requires NEMA 3R, 4, 4X alarms*
Space allowed for this manifold?		*This is a particularly important to configure the header bars*
Is the area ventilated?		*The use of a gas monitoring system might be required in confined spaces*
Fire sprinkers in the room?		*NFPA 55 regulates the quantity of molecules allowed in a given space*
Is it a permanent installation?		*For temporary installation, open-style manifolds might be better suited*
Which country will it be installed?		*Determines the cylinder connection (CGA, DIN, BS, or NEN).*
Is environment explosive or corrosive?		*It helps to determine the type of alarm or the coating of the equipment*
Preferences		
How many cylinders are you planning?		*Hint: Consider one cylinder bank replacement per week.*
Preference for stainless steel over brass?		*You may not have a choice if the gas is corrosive (SS in that case).*
Flexible hoses or rigid pigtails?		*Rigid pigtails rarely leak but they are extremely stiff. Go flexible!*
Do you accept delivery pressure variations?		*It tells us if you need single or two-stage pressure regulation*
Is gas interruption acceptable?		*Determines if an automatic switchover manifold is required*
Manifold in an enclosure or not?		*In North America, cabinet-style is popular. For Europe, not so much*
Preferences		
Do you want to be warned when a bank is depleted?		*In other words, is an alarm required with your manifold?*
We recommend vent valves for UHP applications		*Venting and purging help keep a clean system*
Is equipment regularly attended or supervised?		*For unattended equipment, go with a fully automatic switchover manifold*

Enter your answers in the proper boxes above

Project Name	Location	Contact Name	Phone Number	Date

Calculations

Number Of Cylinders Per Manifold

This section discusses how to properly size a gas manifold. What are the criteria to determine how many gas cylinders should a manifold have? The exercise below details step by step how to do just that.

It is important to work with the gas supplier and the end user. Too many gas cylinder deliveries may end up in high delivery cost for the gas supplier and an accounting nightmare for the end user. Conversely, long periods of time between gas cylinder deliveries may cause a manifold to run dry or require costly emergency deliveries for the gas supplier.

Example

Your customer, an important oil refinery, is giving you the task to determine how many gas cylinders each manifold should have for their new state-of-the-art quality control laboratory they are designing. Because vehicle traffic in gas refineries have to be kept to a minimum. You are asked to make sure there is no more than **one delivery of gas cylinders per week**. You also know that all analytical equipment in the current laboratory will be transferred to the new laboratory. To illustrate our example, we are using Helium.

Step 1 - Determine the gas consumption, purity, and pressure required for each analytical equipment.
The first step you take is visiting the current laboratory. During your visit, you use the questionnaire on **page 18** of this document to gather all gas consumption for each analytical equipment.

Step 2 - Compile the information you collected in Step 1.
This step is about listing each analytical equipment and their respective gas requirements. Obviously, the data shall be segregated by gas and then by other specific requirements such as pressure or purity. You came up with a Table **(see page 19)** that clearly shows the total requirements per gas and then by pressure. The goal is to come up with a total gas consumption for a specific period (in your case it is SCFH).

$$\text{Total gas consumption per hour} = \sum \text{Consumption per point of use per hour}$$

The table on page 19 shows Helium to be at 3.189 SCFH

Step 3 - Duty Cycle
The duty cycle is defined as the percentage of a period in which the gas is required. In your case, because the refinery is running 24/7. The laboratory is also running 24/7.

Because the lab is operating 24/7.
The duty cycle is 100% (24 hours per day)

Example of Duty Cycles expressed in days

- *8 hours per 24 - hour day (33%)*
- *10 min. per hour during 6 hours per 24 - hour day (4%)*
- *2 hours during per 24 - hour day (4%)*

Step 4 - Total gas usage between gas cylinder deliveries
The end user already told you that only one gas cylinder delivery per week is acceptable. The interval between gas deliveries is 7 days.

$$\text{Total gas usage between gas deliveries} = \text{Hourly usage} \times \text{Duty cycle} \times \text{No. of days}$$

$$\text{535 SCF} = \text{3.189 SCFH} \times \text{24 hours per day} \times \text{7 days}$$

Step 5 - Determine the gas cylinder volume (size) to be used.
You contact the gas company and you understand that the refineries has standardized on K-size cylinders for all gases. You consult **page 7** of this manual and you see that a K-size cylinders contains **214 SCF of Helium**.

Step 6 - Determine how many cylinders are required between each gas cylinder deliveries
At this point, you easily determine the following equation:

$$\text{No. of gas cylinders between deliveries} = \text{Gas usage between deliveries} \div \text{Volume of gas per cylinder}$$

$$\text{3(2.5) gas cylinders between deliveries} = \text{535 SCF per 7 days} \div \text{214 SCF per cylinder}$$

Step 7 - Determine how many cylinders are required for the gas manifold.
A manifold system shall always have one gas cylinder bank in use and one complete bank in reserve.

Therefore, in our example, the Helium manifold shall have two (2) banks of three (3) gas cylinders each.

Gas Cylinder Storage

Design Guidelines

Temperature

• **Cool** temperature shall be maintained in the gas cylinder storage area.
• Gas cylinders shall not be exposed to temperature exceeding 125° F [52° C].
• Outdoor storage shall be **above grade,** dry and protected from the weather.
• Gas cylinders shall not be exposed to **direct sunlight.**
• **Excessive heat,** open flame or ignition are forbidden.

Safety

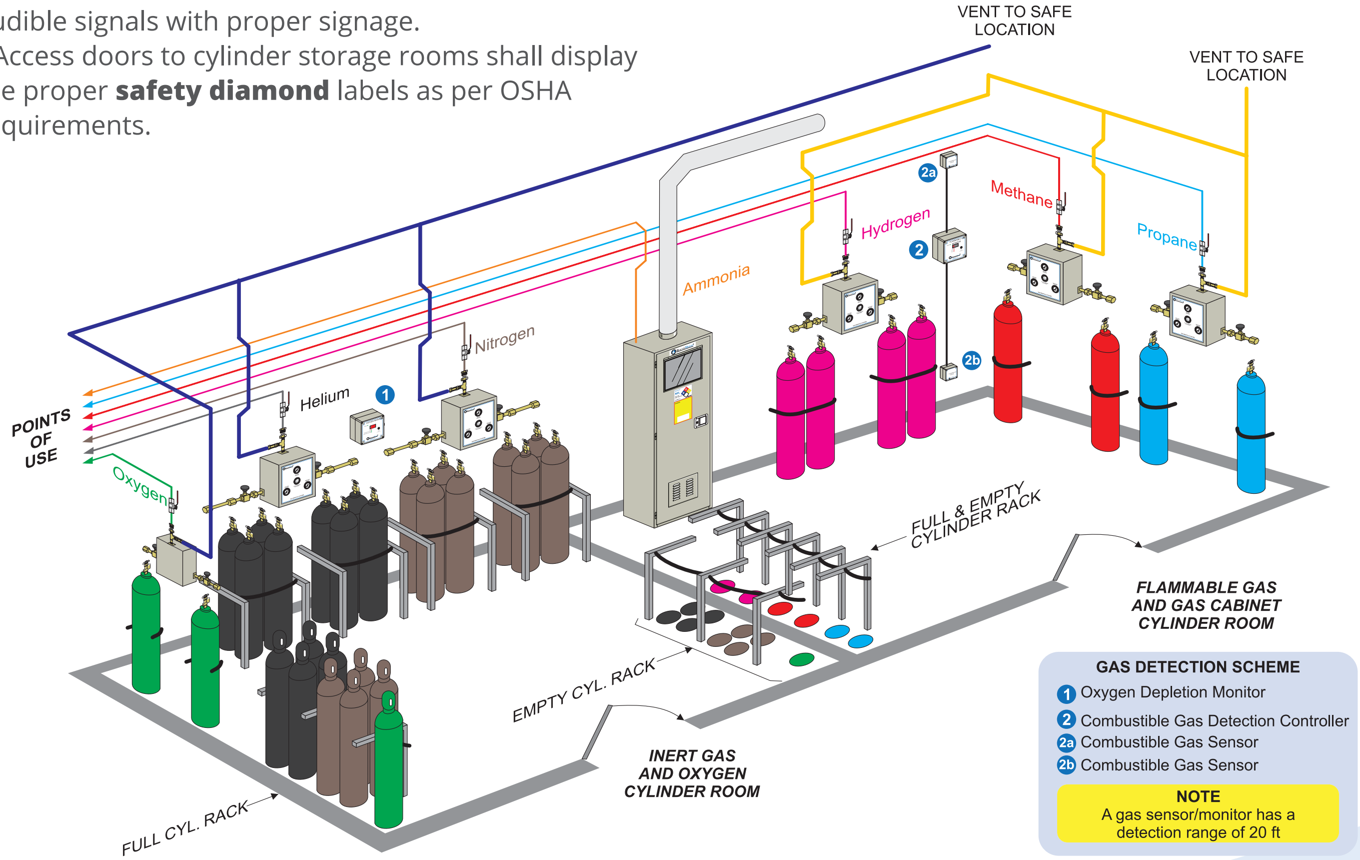
• Gas cylinders shall be **protected from tampering** by unauthorized personnel.
• Cylinders shall have their **caps when not in use**.
• Cylinders whether they are in use or in storage shall be **secured** with a chain or another type of fasteners.
• **Highly toxic and toxic** gas cylinders shall be used only in gas cabinets.
• **Gas detection monitoring system** shall protect personnel and the premises from gas hazards such as oxygen depletion and explosion.
• Upon detection of gas leak, **personnel shall be warned** of the hazardous situation via visual and audible signals with proper signage.
• Access doors to cylinder storage rooms shall display the proper **safety diamond** labels as per OSHA requirements.

Storage Room/Area Design

• **Ventilation** is required.
• The gas cylinder storage room shall be **dry and well lit.**
• Combustible materials and debris shall be removed.
• The storage room walls shall have a fire resistance rating of **2 hours.**
• It is highly recommended to have a **sprinkler system** installed in cylinder rooms.

Room Layout

• **Empty** cylinders shall be **segregated, stored separately** and clearly identified as empty.
• Oxygen and other oxidizing gases shall be **separated** from flammable gas cylinders.
• Segregate gases by **type.**



Gas Cylinder Storage Maximum Allowable Quantity

Material	Class	High Hazard Protection Level	Storage			Use - Closed Systems			Use - Open Systems	
			Solid Pounds	Liquid Gallons	Gas[a] scf (lb)	Solid Pounds	Liquid Gallons	Gas[a] scf (lb)	Solid Pounds	Liquid Gallons
Cryogenic Fluid	Flammable Oxidizing Inert	2 3 NA	NA NA NA	4.5 [b,c] 4.5 [d,e] NL	NA NA NA	NA NA NA	4.5 [b,c] 4.5 [d,e] NL	NA NA NA	NA NA NA	4.5 [b,c] 4.5 [d,e] NL
Flammable, gas [f]	Gaseous Liquefied LP	2 2 2	NA NA NA	NA NA NA	1000 [d,e] (150) [d,e] (300) [g,h,i]	NA NA NA	NA NA NA	1000 [d,e] (150) [d,e] (300) [g]	NA NA NA	NA NA NA
Inert Gas	Gaseous Liquefied	NA NA	NA NA	NA NA	NL NL	NA NA	NA NA	NL NL	NA NA	NA NA
Oxidizing Gas	Gaseous Liquefied	3 3	NA NA	NA NA	1500 [d,e] (150) [d,e]	NA NA	NA NA	1500 [d,e] (150) [d,e]	NA NA	NA NA
Pyrophoric Gas	Gaseous Liquefied	2 2	NA NA	NA NA	50 [d,j] (4) [d,j]	NA NA	NA NA	50 [d,j] (4) [d,j]	NA NA	NA NA
Unstable (reactive) gas	Gaseous 4 or 3 detonable 3 non-detonable 2 1	 1 2 3 NA	 NA NA NA NA	 NA NA NA NA	 10 [d,j] 50 [d,e] 750 [d,e] NL	 NA NA NA NA	 NA NA NA NA	 10 [d,j] 50 [d,e] 750 [d,e] NL	 NA NA NA NA	 NA NA NA NA
Unstable (reactive) gas	Liquefied 4 or 3 detonable 3 non-detonable 2 1	 1 2 3 NA	 NA NA NA NA	 NA NA NA NA	 (1) [d,j] (2) [d,e] (150) [d,e] NL	 NA NA NA NA	 NA NA NA NA	 (1) [d,j] (2) [d,e] (150) [d,e] NL	 NA NA NA NA	 NA NA NA NA
Corrosive Gas	Gaseous Liquefied	4	NA NA	NA NA	810 [d,e] (150) [d,e]	NA NA	NA NA	810 [d,e] (150) [d,e]	NA NA	NA NA
Highly Toxic Gas	Gaseous Liquefied	4	NA NA	NA NA	20 [c,k] (4) [c,k]	NA NA	NA NA	20 [c,k] (4) [c,k]	NA NA	NA NA
Toxic Gas	Gaseous Liquefied	4	NA NA	NA NA	810 [d,e] (150) [d,e]	NA NA	NA NA	810 [d,e] (150) [d,e]	NA NA	NA NA

NA: Not applicable within the context of NFPA 55 (refer to the applicable building or fire code for additional information on these materials).

NL: Not limited in quantity.

Notes:

(1) For use of control areas, see Section 6.2 of NFPA 55.

(2) Table values in parentheses or brackets correspond to the unit name in parentheses or brackets at the top of the column.

(3) The aggregate quantity in use and storage is not permitted to exceed the quantity listed for storage. In addition, quantities in specific occupancies are not permitted to exceed the limits in the building code.

a. Measured at NTP [70°F (20°C) and 14.7 psi (101.3 kPa)].

b. None allowed in unsprinklered buildings unless stored or used in gas rooms or in approved gas cabinets or exhausted enclosures, as specified in this code.

c. With pressure-relief devices for stationary or portable containers vented directly outdoors or to an exhaust hood.

d. Quantities are permitted to be increased 100 percent where stored or used in approved cabinets, gas cabinets, exhausted enclosures, gas rooms, as appropriate for the material stored. Where Footnote e also applies, the increase for the quantities in both footnotes is permitted to be applied accumulatively.

e. Maximum quantities are permitted to be increased 100 percent in buildings equipped throughout with an automatic sprinkler system in accordance with NFPA 13. Where Footnote d also applies, the increase for the quantities in both footnotes is permitted to be applied accumulatively.

f. Flammable gases in the fuel tanks of mobile equipment or vehicles are permitted to exceed the MAQ where the equipment is stored and operated in accordance with the applicable fire code.

g. See NFPA 58 for requirements for liquefied petroleum gas (LP-Gas). LP-Gas is not within the scope of NFPA 55.

h. Additional storage locations are required to be separated by a minimum of 300 ft (92 m).

i. In mercantile occupancies, storage of LP-Gas is limited to a maximum of 200 lb (91 kg) in nominal 1 lb (0.45 kg) LP-Gas containers.

j. Permitted only in buildings equipped throughout with an automatic sprinkler system in accordance with NFPA 13.

k Allowed only where stored or used in gas rooms or in approved gas cabinets or exhausted enclosures, as specified in NFPA 55.

Table 6.3.1 from NFPA 55, 2016 edition.

Gas Monitoring 101

Outside of air, all gases are dangerous to various degrees. Some gases will explode, some gases are very toxic and some gases are both. For the later case, we want to detect those molecules at their toxicity levels as they are all toxic way before they can burn.

Designing gas monitoring systems is not a complicated task when you know the basic principles This page covers the most important topics that will lead to a safe and performing gas monitoring system.

How Do We Determine Alarm Levels?

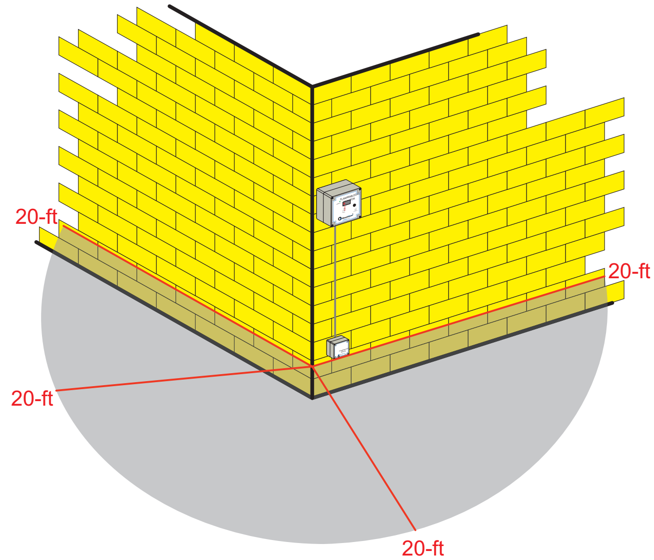
Toxic Gases - 1st Alarm Level
Threshold Limit Value
Time Weighted Average (TLV-TWA)
Refers to the time-weighted average concentration for a normal 8- hour workday and a 40 hour workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

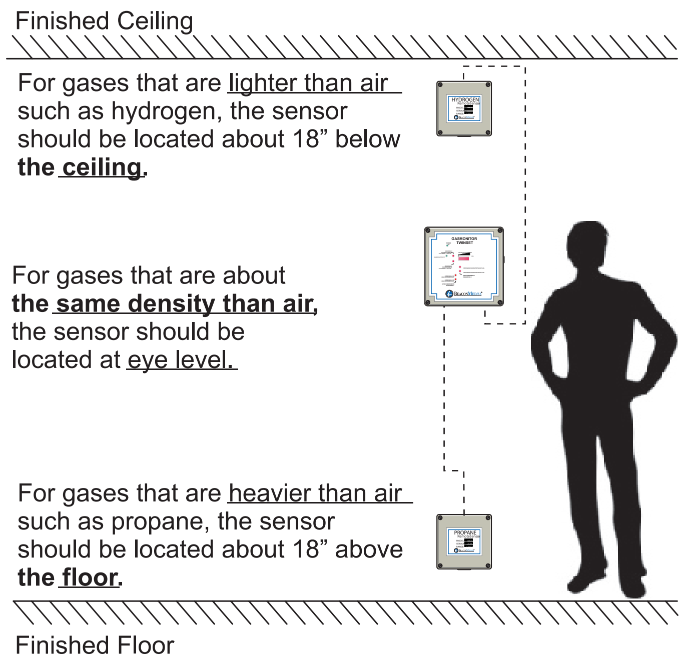
Toxic Gases - 2nd Alarm Level
Threshold Limit Value
Short Term Exposure Limit (TLV-STEL)
TLV-STEL is the maximum concentration of a substance for (a) a continuous 15- minute exposure period, (b) for a maximum of 4 such periods per day, with at least a 60- minute exposure-free period between two exposure periods, and (c) provided the daily TLV-TWA is met.

Flammable Gases - 1st Alarm Level
Lower Explosive Limit (25% LEL)

Flammable Gases - 2nd Alarm Level
Lower Explosive Limit (50% LEL)
Lower Explosive Limit
The minimum concentration of a particular combustible gas or vapor necessary to support its combustion in normal ambient air. Below this level, the mixture is too lean to burn.

Sensor Location

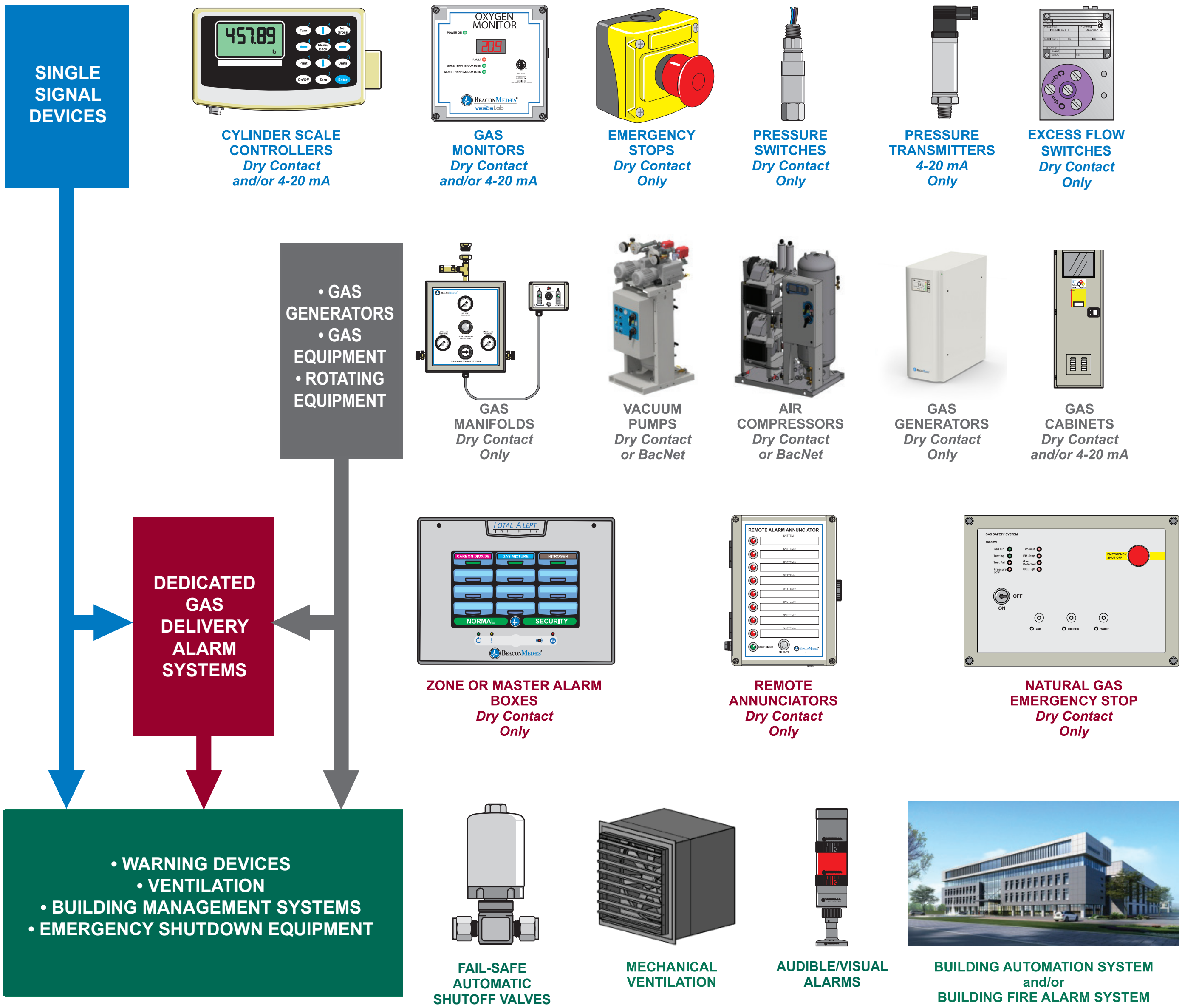




Detection Ranges & Alarm Levels

Common Gases	Hazards	Full Scale Range	First Alarm Level	Second Alarm Level	Sensor Location
Ammonia	Toxic	0-100 ppm	25 ppm (TLV-TWA)	35 ppm (TLV-STEL)	Ceiling or eye level
Carbon Dioxide	Toxic	0-50,000 ppm	5,000 ppm (TLV-TWA)	30,000 ppm (TLV-STEL)	Floor or eye level
Carbon Monoxide	Toxic	0-500 ppm	25 ppm (TLV-TWA)	35 ppm (TLV-STEL)	Eye level
Chlorine	Toxic	0-10 ppm	0.5 ppm (TLV-TWA)	1 ppm (TLV-STEL)	Floor
Hydrogen	Flammable	0-100 % LEL	1 % in AIR (25% LEL)	2 % in AIR (50% LEL)	Ceiling
Hydrogen Sulfide	Toxic	0-50 ppm	10 ppm (TLV-TWA)	15 ppm (TLV-STEL)	Floor
Methane	Flammable	0-100 % LEL	1.25 % in AIR (25% LEL)	2.5 % in AIR (50% LEL)	Ceiling
Nitrogen Dioxide	Toxic	0-10 ppm	3 ppm (TLV-TWA)	5 ppm (TLV-STEL)	0-10 ppm
Oxygen (Low & High Mode)	Oxidizer	0-25 % in AIR	19.5 % (low level)	23.5 % (high level)	Eye level
Oxygen (Depletion Mode)	Oxidizer	0-25 % in AIR	19.5 % (low level)	18 % (very low level)	Eye level
Propane	Flammable	0-100 % LEL	0.5 % in AIR (25% LEL)	1 % in AIR (50% LEL)	Floor

Control Scheme, Remote Actuation & Annunciation

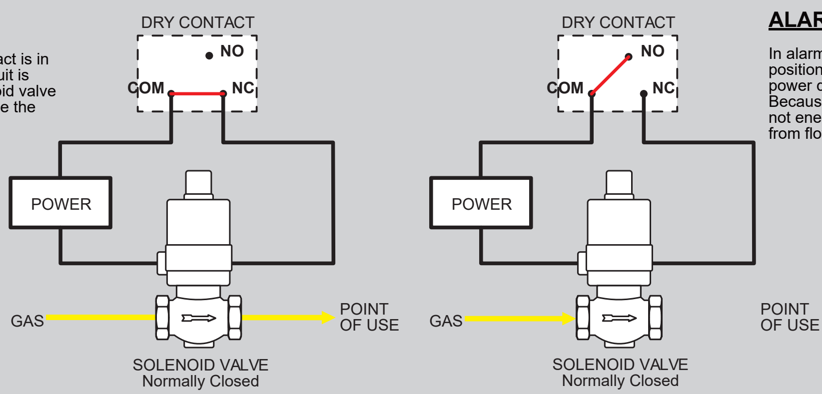


NORMAL CONDITION

Under normal condition, the dry contact is in closed position. That means the circuit is closed and power reaches the solenoid valve which keeps the valve open. Because the valve is open. It lets the gas flowing through the pipeline.

ALARM CONDITION

In alarm mode, the dry contact is in open position. That means the circuit is open and power does not reach the solenoid valve. Because the solenoid valve is closed when not energized. The valve prevents the gas from flowing into the pipeline



DRY CONTACT
How does it work?

Calculations

Pressure Rating For Tubing & Piping

Formula:

$$tm = \frac{P * Do}{2\,(SE + P * y)} * A$$

Where:

tm = Minimum wall thickness
P = Design pressure
Do = Outlet diameter of tube or pipe
SE = Allowable stress
y = Temperature coefficient
A = Threading allowance and/or Derating Value

Stress Value for Common Tubes and Pipes

Material		SE
Copper pipe or tube	ASTM B280	5,000
Copper pipe or tube	ASTM B75	6,000
Brass	ASTM B16	13,000
Aluminum 6061-T6	ASTM B210	14,000
Steel	ASTM A179	15,700
Monel alloy 400	ASTM B175	18,700
Stainless steel 304/316	ASTM A269	20,000

As listed in ASME B31.3

Above are stress values as published in ASME B31.3 for temperature between -20˚F to 100˚F.

For welded tubing, a derating factor must be applied for weld integrity:

- *for double-welded tubing, multiply pressure rating by 0.85*
- *for single-welded tubing, multiply pressure rating by 0.80*

The SE values must be derated to comply to ASME B31.1. The derating factors are different for each material.

Example:
A material testing laboratory wants to use an existing pipeline to test concrete compression resistance. You are requested to verify if the existing pipeline is adequate for the application. Below is the data you have been able to collect:

Conduit type:	Single-Welded Tube	
Material:	Stainless steel 304 (welded)	
Outside diameter:	0.500”	Do = 0.500
Specification:	ASTM A269	SE = 20000
Operating temperature:	70˚F	y = 0.4*
Operating pressure:	3500 psig	P = 3500
Type of fittings:	Compression	A = 0
Actual wall thickness:	0.035”	
Derating factor:	Single A = 0	

$$tm = \left[\frac{3500 \times 0.500}{2\,(20000 + 3500 \times 0.4)}\right] \times 0.8$$

$$tm = \left[\frac{1750}{42800}\right] \times 0.8$$

$$tm = \left[\;0.041\;\right] \times 0.8$$

$$tm = 0.032$$

Existing wall thickness = 0.035”

0.032” < 0.035”

Conclusion, the existing tubing is adequate for the application.

Pressure Rating

Copper Pipes & Tubes

Pipe - Copper - ASTM B280 - Type K

O.D.	NOMINAL	WALL	I.D	MAX. PRESSURE (IN PSIG) at 150˚F
0,375" (3/8")	1/4"	0,035"	0,305"	913
0,500" (1/2")	3/8"	0,049"	0,402"	960
0,625" (5/8")	1/2"	0,049"	0,527"	758
0,750" (3/4")	5/8"	0,049"	0,652"	626
0,875" (7/8")	3/4"	0,065"	0,745"	724
1,125" (1-1/8")	1"	0,065"	0,995"	557
1,375" (1-3/8")	1-1/4"	0,065"	1,245"	452
1,625" (1-5/8")	1-1/2"	0,072"	1,481"	420
2,125" (2-1/8")	2"	0,083"	1,959"	370
2,625" (2-5/8")	2-1/2"	0,095"	2,435"	338
3,125" (3-1/8")	3"	0,109"	2,907"	328
3,625" (3-5/8")	3-1/2"	0,120"	3,385"	311
4,125" (4-1/8")	4"	0,134	3,857"	306

Pipe - Copper - ASTM B280 - Type L & ACR

O.D.	NOMINAL	WALL	I.D	MAX. PRESSURE (IN PSIG) at 150˚F
0,375" (3/8")	1/4"	0,030"	0,315"	775
0,500" (1/2")	3/8"	0,035"	0,430"	662
0,625" (5/8")	1/2"	0,040"	0,545"	613
0,750" (3/4")	5/8"	0,042"	0,666"	537
0,875" (7/8")	3/4"	0,045"	0,785"	495
1,125" (1-1/8")	1"	0,050"	1,025"	420
1,375" (1-3/8")	1-1/4"	0,055"	1,265"	373
1,625" (1-5/8")	1-1/2"	0,060"	1,505"	347
2,125" (2-1/8")	2"	0,070"	1,985"	309
2,625" (2-5/8")	2-1/2"	0,080"	2,465"	285
3,125" (3-1/8")	3"	0,090"	2,945"	270
3,625" (3-5/8")	3-1/2"	0,100"	3,425"	258
4,125" (4-1/8")	4'	0,110"	3,905"	249

Tube - Copper - ASTM 280 - Refrigeration Type

O.D.	NOMINAL	WALL	I.D	MAX. PRESSURE (IN PSIG) at 150˚F
0,125" (1/8")	1/8"	0,030"	0,065"	2613
0,250" (1/4")	1/4"	0,030"	0,190"	1195
0,375" (3/8")	3/8"	0,032"	0,311"	836
0,500" (1/2")	1/2"	0,032"	0,436"	618
0,625" (5/8")	5/8"	0,035"	0,555"	525
0,750" (3/4")	3/4"	0,035"	0,680"	435
0,875" (7/8")	7/8"	0,045"	0,785"	495
1,125" (1-1/8")	1-1/8"	0,050"	1,025"	420
1,375" (1-3/8")	1-3/8"	0,050"	1,275"	373
1,625" (1-5/8")	1-5/8"	0,060"	1,505"	347

Technical Data

Values of allowable internal working pressure for copper tubes in service are based on the formula from ANSI B31, Standard Code for Pressure Piping:

$$P = \frac{2 S t_m}{D - 0.8 t_m}$$

P	=	Allowable pressure	@ 150˚F S = 5100 PSIG annealed
S	=	Allowable stress	@ 200˚F S = 4800 PSIG annealed
t_m	=	Wall thickness	@ 300˚F S = 4700 PSIG annealed
Od	=	Outside diameter	@ 400˚F S = 3000 PSIG annealed

All ratings listed for types K, L, M, DWV and refrigeration service tube in the preceding charts are calculated for tube in the annealed condition. These values should be used when soldering, brazing or welding is employed for joining components in a system. While the ratings for a hard drawn tube are substantially higher, they should only be used for systems using properly designed flare or compression mechanical joints, since joining by any heating process might anneal (soften) the tube. In designing a system, careful consideration should also be given to joint ratings as well as those of the components.

Pressure Rating

Stainless Steel Tubes

PRESSURE (IN PSIG)

WALL THICKNESS

O.D. IN INCH	.020"	.025"	.028"	.035"	.049"	.065"	.083"	.095"	.109"	.120"	.156"	.188"	.250"
1/8	6000	7500	9750	10500	14500								
3/16	4000	4988	5601	5600	9801	14700							
1/4	3000	3750	4200	5250	7350	9750	14250	14250					
5/16	2400	3000	3360	5800	7800	7800	9945	11438					
3/8	2000	2500	3000	3501	4900	6501	8301	9501	10900	12000			
1/2	1500	1875	2100	2625	3675	4875	6225	7125	8175	9000			
5/8	1200	1500	1680	2100	2940	3900	4980	5722	6540	7200	9360	112200	
3/4	1000	1251	1401	1750	2451	3250	4150	4750	5451	6000	7800	9351	
7/8	857	1071	1200	1500	2100	2786	3557	4071	4671	5143	6686	8014	
1	750	938	1050	1313	1838	2438	3113	3563	4088	4500	5850	7013	9375
1 1/8	666	833	934	1167	1633	2168	2768	3167	3634	4000	5200	6233	8333
1 1/4	600	750	840	1050	1470	1950	2490	2850	3270	3600	4680	5610	7500

What is the difference between a tube and a pipe

Stainless Steel TUBE

Why the name?

The outside diameter (O.D.) of the tube defines the tube name. In other words, a 1/2" tube is in 0.500" outside diameter.

The wall thickness of a tube is also called by its actual measurement.

Are tubes threadable?

No

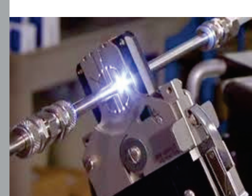
The wall of any tube, no matter the wall thickness may be, it is not thick enough to allow threads.

Furthermore, there are no corresponding female fittings available on the market.

Are tubes weldable?

Yes

The most popular welding technique used to weld tubes and tube fittings together is the orbital welding technique.



Are tubes swageable?

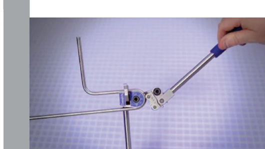
Yes

We are referring to high precision compression fittings popularized by Swagelok and similar brands.

Are tubes bendable?

Yes

In fact, for high purity piping systems, it is preferable to minimize the amount of fittings in a piping network. Bending tubes instead of using compression elbows is the best way to minimize fittings.



Pressure Rating

Stainless Steel Pipes

PRESSURE IN PSIG - LOWER FIGURES ARE WALL THICKNESS

NOMINAL PIPE SIZE	O.D. IN INCH	SCHEDULE									
		5's	10's	10	20	40	STD 40's	80's	E.H. 80's	160	DBLE E.H.
1/8	.405		**4537** .049	**4537** .049		**6296** .068	**6296** .068	**8796** .095	**8796** .095		
1/4	.540		**4514** .065	**4514** .065		**6111** .088	**6111** .088	**8264** .119	**8264** .119		
3/8	.675		**3611** .065	**3611** .065		**5056** .091	**5056** .091	**7000** .126	**7000** .126		
1/2	.840	**2902** .065	**3705** .083	**3705** .083		**4866** .109	**4866** .109	**6563** .147	**6563** .147	**8348** .187	**13125** .294
3/4	1.050	**2322** .065	**3108** .083	**3108** .083		**4036** .113	**4036** .113	**5500** .154	**5500** .154	**7786** .218	**11000** .308
1	1.315	**1854** .065	**3108** .109	**3108** .109		**3793** .133	**3793** .133	**5105** .179	**5105** .179	**7219** .250	**10209** .358
1 1/4	1.660	**1468** .065	**2462** .109	**2462** .109		**3163** .140	**3163** .140	**4315** .191	**4315** .191	**5648** .250	**8630** .382
1 1/2	1.900	**1283** .065	**2151** .109	**2151** .109		**2862** .145	**2862** .145	**3947** .200	**3947** .200	**5546** .281	**7895** .400
2	2.375	**4105** .065	**1721** .109	**1721** .109		**2432** .154	**2432** .154	**3442** .218	**3442** .218	**5416** .343	**6814** .436

What is the difference between a tube and a pipe

Stainless Steel PIPE

Why the name?

Piping dimensions are nominal and not actual. The name is not related to the internal diameter.

A 1/2" pipe is actually 0.840" outside diameter.

The wall thickness are determined by the schedule no. as shown in the table above.

Are pipes threadable?

Yes

You can make threads to a pipe as long as the wall thickness is Schedule 40 or bigger.

Are pipes weldable?

Yes

Piping can be welded using multiple welding techniques and pipe fittings.

Are pipes swageable?

No

We are referring to high precision compression fittings popularized by Swagelok and similar brands.

Are pipes bendable?

No

For the purpose of erecting laboratory piping, change of direction is primarily made by using code-compliant manufactured pipe elbows.

Calculations

Flow Capacity For Tubing

Undersized Lines

An undersized line will result in high pressure drops, making it difficult or impossible to consistently supply the required gas pressure and to the instrument.

Oversized Lines

An oversized line, by contrast, will ensure adequate pressure but will be unnecessarily expensive to purchase and install.

Accurate Flow Calculations

Accurate flow calculation is an art as it has several parameters to consider:

a) Mechanical: Tees, pipes, elbows
b) Fluid: Molecular weight, viscosity, compressibility
c) Operating conditions: Temperature, pressure

Most accurate flow calculations are conveniently made by computers.

Flow Chart

The table on the following page provides a good estimate of potential flow through a given tube diameter.

Both inlet pressure and length of the pipeline have an impact on outlet flow of air.

Gas and Temperature Compensation

The type of gas molecule could greatly affect the flow: the heavier the molecules are, the slower they move in a pipe.

The temperature also plays an important role in the output flow: the warmer the molecules are, the faster they move in a pipe.

Specific Gravity Of Common 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

Formula:
Correction Factor for Gases Other than Air (Cg)

$$Cg = \left[\sqrt{\frac{1}{g}}\right]$$

Formula:
Correction Factor for Temperatures other than 60˚F

$$Ct_{°F} = \frac{[460 + T]}{520}$$

Formula:
Correction Factor for Temperatures other than 16˚C

$$Ct_{°C} = \frac{[273.15 + T]}{288.71}$$

Example

Calculate distribution line size for carbon dioxide of 2000 SCFH at inlet pressure of 150 PSIG and a maximum pressure drop of 5 PSIG per 100 feet at 80˚F

Specific Gravity of Carbon Dioxide:.......................... 1.52

$$Cg = \left[\sqrt{\frac{1}{g}}\right] = \left[\sqrt{\frac{1}{1.52}}\right] = 0.811$$

$$\frac{2000 \text{ SCFH } CO_2}{0.811} = 2466 \text{ SCFH of Air at } 60°F$$

$$Ct_{°F} = \frac{[460 + T]}{520} = \frac{[460 + 80]}{520} = 1.038$$

$$2466 \text{ SCFH of Air at } 60°F \times 1.038 = 2562 \text{ SCFH of Air at } 80°F$$

Calculations

Flow Capacity For Tubing

Flow of Air at 60˚F in SCFH

Inlet Pressure (PSIG)	Pressure Drop per 100 ft. of Tube (PSIG)	Tube Size 1/8"	1/4"	3/8"	1/2" ④	3/4"	1"
50	1	20	180	405	760	1,610	3,040
	5	49	400	910	1,700	3,600	6,800
	10	70	580	1,300	2,410	5,100	9,720
100	1	28	245	550	1,020	2,160	4,070
	5	65	545	1,230	2,280	4,820	9,100
	10	90	775	1,750	3,240	6,820	12,970
150 ❶	1	32	290	660	1,220	2,580	4,870
	5 ❷	75	650	1,470	2,730 ❸	5,775	10,900
	10	110	930	2,100	3,880	8,170	15,540
200	5	85	745	1,680	3,120	6,590	12,450
	10	125	1,060	2,390	4,430	9,330	17,750
300	5	105	900	2,040	3,780	7,980	15,070
	10	150	1,280	2,900	5,370	11,300	21,480
400	5	125	1,040	2,340	4,340	9,160	17,300
	10	175	1,470	3,330	6,160	12,970	24,660
500	5	130	1,180	2,660	4,940	10,440	19,700
	10	190	1,680	3,790	7,020	14,770	28,100
1,000	5	190	2,030	3,920	7,270	15,360	29,000
	10	270	2,470	5,580	10,330	21,740	41,300
1,500	5	230	2,030	4,570	8,470	17,900	33,800
	10	330	2,880	6,500	12,040	25,350	48,200
2,000	5	265	2,340	5,270	9,770	20,650	39,000
	10	380	3,320	7,500	13,890	29,200	55,600
2,500	5	300	2,610 (1,230)	5,890	10,920	23,100 (10,890)	43,550 (20,531)
	10	427	3,710 (1,749)	8,380	15,510	32,650 (15,392)	62,100 (29,276)

Example from previous page

❶ 150 psi is the pipeline pressure.

❷ 5 psi is the maximum pressure drop allowed in the pipeline.

❸ The correction factor for 2000 SCFH of carbon dioxide in equivalent air is 2466 SCFH. In the table above, the value slightly above it is 2,730 SCFH.

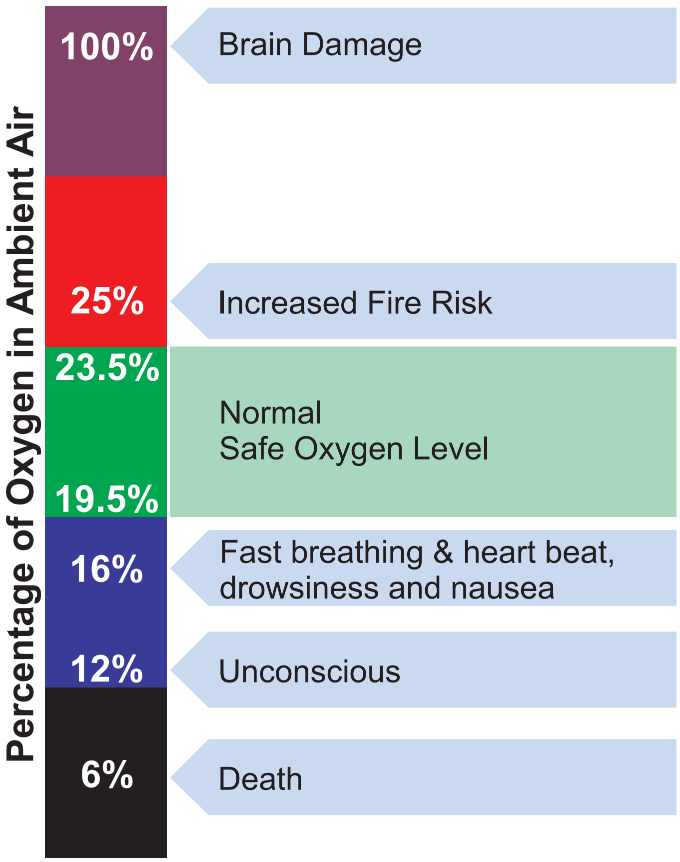
❹ 2,730 SCFH at 150 psi working pressure and 5 psi every 100 ft is 1/2" tube.

Calculations

Assessment Of Ventilation Requirements For Oxygen Depletion

Introduction

It is well known, humans require oxygen to live. OSHA and other safety regulatory bodies consider that the minimum amount of oxygen in air without suffering **adverse is effects 19.5%**



Composition of Air

Normal Constituants	
Nitrogen	78.084% +/- 0.004
Oxygen	20.946% +/- 0.002
Argon	0.934% +/- 0.001
Carbon Dioxide	350 ppm
Neon	18.21 ppm
Helium	5.239 ppm
Krypton	1.14 ppm
Hydrogen	0,5 ppm
Xenon	0.087 ppm
Impurities	
Water	1,000 to 28,000 ppm
Methane	1 to 3 ppm
Nitrous Oxide	0.5 ppm
Carbon Monoxide	0.06 to 1 ppm
Ozone	0.01 to 0.1 ppm
Ethane	0.01 to 0.1 ppm
Ethylene	0 to 2 ppm
Propane	0 to 0.1 ppm
Acetylene	0 to 0.1 ppm
Butanes	0 to 1 ppm
Pentanes	0 to 0.2 ppm
Nitrogen Dioxide	0 to 0.08 ppm
Radon	6×10^{-18}
Nitric Oxide	Traces

Oxygen Depletion

The table beside shows the composition of ambient air. Any changes in the concentration of the gases listed in this table may have a significant impact on the concentration of oxygen in air.

One of the common gases found in laboratories that may have a major impact on the concentration of oxygen is liquid nitrogen. Should a sudden release of liquid nitrogen (and consequently nitrogen gas) occur. There is a risk of asphyxiation where ventilation is inadequate as the nitrogen can build up and displace oxygen.

Calculations

Assessment Of Ventilation Requirements For Oxygen Depletion

Formula

$$[O_2] = \frac{0.2095\,(V_r - V)_g}{V_r} \times 100$$

Where:

$[O_2]$	=	Resulting concentration of oxygen in the room after a release of gas
V_r	=	Volume of the room [1]
V_g	=	Volume of gas released in the room in gas (vapor) phase [1] [2]
0.2095	=	Normal oxygen concentration in the air

Notes

[1] When calculating, you have to use the same unit of measurements for both V_r and V_g. In other words, if your calculations are in metric unit, V_r and V_g shall be both in metric (either m^3 or liters $_{gas}$).

[2] If you make this calculation for a release of liquid nitrogen. You have to use V_g in gas phase although the release could be in liquid phase. Every cryogenic liquid released in the atmosphere will convert into gas at different ratios.

Thermal Expansion Ratio of Cryogens

Molecule	Expansion Ratio
Liquid Nitrogen	1:696
Liquid Oxygen	1:860
Liquid Argon	1:841

What does that mean?

Liquid Nitrogen

It takes 696 cu. ft. of gaseous nitrogen to make 1 cu. ft. of liquid nitrogen

Liquid Oxygen

It takes 860 cu. ft. of gaseous oxygen to make 1 cu. ft. of liquid of liquid oxygen

Liquid Argon

It takes 841 cu. ft. of gaseous argon to make 1 cu. ft. of liquid argon

Calculations

Assessment Of Ventilation Requirements For Oxygen Depletion

Imperial Metric

A pressurized liquid nitrogen cylinder containing 43.6 gallons of liquid nitrogen suddenly loses its vacuum. The pressure of the liquid container suddenly rises and the pressure relief valve releases all nitrogen in the room.

The room dimensions are the following:
Width: 16.4 feet
Length: 32.8 feet
Height: 9.8 feet

Formula

$$[O_2]_{room} = \frac{0.2095\ (V_r - V)_g}{V_r} \times 100$$

Where

V_g: Volume of gas released
V_r: Volume of the room
O_2: Level of oxygen

Determination of V_g

$$V_g = 43.6 \text{ gallons}_{liq} \times 696$$

$$V_g = 30{,}345 \text{ gallons}_{gas}$$

$$V_g = 30{,}345 \text{ gallons}_{gas} \times \frac{0.133 \text{ cu. ft.}}{1 \text{ gallon}}$$

Determination of V_r

$$V_r = 16.4 \text{ ft} \times 32.8 \text{ ft} \times 9.8 \text{ ft}$$

$$V_r = 5{,}275 \text{ cu. ft.}$$

Determination of $[O_2]_{room}$

$$[O_2]_{room} = \frac{02.095\ (5{,}275 - 4{,}054)}{5{,}272} \times 100$$

$$[O_2]_{room} = \frac{258}{5{,}272} \times 100 = 4.9\%$$

Conclusion

A rapid release of liquid nitrogen would deplete the oxygen level in the room at around 4.9% which is a threatening level to human life.

Example Metric

A pressurized liquid nitrogen cylinder containing 165 liters of liquid nitrogen suddenly loses its vacuum. The pressure of the liquid container suddenly rises and the pressure relief valve releases all nitrogen in the room.

The room dimensions are the following:
Width: 5 metres
Length: 10 meters
Height: 3 meters

Formula

$$[O_2]_{room} = \frac{0.2095\ (V_r - V)_g}{V_r} \times 100$$

Where

V_g: Volume of gas released
V_r: Volume of the room
O_2: Level of oxygen

Determination of V_g

$$V_g = 165 \text{ liters}_{liq} \times 696$$

$$V_g = 114{,}840_{gas}$$

Determination of V_r

$$V_r = 5 \text{ m} \times 10 \text{ m} \times 3 \text{ m} \times \frac{1000 \text{ liters}}{1 \text{ m}^3}$$

$$V_r = \frac{150 \text{ m}^3 \times 1000 \text{ liters}}{1 \text{m}^3} = 150{,}000 \text{ liters}$$

Determination of $[O_2]_{room}$

$$[O_2]_{room} = \frac{02.095\ (150{,}000 - 114{,}840)}{150{,}000} \times 100$$

$$[O_2]_{room} = \frac{258}{5{,}272} \times 100 = 4.9\%$$

Conclusion

A rapid release of liquid nitrogen would deplete the oxygen level in the room at around 4.9% which is a threatening level to human life.

The information contained in this document is offered ONLY as a guideline for the design of high purity gas delivery systems.

System designers and end users are cautioned to review the information found in this document and carefully determine the applicability of such information.

All statements, technical information and recommendations contained in this design guideline manual are based on tests and data which BeaconMedaes believes to be reliable. The accuracy, completeness, and applicability of such information is not guaranteed and no warranty of any kind is made or implied with respect thereto.

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