Compressed Gas Safety

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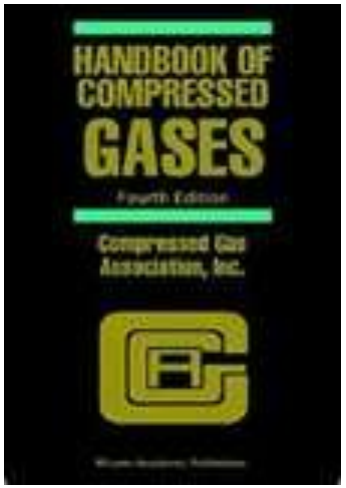
Bureau of Workers' Compensation
PA Training for Health & Safety (PATHS)

OSHA 29 CFR 1910.101
Compressed Gases
(General Requirements)
&
OSHA 29 CFR 1910.253
Oxygen-fuel gas
Welding & cutting

Safe Use, Handling and Storage



Topics

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- Regulations
- Uses
- Properties & Examples
  - Compressed Gas
  - Liquefied Gas
  - Cryogenics
- Terms & Behavior
- Containers & Markings
- Pressure Relief Valves
- Violent Reactions
- Handling & Storage
- Inspections
- Emergency Response
- Assist Standards
- Bibliography

Regulations

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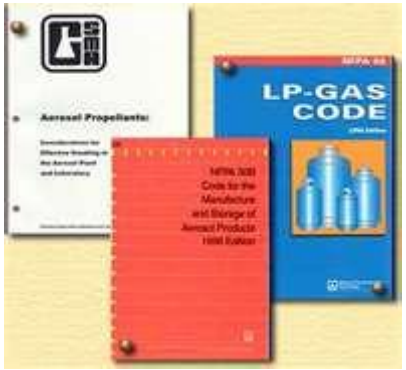
- Regulations for use, storage and handling will be according to the AHJ (Authority Having Jurisdiction
- In the absence of codes, the following may provide guidance:

  - Compressed Gas Association
  - NFPA (National Fire Protection Association)
  - Safety Data Sheet (formerly Material Safety Data Sheet)



Other Sources

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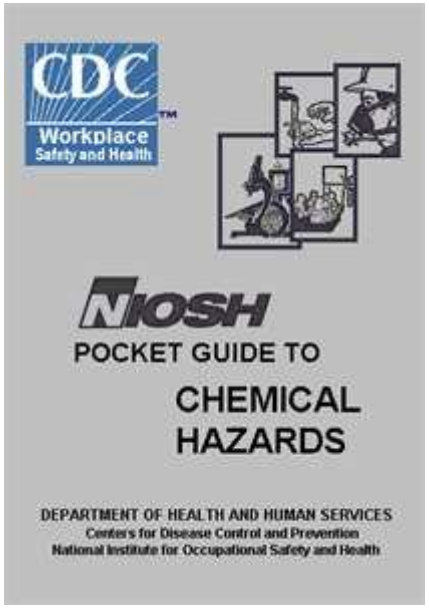
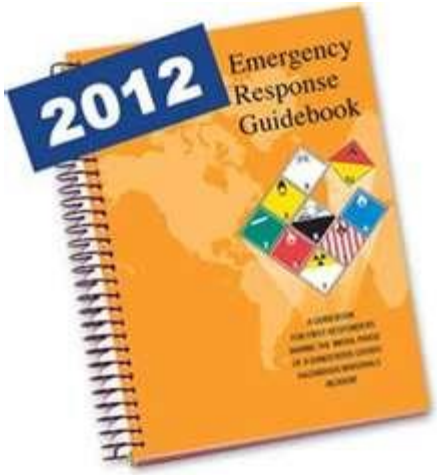
For determining hazards
and for planning purposes:

NIOSH Pocket Guide to Chemical Hazards

2012 Emergency Response Guidebook





Uses

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- Industrial uses include: processes, heating, forklifts. Industrial gases may also have other gases added for process purity
- Medical gases are blends of several gases
- Vehicles converted from gasoline or diesel
- Citizen use for heating

Gas Properties

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Gases can be:

- Flammable
- Non-Flammable
- Oxidizers
- Corrosive
- Asphyxiants
- Poison
- Inert

Or a mixture

Physical States

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Gas	In Cylinder Temperature
Compressed Gas	+70 to +32F in gaseous state
Liquefied Gas	+32 to -130 in liquefied state
Cryogenic Liquid	-130 to -432 refrigerated liquefied gas

Storage temperatures are gas-dependent

Compressed Gas Examples

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Types	Hazard Class	Vapor Density	LEL/UEL	Flashpoint (F)
Methane	2.1 Fl	0.55	5-15%	-306
Ethane	2.1 Fl	1.04	3-12.4%	-211
Propane	2.1 Fl	1.52	2.2-9.5%	-56
Butane	2.1 Fl	2.0	1.8-8.4%	-101
Nitrogen	2.2 Non-Fl	0.96	Inert	------
Oxygen	5.1 Ox	1.1	NF/Oxidizer	------
Arsine	2.1 FL/2.3 PG	2.69	4.5-64%	------
Chlorine	2.2 NFl/2.3 PG	2.48	Oxidizer	------

Fl=Flammable
NFl=Non-Flammable
PG=Poison Gas
Ox=Oxidizer

Definitions

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Gas:

- State of matter in which material has a very low density and viscosity
- Can expand and contract in response to temperature and pressure changes
- Easily diffuses into other gases; distributes itself inside a container
- If the temperature is dropped and pressure increased, the gas can be changed to a liquid or semi-solid state

Compressed Gas

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"Material or mixture having in the container an absolute pressure exceeding 40 psi at 70°F or, regardless of pressure at 70°F, having an absolute pressure exceeding 104 psi at 130°F or any liquid material having a vapor pressure exceeding 40 psi absolute at 100°F as determined by ASTM Test D-323"

page 597, CGA Handbook, 3rd Edition

Liquefied Petroleum Gas

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LP Gas or LPG –

- Any material with a vapor pressure not exceeding that allowed for commercial propane
- Composed predominantly of the following hydrocarbons, either by themselves or as mixtures: propane, propylene, butane (normal butane or isobutene), and butylenes

Liquefied Natural Gas

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- Also called LNG
- A fluid in the cryogenic liquid state that is composed predominantly of methane.

Cryogenic Liquid

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- Cryogenic liquid: Refrigerated liquefied gas with normal boiling point below -130°F

- Hazards include those of the gas, frostbite and asphyxiation if breathable oxygen in air is displaced

Terms

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Boiling Point:

Temperature when a gas converts from its liquefied state to vaporous state

Critical Pressure:

Temperature above which a gas cannot be liquefied by pressure alone

Triple Point

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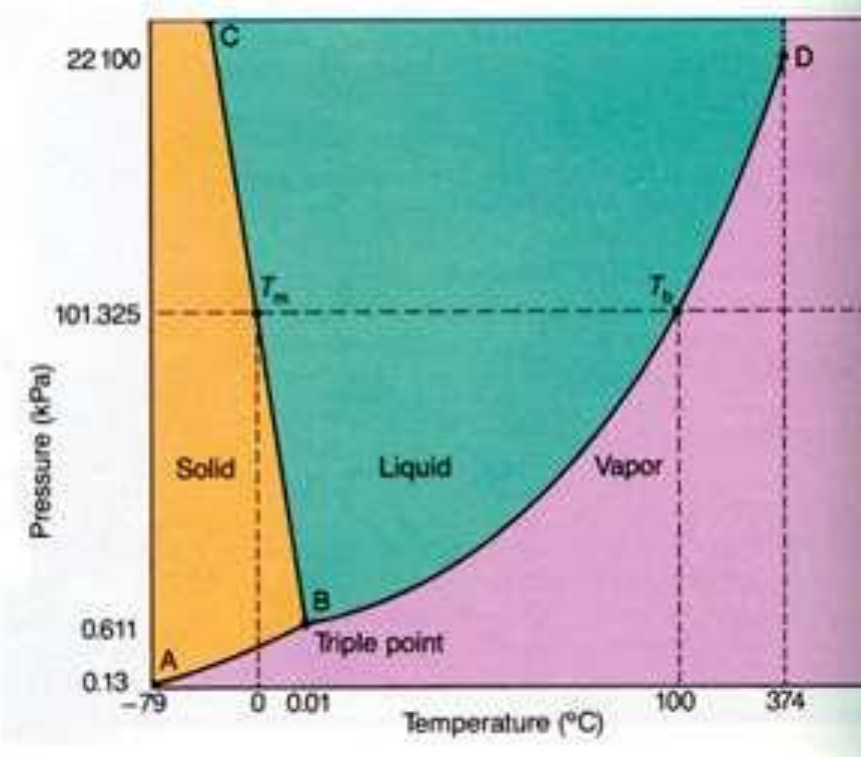
- The only temperature and pressure at which three phases (gas, liquid, and solid) in a one-component system can exist in equilibrium



Compressed Gas Terms

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- Vapor Density (Gas Specific Gravity): A comparison of the weight of the gas to air (1.0). Heavier-than-air gases will have a vapor density greater than 1.0; lighter gases will have a vapor density less than 1.0

TLV-TWA

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- TLV-TWA (threshold limit value-time weighted average): Given in ppm (parts per million). Exposure amount which most people can work in for an 8 hour day without suffering harmful effects

IDLH

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IDLH: Immediately Dangerous to Life and Health. Amounts to which persons should not be exposed due to their harmful effects.

Sources for determining these limits will be found on the SDS, as well in various guides, i.e. "NIOSH Pocket Guide to Chemical Hazards"

LEL

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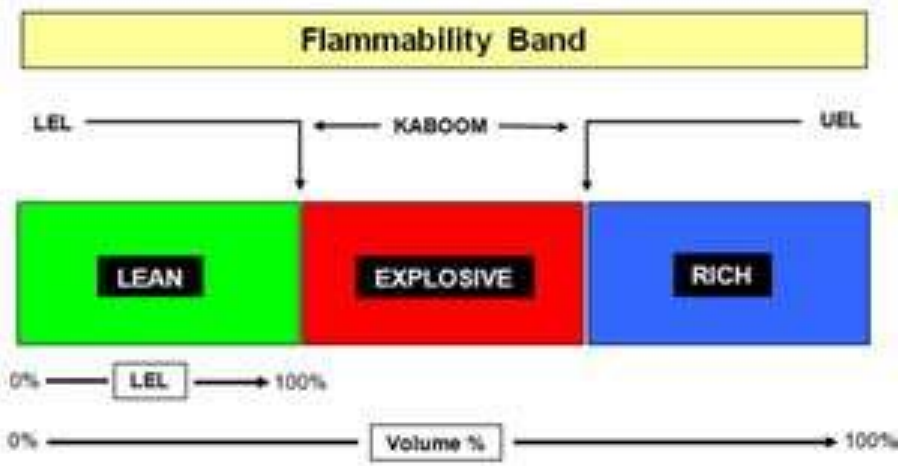
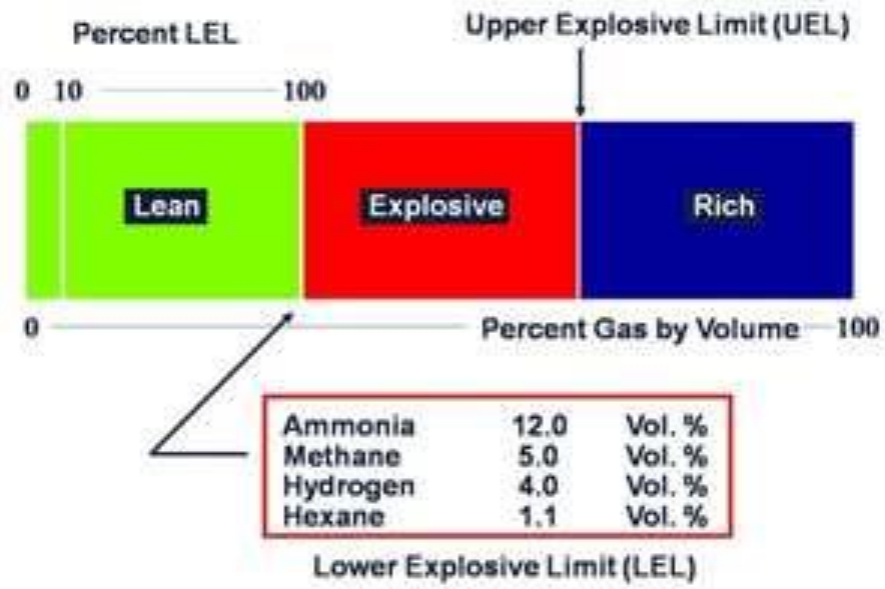
- Lower Explosive Limits (LEL) also known as lower flammable limits (LFL): least percentage of a gas, mixed with the proper proportions of air, whereby having the necessary heat applied, combustion may result



UEL

- Upper Explosive Limits (UEL) also known as upper flammable limits (UFL): greatest percentage of a gas, that when proportioned with air, may permit sustained combustion



Flammable Limits

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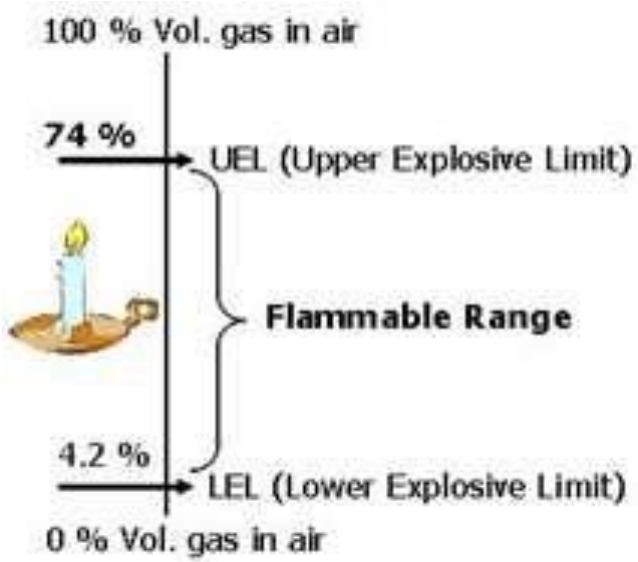
- Flammable Limits also known as the Flammable Range: percentage of gas within the LEL and UEL where combustion may occur and be sustained

- Shown: Hydrogen approximated (4%-75%)



Ignition Temperature

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Ignition Temperature: Unique to various solids, vapors and gases, the requisite heat from an open flame source required to ignite materials.

Autoignition temperature is the temperature required to ignite materials absent an open flame source

Inert Gas

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- Gas which does not react with other materials (e.g. argon, helium, neon)
- Can be an asphyxiant which reduces the amount of breathable air in a location
- Used in fire suppression systems, purging and cleaning

Expansion Rate (or Ratio)

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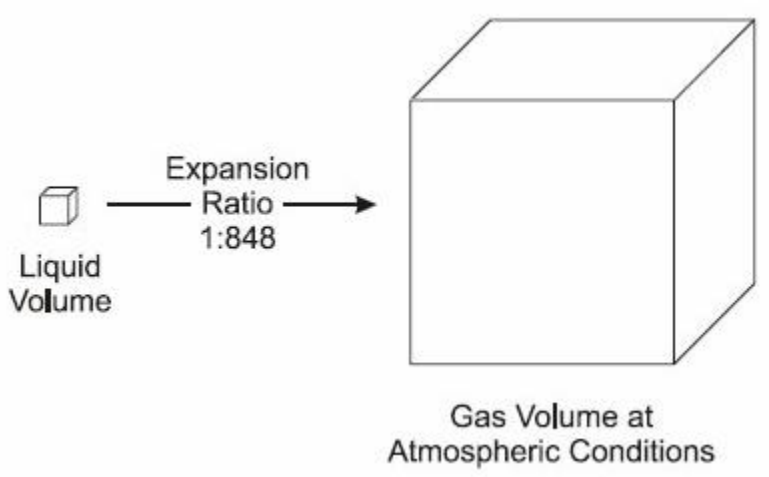
- Conversion of cubic feet of liquid to cubic feet of gas
- Can result in achieving the LEL or Flammable Limits in an inside environment
- Can also result in the toxic levels or IDLH for a gas expressed as percentage by volume or ppm (parts per million)



Expansion Rate

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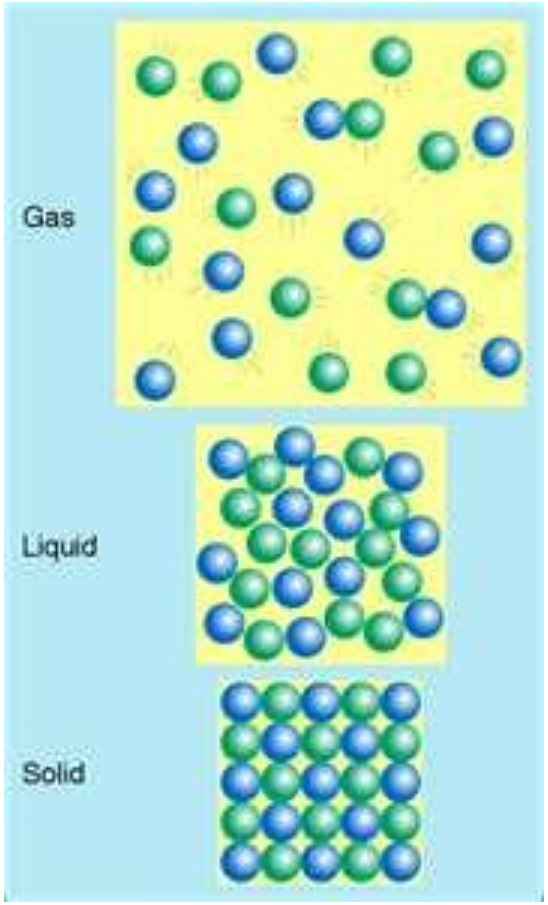
Gas	Expansion Rate
Methane	625:1
Propane	270:1
Butane	284:1
Nitrogen	696:1
Oxygen	860:1
Chlorine	444:1



Gas Laws of Gas Behavior

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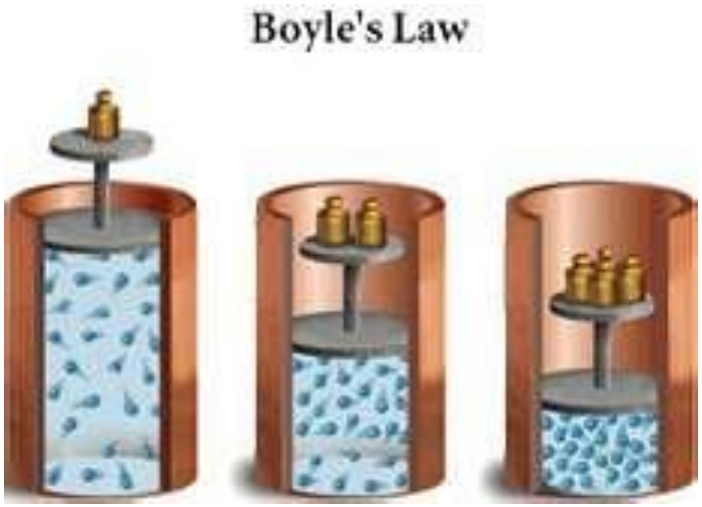
Boyle's Law:

- Decrease container's volume by ½
- Temperature and amount of gas remain constant
- Pressure will double



Gas Laws

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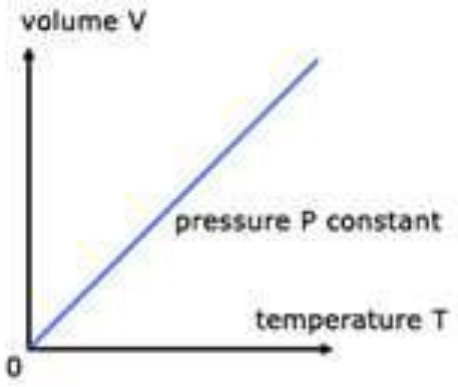

Charles Law

- When the temperature increases, the volume increases

- Perhaps the container won't be able to handle the volume increase

PVT Relationship

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If temperature of a gas increases in cylinder, volume of cylinder can not be increased

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Pressure increases and may activate relief valve

Too rapidly increasing pressures may rupture cylinder

Rule of Thumb

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Increase gas temperature 500 degrees = double pressure
Increase gas temperature 1,000 degrees = triple pressure
Increase gas temperature 1,500 degrees = quadruple pressure

(Some gas cylinders do **NOT** have a pressure relief valve, could be a catastrophic rupture!)

Cryogenic

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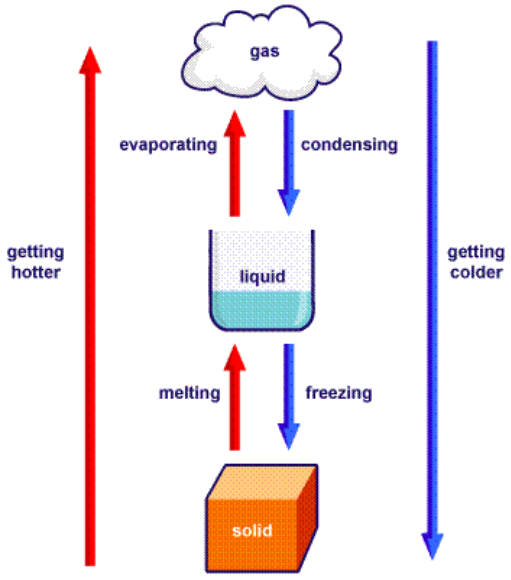
- Heat expands a gas
- If we pressurize a gas while cooling it, we can turn a gas into a liquefied gas
- Further cooling and pressure may convert it to a cryogenic gas
- This increases the amount of product that can be put in a cylinder



Gas Containers

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- Lecture Bottles
- Cylinders
- Tank Trucks

Gas Containers

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- Railroad Tank Cars
- Portable Tanks
- Fixed Storage
- Pipelines

Cylinders

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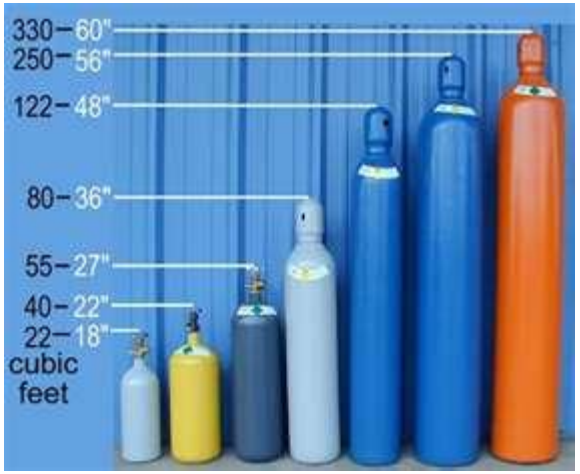


Construction
Must be compatible with the material contained

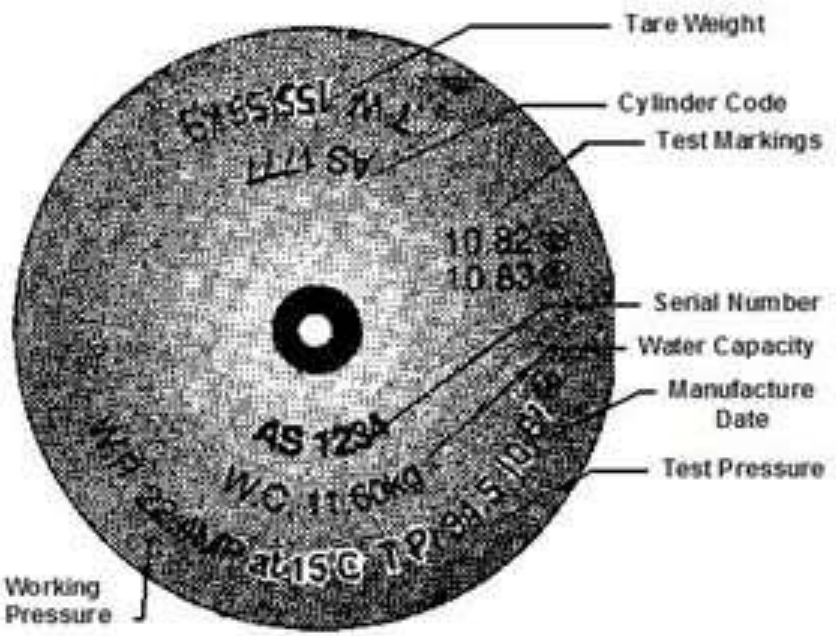
Markings
Labeling required to identify the gas in storage and during shipment

Markings

- Nomenclature related to the cylinder and its contents will assist in the safety process

- Low Pressure: Below 900 psi

- High Pressure: 900 psi or greater



Storage Pressure

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Types	Storage Pressure (PSI)	Ignition Temperature
Methane	up to 6000psi	999F
Ethane	544	959
Propane	109.7	871
Butane	31	761
Nitrogen	2,000/below 200 as cryogen	Inert
Oxygen	2,000/below 200 as cryogen	Inert
Arsine	219.7	(*see note)

*Note: Arsine has no given Ignition Temperature but decomposes into arsenic and hydrogen between 446 F to 464 degrees F

Color Codes

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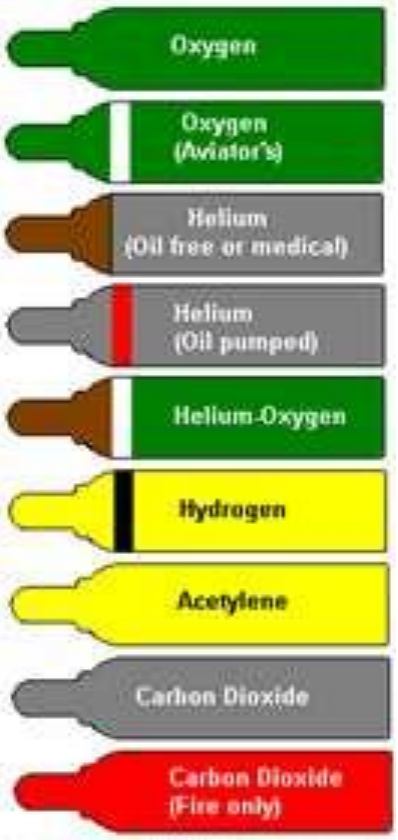
Cylinder shells can also be color coded to better identify the contents permitted into the specific type of cylinder

This eliminates cross-contamination by introducing non-compatible gases into non-specification cylinders



Medical Gas Color Codes

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Medical gases will often be a blend of a parent gas with fractions of other gases introduced for purity and stability

WORDING	WORDING
CARBON DIOXIDE	NITROGEN
CYCLOPROPANE	NITROGEN 180-200 PSI
HELIUM	NITROUS OXIDE
MEDICAL AIR	NITROUS OXIDE 50-55 PSI
MEDICAL AIR 50-55 PSI	OXYGEN
MEDICAL VACUUM	OXYGEN 50-55 PSI
NATURAL GAS 2 PSI	

Labels

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FTSC Code
Standard numerical code for a gas indicating:

- Flammability
- Toxicity
- State of the gas
- Corrosiveness

CGA V-7 pamphlet provides more in-depth information.

Diaphragm Valve

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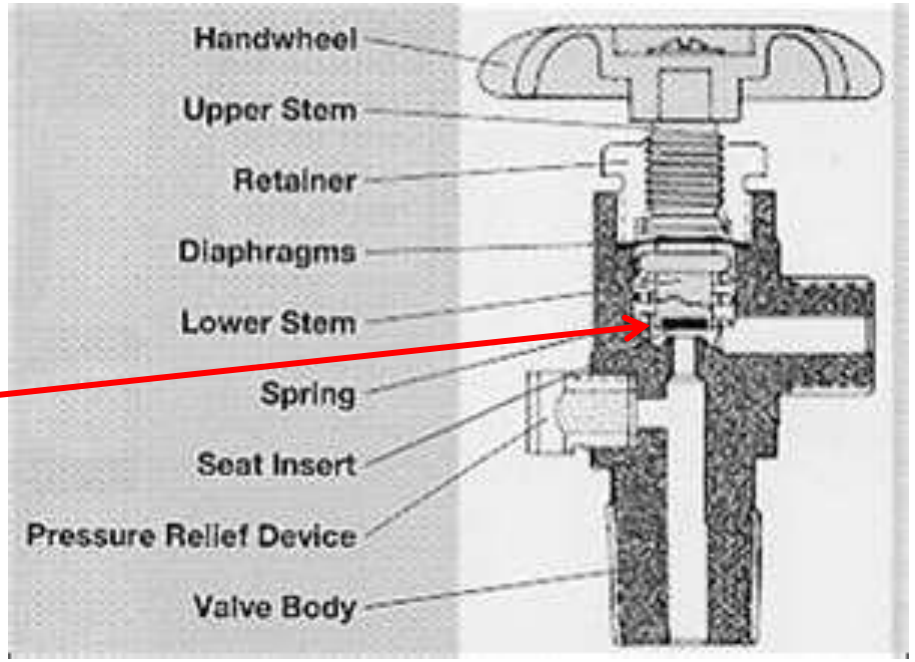
Diaphragm Valve better retains the cylinder contents

Not as prone to leakage as the packed valve

Note the diaphragm's location

Note also the relief valve's location in the product line



Packed Valve

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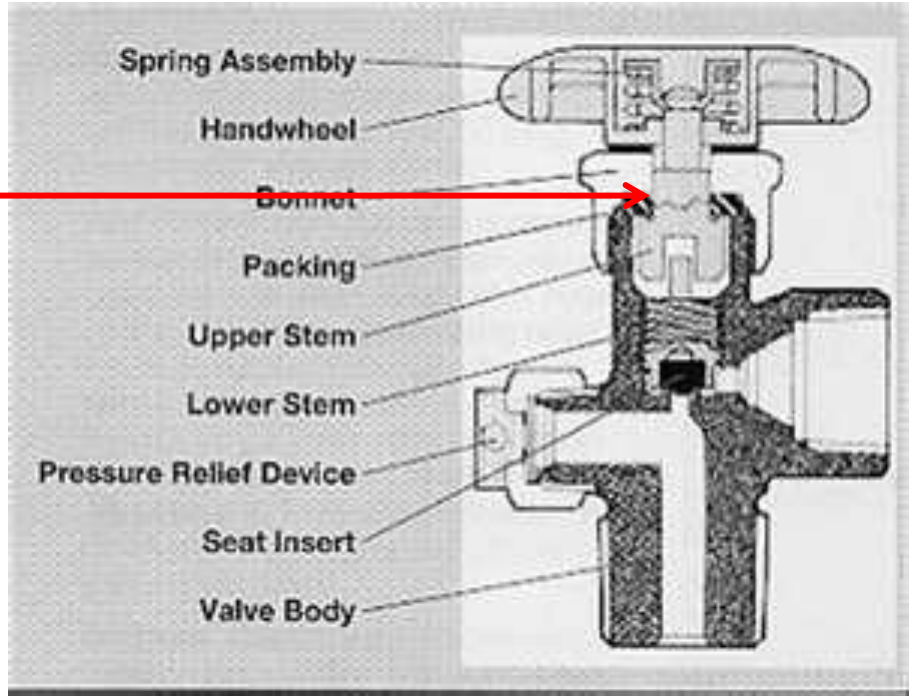
The Packed Valve has packing between the upper stem and bonnet

This type is known for leaking through the packing

Often the leak may be secured by tightening the bonnet nut



Pressure Relief Valve (PRV):

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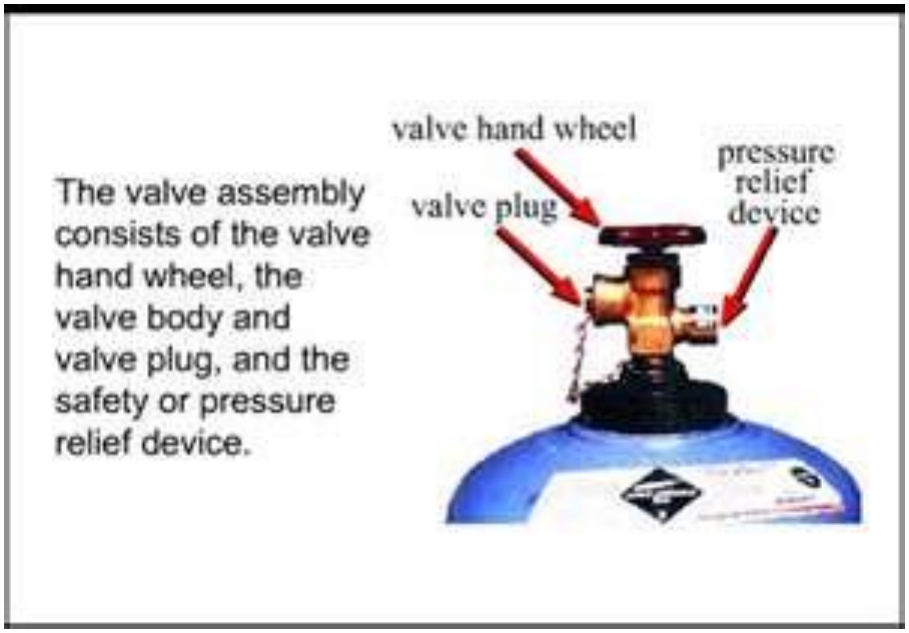
May be pressure, temperature or spring activated to permit container contents to escape thereby averting a container rupture

The PRV is in the product line



Fusible Plug/Combination

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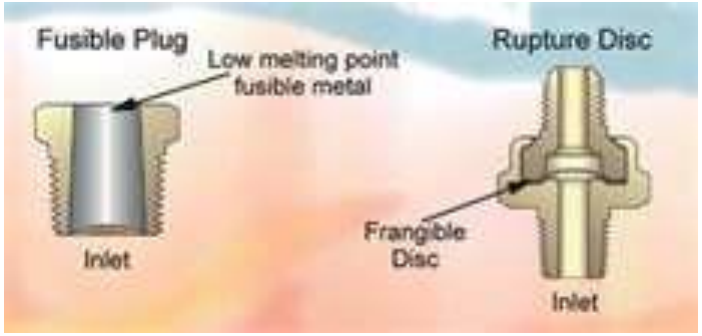
Fusible plug melts at a designated temperature and permits the product of a cylinder to be released to avert a catastrophic rupture

Combination relief: One with a rupture disk and fusible plug

Both are Non-resealing



Rupture Disk

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- Rupture disk (frangible disk) - Operating part of a PRV: ruptures at a predetermined pressure allowing cylinder contents to escape
- Non-resealing
- Poison gas cylinders do not have a PRV Depending on their classification PRVs are "prohibited"

Cylinder Hazards

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Material Hazards

- Flammability
- Spontaneously Flammable (arsine, silane and phosphine)
- Corrosivity
- Reactivity
- Poison
- Carcinogenic

Container Behavior

- Frostbite
- Rupture
- Rocketing
- BLEVE (Boiling Liquid Expanding Vapor Explosion)

BLEVE: Boiling Liquid Expanding Vapor Explosion

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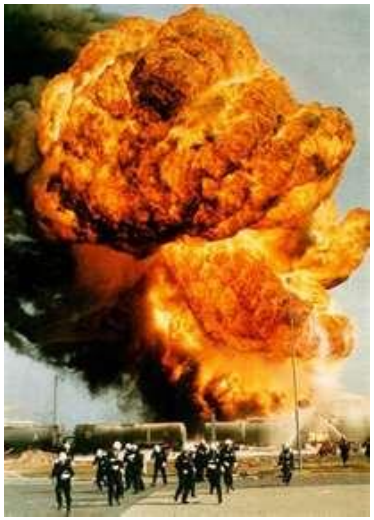
A cylinder or tank is heated.
Contents absorb heat and convert to pressurized vapor.
Relief valve activates.
Pressure increases beyond the PRV capacity.
Container, thermally stressed, violently ruptures.
If the gas is flammable, the fireball is devastating.



BLEVE

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BLEVEs can occur with liquefied nitrogen and helium or refrigerants and cryogens as well as LP Gas or LNG

The Pressure, Volume, Temperature relationship drives the BLEVE

BLEVE

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Cylinder exploded inside a building

Cylinder exploded outside

- May occur with Liquefied Petroleum Gas (LPG) Propane and Butane being main components or
- with Liquefied Natural Gas (LNG) of which Methane is the largest component

Railroad Tank Car BLEVE

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- Crescent City, Illinois, June 21, 1970, 7:30am.
- Train No. 20 derailed involving 3 tank cars
- BLEVE was 34,000 gallons of Propane
- Emergency planning paid off

Fixed Location BLEVE

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65,000 gallons of propane at bulk storage location in Canada, 2008

Hydrocarbon Gases

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Contain flammable hydrogen and combustible carbon in their make-up.

- Flammable
- Non-Corrosive
- Non-Toxic
- Colorless

Examples include:

- Propane and
- Butane

Hydrocarbon Gases

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Gas	Formula	Ignition Temperature (F)
Methane	CH_4	999
Ethane	C_2H_6	959
Propane	C_3H_8	871
Butane	C_4H_{10}	761

Oxygen

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Not flammable

Sensitizes flammable and combustible materials requiring less input heat for ignition.

In some cases, materials impregnated with oxygen can be ignited with static electricity.

PELs/IDLH

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Gas	CAS #	TWA: OSHA PEL	IDLH
Methane	74-82-8		
Ethane	74-84-0		
Propane	74-98-6	1,000 ppm	2,100 ppm (10% LEL)
Butane	106-97-8	None	Not Determined
Nitrogen	7727-37-9		
Oxygen	7782-44-7		
Arsine	7784-42-1	0.05ppm	Ca (3 ppm)
Chlorine	7782-50-5	1 ppm	10 ppm

(*Note: to convert ppm into percent by volume, divide the number given in ppm by 10,000. This will give you the percentage by volume.)

Effects of Exposure

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Explosive rupture of contents which can destroy vehicles

Cylinders may go through barriers or walls

Other Gas Accidents

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- Flammability
- Chemical burns
- Handling safety requires an understanding of the gas properties
- Personal Protective Equipment (PPE):
  - -Gloves
  - -Eye protection
  - -Respirator
  - -Foot/body protection

Safe Handling and Storage

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Determine safe handling and storage needs based on your industry and the gases with which you work

Create or follow check lists to best ensure a continuous safety program

Proper Handling

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Use proper hand trucks-do not roll the cylinder on its side

Provide a forklift cylinder change-out area which maximizes safety for the operator and other staff

Provide:
- Ventilation
- Fire Extinguisher
- PPE

Handling

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Take time to plan what you're going to do with a cylinder and how you're going to do it

Always decide on the side of personal safety

This realistic accident scenario explains why safety shoes shall be worn at cylinder handling.

This accident situation demonstrates, that it is wise to use gloves at cylinder handling

Storage

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Proper ventilation

Out of the weather

Not subject to temperature extremes

Segregate gas types to eliminate fire or chemical reaction hazards

Use good house keeping practices

Post signage

Lab Ventilation

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- Critical for safe and healthy operation
- Occupied lab air exchange rates should be 6 to 10 times an hour per applicable standards
- Unoccupied lab air exchange rates including storerooms should be 4x in 1 hour (NFPA 45)
- Air supplies to labs, storerooms, prep rooms should never be recycled to any other part of the building or offices
- Only conduct experiments the ventilation system can handle without a fume hood
- HVAC filters should be changed quarterly

Fume Hood

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- Provides local exhaust ventilation
- Essential in exhausting hazardous gases, particulates, vapors, etc.
- Use hood to remove airborne chemicals (e.g. aerosols, dusts, fumes, vapors)
- Do not store items within fume hoods
- Place apparatus far back to rear of hood for efficient air flow
- Ensure only necessary materials are under hood during an operation

Fume Hoods

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- Always keep the sash between the face and experiment – sash should be lowered
- Check air flow before and during operation (face velocity of 80-120 fpm)

Compressed Gas Cylinders

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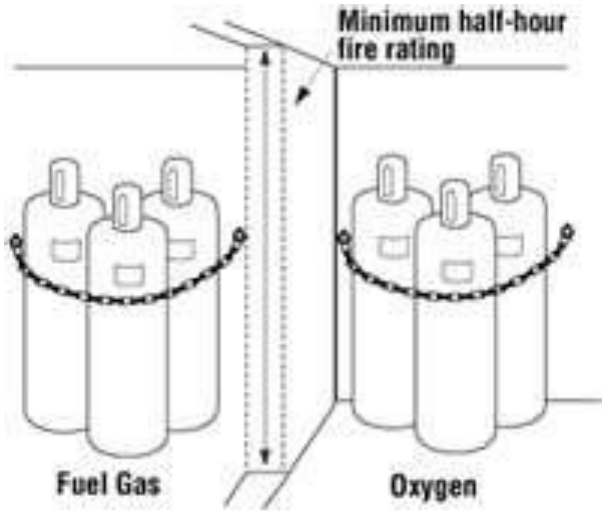
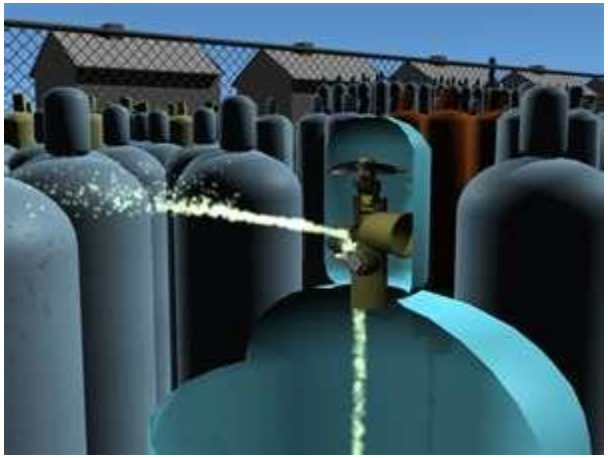


Storage, Maintenance, Handling

Isolate threats:

- Hourly fire rated walls
- Distances
- Methods of securing:

Adjustable bay rack
Individually supported
Eye bolts, chain and latch



Compressed Gas Cylinders

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Compressed gases can be hazardous because each cylinder contains large amounts of energy and may also have high flammability and toxicity potential. Think safety:

- Ensure the contents of all compressed gas cylinders are clearly stenciled or stamped on the cylinder or durable label
- Do not identify a gas cylinder only by the manufacturer's color code
- Never use cylinders with missing or unreadable labels

Compressed Gas Cylinders

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- Check all cylinders for damage before using
- Be familiar with the properties and hazards of the gas inside the cylinder before using
- Wear appropriate PPE before handling/using
- Check for leaks after attaching a cylinder by using a soap solution, “snoop” liquid, or gas detector
- Label empty cylinders as “EMPTY” or “MT”
- Always attach safety caps when storing or moving cylinders

Compressed Gas Cylinders

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- Larger cylinders should be secured to a wall or lab bench by a clamp or chain
- Store cylinders by gas type; separate oxidizing gases from flammable gases by either 20 feet or 30 minute 5 foot high firewall
- Store cylinders in a cool, dry, well-ventilated area away from incompatible materials and ignition sources
- Store empty cylinders separately from full ones
- Do not subject any part of a cylinder to temperatures higher than 125 deg F or lower than 50 deg F

Heating

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Use only approved methods to heat cylinders to guard against rapid temperature and likewise pressure rises in cylinder

Do **NOT** heat with salamander heaters or direct impingement heaters

Inspection

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Physical Inspection for:

- ✓Rust, chemical reactions, fire or heat impact
- ✓Leaking
- ✓Bulging, distortions
- ✓Paint changes due to chemical reaction or heat

Inspection

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- ✓Fatigue or stress
- ✓Dents, gouges, impact points
- ✓Internal problems
- ✓Repair methods and correctness
- ✓Protective valve caps

Inspect

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For leaking fittings and correct connections

Know what to do when finding such situations:

- Handle alone?
- Call a co-worker?
- Call the Supervisor?
- Call 911 and Evacuate?

Checking Connections

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Ensure proper valves have been used

“Snoop” connections to eliminate leakage of gas to surrounding areas*

* “Snooping” uses a soap solution on a compatible gas/connection to determine leakage; no bubbles-no leakage

Welding Gases

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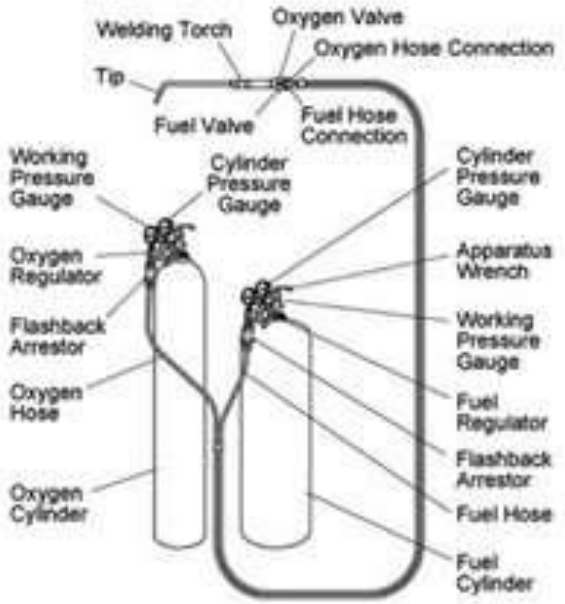
Exercise the needed care when dealing with dual gases such as oxygen and acetylene.

Practice storage and use safety



Secured and capped

Not taken into confined spaces or work areas

Segregated from combustibles

Inspect Set-Ups

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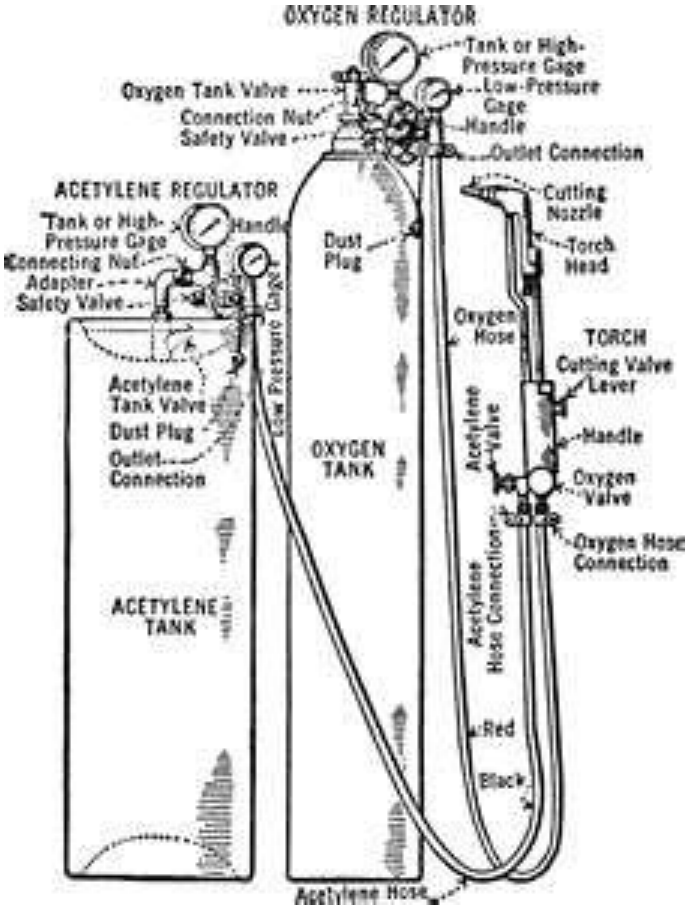
Check:

- ❑Valves
- ❑Hoses
- ❑Flashback arrestor
- ❑Confirm operating pressures
- ❑Connections are secure
- ❑Personal Protective Equipment is in use
- ❑Area secured from other hazards



Hydrostatic Testing (Hydro)

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Pressurizing a cylinder for a period of time then determining if the shell returns to a percentage of its normal shape within a set time period

Determines serviceability of the cylinder

Determine hydro schedule for your cylinders and keep a record on file

Hydro Test Intervals

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- Hydro test intervals are based on the composition of the cylinder

- Retesting of cylinders can be found in
  - 49 CFR 173.34 and
  - CGA C-1 Methods for Hydrostatic Testing of Compressed Gas Cylinders

Emergency Response

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Gas emergency response would fall under Hazardous Materials response per 29 CFR 1910.120(q)

Likely events may result from the gases you use and methods of transport, storage or handling

Possible Gas Accidents

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- LP Gas tank fire

- Gas pipeline explosion

Release Events

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Detection & Monitoring

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Determine leaks with various detectors:

Combustible Gas Indicators (CGI) or

Gas Detector (gas specific)

You will need to know:

Gas LEL/UEL and

IDLH limits before

monitoring for gas

Detection

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- Portable leak detector

- Broom used to detect burning hydrogen due to it burning light blue to almost invisible.

Detection

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Similar "broom" method may also be used:

- If attempting to detect presence of Chlorine, wrap clean cloth around broom
- Put ammonia on cloth and wave in suspected Chlorine cloud
- If cloth fumes, you've detected presence of Chlorine
- If looking for ammonia leaks, cloth treated with Chlorine bleach may be wrapped around broom
- Waved in suspect area, if fuming occurs, ammonia present

Both methods rely on chemical reactions – you'll need training and PPE: <u>USE CAUTION</u>

Emergency Response Methods

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An extraction hood used for daily operations may be used to vent escaping gas from a cylinder up through a filter

Hoods and vents may also be equipped with a “scrubber” to neutralize various gases

Some poison gases may be “scrubbed” this way

Response

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- Do you have a trained team?
- Or will you call specialty responders?
- Will special response equipment be needed?
- Special precautions are required for spontaneously combustible gases such as silane.

Recovery Vessel

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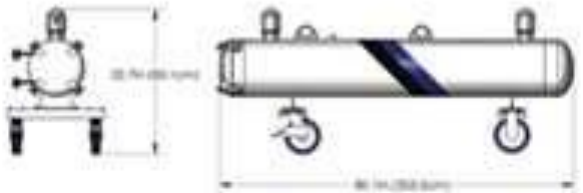
Recovery vessel is a DOT Exempt containment vessel

It can handle large cylinders as well as smaller

Service pressures vary

It may be the most expedient means to control a leaking cylinder



Containment

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Containment is a team effort

Remote openers also exist for containers which may be suspect so responders are not subjected to pressure injuries

Chlorine “A” Kit

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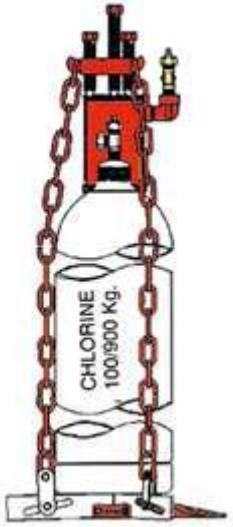
Chlorine “A” kit to be used for leaking Chlorine cylinders

The pressures of some gases may limit the kit’s use to Chlorine

Teams should be trained in proper use



Chlorine "B" Kit

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"B" kit is used to control leaks on 1 ton containers of Chlorine

Where contents can not be pumped out of a container, the container might be able to be drilled

Drilling requires pressure reduction (cooling) and highly trained responders

Response

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Determine if you will handle an event alone or with off-site help

Pre-plan potential zones of harm should your facility have a release

Practice safety and be safe in handling, use, storage and response to gas incidents

Some Standards to Aid You

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The following 29 CFR 1910 Standards may guide you in developing your own program:

1910.101	Compressed Gases (General Requirements)
1910.102	Acetylene
1910.103	Hydrogen
1910.104	Oxygen
1910.111	Storage and Handling of LP Gas

- Compressed Gas Assn., Inc., 14501 George Carter Way, Chantilly, VA 20151

Contact Information

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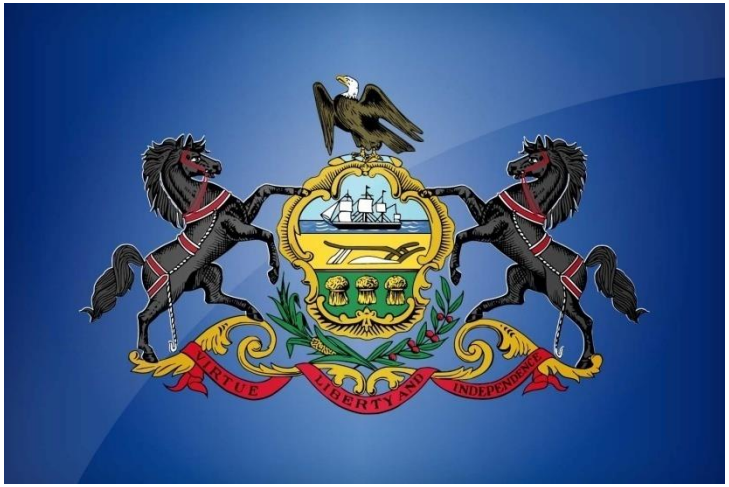

Questions?

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