

## **Safety Guidelines for the Handling and Use of Gases in Thermal Spraying**

Prepared by the ASM-TSS Safety Guidelines Committee

Approved by the TSS Board of Directors

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Comments, criticisms, and suggestions are invited, and should be forwarded to The Thermal Spray Society of ASM International.

## 1 SCOPE

- 1.1 The objective of this document is to provide members of the thermal spray community with practical recommendations for the safe installation, operation, and maintenance of gas equipment used in the thermal spray process. This document should not be considered a complete design publication and its use does not relieve the user from the responsibility of using competent engineering judgment or involving, as required, qualified professionals and suppliers to address specific installation needs.
- 1.2 This document will focus on safety issues concerning gas equipment used in conjunction with thermal spray equipment at consumer sites. It covers the gas sources (bulk or gaseous), the piping (hard and soft) leading to the gas console or the torch, and the specific safety devices used help ensure safe operation.
- 1.3 This document is intended for personnel who are responsible for the safe and efficient operation of thermal spray equipment.

## 2 REFERENCED DOCUMENTS

Where standards and other documents are referenced in this publication, they refer to the latest edition.

Publication	Pub. ID	Available from:
<i>Standard Connections for Regulator Outlets, Torches, and Fitted Hose for Welding and Cutting Equipment</i>	E-1	The Compressed Gas Association: 1235 Jefferson Davis Highway Arlington, VA 22202
<i>Standard for Gas Pressure Regulators</i>	E-4	
<i>Acetylene</i>	G-1	
<i>Oxygen</i>	G-4	
<i>Cleaning Equipment for Oxygen Service</i>	G-4.1	
<i>Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems</i>	G-4.4	
<i>Hydrogen</i>	G-5	
<i>Safety Release Device Standards – Cargo and Portable Tanks for Compressed Gases</i>	G5.1	
<i>Standard for Hydrogen Piping at Consumer Locations</i>	G-5.4	
<i>Carbon Dioxide</i>	G-6	
<i>Standard for Low Pressure Carbon Dioxide Systems at Consumer Sites</i>	G6.1	
<i>Safe Handling of Compressed Gases</i>	P-1	
<i>The Inert Gases Argon, Nitrogen and Helium.</i>	P-9	
<i>Oxygen Deficient Atmospheres</i>	SB-2	
<i>Safety Release Device Standards – Cylinders for Compressed Gases</i>	S1.1	

<i>Standard for Bulk Oxygen Systems at Consumer Sites</i>	NFPA-50	National Fire Protection Association: Battery March Park Quincy, MA 02269
<i>Standard for Gaseous Hydrogen at Consumer Sites</i>	NFPS-50A	
<i>Oxygen-Fuel Gas Systems for Welding, Cutting and Allied Processes,</i>	ANSI/NFPA 51	
<i>Standard for Fire Prevention in Use of Cutting and Welding Process</i>	ANSI/NFPA 51B,	
<i>Guide on Fire Hazards on Oxygen-Enriched Atmospheres,</i>	NFPA 53,	
<i>Non-Flammable Medical Gas Systems,</i>	NFPA 56F	
<i>Standard for the Storage and Handling of Liquefied Petroleum Gases</i>	ANSI/NFPA 58,	
<i>Scheme for Identification of Piping</i>	ANSI A13.1	American National Standards Institute 25 West 43rd Street New York, NY 10036
<i>Chemical Plant and Petroleum Refinery Piping</i>	ANSI/ASM E B31.3	
<i>Safety in Welding and Cutting</i>	ANSI/AWS Z49.1	American Welding Society 550 N.W. LeJeune Road, Miami, Florida 33126
<i>Recommended Practice – Control of External Corrosion on Underground or Submerged Metallic Piping Systems</i>	RP0169-96	National Association of Corrosion Engineers. 1440 South Creek Drive Houston, Texas 77084-4906 USA
<i>Standard Guide for Designing Systems for Oxygen Service</i>	ASTM G88	American Society for Testing and Materials.
<i>Standard Guide for Evaluating Metals for Oxygen Service</i>	ASTM G94	
<i>Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service</i>	ASTM G63	

Publication	Publication ID:	Available From:
<i>MSDS – Acetylene</i>	P-4559	Material Safety Data Sheets  Praxair Inc.  39 Old Ridgebury Road  Danbury, CT 06810-5113
<i>MSDS – Argon</i>	P-4563 (gas) P-4564 (liquid)	
<i>MSDS – Carbon Dioxide</i>	P-4574 (gas) P-4573 (liquid) P-4575 (solid)	
<i>MSDS – Helium</i>	P-4602 (gas) P-4600 (liquid)	
<i>MSDS – Hydrogen</i>	P-4604 (gas) P-4603 (liquid)	
<i>MSDS – Natural Gas</i>	P-4627	
<i>MSDS – Nitrogen</i>	P-4631 (gas) P-4630 (liquid)	
<i>MSDS – Oxygen</i>	P-4638 (gas) P-4637 (liquid)	
<i>MSDS – Propane</i>	P-4646	
<i>MSDS – Propylene</i>	P-4648	

### 3 Terminology

#### 3.1 Definitions

**Blow-down** – A term applied to the process of depressurizing a piping system or source tank by opening a valve, or valves, to atmosphere.

**Bulk Supply** – A bulk supply is typically a gas supply source that is permanently plumbed and has a permanent location. It may be a liquid tank or cylinder, or a bundle of high-pressure cylinders. A single cylinder, cylinder pack, or bottle would not normally be considered a bulk supply unless a permanent position and connections are established.

**Bursting Disk (Rupture Disk, or Safety Head)** – This tank pressure relief device is designed to rupture at typically 20% above the primary relief valve setting, and relieve bulk tank pressure. A bursting disk is designed as a secondary resort to prevent tank damage or rupture. It will not re-close. When a bursting disk ruptures, the tank will be vented to atmospheric pressure and the disk must be replaced before pressure in the tank can be restored.

**Check Valve** – A valve that allows flow in only one direction and will prevent back-flow against that direction.

**Combustible liquid** - Any liquid having a flash point at or above 100°F (37.8°C) at normal pressure.

**Cryogenic** – A term applied to liquefied gases that are stored at temperature below -200° F (-129°C).

**Deflagration** ? An intermediate chemical reaction between combustion and detonation that is accompanied by a vigorous evolution of flame, heat, sparks, or spattering burning particles. Flame travel in a deflagration is at a velocity below the speed of sound.

**Design Pressure** – The same as Maximum Allowable Working Pressure referenced in many codes. The maximum gage pressure permitted at the design temperature. In a *typical piping system* this pressure may be at least 15% greater than the system Operating Pressure; in a *bulk tank and associated components*, the relationship of Design Pressure to the Operating Pressure may be much higher.

**Detonation** ? An exothermic chemical reaction that propagates at the velocity of sound into the surrounding unreacted material, producing a shock wave ahead of the advancing reaction zone.

**Diverter ( 3-way Valve)** – A valve with one input that is switchable to one of two outputs. Used to “divert” the safety vent line of a bulk supply from one set of safety devices to another for maintenance, repair, or incase of safety device failure.

**DMF (dimethylformamide)** – Bulk acetylene supplies or cylinders contain acetylene gas dissolved in either acetone or (DMF) solvent. In addition to the solvent, the cylinders contain a porous filler material and only a small area near the cylinder valve actually contains gas within the cylinder

**Dry Ice** – (CO<sub>2</sub> Snow) The solid state of carbon dioxide. Usually occurs when sudden pressure release occurs such as spraying.

**Excess Flow Valve** - A valve that will automatically close when flow exceeds a designed "trip point", thereby limiting high flow accidental releases.

**Flash Arrestor** – A device commonly used in acetylene or propylene piping to prevent the passage of a flame from a downstream point back into the piping system, or into the gas supply equipment.

**Flashpoint** - The minimum temperature at which a liquid gives off vapor within a test vessel in sufficient concentration to form an ignitable mixture with air near the surface of the liquid. The flash point is normally an indication of susceptibility to ignition.

**Normal Operating Pressure** – The pressure at which a system normally operates; not the pressure to which a system may be subjected during upset, or unusual circumstances. At the inlet to the piping system, the Operating Pressure equals the supply pressure. The Operating Pressure in a portion, or all, of a piping system may be reduced with a regulator (pressure reducing valve).

**Primary Relief Valve?** The bulk supply relief valve that determines the point at which gaseous tank contents must be relieved to atmosphere to limit tank or line pressure.

**Pressure Regulator (Pressure Reducing Valve)** – A device designed to reduce the incoming gas pressure to a lower, constant output pressure in the downstream piping.

**Relief Valve** – A device designed to open and release pressure to prevent damage to downstream components and/or to prevent pipeline pressure from exceeding the Design Pressure. This type valve typically will re-close if the pressure returns to a level below the set pressure.

**Must** – This document contains recommended practices. The use of this term indicates commonly accepted practices considered fundamental to safe operation.

**Should** – This term indicates a recommendation, or that which is preferred.



## 4 THERMAL SPRAY GAS CHARACTERISTICS AND APPLICATION-SPECIFIC SAFETY HAZARDS/PRECAUTIONS

The Gas Characteristics and Safety Hazards in this section are excerpted from Material Data Safety Sheets (MSDS) for the specific gases described. Consult the individual MSDS available from the gas supplier for more detailed information.

### 4.1 Oxygen characteristics

Oxygen (O<sub>2</sub>) is a colorless, odorless, and tasteless gas. Oxygen supports and can vigorously accelerate combustion. This gas is heavier than air (1.1 times the weight of air at 70°F/21°C and 1 atmosphere). Oxygen normally makes up 21% of the atmosphere. Any atmosphere with greater than 21% is considered oxygen-rich. Bulk oxygen supplies typically store this gas in liquid form and vaporize it to the gaseous phase at entrance to facility pipelines for distribution to thermal spray equipment.

### 4.2 Oxygen Safety Hazards

- 4.2.1 **Liquid Oxygen or cold gas may cause severe frostbite to the eyes or skin.** Liquid oxygen temperature is -297°F (-183°C) at atmospheric pressure. Do not touch frosted pipes or valves. If accidental exposure to liquid oxygen occurs, consult a physician at once. If a physician is not readily available, warm the areas affected by frostbite with water that is near normal body temperature.
- 4.2.2 **Do not permit smoking or open flame** in any area where oxygen is stored, handled, or used.
- 4.2.3 **Combustible compounds like grease and oil may ignite spontaneously** when subjected to an oxygen-enriched atmosphere. For this reason combustible materials and sources of ignition must be kept away from oxygen piping and hoses. Keep all surfaces, which may come in contact with oxygen, clean to minimize chances of combustion. Oxygen should never be used to clean clothing, to "cool" work pieces, or to blow off debris. All components of oxygen circuits must be specially cleaned to remove any possibility of combustible material residue. Never use replacement parts in oxygen service that are not clearly marked: Cleaned for Oxygen Service. Where lubricants are required, use only oxygen-compatible products.
- 4.2.4 **Oxygen may accumulate in areas containing oxygen equipment.** Maintain adequate ventilation to prevent and minimize combustion hazards.
- 4.2.5 **Oxygen may saturate clothing or other fabric materials.** Ventilate clothing saturated with oxygen gas or liquid for at least 30 minutes, since it will be highly flammable and easily ignited.

### 4.3 Compressed Air

- 4.3.1 Compressed air should be referred to by its proper name to avoid confusing it with oxygen or fuel gas. Compressed air should never be used to clean clothing. Similarly, oxygen and fuel gas should not be used for this purpose.

- 4.3.2 Compressed air for thermal spraying or blasting operations should not be used at pressures other than those recommended by the equipment manufacturers. Compressed air piping/hoses should be free of oil and moisture. A qualified air compressor dealer or thermal spraying equipment manufacturer should be consulted for recommendations regarding filters and after-coolers.

#### 4.4 Nitrogen, Helium, and, Argon Characteristics

Nitrogen ( $N_2$ ), helium (He), and argon (Ar) are inert, colorless, odorless, and tasteless. These gases can cause asphyxiation and death in confined, poorly ventilated areas. Argon is heavier than air (1.38 times the weight of air at 70°F/21°C and 1 atmosphere); Helium is much lighter than air (0.138 times the weight of air at 70°F/21°C and 1 atmosphere); and Nitrogen is normally lighter than air (0.96 times the weight of air at 70°F/21°C and 1 atmosphere), but may be heavier than air as a cold vapor from a liquid nitrogen supply. Bulk supplies of nitrogen and argon typically store their product in liquid form and vaporize it to the gaseous phase at entrance to facility pipelines for distribution to thermal spray equipment; helium bulk supplies are typically in the gaseous phase.

#### 4.5 Nitrogen, Helium, and, Argon Safety Hazards

- 4.5.1 **Cryogenic liquid or cold gas may cause severe frostbite to the eyes or skin.** Liquid temperatures of these gases range from -302° to -452°F (-186° to -269°C) do not touch frosted pipes or valves. If accidental exposure to liquefied nitrogen, helium, or argon gas occurs, consult a physician at once. If a physician is not readily available, warm the areas affected by frostbite with water that is near normal body temperature.
- 4.5.2 **Nitrogen, helium, and argon can cause asphyxiation** in a confined area by displacing oxygen. Keep equipment areas well ventilated. Any atmosphere that does not contain enough oxygen for breathing (at least 19.5%) can cause dizziness, unconsciousness, or even death. When there is doubt about the adequacy of ventilation, use an oxygen analyzer with a 0 to 25% scale to check for the proper amount of oxygen. It is important to check at different levels in an area (low and high) to ensure that gases both heavier and lighter than air are measured.

#### 4.6 Carbon Dioxide Characteristics

Carbon Dioxide ( $CO_2$ ) is typically stored in bulk supplies in liquid phase, under pressure. At normal distribution temperature and pressure,  $CO_2$  liquid flows like water, but pressure over the liquid must be maintained at all times to keep the gas in its liquid phase. While not normally considered a cryogenic liquid, liquid  $CO_2$  is extremely cold and will change from its liquid phase to its gaseous phase, or to the solid (dry ice) phase, as its pressure and temperature drop. It is the cooling properties that result from sudden pressure release that are useful in thermal spray applications. The Triple Point of  $CO_2$  (where gas, liquid, and solid phases of  $CO_2$  exist in equilibrium) is approx. 60 psig and 70°F (410 kPa and 56.6°C). Below this point, liquid  $CO_2$  will begin to change to the solid phase (dry ice) and may plug any pipe or vessel in which it is contained.  $CO_2$  gas is heavier than air (1.5 times the weight of air at 70°F/21°C and 1 atmosphere).

#### 4.7 Carbon Dioxide Safety Hazards

- 4.7.1 **CO<sub>2</sub> liquid or snow may cause frostbite or skin damage on contact.** Because of the physical characteristics of carbon dioxide and the plumbing of delivery systems, the piping to thermal spray processes may contain CO<sub>2</sub> in liquid form because of a delivery pressure that prevents it from becoming a gas. If this pressure is suddenly released, the gas becomes CO<sub>2</sub> "snow" or dry ice, the temperature of which is about 100 degrees below zero.
- 4.7.2 **Carbon dioxide can cause asphyxiation and death** in confined, poorly ventilated areas. Ventilation is essential when CO<sub>2</sub> is present: Never work in an area with CO<sub>2</sub> on without adequate ventilation.
- 4.7.3 **High concentrations of carbon dioxide will also affect breathing.** Unlike other asphyxiants, which simply displace oxygen, elevated CO<sub>2</sub> levels affect the respiratory system – changing pulse rates and blood pressure. Three percent (3%) CO<sub>2</sub> can impair judgment, increase pulse rate and blood pressure; unconsciousness can result from concentrations of ten percent (10%) or above in less than one minute. Death can follow. Where potential high concentrations of CO<sub>2</sub> are a concern, monitoring CO<sub>2</sub> levels – not oxygen levels – is the appropriate approach -.

#### 4.8 Hydrogen Characteristics

Hydrogen (H<sub>2</sub>) is a very flammable, colorless, odorless, and tasteless gas that is much lighter than air (0.07 times the weight of air at 70°F/21°C and 1 atmosphere). Hydrogen gas in air is extremely flammable in any concentration from 4% to 75% and can be EXPLOSIVE. As the lightest of all elements, it has a tendency to accumulate in the upper portions of confined spaces.

#### 4.9 Hydrogen Gas Safety Hazards

- 4.9.1 **Hydrogen is a very flammable gas.** Hydrogen gas in the air is extremely flammable in nearly any concentration. Any leak, no matter how small, must be addressed immediately. A hydrogen flame is virtually invisible either in an explosion or a deflagration. A flame from a leaky valve or fitting may go undetected.
- 4.9.2 **Hydrogen can cause asphyxiation in a confined area by displacing oxygen.** Keep the equipment area well ventilated. Any atmosphere that does not contain enough oxygen for breathing (at least 19.5%) can cause dizziness, unconsciousness, or even death. Breathing moderate concentrations can cause headaches, drowsiness, dizziness, and vomiting.
- 4.9.3 **Isolate hydrogen from sources of ignition,** and do not permit any accumulation of gas. Hydrogen-air mixtures in nearly any concentration are easily ignited by a low energy spark (such as static electricity) and may cause an explosion. Smoking, open flames, unapproved electrical equipment, and other ignition sources must not be permitted in hydrogen areas. Use non-sparking tools when working on or near hydrogen equipment. . Any leak, no matter how small, must be addressed immediately.

#### 4.10 Acetylene Characteristics

Acetylene ( $C_2H_2$ ) is an unstable gas that is flammable in air in any concentration from 2.5% to 100% and can be *very explosive* if ignited by a spark, flame or other ignition source. Acetylene is lighter than air (0.91 times the weight of air at 70°F/21°C and 1 atmosphere). Unburned acetylene gas has a distinctive odor similar to garlic. Piping systems that carry this gas must be constructed of specific materials to prevent and contain reactions. Any ignition in an acetylene line can cause a detonation that may propagate back through the acetylene plumbing. Any leak, no matter how small, must be addressed immediately.

#### 4.11 Acetylene Safety Hazards

- 4.11.1 **Due to its unstable nature, Acetylene can explode or decompose** with no oxygen or air present. As a result, acetylene is stored in cylinders and is dissolved in a solvent such as acetone or dimethylformamide (DMF). Specific requirements must be met regarding piping and distribution pressures.
- 4.11.2 **Under certain conditions, acetylene forms readily explosive compounds** with copper, silver, and mercury. Contact should be avoided between acetylene and these metals, their salts, compounds, and high concentration alloys.
- 4.11.3 **Acetylene is very flammable when mixed with air.** Keep acetylene away from sources of ignition. Do not permit any accumulation of gas. Concentrations of acetylene between 2.5% and 100% by volume in air are relatively easy to ignite by a low-energy spark and may cause an explosion. Use non-sparking tools when working on or near acetylene equipment.
- 4.11.4 **Acetylene cylinders require special storage conditions.** Store cylinders in an upright position outdoors or in other well-ventilated areas and away from any heat sources such as furnaces, ovens, and radiators. Also keep cylinders away from flammable materials such as gas, kerosene, oil and combustible solids. Never use equipment or a cylinder that is leaking acetylene. Be certain that the regulator to cylinder valve, hose to regulator, and torch to hose connections are leak tight before starting work.

#### 4.12 Kerosene Characteristics

Kerosene is a clear, water-white combustible liquid with a mild, characteristic odor and a flash point ranging from 110 to 150 °F.

#### 4.13 Kerosene Safety Hazards

- 4.13.1 **Kerosene is classified as a combustible fuel, and must be kept from sources of ignition.** Do not permit smoking, open flame, unapproved electrical equipment, or other ignition sources in any area where kerosene is stored, handled, or used. Do not permit any accumulation of vapors. Kerosene vapors can be ignited by a low energy spark (such as static electricity) and may cause an explosion.

- 4.13.2 **Leaking liquid may release flammable fumes and vapors.** Never use equipment that is leaking kerosene. Be certain that all connections are leak tight before starting work.
- 4.13.3 **Kerosene can cause asphyxiation in a confined area by displacing oxygen.** Maintain adequate ventilation to prevent the accumulation of kerosene fumes in areas containing this fuel. Store kerosene outdoors, or in other well-ventilated areas, away from any heat sources such as furnaces, ovens, and radiators.

#### 4.14 Propylene Characteristics

Propylene ( $C_3H_6$ ) is a colorless, easily liquefied, flammable fuel gas with a faintly sweet odor. Propylene is transported in liquid form in cylinders and tanks for greater density. At normal atmospheric pressure and temperature, propylene is a non-toxic, colorless and odorless gas. Typically, an identifying odor is added so that it can be readily identified. Under moderate pressure, propylene becomes a liquid that vaporizes into a clean burning gas when released from its storage container. Flammability Limits from 2% to 11.1% allow formation of explosive mixtures with air. Propylene is a heavy gas in relation to air (1.45 times the weight of air at 70°F/21°C and 1 atmosphere), and has a tendency to accumulate in the lower portions of confined spaces.

#### 4.15 Propylene Safety Hazards

- 4.15.1 **Short-term overexposure to fumes may have anesthetic effects,** cause dizziness, nausea, and dryness or irritation of the nose, throat, and eyes or may cause similar discomfort; longer-term exposure may cause liver damage.
- 4.15.2 **Propylene can cause asphyxiation in a confined area** by displacing oxygen needed for breathing. Maintain adequate ventilation to prevent the accumulation of propylene in areas containing propylene.
- 4.15.3 **Contact with cold gas or liquid may cause frostbite.** If accidental exposure to liquid occurs, consult a physician at once. If a physician is not readily available, warm the areas affected by frostbite with water that is near normal body temperature.
- 4.15.4 **Very flammable gas can easily ignite.** Keep propylene away from sources of ignition, and do not permit any accumulation of gas. Propylene is relatively easy to ignite by a low energy spark (such as static electricity) and may cause an explosion. Smoking, open flames, unapproved electrical equipment, and other ignition sources must not be permitted in areas where propylene is used or stored. Use non-sparking tools when working on or near propylene equipment.

#### 4.16 Propane Characteristics

Propane ( $C_3H_8$ ) or liquefied petroleum gas (LP-gas) is a Colorless, easily liquefied, flammable fuel gas with a faintly disagreeable odor. Flammability Limits from 2.1% to 9.5% allow formation of explosive mixtures with air. Propane is readily liquefied under elevated pressure due to  $-43^\circ F$  boiling point. It is transported in liquid form in cylinders and tanks for greater density. Propane vaporizes into a clean burning gas when release from its storage container. Typically, an identifying odor is added so that the gas can be readily identified if leaking. Propane is a heavy gas in relation to air (1.52 times the weight of air at  $70^\circ F/21^\circ C$  and 1 atmosphere) and has a tendency to accumulate in the lower portions of confined spaces.

#### 4.17 Propane Safety Hazards

- 4.17.1 **Very flammable gas can easily ignite.** Keep propane away from sources of ignition, and do not permit any accumulation of gas. Propane is relatively easy to ignite by a low energy spark (such as static electricity) and may cause an explosion. Smoking, open flames, unapproved electrical equipment, and other ignition sources must not be permitted in propane areas.
- 4.17.2 **Contact with cold gas or liquid may cause frostbite** If accidental exposure to liquid occurs, consult a physician at once. If a physician is not readily available, warm the areas affected by frostbite with water that is near normal body temperature.
- 4.17.3 **Propane can cause asphyxiation in a confined area** by displacing oxygen needed for breathing. Overexposure to fumes may cause dizziness and drowsiness. Maintain adequate ventilation to prevent the accumulation of gas in areas containing propane.

#### 4.18 Natural Gas Characteristics

Natural gas is a very flammable gas with a faintly disagreeable odor. It is lighter than air (0.55 times the weight of air at  $70^\circ F/21^\circ C$  and 1 atmosphere). Breathing moderate concentrations can cause drowsiness, and dizziness. This gas is a mixture of 83% to 99% Methane, up to 13% Ethane, and small percentages of Propane and Butane. Natural gas in the air is extremely flammable in any concentration from 3.8% to 17% and can be *explosive*. Typically, an identifying odor is added so that the gas can be readily identified if leaking.

#### 4.19 Natural Gas Safety Hazards

- 4.19.1 **Very flammable gas can easily ignite.** Keep natural gas way from sources of ignition, and do not permit any accumulation of gas. The gas is easily ignited by a low energy spark (such as static electricity) and may cause an explosion. Smoking, open flames, unapproved electrical equipment, and other ignition sources must not be permitted in areas where this gas is used or stored. Any leak, no matter how small, must be addressed immediately.
- 4.19.2 **Natural gas can cause asphyxiation in a confined area** by displacing oxygen needed for breathing. Overexposure to fumes may cause dizziness, drowsiness, or death. Maintain adequate ventilation to prevent the accumulation of gas in areas containing propane.

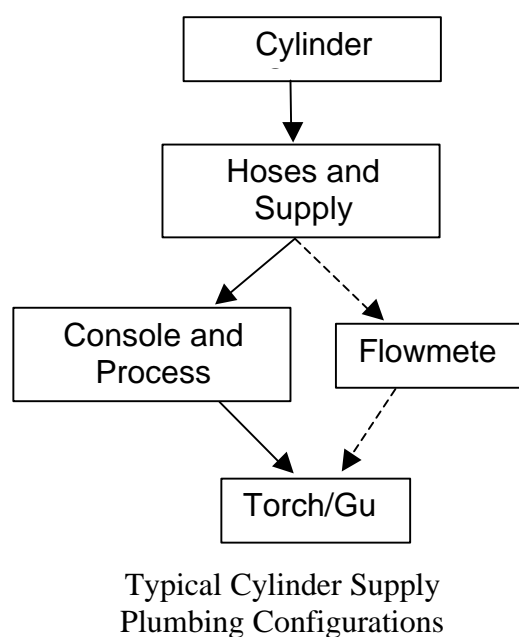
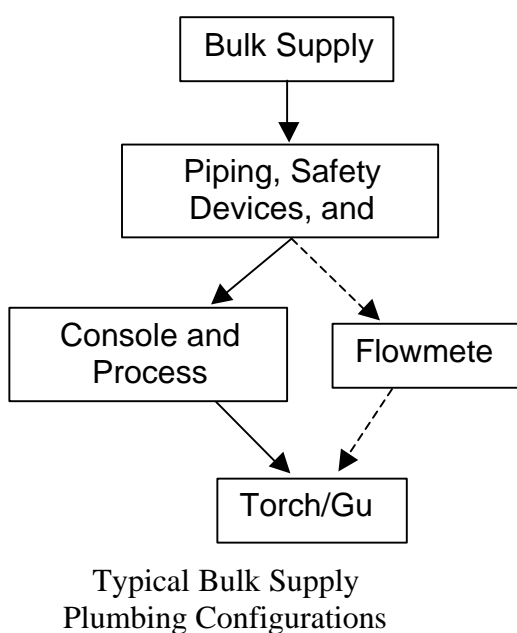


## 5 TYPICAL THERMAL SPRAY GAS PLUMBING CONFIGURATIONS

Process gas supply installations utilize a variety of configurations and technologies depending on the type of gas, purity requirements, usage volume, delivery rate, and supplier capabilities. The gas supplier must be relied upon in many cases to ensure safe gas supply installation and plumbing to the limit of the bulk supply. From this point to the workstation (or use point) all plumbing is typically the responsibility of the operator of the equipment. Gas installation types for typical thermal spray applications can include:

1. Cryogenic liquid tanks (usually oxygen, argon, nitrogen, hydrogen)
2. Refrigerated liquid tanks or cylinders (usually carbon dioxide)
3. Trailer based systems (can be permanent or temporary)
4. Pressurized liquid tanks or bottles (typically propane, propylene)
5. Cylinders containing gas dissolved in solvent (acetylene)
6. High Pressure Cylinders (typically Ar, O<sub>2</sub>, N<sub>2</sub>, H<sub>2</sub>, He and others)
7. Manifolded or interconnected individual cylinders or bottles
8. Pre-assembled packs of cylinders or bottles.

Each of these gas supplies — there can be many employed in one single Thermal Spray workstation, or cell — has pressure and flow control requirements along its path to the torch or gun used with the process. These also vary with the individual equipment. The complexity of a system can range from a single gas cylinder with a regulator and flowmeter, to multiple bulk supplies feeding elaborate spray booths with sophisticated gas control consoles, and many levels in between. While this standard cannot define all these possibilities, the safe practices that must be followed when using typical components are addressed in subsequent sections of this standard.



## **6 BULK GAS SUPPLIES – SUMMARY OF SAFE PRACTICE FOR: INSTALLATION, OPERATION, AND MAINTENANCE**

### **6.1 Bulk Supply Installation Considerations**

- 6.1.1 The Design Pressure of a bulk tank and associated components is always greater than its Operating Pressure. The safety margin between Design Pressure and Operating Pressure depends on the product contained and its storage method (liquid or gas). i.e. Liquefied gas bulk tanks typically have a Design Pressure at least 30% higher than the normal operating pressure; while acetylene supplies typically have a Design Pressure that is 50 times the Operating Pressure.
- 6.1.2 The bulk supply tank or system should have a system plumbing schematic attached to the exterior of the tanks or other accessible location to provide instant reference to the specifics of the tanks internal plumbing and external system plumbing.
- 6.1.3 All bulk liquid tanks typically have a dedicated dual sided safety line with a selector (diverter) valve. With a dual safety configuration, both sides contain a primary relief valve and a bursting disk (CO<sub>2</sub> tanks are an exception in respect to a bursting disk). These functions should not share lines with other tank functions such as blow-down or vent lines.
- 6.1.4 The diverter valves should be clearly labeled as to their function and position.
- 6.1.5 Primary Relief valves and bursting disks must be sized for flow capability, and must have pressure settings relative to operating pressure, maximum design pressure, and tank test pressure
- 6.1.6 Each primary relief valve must be rated for the specific gas service where it is employed. Primary Relief Valves must be protected from humidity and moisture that can freeze and cause the valves to malfunction as ice restricts valve movement.
- 6.1.7 Lines that could contain normally gaseous product in the liquid phase should have trapped liquid relief valves that are set to a higher cracking pressure (min. 20%) greater than the primary relief valve. This is to relieve the dangerous buildup of pressure that will result as liquid trapped between two closed valves warms and expands.
- 6.1.8 In cases where equipment downstream from a pressure-regulating device is insufficiently rated to withstand full pressure resulting from a failure of the pressure-regulating device, a suitable pressure relief valve should be incorporated.
- 6.1.9 Any bulk gas installation should receive a complete design review prior to pressurization and subsequent placement in production. Technical representatives from both customer and supplier should review all design and safety attributes of the system. Emergency measures and plans as well as responsibilities of both customer and supplier should be reviewed, agreed to and documented.
- 6.1.10 Cylinders when manifolded into a bulk supply must be secured against a wall, a column, or some other stiff fixture using a chain, or strap above the center of gravity. It is important that every effort is made to assure that a cylinder will not fall over.
- 6.1.11 Cylinder bundles (i.e. 12 packs) should be rolled onto flat surfaces and secured in place.



## 6.2 Oxygen Specific Requirements

- 6.2.1 All metal and metal alloy pressure-reducing valves or regulators should be constructed from brass, bronze, or copper. Aluminum bronze should not be permitted.
- 6.2.2 Other materials such as stainless steel or carbon steel require flow restrictions. All other components where high velocities and particle impacts can be expected should be made from non-sparking materials.
- 6.2.3 Regulations for the location of the bulk oxygen storage tank with respect to other structures and storage facilities should be strictly adhered to.
- 6.2.4 Bulk storage systems should be installed outdoors and at grade level.
- 6.2.5 Where oxygen is supplied as a liquid, the area under and around the bulk storage tank should be free of debris, vegetation and any combustible materials. This area should also include the area covered by the delivery vehicle.
  - ? Oxygen trailers (or at least the sections that dispense liquid product) should be atop a concrete slab
- 6.2.6 Cylinder bundles containing oxygen should be rolled onto flat concrete surfaces and secured so they cannot move.
- 6.2.7 All nonmetallic materials used for oxygen service must be certified for oxygen service.
- 6.2.8 Rapid pressurization (adiabatic compression) is a potential ignition source in oxygen supply systems. Valves should be opened slowly; safe system designs will avoid the use of fast-acting valves (such as 1/4 turn valves).
- 6.2.9 Aluminum components or component parts should not be allowed. Atmospheric vaporizer fins are an exception to this requirement.
- 6.2.10 All components used on oxygen systems must be cleaned for oxygen service. Particulate contamination (such as fine metal particles, etc.) can be ignition sources in oxygen systems - keep systems clean and free of particulate contamination.
- 6.2.11 Oil or grease should never be used on oxygen equipment. Only special oxidation resistant lubricants may be used with oxygen equipment.
- 6.2.12 Where thread sealants are employed in oxygen piping, oxygen-compatible materials are required. Teflon tape, while oxygen compatible, requires proper installation technique to ensure tape fragments do not enter the piping system and inhibit the operation of other components.

### 6.3 Supply Piping to the Thermal Spray Cell (Underground, Above ground)

- 6.3.1 Material selection is a critical aspect to piping gases (copper, brass, or bronze alloys that contain more than 60% copper may cause decomposition in acetylene piping and are not appropriate for that gas). Make certain that pipe, tubing, flanges, valves, fittings, and other components are suitable for the design pressure of the system and the specific gas involved. Special design consideration should be given to components installed in a corrosive atmosphere or subject to high fatigue. Brass, copper, or stainless steel piping should be considered for installation in corrosive atmospheres or where concealed construction prevents routine inspection and maintenance. Forged or cast steel, stainless steel, malleable iron, copper, or copper alloy flanges and fittings are recommended where compatible with the gas being carried.
- 6.3.2 To avoid possible damage to equipment and injury to personnel, pipes and hoses should be routed where they will not be exposed to excessive temperature changes or contact with power lines. Pipes should be placed in locations where it will not be damaged by moving objects (machinery, vehicles, conveyors) and protected from contamination by oil and grease.
- 6.3.3 Overhead piping should be adequately supported with the appropriate parts. Pipe expansion or contraction due to temperature variation should be included in the design.
- 6.3.4 For underground piping, the piping should be installed 3 feet below the ground surface or below the frost line – whichever is deeper. The trench bottom should be graded to assure continuous and firm pipe support. The soil or sand around the pipe should not contain any rocks, stones, or slag.
  - ? Underground piping should employ welded joints.
  - ? Underground piping should be protected from corrosion using cathodic protection methods and/or corrosion protective coatings or wrapping.
  - ? A protective casing should be provided for underground piping when it is routed underneath roadways or railroad tracks.
- 6.3.5 Piping system Design Pressure ratings should typically be specified to be at least 15% above the normal operating pressure range, however, Acetylene piping typically requires a Design Pressure 50 times the Operating Pressure.
- 6.3.6 Valves that can shut-off gas flow should be specified with a working pressure rating equal to or greater than the primary line safety relief device.
- 6.3.7 For liquid fuel (e.g. kerosene), check valves are recommended to help prevent flow-back and air entrapment

- 6.3.8 Pressure relief valves must be installed between all components that could contain normally gaseous product in the liquid phase and can cut off gas flow.
- ? Pressure relief valves should be rated at least 10% to 15% above the normal line pressure to prevent unnecessary product loss. These flow capacity valves should also be sized to be equal or greater than the maximum flow that could enter the line under any circumstances.
  - ? Pressure relief valves should be located as close as possible to the potential source of overpressure. The discharge of safety relief valves located indoors should be piped to an outdoor location.
- 6.3.9 Pressure reducing valves or regulators should contain a 40 mesh or finer strainer on its upstream side to filter out rust, welding scale, dirt and other foreign material that might interfere with valve or regulator operation.
- 6.3.10 Properly cleaning of pipes and components is extremely important. The appropriate standard should be reviewed for the proper procedure.
- 6.3.11 Pipes should be identified by legend (name), color code, and direction of flow. Refer to ANSI publication A13.1, "Scheme for the Identification of Piping Systems".
- 6.3.12 Piping should be inspected on a regular basis to detect problems and institute corrective action. *A procedure for periodic inspection of each component and for each type of gas should be available. The repair procedures for pipes and components can vary widely due to the gases involved.*
- 6.3.13 Before any new or repaired piping is put into operation, it should be pressure and leak tested as per the appropriate standard.
- 6.3.14 Do not use gas lines for grounding!

#### 6.4 Bulk Supply Operation and Maintenance Considerations

- 6.4.1 A gas supplier should have the primary responsibility for installing, filling/replacing, and maintaining bulk gas sources.
- 6.4.2 Even when a *gas supplier* has the primary responsibility for maintaining the bulk supply source, the *gas user* should be familiar with the following issues for emergency purposes:
- ? The location and operation of safety devices (check valves, pressure relief valves, removal of vegetation)
  - ? The piping arrangement of the gases/liquids
  - ? The factors that can cause product to leak
  - ? The maximum pressure that the bulk source can safely withstand.
  - ? Emergency procedures (i.e. shutting down the flow of gases, handling leaks or fires)
  - ? The gas user should ensure that key personnel are trained in basic function and emergency procedures for bulk gas sources.

## 7 COMPRESSED GAS CYLINDERS

Storage, handling, and operation of compressed gas cylinders shall be in accordance with ANSI/AWS Z49.1, *Safety in Welding and Cutting*, and with CGA Pamphlet P-1, *Safe Handling of Compressed Gases*. The improper connection, storage, handling, and use of gas cylinders constitute a safety hazard in the thermal spraying workplace.

### 7.1 Cylinder Storage

- 7.1.1 Local, state, municipal, and federal regulations relative to the storage of cylinders should be investigated and followed
- 7.1.2 Cylinders should be stored upright and where they will not be exposed to physical damage, tampering by unauthorized persons, or subject to temperatures that would raise the contents above 125°F (52°C).
- 7.1.3 Anytime cylinders are not being moved they must be secured to prevent accidental tip over that could damage the cylinder valve and allow the release of dangerous pressures and large volumes of gas.
- 7.1.4 Cylinders in storage must be separated from flammable and combustible liquids and from easily ignitable materials (wood, paper, oil, grease) by at least 20 feet (6.1 meters).
- 7.1.5 Oxygen cylinders in storage must be separated by at least 20 feet (6.1 meters) from fuel gas cylinders or reserve stocks of calcium carbide.
- 7.1.6 Cylinders must be secured against a wall, a column, or some other stiff fixture using a chain, or strap above the center of gravity. It is important that every effort is made to assure that a cylinder will not fall over.
- 7.1.7 Connecting several cylinders together with a manifold is frequently required in thermal spray installations to obtain a greater gas capacity. If this is done the cylinders must still be properly secured. Similarly, cylinder bundles (i.e. 12 packs) must also be secured if the possibility exists that the bundle may roll or tip over.

### 7.2 Cylinder Transport

- 7.2.1 Cylinders must be transported only by using an appropriate device such as a crane, cradle or gas cylinder hand truck. Slings or electromagnets should not be used.
- 7.2.2 Cylinders must not be dropped. Cylinders, cylinder valves, or safety devices, must not be struck, or permitted to strike other objects. Damage to any of these components may allow the release of dangerous pressures and large volumes of gas.
- 7.2.3 When moving cylinders, they must be kept upright, the cylinder valves must be closed and a valve protection cap should be screwed on. Valve protection caps must always be in place and hand tight – except when the cylinder is secured and connected for use.

### 7.3 Cylinder Operation

- 7.3.1 Pressure reducing regulators must be installed and used properly. Only regulators appropriate for the gas/cylinder should be used. A regulator must not be used on liquid phase product. Only acetylene regulators may be used on acetylene tanks or manifold systems. It is important to use the correct size non-sparking wrench to connect the regulator to the cylinder valve outlet: never force or over tighten a connection.
- 7.3.2 When connecting oxygen and fuel gas cylinders, pressure reducing regulators, and flow meters, the connecting nuts should be drawn up tight, but should never be over tightened. (Over tightening is likely to collapse the nose of the nipple.) If the fitting cannot be sealed without undue force, the fitting should be replaced.
- 7.3.3 Adequate ventilation of the work area should be provided before opening any of the gas valves on compressed gas cylinders. The operator should stand to the side of the pressure reducing regulators when opening cylinder valves, and open the valves slowly, to protect against the rupture of a faulty regulator.
- 7.3.4 In the United States: Acetylene pressures in excess of 15 psig (103 kPa) are considered dangerous and must not be used; In Europe this threshold is 22psig (150 kPa). *Acetylene may detonate at pressures above these points.* When acetylene pressure below these levels is insufficient, special precautions must be taken, or another fuel gas should be used.
- 7.3.5 Pressure regulators should never be set to pressures higher than those recommended for the process. If oxygen and fuel gas pressure required for a process are both more than 3 psi (21 kPa) over recommended pressures, a problem may be indicated with the thermal spray equipment (fouled nozzle or incorrect air cap adjustment). Pressures that are too low usually indicate a serious leak. Equipment should be shut down and the condition corrected before attempting to reuse the system.
- 7.3.6 Flame arrestors should be considered when installing multiple acetylene cylinders or an acetylene backup supply system.
- 7.3.7 Regulator adjusting screws should be turned in slowly to prevent surges that may crack or burst flow meter tubes. Hoses should be blown out to remove any dust that may be present internally.
- 7.3.8 Acetylene and liquefied gas cylinders must be used upright (valve end up) to prevent liquid flow into hoses and regulators.
- 7.3.9 If a cylinder is frozen to the ground, use warm but not boiling water to free it. Pry bars under valves or valve protection caps should never be used to pry cylinders loose!
- 7.3.10 Cylinders must never be used as rollers or supports – whether empty or full.
- 7.3.11 Safety devices should not be tampered with.

#### 7.4 Cylinder Leaks/Fires

- 7.4.1 If a leak is found around the valve stem of a fuel gas cylinder, the packing nuts should be tightened, or the cylinder valve closed immediately.
- 7.4.2 If a leak is found in a fuel gas hose or line, the cylinder valve or in line shut-off valve should be immediately closed.
- 7.4.3 If tightening the packing nuts does not stop a valve stem leak, or if a fuel gas valve is leaking at the seal and can not be stopped by closing the valve firmly, or if a leak should develop at a cylinder fuse plug or other safety device, then the fuel gas cylinders should be moved to a safe location outdoors, away from any source of ignition, and marked properly. The supplier should also be advised.
- 7.4.4 When a leaking cylinder cannot be moved safely to a location outdoors, the area or building should be immediately evacuated and the fire department notified of the emergency.
- 7.4.5 A Warning sign should be posted telling others not to approach the leaking cylinder with a lighted cigarette or source of ignition.
- 7.4.6 If a small fire at a fuel gas cylinder does occur, it is usually better to allow the fire to continue to burn and consume the escaping gas; otherwise it may re-ignite with explosive violence. If circumstances permit, it is often better to allow the cylinder fire to burn out in place rather than attempt to move the cylinder.
- 7.4.7 If the cylinder is located where the fire should not be allowed to burn out in place, attempts may be made to move it to a safer location, preferably outdoors. Personnel should remain as distant as possible, and the cylinder should be kept cool with a water stream.

### 8 REGULATORS, FLOWMETERS, AND HOSES

Only pressure reducing regulators, flowmeters, and hoses approved/certified by the manufacturer for the specific gas and application should be used. Refer to ANSI/AWS Z49.1 *Safety in Welding and Cutting*, and CGA pamphlet E-4, *Standard for Gas Regulators for Welding and Cutting* for more information. Hose and hose connections should be installed and used in accordance with ANSI/AWS Z49.1, and CGA pamphlet E-1, *Regulator Connection Standards*, published jointly by the Rubber Manufacturers Association and the Compressed Gas Association.

#### 8.1 Regulators

- 8.1.1 Pressure reducing regulators should be used only for the gas and gas pressures for which they are labeled. Interchanging regulators will lead to contamination and can then lead to explosions and fire.
- 8.1.2 Union nuts and connections on regulators should be inspected for damage before use. If any defective nuts or connections are found, they should be immediately replaced.

8.1.3 Oxygen regulators and components should be marked with the label “USE NO OIL”. Oil or grease should never be used on a regulator.

8.1.4 Pressure regulators should be set to zero pressure before they are attached to a cylinder, manifold or before a cylinder valve is opened. In addition, cylinder or manifold valves should be opened slowly to control the pressure increase.

## 8.2 Flowmeters

8.2.1 Flow meters should be installed and used in accordance with ANSI/AWS Z49.1. If a flow meter with glass tubes is used, a protective shield should be placed between the flow meter and the gun. In addition, backflow prevention devices should be used in conjunction with flow meters to avoid unsafe operating conditions and to ensure proper flame balance.

## 8.3 Hoses/Hose connections

8.3.1 Hose connections should be able to withstand twice the normal operating pressure without leaking or at least 300 psi – whichever is greater. Oil free air or an oil free inert gas should be used for testing.

8.3.2 The hoses to the thermal spray gun should be periodically checked for leaks at all connections, with leak check solution. Soapy water may be used with some gases, but only oxygen compatible leak check solutions are appropriate for oxygen leak checks. Leak check solutions are applied to each joint while the system is under pressure. A flame should never be used to check for gas leaks. Solutions are safer and provide a more sensitive test than a flame.

8.3.3 The frequency of inspection depends upon how often the hose is used and the severity of usage. Bending areas, particularly at the regulators and the torch connections, are prone to cracking and leaking.

8.3.4 When connection leaks are found, the following operations should be performed: lock out/tag out the gas supply as required; depressurize the affected piping; open the connection, wipe clean the sealing surfaces; ensure that the threads are clean; retighten, pressurize, and retest the section or leaks. If a leak persists, the system should be depressurized. Leaking thermal spray equipment should never be used. A “Danger—Do Not Operate” tag should be placed on the defective equipment.

8.3.5 Damage to hoses should be avoided. Obstructions in the gas lines caused by defective hoses, collapsed hose stems, or dirt in the gas passages of the gun head or the nozzle jets will require excessive pressure to obtain proper gas flow.



## 9 CHECK VALVES, FLASHBACK ARRESTORS, AND EXCESS FLOW VALVES

- 9.1 **Check Valves** should be used in any circumstances where the prevention of a reverse flow of any gas is required, and installed per manufacturer's recommendations - examples include cylinder manifolds, and mixing chambers where oxy-fuel gases are mixed prior to combustion.
- 9.2 **Flashback arrestors** must be specifically rated for the gas in use and should be considered for every thermal spray system. They provide protection against flashbacks, and reverse flow of fuel gases or oxygen or air. In addition, some of the safety features that are found singly or in combination in flashback arrestors include:
- ? **Flame arrestor** – This feature attempts to cool the flame below the self-ignition temperature of acetylene or other fuel gases mixed with oxygen to prevent the flashback from reaching the source of supply.
  - ? **Gas non-return valve** – These devices give protection against slow and/or sudden gas reverse flow by shutting off the flow of gas when an excessive pressure is reached.
  - ? **Temperature activated valve** – This type valve cuts off the flow of fuel gas and/or oxygen automatically once an excessive temperature is reached. The temperature may be achieved via repetitive flashbacks, burn backs or external fires.
- 9.3 **Excess flow valves** should be considered as safety devices for lower flow systems to prevent high flow accidental releases.

## 10 PRESSURE RELIEF VALVES AND VENTS

- 10.1 **Pressure Relief Valves** should be a standard part of every thermal spray system. They ensure that gas lines or compressed gas bottles will not burst due to excessive pressure.
- 10.1.1 Pressure Relief Valves must be rated for the specific gas service where they are employed (i.e. pressure relief valves on CO<sub>2</sub> systems must be rated for CO<sub>2</sub> service - not other low temperature service such as liquid nitrogen).
- 10.1.2 Pressure Relief Valves are rated by pressure and flow. It is possible that extreme temperature can effect the pressure relief valve's operation. The relief valve's normal operating position is closed and when the valve's excessive pressure value is reached, the valve opens to relieve pressure.
- 10.1.3 Pressure Relief Valves should be added to gas piping wherever the potential for over pressurization of a gas line or component exists. A burst line can cause a fire or explosion and damage equipment. It could also injure an operator by asphyxiation, a fire, and/or an explosion.
- 10.1.4 Pressure relief devices should be vented to the outside of a facility. In the event that a pressure relief valve opens, operators will be safe from asphyxiation dangers and/or the operators and equipment will be safe from a possible fire or explosion



- 10.2 **Vent Lines.** The basic purpose of a vent or vent line is to ensure that gases escaping from a pressure relief valve are directed to a safe location where they will not cause any harm. Typically this means directing the gas out of the spray booth, spray area, or from a gas storage area to the outside of the building.
- 10.2.1 Listed below are recommended practices for installing and maintaining vent lines and are applicable for the gases covered by this standard and addressed in Section 4:
- ? Pressure Relief Valve vent line material should be carbon steel, stainless steel, or copper (copper, brass, or bronze alloys that contain more than 60% copper may cause decomposition in acetylene piping and are not appropriate for that gas).
  - ? Vent lines should be constructed so that they do not restrict the full flow of the pressure relief valve.
  - ? Vent line joints should be welded, threaded, or tubing joined with compression fittings.
  - ? Vent lines should terminate outside the facility at a safe location.
  - ? Vent lines for oxygen should be cleaned for oxygen service.
  - ? Flammable gas vent outlets should be adequately separated from any other vent outlet, air intakes, and potential sources of ignition.
  - ? Vent lines should not be interconnected. They should lead separately to the outside.
  - ? Low points in vent stack piping should be avoided, but a low point where moisture can collect should have drip legs, or pots installed. Drain valves having outlets normally closed with threaded caps or plugs should be installed to permit draining of condensate from the stack
  - ? If tubing is used, tube compression fitting material should be brass or stainless steel.
  - ? Vent lines should be constructed so that they will not be obstructed as a result of weather conditions, or living things (i.e. bugs).
  - ? Each tube should have a durable, legible label at each end to identify the gas that would pass through it.
  - ? Each vent outlet should be inspected on a regular basis for damage.

## 11 GAS ANALYZERS / DETECTORS

### 11.1 Permanently Installed Units

Gas analyzers and combustible gas detectors are often incorporated in the design of thermal spray equipment to provide indication of potentially unsafe conditions. Depending on the specific gases in use and the hazards they present, these devices typically either detect improper concentrations of oxygen (too high or too low) or provide warning regarding the presence of unacceptable percentages of combustible or other gases. They may be interlocked with shutoff valves or exhaust systems in some cases.

11.1.1 The use of gas detection equipment can enhance operator and other personal safety. It is important to note that these devices are not substitutes for good design and operating practices/procedures. Improperly selected, installed or maintained gas detectors will only result in a false sense of security.

11.1.2 Typically thermal spray equipment can be designed and installed such that the chances for gas leakage are minimized and, in the case of a leak, little opportunity is provided for accumulation of any appreciable gas concentration. Physical configuration of consoles and gas control panels should maximize the effects of natural ventilation and air circulation to dilute small gas leaks. Positioning and mounting of equipment and individual components should avoid closely confined areas with poor ventilation and – in the case of flammable gases – areas containing potential ignition sources. Manufacturers recommendations regarding installation, maintenance and periodic leak checking must be followed. In addition, a program of periodic inspection and leak checking of supply systems and plumbing must be established.

11.1.3 When either design or installation issues result in concerns regarding maintaining a safe atmosphere, gas detection equipment should be considered. Guidelines as to the proper and most effective use of such equipment are as follows:

- ? **Sensing technologies** - Various technologies employed for sensing gases can result in significant performance differences. A review should be conducted with the supplier to ensure the sensor type being considered is appropriate for the application.
- ? **Mounting** - The physical location(s) of the sensing element can have a significant effect on the sensor's ability to detect certain gases as well to protect against certain hazards. Facts regarding whether a gas will likely rise or fall (See: specific Gas Characteristics Paragraph 4.x) and typical locations of personnel in work areas should be considered in determining sensor location.
- ? **Calibration/Maintenance** - Each type of sensor will present differing calibration / maintenance requirements. Some devices require that sensor elements be replaced as often as twice yearly and require regular calibration. Consult the manufacturers literature to develop calibration intervals, then follow regular maintenance and calibration procedures, and conduct regular performance testing without fail.

## 11.2 Portable Gas Detector Units

Portable gas detectors can provide a significant, additional measure of safety during operation and maintenance of thermal spray equipment.

11.2.1 Routine gas pack change-out, new equipment installation, maintenance, and calibration activities often result in opening lines and operating valves as well as in the moving and disturbing of normally fixed pieces of equipment. Often these activities present a prime situation in which leaks develop. Use of a handheld gas detector can significantly increase safety during such operations by confirming plumbing integrity, or providing local and immediate detection of leaks.

11.2.2 Units typically are battery powered and have adjustable sensitivity. Proper operation of the unit should be confirmed prior to each use.