CLEMSON
RESEARCH SAFETY

Gas Monitoring Program

1.1 INTRODUCTION

Requirements for gas monitoring apply to the use of any highly toxic, toxic, corrosive, flammable, and/or pyrophoric gases. Plans to purchase monitoring equipment must be reviewed and approved by the Office of Research Safety.

1.2 Goal

This program outlines the requirements and responsibilities necessary to provide suitable gas monitoring systems. The goal is to assure standardization of alarm set points, calibration of monitors, and uniform response to alarms such as positive gas flow shutdown when certain set points are exceeded. This document also encompasses annunciation requirements to assure emergency response personnel need not enter the danger zone to ascertain the status of alarms.

1.3 Scope

This procedure applies to all use of compressed gases other than short term use of limited quantities of compressed gases in a chemical fume hood. Fume hood applications involving hazardous gases shall be reviewed by the Office of Research Safety before experiments commence.

2.1 PROCEDURES

2.2 Monitoring Requirements

2.1.1 Highly Toxic Gases

Highly toxic gases include:

- Gases that have a median Lethal Concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 or 300 grams each.
- A Threshold Limit Value (TLV) as established by ACGIH or a Permissible Exposure Level as established by OSHA, less than or equal to one part per million.
- Designated as a "Poison A" by the DOT, and defined as poisonous gases or liquids of such nature that a very small amount of the gas, or vapor of the liquid, mixed with air is dangerous to life (49CFR173.326).

These gases shall be monitored by a continuous monitor except when the cylinder of highly toxic gas concentration (in ppm) is less than the National Institute for Occupational Safety and Health (NIOSH) Immediately Dangerous to Life and Health (IDLH) level. If an IDLH concentration is not available for the chemical and the cylinder concentration is greater than the Occupational Safety and
Health Administration (OSHA) Permissible Exposure Value (PEL), the Principal Investigator and Research Safety Industrial Hygiene representative shall determine the need for continuous gas monitoring . Continuous monitoring is defined as gas detection by the monitor at any sampling point within 30 seconds at ½ the TLV concentration.

Examples of gases requiring continuous gas monitoring include: Arsine, diborane, germane, phosphine, nitric oxide, methyl bromide, boron trifluoride, chlorine, chlorine trifluoride, dichlorosilane, hydrogen fluoride, fluorine, nitrogen dioxide, phosgene, sulfur tetrafluoride.

Highly toxic gases are exempt from continuous monitoring if the gas quantity is limited to 500 cc of gas phase by volume in a lecture bottle or sample cylinder, a flow restricting orifice is installed in the CGA fitting and:

- 100 linear feet per minute exhaust flow is provided across the cylinder valve/fittings or
- Cylinder pressure is less than 15 psig and will be used in a vacuum system which will be used to fully evacuate the cylinder, or
- A temporary monitoring system is utilized at all times while the gas cylinder valve is open. Examples of temporary use, single point monitors are available by contacting Research Safety at 656-0341.

2.1.2 **Toxic Gases**

Toxic gases include:

- Gases that have a median Lethal Concentration (LC50) in air of more than 200 parts per million, but not more than 2000 parts per million by volume of gas or vapor when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.
- A Threshold Limit Value (TLV) as established by ACGIH or a Permissible Exposure Level as established by OSHA, greater than one part per million but less than or equal to 50 parts per million.

Toxic gases shall be monitored by a continuous monitor except when the cylinder toxic gas concentration is less than the National Institute for Occupational Safety and Health (NIOSH) Immediately Dangerous to Life or Health (IDLH) level. If an IDLH concentration is not available for the chemical and the concentration is greater than the Occupational Safety and Health Administration (OSHA) Permissible Exposure Value (PEL), the laboratory Principal Investigator and Research Safety Industrial Hygiene representative shall determine the need for continuous monitoring.

Examples toxic gases include: Ammonia, boron trichloride, boron trifluoride, carbon monoxide, carbonyl sulfide, ethyl chloride, hydrogen bromide, hydrogen chloride

Toxic gases are exempt from continuous monitoring if the cylinder contains less than 100 grams of material, the cylinder valve has a CGA fitting and

- 100 linear feet per minute of exhaust flow is provided over the cylinder valving and all fittings containing the gas and the exhaust fan is on emergency power or
- 100 linear feet per minute of exhaust flow is provided over the cylinder valving and all fittings containing the gas, the cylinder gas can be reliably detected by odor at a concentration less than the IDLH, remote shutoff is present, and the experiment is continuously attended while the gas cylinder valve is open or
- Temporary monitoring system is used during gas use, the experiment is continuously attended, and the provision for remote shutoff is present. Examples of temporary single point monitors can be identified by contacting Research Safety at 656-0341.

2.1.3 **Flammable Gases** (non-toxic or corrosive)

Flammable gases include:

- Gases that at ambient temperature and pressure form a flammable mixture with air at a concentration of 13% by volume or less OR wider than 13% by volume, regardless of lower limit (29CFR1200).

These gases shall be monitored by a continuous monitor except when the cylinder contains less than or equal to 10 cubic feet of gas by volume or:

- When contained in a gas cabinet/enclosure with a flow restrictor and exhaust monitor/interlock for gas flow shutdown upon exhaust loss or
- When contained in a gas cabinet/enclosure with a flow restrictor and exhaust ventilation for gas cabinet and tool enclosures is provided with emergency power
- When located outside of gas cabinets but are equipped with flow restrictors and located in labs with sprinkler protection. Any flammable gas cylinders containing greater than 10ft3

of gas must be contained in an exhausted gas cabinet if sprinkler protection is not provided in the lab.

Natural gas plumbed as a "house gas" need not be monitored by continuous monitoring in the lab. It is strongly recommended that flammable gas monitors calibrated for hydrogen respond to 5% of the LEL (warn, see 2.5) and 10% of the LEL (alarm). Flammable gas detectors which respond to very low ppm concentrations of flammable gases are not required nor recommended.

Examples: Hydrogen, Acetylene, Propane

2.1.4 **Pyrophoric Gases**

Pyrophoric gases include:

Gases that shall be monitored by a continuous monitor except when the cylinder gas concentration is below the pyrophoric limit for that gas (for example, 2 % or less silane or disilane).

If the following conditions are met, pyrophoric gases are exempt from monitoring.

- Quantity is limited to 20 grams or less in a lecture bottle or sample cylinder with a flow restricting orifice in the CGA cylinder valve and
- The exhaust is monitored/alarmed or
- Cylinder pressure is less than 15 psig and will be used in a vacuum system which will be used to fully evacuate the cylinder and
- The vacuum exhaust is N2 purged/interlocked

These gases will almost always ignite spontaneously in contact with air at a temperature of 130 degree F (54.4C) or below (29CFR1200).

Examples: Silane, disilane

2.2 **Location of Monitoring Sensors**

Highly toxic gas, toxic gas and pyrophoric gas monitoring requires that sensing ports be located in the gas cabinet and at least each of the following locations:

- In the equipment (where the delivery gas line terminates at the equipment)
- In the lab operator area

Flammable: Monitoring requires at least one sensing point located in the laboratory for cylinders, e.g., monitors are not required for non-toxic flammable gas when the gas is an exhausted enclosure.

2.3 **Continuous Versus Temporary Monitoring System**

A continuous monitoring system is one that is permanently installed and is required to be on-line as long as the gas is in use in the laboratory. It will provide both alarms and safety interlock functions.

A temporary monitoring system is one that may be portable and is used only when the gas system is on-line with the person running the tool. It will only provide an alarm that is visual and audible. In this case, alarm conditions do not result in automatic gas shutdown, therefore the experiment must be continuously attended during gas use and means for remote gas shutdown must be present.

2.4 **Gas Monitoring Responsibility**

The person designated as being responsible for the monitors shall be identified in the Safety Plan. Procedures shall be documented for response to all monitor alarms. Contact names and numbers must be provided for on and off hour response.

2.5 **Gas Alarm Set Points**

When a gas is both toxic and flammable or pyrophoric, the more stringent (sensitive) monitoring requirement shall be used. Both monitors are not required.

Detectors shall provide constant visual detection level readout with the following alarm set points established:

Gas detected in contained/exhausted enclosures	* TLV for 4 seconds * All gases shutdown in lab * Evacuate lab (local alarm)
Gas detected in ambient/breathing air locations	* 1/2 TLV for 4 seconds * All gases shutdown in lab * Evacuate building (building alarm)

- Flammable gases such as H2 should be monitored at 5% LEL
- Alarm condition should be annunciated locally such as with a buzzer or flashing strobe so the laboratory occupant(s) can take corrective action. The time corresponds to the time period the sensor should "see" the target gas before responding.

2.6 **Action Triggered by Monitoring Alarm**

The following items shall be included in the actions taken when a local alarm or building alarm is triggered:

- Gas flow shall be shutoff via a high pressure pneumatically controlled Emergency Shut Off (ESO) valve in the gas cabinet and/or an air actuated cylinder valve and where feasible, in the gas control box of the equipment using the gas
- A visual and audible alarm is activated in the laboratory and at the monitor
- Emergency Response plan is activated per the documented procedure
- Additional actions may be required, e.g., automatic shutdown of recirculating air in clean rooms in the event of a "building alarm."

2.7 **Alarm Annunciation**

- All alarms shall be annunciated locally either visually or audibly within the laboratory. Main lab annunciation panels will be located immediately outside of the lab, permitting personnel to read annunciator displays after exiting the lab.
- Building alarms shall be annunciated in a remote location so emergency response personnel can review the alarm condition without entering the danger zone. Annunciation shall preferably be located near the fire alarm annunciation point. Building alarms may also be annunciated at Clemson Police.
- Information which shall be available to emergency response personnel must include alarm location, set point, gas monitored, and real time concentration.

2.8 **Compatibility Requirements**

- All hazardous gas monitoring systems shall be designed to interface with the building fire alarm system.
- Clemson Fire Alarm System requirements are available through the Design Standards.

3.1 **RESPONSIBILITIES**

3.2 **Management**

The owning manager of the tool/process/experiment requiring gas monitoring per this procedure shall ensure the following areas are addressed:

- Gas usage which requires monitoring according to this procedure shall not commence prior to meeting all applicable elements.
- Procurement of the gas monitor shall be approved by the Office of Research Safety.
- Monitoring operation meets the requirements of this procedure.
- Employees utilizing gases requiring monitoring are trained in the operation of the monitor.

- Monitor calibration is conducted annually or per vendor specifications.
- "Building" alarm conditions are automatically annunciated at Campus Police and a building central monitoring location for ready / safe access by emergency response personnel.
- Report warning and alarm conditions to the Office of Research Safety..
- Final system review by Research Safety prior to start-up.
- Emergency response procedures are documented and all laboratory personnel are fully trained in cooperation with Research Safety.
- Bottle change and equipment purging procedures are fully documented and all personnel are fully trained regarding the procedures.
- Emergency Response Plan/Procedure shall be reviewed and documented with the Research Safety, when required.

3.3 **Facilities Services and Campus Police**

Assure appropriate personnel are knowledgeable about building alarms.

3.4 **Office of Research Safety**

Research Safety is responsible for:

- Providing technical advice and counsel to management and facilities engineering.
- Review with laboratory management the type of monitoring required, temporary or continuous.
- Reviewing design and installation of the monitoring system.
- Conducting periodic audits as appropriate or requested.
- Follow-up investigation of reported alarms.
- Assure appropriate personnel are knowledgeable about building alarms.

4.1 **REFERENCES**

- OSHA 29CFR 1910.1200 Appendix A "Health Hazard Definition"
- OSHA 49CFR 173.326 Poison A
- IBM Corporate Labeling Standard
- "Guide to Safe Handling of Compressed Gases" Matheson, 1983
- Toxic Gas Ordinance, City of San Jose, September 27,1990
- A Model Ordinance for toxic Gas Regulation, Santa Clara County - Fire Chief s Association, November 1988
- The BOCA National Fire Prevention Code/1987, Building Officials &
- Code Administrators International, Inc.
- Uniform Fire Code - Article 80, California Fire Chiefs Association, January 15 1987
- CGS-413-02A Gas group Listing and Definitions IBM EF 1-5-90
- International Fire Code 2012 and NFPA 45
- NC State Gas Monitoring Program, Environmental Health and Safety, 2015
- ANSI/CGA-G-13-2015 (American National Standards Institute/Compressed Gas Association- Storage and Handling of Silane and Silane Mixtures.
- NFPA 1, 2012 Revision