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| **Title:** Gas Monitoring Program**Document #:** EHS-0014 **Issued:** 10/21/2017 |
| **Responsible Dept.:** EHS **Version:** New**Approved By:** Director, Environmental Health & Safety **Page:** 1 of 11 |

**1.0 Purpose:** This program outlines the University’s (except the Hershey Medical Center and the College of Medicine) requirements associated with the design, installation, and communications associated with highly toxic, toxic, flammable, asphyxiants, and/or pyrophoric gas monitoring systems. The intent of the program is to assure standardization of life safety criteria necessary to handle gases covered by these requirements safely. Deviations from this program must be reviewed and approved by the Department of EHS.

**2.0 Scope:** Applies to use of compressed gases covered by University Safety Policy SY25 – Compressed Gas Cylinders, except in situations for short term use of limited quantities (lecture bottles – typically 12-18 inches long and 1-3 inches in diameter) in a chemical fume hood. For the purpose of this program, short term is considered less than 14 calendar days. Additional exclusions may be identified within the document as appropriate for the gas in question.

**3.0 Responsibility:** The following employees have specific responsibilities in accordance with the requirements of this program. Specific Budget Executives and Budget Administrators may assign these responsibilities to a Department or individual other than the one identified in this program as appropriate.

 Budget Executives and Budget Administrators:

1. Maintain a safe work environment within their jurisdiction, by monitoring and exercising control over their assigned areas.
2. Assign a representative from each academic and administrative unit to ensure compliance with the Gas Monitoring program.
3. Monitor compliance to this program associated with identified covered activities.

Director of Design and Construction (OPP):

1. Ensure employees within their area(s) of responsibility are aware of and understand the requirements outlined in this program.
2. Ensure appropriate mechanisms exist to include appropriate gas monitoring systems within the design phase of projects managed through the group.

Facility Coordinators / Safety Officers:

1. Evaluate activities within their area of responsibility, including proposed research against applicability to the Gas Monitoring program requirements.
2. Communicate newly identified activities to the Department of EHS and ensure records associated with this program are provided to EHS.
3. Coordinate program compliance initiatives and opportunities to enhance effectiveness with the Department of EHS requirements.

Principal Investigators:

1. Understand the program requirements and ensure employees within their area(s) of responsibility adhere to the requirements outlined in this program.
2. Develop appropriate Standard Operating Procedures (SOP’s) for proper handling of gases covered by this program including procurement, handling, storage, use and emergency response.
3. Ensure individuals working in their areas understand their responsibilities relating to specific alarm conditions that may be encountered.
4. Immediately notify the Office of Physical Plant or campus Maintenance Supervisor of any operational issues associated with the equipment included within the Gas Monitoring program.
5. Communicate any modifications that impact program requirements within their area(s) to their Facility Coordinator / Safety Officer and the Department of EHS.

Control and Communications Services (OPP):

1. Monitor alarm systems connected through the University Park Building Automation System (BAS) and communicate alarm/trouble conditions to the Work Reception Center
2. Ensure alarm systems are identified correctly and programmed through BAS

Physical Plant / Maintenance Supervisors:

1. Understand the program requirements and ensure employees within their area(s) of responsibility adhere to the requirements outlined in this program.
2. Manage the Preventive Maintenance requirements associated with equipment included within the Gas Monitoring program and maintain all applicable records.
3. Communicate any modifications that impact program requirements to the Building Facility Coordinator / Safety Officer and the Department of EHS.

Work Reception Center (OPP):

1. Maintain the appropriate University Park contact list prepared by the academic or administrative unit and notify designated personnel of alarm conditions in a timely manner.
2. Ensure personnel are familiar with and understand their responsibilities relating to alarm notifications.

Police and Public Safety:

1. Monitor and report alarm conditions to the appropriate responding groups.
2. Maintain appropriate alarm response procedures for areas covered by the Gas Monitoring program.
3. Ensure responding personnel are familiar with and understand their responsibilities relating to alarm conditions that are encountered.

Department of EHS:

1. Oversee and maintain the written Gas Monitoring program for the University.
2. Provide technical advice and counsel to research and facility personnel regarding gas monitoring requirements and emergency response procedures.
3. Review design and installation of gas monitoring equipment.
4. Periodically review program effectiveness, consult with program stakeholders and update the requirements as appropriate.

Employees:

1. Adhere to the requirements of the Gas Monitoring program.
2. Understand responsibilities and actions relating to alarms within their work environment.
3. Communicate any difficulties or challenges relating to program requirements to their immediate supervisor.

Other Individuals:

1. Adhere to University requirements including appropriate response actions as outlined within the Gas Monitoring program.
2. Understand responsibilities and actions relating to alarms while on University property.

**4.0 Definitions:**

*ACGIH –* American Conference of Governmental Industrial Hygienists, scientific organization to advance occupational and environmental health.

*Asphyxiant* – Any material which reduces the amount of available oxygen for respiration, either by simple dilution or by internal physiochemical reaction.

*CGA* – Compressed Gas Association, an organization created to promote ever-improving safe, secure, and environmentally responsible manufacture, transportation, storage, transfilling, and disposal of industrial and medical gases and their containers.

*CGA Fitting* – is the standardized system for the attachment of a compressed gas cylinder to the required regulator or transfer line.

*Continuous Monitoring* – gas detection system where the analytical instrument is maintained in continuous operation and sampling is performed without interruption. Analysis is allowed to be performed on a cyclical basis at intervals not to exceed 30 minutes.

(Ref. – Chapter 18; International Fire Code)

*DOT* – Department of Transportation, federal agency with statutory authority to regulate transportation services.

*Flammable Gas –* A material which is a gas at 68 oF (20 oC) or less at 14.7 pounds per square inch atmosphere (psia) of pressure which:

1. Is ignitable at 14.7 psia when in a mixture of < 13% by volume with air; or
2. Has a flammable range at 14.7 psia with air of at least 12%, regardless of the lower limit

(Ref. – Chapter 35; International Fire Code)

*Gas Cabinet* – an exhausted enclosure that is constructed of materials that are compatible with the hazardous materials stored, self-closing limited access ports, self-closing doors and ventilated to operate at a negative pressure. Note: Due to the technical requirements within the International Fire Code (IFC – Chapters 27/37) associated with design of a gas cabinet based on the type of material to be stored (e.g., average face velocity, sprinkler system, quantities, etc.), gas cabinet selection should be completed with consultation with a Building Operation Engineer or the Department of EHS.

*Highly Toxic Gas* – A gas that includes:

a) A chemical that has a median lethal concentration (LC50) in air of 200 parts per million (ppm) 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.

b) A chemical that has a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

c) A TLV as established by ACGIH or a PEL as established by OSHA, less than or equal to 1 ppm.

d) Designated as a "Toxic – Inhalation Hazard” (poisonous material) 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.

*LC50* - Lethal Concentration 50, Median Lethal Concentration, the calculated concentration of a material in air, which based on laboratory tests (respiratory route), is expected to kill 50% of a group of test animals when administered as a single exposure in a specific time period, usually 1 hour.

*LD50* – Lethal Dose 50, Median Lethal Dose, the amount of a solid or liquid material that, when administered by oral or dermal route, kills 50% of a group of test animals when administered as a single dose, or by continuous dermal contact in a specified time period (typically within 24 hours).

*Lecture Bottle* – A small compressed gas cylinder, typically 12 – 18 inches (~ 300 – 460 mm) long and 1 – 3 inches (~ 25 – 76 mm) in diameter, typically used in laboratories working with small quantities of gases or specialty gases.

*Lower Explosive Limit (LEL) –* The minimum concentration of flammable gas or vapor mixed with air that can be ignited. LEL is typically expressed as a percent of flammable gas or vapor in air.

*OSHA –* Occupational Safety and Health Administration, federal agency with statutory authority to regulate safe and healthful working conditions.

*NIOSH –* The National Institute for Occupational Safety and Health, federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness.

*Permissible Exposure Limit (PEL) –* The Permissible Exposure Limit is the maximum permitted 8-hour time-weighted average concentration of an airborne contaminant established by the Occupational Safety and Health Administration (OSHA).

*Pyrophoric Gas –* Gases that ignite spontaneously in contact with air at a temperature of < 130 0F (54.4 0C).

*Threshold Limit Value (TLV) –* The Threshold Limit Value is an 8-hour time-weighted average concentration of a hazardous chemical that an average person may be exposed to day after day without any adverse effect. TLVs are guidelines established by the American Conference of Governmental Industrial Hygienists (ACGIH).

*Toxic Gas –* A gas that includes:

a) A chemical that has an LC50 in air of more than 200 ppm, but not more than 2000 ppm 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 200-300 g each.

b) A chemical that has a median lethal dose (LD50) of more than 50 milligrams per kilogram, but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

c) A TLV as established by ACGIH or a PEL as established by OSHA, greater than 1 ppm but less than or equal to 50 ppm.

**5.0 Program:** The following program requirements are intended to supplement the Compressed Gas Cylinders Policy (SY25) that outlines the safe and proper handling, storage and use of compressed gas cylinders within the University. This program outlines the necessary elements to provide a suitable gas monitoring system for the specific hazards encountered. The focus within this program is life safety through standardization of monitoring set points, calibration requirements and defined response to alarms. The focus is on portable gas cylinders and utility gas systems are excluded from this program.

 This program is intended to be a component of the broader safe gas handling and storage designs utilized within the University. Depending on the specific gas, research, or equipment configuration (e.g., length of transfer lines, building occupancy considerations, etc.) additional life safety considerations may be required (e.g., separate purge gas for Highly Toxic gas cabinets, Emergency Gas Off buttons in room, transfer line within a secondary line – coaxial vacuum with leak monitoring, etc.).

 **5.1 Gas Classifications**

**5.1.1 Highly Toxic Gases**

Highly Toxic gases shall be monitored by a continuous monitor except when the cylinder 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 value is not available for the chemical and the cylinder concentration is greater than the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL), the department or work unit representative and EHS will determine the need for continuous monitoring.

Highly Toxic gases shall only be used within a gas cabinet or within a similar enclosed direct exhaust air system and a restricted flow orifice (RFO) or similar flow-limiting device.

Gases that would be considered within the Highly Toxic definition include but are not limited to arsine, boron trifluoride, chlorine, chlorine trifluoride, diborane, dichlorosilane, germane, hydrogen fluoride, methyl bromide, nitric oxide, nitrogen dioxide, phosgene, phosphine, and sulfur tetrafluoride.

5.1.1.1 Exempted Cylinders (< 500 cc by volume)

Highly Toxic gases are exempt from continuous monitoring if the gas quantity is limited to less than 500 cc of gas phase by volume in a lecture bottle or sample cylinder if 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 pounds per square inch gauge (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.

**5.1.2 Toxic Gases**

Toxic gases shall be monitored by a continuous monitor except when the cylinder toxic gas concentration (in ppm) is less than the National Institute for Occupational Safety and Health (NIOSH) IDLH level. If an IDLH value is not available for the chemical and the cylinder concentration is greater than the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL), the department or work unit representative and EHS will determine the need for continuous monitoring.

Toxic gases shall only be used within a gas cabinet or within a similar enclosed direct exhaust air system and a restricted flow orifice (RFO) or similar flow-limiting device.

Gases that would be considered within the Toxic definition include but are not limited to ammonia, boron trichloride, boron trifluoride, carbon monoxide, carbonyl sulfide, ethyl chloride, hydrogen bromide, and hydrogen chloride.

 5.1.2.1 Exempted Cylinders (< 100 grams of material)

 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 concentrations less than the IDLH, remote shutoff is present, and the use is continuously attended while the gas cylinder valve is open or
* Temporary monitoring system is used during gas use, the use is continuously attended, and the provision for remote shutoff is present.

**5.1.3 Flammable Gases**

Flammable 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 equipment enclosures is provided with emergency power.

Note – any flammable gas cylinder containing greater than 10 ft3 of gas must be contained in an exhausted gas cabinet if sprinkler protection is not provided in the lab/room

Flammable gas monitoring shall be located in a gas cabinet if applicable. If a flammable gas cylinder is located outside a gas cabinet, it must be equipped with a flow restrictor, located in a lab/room with sprinkler protection and at least one room detector shall be located factoring in the cylinder storage and use arrangements for the space in question.

Gases that would be considered within the Flammable definition include but are not limited to acetylene, hydrogen, and propane.

Note – pursuant to University Safety Policy SY25 – Compressed Gas Cylinders, propane used for cooking or for forklift applications are excluded from this program

**5.1.4 Pyrophoric Gases**

Pyrophoric gases shall be monitored by a continuous monitor except when the cylinder gas concentration is below the pyrophoric limit for that gas (e.g. < 2% disilane or silane). These gases will almost always ignite spontaneously in contact with air at a temperature of 130 oF (54.4 oC) or below (reference 29 CFR1200).

Pyrophoric gases shall only be used within a gas cabinet or within a similar enclosed direct exhaust air system.

Gases that would be considered within the pyrophoric definition include but not limited to disilane or silane.

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 and the exhaust is monitored/alarmed or

● Cylinder pressure is < 15 psig and will be used in a vacuum system which will be used to fully evacuate the cylinder and the vacuum exhaust is nitrogen purged/interlocked.

**5.1.5 Gases contributing to Oxygen Deficient Atmospheres**

Gases that can reduce the amount of available oxygen for respiration, both by simple dilution or by internal physiochemical reaction, are included in this section and can also be referenced as asphyxiants.

All labs/rooms handling or storing inert gases shall have continuous room ventilation and areas that are handling a large number of cylinders in series (e.g. > 3), should evaluate and document that the size and ventilation within the space is sufficient to maintain the oxygen content > 19.5% during a catastrophic cylinder failure event (contents of all cylinders lost within 15 minutes). If there is a risk of oxygen deficient atmosphere the area shall be monitored by a continuous oxygen monitor.

For cryogenic materials including liquid nitrogen and helium continuous oxygen monitoring shall be used if the evaluation of a spill during filling can deplete the oxygen content in the space below 19.5% oxygen using the following formula:

**Coxygen = 100 x Voxygen / Vroom**

Voxygen = calculated below, and

Vroom = the room volume in cubic meters (m3)

 *Note: 1 cubic foot (1f3) = 0.028 m3*

Voxygen (m3) = 0.21 [Vroom − (1.1 x Vvessel x GEF x 10-3)]

Vvessel = the vessel’s capacity in liters

GEF = gas expansion factor from liquid (e.g.

nitrogen; 1 liter of liquid nitrogen produces

about 710 liters of nitrogen gas)

1.1 = 110% or 10% filling loss + 100% loss of the

 vessel’s contents by spillage

Additional guidance on handling cryogenic materials can be obtained through the EHS webpage and the Liquid Nitrogen & Cryogenic Materials – Storage, Use, Handling, Transportation and Disposal (*EHS-0015*).

**5.2 Location of Monitoring Detectors**

Highly Toxic, Toxic and Pyrophoric gas monitoring shall have the appropriate sensing detectors located in the gas cabinet and at least at each of the following locations:

● As close as possible to the equipment, where the delivery gas line terminates at the equipment. Consideration should be given depending on the size of equipment in use if the detector can/should be located within the equipment

● In the employee occupied area(s).

Flammable gas monitoring shall be located in a gas cabinet if applicable. If located outside a gas cabinet, it must be equipped with a flow restrictor, located in a lab/room with sprinkler protection and at least one detector shall be located factoring in the cylinder storage and use arrangements for the space in question.

When a gas is both toxic and flammable or toxic and pyrophoric, the more stringent (sensitive) monitoring requirement shall be used.

**5.3 Gas Alarm Set Points**

Detectors should provide a constant visual detection level readout whenever possible with the following alarm set points:

● Gas cabinet and exhausted enclosures should alarm at ½ TLV for 4 seconds

● Gas detected in ambient/breathing air locations should alarm at ½ TLV for 4 seconds

● Flammable gases should be monitored at 5% LEL

Secondary alarm set points can be used above the initial levels identified above and can take additional action appropriate for the area (e.g. additional equipment shutdown, building wide notification, etc.). Where secondary alarm set points are used, a clear listing of the actions associated with activation will be included in the areas procedures.

**5.4 Alarm Annunciation**

All alarms shall be equipped with a visual and audible alarm within the lab/room and where multiple gases are in use a method to determine the leaking cabinet or gas system. A remote monitoring panel should also be available to enable emergency response personnel to review alarm conditions without entering a potentially dangerous area. This remote monitoring panel can be centrally located for the building or placed in close proximity to areas handling Highly Toxic gases.

Alarm information which shall be available to emergency response personnel, including at the Police and Public Safety remote location, must include alarm location (e.g., room, area within lab, etc.), alarm set point, gas monitored and concentrations being reported through the detector.

During the design phase of new areas handling gases covered by this program, gas detection alarms may be tied directly into the building evacuation system.

 **5.5 Alarm Monitoring and Reporting**

Continuous monitoring systems shall be on-line as long as the gas is in use within the space and monitored 24/7, at a minimum, through Police and Public Safety personnel. All systems require an Emergency Notification Call list to be available by the monitoring personnel to report all alarm notifications.

If the alarm system is tied directly into the University’s Building Automation System (BAS), additional alarm monitoring capabilities exist including automatic notifications through the alarm text messaging protocol. If additional remote monitoring services are utilized, all monitoring groups shall have specific procedures to follow when an alarm is activated including an Emergency Notification Call list.

**5.6 Actions Triggered by Alarms**

The following actions are required to occur and be included within the response procedures when a gas monitoring alarm is triggered:

● A visual (recommended that a blue light is used for Gas Alarms) and audible alarm is activated in the lab/room and the area evacuated. Note: signage describing the alarm shall be posted

● Gas flow shall be automatically shut-off at the cylinder and where feasible at the equipment using the gas

● For alarms triggered in the ambient/employee occupied areas of the lab/room consideration for complete building evacuation should be assessed

● Emergency Notification Call list is activated with appropriate response procedures predefined

● Additional actions should be considered during design including automatic shutdown of recirculating air in clean rooms, increasing direct exhaust air systems (e.g. fume hoods, etc.), building wide notifications, etc.

Depending on the specific application the additional actions should be evaluated with the assistance of the EHS as appropriate.

 **5.7 Maintenance and Calibration**

All detectors required by this program will be on a defined maintenance and calibration schedule. The calibration frequency will be established by the equipment manufacturer and monitored through the University’s asset management program. Where appropriate a more frequent calibration schedule can be established. The actual maintenance and calibration of detectors can be conducted through the Office of Physical Plant or a contracted 3rd party. All records associated with calibration will be retained at a minimum while the covered gases are being used within the area.

Maintenance or inspection of other components of the Gas Monitoring system should also be evaluated periodically to verify proper operation. These can include audio/visual indicators, connection to building evacuation systems, safety interlocks and communications to the remote monitoring group(s). All records associated with testing/inspecting these components will be retained at a minimum while the covered gases are being used within the area.

During routine maintenance a system failure associated with the gas monitoring system may be identified. Depending on the type of failure, further investigation may be warranted to assess potential actions to prevent a similar occurrence.

Each area should have robust procedures for maintenance and testing/inspecting equipment covered by this program. It is important that the gas monitoring systems are placed back into service if they are temporarily disabled during these activities. In addition, if problems are identified with the monitoring system, specific steps need to be implemented to continue to maintain gas detection or the use of the gas shall be stopped until the monitoring system can be brought back online.

1. **Relationship to other University Programs and Regulating Agencies**

6.1 NFPA 55 – Compressed Gases and Cryogenic Fluids Code

 6.2 NFPA 318 – Protection of Semiconductor Fabrication Facilities

 6.3 EHS-0004 – Laboratory & Research Safety Plan

6.4 EHS-0015 – Liquid Nitrogen & Cryogenic Materials – Storage, Use, Handling, Transportation and Disposal

 6.5 SY25 – Compressed Gas Cylinders

 6.6 EHS-0013 – Refrigerant Management Program

 6.7 International Fire Code

1. **Attachments**

N/A

**8.0 Revision Tracking**

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