



Department of Environmental Health and Safety & Emergency Management

Subject: Research Use of Toxic, Flammable or Pyrophoric Gases

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SUMMARY:

The use of hazardous gases on the University of Michigan – Dearborn campus has increased with growing research, especially in the areas of high-energy laser technology and other laboratory work. Individuals working with toxic, flammable or pyrophoric gases must be aware of potential hazards associated with them, and must be trained and proficient in methods to work with the gases in a safe manner. This is essential to safeguard both the individual as well as surrounding facility areas. A release of the gas can easily impact an entire facility as it is carried through the ventilation systems.

SCOPE:

This Guideline applies to all UM-Dearborn researchers and employees who use a hazardous production material (HPM) gas that is toxic, flammable or pyrophoric. This Guideline does not apply to the use of liquefied (cryogenic) gases. EHSEM may grant exemptions to small-scale operations or low concentrations of HPM gas. Contact EHSEM for an evaluation.

REFERENCE

REGULATIONS:

Control of Hazardous Energy (Lockout/Tagout)([MIOSHA Part 85](#))
Hazard Communication ([MIOSHA Part 430](#))
Hazardous Work in Laboratories ([MIOSHA Part 431](#))
Personal Protective Equipment ([MIOSHA Part 433](#))
International Building Code
International Fire Code
NFPA 45 – Standard on Fire Protection for Laboratories Using Chemicals
NFPA 50A – Standard for Gaseous Hydrogen Systems at Consumer Sites
Factory Mutual 7-7, 17-12 (Semiconductor Fabrication Facilities)
Extremely Hazardous Substances List and Threshold Planning (EPA 40 CFR Part 355)

DEFINITIONS:

Buddy system – an administrative control requiring the presence of two trained persons when work of a potentially hazardous nature is being performed. All gas systems work is considered potentially hazardous.

Continuous gas monitoring system (GMS) – uninterrupted monitoring, occurring in real-time, with associated alarms.



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Cryogenic liquid – a cryogenic liquid is a liquid having a boiling point colder than $-150^{\circ}\text{Fahrenheit}$ (-65.5°C) at 14.7 psia (101.325 kPa).

Decontamination – the removal of materials in or on equipment, people, or personal protective equipment.

EMO – emergency off button.

Exhaust treatment devices – systems designed to remove specific toxic particles and gases from an exhaust stream. These include but are not limited to scrubbers, charcoal traps and burn boxes.

Flammable gas – a gas is considered flammable when either a mixture of 13 percent or less (by volume) with air forms a flammable mixture or the flammable range with air is wider than 12 percent regardless of the lower limit. The limits shall be determined at atmospheric temperature and pressure.

Gas cabinet – cabinet used to house and contain gas cylinders, and connected to gas distribution piping or to equipment using the gas.

Gas delivery system – the system made up of a gas source, gas panel, piping and all associated valves and safeguards.

Gas panel – an arrangement of gas handling components (e.g., valves, filters, mass flow controllers) that regulates the flow of gas into the process.

Gas panel enclosure – an enclosure designed to contain leaks from gas panel(s) within itself.

Hazardous Production Material (HPM) – a solid, liquid, or gas that has a degree of hazard rating in health, flammability, or reactivity of class 3 or 4 as ranked by NFPA 704 and which is used directly in research, laboratory, or production processes that have as their end product materials that are not hazardous.

High Efficiency Particulate Air (HEPA) – refers to an air filter that must be 99.97% efficient (i.e. a maximum of three particles of 0.3



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micron aerodynamic diameter can pass for every ten thousand particles fed to the filter).

Just in time delivery (JIT) – refers to the practice of having gases delivered as they are needed rather than storing gases on site.

Local exhaust ventilation (LEV) – a ventilation system that captures air contaminants at their point of origin and moves the air to the external environment.

Personal protective equipment (PPE) – devices worn by workers to protect against hazards in the environment. Examples include gloves, safety glasses, face shields, respirators, hard hats, steel-toed shoes and hearing protection.

Pyrophoric material – a chemical that will spontaneously ignite in air at or below a temperature of 54.4°C (130°F).

Restrictive flow orifice – a flow-limiting device inserted in the cylinder valve by the gas vendor to control excess flow in an unrestricted gas release.

Standard Operating Procedure (SOP) - the technical requirements necessary to complete laboratory procedures and actions safely. Once developed, SOPs are documented and implemented in the workplace and used for training purposes.

Threshold Limit Value® (TLV®) - TLVs® refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.

TLV-TWA – Threshold limit value as an 8-hour time-weighted average.

RESPONSIBILITY:

Deans, Directors, and Department Heads

Ensure compliance with this Guideline by supporting the proper design, purchase, and installation of equipment, ongoing maintenance, and training of staff.



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Principal Investigators

Ensure that a comprehensive plan for the design, installation and maintenance of the gas delivery and continuous gas monitoring systems (GMS) is drawn up prior to bringing the gas on site.

Assume the responsibility for installation, operation, maintenance and training for the gas delivery and GMS systems.

Identify proper storage locations for gas bottles unless using a just in time delivery system.

Develop SOPs for routine tasks, maintenance and decontamination procedures on each gas delivery and GMS, and for any specialized exhaust treatment systems. This includes incorporating emergency response procedures to address the potential for fire and liberation of toxic gases.

Ensure that their research staff is trained on the SOPs and able to safely operate each gas owned or used by the lab. Ensure written records of training are maintained for review by EHSEM or other investigators following an adverse event.

Ensure that all engineering controls are in place and operational prior to commencing research operations involving use of the gas (EHSEM prior approval contingency).

Maintain as built drawings of the gas delivery, GMS and exhaust treatment equipment installation for future reference and updating as modifications occur.

Research Staff

Be knowledgeable and familiar with each gas used in the lab.

Perform only those functions for which they have been trained.

Be able to implement emergency response procedures associated with the use of the gas.



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Properly use all safety equipment and follow safety procedures.

EHSEM

Review and revise this Guideline as necessary.

Assist in reviewing the design and installation of the gas delivery and GMS and in the development and review of SOPs.

Advise Principal Investigator in matters of safety including precautions to be taken when handling chemicals associated with use of the gas, requirements for safety equipment and monitoring.

Provide inspections and exposure monitoring as needed. This includes initial startup and periodically thereafter as dictated by findings and available industrial hygiene evaluations of the equipment or processes.

PROCEDURES:

I. Design & Installation

Contact the appropriate University departments (Facilities Planning, Facilities Management, and EHSEM) early in the planning and design phase to ensure tie in to building utilities and other construction and installation aspects are carried out in accordance with University standards.

At a minimum, design of safety systems must comply with the International Building Code (IBC) and International Fire Code (IFC), which have been adopted by the University. For additional guidance on safety systems, see NFPA Standard 45 and NFPA 55, Mechanical Code and Michigan Building Code.

II. Safety Systems

All researchers using HPM gases must address the following safety features prior to bringing the gases on site:



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1. Quantity of HPM

HPM in use or in storage must not exceed the quantities listed in IBC and IFC. Quantities must also stay below 10% of the Threshold Planning Quantities as listed by the Environmental Protection Agency, 40 CFR Part 355. Quantities must be kept to the minimum necessary for normal operation of the lab. This will usually mean one cylinder of an appropriate size in use to allow for change out of the cylinder once or twice per year (change out is a high risk task, requiring use of the buddy system). Just in time (JIT) delivery is preferred over storage of a backup cylinder on site.

2. Containment and delivery of HPM gas

All HPM gases must be delivered through continuous, orbitally welded, coaxial tubing that is of a material compatible with the gas. Only employees who are specifically trained and qualified to perform orbital welding on coaxial tubing may do so. Hydrogen, methane and fluorine, though HPM gases, can be delivered in single wall stainless steel tubing provided all mechanical connections are inside exhausted enclosures equipped with GMS. No mechanical connections exposed to the process gas stream are to be outside of exhausted enclosures equipped with GMS.

All HPM gases in use and in storage must be kept in locally exhausted gas cabinets or in suitable gas storage bunkers. Each of the storage locations must also have provisions for actively monitoring the ambient environment and exhaust to detect for the gases stored. This provision must provide for both local and remote alarm annunciation in the event there is a gas leak. This annunciation may also be required to be tied into a building type alarm (facility dependent).



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Restrictive flow orifices, where appropriate, must be used to preclude massive releases in the event of a catastrophic failure.

Follow all requirements of the IBC and IFC pertaining to gas delivery systems and any other applicable codes.

3. Continuous gas monitoring system (GMS)

Areas where HPM gases are used and stored must be equipped with continuous GMS applicable to the material(s) in use with remote readout capability. The GMS must be designed according to IBC, IFC and any other applicable codes.

4. Fire Detection & Suppression

The fire detection system that includes detectors, alarms and their associated controls should be installed and certified in accordance with all applicable fire and University standards. The system should be capable of interfacing with the facility's alarm system and the University's system at the Department of Public Safety.

All aspects of the fire detection and suppression system must meet the requirements of the IFC and other applicable codes.

5. Ventilation

Local exhaust ventilation must be available in the lab to capture and remove contaminants at the source. This includes but is not limited to gas cabinets for cylinders, gas panel enclosures and snorkel exhaust for chamber openings and pump exhaust, and exhaust treatment devices for pyrophoric and corrosive gases. Ventilation systems must meet all University standards and the IBC, IFC and the International Mechanical Code and must be reviewed by Facilities Management, Facilities Planning, and EHSEM.



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The exhaust system for removal of HPM gases must be a dedicated system. Prior to installation, contact EHSEM for review of all effluent waste treatment systems and other environmental compliance issues.

6. Emergency Safeguards and Procedures

The gas delivery system, and other high hazard processes that could potentially produce an uncontrolled emergency release of HPM, must be capable of automatic and remotely activated emergency shutdown, as per IBC and IFC. The EMO actuator should be readily accessible along the emergency egress path from the room or facility, and its activation should place all equipment in a safe mode. Activation of the EMO should not affect fire, gas monitoring or safety systems. See IBC and IFC for further details.

All safety systems including ventilation, GMS, fire protection, EMOs, and suppression must have emergency backup power capable of supporting the system for 24 hours or be integrated into an Uninterrupted Power Supply system.

The EMO system, GMS and fire detection should be tied into the facilities emergency notification system. A written Emergency Response Plan specific to the lab must be developed. The Plan must be integrated with the UM-Dearborn Contingency Plans and coordinate with other University emergency response units such as DPS and EHSEM as well as outside response agencies where appropriate. The department or PI will coordinate with EHSEM and DPS in ensuring that adequate staff for emergencies is trained, equipped and available to assist in emergency response operations in the lab. EHSEM will assist in the development, review and maintenance of this plan.

II. Standard Operating Procedures



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All researchers using HPM gases must develop and implement standard operating procedures (SOPs) for normal operation and maintenance. This includes incorporation of emergency procedures to address personal exposure as well as the potential for fire and release or generation of toxic gases. The SOPs need to be reviewed and/or updated at least annually.

SOPs must include the following information on routine tasks, as well as appropriate maintenance and decontamination methods to enable safe operation and maintenance of the gas delivery, containment and detection systems:

1. A list of all personnel authorized to perform gas bottle changes, and a description of the access requirements to the gas storage/delivery area.
2. A description of any safety measures provided in and associated with the gas (i.e., safety interlocks, restrictive flow orifices on gas bottles, emergency off (EMO) circuits, local exhaust ventilation).
3. An explanation of any hazard alerts including but not limited to visual alerts, auditory alarms, status indicators, and hazard alert systems integral with the equipment's operating system.
4. Specific instructions for routine operation of the gas delivery, containment and GMS systems.
5. Hazardous energy control procedures for any source of electrical, chemical, thermal or mechanical energy, radiation and compressed air or liquid energy that exists in the gas delivery, containment and GMS systems. Refer to the EHSEM Guideline on Lockout/Tagout (http://www.umd.umich.edu/fileadmin/env-health-safety/public/files/UMD_Lockout_rev_2010-1.pdf).
6. The hazards associated with each gas, the personal protective equipment required to prevent exposure, and



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emergency procedures to follow in the event of exposure or release of a chemical. When listing necessary PPE, be as specific as possible (i.e., butyl rubber gloves as opposed to “gloves”). Attaching the Material Safety Data Sheets for each gas to the SOP is ideal.

7. Waste handling procedures as applicable
8. Procedures for ordering, receiving, inspecting, transporting, storing and changing the gas bottles. Procedures for when and how DPS will be notified. A description of when and how leak check procedures will be performed must also be included. A gas cylinder change checklist and use of the buddy system for cylinder change outs are highly recommended. Laboratories should arrange for JIT delivery of gases to minimize the quantities stored on site.
9. Emergency and decontamination procedures in the event of toxic or flammable/pyrophoric gas release, fire, or personal exposure.
10. A description of the training and qualification requirements for each person who will use or work on the gas delivery and GMS systems.
11. Maintenance and calibration procedures for GMS equipment.
12. Maintenance procedures for any specialized exhaust treatment systems.

III. Routine Tasks, Maintenance and Decontamination procedures

1. If applicable, ensure the lockout/tagout procedure has been followed.
2. Prior to beginning work, ensure that all necessary PPE is available, and then used as necessary during the work.



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3. Pumping and purging of gas lines may not always remove all toxic material. Use local exhaust ventilation (LEV) whenever possible to capture and remove any airborne particulate or gas that may be released. LEV must remain in operation during maintenance and decontamination procedures unless alternate exhaust provisions have been arranged. If it is not possible to use LEV, respiratory protection must be used.
4. While disconnecting equipment or removing components, gas monitoring at the source for toxic gases must be performed.
5. Any surface potentially contaminated with toxic solids must be thoroughly wiped down with water. Specify how this waste will be collected for eventual disposal by EHSEM.

IV. Training

Training will include:

1. Information on the physical and chemical hazards associated with the gases.
2. A review of all established SOPs pertaining to use and maintenance of the gas delivery, containment and GMS systems, and any specialized exhaust treatment systems.
3. Access requirements for those personnel authorized to change the gas bottles.
4. A review of emergency procedures.

RELATED DOCUMENTS:

SEMI S12-0298 *Guidelines for Equipment Decontamination*
SEMI S2-200 *Environmental, Health & Safety Guideline for*



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Semiconductor Manufacturing Equipment
[Hazard Communication Program](#)
[Personal Protective Equipment, General](#)
[Lock-out/Tag-out – Control of Hazardous Energy Sources](#)

TECHNICAL SUPPORT:

All referenced guidelines and regulations are available through EHSEM (3-4914).

[Additional Requirements for Toxic, Pyrophoric and Flammable Gases](#)

[Evaluating Flammable and Toxic Compressed Gases in Laboratories](#)

[Hazards of Common Compressed Gases](#)

[Maximum Allowable Quantities](#)

[Generic Compressed Gas SOP Template](#)