Guideline for Evaluating Flammable and Toxic Compressed Gases in Laboratories

Introduction:

This Guideline was developed by the University of Michigan Ann Arbor campus. This guide was adopted by reference at the University of Michigan-Dearborn campus. The University of Michigan – Dearborn's Environmental Health and Safety & Emergency Management (EHSEM) office shall be contacted for questions pertaining to this guideline. EHSEM will work in conjunction with OSEH as needed.

Background:

Flammable and toxic compressed gas inventories in laboratories are regulated by both the NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals and the International Fire Code. This guideline is meant to be used both by University researchers, EHSEM, and OSEH staff in evaluating existing laboratories, and by OSEH Fire Safety and Laboratory Safety staff in evaluating plans submitted for laboratory construction or renovation.

This guideline deals only with the quantities of flammable and toxic or highly toxic gas that are allowed in laboratories. Once quantities have been reduced (if necessary) to fall within these limits, other factors must also be evaluated. These factors include the proper construction and function of exhaust systems, gas cabinets, exhausted enclosures, gas rooms, and the construction and arrangement of manifolds, piping systems, and valves. Both NFPA 45 and the International Fire Code contain specific requirements regarding these safety features. OSEH Industrial Hygiene, Biological and Laboratory Safety, and Fire Safety can assist in evaluating the appropriateness of existing systems, and the potential need for additional equipment or upgrades to existing equipment and systems.

The State of Michigan Bureau of Fire Services uses the 1996 edition of NFPA 45 for laboratories located in buildings containing classrooms, and the 2004 edition of NFPA 45, along with the 2005 edition of NFPA 99 (Standard for Health Care Facilities) for laboratories located within State-regulated health care occupancies. In addition to the State regulations, the University independently requires all newly constructed laboratories, and renovations of existing laboratories, to comply with the 2004 edition of NFPA 45. The process outlined in this document is based on the 2004 edition of NFPA 45, along with the 2006 editions of the Michigan Building Code and the International Fire Code, as adopted by the University. In general, laboratories that comply with the 2004 edition of NFPA 45 will also be in compliance with the 1996 edition, but A/E's working on projects in State-regulated classroom facilities should consult both documents. NFPA 99 requirements are not covered by this guideline, but A/E's working on laboratory projects in health care facilities must be aware of, and follow, all NFPA 99 requirements.

1. Determine the boundaries of the area to be evaluated.

The first step in conducting an evaluation is to define the boundaries of the area to be evaluated.

NFPA 45, the International Fire Code (IFC), and the Michigan Building Code (MBC) use different terms and definitions when determining the boundaries of a laboratory. In general, NFPA 45 limits on compressed gases are based on the boundaries of a "laboratory unit" or of a "laboratory work area." The IFC and MBC limits are based on the boundaries of a "control area."

NFPA 45 defines a "**laboratory unit**" as: *An enclosed space used for experiments or tests. A laboratory unit can include offices, lavatories, and other incidental contiguous rooms maintained for or used by laboratory personnel, and corridors within the unit. It can contain one or more separate laboratory work areas. It can be an entire building.*

NFPA 45 defines a "**laboratory work area**" as: *A room or space for testing, analysis, research, instruction, or similar activities that involve the use of chemicals.*

In most cases, "laboratory work areas" will simply be rooms, with the boundaries defined by the walls and doors separating the room from other rooms, corridors, etc. However, for large, open-plan labs, individual benches or alcoves may be considered separate "laboratory works areas."

As noted in the definition, a "laboratory unit" may include offices and other spaces that are contiguous to the actual laboratory work space. Offices and workrooms that open directly into a larger laboratory, as well as laboratory service corridors, will generally be considered part of the same "laboratory unit." Public corridors that lead from a building entrance to a laboratory will generally NOT be considered part of the "laboratory unit," and adjacent, separate laboratories occupied by different groups of researchers will generally be considered as distinct "laboratory units." Depending on the amounts and types of flammable chemicals being used in the laboratory unit, NFPA 45 may also require 1 or 2 hour fire-resistance-rated construction to separate the laboratory unit from adjacent spaces, and the presence or absence of such fire-resistance-rated construction may assist in determining the boundaries of existing laboratory units. If the boundaries of a laboratory unit are in question, EHSEM can assist in evaluating the space. However, in most cases, the determination will be relatively straightforward.

The IFC and MBC define "**control areas**" as: *Spaces within a building where quantities of hazardous materials not exceeding the maximum allowable quantities per control area are stored, dispensed, used or handled." Section 2703.8.3.1 further requires that "Control areas shall be separated from each other by fire barriers constructed in accordance with Section 706 of the Michigan Building Code or horizontal assemblies constructed in accordance with Section 711 of the Michigan Building Code, or both.*

In many cases, "control areas," as defined by the IFC and MBC, will be the same as "laboratory units," as defined by NFPA 45. However, in some cases, a "control area" may include more than one "laboratory unit." EHSEM can assist in determining the boundaries of a control area in an existing building, if there are questions about the locations of fire-resistance-rated features of building construction.

Based on the definitions presented above, complete the following table:

Building Name:		UM-Dearborn Building:	
Control Area Room Number(s):		Control Area Square Feet:	
Laboratory Unit Room Number(s):		Laboratory Unit Square Feet:	
Laboratory Work Area Room Number:		Laboratory Work Area Square Feet:	
Laboratory Work Area Room Number:		Laboratory Work Area Square Feet:	
Laboratory Work Area Room Number:		Laboratory Work Area Square Feet:	
Laboratory Work Area Room Number:		Laboratory Work Area Square Feet:	
Laboratory Work Area Room Number:		Laboratory Work Area Square Feet:	

2. Inventory the gases in the control area being evaluated, including cylinders in use, and cylinders in storage.

The inventory should include the type of gas in each cylinder, the quantity of gas in each cylinder (in cubic feet at normal temperature and pressure), the internal volume of each cylinder (in standard cubic feet – water volume), along with the Material Safety Data Sheet (MSDS) for each gas. MSDS information should include the NFPA hazard classifications (fire, health, and reactivity) along with the information necessary to determine if the gas should be classified as "toxic" or "highly toxic" in accordance with the International Fire Code. Complete the following table, referring to the definitions printed below the table when necessary:

Type of Gas (Chemical Name or Formula)	Number of cylinders in use	Number of spare cylinders	Cylinder Capacity (cubic feet of gas at NTP)	Internal Cylinder Capacity (standard cubic feet – water volume)	Flammable Gas, Liquefied Flammable Gas, Oxidizing Gas, or Other	Toxic or Highly Toxic	NFPA 704 Fire Hazard Classification	NFPA 704 Health Hazard Classification	NFPA 704 Reactivity Hazard Classification

The International Fire Code (Section 3502.1) defines a **flammable gas** as:

A material which is a gas at 68°F or less at 14.7 pounds per square inch atmosphere of pressure [a material that has a boiling point of 68°F or less at 14.7 psia which:

> *1. Is ignitable at 14.7 psia when in a mixture of 13 percent or less by volume with air; or*
>
> *2. Has a flammable range at 17.4 psia with air of at least 12 percent, regardless of the lower limit.*
>
> *The limits specified shall be determined at 14.7 psi of pressure and a temperature of 68°F in accordance with ASTM E 681.*

A **liquefied flammable gas** is defined as:

> *A liquefied compressed gas which, under a charged pressure, is partially liquid at a temperature of 68°F and which is flammable.*
>
> Note: NFPA 45 also provides a definition for "flammable gas," but it is less specific than the definition found in the International Fire Code. The IFC definition should be used for the purpose of completing this evaluation.

The International Fire Code (Section 3702.1) defines "**toxic**" and "**highly toxic**" gases as follows:

> ***Toxic**. A chemical that has a median lethal concentration (LC_{50}) in air of more than 200 parts per million but not more than 2000 parts per million by volume of gas, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each.*

***Highly Toxic**. A chemical that has a median lethal concentration (LC_{50}) in air of 200 parts per million by volume or less of gas, when administered by continuous inhalation for one hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each.*

3. Determine if the quantity of gas and the number of cylinders falls within the limits imposed by NFPA 45.

a. NFPA 45 (Chapter 11) contains a basic requirement that any cylinders not necessary for current laboratory requirements be stored outside the laboratory. Any unnecessary cylinders should be identified and removed from the laboratory. Cylinders removed from the laboratory should be stored in a designated, safe location. If no safe location has been identified, EHSEM should be contacted to remove the cylinder(s).

b. NFPA 45 (Chapter 11) requires that cylinders of pyrophoric gas, and gases with an NFPA Health Hazard rating of 3 or 4, or a Health Hazard rating of 2 without physiological warning properties be protected as follows:

i. Lecture bottle-sized cylinders must be kept in a continuously mechanically ventilated hood or other continuously mechanically ventilated enclosure.

ii. For gases with a Health Hazard rating of 3 or 4 (or 2 without physiological warning properties): cylinders larger than lecture bottle-size must be stored in approved continuously ventilated gas cabinets.

iii. For pyrophoric gas cylinders larger than lecture bottle-size, approved continuously mechanically ventilated gas cabinets equipped with automatic sprinkler protection (within the cabinet) are required.

Confirm that gas cylinders are protected as required above. If gas cylinders are not protected appropriately, they must be removed from the laboratory, or appropriate protection must be installed.

c. NFPA 45 (Chapter 11) allows only cylinders that are “in use” to be located within a laboratory unit. Any cylinders that are not “in use” must be removed from the laboratory. “In use” is defined as meeting at least one of the following three conditions:

i. Connected through a regulator to deliver gas to a laboratory operation.

ii. Connected to a manifold being used to deliver gas to a laboratory operation.

iii. A single cylinder secured alongside a cylinder connected through a regulator to deliver gas to a laboratory operation, to serve as a reserve cylinder.

d. NFPA 45 (Chapter 11) establishes the following absolute limits for the quantities of different types of gases in each laboratory work area. The limits for instructional laboratories are less than the limits for research laboratories. The table on the next page presents the limits for flammable gases, liquefied flammable gases, oxidizing gases, and Health Hazard Rating 3 or 4 gases. Complete the worksheets that appear below the table in order to determine if the work area falls within the limits. **In addition to the limits in the table, there must be no more than 25 lecture bottle-size cylinders (combined) of all of these types of gases.**

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NFPA 45 Quantity Limits for Gases in Laboratory Work Areas

	Research Laboratory Work Area Less Than 500 Square Feet in Size	Research Laboratory Work Area Greater Than 500 Square Feet in Size	Instructional Laboratory
Flammable Gas	Maximum internal cylinder volume of 6 standard cubic feet	Maximum internal cylinder volume of 0.012 standard cubic feet per square foot of laboratory work area	Maximum internal cylinder volume of 6 standard cubic feet
Liquefied Flammable Gas	Maximum internal cylinder volume of 1.2 standard cubic feet	Maximum internal cylinder volume of 0.0018 standard cubic feet per square foot of laboratory work area	Maximum internal cylinder volume of 1.2 standard cubic feet
Oxidizing Gas	Maximum internal cylinder volume of 6 standard cubic feet	Maximum internal cylinder volume of 0.012 standard cubic feet per square foot of laboratory work area	Maximum internal cylinder volume of 6 standard cubic feet
Health Hazard Rating 3 or 4 Gas	Maximum internal cylinder volume of 0.3 standard cubic feet	Maximum internal cylinder volume of 0.0006 standard cubic feet per square foot of laboratory work area	Maximum internal cylinder volume of 0.3 standard cubic feet **Or** 10 lecture bottle-size cylinders

Flammable Gas Worksheet

Type of Laboratory (Research or Instructional)	Laboratory Work Area Room Number	Laboratory Work Area Total Square Feet	Maximum Internal Cylinder Volume Allowed per NFPA 45

Type of Gas	Total Internal Cylinder Volume for this Gas

Total Internal Cylinder Volume for All Flammable Gas in this Laboratory Work Area	

Liquefied Flammable Gas Worksheet

Note regarding liquefied petroleum gas (propane): MIOSHA General Industry Safety Standards [Part 56. Storage and Handling of Liquefied Petroleum Gases, Section (c)(5)(ii),(iii), and (vi)(c)] also regulate propane cylinders used inside of buildings. The MIOSHA standard generally allows 2 ½ pound containers of propane when used as part of approved self-contained hand torch assemblies. The standard limits containers used for classroom demonstrations to 5 pounds (LP-gas capacity), and to 100 pounds (LP-gas capacity) for containers used in industrial occupancies for processing, research, or experimental purposes. MIOSHA also requires that quantities of propane kept in buildings for research or experimental use to be limited to "the smallest practical quantity." Laboratories must comply with both the MIOSHA requirements and the limits set by NFPA 45 and the International Fire Code. When the quantities and/or cylinder sizes allowed by the various standards differ, the standard allowing the smallest quantity and/or cylinder size must be followed.

Type of Laboratory (Research or Instructional)	Laboratory Work Area Room Number	Laboratory Work Area Total Square Feet	Maximum Internal Cylinder Volume Allowed per NFPA 45

Type of Gas	Total Internal Cylinder Volume for this Gas

Total Internal Cylinder Volume for All Liquefied Flammable Gas in this Laboratory Work Area	

Oxidizing Gas Worksheet

Type of Laboratory (Research or Instructional)	Laboratory Work Area Room Number	Laboratory Work Area Total Square Feet	Maximum Internal Cylinder Volume Allowed per NFPA 45

Type of Gas	Total Internal Cylinder Volume for this Gas

Total Internal Cylinder Volume for All Oxidizing Gas in this Laboratory Work Area	

Health Hazard Rating 3 or 4 Gas Worksheet

Type of Laboratory (Research or Instructional)	Laboratory Work Area Room Number	Laboratory Work Area Total Square Feet	Maximum Internal Cylinder Volume Allowed per NFPA 45

Type of Gas	Total Internal Cylinder Volume for this Gas

Total Internal Cylinder Volume for All Health Hazard 3 and 4 Gases in this Laboratory Work Area	

4. After reducing the quantity of gas (if necessary) to comply with NFPA 45 (see Step 3, above), and protecting the remaining gas cylinders, if required (with ventilated hoods, ventilated enclosures, ventilated gas cabinets, or sprinkler-protected and ventilated gas cabinets), record the revised gas inventory for the control area being evaluated.

Type of Gas	Number of cylinders in use	Cylinder Capacity (cubic feet of gas at NTP)	Internal Cylinder Capacity (standard cubic feet – water volume)	Flammable Gas, Liquefied Flammable Gas, Oxidizing Gas, or Other	Toxic or Highly Toxic	NFPA 704 Fire Hazard Classification	NFPA 704 Health Hazard Classification	NFPA 704 Reactivity Hazard Classification

5. For the purposes of compliance with the Michigan Building Code (MBC) and the International Fire Code (IFC), the type and quantity of gases being used and/or stored in each control area must be evaluated in order to determine if the building or space would be considered a "High Hazard" occupancy.

University research and classroom laboratories are generally considered "Group B" Business occupancies. If the maximum allowable quantity of compressed gases is exceeded, the occupancy classification of the building or space will change. If the maximum allowable quantity of flammable gas is exceeded, the building or space will become a Group H-2 high hazard occupancy. If the maximum allowable quantity of toxic or highly toxic gas is

exceeded, the building or space will become a Group H-4 high hazard occupancy. The Fire and Building codes contain numerous requirements for these high hazard occupancy types.

In almost all cases, it will not be possible for an existing laboratory or workshop, which was not designed to accommodate a high hazard use, to be modified to meet the requirements for a Group H-2 high hazard occupancy. Therefore, if the maximum allowable quantity of flammable gas is exceeded, the only practical way to correct the noncompliant condition will be to reduce the quantity of flammable gas.

In some cases, if the quantity of toxic or highly toxic gas exceeds the maximum allowable quantity, it may be possible to modify a laboratory to allow the Group H-4 high hazard use. However, at a minimum, gas detection and emergency alarm systems would be required, along with exhaust ventilation upgrades. If it is not possible or practical to meet the requirements for a Group H-4 occupancy, the quantity of toxic and/or highly toxic gas will need to be reduced.

Follow the steps outlined below to determine if the maximum allowable quantity of flammable and/or toxic gas has been exceeded.

Note: If a gas is both flammable AND toxic or highly toxic, it must be evaluated according to both criteria, in accordance with steps “b” and “c” as outlined in the guide.

a. The International Fire Code limits the sizes of individual cylinders for flammable gases and oxidizing gases when the cylinders are installed inside a building. Cylinders may not exceed 250 cubic feet of gas at normal temperature and pressure (NTP). Any cylinders of flammable or oxidizing gases that exceed 250 cubic feet at NTP must be removed from the laboratory. Proceed with this evaluation after the large cylinders have been removed, and account for any new, smaller, cylinders that have been installed.

b. In order to determine if a control area would be classified as a Group H-2 high hazard occupancy, the quantity of flammable and oxidizing gases must be analyzed. Both flammable gasses and oxidizing gasses are considered to be “physical hazards.” The quantity limits for gasses that pose a physical hazard are found in Table 2703.1.1(1) of the Fire Code (Maximum Allowable Quantity per Control Area of Hazardous Materials Posing a Physical Hazard). If the listed quantities are exceeded, the area is considered to be a Group H-2 Occupancy.

For flammable gasses, the basic limit is 1000 cubic feet of gas (at normal temperature and pressure) per control area. This limit can be doubled if the area is protected with automatic sprinklers, and doubled again if the gas cylinders are stored in approved gas cabinets or ventilated enclosures.

For oxidizing gasses, the basic limit is 1500 cubic feet of gas (at normal temperature and pressure) per control area. This limit can be doubled if the area is protected with automatic sprinklers, and doubled again if the gas cylinders are stored in approved gas cabinets or ventilated enclosures. If the limit is exceeded, the gas must be relocated to a separate, detached building.

Group H-2 occupancies for storage or use of flammable gases are also required to have the following features:

- Storage areas must be equipped with a supervised emergency alarm system.
- Explosion control (deflagration venting or an explosion prevention system in accordance with NFPA 69).
- Not less than 25% of the perimeter wall of the occupancy shall be an exterior wall.
- If the area of the occupancy exceeds 1000 square feet, it must be separated from lot lines and from the public way by a distance of at least 30 feet.
- Be located in a separate, detached building, if there are more than 2000 cubic feet of pyrophoric gasses.
- Automatic sprinkler protection is required.

- 2 hour fire-resistance-rated construction is required to separate the Group H-2 occupancy from adjacent Group B (Business) occupancies, such as university classroom / instructional building spaces. In some cases, 3 hour fire-resistance-rated construction may be required.

Group H-2 occupancies for storage or use of oxidizing gases are also required to have the following features:

- Be located in a separate, detached building and must be equipped with a supervised emergency alarm system.
- Be separated from lot lines and from the public way by a distance of at least 50 feet.
- Automatic sprinkler protection is required.

c. In order to determine if a control area would be classified as a Group H-4 high hazard occupancy, the quantity of toxic and highly toxic gases must be analyzed. Toxic and highly toxic gases are considered to be "health hazards." The quantity limits for gasses that pose a health hazard are found in Table 2703.1.1(2) of the Fire Code (Maximum Allowable Quantity per Control Area of Hazardous Materials Posing a Health Hazard). If the listed quantities are exceeded, the area is considered to be a Group H-4 Occupancy.

For toxic gases, the basic limit is 810 cubic feet of gas (at normal temperature and pressure) per control area. This limit can be doubled if the area is protected with automatic sprinklers, and doubled again if the gas cylinders are stored in approved gas cabinets or ventilated enclosures. For instructional laboratories, any individual cylinder of toxic gas must not exceed 20 cubic feet of gas (at normal temperature and pressure), and must be kept in a gas cabinet or fume hood.

For highly toxic gases, the basic limit is 20 cubic feet of gas (at normal temperature and pressure) per control area. These gases must be kept in approved exhausted gas cabinets or exhausted enclosures.

There is also a special limit imposed by the IFC for **anhydrous ammonia**. For buildings equipped with an automatic sprinkler system, the maximum allowable quantity of anhydrous ammonia in a single control area is two cylinders containing 150 pounds (or less) each. For buildings without an automatic sprinkler system, the limit is a single cylinder containing 150 pounds or less.

Group H-4 occupancies for storage or use of toxic and highly toxic gases are also required to have the following features:

- Storage areas must be equipped with a supervised emergency alarm system.
- All cylinders must be located within gas cabinets, exhausted enclosures or gas rooms.
- Exhaust ventilation must be provided for the room or area in which gas cabinets or exhausted enclosures are located. The exhaust ventilation system may be required to have a standby or emergency electrical power source.
- Automatic sprinkler protection is required.
- An automatic fire detection and alarm system is required.
- A gas detection system must be provided to detect the presence of gas at or below the PEL or ceiling limit of the gas for which detection is provided. However, the gas detection system is not required if the physiological warning threshold for the gas is at a level below the PEL. If a gas detection alarm system is required, it must transmit a signal to a constantly attended control station, along with audible and visible local alarms. Under some conditions, the gas detection system may be required to activate an automatic shut off valve for the gas supply.
- Gas rooms must be separated from other spaces with a minimum 1-hour rated fire barrier.

- 1 or 2 hour fire-resistance-rated construction may be required to separate the Group H-4 occupancy from adjacent Group B (Business) occupancies, such as university classroom / instructional building spaces, depending on the size of the area and the presence or absence of automatic sprinkler protection.

6. After reducing the quantity of flammable and/or toxic and highly toxic gases in order to meet the criteria outlined above (if necessary), record the final gas inventory for the laboratory in the table below.

Type of Gas	Number of cylinders in use	Cylinder Capacity (cubic feet of gas at NTP)	Internal Cylinder Capacity (standard cubic feet – water volume)	Flammable Gas, Liquefied Flammable Gas, Oxidizing Gas, or Other	Toxic or Highly Toxic	NFPA 704 Fire Hazard Classification	NFPA 704 Health Hazard Classification	NFPA 704 Reactivity Hazard Classification