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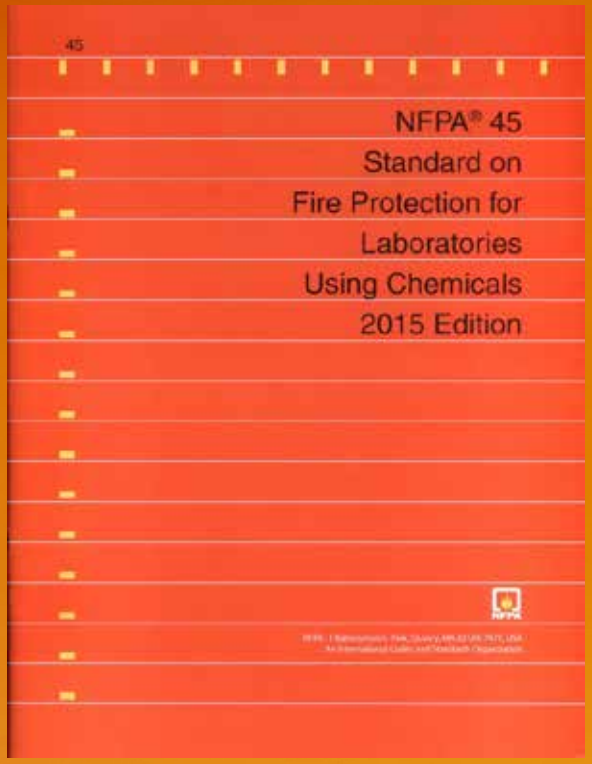
NFPA 45-2015: Fire Safety in Research Laboratories



Lawrence Berkeley National Laboratory

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Andrew Minister, PE

** Disclaimer **

In the course of this presentation, any comment as to the “meaning” of any part of any NFPA code or standard is only the opinion of the presenter and is NOT to be relied upon as either accurate or official. Only the NFPA may issue a formal interpretation of its codes and standards.

This presentation is not on behalf of any vendors or their products.

OBJECTIVES

- Understand NFPA codes and standards as they relate to laboratory safety
- Understand the requirements in NFPA 45
- Understand laboratory fire hazards
- To know about other laboratory safety resources that are available
- Review lessons learned from laboratory fire/fire related events
- Provide operational practices to reduce the impact of a fire on research and laboratory staff/students

Why Use NFPA 45

What are the consequences of a lab fire?

- Injuries to researchers/others in the lab
- Loss of research equipment & data
- Loss of research funding
- Affect on other operations in the building/campus/site
- Impact on the reputation of the research organization/university/company
- Litigation issues
- Fines from regulators

Headlines From Lab Fires & Explosions

- Fire destroys top research centre – Highfield, England
- Ethylene gas suspected in school explosion – France
- Chemical Ignites, Damaging Lab
- Explosion Rocks Ortho-McNeil Lab
- Blame in UCI Fire Severity: No Sprinklers (7/01)/Cost of Blaze at UCI Labs: $3.5 Million
- School fined over Chemistry Explosion
- Fire Guts UC Labs (2/02)
- Students Burned in Lab Fire Settle
- Laboratory Researcher Dies of Burns from a Pyrophoric Chemical
- CSB Releases Investigation into 2010 Texas Tech Laboratory Accident; Case Study Identifies Systemic Deficiencies in University Safety Management Practices

Safety Costs

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"If you think Safety is expensive,

… try an Accident!"

Dr. Trevor Kletz
Adjunct Professor
Texas A&M
Mary O'Conner
Process Safety Center

Typical Labs

Typical Labs

Typical Labs

Typical Lab – I Hope Not!

NFPA 45 - 2015:
Standard on Fire Protection for Laboratories Using Chemicals

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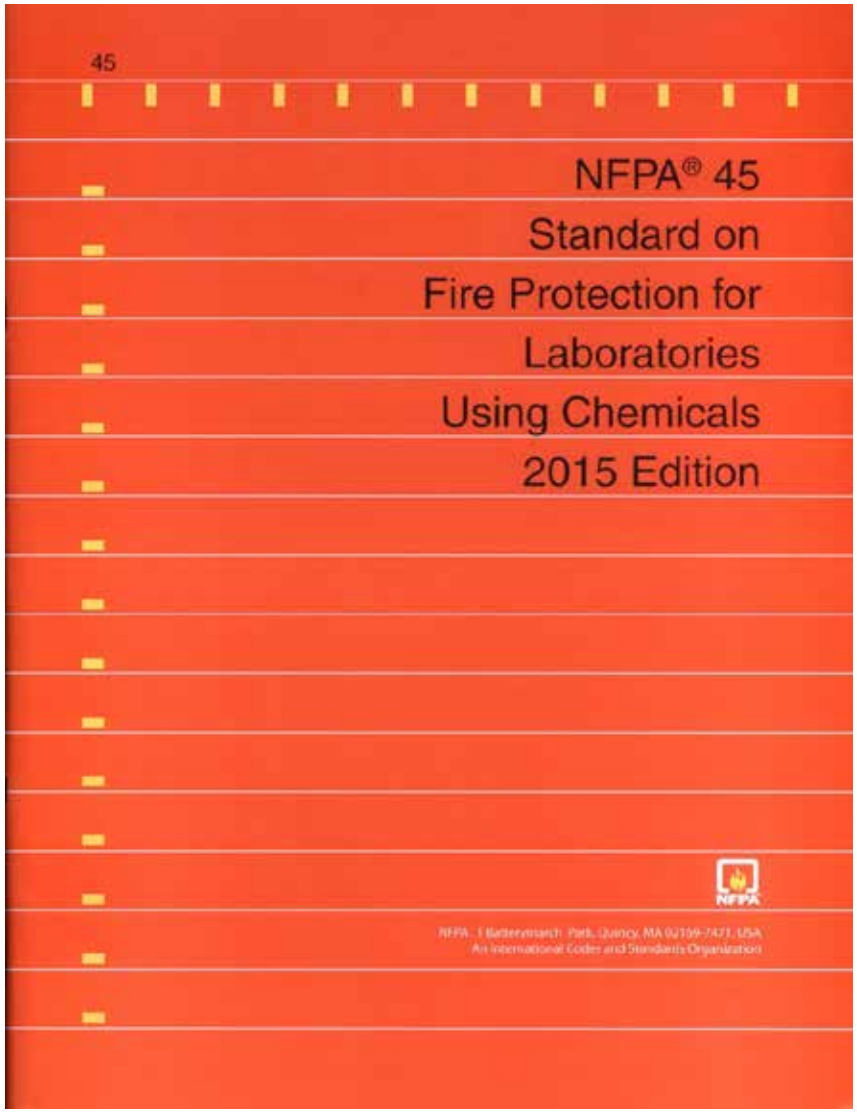
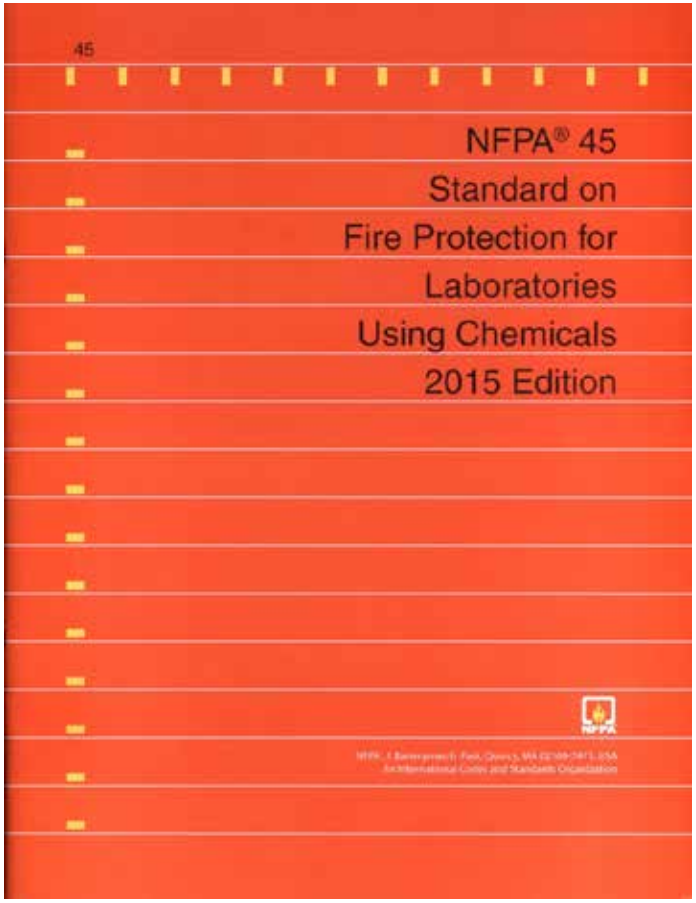
NFPA-45: History

- First edition – 1975
  - "Prudent Practices …." - 1981
- Second edition - 1982
- Third edition – 1986
  - OSHA Lab Standard - 1990
- Fourth edition – 1991
  - ANSI Z9.5 "Laboratory Ventilation - 1992
- Fifth edition – 1996
- Sixth edition – 2000
- Seventh edition – 2004
- Eighth edition – 2011
- Ninth edition – 2015



NFPA-45: Overview

- Thirteen (13) chapters
  - Regulatory information - Enforceable
- Seven (7) annexes
  - Explanatory or advisory -NOT enforceable



NFPA-45: Chapter Overview

- 1 – Scope; Purpose; Applicability; Retroactivity; and Equivalency
- 2 – Referenced Publications
- 3 – Definitions
- 4 – Laboratory Unit Hazard Classification
  - Based upon quantities of “flammable liquids”

NFPA-45: Chapter Overview

- 5 Laboratory Unit Design & Construction
  - Size, separation, egress, and electrical features
- 6 Fire Protection
- 7 Ventilating Systems & Hood Requirements
- 8 Chemical Storage, Handling, & Waste Disposal
- 9 Flammable & Combustible Liquids

NFPA-45: Chapter Overview

- 10 Compressed & Liquefied Gases
- 11 Laboratory Operations and Apparatus
- 12 Educational and Instructional Laboratory Operations
- 13 Hazards Identification

NFPA-45: Annex Overview

Annexes are provided for informational purposes and contain explanatory information

- A Explanatory Material
- B Supplementary Definitions
- C Info on Explosion Hazards & Protection
- D The Concept of the “Laboratory Unit”

NFPA-45: Annex Overview

- E Flammability Characteristics of Common Compressed and Liquefied Gases
- F Safety Tips for Compressed Gas Users
- G Informational References

Chapter 1: Scope

This standard shall apply to laboratory buildings, laboratory units, and laboratory work areas whether located above or below grade in which chemicals, as defined in NFPA 704 with one or more of the following hazard ratings are handled or stored: health — 2, 3, or 4; flammability — 2, 3, or 4; or instability — 2, 3, or 4. (1.1.1)

- See Diagram Annex A - A.1.3

Chapter 1: Scope

Applies to **all** educational laboratory units and instructional laboratory units in which any quantity of chemicals, as defined in NFPA 704 with one or more of the following hazard ratings where chemicals are handled or stored: health — 2, 3, or 4; flammability — 2, 3, or 4; or instability — 2, 3, or 4. (1.1.2)

Chapter 1: 1.1.2 Scope – Not Applicable If:

1. Small quantities in laboratory unit:
   - Less than or equal to 4 L (1 gal) of flammable or combustible liquid, or less than 2.2 cu m (75 scf) of flammable gas;
2. Pilot plants:
   - See definition – 3.3.50
3. Low hazard chemicals only:
   - Hazard rating of “0” or “1” for health, flammability and reactivity per NFPA 704
4. Manufacturing plants (NFPA 30)
5. Incidental testing facilities

Chapter 1: 1.1.2 Scope – Not Applicable If:

6. Physical, electronic, or instrument type labs that use hazardous chemicals only for incidental purposes (cleaning)
7. Labs with only radioactive materials (NFPA 801)
8. Labs with only with explosive materials (NFPA 495)
9. Laboratory work areas containing an explosion hazard great enough to cause property damage outside that laboratory work area or injury outside that laboratory work area requiring medical treatment beyond first aid

Chapter 1: Explosion Hazard Classification Criteria

A laboratory work area contains an explosion hazard if an explosion of quantities or concentrations of reactive materials could result in serious or fatal injuries to personnel within that laboratory work area. Such quantities or concentrations include, but are not limited to, the following:

1. Storage of instability hazard 4 materials (> 1 lb.) (Class 4 oxidizers for example)
2. Use or formation of instability hazard 4 materials (> 0.25 lb.)
3. Highly exothermic reactions in glass or open reaction vessels (> 10 grams) - polymerizations, oxidations, nitrations, peroxidations, hydrogenations, or organo-metallic reactions

Chapter 4: Explosion Hazard Classification (4.3)

4. Use or formation of materials in glass or open reaction vessels whose chemical structures indicate a potential hazard, but whose properties have not been established, such as salts of alkenes, triple bonds, epoxy radicals, nitro and nitroso compounds, and peroxides (> 10 grams)
5. Other hazards as determined by a qualified person

Chapter 1: 1.2 Purpose

Protection of life and property through prevention and control of fires and explosions involving the use of chemicals in laboratory-scale operations.

- Control hazards
- Protect the lab worker(s)/occupants
- Protect the emergency responders
- Limit loss to the laboratory unit of origin

Does not address financial losses or business interruption impacts

Chapter 1: 1.3 Application

- To provide a reasonable level of protection from loss of life and property from fire and explosion.
- Labs in Health Care Facilities (Used to be covered by NFPA 99)
- Due to the special nature of labs, the standard modifies or supplements other codes/standards to apply specifically to areas used for laboratory operations
- More stringent construction or protection requirements of AHJ apply

Chapter 1: 1.4 Retroactivity and 1.5 Equivalency

- Generally, not retroactive, but AHJ may apply where unacceptable conditions exist. (1.4)
  - Some requirements in Chapters 6 (6.5 & 6.6), 11 & 12 are now retroactive – apply to new and existing laboratories
- Not intended to prevent systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by standard. (1.5)
  - Approval by “authority having jurisdiction” (AHJ) needed for alternatives.

Chapter 2 & Annex G: References

Recommended Resources

Fire Protection:

- § NFPA – Other codes and standards (2.2)
- § NFPA Fire Protection Guide to Hazardous Materials
- § NFPA 1 Uniform Fire Code

Laboratory Design/Operations:

- § CRC Handbook of Laboratory Safety – 5th Ed.
- § ACGIH Industrial Ventilation
- § Handbook of Chemical Health and Safety
- § National Research Council - Prudent Practices in the Laboratory (2011 edition)

Chapter 2 & Annex G: References

Compressed Gas Safety

- § CGA Handbook of Compressed Gases – 4th Ed.
- § CGA P-1 Safe Handling of Compressed Gases in Containers
- § CGA P-23 Standard for Categorizing Gas Mixtures Containing Flammable and Nonflammable Components
- § Matheson Gas Data Book
- § US Bureau of Mines Bulletin 627 – Flammability Characteristics of Combustible Gases and Vapors
- § Hydrogen Best Practices: http://h2bestpractices.org/
- § Hydrogen Incidents: http://h2incidents.org/

Chapter 2 & Annex G: References

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Additional references:

- § ANSI/AIHA Z9.5, Laboratory Ventilation, 2003
- § NIOSH Pocket Guide to Chemical Hazards

Other References not in NFPA 45

- § NIOSH School Chemistry Laboratory Safety Guide
- § International Building Code 2012
- § International Fire Code 2012
- § An Investigation of Chemical Fume Hood Fire Protection Using Sprinklers and Water Mist Nozzles FMRC June 1999
- § Hazardous Laboratory Chemicals – Disposal Guide
- § The Laboratory Safety Institute: http://www.labsafety.org/
- § AIHA Laboratory Safety Incidents: https://www.aiha.org/get-involved/VolunteerGroups/LabHSCommittee/Incident%20Pages/Lab-Safety-Fire-Incidents---Chemical-based.aspx

Chapter 3: Definitions

- Chemical Fume Hood (3.3.8)
  - A ventilated enclosure designed to contain and exhaust fumes, gases, vapors, mists, and particulate matter generated within the hood interior.
- Laboratory (3.3.33)
  - A facility where the containers used for reactions, transfers, and other handling of chemicals are designed to be easily and safely manipulated by one person. It is a workplace where chemicals are used or synthesized on a nonproduction basis.
- Laboratory Scale (3.3.36)
  - Work with chemicals in which the containers used for reactions, transfers, and other handling of chemicals are designed to be easily and safely manipulated by one person.

Chapter 3: Definitions

- Educational Laboratory Unit (3.3.13)
  - A laboratory unit that is under direct supervision of an instructor and used for educational purposes for students through the twelfth grade..
- Instructional Laboratory Unit (3.3.31)
  - Used for education past the 12th grade and before post-college graduate level instruction
  - Under the direct supervision of an instructor
  - Does not apply to labs used for graduate or post-graduate research

Chapter 3: Definitions

- Laboratory Unit (3.3.37)
  - An enclosed space used for experiments or tests
  - Can include offices, lavatories, and other incidental contiguous rooms maintained for or used by laboratory personnel, and corridors within the unit
  - Can contain one or more separate laboratory work areas
  - Can be an entire building
  - A laboratory unit is classified as A, B, C, or D
  - See Annex D for example diagrams
- Laboratory Work Area (3.3.39)
  - A room or space for testing, analysis, research, instruction, or similar activities that involve the use of chemicals

Chapter 3: Definitions

- Qualified Person (3.3.54)
  - A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems relating to a particular subject matter, work, or project.
- Unattended Laboratory Operation (3.3.59)
  - A laboratory procedure or operation at which there is no person present who is knowledgeable regarding the operation and emergency shutdown procedures.

Service Corridor in Laboratory Unit

Chapter 4: Fire Hazard Classifications (4.2.1)

Based on total volume of flammable & combustible liquids in the laboratory unit (see Table 9.1.1)

- Class A - high fire hazard
  - Petrochemical & pharmaceutical labs
- Class B - moderate fire hazard
  - Organic chemistry labs
- Class C - low fire hazard
  - Instructional & biological labs
- Class D - minimal fire hazard
  - Educational, clinical, & sample testing labs

NFPA 45: Table 9.1.1(b)

Table 9.1.1(b) Maximum Quantities of Flammable and Combustible Liquids in Laboratory Units Outside of Inside Liquid Storage Areas (U.S. Customary Units)

		Quantities in Use[a]		Quantities in Use and Storage[a]	
Laboratory Unit Fire Hazard Class	Flammable and Combustible Liquid Class[a]	Maximum Quantity[b] per 100 ft^2 of Laboratory Unit[c] (gal)	Maximum Quantity[b] per Laboratory Unit (gal)	Maximum Quantity[b] per 100 ft^2 of Laboratory Unit[c] (gal)	Maximum Quantity[b] per Laboratory Unit (gal)
A	I	10	480	20	480
(high fire hazard)	I, II, and IIIA	20	800	40	1600
B[d]	I	5	300	10	480
(moderate fire hazard)	I, II, and IIIA	10	400	20	800
C[e]	I	2	150	4	300
(low fire hazard)	I, II, and IIIA	4	200	8	400
D[e]	I	1	75	2	150
(minimal fire hazard)	I, II, and IIIA	1	75	2	150

Note: For maximum container sizes, see Table 9.1.2.

[a]The maximum amount in use in open systems is limited to 10 percent of the quantities listed.

[b]See 4.2.2 for additional requirements for educational and instructional laboratories.

[c]The quantities per 100 ft^2 do not imply the quantities must be within that 100 ft^2 area; the quantities per 100 ft^2 are for calculation purposes to determine the total quantity allowed per laboratory work area and the total amount overall in the laboratory unit.

[d]Reduce quantities by 50 percent for B laboratory units located above the 3rd floor.

[e]Reduce quantities by 25 percent for C and D laboratory units located on the 4th–6th floors of a building, and reduce quantities by 50 percent for C and D laboratory units located above the 6th floor.

NFPA 45: Table 9.1.1

- Footnote a: The maximum amount (of flammable or combustible liquid) in use in open systems is limited to 10 percent of the quantities listed (per laboratory unit).
  - For Class A labs, the limit would be 48 gallons of flammable liquid
  - For Class B labs, the limit would be 30 gallons of flammable liquid
  - For Class C labs, the limit would be 15 gallons of flammable liquid
  - For Class D labs, the limit would be 7.5 gallons of flammable liquid
    - Open System Use. Use of a solid or liquid hazardous material in a vessel or system that is continuously open to the atmosphere during normal operations and where vapors are liberated, or the product is exposed to the atmosphere during normal operations. (NFPA 400)

Class A Laboratory Units Chapters 4 & 5

- Maximum height: 3 stories
- Maximum of 10,000 sq. ft (930 sq. m) per unit
- Class I flammable liquids limitations:
  - “In use” – 480 gals (1820 L) maximum
  - “In use” – not more than 10 gals 100 per sq ft (38 L per sq m)
  - “In use” and storage – 480 gals (1820 L)
- Class I, II, IIIA flammable liquids limitations:
  - “In use” – not more than 20 gals 100 per sq ft (76 L per sq m)
  - “In use” and storage – 1600 gals (6060 L)

Class B Laboratory Units Chapters 4 & 5

- Maximum height: 6 stories
- Maximum of 10,000 sq. ft (930 sq. m) per unit
- Hazardous materials reduced 50% on floors 4–6
- Class I flammable liquids limitations:
  - “In use” – 300 gals (1136 L) maximum
  - “In use” – not more than 5 gals 100 per sq. ft (20 L per sq. m)
  - “In use” and storage – 480 gals (1820 L)
- Class I, II, IIIA flammable liquids limitations:
  - “In use” – not more than 10 gals 100 per sq. ft (38 L per sq. m)
  - “In use” and storage – 800 gals (3028 L)

Class C Laboratory Units Chapters 4 & 5

- No area limitations
- No fire separation on floors 1–3

  1-hour separation on floors 4–6

  2-hour separation over 6 stories
- Hazardous materials reduced 25% on floors 4–6, 50% on floors above 6 stories
- Class I flammable liquids limitations:
  - “In use” – 150 gals (570 L) maximum
  - “In use” – not more then 2 gals per 100 sq. ft (7.5 L per sq. m)
  - “In use” and storage – 300 gals (1136 L)

Class D Laboratory Units Chapters 4 & 5

- No area limitations
- No fire separations to non-laboratory areas
- Hazardous materials reduced 25% on floors 4–6, 50% on floors above 6 stories
- Class I flammable liquids limitations:
  - “In use” – 75 gals (284 L) maximum
  - “In use” – not more than 1 gal per 100 sq. ft (4 L per sq. m)
  - “In use” and storage – 150 gals (570 L)

Chapter 4: Instructional and Educational Labs

- Instructor supervision required (12.1.1)
- Quantity limitations – flammable & combustible liquids (4.2.2)
  - Instructional lab units **above Grade 12**, classified as Class C or D laboratory units.
  - Educational lab units **up through Grade 12**, classified as Class D laboratory units.

Instructional Lab

Chapter 5: Design Considerations

- Types and quantities of chemicals in use;
- Size of lab unit (square footage);
- Fire rating of construction materials;
- Automatic sprinkler systems required since 2004 edition
- Relative hazard of lab area to other non-lab areas.

Table 5.1.1

Table 5.1.1 Separation Requirements and Height Allowances for Laboratory Units

Laboratory Unit[a]	Area of Lab Unit	Fire Separation[b]	Permitted Stories Above Grade	Permitted Stories Below Grade
A	≤929 m^2 (≤10,000 ft^2)	2 hours	1–3	Not permitted
	>929 m^2 (>10,000 ft^2)	Not permitted[c]		
B	≤929 m^2 (≤10,000 ft^2)	1 hour	1–3	1
	≤929 m^2 (≤10,000 ft^2)	2 hours	4–6	
	>929 m^2 (>10,000 ft^2)	Not permitted[c]		
C	Any size	Not required	1–3	1–2
	Any size	1 hour	4–6	
	Any size	2 hours	Over 6	
D	Any size	Not required	No limit	No limit

[a]Refer to Table 9.1.1 for laboratory unit classification.
[b]Separation in this table refers to fire separation from laboratory unit(s) to non-laboratory areas and/or fire separations from laboratory unit(s) of equal or lower hazard classification.
[c]Labs of this classification and size are not permitted.

Chapter 5: Design Considerations

- Separation requirements
  - Includes walls, floors, & ceilings
  - Class A lab units - 2 hour-rated
  - Class B lab units - 1 hour-rated minimum
  - Educational occupancies separated from other non-lab areas - 1-hr fire-rated (5.1.3)
  - Penetrations through fire rated assemblies protected per NFPA 101 (5.1.4)
  - Sealed floor, floor opening/penetrations to prevent leakage to lower floors (5.1.6)
    - Floor openings & penetrations sealed or curbed to prevent liquid leakage to lower floors
    - Fire rated seals may need to be leak rated if not curbed

Chapter 5: Life Safety

- Comply with NFPA 101, *Life Safety Code*, unless modified by NFPA 45 (5.3)
- Class A, B & C – industrial occupancies (5.3.1)
- Class D – business occupancy (includes instructional labs) or educational occupancy for educational labs (5.3.2 & 5.3.3)
- Arrange furniture, casework, and equipment to keep exits clear (5.5)
- Keep lab doors closed to protect corridor
  - Use smoke detector activated door holders as an alternative
  - Required with VAV type fume hood operations

Lab Door Holders

The wrong way or the right way!

Chapter 5: Life Safety

Requires a 2nd means of exit access when any of the following exist in a laboratory work area: (5.4.1)

- (1) Lab work area contains explosion hazard that could block escape from or access to the laboratory work area
- (2) Class A lab over 500 square feet
- (3) Class B, C, or D lab over 1000 square feet
- (4)Fume hood located adjacent to exit
- (5) Gas cylinder located where it could prevent safe egress in event of accidental release of contents
- (6) Cryogenic container located where it could prevent safe egress in event of accidental release of contents

Chapter 5: Life Safety

- A 2nd means of egress can be through an adjacent laboratory work area (A.5.4.1)
- Swing of doors:
  - A and B: In direction of exit travel (5.4.2)
  - C and D: In either direction, or slide horizontally, if they comply with NFPA 101 (5.4.3)
- Emergency lighting required when 2nd means of egress to exit required for lab (5.4.4)
- Emergency lighting installed per NFPA 101 (5.4.5)

Chapter 5: Life Safety

Chapter 5: Life Safety

Second means of egress through an adjacent laboratory

Obstructed Egress

Obstructed aisles in lab

Chapter 5 & 6: Electrical Provisions

- Electrical installations, wiring, etc., In compliance with NFPA 70, *NEC* (5.6)
- No receptacles, switches, or controls located subject to liquid spills. (5.6.1)
- Laboratory work areas, units, and hood interiors "unclassified" electrically. (5.6.2)
  - Exception for special conditions
- Fire prevention procedures – Use and arrangement of portable cords – (6.5.1.2 (3))

Electrical Safety

Electrical equipment subject to liquid spills and improperly supported cords

Electrical Safety

Note: Power strip suspended in hood – electrical outlets exposed to fumes in hood

Electrical Safety

No flammable liquids in this hood
Hood is out-of-service

Electrical Safety

New hoods have opening below sash plate for cords – allows sash to close fully

Chapter 6: Fire Protection

- Automatic fire extinguishing systems required (6.1.1.1)
  - (1) Class A & B – Ordinary hazard Group 2
  - (2) Class C & D – Ordinary hazard Group 1
- Quick response type heads in new labs (6.1.1.2)

  http://www.nist.gov/fire/upload/No-Sprinkler.wmv

  http://www.nist.gov/fire/upload/QRS-Pendent.wmv
- Other types of suppression may be installed (6.1.2)
- Standpipe and hose systems for buildings over 2-stories above or below grade (6.2)
  - Class 1 for fire department use

Fire Suppression Equipment

Chapter 6: Fire Protection

- Portable fire extinguishers per NFPA 10 (6.3)
  - NFPA 10 Table 6.3.1.1 for Class B (flammable liquids) hazards
  - Class A labs – Extra (high) hazard
  - Class B, C & D labs – Ordinary (moderate) hazard
- Fire alarm systems provided per NFPA-72 (6.5)
  - Manual pull stations in Class A & B
  - Alarm to emergency responders

From NFPA 10

Table 6.3.1.1 Fire Extinguisher Size and Placement for Class B Hazards

Type of Hazard	Basic Minimum Extinguisher Rating	Maximum Travel Distance to Extinguishers	
		ft	m
Light	5-B	30	9.14
	10-B	50	15.25
Ordinary	10-B	30	9.14
	20-B	50	15.25
Extra	40-B	30	9.14
	80-B	50	15.25

Note: The specified ratings do not imply that fires of the magnitudes indicated by these ratings will occur, but, rather, they are provided to give the operators more time and agent to handle difficult spill fires that have the potential to occur.

Fire Extinguishers

Water Mist Type Extinguishers

Fire Extinguishers

Where is it?

Now I can see it!

Fire Alarm Systems

Control Panel

Alarm/Strobe

Chapter 6: Fire Prevention (6.5)

- Requirements of 6.5 are retroactive to all labs
- Requires fire prevention procedures to be established (6.5.1.1)
- Requires procedures for: (6.5.1.2)
  - (1) Handling and storage of chemicals including flammable/combustible liquids, pyrophoric/reactive compounds and gases
  - (2) Permit system for open flame and spark-producing work in labs
  - (3) Arrangement and use of portable electric cords
  - (4) Smoking area controls

No Smoking Area

Chapter 6: Maintenance Procedures (6.5.2)

- Maintenance procedures shall be established for labs
- Procedures for inspection, testing, and maintenance of: (A.6.5.2)
  - Utilities (Electrical, gas, steam)
  - HVAC systems
  - Fire protection systems/equipment
  - Compressed gas regulators/PRVs/other safety devices
  - Fire doors/barriers
  - Emergency lighting/exit signs
  - Other equipment/systems important to safety of laboratory operations

Chapter 6: Emergency Plans (6.5.3)

- Emergency operations procedures needed in the event of a chemical emergency, fire, or explosion (6.5.3.1)
  - (1) Procedures for sounding the alarm
  - (2) Procedures for notification and coordination with the fire department, governmental agencies and other emergency support organizations
  - (3) Procedures for evacuation and accounting for personnel
  - (4) Procedures for establishing rescue/medical duties
  - (5) Procedures and schedules for emergency drills
  - (6) Procedures for shutdown/emergency operation for equipment, processes, ventilation devices, enclosures

Chapter 6: Emergency Plans (6.5.3)

- Emergency operations procedures needed in the event of a chemical emergency, fire, or explosion (6.5.3.1)
  - (7) Appoint and train emergency response personnel
  - (8) Alternative measures for lab occupants as needed
  - (9) Dedicated aisles/lanes for movement of people and emergency response
  - (10) Maintenance of fire protection equipment
  - (11) Procedures for restart/re-entry plans after an emergency
- Train laboratory uses/instructors/students on the emergency plan and at least annually (6.5.3.3)

Emergency Plans

- Plans Should Address
  - Emergency response personnel – Emergency Director
  - Response to fire
  - Spill response
  - Response to power or ventilation failures/outages
  - Adverse weather – floods, high winds, tornados
  - Hazard identification marking for chemical storage areas
  - Location or access to MSDS/SDS
  - Pre-fire Planning with fire department
    - Location of emergency shutoff valves
    - Ventilation system control

Extinguishing clothing fires (6.5.3.2 & A.5.6.3.2)

- Establish procedures for extinguishing clothing fires (6.5.3.2)

STOP, DROP, and ROLL

- Train others to knock the victim to the floor and roll them to smother the flames and to keep the flames out of the victim's face
- Use fire retardant clothing for staff with routine exposure to sparks, flames or pyrophoric liquids
- Safety showers, fire blankets, or fire extinguishers are of secondary importance
  - Wrapping in a fire blanket creates a chimney effect and directs the hot, toxic gases, and flames into your face, breathing zone and lungs. Someone else can use them to smother the flames
  - Use safety showers only if they are within a step or 2

Chapter 6: Fire Retardant Clothing

- Requirements of 6.6 are retroactive to all labs
- Wear fire-retardant lab coats and gloves to handle pyrophoric reagents outside of an inert atmosphere glovebox (6.6.2 & 6.6.3)
  - Consider the use of fire-retardant lab coats when handling flammable liquids and other hazardous materials that are easily ignited (A.6.6.2)
    - MSDS/SDS PPE section may indicate the need for fire-retardant clothing
  - In addition to fire resistance, gloves need to provide chemical resistance for the hazards of the reagents being handled (A.6.6.3)
- Wear natural-fiber clothing on legs and feet (6.4.4)
- Fire-retardant clothing per NFPA 2112 (6.6.5)

Chapter 6: Fire Retardant Clothing

Fire-retardant lab coat and gloves being used during the transfer of pyrophoric liquids

Chapter 7: Laboratory Ventilation

- Includes Design Requirements for Supply and Exhaust Ventilation
- Requirements for control of flammable vapors, gases and mists
- Basic Requirements:
  - Laboratory ventilation systems designed to ensure that fire hazards and risks are minimized (7.2.1)
  - Labs with chemicals must be continuously ventilated to minimize fire hazard and other risks (7.2.2)
    - See additional ventilation design criteria in A.7.2.2
  - Suspend lab operations when exhaust system is out of service or inoperable. Secure hazardous materials or remove them from the lab (7.2.2.1)

Chapter 7: Laboratory Ventilation

- Basic Requirements:
  - Chemical fume hoods do not provide blast protection unless specifically designed to do so (7.2.3)
  - The release of chemical vapors into the laboratory shall be controlled by enclosure(s) or captured to prevent any flammable and/or combustible concentrations of vapors from reaching any source of ignition. (7.2.6)
  - Air exhausted from chemical fume hoods and other special local exhaust systems shall not be recirculated. (7.4.1)

Chapter 7: Laboratory Ventilation

- Supply and Exhaust Ventilation Design
  - Exhaust and supply systems designed to prevent a pressure differential that would impede egress or ingress when either system fails or during a fire or emergency scenario. This design includes reduced operational modes or shutdown of either the supply or the exhaust ventilation system (7.2.5)
  - See also 7.10.3.1 and 7.10.4
- Control of Chemical Vapors
  - The release of chemical vapors into the laboratory shall be controlled by enclosure(s) or captured to prevent any flammable and/or combustible concentrations of vapors from reaching any source of ignition (7.2.6)

Chapter 7: Laboratory Ventilation

- Supply Air Systems:
  - Clean outside air
  - No recirculation/no contaminated makeup air (7.3.1 & 7.4.1) http://www.csemag.com/single-article/designing-lab-ventilation-systems/f38d22638a5a42b4a5e4fdb44a89bf53.html
    - Energy wheels for energy conservation – must be coil-type heat exchanger not membrane type per IMC 2015
  - Lab work areas are negative to corridors/non-lab areas except for: (7.3.3)
    - Clean rooms
    - Momentary variations for doors, hood sash position changes
    - Pressurized enclosures for electrical equipment
  - Locate lab supply air diffusion to avoid air currents that would adversely affect performance of fume hoods or other exhaust devices, and fire detection/suppression systems (7.3.4)

Chapter 7: Laboratory Ventilation

- Ventilation – requirements:
  - 7.4.2 Energy Conservation Devices
    - 7.4.2.1 If energy conservation devices are used, they shall be designed in accordance with 7.3.1 and 7.3.2.
    - 7.4.2.2* Energy conservation devices shall only be used in a laboratory ventilation system when evaluated and approved by a qualified person. These systems must meet, or exceed, the criteria established by Section 5.4.7 and Section 5.4.7.1 of ANSI/AIHA Z9.5-2012, Laboratory Ventilation. Systems that recirculate within their respective laboratory work area, such as fan coil units for sensible heat loads, are exempt from these requirements.
    - A.7.4.2.2 It is not the intent of the standard to prohibit or impede the use of any energy conservation devices. However, the committee is concerned that adequate design consideration should be given as to how to clean and maintain these devices as the systems age.

Chapter 7: Laboratory Ventilation

- Energy Conservation (7.4.2)
  - Variable Air Volume (VAV) vs. Constant Air Volume (CAV) Hoods
  - Low Flow Hoods - CAV or VAV
  - Ductless Fume Hoods – limited use (A.7.4.1)
  - Heat Recovery
    - Coil-type energy wheels
    - Air-to-air plate heat exchanger
    - Refrigerant heat pipe
    - Runaround loop
  - Fume hoods that reduce the exhaust volume as the sash opening is reduced should maintain a minimum exhaust volume Annex A.7.4.7

Chapter 7: Laboratory Ventilation

- Exhaust Systems:
  - Exhaust ducts in labs maintained under negative pressure (7.4.4)
    - Ducts should be sealed to prevent leakage into occupied areas. (A.7.4.4)
  - Positive pressure portions of exhaust ducts sealed air tight or in continuously vented room (7.4.5)
  - Hood face velocities and exhaust volume need to contain contaminates to hood and exhaust them outside of the building (7.4.6)

Chapter 7: Laboratory Ventilation

- Exhaust Systems: (continued)
  - Hoods provided to contain possible hazards and protect lab personnel when chemicals are present in hood (7.4.7)
    - Low flow hoods and hoods with VAV controls require additional review for operations in the hoods (A.7.4.7)
  - Discharge location – on roof to prevent re-entrainment and personnel exposure (7.4.11)
- Duct construction
  - Metal ducts or ducts with flame spread <25 (7.5.1)
  - No duct linings that could accumulate chemicals (7.5.3)
    - Linings to prevent duct corrosion (fluoropolymer thermoplastic resin) see ANSI Z9.5 5.4

Chapter 7: Laboratory Ventilation

- Exhaust Systems: (continued)
  - No flexible connectors to collect chemical contaminates (7.5.7)
  - Controls/dampers shall fail open (7.5.8)
  - Manifolding of ducts permitted within Lab unit (7.5.10.3)
- Duct Velocities
  - Air volume and duct velocities to prevent condensation and deposition of particles (deposition of hazardous materials in ducts could present an explosion hazard) (7.6)
  - For significant amounts of condensation, other measures need to be provided. (7.6.2)

Chapter 7: Laboratory Ventilation

- Fans & Motors (7.7)
  - Select fans to meets requirements for fire, explosion and/or corrosion resistance (7.7.1)
  - Fans – non-sparking per AMCA Standard 99-0401-86 (7.7.4) http://www.greenheck.com/media/pdf/catalogs/VektorH_catalog.pdf
  - Variable speed motors and controls for VAV
  - Located for easy access (7.7.3)
  - Motors, belts and controls located outside of the exhaust air stream (7.7.5)
  - Fans marked to show direction of rotation and with hoods/area served (7.7.6)

Roof Top Exhaust Fan

Chapter 7: Laboratory Ventilation

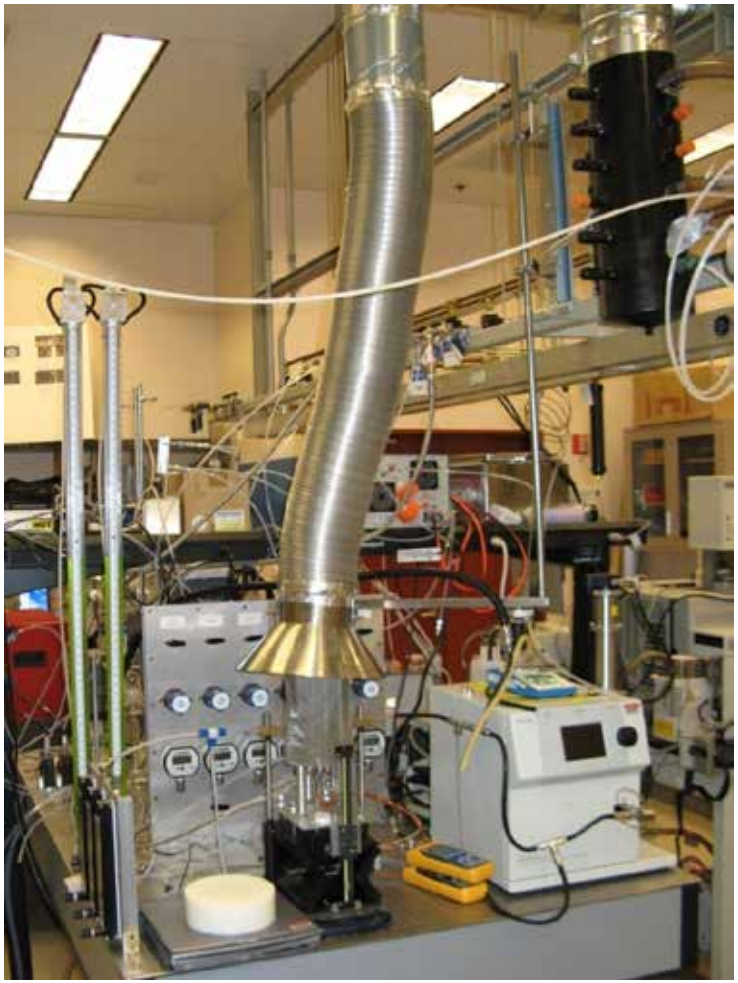
- Chemical Fume Hood Construction (7.8)
  - Interior construction of hoods – flame spread 25 or less (7.8.1.1)
  - Contain a spill of 2 L of liquid (7.8.1.4)
  - Sash glazing to protect operator (safety glass) (7.8.2)
  - Electrical outlets should be outside of hood (7.8.4)
  - Service controls on the face (7.8.5.1)
  - Permanent air flow monitor with constant indication of adequate or inadequate air flow – alarms recommended (7.8.7)
- UL 1805 “Fume Hoods and Cabinets”
  - Specify listed and labeled hoods for new construction (7.8.1.2)

Chapter 7: Hoods

- Types of Hoods
  - Snorkel Exhaust (7.4.8)
  - Canopy, Laminar Flow Cabinets and Ductless Enclosures (7.4.9)
    - Do not use for chemical fume hoods
  - Biological Safety Cabinets (7.4.10)
    - Types: Class I, Class II A, Class II B2, & Class III
  - Chemical Fume Hoods (7.8)
  - Perchloric Acid Hoods (7.11)
- Keep the sash closed whenever possible (7.8.3)
  - Fume hood safety video: https://www.youtube.com/watch?v=yqU5bGP0i5I

Hoods

Canopy Hood



Snorkel Exhaust

Hoods

Proper Venting of Research Equipment?
What is the vent for?
Heat removal, health hazard or both?

Hoods

Class II-A2 Biosafety Cabinet

Hoods

Class II-B2 Biosafety Cabinet

Hoods

Laminar Flow Hoods

Hoods

Bypass Type CAV Chemical Fume Hood

Hoods

VAV Type Chemical Fume Hood

Monitor Panel

Hoods

Low Flow Type Chemical Fume Hood with VAV

Low Flow Fume Hood

- Installed December 2010
- Operated at 65 lfpm with sash at 18 inches
- VAV reduces air flow to about 40 lfpm with sash closed
- Note: Airflow monitor in lower left corner

Hoods

Double sided fume hood with baffles on sides – like a California Hood

Hoods

Floor Mounted (Walk-in) Type Hood

- For large equipment
- Roll carts in and out
- May not have the same capture velocity as standard chemical fume hood

Hoods – Ductless Fume Hoods and Enclosures

- Limited use NFPA 45 - 8.4.1 and A.8.4.1
- Recirculates air from hood through carbon or chemically active adsorbent filter back into lab
- Not for use with toxic/highly toxic materials
- Modern ductless hoods have 2 levels of filters and break though alarms
- Filters may not capture many common gases like hydrogen, CO
- Refer to ANSI/AIHA Z9.5 section 4.2 and supporting text for additional information. Also, Section 2, 3.3 & 5.3.6.2. Recirculation hazards are addressed in 9.3 & 9.4

Ductless Enclosure

Hoods – Ductless Fume Hoods and Enclosures

- Not appropriate for changing chemistry
- Heat producing operations can drive off hazardous gases/vapors from filters – recommended operating below 100º F
- Dust and other particulate can plug the filters and reduce air flow
- See: http://airscience.com/filtration-guide
- See Article – Part III on page 5 at: http://www.safelab.com/DOWNLOAD/SCRUBBER.pdf
- Enclosures will not capture heavier than air vapors
- One universities policy on ductless hoods http://www4.uwm.edu/usa/safety/laboratory_safety/ductless_fumehoods.cfm

Hoods

Acid Resistant Hood

- Composite plastic – this one is not fire retardant plastic
- Controls in place – flammable and combustible liquids not allowed

Chapter 7: Hood Fire Protection

- Automatic fire suppression (7.10)
  - Provide in existing hoods with interior flame spread >25 with flammable liquid use (7.8.1.1 & 7.10.1(1))
  - If a hazard assessment shows need for suppression (7.10.1 (2))
  - Types of Suppression (7.10.2)
    - Automatic fire sprinklers
    - Dry or wet chemical
    - Carbon dioxide
    - Water mist
- Designed to suppress hood fire under anticipate conditions of use (size according to the hazard) (7.10.2.1)

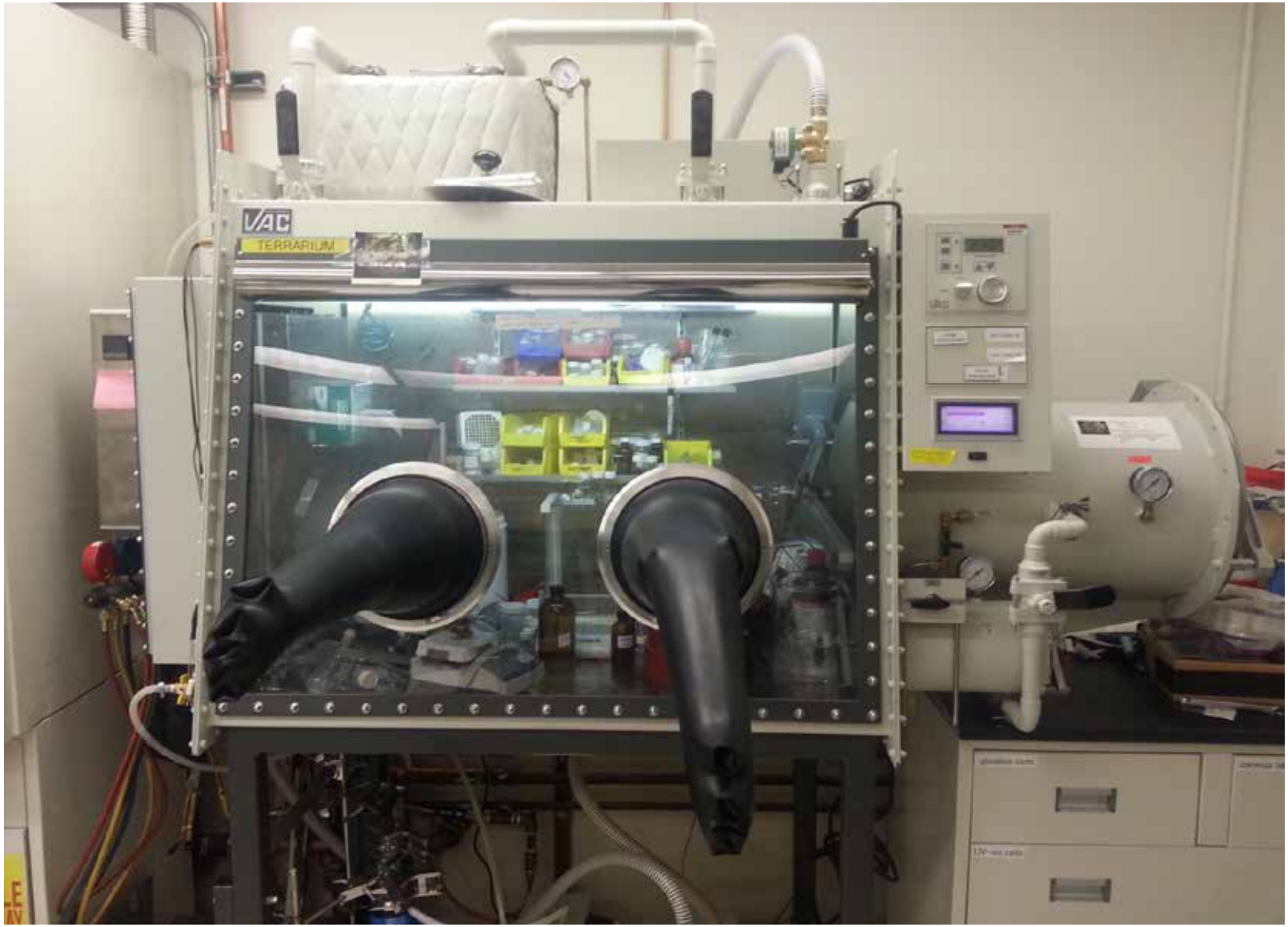
Chapter 7: Hood Fire Protection

- Design of ducts per NFPA 91 except specific NFPA 45 requirements have precedence (7.10.3)
- No automatic fire dampers in exhaust ducts (7.10.3.1)
  - Also see A.7.10.3.1
- Fire alarm system not interlocked to shutdown exhaust fans (7.10.4)
- If supply fans shutdown or dampers close off supply, may need to install pressure relief so that doors to labs will open for egress (7.10.5)
- VAV hoods need emergency override capability (7.10.6)

Chapter 7: Laboratory Ventilation

- Inert Atmosphere Glove Boxes (7.11)
  - Design and operate glove boxes in accordance with Section 4.1 of ANSI/AIHA Z9.5, Laboratory Ventilation (7.11.1)
  - Glove boxes that are vented shall be vented to the chemical exhaust system (7.11.2)
  - Operate glove boxes at positive pressure (7.11.3)
  - Provided pressure controls to limit the pressure inside glove boxes (7.11.4)
  - Provide glove boxes with pressure relief to prevent enclosure failure; glove failure is not acceptable pressure relief (7.11.5)

Inert Atmosphere Glove Box



Chapter 7: Perchloric Acid Hoods

- Required where perchloric acid is heated above ambient temperature (7.12.1)
- Stainless steel or acid resistant construction (7.12.2)
- Exhaust duct must take most direct route out of the building – no horizontal ducts or flex connectors (7.12.6)
- Water wash down system in baffles, ducts & fan with drainage (7.12.8)
- Not used for any other operations – no organic chemistry (7.12.10)
- Methods for testing and inspection of hoods (see also CRC Handbook of Laboratory Safety) (A.7.12.10)
- Alternative: Operations with fume scrubber - can use reflux head with sodium hydroxide solution scrubber or hood scrubber system (7.12.1 exception)

Perchloric Acid Hood

Perchloric acid hood

Perchloric Acid Hood Exhaust Fan

Perchloric acid exhaust fan

RAD Perchloric Acid Hood

Built-in Caustic Scrubber with 2 Levels of Scrubbing

Chapter 7: Laboratory Ventilation

- Identification for special use hoods and local exhaust systems (7.13.1)

Chapter 7: Laboratory Ventilation

- Hood inspection information available on hood or in log to provide inspection interval, date of last inspection, average face velocity, fan that serves hood and inspectors name. (7.13.2)

Chapter 7: Laboratory Ventilation

Inspection, testing, and maintenance for fume hoods, chemical exhaust systems, and special exhaust systems (7.14)

- New or modified systems and at least annually thereafter
- Includes:
  - Visual inspection of the physical condition
  - Measuring device for hood airflow
  - Test low/loss of airflow alarms
  - Face velocity
  - Verification of inward flow over the entire hood face
  - Changes in work area conditions that might affect hood performance

Chapter 7: Laboratory Ventilation

Inspection, testing, and maintenance (continued)

- Hood performance deficiencies: (7.14.2)
  - Suspend all activity in the hood until it is repaired
- Recheck hood performance after adjusting ventilation system balance (7.14.3)
- Air flow detectors/alarms tested annually or more often if corrosive of obstructive conditions exist (7.14.4)
- Fans and motors/components inspected and tested at least annually (7.14.5.1)
- Belts quarterly where air flow monitoring is not provided
  - Promptly replace frayed or broken belts (7.14.5.2 & 3)
- Quarterly inspection for fire extinguishing system nozzles
  - Clean as needed

Chapter 8: Chemical Handling and Storage

- Ordering Procedures (8.1)
  - Have a procedure/process for ordering chemicals and getting the information on the hazards, MSDS/SDS to those who will receive, store, use or dispose of the chemicals (8.1.1)
  - Follow governmental and company restriction (8.1.2)
- Facilities (8.2)
  - Buildings designed for quantities & hazards of the materials (8.2.2.2)
  - Storage and handling of hazardous chemicals in labs is limited to 5 gallons (20 liters) spill scenario (8.2.2.3)

Chapter 8: Chemical Handling

- Handling (8.2.3)
  - Receiving, handling, and unpacking by trained personnel (8.2.3.1)
  - Verify chemical compatibility of piping, ducts, or vessels that are used to transfer chemicals (8.2.3.2) – see A.8.2.3.2 also
  - Before use, determine how hazardous materials and waste will be disposed of (8.2.3.3)
  - Class I liquids shall not be stored or transferred from one vessel to another in any exit access corridor (8.2.3.4)
  - Chemical quantities outside of storage shall be maintained at the lowest possible level necessary for the work performed (8.2.3.6)

Special Storage

Gas Cylinder Storage Cabinets

Special Storage

Flammable Liquid Storage Cabinets

Storage in Corridor – Not Allowed

Chapter 8: Chemical Storage

- Maximum Allowed Quantities (MAQ) of hazardous materials other than flammable liquids as listed in the applicable building or fire code (8.2.4.1)
- MAQ reduced in labs based on lab floor level and lab unit classification (8.2.4.1.1-3)
- Limited to 5 gal (20 L) size containers in labs to limit the maximum spill for new materials and waste containers (8.3.4)

Chapter 8: Chemical Storage

- Storage
  - Segregation of incompatible materials (8.2.4.2)
  - Time sensitive chemical – date & track storage (8.2.4.4 & A.8.2.3.4)
    - Peroxide formers (ethyl ether)
    - Unstable reactive upon depletion of inhibitor (acrolein)
    - Explosive when dry (picric acid)
    - Gases corrosive to the container (hydrogen fluoride) (10.1.2 & A.10.1.2)
    - Test, treat or dispose of out dated chemicals (8.2.4.4.2 – 8.2.4.4.3)

Old Corrosive Gas Cylinder Hazard

Old Hydrogen Fluoride Cylinder
See A.10.1.2

Damage in lab

Chapter 8: Chemical Storage and Use

- Storage
  - Special storage for chemicals with unique physical or hazardous properties – Temperature sensitive chemicals - my need refrigeration or temperature control to store safely (8.2.2.2)
    - Organic peroxides, polymerization agents
    - Some spontaneously react above a certain temperature (SADT)
      - SADT is the Self Accelerating Decomposition Temperature of an Organic Peroxide: that temperature at which the heat generated by decomposition is greater than the heat removal capacity of the environment - hence the temperature increases thereby accelerating the decomposition
      - Examples:
      - Methyl ethyl ketone peroxide (MEKP): SADT > 60º C (140º F)
      - Diisopropyl peroxydicarbonate : SADT > -20º C (-4º F)
      - http://www.youtube.com/watch?v=98jOeCr06Xs

Chapter 8: Chemical Storage

- Storage (cont.)
  - Flammable liquid storage cabinets are not required to be vented for fire protection purposes (8.2.4.5)
    - Could be for health or facility concerns/stench chemicals
    - Vent flammable cabinets per NFPA 30 6.3.4
  - Storage of chemicals in hoods is prohibited (8.2.4.7)

Cabinet Venting (8.2.4.5)

What's wrong with this?
Supply air from the ceiling

- Cabinet Grounding?

Cabinet Venting (8.2.4.5)

PVC Venting?

Steel vent pipe with fusible link shutoff valve

Fume Hood with Chemical Storage

Is This Acceptable?

Chapter 8: Chemical Storage and Use

- Storage (cont.)
  - Routine inspection of chemical storage (8.2.4.6)
    - Verify proper storage/segregation/labeling of chemicals
    - No spills or leaking containers
    - Out of date chemicals
    - Inventory verification
    - Fume hoods not used for storage of chemicals
  - Waste Handling & Disposal (8.3)
    - Handled the same as new chemicals (8.3.1)
    - Evaluate reactions before mixing waste chemicals (8.3.2)
      http://www.depts.ttu.edu/vpr/integrity/lessons-learned/February-2015.php
    - Waste chemicals containers types and sizes per Table 9.1.2 and not over 5 gallons (8.3.4 & 8.3.5)
    - Waste containers subject to the maximum allowed quantities (8.3.6)

Poor Chemical Management

Good Chemical Management

Chemical Management Issues

Broken Acid Waste Storage Bottle – Note: Plastic coated bottles will break. Use vented caps to relieve pressure prior to shipping. See:
http://www.psix.com/products/proprietary-products/

Broken bottle of hydrogen peroxide breaks adjacent bottles of flammable liquids. Several storage issues in this cabinet!

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Table 9.1.1 Notes

- Maximum amount in open use is limited to 10% of total in use quantity is laboratory unit
  - NFPA 5000 3.3.641.2.2* Open System Use (Material). Use of a solid or liquid hazardous material in a vessel or system that is continuously open to the atmosphere during normal operations and where vapors are liberated, or the product is exposed to the atmosphere during normal operations.
- The quantity per 100 square feet is an average amount over the entire laboratory unit.

Chapter 9: Flammable Liquids

- Maximum container sizes for flammable and combustible liquids per Table 9.1.2 based on type of container
  - Glass – 4 L maximum for Class IC & II liquids
    - 9.1.2 (1) Exception for IA & IB if (a) corrosive to metal/plastic, (b) smaller glass bottles are not available, & (c) for purity reasons, 4L permitted
  - Metal can/safety cans/HDPE – 20 L except Class IA
  - Drums – limited to Class II & III
  - PDLC – 227 L except Class IA
  - 9.1.2(3) limits container size in Educational and Instructional labs

Chapter 9: Flammable Liquids

- Supply piping installed per NFPA 30 (9.2)
- Liquid dispensing (9.3)
  - Class I liquids limited to 20 L (5 gallons) (9.3.1)
  - In chemical fume hood or other approved area with adequate ventilation (9.3.1(1))
  - Large containers – outside or in “Inside Liquid Storage Area
- Liquid transfer operations
  - Bonding and grounding (9.3.3)
  - Non-metallic may require other measures to ground static (9.3.4)

Chapter 9: Flammable Liquids

- Pressurized Liquid Dispensing Containers (9.4)
  - Listed or labeled (9.4.1)
  - Vent relief to a “safe” location (9.4.3)
  - Piping/hose pressure rated and protected from mechanical damage (9.4.4)
  - Leak testing (9.4.5)
  - Remote means to isolate flow from the container – dead man switch, isolation valve or gas pressure shutoff valve (9.4.6)
  - Nitrogen or inert gas to pressurize container (9.4.7)
  - Gas supply with check valve to prevent backflow (9.4.8)

Chapter 9: Flammable Liquids

- Equipment (9.5)
  - Flammable liquid storage cabinets per NFPA 30 (9.5.1)
    - Note: IFC requires self-closing doors
    - Wood vs. metal cabinets http://cenblog.org/the-safety-zone/2015/02/flammables-cabinets-metal-or-wood/
  - Closed containers in refrigerated equipment (9.5.2)
  - Lab heating equipment must be designed for use with flammable and combustible liquids to prevent fires or explosions (9.5.3)
  - Ventilation of baths with flammable liquids to prevent accumulation of vapors (fume hood) (9.5.4)
  - Use rated electric motors where hazardous concentrations of vapors may be present (9.5.5)
  - Motors located in fume hoods or other special ventilation to prevent a flammable atmosphere do not need to be rated for hazardous location (9.5.6)

Special Flammable Liquid Waste Containers

HPLC Waste Safety Cans

- Quick-disconnect fittings to prevent spills
- Vent line to vent vapors to chemical exhaust (hood) or carbon filter
- Pressure relief to prevent back-pressure

Justrite Link: http://www.justritemfg.com/products/safety-cans-and-containers/laboratory-dispensing-containers/

Slope Jar Safety Can with Pop-up

Flammable Liquid Safety

- Flash point of flammable liquids & water mixtures
  - See NFPA 325 also charts available
- Flammable liquid storage cabinet events
  - Use only shelves from the cabinet manufacturer that are designed for the cabinet
  - Make sure that they are properly installed
  - Shelf collapse events (3)
  - Maintenance of cabinets
    - Make sure door latches latch
    - Self-closing doors close and coordinators work

Broken Latch

This door will not latch and will not provide protection for the flammable liquids in the cabinet

Good Latches

Chapter 10: Compressed Gas

- Gas cylinder safety (10.1.1)
  - Gas cylinders handled by trained personnel
  - Annex E – Gas Flammability
  - Annex F – Compressed Gas Safety Tips
  - Cylinders not needed for current operations stored outside of the laboratory unit per NFPA 55
- Cylinders not “In use” shall not be stored in the laboratory unit (10.1.6.4)

Chapter 10: Compressed Gas

- Special ventilation for gas cylinders (10.1.4)
  - Health hazard 3 & 4; health hazard 2 with no warning properties; and pyrophoric gases (10.1.4.2 & 3)
  - Lecture bottles in hood or other ventilated enclosure – see A.10.1.4
  - Larger cylinders stored in gas cabinets
  - Pyrophoric gases stored in gas cabinets with fire sprinklers (10.1.4.4)
  - Does not apply to gases that are health hazard 3 due cryogenic hazard with no other health hazards

Gas Cabinets

Gas Cabinet with Lecture Bottles

Gas Cabinet Used to Store Lecture Bottles of Toxic and Highly Toxic Gases

Chapter 10: Compressed Gas

- Cylinder Safety (10.1.5)
  - Cylinders secured by holders designed for such service (10.1.5.1)
  - Cylinders equipped with a regulator designed for the gas and marked with maximum cylinder pressure (10.1.5.2)
  - Regulator system with 2 gauges to show cylinder pressure and outlet pressure (10.1.5.2.1)
  - Where gas supply is outside of lab, provide a station regulator and gauge at point of use (10.1.5.2.2)
  - Cylinder shall have a manual shutoff (10.1.5.2.3)
  - Quick connect fitting prohibited (10.1.5.3)
    http://h2tools.org/lessons/incident.asp?inc=285&cat=2&val=1
  - Clamp gas hoses to push on connections – best practice

Cylinder Safety

Proper Cylinder Support

Double chains required for Seismic zones

Cylinders supported at 2/3 of height or higher with 1 support

Support for Small Cylinders

Chapter 10: Compressed Gas

- Cylinders in Use (10.1.6)
  - Connected to delivery system that was designed by a qualified person (10.1.6.1)
  - For instrument use, connected with a regulator (10.1.6.2)
  - “In Use” means: (10.1.6.3)
    - Connected to deliver gas to a laboratory operation
    - A single standby cylinder as a reserve
  - Cylinders not in use shall not be stored in lab (10.1.6.4)

Chapter 10: Compressed Gas

- Maximum allowable gas quantity in lab work area of a given size.
  - For compressed and liquefied gases (10.1.6.5 – 7)
    - Class A, B, & C per NFPA 55 Table 6.3.1
    - Lecture bottles limited to 25 (10.1.6.6)
    - Class D – 50% of amounts in NFPA 55 Table 6.3.1
  - Instructional laboratory work areas limited to: (10.1.6.8)
    - 10% of amounts in NFPA 55 Table 6.3.1
    - 10 lecture bottle size cylinders
  - Educational laboratory work areas limited to: (10.1.6.9)
    - 100 ft^3 of flammable and oxidizing gas
    - 1 lb of liquefied flammable gas
    - No health hazard 3 or 4 gases permitted

Chapter 10: Compressed Gas

- Cylinder storage and piping systems (10.2)
  - Per other applicable NFPA standards (51, 54, 55, 58)
  - Bulk systems
  - Piping standards
  - Point of use valves (accessible and within 6 ft.) (10.2.3)
  - Educational and Instructional labs need emergency gas shutoff valve at an exit from labs(10.2.3.4)
  - Pressure relief for every section of piping (10.2.4)
  - Design piping to a pressure greater than the maximum pressure under abnormal conditions (10.2.4..2)
  - PRV discharge to a safe location (10.2.4.3)
  - Piping identified at source and discharge points (10.2.5)
  - Components designed for gas in use (10.2.6)

Compressed Gas - Safety

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Separation Between Flammable and Oxidizing Cylinders

Chapter 10: Compressed Gas

Cylinder Installation

- Separation of incompatible gases per NFPA 55 7.1.10
  - Separation for flammable and oxidizing gases in labs
  - 1/2 hour fire barrier and interrupts the line of sight between the containers (7.1.10.2.1), or
  - 20 feet separation between cylinders, reduced to 5 feet if 1 of the gases is in a cabinet, 0 feet if both are in cabinets (7.1.10.2.2)
  - Cylinders without pressure-relief devices shall not be stored without separation from flammable and pyrophoric gases with pressure relief devices (7.1.10.2.3)
- Flashback Arrestors
  - Needed when fuel and oxidizing gases are connected to a torch or other equipment where gases mix
  - Check valves will not stop a flashback
  - Good video at: http://oxyfuelsafety.com/flashback-demo

Compressed Gas - Safety

Laboratory gas cylinders with 30 minute fire separation panel to separate flammable gases from oxidizing gases.
Meets OSHA/NFPA 30 minute barrier criteria.
5/8 inch type X sheetrock wrapped with sheet metal.

Chapter 10: Compressed Gas

- Outdoor gas cylinder installations (10.3)
  - Per NFPA 55
  - Store toxic and flammable away from building openings, exits, and building supply air intakes
- Cryogenic liquids (10.4)
  - Primarily nitrogen, argon, & helium; rarely oxygen or hydrogen
  - Prevent freezing of surrounding atmosphere to prevent condensing oxygen – oxygen enrichment (10.4.1.2)
  - Using cryogenic traps – watch out for oxygen in trap (blue glow)
  - Systems using liquid oxygen must prevent contact with organic material (10.4.2.1.3)
  - Proper design and pressure relief for Dewars (10.4.2)
  - Adequate ventilation for labs with cryogenic liquid use (10.4.3)

Outside Gas Storage

Outside Gas Storage

Outside Gas Storage

Outside Gas Storage

Cabinets with fire rated separation panels
Meet OSHA/NFPA 30 minute barrier criteria

Cryogenic Liquids

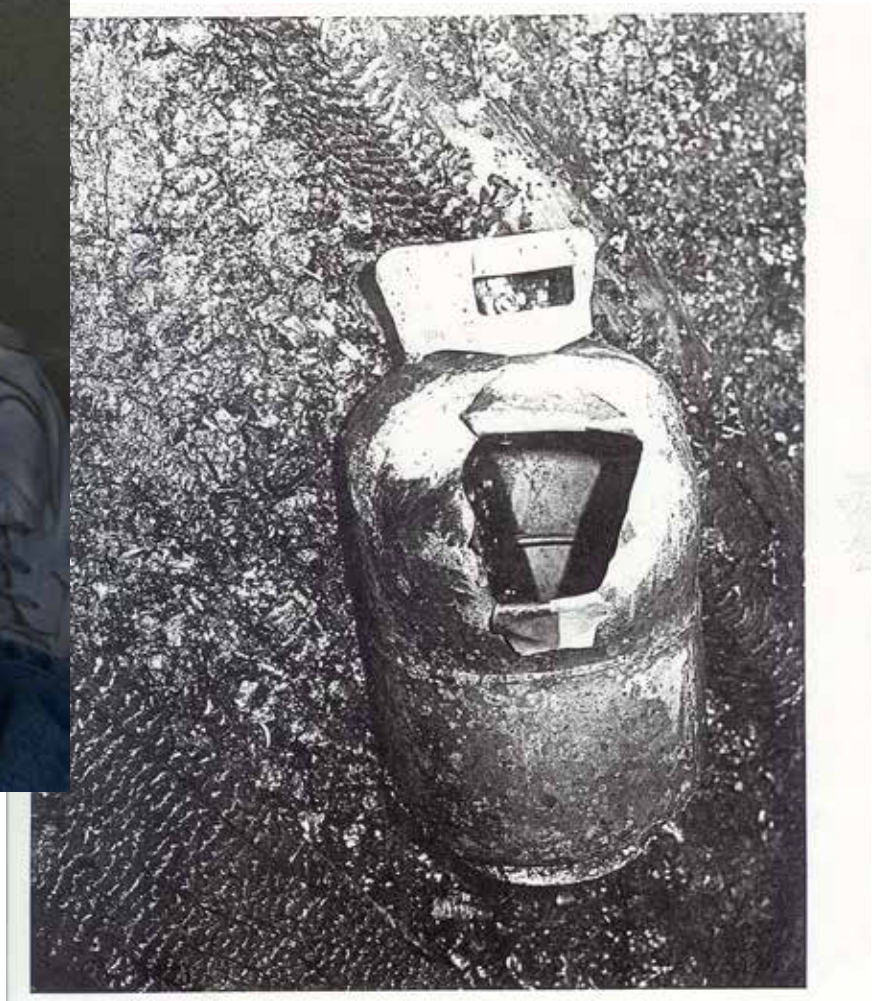
LPG Gas Safety

LPG outside
plumbed into lab

LPG tank in lab?

LPG Gas Safety

Label – “FOR OUTDOOR USE ONLY”



After an Exposure Fire

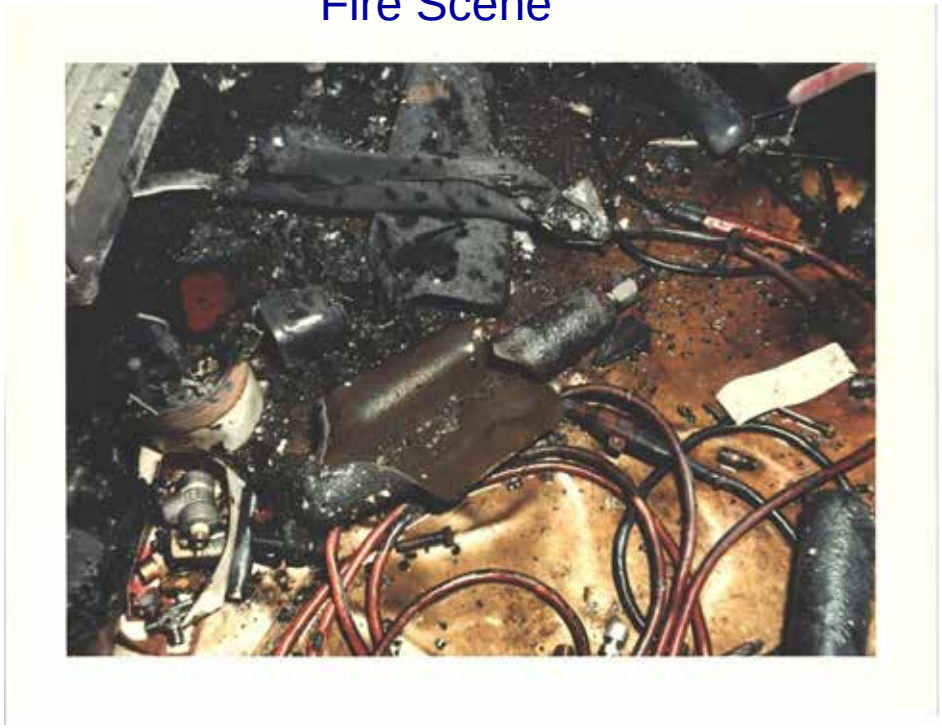
LPG Gas Safety

LPG Containers should not be stored in fume hood

Lecture Bottle Hazard

No PRV on lecture bottles

Fire Scene



Do Not Refill Gas Cylinders

Old blue print machine,
BUT
this could happen in a lab

Refilled ammonia cylinder
ruptures in office
when cylinder heats up

Chapter 11: Laboratory Operations

- Requirements of Chapter 11 are retroactive to all labs (11.1)
- Hazardous or Un-tried (1st time) reactions (11.2)
  - Preliminary evaluation to determine
    - Hazard properties and reactivity of materials/chemicals
      - What kind of process do you have to define the chemicals or hazardous materials the will be used and to evaluate the risks of the research activities
    - End products that will be created
    - Hazards of operations and associated equipment
    - Peer review of new reactions
  - Regular reviews of operations and procedures (11.2.1.3)
    - Special attention to change in materials, operation, or personnel

Chapter 11: Laboratory Operations

- Hazardous or Un-tried (1st time) reactions (11.2)
  - For reactions performed to synthesize new materials, control the hazards based upon the highest possible hazard based on the hazards of similar materials (11.2.1.4)
    - A.11.2.1.4 references NFPA 49, 325 & 491
  - Special controls/barricades for new materials that my present an explosion or rapid reaction (exothermic) (11.2.1.5)
    - Use the smallest scale possible
    - Double check calculations when scaling-up reactions https://www.aiha.org/get-involved/VolunteerGroups/LabHSCommittee/Pages/A-Bench-Scale-Chemical-Reaction-Results-in-an-Explosion-.aspx
  - Regular surveillance for unattended or automatic operations involving hazardous chemicals (11.2.1.6)

Chapter 11: Laboratory Operations

- Heating operations (11.2.2)
  - Heating of flammable/combustible liquids to minimize fire hazards (11.2.2.1)
  - Secondary containment for glass apparatus with > 0.25 liters heated to or over flash point (11.2.2.2)
  - Provide fire extinguishing equipment as needed (11.2.2.2)
  - Override and automatic shutdown for unattended operations for over temperature or if cooling equipment/services fail (11.1.2.4)
  - Don’t heat strong oxidizing materials with open flame or oil baths (11.1.2.5)

Chapter 11: Laboratory Operations

- Distillations and Separations
  - Equipment designed for operations (11.2.3.1)
  - Test for unstable reactive compounds (peroxides) (11.2.3.2)
  - Inspected prior to each use – especially glass apparatus (11.2.3.3)
  - Damaged equipment repair or discarded (11.2.3.4)
  - Prevent overheating
  - Provide ventilation for removal of flammable vapors
- Other Separation Operations
  - Provide adequate ventilation for filtrations, extractions, sublimations, adsorptions, evaporations, centrifuging operations, and other separation techniques (11.2.4)

Distillation Operations

Automatic Formalin Distillation Process

Chapter 11: Distillation Operations

Stills in Floor Mounted Fume Hood with Secondary Containment

Distillation Operations

Rotary Evaporator or ROTOVAP

Operated under vacuum with a heat bath to evaporate solvent from samples.

Hazards:

1. Implosions from damaged glassware or to high or vacuum.
2. Too hot of bath solution that causes the sample solution to boil.
3. Impurities in the sample solution such as peroxides that may cause an explosion when concentrated.
4. Unstable compounds in the sample solution such as nitro-compounds, organic azides, etc.

Pure-Solv System

Pure Solv – Solvent Dispensing System

Chapter 11: Laboratory Operations

- Mixing and Grinding (11.2.5)
  - Know the hazard properties of chemicals when mixing, grinding, stirring or agitating flammable or combustible materials (11.2.5.1)
  - Avoid overheating during mixing or grinding of solids (11.2.5.2)
  - Pure metals (unoxidized) are very dangerous (explosion hazard)

Flammable Dusts

- Finely divided metals in labs can results in a fire or explosion
  - Any un-oxidized metal can present a hazard
  - If you don't know the hazard, get it tested
  - Use inert gas to blanket grinding/mixing operations
  - Avoid plastic containers
  - Ground all equipment to eliminate static electricity
- Powdered chemicals could also be flammable if suspended in air
- Nano particles that are combustible can cause fires or explosions

Flammable Dusts

Chapter 11: Pyrophoric Reagents and Water Reactive Materials

- Pyrophoric reagents and water reactive solid and liquids
  - Handled in systems or enclosures that prevent the chemicals from igniting when a dry or an inert atmosphere is required by the manufacturer or the SDS (11.2.6.1)
  - Handled only by those with experience in their hazards and properties or under close, direct supervision by those with experience; do not work alone during transfers or cleanup operations (11.2.6.2)
  - Wear PPE per Section 6.6 (11.2.6.3)
  - Pyrophoric liquids dispensed in a chemical fume hood shall be from sure-seal-type bottles with syringes or double-tipped needles in accordance with the manufacturer's recommendation and nationally established laboratory safety practices (11.2.6.4)

Chapter 11: Pyrophoric Reagents and Water Reactive Materials

- Pyrophoric reagents and water reactive solid and liquids
  - Perform open dispensing of pyrophoric liquids only in an inert atmosphere glove box (11.2.6.5)
  - Handle/dispense pyrophoric solids in an inert atmosphere glove box (11.2.6.6)
  - Handle/dispense water reactive solids that are not protected by mineral oil or solvents in an inert atmosphere glove box (11.2.6.7)
  - Remove residual moisture and contaminates from reaction vessels, glassware, needles, and other lab equipment that will be exposed to pyrophoric reagents and water reactive materials. Purge with inert gas before use (11.2.6.8)
  - Do not use plastic syringes unless in inerted glove box

Chapter 11: Pyrophoric Reagents and Water Reactive Materials

- Pyrophoric reagents and water reactive solid and liquids
  - Backfill void space at the top of containers of pyrophoric reagents shall be backfilled with a high-purity dry inert gas as the reagent is removed (11.2.6.9)
  - Needles, spatulas, wipes, and tools that have been in contact with pyrophoric reagents and water reactive materials shall be stored in an inert atmosphere or shall be neutralized in accordance with the manufacturer's written instructions (11.2.6.10)
  - Pyrophoric reagents and water reactive materials in glove boxes shall be sealed in airtight containers when the chemicals are not in use (11.2.6.11)

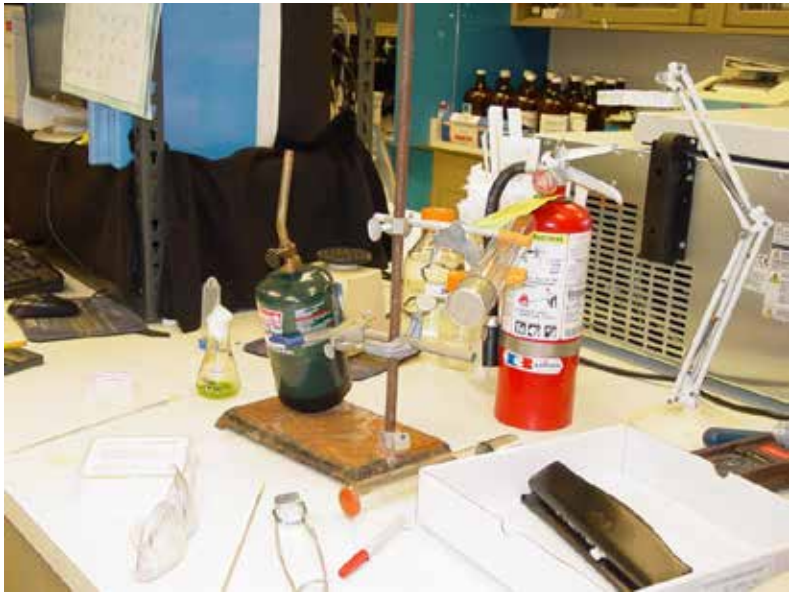
Chapter 11: Open Flame Operations

- Perform open flame operations in labs in accordance with: (11.2.7.1)
  - Use alternatives to open flame such as heating mantels, hot plates, glass bead sterilizers, or infrared loop sterilizers, whenever possible
  - Gas hoses/tubing rated for 150% of operating pressure; clamp tubing to gas supply outlet
  - Clamp, weight or hand held for small gas cylinders with a torch head attached.
  - Don’t perform open flame operations under shelves, cabinets, or other overhanging equipment.

Chapter 11: Open Flame Operations

Gas tubing clamped to gas supply outlet. Note: point of use valves and pressure relief device for each gas supply.

Torch support



Chapter 11: Open Flame Operations

- Biological Operations (11.2.7.2)
- Operations using open flame and flammable liquids performed in accordance with 11.2.7.1 and the following:
  - Open containers limited to 50 ml of flammable liquid and container must be glass or metal with a tight fitting slip on lid
  - Keep flammable liquid at least 12 inches away from the flame
  - Remove and store flammable liquids and other hazardous materials that are not in use
  - Keep combustible materials at least 2 feet away and do not use adsorbent paper under biological open flames

Chapter 11: Open Flame Operations

- Biological Operations – Other best practices
  - Open flame operations in bio-safety cabinets can disrupt the air flow within the cabinet – use alternatives whenever possible
  - Use of flammable liquids in bio-safety cabinets – most biosafety cabinets recirculate 80% of the air within the cabinet so flammable vapors are not removed
  - Fire events

Chapter 11: Laboratory Operations

- Other Operations (11.2.8)
  - Minimize hazards when operating at temperatures above or below ambient (11.2.8.1)
  - Use shielding whenever there is a reasonable probability of explosion or vigorous chemical reaction and hazards associated with filling, sampling, venting, or emptying systems (11.2.8.2)
  - Protection for glass apparatus (11.2.8.3)
  - Condense, trap or vent flammable gases/vapors (11.2.8.5)
  - Flammable paints and varnishes applied per NFPA 33 (11.2.8.6)

Chapter 11: Laboratory Operations

- Refrigeration and Cooling Equipment (11.3.2)
  - Mark lab refrigerators/freezers to show that they are or are not approved to store flammable liquids (11.3.2.1)
  - Refrigerators/freezers used to store flammable liquids shall be listed/approved for such use (11.3.2.2)
    - NFPA 45 2015 edition removed the provisions that allowed modifications to household refrigerators – approved refrigerators/freezers are commercially available
    - Cold rooms and environmental chambers should use the same criteria
  - Hazardous material refrigerators/freezers vs. explosion proof refrigerators/freezers
    - What is the difference between 11.3.2.2 and 11.3.2.3?
  - Limit quantity to 10 gallon or less
  - Events

Refrigeration and Cooling Equipment

Unapproved freezer

Refrigeration and Cooling Equipment

Approved Flammable Material Refrigerator/Freezer and Explosion Proof Refrigerator/Freezer

Refrigeration and Cooling Equipment

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"DRUG LAB FIRE CAUSES $7 MILLION IN DAMAGES"

Naeja Pharma Inc. Edmonton, Canada - July 2011
Fire started in a refrigerator used to store flammable chemicals – staff heard bottles popping and tried to fight the fire. No fire sprinklers – fire caused significant damage to the facility

Chapter 11: Laboratory Operations

- Heating Equipment (11.3.3)
  - Provide with over temperature shutoff if overheating could result in a fire or explosion (11.3.3.1)
  - Where circulation fans or water cooling are relied upon to cool laboratory equipment, provide interlocks to shut down heating elements if fans or cooling water fail (11.3.3.2)
  - Keep heat-producing equipment away from combustible/flammable materials and compressed gases (11.3.3.3)
  - Comply with NFPA 86 for oven and furnaces (11.3.3.4)

Chapter 11: Laboratory Operations

Combustible materials were placed on top of an oven over the oven exhaust vent that was in operation on a timer. The oven was in an off part of the cycle.

Chapter 11: Laboratory Operations

- Heated Constant Temperature Baths (11.3.4)
  - Provide with over temperature shutoff
  - Bath containers – noncombustible material
- Pressure Equipment and Vessels (11.3.5)
  - Design and construction for expected use with relief devices
  - Pressure relief or rupture disk vented to safe location
  - Routine Inspection/maintenance
  - Degraded equipment de-rating or discarded
- Analytical Instruments (11.3.6)
  - Install and operate per manufacturer's instructions
  - Provide barriers to protect against hazards

Chapter 12: School Laboratory Operations

- Requirements are retroactive where experiments are conducted or demonstrations are performed using hazardous materials (12.1)
- Responsibilities of Instructors (12.2)
  - Perform a risk assessment for hazardous experiments
  - Safety briefing for students
  - Provide appropriate PPE for students
  - Provide a safety barrier between the students and the demonstration/experiment
  - Instructors trained on fire safety procedures, emergency plans, hazards present in the lab, appropriate use of PPE, & how to conduct a risk assessment. (12.2.1)

Chapter 12: School Laboratory Operations

- Chemical Storage and Handling (12.3)
  - Store bulk quantities of chemicals in a locked room outside of the classroom in educational labs (12.3.1)
  - Chemicals stored and in use in an educational lab classroom shall be limited to the amount needed for one day's use, preapportioned to the amount needed for each class session
  - Chemicals that are not in use during an individual class session shall be kept in an appropriate, locked cabinet
  - Chemicals in an instructional lab shall be limited to the lowest possible level necessary and can't exceed the NFPA 45 limits in Chapter 9/MAQs in fire code (12.3.1.1)

Chapter 12: School Laboratory Operations

- Chemical Storage and Handling (12.3)
  - Dispensing of bulk quantities of chemicals for an experiment or demonstration shall be performed in a prep room outside of the classroom. (12.3.1.2)
  - For existing educational and instructional laboratories that do not have a separate preparation room, the dispensing of bulk quantities of chemicals for experiments or demonstrations shall be performed prior to the arrival of the students in the classroom (12.3.1.3)
  - The minimum amount of chemical(s) needed to perform the experiment or demonstration shall be transferred to a small, appropriately labeled sealed bottle (12.3.1.4)
  - Bottles of chemicals shall only be open in the classroom when the experiment or demonstration is being performed (12.3.1.5)

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- Performance of Experiments or Demonstrations
  - Perform experiments or demonstrations for students involving open flames; fire; or the use of flammable, reactive, toxic or corrosive chemicals in accordance with the following: (12.3.2.1)
    - Performed in a location that does not block access to the primary means of egress from the laboratory work area (12.3.2.1.1)
    - Experiments or demonstrations that involve or produce hazardous quantities of fumes, vapors, particulates, or gases shall be performed in a chemical fume hood or other ventilation device adequate to capture the materials being evolved – for classroom consider a demonstration type hood (12.3.2.1.2)

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Demonstration Type Chemical Fume Hood

Demonstration Type Fume Hood

- Used for teaching or classroom type settings
- Provides protection for observers for operations within the hood
- Provides the same protection for the user as a standard chemical fume hood.

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- Performance of Experiments or Demonstrations (continued)
  - Experiments or demonstrations involving chemicals that are performed outside a fume hood where the separation distance in 12.3.2.1.4 is not possible shall be performed behind an impact-resistant plastic or tempered-glass safety shield (12.3.2.1.3)
    - Minimum 24 inches high and 12 inches beyond the sides of the hazard and wrap 180° the hazard
    - Secure the shield
  - Where a shield is not used, provide at least 10 feet of separation from the students

Chapter 12: School Laboratory Operations

Bench Top Shield

Chapter 12: School Laboratory Operations

- Performance of Experiments or Demonstrations (continued)
  - Experiments or demonstrations using flammable liquids and open flames shall be performed by a knowledgeable instructor. (12.3.2.2)
  - In educational and instructional laboratories where experiments are conducted by students, the instructor shall be responsible for conducting a safety briefing prior to the start of each experiment to review the hazards of the chemicals used, the personal protective equipment required for the experiment, and a review of the emergency procedures (12.3.2.3)

Chapter 13: Hazard Identification

- Requirements of Chapter 13 are retroactive to all labs (13.1)
- Signs at entrances to labs – NFPA 704 does not work well (13.2.1 & A13.2.1)
  - Warning signs for unusual or severe hazards or conditions
  - The hazards shall be communicated in the plans for fire fighting
  - Marking hazardous exhaust systems to warn personnel of possible hazards (13.3)
  - Mark hazardous material containers

Chapter 13: Hazard Identification

- Container Marking (13.4)
  - Hazardous material containers, original and secondary containers, must be marked with the container contents and precautionary information (13.4.1)
    - Small containers, like micro-vials, can be labeled with a numbering system. Maintain log in the lab. See A.13.4.1.
  - Label containers of materials that become hazardous during prolonged storage shall be dated upon receipt and when first opened. Include the expiration date. (13.4.2)
- Label per applicable ANSI Z535.1, Z535.2, Z535.3 or Z535.4 (13.5)

Chapter 13: Hazard Identification

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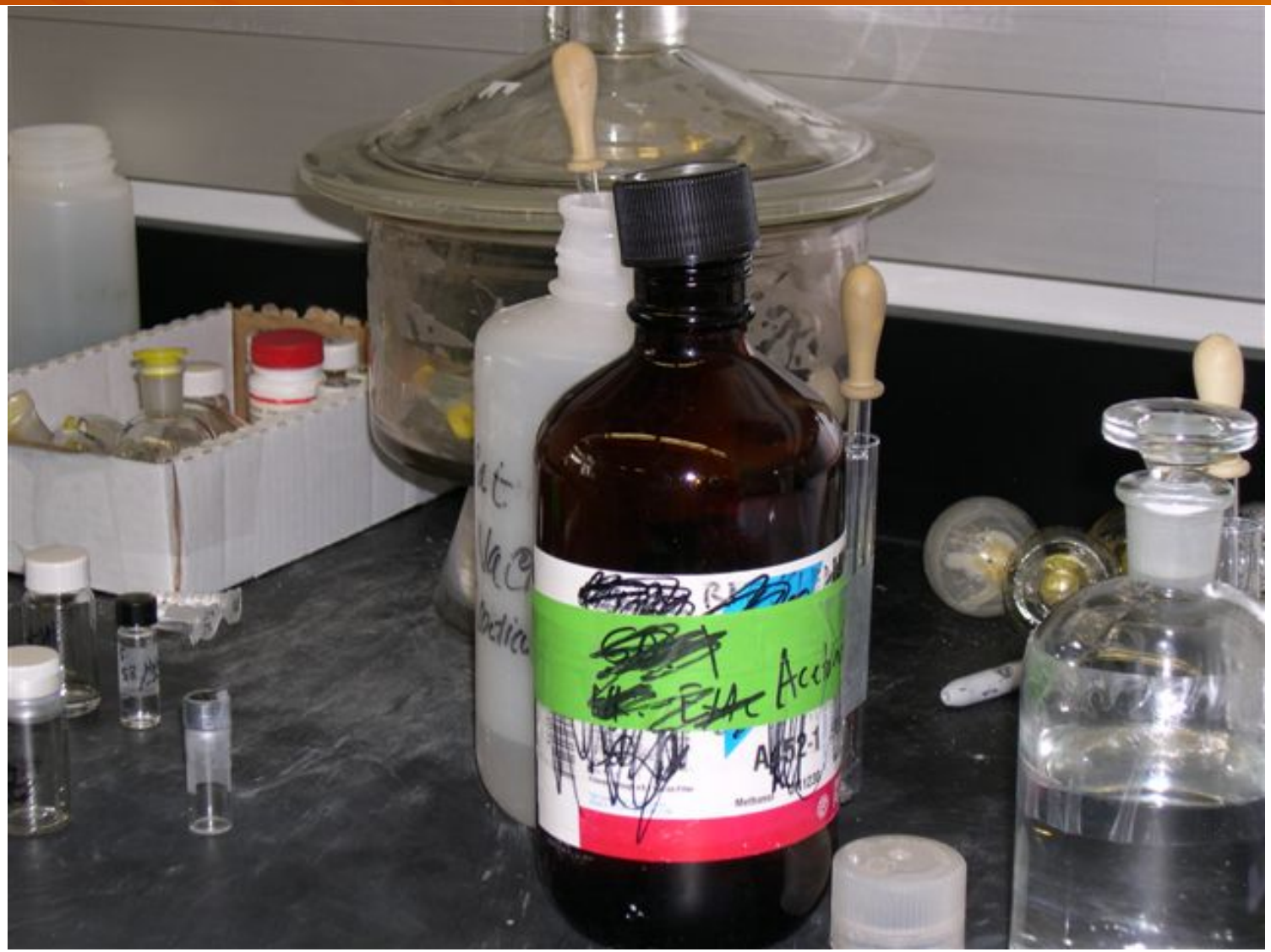
Unique Hazard Posting

Multiple Hazard Awareness Posting

Labeling



Lab Operations

- Other Chemical Management Issues
  - Acid–Organic Reactions
  - Waste Chemical Management
  - Failure to Follow Procedures
  - Sample Chemical Process Permit
  - Sample Compressed Gas Use Plan
  - Scott Compressed Gas Design and Safety Handbook
- NFPA Analysis of Lab Fires

Lab Operations

Resent E-mail Message on Lab Safety List Server:

Our Powers-That-Be also setback the campus during breaks, but we are opted out of those setbacks for reasons of safety and animal care. Just in case, I remind them before every break. They always tell me "we know," but I just want to cover our bases, especially since I am the one who is called if there is an incident. We had one incident Thanksgiving 2006 when one enthusiastic HVAC tech setback our building over the break by mistake. I got called in on Friday when the problem was actually with animal care. If you haven't already, made friends with your facilities people and make sure they know that science buildings should not be setback. Science buildings will need temperature controlled and exhaust maintained for safety reasons.

Best of luck.

Linda

At 11:54 AM 6/18/2008 -0400, you wrote:

One holiday weekend in Oklahoma the powers-that-be decided to shut off the AC over the 3-day weekend. On Monday morning, one of our chemists took a bottle of Bromine off the shelf, went to the hood and opened it. The entire hood filled with Bromine vapor, overwhelming the hood exhaust and causing the chemist to inhale the fumes. Although she was wearing safety glasses they did not protect her eyes from the vapor. She suffered eye, nose, mouth and sinus burns and could not see, smell or taste for several days.

Although she did recover completely, she transferred to a non-lab position.

To this day I always store Bromine in the refrigerator.

Biological Labs

Bio-reactors

Incubators

Anaerobic glove bags

http://www.columbiatribune.com/news/2010/jun/28/explosion-injures-4-mus-schweitzer-hall/

Annex C: Explosion Hazard Protection

- Explosion protection to consider:
  - Limiting quantities of such chemicals
  - Using special protective measures (shields)
    http://cen.acs.org/articles/90/i21/Safety-Alert-Explosion-During-Prep.html
  - Using explosion-resistant construction http://cenblog.org/?s=nitric+oxide+event
  - Limiting access to area
  - Using explosion suppression in combination with explosion venting
- Chemical fume hoods do not provide blast protection unless specifically designed to do so – (7.2.3)

NFPA Technical Support

- Members' Advisory Service: (617) 770-3000
- Questions by FAX: (617) 984-7110
- NFPA Publications: 1 (800) 344-3555
- NFPA Web Site: http://www.nfpa.org/
- Formal interpretation: Use "Formal Interpretation Request Form"

NFPA 45: How You Can Participate

- As soon as the standard is adopted, the timer starts on a new review cycle – 4 year cycle
- Next Edition 2019
- Anyone may submit a proposal or comment to change the content of the standard
  - Proposal MUST be on proper NFPA form

NFPA 45: How You Can Participate

- To be considered for membership on a committee, you must submit an application.
- Not required to be a member of NFPA
- Categories of members
- "Technical Committee Membership Application"
  - Committees must be "balanced"
  - Committees have waiting lists

NFPA 45: How You Can Participate

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Staff Liaison, Technical Committee on Laboratories Using Chemicals

Laura Montville

National Fire Protection Assn.

1 Batterymarch Park

P.O. Box 9101

Quincy, MA 02269

Contact Information

Andrew (Andy) Minister P. E.

Chief Fire Protection Engineer

Fire Protection Engineering

Pacific Northwest National Laboratory

PO Box 999, MSIN J2-38

Richland, WA 99352

Phone 509-371-7902; Cell 509-308-7658

Fax 509-371-7890

andrew.minister@pnnl.gov

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Questions?

Promote fire safety!

NFPA 45

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End

Thank you