A Guide on Laboratory Design & Certification; Three Critical Criteria

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Laboratory Design & Certification; Three Critical Criteria
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About this Guide

The purpose of the Laboratory Design & Certification; Three Critical Criteria Guide is to provide laboratory owners, operators, design professionals and any other stakeholders a reference for laboratory design and safety guidelines. The Guide outlines the main codes, standards and regulations to help guide the designers, lab users, stakeholders and authority having jurisdiction (AHJ) in order to make the best decision.

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1 Executive Summary

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There are countless laboratory design standards, guidelines and practices to review and observe during the design process. This Laboratory Design & Certification; Three Critical Criteria Guide(the Guide) helps summarize, consolidate, and allow for initial design evaluation to ensure the laboratory stakeholders are making informed design decisions.

Safety is the first design criterion when designing a laboratory and this document will help provide options and resources for stakeholder decision making. Ventilation, Fume Hood Certification and Maximum Allowable Quantity Evaluations are just a few of the major safety considerations during the design process that the Guide addresses. Every laboratory must be evaluated individually, and there are several other safety criteria that need to be reviewed when designing a laboratory; however, these three topics are crucial for laboratory safety and functionality.

> "Safety is the first design criterion when designing a laboratory "

Laboratory ventilation is highly variable and sometimes difficult to determine. The Guide outlines the main codes, standards and regulations to help the designers, lab users, stakeholders and authority having jurisdiction (AHJ) make the best decisions.

The fume hood certification process is also discussed within the Guide, and describes each prescriptive fume hood certification test, as outlined in ASHRAE Standard 110 – 1995 (Updated in 2016), Method of Testing Performance of Laboratory Fume Hoods. Although passing criteria must be evaluated by lab users, designers and safety officials; the Guide provides some typical passing criteria that may be used for reference.

Lastly, Maximum Allowable Quantity (MAQ) is reviewed within the Guide. Strategies for meeting the acceptable limits for hazardous materials within typical buildings is presented.

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DESIGN CRITERIA

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2 Laboratory Ventilation

When designing a laboratory, identifying the proper ventilation is a crucial aspect of the design process. Many different variables must be considered when evaluating how to properly ventilate and control the lab space to ensure occupant safety. Every laboratory must be evaluated with facility Environmental Health and Safety (EH&S) officials, laboratory users, design staff and any other stakeholders. Every laboratory is different. Identification of chemicals, occupancy, schedules, storage, and any other relevant factors must be considered.

There are many documents that may be referenced when designing a laboratory space. Particularly in education laboratories where there may be a wide range of tasks and occupants throughout the lifecycle of a space. The following codes, standards and regulations may be used for initial evaluation; however, final ventilation rates must be a consensus decision with all laboratory stakeholders, safety officials, local code enforcement officials and the authority having jurisdiction (AHJ). The local AHJ has ultimate authority, and it is important to review all design intent and parameters with him/her during design.

International Mechanical Code, 2012 – Table 403.3

Table 403.3 lists 'Science Laboratories' under the Education sub-classification as requiring:

- 10 CFM/person and 0.18 CFM/sq. ft; with a minimum exhaust rate of 1.0 CFM/sq. ft.

Additionally, it is noted that, "Mechanical exhaust is required and recirculation is prohibited except that recirculation shall be permitted where the resulting supply airstream consists of not more than 10 percent air recirculated from these spaces."

ASHRAE 62.1, 2010 – Table 6-1

ASHRAE 62.1 and the IMC are mostly aligned, as is the case with laboratory ventilation rates. Under the Educational Facilities sub-category, the table lists 'Science Laboratories' and 'University/College Laboratories' as both requiring:

- 10 CFM/person and 0.18 cfm/sq. ft.

Furthermore, Table 6-4 lists 'Educational Science Laboratories' as requiring a minimum exhaust rate of 1.0 cfm/sq. ft.

Prudent Practices in the Laboratory - Handling and Management of Chemical Hzards, 1995

OSHA 29 CFR Part 1910 Appendix A references this book when discussing laboratory ventilation. Within Table 9.3 of the text, 'General Laboratory Ventilation' is listed as '6-12 air changes per hour, depending on laboratory design and system operation'.

2015 ASHRAE Handbook – HVAC Applications

The ASHRAE Handbook, Chapter 16 mentions that "Fixed minimum airflow rates of 4 to 12 air changes per hour (ACH) when the space is occupied have been used in the past. Recent university research (Klein et al. 2009) has shown a significant increase in dilution and clearing performance by increasing the air change rate from 6 to 8 ACH with diminishing returns above 12 ACH".

NFPA 45: Standard for Fire Protection for Laboratories Using Chemicals, 2015

The NFPA 45 standard typically provides general standards and best practices for ventilation within laboratories. However, in Appendix A: A.7.2.2, the standard states that a "minimum ventilation rate for unoccupied laboratories (e.g., nights and weekends) can be as low as four air changes per hour with proper laboratory operations and storage of chemicals. Occupied laboratories typically operate at rates greater than six air changes per hour, consistent with the conditions of use for the laboratory. Occupied laboratories should determine their supply airflow based on cooling requirements, amount of exhaust air required for the hoods or exhaust devices in the lab, whichever is greatest. Use of only an 'air change per hour' criteria is not considered proper design.

ANSI/AIHA Z9.5-2003: American National Standards for Laboratory Ventilation

ANSI Z9.5 provides general, non-prescriptive discussion of laboratory ventilation and references many of the standards referenced herein. Section A6.3.3 references NFPA 45, in which minimum ventilation rates are recommended to be a minimum of 4 air changes per hour (ACH), while occupied laboratories typically operate at rates greater than 8 ACH.

In conclusion, these are a several codes, standards and regulations that may help guide the decision of how to design a laboratory ventilation system. Final design direction must be reviewed with laboratory users, stakeholders, EH&S and the local AHJ.

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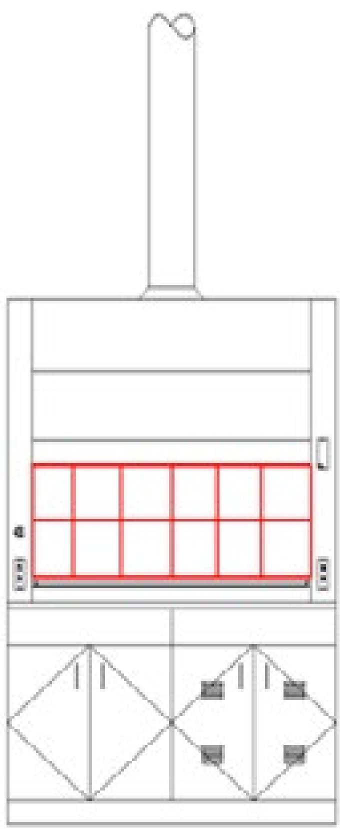
3 Fume Hood Certification

Cost Savings

ASHRAE Standard 110 – 1995 (Updated in 2016), Method of Testing Performance of Laboratory Fume Hoods, is the most widely accepted certification process for laboratory fume hoods. The purpose of the standard to define reproducible methods of fume hood testing. It is often thought that ASHRAE 110 provides a prescriptive passing criteria or safety measures, however it merely provides testing criteria. It is up to the testing agent, user and/or operator to define the passing criteria, depending on the fume hood application. The testing criteria can be best summarized as follows:

Face Velocity Measurements

Testing agent form an imaginary grid and reads face velocity within each rectangular grid using an anemometer.



Hood Face-Velocity Test Results:

	Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Row 1	89	85	88	89	92	104
Row 2	101	95	94	90	101	107

Figure 1 - Face Velocity Grid & Sample Test Results

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Figure 2 - Face Velocity Measurement Using Anemometer

Exhaust Air Stability

The purpose of the exhaust air stability test is to verify uniform and consistent exhaust. The test calls for measurement of slot velocity (or exhaust duct velocity). Readings are provided which then calculate a 'Coefficient of Variation (COV)', as follows:

$$COV = 3^* (\sigma/average)$$
$$\sigma = \text{standard deviation}$$

Figure 3 - Exhaust Slot Measurement Using Anemometer

Expected coefficient of variation typically shall be below 10%.

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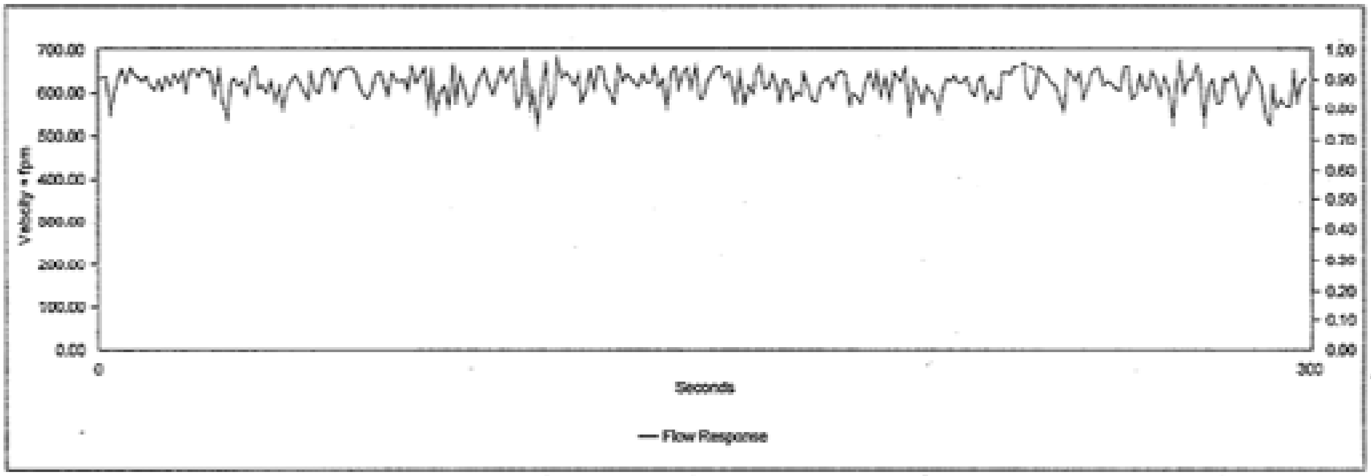
Exhaust Air Flow Stability Test

Report printed on 3/22/2012

Hood:	327-3	Sash Opening:	18" sash height	# Samples:	1
Date:	3/14/2012	Other Test Conditions:		Sample Duration:	300
Cycle:	1			# Samples per Second:	1



		Flow Response
	Average:	619
1 ... 300 seconds	Maximum:	682
	Minimum:	525

Speed of Response Rating:	N/A	Stability Rating:	Pass
Speed of Response Time:	< N/A seconds	Stability Percent Variation:	1%
VAV Comment:			

Figure 4 – Sample Exhaust Air Stability Results

Variable Air Volume (VAV) Linearity

The VAV Linearity test is used for laboratory fume hoods that implement VAV controls that modulate with sash movement to maintain a desired face velocity. The VAV Linearity test calls for measurement of face velocity during movement of sash positions. Measurements are taken to identify time elapsed for face velocity to stabilize back to design condition after sash movement.

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Figure 5 - Testing Agent Moving Sash

A testing agent may move the sash to positions such as 6″ to 18″ (measure); 18″ to 28″ (measure); 28″ to 18″ (measure); 18″ to 6″ (measure). This allows a full spectrum of sash movement and position measurement.

Typical acceptable results of VAV Linearity may be between 5 and 10 seconds for stabilization to occur.

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VAV Speed of Response

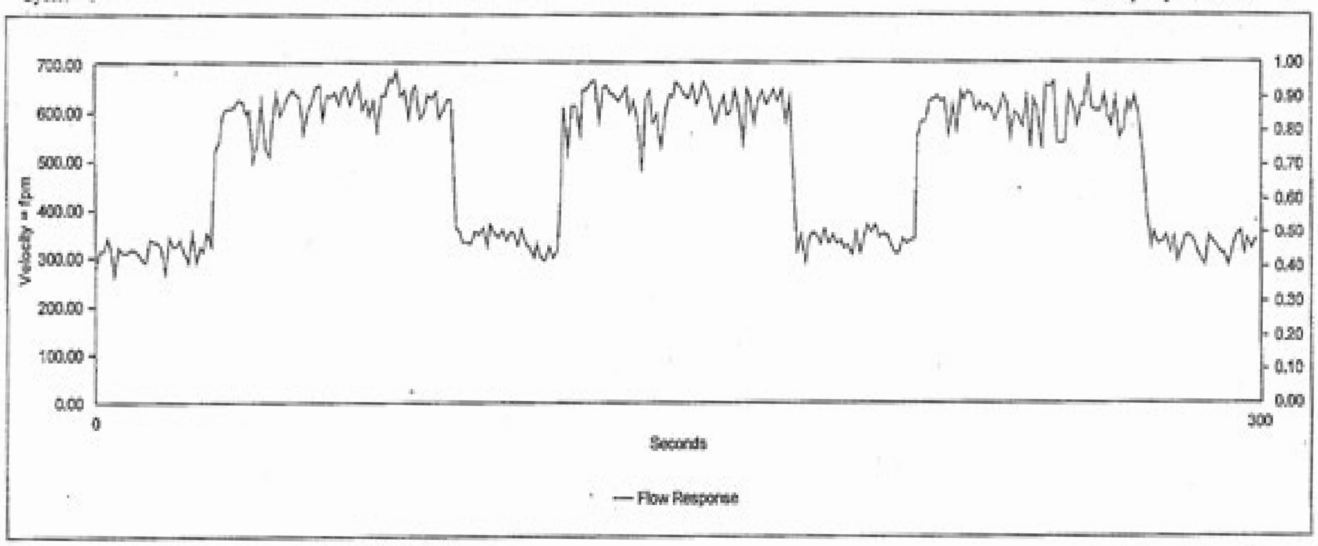
The VAV Speed of Response test measures the time, measured from the start of sash movement, for the VAV system to restore slot velocity or airflow. Similar to the VAV Linearity test, this is a speed of response test in a variable air flow design.

A typical test may include the following steps:

- Closed sash for 30 seconds.
- Open sash to 18"; hold for 30 seconds.
- Closed sash for 30 seconds.
- Repeat 3 times for 5-minute test

VAV Speed-of-Response Test — Report printed on 3/22/2012

Hood: 327-3 | Sash Opening: 6" sash height | # Samples: 1
Date: 3/14/2012 | Other Test Conditions: | Sample Duration: 300
Cycle: 3 | | # Samples per Second: 1



		Flow Response
1 .. 300 seconds	Average:	498
	Maximum:	688
	Minimum:	266

Speed of Response Rating: Pass
Speed of Response Time: < <5 seconds
VAV Comment:
Stability Rating: N/A
Stability Percent Variation:

Figure 6 - Sample VAV Speed of Response Results

Smoke Visualization Tests

There are typically two smoke visualization tests conducted to identify (and observe) a hoods ability to contain vapors. They consist of a low-volume (or local) and high-volume tests. A testing agent (or mannequin) is located in front of the hood sash in order to show real operating condition of a laboratory user location. Typically, a smoke machine or dry ice vapors are used for smoke/vapor creation.

The low-volume (or local) test calls for small amount of smoke/vapors at various locations within the hood, including the airfoil, baffle, and back slots. The testing agent observes the smoke at these locations to ensure total capture of smoke/vapors in the fume hood without escape.

The high-volume test calls for a large (plume) of smoke to be released within the hood, typically at a stationary position. The testing agent again observes the smoke/vapor to ensure total capture.

Since this is a subjective or observant test, typical test results may be as follows:

- FAIL: Smoke observed escaping from hood, lazy flow along sash/airfoil.
- PASS: Smoke to back of hood and exhausted, no observed potential to escape.

Tracer Gas Containment Test

For objective, measurable results a Tracer Gas Containment Test may be conducted. Typically sulfur hexafluoride (SF6) is used for the trace gas. This is a colorless, odorless, non-toxic, non-flammable gas that may be measured at very low concentrations. However, SF6 is a greenhouse gas with very high global warming potential, so there has been recent interest in finding alternatives that are environmentally friendly. The gas (SF6) is quite heavy, so if there are much lighter gases/vapors being used in a fume hood, another alternative may be pursued. A mannequin is positioned 3" in front of the fume hood. The mannequin is provided with a port located at the mouth/nose area with gas tubing that is then connected to a sampling probe. The sulfur hexafluoride canister/tank is piped to a release cylinder, which is located in the middle of the fume hood (typically 6" in from the sash). The canister then releases the gas at a rate of 4.0 liters/minute.

Figure 7 - Tracer Gas Containment Test Setup

Typical acceptable maximum control levels may range from 0.05 ppm to 0.1 ppm.

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Sash Movement Containment Test

A Sash Movement Containment Test allows for measurement of potential gas/vapor escape from the fume hood during sash movement. The test allows for evaluation of exhaust control reaction time and containment capability. This may be conducted on VAV and CAV systems.

Figure 8 - Tracer Gas Tests Setup

Using the same mannequin setup as the Tracer Gas Containment, the test is conducted in a 5-minute measurement period. Typically, measurements are taken every second for 5 minutes, with following:

- 30 seconds with sash closed.
- 60 seconds with sash open.
- Repeat for 5 minutes.

A typical maximum allowable average tracer gas spike magnitude is 1.0ppm with a 5sec to 10sec recovery to stability.

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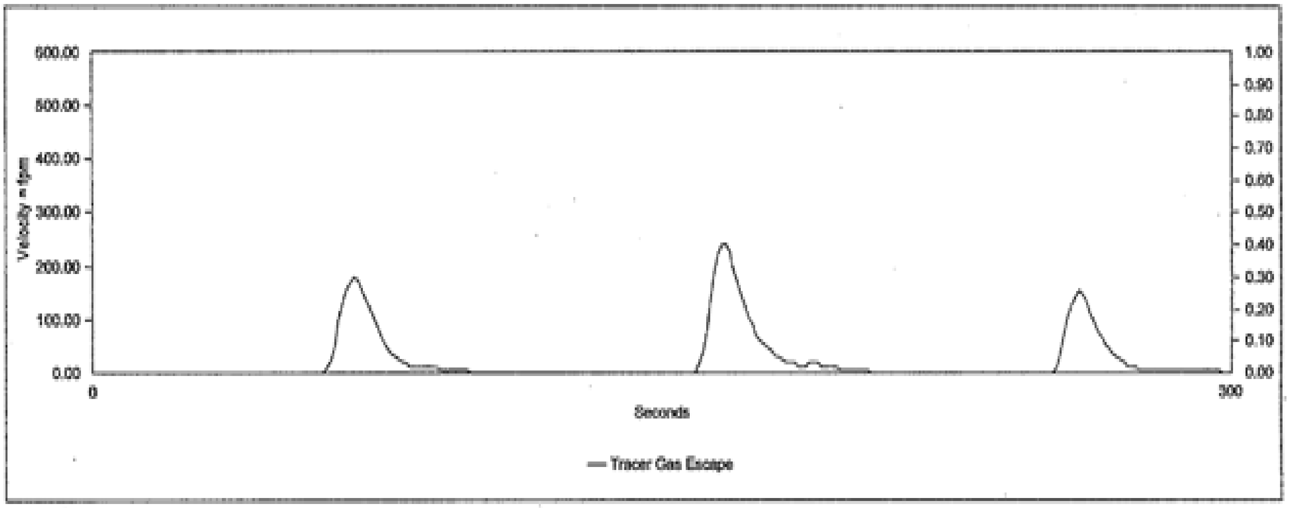
VAV Sash Movement Effect Test Report printed on 3/22/2012

Hood:	327-4	Sash Opening:	VAV Linearity Test	# Samples:	1
Date:	3/13/2012	Other Test Conditions:		Sample Duration:	300
Cycle:	4			# Samples per Second:	1



		Tracer Gas Escape
1 .. 300 seconds	Average:	.04
	Maximum:	.40
	Minimum:	.00

Speed of Response Rating:		Stability Rating:	
Speed of Response Time:		Stability Percent Variation:	
VAV Comment:			

Figure 9 – Sash Movement Containment Test Sample Results

3 Fume Hood Certification

Additional Tests

In some cases, laboratory operators may seek to provide additional testing not listed within ASHRAE 110. This may be due to particular EH&S standards, laboratory/chemical use, or operation variability. Some of those tests may include:

- Room Smoke Tests

Similar to Visualization tests, discussed herein, the room smoke test may be used for visual assurance that the laboratory itself (not just fume hoods) are under negative pressure from adjacent spaces. Additionally, this provides visualization of smoke paths within the laboratory.

- Adjacent Space Differential Tests

Similar to Room Smoke Tests, this allows for objective, measurable data to ensure laboratory spaces are negative to adjacent spaces.

- Occupant Movement Tests

All tests described within ASHRAE 110 are static as it relates to occupant movement. In a real laboratory environment, occupants/users will be moving within the space during fume hood operation. Tests may be developed that simulate movement of occupants in front of the sash to ensure proper fume hood capture.

- Room Air Testing

US EPA Methods for Determining Air Pollutants in Indoor Air or other sampling methods may be used for lab space air testing during fume hood use.

4 Maximum Allowable Quantities of Hazardous Materials

Applicable building and fire codes set acceptable limits for hazardous materials within typical buildings, through a concept known as control areas. The specific content of this guide is based upon the 2009 Edition of the International Building Code (IBC), which is currently the model code for numerous states.

Control Area Basics

One method of addressing the use of high-hazard materials within a building is to classify the occupancy as a Group H occupancy. Group H occupancies have relatively high limits on the amount of high-hazard materials. However, Group H occupancies have higher construction cost, lower flexibility of use, and stricter limits on maximum height and area. In many situations, control areas can be utilized as an alternative to classifying a space as a Group H occupancy. A 'control area' is defined by the IBC as, "Spaces within a building where quantities of hazardous materials not exceeding the maximum allowable quantity per control area are stored, dispensed, used or handled." The control area concept gives the building user more flexibility by limiting the use of hazardous materials in each control area instead of throughout the building. The model codes provide more flexibility because control areas require breaking up the building into numerous fire compartments that are bound by fire barriers (rated walls) and horizontal assemblies (rated floors). It is important to note that although the definition of control areas discusses indoor areas, there are also limits on storage in outside control areas.

Impact of Floor Level Above Finished Grade on Control Area Compliance Strategy

One of the most important considerations when developing a control area strategy is to account for the effects of storage, use, or handling of hazardous materials on floors other than the first floor above grade plane. This issue is often overlooked in the early phases of projects and can lead to construction delays, costly change orders, and space that does not meet future needs. There are more restrictions on storage, use, and handling of hazardous materials on floors other than the first floor above grade plane due to emergency response challenges.

The following parameters vary based upon floor level in relation to grade plane:

1. **Number of allowable control areas on each floor.** The first floor above grade plane may be subdivided into four control areas. Locations three or more stories below finished grade are prohibited from storing hazardous materials. All other floors allow less than four control areas. Refer to Figure 10 for details on the number allowable control areas per floor.
2. **Required fire resistance to separate control areas.** A 1-hour fire resistance rating for walls and floors / ceilings is required to separate control areas for floors ranging from two stories below grade plane to three stories above grade. 2-hour fire resistance rated walls and floors/ ceilings are required to separate control areas for floors located four or more stories above grade.
3. **Limits on allowable quantities of hazardous materials on each floor.** The

maximum allowable quantity (MAQ) of each specific type of hazardous materials for the first floor above grade plane are listed in Table 307.1(1) and 307.1(2) of the IBC. On all other floors, only a percentage of the first floor MAQ is allowed in each control area. This percentage can range to as low as 5% of the at grade plane floor for floors seven or more stories above grade plane.

The following example illustrate how drastic the effect of floor level can have on MAQ:

- On the first floor above grade plane:
    - Number of control areas allowed: 4
    - Fire resistance rating required: 1-hour
    - MAQ: 100% of Table 307.1(1) and 307.1(2) values in each of the four control areas
- On the tenth floor above grade plane:
    - Number of control areas allowed: 1
    - Fire resistance rating required: 2-hour
    - MAQ: 5% of Table 307.1(1) and 307.1(2) values in the single control area
- Conclusion: Eighty times more hazardous material can be stored, handled, and used on the first floor above grade plane when compared to the tenth floor above grade plane. Additionally, separation requirements are 1-hour vs. 2-hour on the first floor.

4 Maximum Allowable Quantities of Hazardous Materials

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	FLOOR	GRAPHICAL REPRESENTATIVE OF MAQ AND # OF ALLOWABLE CONTROL AREAS	ALLOWED CONTROL AREAS	% OF 1ST FLOOR MAQ	FIRE SEPARATION (HRS)
ABOVE GRADE PLANE	10+		1	5%	2
	9 8 7		2	5%	2
	6 5 4		2	12.50%	2
	3		2	50%	1
	2		3	75%	1
	1		4	100%	1
BELOW GRADE PLANE	B1		3	75%	1
	B2		2	50%	1
	B3+	NOT ALLOWED			

Figure 10 – Effect of Location Above / Below Grade Plane on Control Area Strategy

4 Maximum Allowable Quantities of Hazardous Materials

Other Considerations that Affect MAQ per Control Area

There are some ways to increase the MAQ in a given control area. One of the most common MAQ increases is a 100% increase in MAQ allowed for most hazardous materials when the building is fully sprinklered. It is important to note that the entire building must be fully sprinklered per NFPA 13, not just the control area in which the increase is sought. Another potential 100% increase in MAQ for specific hazardous materials can be realized by storing the hazardous materials in a given control area in approved storage cabinets, day boxes, gas cabinets, exhausted enclosures, or listed safety cans. This increase can be critical to provide the owner flexibility, particularly in labs at higher elevations. Each hazardous material arrangement is different and it is important that a full hazard analysis be performed against all applicable condes and standards.

Challenges and Recommendations for Continued Compliance

One challenge Owners face is ensuring long-term compliance with the control area strategy at the time of construction. Often times, the compliance strategy is not clearly documented or communicated to the Owner by the design team. Buildings containing labs frequently undergo changes of use and a documented control area strategy is often not available. In the case of changing use of labs or adding labs to the floor of a building, the current control area strategy should be consulted. If it cannot be located, a study should be performed to document the current use of hazardous materials to ensure that the use of the space at the completion of the project will be in accordance with applicable codes and standards.

The following recommendations will help to ensure future compliance for storage of hazardous materials:

1. Ensure future lab uses for the building are planned for in initial control area strategy. Based on need for future flexibility, control area boundaries can be strategically located. Adding control area boundaries after initial construction often proves excessively costly.
2. Clearly indicate control area boundaries on life safety plans. Control area boundaries should be clearly identified on construction documents. It is also recommended that wherever egress / life safety plans are posted in the building that these plans also identify control area boundaries.
3. Communicate the limits on MAQ in each control area as well as how control areas are laid out in writing to the owner. The Owner needs to be informed on what requirements they are responsible for complying with at the end of a project. A clearly documented control area strategy should be turned over to the owner at project completion.
4. Establish a continued compliance program. This program should include inspections by appropriate staff at regular intervals to ensure continued compliance.

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4 Maximum Allowable Quantities of Hazardous Materials

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Soon-to-be-Released Guidance on University Labs

University labs can be a challenge to achieve and maintain compliance with applicable codes and standards due to the constantly changing nature and use of some labs. Fortunately, the 2018 edition of the IBC is planned to have new code sections that address higher education laboratories. Although at the time of publishing of this guide the new code wording is not yet available, the hope is that the new guidance will provide more flexibility to MAQs in higher education labs.