

LABORATORY VENTILATION

Definition: *International Mechanical Code (IMC)* identifies a laboratory (lab) as a room or building in which vapors, gasses, fumes, mists, dusts, etc. are used related to testing, analysis, teaching, research or developmental activities. Such facilities are limited to non-production activities rather than manufacturing processes. Subject to compliance, when the exposure level of a substance within the laboratory is above allowable limits a “hazardous exhaust system” shall be provided.

Compliance: In addition to compliance with *IMC*, chemical and biological laboratories where hazardous materials or pathogens are handled or stored shall comply with the following codes and standards:

1. *ANSI/AIAH Standard Z9.5 - American National Standard for Laboratory Ventilation*
2. *NFPA 45 - National Fire Protection Association Standard on Fire Protection for Laboratories Using Chemicals*
3. *OSHA 29CFR 1910.1450 – Occupational Exposure to Hazardous Chemicals in Laboratories*
4. *CDC/NIH - Biosafety in Microbiological and Biomedical Laboratories*
5. *NIH Design Requirements Manual for Biomedical Laboratories*
6. *I2SL - Best Practice Guide*
7. *Task Sheet 1C - Laboratory Airflow Distribution by Rowan, Williams, Davies & Irwin, Inc. (RWDI) and Exposure Control Technologies, Inc. (ECT, Inc.)*
8. *ACGIH Industrial Ventilation: Manual of Recommended Practice for Design*
9. *ASHRAE Standard 62.1 – Ventilation for Acceptable Indoor Air Quality*
10. *ASHRAE HVAC Applications Handbook*
11. *ASHRAE Laboratory Design Guide*

Laboratory Safety: The focus of safety within chemical laboratories is protection from harmful effects of hazardous chemicals. The focus of safety within biological laboratories is protection from harmful effects of pathogens.

ASHRAE HVAC Applications Handbook: Identifies four laboratory types. All four types can be found on the UIUC campus in substantial quantities.

1. **Chemical:** Laboratories supporting both organic and inorganic syntheses and analytical functions. Often equipped with chemical fume hoods. May be “wet lab” or “dry lab” as defined below.
2. **Biological:** Laboratories containing biologically active materials or involving chemical manipulation of these materials. Typically equipped with biological safety cabinets, recirculating and/or exhausted. Typically “dry lab” but may be “wet lab” as defined below”
3. **Animal:** Laboratories where manipulation, modification and observation of laboratory animals occurs. Animal facilities are treated separately within these *Standards*. See section entitled *Animal Facilities* within these *General Guidelines*.
4. **Physical:** Laboratories associated with physics commonly incorporating lasers, optics, electronics, low and high temperature and radioactive materials. Such laboratories are typically classified as “dry labs” as defined below.

ASHRAE Standard 62.1: Identifies four air classifications particularly applicable to chemical laboratories.

1. Class 1 - Low sensory-irritation intensity and inoffensive odor.
2. Class 2 - Mild sensory-irritation intensity or mildly offensive odor.
3. Class 3 - Significant sensory-irritation intensity or highly offensive odor.
4. Class 4 - Highly objectionable and/or potentially dangerous contaminated air.

All four classifications can be found in UIUC laboratories and must be managed in safe and appropriate manner as determined by applicable codes and standards.

U.S. Centers for Disease Control (CDC):

Identifies four laboratory biosafety levels applicable to biological laboratories.

1. BSL-1 Non-disease causing agents. Non-restricted access area. No special ventilation requirements.
2. BSL-2 Agents that pose moderate hazard. Restricted access area. HEPA filtered air from Class 2 BSC can be recirculated within the lab but not to spaces outside the lab
3. BSL-3 Indigenous or exotic agents that may cause serious or lethal disease. Highly restricted access areas.

4. BSL-4 Dangerous and exotic agents that pose high individual risk of aerosol-transmitted infections and disease that is frequently fatal for which no vaccines or treatments are available. Requires separate building or entirely isolated zone within existing building. Ventilation requirements are not addressed herein. BSL-1, 2 and 3 labs are present on the UIUC campus. No BSL-4 labs currently reside on campus.

Lab Classification: The terms “wet lab” and “dry lab” are frequently used to broadly categorize chemical laboratories on campus. Chemical laboratories fitted with one or more exhausted fume hoods and/or ventilated chemical storage cabinets are typically identified as wet labs. Air within these spaces is typically identified as Class 3 or 4 per *ASHRAE Standard 62*. Thus, air within these spaces may not be recirculated to other spaces and must be properly exhausted to outdoors. Laboratories without exhausted fume hoods or ventilated chemical storage cabinets are typically identified as dry labs. Air within these spaces may be identified as Class 1 or 2. As such, air within these laboratories may be recirculated to other spaces of similar class subject to limitations of applicable codes and standards. Chemical Laboratories may be either wet labs or dry labs. Biological labs are typically dry labs but may be wet labs if they include exhausted bio-safety cabinets or fume hoods. Physical labs are typically dry labs.

Ventilation Rate: Unless otherwise indicated by code, air distribution systems serving wet labs shall operate continuously and shall be “once through” systems, exhausting to outdoors 100% of air supplied to the space. Determination of ventilation rate may be based upon one of three factors. These being air exchange rate, exhaust make-up rate and airflow rate required for thermal comfort. At any given time any of these three may determine minimum lab ventilation rate.

Air Exchange Rate: Determination of minimum air exchange rate may be performance based or prescriptive. Airflow

rates may not be reduced below allowable levels for safety and functional requirements.

Performance based: Determination of minimum ventilation rate based upon specific requirements of a given laboratory is encouraged. However, in educational facilities such as UIUC, laboratory operations, chemicals used, etc may be indeterminate or may change over the course of time, thus making performance based design impractical.

Prescriptive: A prescriptive approach based upon air changes per hour (ACH) is often more practical. Thus, the University has identified the following prescriptive minimum ventilation rates subject to code requirements. Ventilation rate may be higher but shall in no case be lower than the following:

- Occupied laboratory: 6 ACH minimum
- Unoccupied: 4 ACH minimum

Use of a demand control ventilation system (e.g. Aircurity) allows reduction of ventilation rates as follows:

- Occupied: 4 ACH minimum
- Unoccupied: 2 ACH minimum

It is essential that calibration of such equipment be maintained in manner and frequency recommended by the manufacturer. Airflow rates may not be reduced below allowable levels for safety and functional requirements.

Exhaust Air Make-up: At a minimum, supply airflow to a lab must be adequate to replace air exhausted via fume hood or general exhaust.

Thermal Comfort: At a minimum, supply/exhaust airflow must be adequate to provide heating/cooling as required for occupant comfort.

BSL Ventilation Requirements:

Bio-safety labs have similar ventilation requirements as comparable chemical labs.

1. BSL-1 No special ventilation requirements.
2. BSL-2 HEPA filtered air from Class 2 BSC may be recirculated within the lab but not to spaces outside the lab. Otherwise ventilation requirements are the same as for chemical laboratories. Exhaust from biological labs may be

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combined with exhaust from chemical laboratories only if approved by Owner. Exception to “once through” requirement may be discussed with Owner for existing facilities.

3. BSL-3 A visual monitoring device, which confirms directional airflow is to be provided at the laboratory entrance. Otherwise ventilation requirements are the same as those for BSL-2 except that “once-through” ventilation is required without exception.
4. BSL-4 Given that no BSL-4 labs reside on campus ventilation requirements are not addressed herein.

Constant Volume vs. VAV: Laboratories may have constant volume or variable volume ventilation systems. Both system types can be found within laboratories across campus. Lab system type is typically determined by fume hood/exhaust system type, whether constant volume or variable volume. The University has a general preference for VAV systems given their increased potential for energy use reduction. System type shall be discussed with *F&S Engineering* prior to project design.

Room Pressure Control: Air distribution systems serving laboratories shall be designed to minimize transfer of odor and airborne contamination. This can be accomplished to a large extent by maintaining appropriate relative air pressurization between laboratories and adjacent corridors and between the corridor system and any adjacent non-laboratory area. For non-critical applications, this is typically accomplished via volumetric airflow tracking. For critical applications it may be necessary to use direct pressure differential control. In such cases it is essential to have well-sealed laboratory envelopes and effective means for preventing transient pressure disturbances as typically occur when entry/exit doors are opened/closed. It is typically preferred or required that laboratories be maintained at negative air pressure to prevent migration of lab air into adjacent areas. However, in limited cases positive pressurization may be preferred or required to promote lab cleanliness relative to adjacent spaces.

Fume Hood Placement: Fume hoods shall be placed to optimize fume capture performance and minimize transient disturbance of airflow at the face of the hood during lab operations. See *Section 11 53 13 Chemical Fume Hoods* for fume hood placement guidelines. Such requirement may apply to exhausted bio-safety cabinets as well.

Supply Air: Supply air devices are to be located and oriented such that supply airflow is introduced into a lab without creating turbulence at or near the face of fume hoods or other equipment sensitive to air currents. In many cases this requires the use of specialized air terminal devices. The type, location and discharge velocity of supply devices can be key factors influencing fume hood location and density within a laboratory. The converse may also be true. To minimize turbulence supply devices may be radial or hemispherical type designed specifically for laboratory applications.

Device Location: The distance of 5 feet from the front and sides of each fume hood defines a zone (No Diffuser Zone, NDZ), in which lab designers are to avoid placing air supply devices. Placement of any device within the NDZ is to be avoided unless required for room air circulation and air supply from the device does not impact fume hood performance. See *Section 11 53 13 Chemical Fume Hoods* for additional guidelines for placement of supply air devices. Such requirement may apply to exhausted bio-safety cabinets as well.

Displacement Ventilation: The use of displacement ventilation systems to serve laboratories is encouraged. Such systems provide low velocity air to minimize air currents while simultaneously flushing the lower portion of the room with clean air to improve air quality for lab personnel.

General Exhaust Systems: When the exhaust airflow rate required to satisfy the minimum air change rate within a laboratory exceeds that required to support fume hoods and other exhausted equipment, the difference may be removed from the space through a general exhaust system. This system may be combined with the fume exhaust system to increase dilution within

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the larger system. Alternately, if deemed more beneficial, it may be maintained as an independent system to facilitate optimization of energy recovery (e.g. use of a heat wheel in conjunction with general exhaust and heat pipe in conjunction with fume hood exhaust). For a given installation such shall be discussed with *F&S Engineering*. When combined with the fume hood exhaust system general exhaust ductwork is to be of the same material and construction as fume exhaust ductwork. Note: Subject to compliance, the general exhaust system shall be designed as "laboratory exhaust" as identified by code.

Fume Exhaust System: Laboratory fume hoods, chemical storage cabinets and similar equipment within a building are typically served by one or more manifolded exhaust systems, preferably with round ducts. Each manifolded system should be served by "N+1" exhaust fans. Each exhaust fan is to be sized, configured and controlled such that full system design capacity can be maintained should any one fan fail or be taken out of service. Automated isolation dampers are to be provided to facilitate selective fan operation while preventing backflow through idle units. Exception: When approved by the using agency and *F&S Engineering*, this requirement for N+1 exhaust fans and isolation dampers may be waived. In so doing it is understood that the exhaust system becomes interruptible service. Note: Although rarely provided, N+1 supply air units should be considered as well. Note: Subject to compliance, the fume hood exhaust system shall be designed as "hazardous".

Manifolded vs. Dedicated Systems: Chemical fumes from dissimilar service hoods including acid fumes and solvent vapors are typically exhausted through a common manifolded exhaust system provided that adequate dilution is achieved prior to mixing of potentially reactive substances. However, vapors from hoods containing highly concentrated volatile acids at elevated temperatures are not to be exhausted through a common exhaust system serving dissimilar operations without first obtaining approval from the *Division of Research Safety* and the *F&S Division of*

Safety and Compliance. The same is true of vapors from biological safety cabinets as well as vapors from radioisotope hoods. Fume hoods in which perchloric acid is used or stored shall be served by dedicated exhaust systems with special features required for such application (e.g. a water wash-down system). The *Division of Research Safety and/or F&S Division of Safety and Compliance* shall be contacted for guidance. Fume hoods in which highly toxic vapors or pyrophoric gases are used shall be served by dedicated exhaust systems with special features appropriate for such application (e.g., scrubbers, wash-down systems). As required by *NFPA Standard #45* any hood protected by a gaseous fire extinguishing system shall be provided with an independent duct system and fan interlocked to shut down upon activation of the extinguishing system. It may be connected to a manifolded system only if provided with an approved automated isolation damper similarly interlocked to close upon activation of the extinguishing system.

High Plume Exhauster: A dedicated exhaust discharge stack is to be provided at each fume exhaust fan. The stack height plus momentum of airflow must be adequate to discharge air above the building's turbulent zone, thus preventing recirculation of contaminated air back into intake air openings. High plume exhausters are particularly effective at accomplishing this and thus are required for all sizable laboratory exhaust applications. Dilution equations, mathematical plume analysis and/or wind tunnel testing may be used to predict performance of such installations. Such analysis is to be performed when deemed necessary by qualified professionals.

Traditional Stack: A traditional exhaust stack design may be used for smaller applications. In such cases recommendations of *ANSI/AIAH Standard #Z9.5* shall be applied. Typically each stack is extended a minimum of 10 ft. above adjacent roof structures and contaminated air is discharged vertically upward at a velocity of 3,000 FPM minimum.

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Corrosion Resistance: All fume exhaust ductwork, plenums, exhaust fans and heat recovery system components exposed to corrosive fumes shall be constructed of appropriate, durable, corrosion resistant materials (e.g. stainless steel, ceramic materials, phenolic coatings, etc.) Default material for fume hood exhaust ductwork is type 316L welded stainless steel for dedicated branch ducts and type 304 welded stainless steel for exhaust manifolds.

Energy Recovery: Laboratories shall be defined as requiring “laboratory” and/or “hazardous” exhaust systems as defined by code. Subject to compliance, energy recovery ventilation systems may be utilized in conjunction with laboratory exhaust airflow. Energy recovery systems subject to contamination of a “clean” airstream (e.g. energy recovery wheels) may only be utilized in conjunction with general lab exhaust. Energy recovery systems which are not subject to contamination (e.g. coil-type heat exchangers) may be utilized in systems containing hazardous exhaust given that codes are complied with. Careful consideration shall be given to issues related to safe operation and maintenance. System designs that limit cross-contamination of airstreams to a compliant minimum level shall be employed. Within this discussion of laboratory exhaust it is acknowledged that heat recovery is inappropriate for certain specialty applications. Examples include exhaust of perchloric acid vapors, regulated carcinogens, highly toxic chemicals, nanomaterials of unknown toxicity or other compounds of unknown (and suspect) toxicity.

Filtration: Filtration is to be provided upstream of each heat recovery device. Each air stream will be filtered by a minimum of one MERV 8 (30% efficient) filter bank. Filters/housings in contaminated air streams are to be configured such that filters can be changed during system operation without exposing service personnel to harmful contaminants. Exception: Such configuration requirements may be waived by the Owner with the understanding that the exhaust system will be taken out of service for filter replacement.

Cleaning: Provisions are to be made for routine cleaning of heat exchange surfaces. Such provision includes incorporation of drain pan(s) for water wash-down as well as isolation/access features as identified below.

Isolation/Access: Each device located within an air distribution / exhaust air system of critical nature, such that continuous operation of the air system is required, are to be configured such that it can be isolated, taken out of service and accessed for cleaning, maintenance or repair while leaving the system in operation. Options include provision of a bypass duct with isolation dampers and provision of N+1 heat recovery devices with isolation capability. Further, such provision is to be configured such that service personnel need not be exposed to contaminated exhaust airflow. This requires that the accessed area(s) be maintained at a positive air pressure relative to contaminated air streams with which it could potentially communicate. Exception: As with filters, such requirements may be waived by the Owner with the understanding that the exhaust system will be taken out of service for cleaning, maintenance or repair.