Laboratory Ventilation Design Standard

This standard defines Clemson's expectations for the design of laboratory spaces, including space layout and the design of ventilation systems. Such designs shall strive to balance the sustainability goals of the university while maintaining the safety and health of laboratory occupants and the general public.

This standard applies to construction of new facilities and renovations to existing facilities in which chemical work is to be done at laboratory scale. Facilities in which chemical work is conducted beyond lab scale, or for which other hazards, such as high chemical hazard, radiological, or biological hazards are the design drivers, may require specialty design criteria. Designers shall consult with Facilities Services and OES before proceeding to determine a basis for design in order to address the special considerations for these types of spaces.

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Definitions:

Laboratory: A space or facility where relatively small quantities of hazardous chemicals (i.e. amounts that can be safely handled by one person) are used on a nonproduction basis.

General exhaust ventilation: Also called dilution ventilation, differs from local exhaust ventilation in that in lieu of capturing emissions at their source and removing them from the air, general exhaust ventilation allows the contaminant to be emitted into the workplace air where it is diluted at an acceptable level (e.g. to the Permissible Exposure Level or below).

Local exhaust ventilation: Local exhaust ventilation is designed to capture an emitted contaminant at or near its source before the contaminant has a chance to disperse into the workplace air.

Computational fluid dynamics (CFD): The use of numerical methods to calculate and visualize air flow patterns or particulate migration.

Vacant: A laboratory that is unassigned to an occupant and therefore can have the general ventilation and fume hoods turned off or turned down to levels needed only for general temperature control.

Occupied: Mode in which the building controls system sensors recognize that a person is physically within the room.

Unoccupied: mode in which the building controls system sensors recognize that there is no one present in the room.

Hibernation: Describes when the lab is assigned to an occupant, but the operation of the fume hood is not required, and the fume hood exhaust can be temporarily shut down.

Air changed per hour (ACH): A common means for expressing a volumetric airflow through a room. Each ACH for a room is intended to represent an amount of air equal to the gross volume of air passing through the room each hour. An ACH rate for a room can be converted to volumetric airflow by multiplying the ACH number times the gross volume in the room. The air change rate depends on the exhaust flow for a negatively pressurized room and on supply flow for a positively pressurized room. The term does not reflect actual mixing factors and therefore does not indicate the effective air exchange rate in the room.

Constant Air Volume (CAV) Ventilation system: A ventilation system designed to maintain a constant quantity of airflow within its ductwork. The airflow quantity is typically based upon heating or cooling load, make-up air requirements, or minimum air change requirements. Although relatively simple, a constant volume system typically requires the maximum ongoing energy usage.

Discharge Velocity: The speed of the exhaust air normally expressed in feet per minute at the point of discharge from a laboratory exhaust system. Since laboratory exhaust fans may be configured to discharge into a vertical exhaust stack or may utilize fans specifically designed to discharge directly upward, the discharge velocity normally refers to the air velocity as it leaves the last element of the exhaust system. Since the top of an exhaust stack may be conical (or other type of configuration), the velocity of the exhaust air at the point of discharge may differ from the velocity of the air within the vertical stack. The term “stack velocity” is sometimes used when referring to the speed of the exhaust airstream as it is discharged into the outside air.

Face Velocity: The air velocity of the plane of and perpendicular to the opening of a laboratory chemical hood.

HEPA: High Efficiency Particulate Air (filter) for air filters of 99.97% or higher collection efficiency for 0.3 micrometers diameter droplets of an approved test aerosol operating at a rated airflow.

Variable Air Volume (VAV) Ventilation System: A type of HVAC system specifically designed to vary the amount of conditioned air supplied and exhausted from the spaces served. The amount of air supplied and intended to meet (but not exceed) the actual need of a space at any point in time.

I. Laboratory ventilation design requirements

General design requirements: The following subsection provides general guidance for contractors and project managers engaged in new design or renovation of Clemson laboratory facilities.

1. All laboratory exhaust systems must comply with applicable South Carolina Codes (i.e. building, fire, mechanical, etc.), ANSI / AIHA Z9.5-2022 and Sheet Metal and Air Conditioning Contractors National Association (SMACNA) standards

2. General room ventilation shall be provided to prevent the buildup of fugitive emissions in the laboratory. A general room ventilation system shall be designed to maximize the removal of contaminants from the room while minimizing overall energy use. Demonstrating ventilation effectiveness through design to optimize laboratory room air mixing and dilution is more important than delivering a bulk quantity of ventilation (air change per hour - ACH). Each lab should be designed to meet required fume hood face velocity, directional airflow within the laboratory, and an established air change rate. In laboratories where the heat load exceeds the required ventilation rate, supplemental local recirculating systems such as fan coil units should be considered.

3. The project engineer shall provide a “Basis of Design” statement for all lab designs that clearly defines all system criteria and assumptions made during the project design process. Documentation shall include, but not be limited to, design and operational criteria such as laboratory air change rates, anticipated chemical usage, description of the lab ventilation control system, equipment heat loading, anticipated occupancy and diversities, as well as references to codes and standards used. Clemson shall provide the occupants project requirements upon which the Basis of Design is developed.

4. CFD modeling should be considered to verify ventilation effectiveness on all new buildings and major renovations. The discussion / development will be defined in the occupant’s project requirements.

5. The mechanical system selection, including heat recovery systems, shall be supported by a life cycle cost analysis of the options. The designer shall submit an economic analysis during schematic design. **Heat wheels are not permitted in chemical hood exhaust** but may be in general exhaust if approved by OES. **Heat wheels are not permitted in animal facilities**.

6. Prior to the design of new laboratory facilities, OES will provide a chemical usage questionnaire (POSHER form) to be completed by the occupants or other appropriate university personnel having knowledge of the chemicals or types of chemicals to be used. The completed form will be reviewed by OES, occupants, and the design consultant after completion.

7. All hazard control ventilation system plans / blueprints / change orders must be reviewed by OES. No chemical hood or other laboratory ventilation device may be installed without the approval of OES. Ventilation devices should not be purchased until a Facilities permit to install them has been approved.

8. The consultant shall be required to perform an analysis to classify the exhaust system when the use of flammable vapors, gases, fumes, mists or dusts, and volatile or airborne materials posing a health hazard, such as toxic or corrosive materials, are expected. Classification shall be made in accordance with the South Carolina Mechanical Code Section 510 concerning Hazardous Exhaust Systems.

Specific laboratory ventilation design criteria:

1. No chemical hood installations are allowed in rooms with return air to other spaces. All chemical use rooms (wet labs) shall have once-through ventilation.

2. Provisions shall be made for local exhaust of instruments, gas cabinets, vented storage cabinets or special operations not requiring the use of a chemical hood (local capture devices) where required.

3. Airflow shall be from areas of low hazard, unless the laboratory is used as a Clean Room (Class 10,000 or better) to areas of higher hazard level. When flow from one area to another is critical to exposure control, airflow monitoring devices shall be installed to signal or alarm a malfunction.

4. Supply air delivery must be designed to ensure hood performance and maintain pressurization requirements. Supply diffuser type and location within the room shall be such that the effectiveness of the ventilation to remove contaminants is enhanced and that the exhaust systems and fire protection or extinguishing systems are not adversely affected.

5. Diffusers shall be located at least 5 feet from the front and sides of the hood (measured horizontally).

6. Perforated duct or fabric diffusers may be used. Discharge velocities shall not exceed 30% of average hood velocity at the diffuser outlets (or anywhere else within the lab).

7. Air velocity caused by supply outlets, window drafts, traffic, etc. shall not exceed of the hood face velocity to avoid disrupting hood (capture).

8. Supply diffusers shall provide patterns that sweep air across work surfaces and away from occupant breathing zones.

9. Duct velocities should typically be maintained between 1800-2000 fpm to minimize noise, static pressure loss, and blower power consumption within the duct system.

10. Effluent discharge shall be a minimum of ten feet above the roof surface with a velocity of 3,000 feet per minute (fpm) velocity unless it can be demonstrated that a specific design meets the dilution criteria necessary to reduce the concentration of hazardous materials in the exhaust to safe levels at all potential receptors (ANSI / AIHA Z9.5).

11. Horizontal runs of branch ducts shall be kept at a minimum.

12. Branch ducts shall enter a main duct so the branch duct centerline is on a plane that includes the centerline of the main duct. For horizontal main ducts, branch ducts shall not enter a main duct on a plane below the horizontal traverse centerline of the main duct. If condensation within the duct is likely, all horizontal duct runs shall be sloped downward at least 1 inch per 10 ft. in the direction of the airflow to a suitable drain or sump. In addition, appropriate cleanout ports shall also be provided. Exhaust duct sizes should be selected to ensure sufficiently high airflow velocity to retard condensation of liquids or the adherence of solids within the exhaust system.

13. Duct chases shall be reasonably oversized for future additional ducts (generally 25% is typical). This should be determined during the design phase and with input from Facilities Services HVAC.

14. Systems and devices that require maintenance or inspection shall be accessible. Laboratories backed on utility corridors are encouraged.

15. Filtration design shall be based on ASHRAE 52.2-2017 to provide appropriate filtration according to the application. Higher standards may be necessary for some laboratory applications and clean room designs.

16. Hoods which are high hazard or unique use, such as perchloric or other acid digestion systems and radioisotope hoods, shall not be installed in a manifold type exhaust system and must be separately exhausted.

17. Casework and other furniture shall be located to allow for the sweeping of the general ventilation from supply diffusers to exhaust points without creating areas where there may be accumulation of chemical vapors or fumes.

18. The design shall carefully consider acoustics and result in a laboratory noise level between NC 35 and NC 45. Proper acoustic design should be accomplished by providing appropriate fan size and type. Sound attenuators are acceptable, though not preferred. When used, sound attenuators must be packless and constructed of 304 stainless steel.

Ventilation rates: A prescriptive air exchange rate (air changes per hour) cannot be specified that will meet all conditions in a laboratory. Table 1 identifies default ventilation rates utilizing generic control banding principles for common chemical use laboratory operations. OES shall provide a recommendation for the ventilation rate. Higher ventilation rates may be required, and less may be acceptable, when the laboratory process is well defined. The designer must demonstrate that the proposed ventilation rate will control room air contaminant concentrations below the current PELs or threshold limit values (TLV-TWA) established by the American Conference of Governmental Industrial Hygienists (ACGIH).

Table 1. General lab exhaust ventilation rate per control band rating.

Laboratory Ventilation Control Bands	**General Ventilation Rate**
High hazard	8 ACH occupied / 4 ACH unoccupied
Moderately hazard	6 ACH occupied / 3 ACH unoccupied
Low hazard	single pass air required, but ventilation rate is determined by specific operating schedules or other management practices
Specialized ventilation	to be determined by engineering analysis

A detailed description of control banding used to determine general ventilation rates is provided in Appendix 1.

Ventilation rates for hibernation and vacant modes shall be determined on a case-by-case basis when the space use is changed.

Some specific laboratory uses of chemicals may require higher or lower ventilation rates than those generically described above due to specific hazards or requirements that arise from the processes conducted in the laboratory. Assignment of ventilation requirements for these situations lies outside the scope of the generic control banding process and requires specific analysis and risk assessment to determine ventilation needs. Such analysis will be documented by a "basis of operation" report outlining the considerations used in defining the ventilation parameters. This analysis will be supported by development of specific training programs to assure that laboratory workers understand the assumptions and operation of the laboratory ventilation system. Examples of such situations include animal use areas, semiconductor processing facilities, glass cleaning rooms without local exhaust ventilation, or areas where non-chemical hazards are present. OES and Facilities Services will assist in establishing ventilation rates for these special areas.

<u>Fume hoods</u>:

Fume hoods shall be selected according to the criteria outlined in the *Laboratory Equipment Design Standard*.

Occupied hood exhaust rate shall be designed to **provide an average face velocity of 100 FPM at an 18-inch sash opening height**. Minimum chemical hood exhaust shall be determined based on the expected chemical use as determined by OES

Placement: The location of chemical hoods, supply air terminals, laboratory furniture, and pedestrian traffic should encourage horizontal, laminar flow of supply air into the hood, perpendicular to the hood opening.

1. In general, hoods should not be placed in the line-of-egress from the laboratory; locate at least 4 feet from any doors (except emergency doors, 8ft if the door is opposite the hood).

2. Hoods shall be separated from each other as far as practical.

3. Corner locations shall be avoided, locate hood a minimum of 12” inches away from a perpendicular wall.

4. Hoods shall be placed to avoid pedestrian traffic immediately in front of the hood.

5. Large pieces of equipment shall not be positioned in front of a hood.

6. Hoods shall not be placed where they would face each other across a narrow aisle (8 ft. minimum spacing), as this will cause turbulence at the face of the hood.

II. Materials and equipment

Exhaust ducts:

1. Duct materials shall be compatible with vapors to be exhausted and in conformance with applicable Codes (South Carolina Building Codes, SMACNA, ANSI/AIHA Z9.5, etc.). Manifold exhaust systems are permitted.

   a. Stainless steel used for hood ducting must be 316 stainless, minimum 18 gauge, and seams welded (any exception to this must be approved by OES). Materials selected for hood ductwork must be resistant to corrosion and determined by the agents used.

   b. Horizontal branch ducts on most duct systems using solvents and potentially flammable vapors installed from a chemical hood connection to the point where the duct connects to a main or riser shall be stainless steel (Type 316, minimum 18 gauge).

   c. The use of galvanized duct is acceptable for laboratory general exhaust ducts and risers.

   d. For systems using corrosive vapors and perchloric acid, FRP or plastic duct shall be specified.

   e. Chemical hoods must have dedicated ductwork, which is not integrated with other general ventilation ducts. Manifold exhaust systems are acceptable.

   f. Chemical hood exhaust ducts shall not contain fire dampers.

2. All duct seams and joints shall be sealed. Stainless steel ductwork shall be welded. Solvent welding is acceptable for PVC and FRP ductwork.

3. Traverse joints shall be welded whenever possible or they may be Van Stone flanges under certain circumstances with the approval of OES. When nonmetallic materials are used, joints shall be cemented in accordance with the manufacturer's procedures. If the duct is coated with a corrosion-resistant material, the coating shall extend from the inside of the duct to cover the entire face of the flange. Flange faces shall be gasketed or beaded with material suitable for the service.

Exhaust fans:

1. All fans used for chemical exhaust shall be AMCA Type-B spark resistant construction.

2. Fans must be located physically outside the building, preferably on the highest level roof of the building served, so that all duct in the building is negatively pressurized. If it is determined that it is impossible to locate the fan on the roof and a fan must be located in a penthouse or roof mechanical room, an airtight enclosure should be constructed around the fan(s). Also ensure the penthouse is maintained at a negative pressure with respect to the facility and provide direct fan discharge into the exhaust stack.

3. Exhaust fans must be adequately sized to provide the necessary amount of exhaust airflow in conjunction with the size, amount, and configuration of the connecting ductwork. Each fan's rotational speed and motor horsepower shall be sufficient to maintain both the required exhaust airflow and stack exit velocity. Where exhaust fans are applied to centralized or manifold laboratory exhaust systems, all fans and motors shall be adequately sized and the overall system controlled to provide the necessary amount of exhaust airflow, stack exit velocity, and the necessary negative static pressure in all parts of the exhaust system. Manifold systems shall operate continuously to provide adequate ventilation for any hood at any time it is in use and to prevent backflow of air into the laboratory or other parts of the building.

4. All laboratory exhaust fans shall include provisions to allow periodic shutdown of inspection and maintenance without worker exposure to the exhaust airflow. Such provisions include: 1) Ready access to all fans, motors, belts, drives, isolation dampers, associated control equipment and the connecting ductwork. 2) Sufficient space to allow removal and replacement of a fan, its motor and all other associated exhaust system components and equipment without affecting other mechanical equipment or the need to alter the building structure.

5. Fans should be Class 1 belted utility sets with a steel scroll sized to operate below 2,000 RPM. All components exposed to the air stream shall be coated with primer, baked enamel and a baked phenolic coating. In-line centrifugal fans of the same material and coatings are acceptable where space precludes the use of a utility fan. Fans constructed of PVC or FRP shall be used where high concentrations of corrosives are anticipated. High velocity fans are permitted with the approval of OES.

6. There should be no flexible connections on the discharge side of the fan and all ductwork on the discharge side of the fan must be welded and/or flanged and gasketed construction.

7. Consideration for emergency power to the fans shall be provided depending on the risk or business continuity of the operation.

8. Fan redundancy must be included where hoods are manifolded.

    a. For lab exhaust systems over 10,000 CFM capacity, provide 100% redundant standby fans or N+1 redundancy should be considered

    b. For systems 10,000 CFM or less two fans at 50% capacity each may be utilized

III. Ventilation control systems

Laboratory Pressurization Controls to Building Automation System (BAS) interface shall be BACnet MS / TP protocol with design details worked with University Facilities, OES, and the university's contract BAS provider. Below are the typical design configurations. The type of system selected will be dependent on the project and approved by University Facilities and OES.

Lab Monitoring & Reheat Control:

1. General: Control shall be reheat control as specified below with scheduled occupancy, with optimum preoccupancy, occupancy override with a BAS occupied/unoccupied enable feature.

2. Space Temperature Control: Normal setpoint shall be 72°F (adj.) and setbacks shall be heating 65°F and cooling 80°F.

3. Occupancy Sensors: Occupancy shall be established using single or multimode sensors with a minimum of two per laboratory space to establish occupied/unoccupied intervals. Scheme that utilize Time of Day (TOD), light switches and/or manual switches to establish occupancy shall be avoided.

4. Hydronic Reheat: N.O. Zone reheat coil valve shall modulate in a PI loop to maintain space temperature heating setpoint as defined above with a 2°F throttling range. Valve shall be closed whenever the associated main air handler is off.

5. Hood Alarms: BAS shall monitor Hood alarms as indicated. When alarm condition is detected, the BAS shall enunciate an alarm.

6. Reports: Configure a tabular report using real-time data with the following column headings: TERMINAL DESCRIPTION, ZONE TEMPERATURE, REHEAT OUTPUT (0 to 100% heating). At the top of the table, list building, room number, floor or area description if applicable, air handling unit designation, and air handler discharge air temperature.

Lab flow tracking zone with variable air volume hood (common exhaust AFMS):

1. General: BAS shall control the supply air systems in the zone including the supply air reheat box (SA). Generally, the BAS will monitor total exhaust flow from a single total exhaust air flow monitoring station (AFMS) and adjust supply air to maintain the specified offset. Factory controllers shall control the lab exhaust and general exhaust systems providing data to the BAS for monitoring and alarming purposes. The system shall be controlled to maintain a negative pressure in the room by maintaining the supply flow less than the exhaust.

1. Hood Monitoring Interface: BAS shall continuously monitor the face velocity, on the hood and provide a local and remote indication of the status of the hood. Local visual and audible indication of unsafe conditions shall be enunciated. Include a silence button, and emergency purge button at the hood.

2. Supply Box Control: BAS shall modulate the damper on the supply box to maintain the supply flow setpoint. The supply flow setpoint shall equal the sum of all respective exhausts in the zone served, minus an offset value which shall be determined as follows:

   a. It shall be fixed at the differential scheduled on the drawings and/or as refined by the balancing contractor

   b. It shall be reset between adjustable limits based on sensed room differential proportional loop both with a no adjustment dead band.

3. Emergency Purge Button: Panic buttons shall be located adjacent to all exits which, when depressed will start emergency purge mode for the zone. Mode shall remain active until manually reset by the operator via the graphic interface with a remote alarm via the BAS.

Lab flow tracking zone with VAV hood:

1. Space Temperature Control: Three setpoints shall apply. Normal (72°F (adj.)), setback heating (65°F (adj.)), and setback cooling (80°F (adj.)). These three values shall be the only values changed by the operator to adjust space temperatures. All other deadbands, differentials, etc. shall be calculated in the program logic (unless another means is provided to prohibit overlap of the heating and cooling loops and ensure a dead band such as function block templates that restrict the setpoint input). During the normal periods, separate heating and cooling setpoints shall be calculated.

    a. Normal space cooling setpoint: shall be the normal space temperature plus 2°F (adj.)

    b. Normal space heating setpoint: shall be the normal space temperature minus 2°F (adj.)

2. The fume hood exhaust valves (FEV) shall be controlled by packaged lab controllers. The BAS shall monitor the fume hood exhaust flow via a 0-10v (or similar) signal directly from the Fume hood controller. The BAS shall also monitor each fume hood controller via a direct LAN interface. Provide all points available via the interface for display on the BAS graphic.

3. Response Time: The FEV packaged lab controllers shall respond quickly to ensure that FEV has completed adjustment no more than 3 seconds after the hood sash height is changed. BAS controllers shall respond quickly to ensure that all SAV and GEV adjustments are complete no more than 7 seconds after FEV adjustment is complete (a total for 10 seconds to respond reach setpoint for each zone).

4. Snorkel Exhaust Terminal Unit (SETU) Control: The BAS shall control the damper via a PID loop to maintain the SETU constant volume setpoint.

5. General Exhaust Terminal Unit (GETU) Control: The BAS shall control the damper via a PID loop to maintain the GETU volume at setpoint.

a. BAS shall continuously calculate a total zone exhaust flow setpoint based on the temperature in the zone. This setpoint shall be reset between maximum and minimum volume settings to maintain space temperature cooling setpoint with a 2°F (adj.) reset range. Zone exhaust volume setpoint shall remain at the minimum volume setting whenever space temperature is below the cooling throttling range.

b. The GETU flow setpoint shall be equal to the Zone total exhaust flow setpoint minus the Fume Hood exhaust and Snorkel Exhaust flows.

Supply Air Terminal Unit (SATU) Control: The BAS shall control the damper via a PID loop to maintain the SATU volume at setpoint.

a. BAS shall continuously calculate a zone total supply flow setpoint. The supply flow setpoint shall equal the sum of all respective exhausts in the zone served, minus a Zone Flow Offset value which shall be as shown on the drawings.

b. Note that if the Zone Total Exhaust flow is greater than or less than the scheduled minimum and maximum Total Exhaust Flow values, then the Total supply flow setpoint may be less than or greater than the supply scheduled minimum and maximum values.

c. Purge Button: Upon indication of emergency purge mode, which shall be started when the panic button is depressed, the total Zone Exhaust Flow setpoint shall be overridden to its maximum setpoint (regardless of the cooling loop output) and send an alarm via the BAS.

d. Hydronic Reheat: N.O. Zone reheat coil valve shall modulate in a PI loop to maintain space temperature heating setpoint as defined above with a 2°F throttling range. Valve shall be closed whenever the associated main air handler is off.

Lab flow tracking with multiple VAV hoods:

1. Tracking Zones: In all lab spaces with combinations of supply air terminal units (SATU), general exhaust terminal units (GETU), snorkel exhaust terminal units (SETU), and fume hood exhaust valves (FEV), the Zones shall control as follows:

2. Space Temperature Control: Three setpoints shall apply. Normal (72°F adj.)), setback heating (65°F (adj.)), and setback cooling (80°F). These three values shall be the only values changed by the operator to adjust space temperatures. All other deadbands, differentials, etc. shall be calculated in the program logic (unless another means is provided to prohibit overlap of the heating and cooling loops and ensure a dead band such as function block templates that restrict the setpoint input). During the normal periods, separate heating and cooling setpoints shall be calculated.

    a. Normal space cooling setpoint: shall be the normal space temperature plus 2°F (adj.)

    b. Normal space heating setpoint: shall be the normal space temperature minus 2°F (adj.)

3. The fume hood exhaust valves (FEV) shall be controlled by packaged lab controllers. The BAS shall monitor the fume hood exhaust flow via a 0-10v (or similar) signal directly from the Fume hood controller. The BAS shall also monitor each fume hood controller via a direct LAN interface. Provide all points available via the interface for display on the BAS graphic.

4. Response Time: The FEV packaged lab controllers shall respond quickly to ensure that FEV has completed adjustment no more than 3 seconds after the hood sash height is changed. BAS controllers shall respond quickly to ensure that all SAV and GEV adjustments are complete no more than 7 seconds after FEV adjustment is complete (a total for 10 seconds to respond reach setpoint for each zone).

5. Snorkel Exhaust Terminal Unit (SETU) Control: The BAS shall control the damper via a PID loop to maintain the SETU constant volume setpoint (typical for each Snorkel Exhaust Terminal Unit in the zone).

6. General Exhaust Terminal Unit (GETU) Control: The BAS shall control the damper via a PID loop to maintain the GETU volume at setpoint for each GEV in the Zone.

    a. BAS shall continuously calculate a zone total exhaust flow setpoint based on the temperature in the zone. This setpoint shall be reset between maximum and minimum volume settings to maintain space temperature cooling setpoint with a 2 F (adj.) reset range. Zone exhaust volume setpoint shall remain at the minimum volume setting whenever space temperature is below the cooling throttling range.

b. The total General Exhaust flow setpoint shall be equal to the total exhaust flow setpoint minus any Fume Hood exhaust flows and Snorkel Exhaust flows.

c. The BAS shall reset the flow setpoint of all GETUs in a zone proportionally between their minimum and maximum flow values to maintain the total General Exhaust flow at setpoint (and thus, the total Zone Exhaust flow).

d. The BAS shall modulate the damper of each GETU in a zone to maintain each individual exhaust flow setpoint.

7. Supply Air Terminal Unit (SATU) Control: The BAS shall control the damper via a PID loop to maintain the SATU volume setpoint for each SATU in the Zone.

a. BAS shall continuously calculate a zone total supply flow setpoint. The supply flow setpoint shall equal the sum of all respective exhausts in the zone served, minus a Zone Flow Offset value which shall be as shown on the drawings.

b. The BAS shall reset the flow setpoint of all SATUs in a zone proportionally (based on their scheduled minimum and maximum flow setpoints) to maintain the Zone Flow Offset at setpoint. Note that if the Zone Total Exhaust flow is greater than or less than the scheduled minimum and maximum Total Exhaust Flow values, then the Total supply flow setpoint (and thus the individual SATU flow setpoints) may be less than or greater than the supply scheduled minimum and maximum values.

c. The BAS shall modulate the damper of each SATU in a zone to maintain each individual supply flow setpoint.

8. Purge Button: Upon indication of emergency purge mode, which shall be started when the panic button is depressed, the total Zone Exhaust Flow setpoint shall be overridden to its maximum setpoint (regardless of the cooling loop output) and send an alarm via the BAS.

9. Hydronic Reheat: N.O. Zone reheat coil valve shall modulate in a PI loop to maintain space temperature heating setpoint as defined above with a 2 F throttling range. Valve shall be closed whenever the associated main air handler is off.

10. Tracking Zone Combinations: The control of each tracking zone shall be as stated above. There are multiple combinations of different quantities of supply, general exhaust, snorkel exhaust and fume hood exhaust valves. The control shall be similar in that the total supply shall track the total exhaust flow to maintain the zone flow offset at setpoint. The general exhaust shall be modulated to maintain the total exhaust at setpoint that is reset based on the space temperature.

Other general controls related guidelines:

1. The hood static pressure shall be measured above the outlet collar of the hood at the flows required to achieve the design average face velocity.

2. VAV control systems are preferred. Two-position control systems shall be full analog with setpoints established via programming.

    EXCEPTION: Hoods used for volatile radioactive material discharge must maintain a relatively steady flow rate. The use of occupancy based variable volume air systems that change the hood flow rate are not allowed.

3. Pressurization shall be established by initial balance and maintained by supply tracking the exhaust. Through-the-wall pressurization controllers shall be avoided. Special care should be made during renovations to seal windows and corridor wall penetrations. Monitoring of exhaust shall be reported to a monitoring system managed and maintained by Facilities or a Clemson Contractor.

4. The design professional shall specify the following parameters for each laboratory airflow control device (supply, exhaust, and general): flow at maximum cooling mode; flow at occupied sash open position; flow at occupied sash closed position; flow at unoccupied sash full open position; flow at unoccupied sash open position; flow at unoccupied sash closed position; flow at occupied hibernation mode; flow at unoccupied hibernation mode; flow for vacant mode; and response time of controls.

5. Single mode infrared sensors, with a minimum of two sensors per laboratory area, shall be used to establish occupancy/unoccupancy intervals. Schemes that utilize Time-of-Day (TOD), light switches and/or manual switches to establish lab occupancy shall be avoided.

IV. Laboratory Commissioning

1. All new and renovated laboratory ventilation systems shall be properly commissioned. Total laboratory airflows shall be measured via a duct traverse in addition to hood face velocity measurements. If the hood is equipped with VAV or two position controls, the airflows shall be measured and documented in all modes of the intended operation. The project team should be made aware that a controls technician will be necessary to accomplish these commissioning efforts. Coordination between OES and the commissioning agent shall be made well in advance of the scheduling of final commissioning activities.

2. A written commissioning plan shall be developed by the commissioning agent (who is not part of the design team). The commissioning plan shall address operation of the entire ventilation system where the hoods, laboratories, and associated exhaust and air supply ventilation systems are considered subsystems.

   The commissioning plan shall include written procedures to verify or validate proper operation of all system components and include:

   a. Laboratory chemical hood specification and performance tests
   b. Pre-occupancy hood and ventilation system commissioning tests
   c. Pre-occupancy laboratory commissioning tests
   d. Laboratory and System Drawings for Final System Design

3. An OES approved vendor will perform new chemical hood commissioning including smoke capture and tracer gas tests to qualitatively / quantitatively determine the hood's ability to contain contaminants. Commissioning will require passing the ASHRAE 110 Test.

4. For projects involving the renovation of an exhaust system involving multiple hoods, OES may permit that only a percentage of hoods involved receive ASHRAE 110 tests with tracer gas. Hoods will be selected in consultation with project engineers such that the hood configurations provide a representative assessment of overall system performance.

5. The design documents should include requirements to perform a tracer gas capture test on one hood of each type specified in the project. The Project Manager and OES shall procure qualified individuals to perform this test. This can be a modified ANSI/ASHRAE Standard 110 test recommended by OES. Criteria will be determined by OES.

6. Preliminary and final commissioning documents shall be issued to OES. The documents shall include:

   a. Design Flow Specification
   b. A copy of Test and Balance Report
   c. Commissioning Test Data
   d. List of all ventilation system deficiencies uncovered and details of how (and if) they were satisfactorily resolved

7. All test instrumentation utilized for the commissioning process shall be in good working order and shall have been factory calibrated within 1 year of the date of use.

8. Signage will be placed on the chemical hood upon final acceptance by OES.

9. Laboratory noise levels shall be measured and documented to ensure they meet the maximum design conditions between NC 35 and NC 45.

V. Appendix I. Laboratory ventilation control banding

"Control Banding" is a system for assigning generic protection strategies to similar hazards based on a risk assessment of specific instances of those hazards. The hazards are grouped into "bands" that can be managed by the same suite of controls. The control banding strategy was developed by industrial hygienists to identify control methods to deal with situations in which hazard information is limited, or the hazards of concern change regularly.

In the chemical laboratory setting, general dilution ventilation of laboratories beyond that recommended by the ASHRAE 62-2022, is a core engineering control of occupant chemical exposures during normal operations. For this reason, specification of general ventilation rates in laboratories should be based on a risk assessment of the hazards associated with the use of volatile chemicals in the laboratory.

In order to assure the operational, financial, environmental flexibility, and sustainability of laboratory operations, these ventilation rates should be minimized as much as possible. Over-ventilation of laboratory spaces can interfere with the use of the laboratory for specific operations, can make the detection and diagnosis of operational and ventilation problems in the laboratory more difficult, and increases the carbon impacts and dollar costs of operating the laboratory facility.

Balancing these factors in an ongoing way that is accessible to a variety of stakeholders is the key goal of the Laboratory Ventilation Standard developed by the American Industrial Hygiene Association (ANSI Z9.5-2022). This standard requires a procedure for characterizing hazardous processes in the laboratory.

The optimization process consists of review of laboratory chemical use to determine whether they require high, medium, or specialized general ventilation. OES shall determine the ventilation category.

<u>High ventilation:</u>

Laboratories in which there are significant volatile chemical or specific process hazards for which employee exposures are expected to be controlled by the general ventilation system are designated for ventilation at 8 air changes per hour (ach) when the laboratories are occupied and 4 air changes per hour when the labs are unoccupied.

This recommendation relies on the expectation that significant point sources of volatile chemicals are contained by effective local exhaust, in the form of a chemical hood, local point exhaust, or an appropriate chemical storage cabinet.

For this reason, in these control bands laboratory workers will be trained in best practices for using ventilation systems in the laboratory, specifically in the proper use of the specific hood models and control systems provided in their laboratory and the process of deciding which processes should be located in a hood based on risk criteria.

Specific chemical classes that require this level of ventilation are those used in concentrations and quantities sufficient to create significant volatility hazards.

Moderate ventilation:

In many cases, where use of volatile chemicals are more limited, the specified ventilation rates can be lowered to 6 ach occupied / 3 ach unoccupied. In these cases, worker education about laboratory ventilation can be more generic and simplified.

Specific chemical classes that require this level of ventilation are those that are used in concentrations and quantities that can create odors and nuisances.

Low ventilation:

In the lowest hazard control band are laboratories where the chemicals used are minimal and ventilation requirements can possibly be lowered to those required to support air exhaust from the space, temperature, and human occupancy needs for the room. It should be noted that such rooms may have other hazards, such as lasers, welding fumes, or significant heat sources which may drive risk-based ventilation needs. One potential strategy is to manage these occasional or discrete chemical risks with local exhaust ventilation rather than general ventilation. Provision of portable exhaust systems with HEPA and/or carbon filters could potentially allow reduction of general ventilation rate in these situations. The ACGIH's Industrial Ventilation manual can be consulted for information about the design criteria of such systems. Depending on the contaminants expected to be used in the room, air exhausted may or may not be of an appropriate quality to be returned to occupied spaces. Determinations in this regard should be made on a case by case basis and include chemical spill scenarios when these determinations are made. In any case, chemical use is not the driving factor in ventilation rates, so there is no generic ventilation rate associated with this band, rather specific design review based on the actual use of the room is required.

Laboratory situations that may allow a lower level of air exchanges that require specific review include temperature control rooms, class laboratories whose occupancy periods are well defined, and storage rooms for non-volatile chemicals.

Specific ventilation design required:

Some specific laboratory uses of chemicals may require higher or lower ventilation rates than those generically described above due to specific hazards or requirements that arise from the processes conducted in the laboratory. Assignment of ventilation requirements for these situations lies outside the scope of the generic control banding process and requires specific analysis and risk assessment to determine ventilation needs. Such analysis will be documented by a "basis of operation" report outlining the considerations used in defining the ventilation parameters. This analysis will be supported by development of specific training programs to assure that laboratory workers understand the assumptions and operation of the laboratory ventilation system. Examples of such situations include animal use areas, semiconductor processing facilities, glass cleaning rooms without local exhaust ventilation, or areas where non-chemical hazards are present. OES and Facilities Services will assist in establishing ventilation rates for these special areas.

VI. Appendix II. Animal facilities

If the project includes housing for animals, the consultant shall contact Godley-Snell Research Services and the university IACUC for information on animal facilities and housing.

Recirculation of exhaust air is prohibited. Directional air flow is recommended. Recommend compliance with the Institute of Laboratory Animal Resources, "Guide for the Care and Use of Laboratory Animals."

Compliance with the NIH "Design Requirements Manual" may also apply based on facility use.

VII. Applicable codes and standards

a. ANSI/AIHA Z9.5-2022
b. ASHRAE 62.2-2017
c. ASHRAE 62.1-2022
d. ASHRAE 110-2016
e. SC Fire Code
f. SC Building Code
g. SC Mechanical Code
h. NFPA 30
i. NFPA 45
j. NFPA 55
k. AMACNA Duct Construction Standards
l. All codes and standards incorporated by reference in above.