1.0 Purpose

A. The following guidelines provide information on laboratory fume hood and laboratory exhaust construction, materials, installation and certification requirements.

2.0 General Requirements

A. Codes, Standards, References

1. ACGIH Ventilation Manual
2. ANSI/AIHA Z9.5
3. ANSI/ASHRAE 55
4. ASHRAE 110
5. NSF 49
6. ASTM E84
7. NC State Biological Safety Manual
8. NFPA
9. SEFA
10. ASHRAE Classification of Laboratory Ventilation Design Levels
11. OSHA
12. North Carolina State Building Codes
    a) NC Mechanical Code – Section 510

B. General

1. Specific Applications not covered in this document shall follow the requirements listed in the latest version of the *ACGIH Ventilation Manual*.
2. When considering equipment for which specific design references do not exist, design parameters shall be approved by NC State.
3. The ANSI/AIHA Z9.5 guidelines do not apply to lab ventilation for the following conditions:
    a) Laminar Flow Chemical Hoods: Contact NC State for requirements
    b) Biological Safety Cabinets shall meet NSF 49 requirements. Contact NC State for additional requirements.
4. Design must result in a laboratory noise level of NC 50 or lower. Proper acoustic design should be accomplished by appropriate fan size and type. Sound attenuators must be approved by NC State. Sound attenuators must be constructed of 304 stainless steel.

5. Laboratories and offices shall be configured to be served by separate supply air systems to allow individualized scheduling of occupied periods. Makeup air shall be provided from the lab air handling unit system and not a separate system.

6. All hazardous exhaust systems shall be connected to emergency power in lieu of standby power. Variable volume manifold systems are preferred so that mechanical redundancy and more efficient provision of emergency power can be achieved. For manifold systems, at least two exhaust fans (prefer 3 fans) shall provide N+1 mechanical redundancy for normal power conditions and maintain 50% of normal exhaust flow under emergency power conditions to all connected exhaust devices. Manifold exhaust fans shall include dampers to prevent backdraft during failure.

   a) For existing buildings, evaluation must be done to verify the generator capacity and availability of non-life safety automatic transfer switches.

7. Designer shall provide a schematic line diagram for each supply and exhaust system in the design documents and furnish to the NC State project manager. The diagram shall include duct sizes, air flow rates, fan capacities and shall show all connected exhaust devices.

8. Designer shall provide a floor plan with room airflow balance and pressurization indicated. Designer shall provide a room airflow summary document that indicates air changes, minimum cfm, and maximum cfm.

9. The diversity factor for VAV systems shall be approved by NC State. Program growth, change, and system diversity should be factored into lab ventilation design. Supply and exhaust air systems design to include additional capacity to account for future growth, additional fume hoods, and system performance degradation over time (recommend at least 20%)

C. Lab Ventilation Rates

1. Wet Lab: Between six and eight (6-8) air changes per hour (ACH) based on the lab/building application and NC State hazard evaluation. Rates lower than 6 ACH may, depending on the results of a hazard review by EH&S, be appropriate for lower hazard (non-chemistry) labs. High hazard potential operations and associated safety controls or temperature demands may dictate a design, which results in air change rates in excess of 8 ACH. Where air change rates lower than 6 ACH or greater than 8 ACH are proposed, NC State approval shall be obtained at the SD stage of design.

2. Off-hour/night setback: Room can typically be reduced to 4 ACH and requires NC State Approval. Setback shall not impact fume hood or local exhaust devices.

D. Supply Air System

1. The supply air system shall be equipped to control humidity to minimum and maximum levels. Designer shall indicate the design space temperature and humidity requirements on the documents.

2. Supply air diffusers in laboratories shall be non-directional and low velocity. Air velocity from supply diffusers shall be less than $^1/_3$ of the chemical hood's average face velocity, measured as specified in ASHRAE 110.

3. Laboratories shall be maintained negative with respect to the surrounding spaces at a minimum differential pressure between -0.01" and -0.02" w.g. The laboratory envelope control shall be maintained by volumetric differential controls with respect to exhaust and supply. Adequate makeup air from adjacent spaces shall be considered to facilitate laboratory pressurization control.

4. Provide room pressurization sensors with visual alarms in critical environments: clean rooms, BSL-3, BSL-4 laboratories, etc. as required by EH&S. Room pressurization sensors shall include BACnet communication or digital output to building automation systems to monitor alarm status and/or pressurization value.

   a) Through the wall differential pressurization controllers are not allowed (exceptions may be made for specific applications such as clean rooms and BSL-3/BSL-4 laboratories).

5. Variable Air Volume (VAV) and Constant Air Volume (CAV) systems shall maintain laboratory negative pressurization regardless of laboratory hood sash position and/or other exhaust devices flow adjustment damper position.

6. The minimum horizontal distance from a supply diffuser to the face of the hood is 5 feet. The intent is to prevent supply air currents disturbing the fume hood containment.

7. Supply diffusers shall be located to maximize room air mixing and avoid short circuiting of supply air to exhaust.

8. The minimum distance from the lab entrance door and/or operable windows to the hood is 10'.

9. Supply Flow Monitors: Workstations used for the control/exhaust of hazardous materials, that contain HEPA filtered air supply systems, shall include a differential pressure gauge visible to the operator to measure the static pressure drop across the filter. The differential pressure gauge shall be labeled to indicate when the filter needs to be changed. Consider BAS integration where filter change-out responsibility is with building maintenance and operation.

10. Maximum supply air velocity at any laboratory workstation shall meet the ANSI/ASHRAE 55 requirements for comfort conditioning.

11. When adding one or more exhaust devices to an existing space, the equivalent supply of outside makeup air shall be provided to the space to offset laboratory exhaust load increases.

E. Chemical Hood Design Requirements

1. Bypass hoods are required for CAV applications. The bypass shall be able to maintain the exhaust volume unchanged (<5%) when the sash is in the fully closed position. Bypass is not required for VAV hoods.

2. Auxiliary air hoods and ductless hoods are not allowed.

3. Designers are encouraged where appropriate to propose high performance low flow hoods as a design alternative during the programming stage of design. The proposed hardware and design assumptions for energy savings shall be provided to NC State for review and approval at the programming stage of design. Other requirements in the design guideline shall be satisfied.

4. High performance fume hood's election and modification must mee the criteria set forth at the following document https://drive.google.com/file/d/1FLCZUd202bY9_tl6bzsbJKljrpzgxcaO/view

5. A mechanical sash stop is required to limit the maximum vertical sash height at 18". Electromechanical or automatic sash closure mechanisms are not acceptable.

6. For the VAV hoods, in addition to the sash stop, a sash position alarm is also required. Sash position alarm shall activate when the sash is raised above 20". The mute button for the sash position alarm shall not mute the alarm for more than one minute.

7. Non-combination vertical sashes are required. Horizontal or combination sash is not approved.

8. For a 5-foot hood, a vertical sash opening shall not require more than 5 lbs force. For larger hoods, an additional one lb of force may be required for each additional linear foot of fume hood width, and sash should remain stationary when force is removed.

9. Hoods shall be equipped with front edge airfoils. A spill tray or similar method is required to collect material spilled over the airfoil. Spill tray shall be easily accessible for cleanup.

10. All utility valves and switches shall be located outside the hood. Non-electrical utilities may be installed inside the hood provided they have outside cutoffs. Fume hoods shall be listed by a 3rd party testing agency approved by the state construction office such as UL listing.

11. The finished installation for all hood working surfaces shall be 33"-34" above the finished floor. Coordinate with architects for ADA hood requirements.

12. The hood work surface shall be recessed at least 1/4 in. with a seamless vertical lip. If the hood is provided with a recessed sink, the perimeter of the sink shall also contain a 1/8 in. lip.

13. Corrosive storage cabinets beneath the hood shall be vented. Direct venting pipe connection to the hood exhaust duct is the preferred method.

14. Flammable storage cabinets beneath the hood shall not be vented. Flammable storage cabinets require a flame arrestor. Flammable storage cabinets located under hoods shall be NFPA 30 approved and listed by a 3rd party listing agency approved by state construction.

15. The hood light shall be in a vapor resistant panel accessible from outside the hood. The light shall provide a minimum of 80 foot-candles on any part of the bench level.

16. Chemical hoods shall be designed to provide a continuous face velocity of 110 fpm at a sash height of 18". Final balance shall indicate 100 fpm at 18" sash height.

17. Design and balance face velocities for CAV high performance hoods are 90 fpm and 80 fpm respectively.

18. VAV high performance hoods are not allowed.

19. VAV chemical hoods shall draw a minimum rate of 25 cubic feet per square foot of hood surface area with the hood sash in the closed position.

20. Room VAV response time shall not be more than 10 seconds for laboratories to maintain pressurization.

21. Fume hood VAV response time shall not be more than 3 to5 seconds.

22. Iodination and hard ducted biological safety cabinets shall be connected to a dedicated exhaust system.

23. Provide eyewash and shower in locations where fume hoods are installed. See plumbing design and construction guidelines.

F. Chemical Hood Material

1. Liner material shall be flame retardant, self-extinguishing and have a flame rating of 25 or less in accordance with ASTM E84.

2. The chemical hood sash shall be constructed of shatter- proof transparent material.

G. Chemical Hood Selection

1. Reuse or relocation of existing laboratory hoods shall require approval to include NC State environmental health and safety. Fume hoods removed from service shall not be reused on campus unless an exemption is approved. EH&S must approve any exemptions requested by the user. Exemption requests shall be completed by means of email to the env-health-fumehood@ncsu.edu and include information on the existing fume hood, new location, and new fume hood application/use.

2. Only manufacturer-certified high performance (high efficiency) hoods shall be selected.

3. NCSU pre-qualified fume hoods and alarms

   a) Pre-approved fume hoods

      (1) Thermo Scientific SafeAire II

      (2) Fisher Hamilton Concept

      (3) LABCONCO Protector XStream

      (4) LABCONCO Protector XL

      (5) Kewaunee Supreme Air LV

      (6) Kewaunee Venturi with airfoil spill tray

      (7) Mott Manufacturing RFV2

   b) Pre-approved perchloric acid and acid digestion hoods

(1) TFI Inline Design Corp Polypropylene countertop fume hood flame retardant

(2) NuAire Fumegard 156 Polypropylene hood

(3) LABCONCO Protector Stainless Steel Perchloric Acid Laboratory Hood

c) Pre-approved fume hood flow monitor /alarms

(1) AFA 1000 Alarm by TEL

(2) TSI FHM-10-01 Fume Hood Face Velocity Meter

4. Selected fume hoods from the list above for any new project will require final NCSU EH&S compliance review and approval.

5. All new fume hood selections shall be suitable for use in both variable volume and high-performance constant volume applications.

6. For design projects, submit fume hood selections as early as possible to ensure compliance review approval.

7. For applications in which exhaust capacity may be limited for CAV hoods, consider referring to NCSU “high performance/low flow hood” requirements here.

H. Exhaust Flow/Velocity Monitor and Alarm

1. All chemical hoods shall be equipped with an exhaust flow/velocity monitor with digital readout and alarm which shall sound whenever average face velocity drops below 70 fpm at 18” sash height. The low velocity set point for high performance fume hoods is 65 fpm.

I. Hazardous Exhaust Systems

1. Any exhaust system with a fume hood connection shall be classified as a hazardous exhaust system.

2. Facilities preference is for variable volume manifold hazardous exhaust systems where considerations into exhaust fume hood count and location (cost), flexibility (future additions/relocations), heat recovery (coil type only), redundancy, dilution, and codes/standards are satisfied.

3. For large new buildings adjacent to existing facilities, provide plume dispersion modeling to ensure no re-entrainment.

4. Determine exhaust feasibility for manifold vs dedicated hazardous exhaust fan systems.

5. Exhaust systems shall be mounted on the roof of the building. Alternate locations must be approved by NCSU.

6. Determine the feasibility of variable volume or constant volume exhaust systems by considering the energy savings of the system, flexibility, hood compatibility, and room airflow requirements.

7. Variable volume manifold hazardous exhaust systems may utilize stepped fan operation and/or fan speed modulation to maintain manifold duct static pressure.

8. Variable volume manifold hazardous exhaust systems may utilize variable nozzles or multiple outside air bypass dampers to maintain stack velocity. Bypass dampers shall be designed to limit face velocity for better control and long-term durability. Provide multiple exhaust fan stages for redundancy and to provide lead/lag fan control to limit the amount of bypass air required to maintain stack velocity. Facilities' preference is that the exhaust system utilizes dual stage exhaust fans to reduce or eliminate the bypass damper operation.

9. Manifold hazardous exhaust systems shall utilize a minimum of 2 exhaust fans capable of providing the maximum total exhaust requirements of the connected labs with a single fan failure, with all hoods and equipment in use. Facilities preference is for 3 or more fans for variable volume manifold systems to provide additional staging, redundancy, smaller fans/motors, and flexibility for service.

10. Manifold hazardous exhaust fans shall include outlet gravity or motorized style backdraft dampers to prevent reverse flow through idle lag or backup fans.

11. In the case of high hazard or unique use hoods, such as perchloric acid, acid digestion and radio iodination hoods. High hazard hoods shall not be installed in manifold systems and shall be separately exhausted.

12. High hazard hoods cannot be VAV or high performance.

13. Variable nozzle exhaust stack may be used where the discharge elevation is less than 12 feet and where the exhaust fan is greater than 15 feet from a roof edge for safety and maintenance purposes. In all cases, there must be convenient and safe maintenance access.

14. Manifold exhaust systems shall include a DDC BAS controller that includes at least the following points:

   a) Fan status
   b) Isolation damper position
   c) Manifold duct static pressure
   d) Bypass damper position
   e) Exhaust stack discharge velocity (VAV)
   f) Fan speed input (VAV)

15. Provisions shall be made for local exhaust of instruments. Equipment emitting hazardous gases or vapors, including but not limited to gas cabinets and gas chromatographs, shall be exhausted via point of use exhaust ventilation. Refer to *ACGIH Ventilation Manual*.

16. Exhaust discharges from vacuum pumps shall be connected to local exhaust systems. Materials and methods shall be determined based on application and will required NC State approval.

17. Exhaust systems for gas cabinets and other exhaust devices housing high hazard materials shall be equipped with an exhaust flow monitor which includes an auxiliary relay for process control.

18. Gas cabinets for gas cylinders shall have an average face velocity of 200 fpm at the inspection door when the inspection door is fully opened.

19. Balancing dampers or control valves shall be installed in each exhaust duct branch connected to exhaust devices as allowed by code. Dampers shall include locking mechanisms to prevent adjustment after testing and balancing is completed. Balancing dampers shall be locked out or in a limited access location.

20. Air flow requirements for the canopy hoods, snorkels, balance enclosures, and other local exhaust devices need to be reviewed and approved by NC State. All devices need to be labeled with the design airflow rate (CFM).

J. Exhaust Duct

1. General-purpose chemical hood duct work shall be butt-welded 304 stainless steel with 304 stainless steel fillet material.

2. Flanged joints may be used only where field conditions prevent welded joints.

3. See the Perchloric Acid and Hoods and Exhaust Systems and Acid Digestion hoods section for special considerations.

K. Exhaust Fans

1. Exhaust stacks shall have a minimum discharge velocity of 3000 fpm with preferable velocities approaching 4000 fpm.

2. The fan set for manifold exhaust systems shall be of the radial, direct drive, high plume, induced air type.

3. Fans shall be direct drive. Air induction shall take place upstream of the fan impeller.

4. For dedicated fume hood exhaust systems, each fan shall be connected to emergency power.

5. For manifold systems, 100% redundancy shall be provided and at least one fan shall be connected to emergency power.

6. Fans shall have stainless, motorized isolation dampers.

7. For perchloric acid systems, the fan should be acid and spark resistant. The exhaust fan motor and drive belts should not be located in the air stream.

L. Hazardous Exhaust Discharge Stack

1. Exhaust stacks shall extend a minimum of 10 ft. above adjacent roof lines and air intakes.

2. Exhaust stacks may be supported by bolting to a flanged fan discharge or by extending support steel from the fan support curb or steel frame. Guy wire supports should be avoided wherever possible to avoid trip hazards.

3. Exhaust stacks shall have a coned discharge to achieve discharge velocity. Fans shall be provided with a zero-loss style exhaust discharge. Fans shall be provided with a drain and ball valve at the bottom of the scroll.

4. During initial design scope meetings, verify with NCSU BM&O and EHS the emergency power requirements for any exhaust fans provided.

M. Perchloric Acid Hoods and Exhaust Systems

1. A perchloric acid hood and exhaust system is a dedicated CAV hood/system for use only with perchloric acid applications, utilizing a “one hood, one fan” system.

2. With NCSU EHS approval, some limited perchloric acid applications/concentrations may not require a dedicated perchloric acid hood.

3. Provide a placard that complies with NC State’s Interior Signage Manual stating: (first line) "PERCHLORIC ACID HOOD”; (second line) “Do NOT Use or Store Other Chemicals, Specifically Organic Compounds in This Hood”; (third line) “Wash Down Before and After Each Use to prevent shock-sensitive explosives build up”.

4. Perchloric acid hoods and exhaust systems shall be constructed of specialized stainless steel or flame retardant materials and shall have non-reactive/acid resistant duct, exhaust fan, gaskets and other components, and built-in water wash-down system.

5. Perchloric acid hoods and exhaust systems shall meet the ANSI Z9.5 and NFPA 45 requirements.

6. Hood baffles shall be removable and accessible.

7. Ductwork shall take the most direct and straightest path to the exterior. Positive drainage shall be provided back to the hood.

8. A water spray system shall be provided to wash down the entire exhaust system from the hood interior behind the baffle, through the fan, up to the roofline. The hood work surface shall be watertight with a minimum depression of ½” at the front and sides. An integral trough shall be provided at the rear of the hood to collect wash down water and direct it to a building-wide laboratory waste system. A hose bib shall be provided within 40 feet of the discharge stack to allow for manual wash-down.

9. Provide controls to initiate wash down.

N. Acid Digestion Hoods (non-perchloric)

1. Acid digestion and certain large volume/high temperature (e.g. boiling) acid applications shall require CAV acid hoods.

2. Connecting ductwork from acid hoods to other exhaust equipment is prohibited.

3. Ductwork shall take the straightest, most direct path to the outside. Positive drainage shall be provided back to the hood.

4. Hoods, exhaust ductwork, fans, gaskets, and other material/components shall be constructed of acid resistant, non-reactive, compatible, and impervious materials.

5. Based upon a hazard review by NCSU EHS, a water wash down system may be required.

O. Other local exhaust ventilation systems

1. Canopy hoods may only be used for non-hazardous odor or heat control at the source and shall not be used to control exposure against hazardous materials in laboratories.

2. Slot hoods, snorkels, and special design/purpose hoods shall not be used as the primary engineering protection or as a replacement for chemical laboratory hoods.

3. Glove boxes shall meet the requirements of ANSI Z9.5 and shall require NC State approval.

4. Exhausted enclosures shall meet all fume hood requirements listed/referenced in this document and require NC State approval.

5. Downdraft tables are preferred for anatomy lab dissection.

6. Canopy hoods, slot hoods, snorkels, exhausted enclosures, downdraft tables, and special design/purpose hoods shall meet the *ACGIH Industrial Ventilation* Guidelines and shall require NC State approval.

P. Testing/Commissioning

1. The exhaust air flow quantity of each hood shall be tested and certified by an independent testing agency and submitted to NC State. The results shall be certified by the contractor and engineer and submitted to NC State.

2. Balancing and certification shall be performed by persons certified by the Associated Air Balance Council (AABC) or the National Environmental Balancing Bureau (NEBB).

3. Balancing is required for chemical hoods, gas cabinets, laminar flow chemical hoods, and other exhausted devices.

4. A white sticker containing exhaust device identification information shall be applied by the balancing contractor to the face panel of the exhaust device. Where this is not practical, the sticker can be applied to the duct that is measured. The sticker shall contain the following:

   a) Required and measured face velocity at 18-inch sash height,
   b) Name/tag of fan serving the hood
   c) List of any other hoods served by the same fan,
   d) Testing date
   e) Name, company, and signature of testing personnel/technician.

5. Duct traverse pitot holes shall be plugged with a removable plug to allow for future readings at the same location.

6. The Designer shall incorporate the NC State Project Manager's Fume Hood Checklist in its entirety and un-modified in the project specifications for the NCSU Construction Project Manager to complete and return to EH&S.

  a) See: https://ehs.ncsu.edu/fume-hood-information-for-new-projects/

7. All newly installed laboratory chemical hoods shall be third party tested to As Installed test criteria (per NC State University modified ASHRAE 110 test requirements). All readings/data recordings shall be directly downloaded from the instruments. Unless otherwise stated, test results shall meet both ASHRAE 110 and ANSI Z9.5 requirements. This test shall include the following:

  a) Exhaust flow measurement

  b) Hood static pressure measurement

  c) Hood monitor and alarm calibration

    (1) Minimum flow alarm set at 80 fpm for VAV/CAV hoods and 65 fpm for high performance hoods

    (2) VAV sash position alarm set at 20”

  d) Room pressurization check (differential pressure measurement)

  e) Face velocity test - Average face velocity shall be between 95-110 fpm range (with 100 fpm as target face velocity) for VAV/CAV hoods and 75-85 fpm for high performance hoods

  f) Cross draft evaluation per ASHRAE 110 - Corrections required if more than 50% and ideally 30% of the average hood face velocity

  g) Airflow visualization (both small and large volume smoke tests)

  h) Tracer gas containment test

    (1) Static test

    (2) Dynamic/sash movement affect test

    (3) Hood perimeter scan

  i) Additional commissioning tests for VAV systems

    (1) Flow/face velocity measurements with sash at full open, 18” and 12”. VAV systems shall prevent flow variations more than 10% from design at each sash location.

    (2) VAV response time measurement of 3-5 sec shall be measured at the baffle slot or exhaust duct.

  j) The contractor shall be financially responsible for all testing, repairs, modifications, and replacements necessary to pass the full ASHRAE 110 Test. If the As-Installed test reveals any hood design/installation deficiency, the contractor shall remediate the deficiency and repeat the full ASHRAE 110 test. The contractor shall be financially responsible for all additional tests required after modifications/repairs are made. If the remediated hood cannot pass the ASHRAE 110 Test, then it cannot be used.