Design Guideline 230030
Laboratory Ventilation

Information for mechanical design engineers as well as architects/lab planners regarding laboratory ventilation design at U-M, including but not limited to the following:

- Equipment information (chemical fume hoods, chemical storage cabinets, BSCs, specialty hoods, and environmental rooms).
- Computational Fluid Dynamic and exhaust stack dispersion modeling requirements.
- Lab HVAC and exhaust design: guidance regarding lab minimum air change rates, duct materials, exhaust fan selection, system diversity, future capacity, etc.
- Vivarium requirements.
- Type and control of terminal airflow units for laboratories.
- Lab energy conservation.

Related Sections

U-M Design Guideline Sections:
SBA 5.2 - Animal Facilities
Sustainability 3.2 - Energy and Water Conservation
115313 Laboratory Fume Hoods
230900 Mechanical Systems Controls

U-M Master Specification Sections:
115313 Laboratory Chemical Fume Hoods
230593 Testing Adjusting, and Balancing
233600 Air Terminal Units
230900 Mechanical Systems Controls
230910 VAV/Combination Sash Fume Hood Laboratory Controls-DDC
230920 Laboratory Terminal Air Flow Units and Controls

U-M Standard Details:
Laboratory Terminal Air Flow Unit Sample Schedule
Supply Air LTAU Clearance Detail
Supply Air TAU Clearance Detail

General

Where this Design Guideline requires consultation with U-M Occupational Safety and Environmental Health Department (OSEH), all such contacts shall be made via the U-M Design Manager.

Lab Equipment Parameters

Chemical Fume Hoods

General:

U-M Master Specification Section 115313 Laboratory Chemical Fume Hoods shall be used as the basis for chemical fume hood specification on all projects. 115313 must be edited to make it project specific.

U-M Master Specification Section 115313 describes fume hood types in terms of face velocity characteristics in a "Definitions" article. These definitions shall be used when specifying fume hoods and when designing fume hood exhaust systems at the University of Michigan. Fume hood air volume requirements depend upon the particular hood type being used, therefore the mechanical designer should carefully review the hood definitions section of 115313. 115313 also describes performance requirements for Reduced Face Velocity (RFV) hoods. Extensive spec editors notes are included in 11610 to assist the A/E. Be sure to turn on hidden text and read those notes.

Multiple fume hood types may be included on a given project. Clearly delineate on the mechanical drawings the air balance and fume hood monitor alarm settings for each hood type. See "Type and Control of Terminal Airflow Units for Labs", below.

The required exhaust flow (CFM), static pressure, and hood opening area (sq. ft.) vary by fume hood manufacturer. Refer to manufacturer's data and then size duct, terminal airflow units (TAU), and fans to accommodate the manufacturer with the worst case (highest air flow and pressure drop) requirements. Provide the hood basis of design (manufacturer and model) on the mechanical design documents.

For vertical opening sashes, U-M requires sash stops be provided to restrict normal sash operation to no higher than 14" above the work surface, NOT the typical 18”. Note that some Reduced Face Velocity fume hoods incorporate an air foil mounted above the hood's working surface. U-M spec section 115313 requires that the sash stop location be adjusted proportionally upward to account for air foils mounted more than 2" above the hood's working surface. The resulting higher sash stop location will result in a somewhat larger fume hood air volume requirement. This should be accounted for in the mechanical design.

Assure the TAB specification requires that the air balancer adjust the TAUs to the air volume required for the particular manufacturer’s hood that is installed. U-M's TAB specification 15990 includes this requirement.

U-M projects use standard chemical fume hoods that operate at an average face velocity of 100 FPM, and Reduced Face Velocity (RFV) fume hoods that operate at an average face velocity of 70 FPM. Refer to the "Design Fundamentals" section of this design guideline for exhaust system sizing requirements for the various hood types.

Constant volume hoods of any type are not safe with combination sash arrangements because correct face velocity can't be assured as the horizontal sash is adjusted. If combination sashes are required, Restricted Bypass VAV hoods shall be used with the corresponding VAV type lab terminal air flow unit control.

Requirements for Floor Mounted Hoods:

- Due to the wide variation of sash configurations available on these type hoods, floor mounted hoods shall be Restricted Bypass VAV hoods.
- Sash stops shall be supplied for every section of vertical sash, set to stop the sash at 14” above the sash’s closed position

Fume Hood Monitor:

Fume hood monitors are provided by the lab air flow controls contractor, NOT the hood manufacturer. U-M specification 230900, 230910 and 230920 include specifications for fume hood monitors.

Fume Hoods in Explosion Proof Rooms

Since typical VAV controls are not explosion proof, constant volume hoods are recommended in explosion proof rooms.

Mount fume hood controls and alarm monitors outside of explosion proof rooms. Mount an explosion proof audible and visual low exhaust flow alarm indicator inside the room, triggered by the fume hood alarm monitor.

Laboratory Fume Hoods for use with Radioactive Materials (Isotope Hoods)

Although a special fume hood is generally required for use with radioactive materials, verify the need for special filtration, or a direct exhaust duct route to the outside, with U-M OSEH. Filtration and direct exhaust are not typically required.

In all cases, delineate space for a future filter box directly above radioisotope hoods.

Flammable Liquid and Corrosive Storage Cabinets

Chemicals shall not be stored within fume hoods. Where a storage space for chemicals is required, a storage cabinet below the fume hood may be provided.

Corrosive storage cabinets shall be ventilated at a rate of approximately 2 CFM exhaust per square foot of cabinet footprint. Do not duct into the fume hood bench top. Instead run a separate exhaust from the cabinet up to the exhaust duct. Connect cabinet exhausts to constant volume (CV) venturi style TAUs. This could be a CV venturi style TAU serving a CV hood, other nearby CV venturi style TAUs (serving snorkels, for example), or, gang multiple cabinet exhausts on to a dedicated CV venturi style TAU. Normally exhaust connections for cabinets should consist of a 2 inch polypropylene vent pipe equipped with a non-corrosive ball valve for balancing.

Flammable liquid storage cabinets shall not normally be ventilated. If the lab occupant requests flammable liquid storage cabinets be ventilated, obtain approval from U-M OSEH before doing so.

Biological Safety Cabinets (BSC) and Other Specialty Cabinets and Hybrid Hoods

Selection of the type, size, class, and manufacturers of BSCs and special "hybrid" hoods shall be made by the researcher and the U-M OSEH representative, in coordination with the Architect/Lab Planner/Mechanical Engineer.

If exhaust connection is required to a BSC, do not assume a direct connection is required since more often the BSC type will allow an indirect, hood mfg. provided, thimble (canopy) connection. Verify the BSC type and the corresponding exhaust connection required, direct or thimble connect, with U-M OSEH.

Many specialty cabinets and hybrid hoods (which often filter downflow supply air) require higher than typical exhaust flow rates (i.e. rates higher than would be suggested based on hood face area) or have high static pressure drop. Always consult the manufacturer's product manuals and design accordingly.

Environmental (Cold) Rooms

Ventilation air is required in all environmental rooms where work with volatile chemicals, compressed gasses, or continuous work activity is planned. Ventilate at 6 air changes per hour or as required by code, whichever is higher.

Ventilated environmental rooms typically require desiccant dryers to avoid excess defrost cycle times. Thus, in addition to a ventilation supply and exhaust air connection to the room, the mechanical engineer will need to provide an exhaust connection for the removal of hot, moist air rejected from the desiccant unit.

Where multiple environmental rooms are located in close proximity to one another, consider ganging the rooms on common CV TAUs, to provide the required supply and exhaust air.

Perchloric Acid Fume Hood Systems

Refer to Appendix B of this Design Guideline.

Lab Room Airflow Modeling

Computational Fluid Dynamic (CFD) studies are typically required when multiple hoods are located near each other and within the same room, unless this requirement is waived by the U-M Design Manager.

New lab buildings with "typical" fume hood alcoves or lab modules shall have CFD modeling done for each module type. CFDs shall demonstrate hood capture effectiveness, optimize air-change-rates (ACH), and evaluate supply outlet and exhaust inlet locations.

CFD Studies shall be considered for other unique air flow arrangements where proper ventilation, air conditioning, or exhaust are considered critical.

<u>HVAC and Exhaust Systems Design</u>

Exhaust Dispersion Assessments

Dispersion studies ensure proper, safe, dilution of exhaust emissions. Dispersion studies shall be done by qualified firms that have a minimum of 5 years of experience performing such studies.

All new lab buildings shall have a comprehensive dispersion study performed.

All critical exhaust sources shall have a dispersion study.

Renovation projects with exhaust fan volumes $\geq$ 5000 cfm capacity shall have a dispersion study.

Dispersion studies shall be *considered* for all other renovation projects. For example, a project installing a new outdoor air intake on a lab building likely would justify a study.

Since the results of dispersion studies often require the A/E's initial design to be modified, they should be started as early as possible in the design process.

Design Fundamentals

<u>General:</u>

The specific standards that apply to a particular project should be determined during programming. The following are typical requirements:

> <u>Research labs</u>: NFPA 45 Standard for Fire Protection for Laboratories Using Chemicals.
>
> <u>Hospital</u>: All hospital projects governed by the Michigan Department of Health, Health Facilities Evaluation Section, shall comply with the Minimum Design Standards for Health Care Facilities in Michigan, and NFPA 99 Standard for Health Care Facilities.

The guidelines expressed herein are meant to supplement, not supersede, code requirements. Where conflicts exist, the AE shall review with the U-M Design Manager.

Designs may also need to comply with various U.S. Government standards or guidelines (e.g. National Institute of Health, Department of Agriculture, etc.); establish which apply during project programming phase.

Laboratory supply and exhaust air shall be dedicated to lab areas within the building and shall not be part of HVAC systems serving other building areas (offices, toilet rooms, vivariums, etc.).

Because U-M specifications and details specifically address laboratory spaces, it is critical that the A/E clearly delineate on the project drawings which spaces are laboratories.

Lab general and fume hood exhaust shall be manifolded whenever possible, as permitted by code, to reduce first cost and improve energy efficiency and maintainability.

Supply air shall be “once through” (100% outside air); it shall not be recirculated outside a laboratory room. Air may be recirculated within the laboratory room itself, e.g. local fan coils. Some very low hazard level labs may use recirculated air when approved by U-M OSEH.

The use of non-DX type fan coils or chilled beams for sensible loads is encouraged to reduce the amount of outside air required for lab cooling. For labs affecting patient care in hospital facilities, the Minimum Design Standards for Health Care Facilities in Michigan precludes the use of recirculating fan coil units in labs unless outfitted with a HEPA filter.

Rooms and all TAUs serving laboratories shall be scheduled. Provide all of the information contained on the U-M sample schedule Laboratory Terminal Air Flow Unit Sample Schedule.

HVAC systems serving laboratories, including rooms with chemical fume hoods, shall be designed for variable air volume (VAV) using tracking supply, general exhaust and fume hood TAUs. While this means supply and general exhaust shall be variable flow, it does not necessarily mean fume hoods are to be variable flow:

For purposes of initial program budget, the use of VAV fume hoods/controls should be assumed. As the program is further developed, evaluate and justify VAV vs CV fume hoods. When analyzing the potential benefit of VAV type fume hoods, evaluate with and without automatic sash lowering devices.

- Evaluate if the LMVR (see LMVR discussion below) for the room precludes the use of VAV hoods because general exhaust would increase to maintain the LMVR as the hood sash was closed.
- Assume fume hood sashes with automatic devices will result in an average hood air flow reduction of 30%,
- Assume fume hood sashes without automatic devices will result in an average hood air flow reduction of 10%.

- Hood with combination sashes must be equipped with VAV TAUs/controls.

Do not diversify fume hood loads relative to exhaust fan/system sizing; assume all hoods are at 14" sash position at all times.

Size supply and exhaust systems with additional capacity for future use. Determine the appropriate additional capacity in consultation with the U-M Design Manager. Minimum additional capacity: 10%.

Size fume hood TAUs and the associated TAU branch duct as follows:

- <u>Full Bypass Constant Volume Type</u>: For the air volume required to attain 100 FPM at full open sash position.
- <u>Partial Bypass Constant Volume Type</u>: For the air volume required to attain 100 FPM with sash at sash stop position.
- <u>Restricted Bypass VAV Type</u>: For the air volume required to attain 60 FPM at full open sash position, 100 FPM with sash at sash stop position.
    - <u>Combination Sashes</u>: 100 FPM must be achieved with the sashes in the position that creates the maximum free area opening. Example: If the sash has 4 horizontal sashes, the face velocity must be achieved with 2 sashes in the full open position (with the sash vertical position closed).
- <u>Full Bypass Constant Volume **RFV** Type</u>: For the air volume required to attain 70 FPM at full open sash position.
- <u>Partial Bypass Constant Volume **RFV** Type</u>: For the air volume required to attain 70 FPM with sash at sash stop position.
- <u>Restricted Bypass VAV **RFV** Type</u>: For the air volume required to attain 60 FPM at full open sash position, 70 FPM with sash at sash stop position.
    - <u>Combination Sashes</u>: 70 FPM must be achieved with the sashes in the position that creates the maximum free area opening. Example: If the sash has 4 horizontal sashes, the face velocity must be achieved with 2 sashes in the full open position (with the sash vertical position closed).
- <u>Exhaust Valves for Floor Mounted Hoods</u>: Must use VAV type TAU/controls. The exhaust air valve shall be sized so that the required face velocity can be achieved with one sash fully open. Example: If sash is 28" high and can be opened to create a free area opening 28" high, the exhaust air valve must have enough capacity to achieve the required face velocity (e.g. 100 FPM) at 28".

<u>LMVR: Lab Minimum Ventilation Rate</u>

Each lab room shall be ventilated at a minimum Lab Minimum Ventilation Rate. The LMVR shall be established in consultation with U-M OSEH, and shall be in compliance with codes and the Minimum Design Standards for Health Care Facilities in Michigan (when applicable). Typical LMVRs, room pressurization, and air flow control requirements can be found in Appendix A of this Design Guideline.

Snorkels and Similar Local Exhaust Terminations

To obtain U-M OSEH certification, designs shall provide a 100 FPM capture velocity 4” from the centerline of the plane of the device opening. Obtaining 100 FPM may require very high flows in the upstream connection to the device opening, resulting in high pressure drop and noise. Therefore, these devices should be carefully selected and specified and performance capability reviewed and approved by U-M OSEH.

Negative or Positive Pressure

Pressurization in and out of rooms shall be indicated on plans with directional arrows and airflow quantities (CFM).

Sealing of all room penetrations and joints shall be specified to maintain space pressurization.

If a local means of adjusting space pressurization is requested (typically accomplished with a potentiometer), specify that the adjustment device be clearly labeled to identify which direction produces positive or negative pressurization adjustment. Specify a locking enclosure for the adjustment device. Local means of adjusting pressure is discouraged.

Laboratory Pressurization Gauge

All laboratory rooms including animal rooms of all types shall be provided with a room differential pressure indicator so that room occupants can locally verify the direction of room pressurization. Provide room pressurization gauges outside and above the laboratory entrance expected to be most frequently used, in the corridor wall at the lab room. (Provide *inside*, outside, and above all BSL-3 lab doors). Analog gauges shall be used and are specified in U-M master specification 230900 and 230910. The location of the pressurization gauges shall be indicated on the lab HVAC floor plan drawings.

Emergency Operation

Provide emergency power for laboratory systems where a power failure endangers life safety.

Exhaust fans and corresponding supply fans shall automatically restart when power is restored after a power failure.

Fire detection and alarm systems shall not be interlocked to automatically shut down chemical fume hood exhaust. Exhaust fans shall continue to operate in the event of a failure or alarm condition of the supply air system. For example, if the supply air handler trips on freeze stat or smoke detector, the associated lab exhaust fan(s) shall not shut down. Proper door operation for egress shall be maintained when the supply system shuts down and the lab exhaust system continues to operate, creating a pressure differential. Some large systems may require a design that automatically reduces exhaust fan volumes, to prevent excess negative pressure at egress doors.

Indicate in the Design Intent Document, exhaust system operation under all emergency conditions (loss of power, fire, supply air failure, etc.).

Vivariums:

Vivariums require dedicated, fully redundant air handlers. Vivarium air handlers, animal room exhaust systems, terminal units, and controls shall be fed from the emergency power system.

The TAUs serving animal holding rooms shall be selected such that air flow to those rooms can be increased an additional 10% minimum, future. Size the vivarium air handler with sufficient capacity to accommodate this additional air flow capability.

Reheat coils shall utilize normally closed (N.C.) control valves to prevent over-heating animals upon a valve failure.

Each animal room exhaust shall be equipped with a duct mounted filter rack. Exhaust grille style filter frames are not preferred but may be used with the permission of the U-M Design Manager.

Laboratory Exhaust Duct

Materials

The below descriptions are considered normative for U-M lab projects; however the A/E shall give consideration to the nature of materials being exhausted and shall specify appropriate duct materials, construction methods (e.g. gasket and sealant types, etc.), and duct coatings.

> Lab General Exhaust: G-90 galvanized where accessible. Specify plastic coated duct (PCD) in concealed spaces, including shafts.
>
> Chemical Fume Hood Exhaust: PCD from hood to main lateral. If there is insignificant general exhaust flowing through the main lateral, specify PCD for the entire exhaust duct run.
>
> Cage and rack washers, sterilizer and glass washer hoods, and any ductwork carrying moist air: "seal" welded (water leakage tight) 316 stainless steel, from hood to main lateral. Duct shall slope back toward the hood so that any condensate formed in the duct drains away from the main lateral duct. Hoods shall have drain lips, piped to a local floor drain.
>
> Acid Exhaust: Teflon lined stainless steel duct shall be consider in lieu of FRP duct. Note: Obtain concurrence from U-M OSEH that exhaust acidity justifies these specialized materials.

Cage and rack washers shall be exhausted via a dedicated exhaust fan. Therefore, the associated duct shall be stainless steel all the way to the exhaust fan, routed as directly as possible, avoiding horizontal runs. TAUs shall not be used.

Construction

Prohibit tie-rod re-enforcement methods for PCD. Prohibit tie-rods in any duct carrying corrosive exhaust.

Exhaust ducts running on the building exterior will typically require insulation to prevent condensation formation inside the duct during cold outside air conditions. Evaluate the need for drains on exterior horizontal exhaust duct work; see “Fan Construction” for additional considerations regarding such drains.

For exhaust duct connected to animal rooms, specify riveted duct upstream of filters.

Fire and/or Smoke Dampers

Not allowed in laboratory exhaust ductwork per NFPA 45.

Fire Wrap for Laboratory Hood Exhaust Duct

All laboratory hood exhaust duct is considered hazardous due to the health class of chemicals utilized as defined by code.

Fire wrap shall be permitted when the exhaust system would require, by code, a fire damper installed but is prohibited due to the hazardous nature of the exhaust. Refer to UM specification section 220719 Mechanical Systems Insulation for the requirements of the fire wrap product.

Installation requirements will vary based on the routing of the exhaust duct through the building. The engineer of record shall coordinate with UM Environment Health & Safety to review the proposed installation on a project-by-project basis.

Exposed fire wrap insulation shall be protected against physical damage to ensure that the integrity of the insulation is maintained. Additional jacketing or other means of protection for the insulation may be required to accomplish this in spot areas of the duct run but may not be required for the entire system. An **example** application includes, but is not limited to, a fire wrapped duct routed vertically through a janitor’s closet where environmental services could damage the insulation with mops, buckets, carts, etc.

Additionally, fire wrap may be considered or required in other, non-laboratory hazardous exhaust applications, but will need to be reviewed with UM design team as well as UM Environment Health & Safety prior to issuing documents for bidding.

Exhaust Fans

Fan Capacity

Specify at least 10% additional design flow at the required system static pressure for all lab exhaust fans.

Fan Selection/Number of Fans

For lab exhaust systems over 10,000 CFM capacity, provide 100% redundant standby fans.

For systems 10,000 CFM or less, consider two fans at 50% capacity each.

For all critical exhaust systems, e.g. Biosafety Level 3 labs, provide 100% redundant standby fans.

Cage and rack washers shall be exhausted via a dedicated exhaust fan.

Fan Types

Centrifugal fan systems are preferred, provided it can be shown they safely disperse the effluent. Provide direct drive fans when available.

Direct-drive, high-plume exhaust fans shall be provided on systems above 5000 CFM when no fan redundancy is provided, or when found to be required by dispersion studies.

Location and Design

Exhaust fans shall be located on a roof so that all duct in the building is negatively pressurized. If a roof location is impossible and the fan(s) must be located in a mechanical penthouse or room, design an air tight enclosure around the fan(s) and specify that the discharge duct from the fan be seal welded. Contact the U-M HVAC/Controls Mech Tech team for additional info on air-tight enclosures. Provide windows in enclosures to facilitate maintenance.

The fan stack velocity shall be maintained by the use of normally-closed bleed-in dampers or other means. VFDs on lab exhaust fans to maintain stack velocity or for other reasons are generally not used and if proposed require the review and approval of the U-M HVAC Mech Tech Team.

Orient the fan discharge duct (stack) vertically from the fan outlet. Extend stacks a minimum of 10 feet above the highest local roof. Design the stack to provide a minimum stack discharge exit velocity of 3000 FPM unless a dispersion study demonstrates a lower tip velocity achieves the required dilution target. Stack tips shall be designed to discharge exhaust straight vertically upward without obstruction. Provide designs similar to those recommended by the American Conference of Governmental Industrial Hygenists handbook "Industrial Ventilation - A Manual of Recommended Practice for Design". Rain caps, including those with deflectors, shall not be used.

Fan stacks shall be self-supporting. Guy wires shall not be used without the permission of the U-M Design Manager.

Fan Construction

Fan housings (centrifugal fans) shall be welded construction with a cleanout door.

Typically, fans, fan blades, fan plenums, plenum access doors, and fan back-draft dampers should have a Heresite anti-corrosion coating. Specific applications may require different anti-corrosion coatings. It is the A/E/Lab Planners' responsibility to select appropriate coatings. Also specify a heavy-duty coating for the exterior surfaces that prevents corrosion.

Provide a scroll drain for centrifugal fans (drain valve with hose connection). Fans located in enclosures shall have scroll drains piped to the enclosure exterior, with the drain valve and hose bib on the outside, and the drain labeled as a hazard.

Similar to scroll drains, provide drains in exhaust plenums located outside (drain valve/hose connection/cap). Depending on the relative humidity of the space being exhausted, some exterior plenums will require drains that continuously remove routine condensation formation occurring in winter months. Such drains shall be routed to termination points inside the building, and be properly trapped. Provide trap primers. Portions of such drains located outside must be heat traced. Similarly, evaluate the need for drains on exterior horizontal exhaust duct work.

Flexible Connectors

On positively pressurized duct work, flexible connectors are prohibited indoors, except for exhaust fans mounted inside enclosures. Fabric flexible connectors shall never be used. Onepiece flexible rubber/elastomeric connectors may be used in some low risk applications, with the approval of the U-M Design Manager

Dampers

Motorized control dampers shall be used to prevent back drafting of exhaust fans. Such dampers shall be designed to fail to the "open" position on loss of power. These same dampers shall close when the fan is turned off by normal means.

Motorized bleed-in dampers shall fail to "closed" position.

Damper actuators shall be located outside of the exhaust air stream.

A method of preventing excess negative duct/plenum pressure shall be provided.

Damper construction shall meet or exceed ductwork construction (i.e. protective coating, stainless steel, etc.)

Exhaust Filters

The installation and type of filter in the laboratory exhaust system (if any) shall be determined by the U-M department of Occupational Safety and Environmental Health (OSEH), and for health care facilities in compliance with requirements stated in Minimum Design Standards for Health Care Facilities in Michigan.

Radioactive hoods typically do not require filters.

All exhaust filters shall be provided with a differential pressure gauge to indicate pressure drop across filter.

Exhaust systems with filters that require a specific stack velocity to achieve required dilution targets must include provisions to maintain stack velocities as filters load up.

Exhaust System Fan Control

Exhaust fans shall be controlled by the owners Building Automation/DDC System. See U-M Design Guideline 15975 Mechanical Systems Controls.

Type and Control of Terminal Airflow Units for Labs

In August of 2016 U-M revised its long standing practice of requiring venturi style valves for all laboratory spaces, to only requiring them for labs with VAV or combination sash hoods:

For laboratory spaces which **do not contain VAV hoods or hoods with combination sashes**, (including animal rooms) use conventional terminal air flow units for supply and general room exhaust and venturi style terminal airflow units for constant volume fume hoods and any other constant volume exhaust point. Conventional supply and exhaust TAUs as well as the constant volume venturi valves are specified in U-M Master Specification Section 233600 Air Terminal Units. The laboratory controls for these rooms, including constant volume fume hood monitors and room differential pressure gauges, are specified in U-M Master Specification 230900 Mechanical Systems Controls. *Note that constant volume venturi style TAUs used to serve such rooms must be labeled "CVV Terminal Airflow Units" on the design drawing to match the designation in U-M Master Spec 233600.*

For laboratory spaces which **do contain VAV hoods or hoods with combination sashes** (including animal rooms - rare) use venturi style terminal air flow units for supply, general room exhaust and for variable volume and combination sash fume hoods. Venturi style valves must be used because of the speed of response required for labs with VAV or combination sash hoods. Venturi style valves along with associated controls, fume hood monitors and room differential pressure gauges are specified in U-M Master Specification Section 230910 VAV/Combination Sash Fume Hood Laboratory Controls-DDC. *Note that if constant volume venturi valves are also required to serve spaces with VAV and/or combination sash hoods, U-M Master Specification 230910 requires the contractor responsible for 230910 to supply them.*

Further note that:

- U-M Master Specification **230910** covers **digitally controlled** lab terminal air flow unit controls and is typically used for all new buildings and major renovations.
- U-M Master Specification **230920** covers **analog electronic** lab terminal airflow unit controls and is typically used for smaller renovations where analog electronic air flow controls already exist and it makes sense to reuse them. Generally, projects in such spaces shall be upgraded to digitally controlled TAUs. Early in design, consult the U-M Design Manager to establish which type lab controls shall be used for such projects.

Because these U-M specifications specifically address laboratory spaces, it is critical that the A/E clearly delineate on the project drawings which spaces are laboratories.

Sizing fume hood TAUs: See "HVAC and Exhaust Systems Design", above.

Vivarium TAU Sizing: The air valves serving animal holding rooms shall be selected such that air flow to those rooms can be increased an additional 10% minimum, future.

Hood Type: Designate hood type served by each TAU on the architectural/lab plan as well as the mechanical design drawings.

Sash Type: For VAV TAUs, designate if sash is vertical rising or combination type on the design drawings. Combination sashes shall not be used on constant volume hoods.

Sash Alarms: Are to be provided for all hoods. U-M Master Specifications 230900 and 230910 (see discussion above) include fume hood monitor specifications that include the sash alarm features required by U-M.

Air Balancing: Indicate on drawings that the TAU air volume is to be balanced to achieve 100 FPM average face velocity with sash at sash stop position for standard hoods, 70 FPM average face velocity with sash at sash stop position for RFV hoods.

Fume Hood Exhaust Monitor Alarm Setting: Indicate settings on drawings as 80 FPM for standard hoods, 60 FPM for RFV hoods.

Fail Mode: Generally, supply TAUs shall be indicated to fail closed and exhaust TAUs shall be indicated to fail open.

Coatings: Specify Heresite coating (minimum) for TAUs serving chemical fume hoods. Specify other protective coating types, as application dictates.

Balancing Damper: Provide a stainless steel balance damper downstream of all TAUs serving chemical fume hoods, for testing purposes.

Clearances: Utilize U-M Standard Details "Supply Air TAU Clearance Detail" and "Supply Air LTAU Clearance Detail " to indicate required clearances. "Dash out" required clearances at each TAU on the plan views. Require that TAUs be mounted no higher than 2' above the ceiling grid.

Power Requirements for TAUs: Designate circuits in receptacle panels on each floor for TAU power supplies. Work with TAU suppliers to determine the number of 20 amp circuits required. Do not exceed 50 TAUs per 20 amp circuit.

Power Requirements for Fume Hood Exhaust Monitors: Designate circuits in receptacle panels on each floor for Fume Hood Monitors. Work with TAU suppliers to determine the number of 20 amp circuits required. Do not exceed 10 Fume Hood Exhaust Monitors per 20 amp circuit.

TAUs are Prohibited: On exhaust connected to cage and rack washers, due to severe corrosion problems U-M has experienced even when coated TAUs have been provided. A dedicated exhaust fan is required to serve cage an rack washers.

Laboratory Supply Air Diffusers and Registers

Terminal Velocity

Terminal velocity of supply air near fume hoods, bio-safety cabinets, etc., is as important as hood velocity and should preferably be no more than 1/2 the hood or cabinet face velocity (near the hood). Therefore terminal throw velocities in areas with hoods or cabinets should be far less than typical for general lab air supply locations.

Optimize design and layout of supply air devices in consideration of all lab requirements, including velocity, throw and low flow performance.

Perforated Diffusers

To avoid cross draft problems, when supply diffusers must be located near fume hoods or other sensitive cabinets, consider perforated diffuser technology (similar to Titus RadiaTec, VersaTec ,or TriTec) that diffuses supply air at high volumes and low velocity. When RFV hoods are used, Titus VersaTec diffusers shall be specified for the immediate ceiling vicinity near the RFV hood.

Wall Registers

If wall registers are used in labs with hoods or cabinets, they should have double deflection louvers and shall be set for maximum deflection position away from the hood.

First Cost Optimization/Energy Conservation

Comply with U-M Design Guideline SID-D.

Provide fan coils/chilled beams or other strategies to reduce the quantity of "once-through" outside air required for cooling.

In spaces with high once through air requirements (> 6 ACH), evaluate strategies to reduce reheat coil pressure drops, such as larger face area reheat coils or radiant heating panels or floors in lieu of duct reheat coils.

At each phase, the A/E/Lab Planner shall calculate the following and indicate the result in the Design Intent Document:

- Fume hood density per 5000 gsf of building
- Fume hood density per 5000 nsf of lab

Densities above 3 hoods per 5000 gsf shall be justified. Consider alternatives such as snorkels and chemical storage cabinets.

Evaluate the following technologies (also see "HVAC and Exhaust Systems Design", above, for required analysis parameters):

- Variable volume hoods
- Automatic sash closure systems
- Controls to reduce the minimum room air change rate when the lab is unoccupied.

Note: By ruling of U-M OSEH, devices to reduce hood face velocity when users are not standing in front of the hoods, e.g. "zone presence sensors" or other means, SHALL NOT be used.

Evaluate Reduced Face Velocity hoods.

Improve ventilation air flow efficiency by reducing the pressure drop of air system components. The following targets (maximums at full design flow) shall be met for all once through air handlers that will run continuously:

- Air Handler Component Face Velocity: 400 FPM
- Total supply and exhaust duct pressure drop: 2.25 in. w.g.
- Noise Control (silencers) 0.25 in. w.g.

For manifolded exhaust systems, evaluate the energy benefit gained from additional fan staging (i.e., from smaller staging increments), by increasing the number of fans drawing air from common exhaust plenums.

Exhaust Air Heat Recovery: Evaluate heat recovery (enthalpy) wheels, flat plate air-to-air heat exchangers, heat pipes (including pumped type), and run-around coils. Include impact of additional pressure drop through each device type.

Avoid tight temperature and humidity requirements. Normal lab setpoints are:

Summer: 76 dbt minimum, humidity floating but no greater than 60% RH

Winter: 71 dbt maximum, humidity floating but no less than 25% RH.

Setpoints outside these ranges shall be justified in the Owner's Project Requirement/Basis of Design (aka Design Intent) Document.

Measure comparable U-M laboratories to establish HVAC plug/equipment loads during early SD phase, and base the lab design on this measured data. For each comparable laboratory space, obtain 7 days of continuous power metering at the branch circuit panel level of all lab equipment, including plug loads and hard wired equipment, while the spaces are fully occupied. Continuous metering data shall include:

- Apparent instantaneous power
- Real instantaneous power
- Real power averaged over 15 minute intervals

The design heat load criteria shall be based on the 15 minute time averaged Real power draw of the comparable space, unless the lab user group can validate higher heat load requirements. U-M will provide the labor to take the measurements, however the A/E/Lab Planner in conjunction with the U-M Design Manager will identify comparable laboratories and analyze the collected data.

Laboratory luminance levels shall not exceed IESNA Handbook (most recent edition) foot candle levels.

Appendix A

Laboratory Minimum Ventilation Rates (LMVR)

Each lab **room** shall be assigned a Lab Minimum Ventilation Rate (LMVR). The LMVR assigns the minimum air change rates to each lab room based upon an assessment of the potential airborne hazards. This minimum air change rate is the amount of 100% outside air that must be delivered to the space, expressed in air changes per hour (ACH) [1].

The LMVR shall be assigned by U-M OSEH Research, Health, and Safety. The assessment involves a review of potential airborne hazardous materials present, quantities, operations, engineering controls and facility history. Table 1 provides the typical LMVR and other requirements by lab room type, for use prior to U-M OSEH approval. The minimum amount of 100% outside air to be delivered to the lab room shall be the higher of the LMVR or any code (e.g. ASHRAE 62.1) or governing standard's requirement.

There are five LMVR classes ranging from the least hazardous (LMVR 0) to the most potentially hazardous (LMVR 4). Air change rates are provided for both occupied and unoccupied conditions. Where an unoccupied ACH is allowed and implemented, automated methods must be provided to notify lab occupants when the room is in unoccupied mode, and to return the room to the occupied mode air change rate. One method acceptable in many lower risk labs is to set back to unoccupied LMVR based upon occupancy sensors which simultaneously turn lab general lighting off. When the lab is re-occupied, the lights automatically switch back on and the occupied LMVR is reestablished. Local indication, such as by a blinking pilot light near the lab door(s), may be required for higher risk labs. The automatic set back method and occupied/unoccupied indication for each lab room shall be approved by U-M OSEH. Flow rates through fume hoods and similar hazardous exhaust capture devices shall remain the same in both the occupied and unoccupied lab modes.

LMVR 0: No Laboratory Hazards (4 ACH occupied, 1 ACH Unoccupied)

Laboratories in this category have no significant airborne hazards or materials. LMVR 0 typically includes dry research labs, laser labs without gases, electronics labs, machine shops, and fabrication labs, with appropriate engineering controls at low hazard emission sources.

LMVR 1: Low Hazard (6 ACH occupied, 4 ACH Unoccupied)

Laboratories typically in this category are open wet research labs, microbiology, genomics, or proteomics labs with minimal quantities of hazardous chemicals,. Hazardous air emissions may exist but are well controlled with standardized equipment and procedures. Includes standard biomedical research involving CDC Risk Group 1 or 2 agents. Only low hazard compressed gases in small quantities are allowed. A risk assessment of actual conditions of use may dictate a higher LMVR depending on bulk quantities and dispensing methods.

[1] Air exhausted from the space to meet the LMVR must not be recirculated. Supplemental, recirculated, and cooling air does not apply toward ACH.

<u>LMVR 2:</u> Constant Hazard – Constant flow required (6 ACH occupied, 6 ACH Unoccupied)

LMVR 2 labs are relatively low hazard labs. Typical chemical work involves small volumes of solvents, acids and toxic chemicals. Hazardous materials are used with good engineering controls as necessary. Only low-hazard gases are used like CO2 and N2. Well managed clinical labs working with solvent, formaldehyde, and tissue preparation procedures with good engineering controls are included in LMVR 2. Flammable liquid storage rooms are LMVR 2.

<u>LMVR 3:</u> Moderate Hazard (8 ACH occupied, 4 ACH Unoccupied)

Labs working with non-production volumes of many toxic and flammable chemicals and volatile solvents. Use of carcinogens, pyrophorics, acutely toxic materials, sensitizers, and reproductive toxins is in small quantities. Chemistry or pharmacy teaching labs are in this group.

<u>LMVR 4:</u> High Hazard (10 ACH occupied, 6 ACH Unoccupied)

LMVR4 has the highest potential severity of hazards present. LMVR 4 labs typically work with large or production volumes of solvent or corrosives, and/or large quantities of particularly hazardous materials (nanomaterials, chemotherapy agents, highly toxic compounds). Labs working with gas cylinders of toxic, pyrophoric, or flammable gases are included in this rank. Synthetic chemistry and CDC Risk Group 3 biological agents or Select Agents are typically included in LMVR 4. Unique use of hazardous materials, lab equipment, or research fabricated equipment with the potential for air emissions may also be classified into LMVR4.

<u>Table 1</u>:Lab Minimum Ventilation Rate, Pressurization, and Air Flow Control

Room Type	LMVR	Air Flow Control	Pressurization	Comments
Dry Research Labs	0	V	N	
Laser Labs	0	V	N	Without gases
Open Wet Research	1	V	N	Includes both research and teaching type
Microbiology Labs	1	V	N	
Genomics Labs	1	V	N	Including DNA processing type
Proteomics Labs	1	V	N	
Analytical Labs	1	V	N	
Tissue Culture Rooms	1	V	N	Pressure relationship is dependent on project, typically negative.

Linear Equipment Corridors s	1	V	N	And similar equipment rooms
Equipment Rooms with Freezers	1	V	N	
Lab Storage Rooms	1	V	N	Including similar lab support spaces
Autoclave and Dishwashing Rooms	1	V	N	
Flammable Liquid Storage Rooms	2	C	N	
MRI and NMR Rooms	2	V		
Cryogenic Liquid Storage or Dispensing Rooms	2	V		
Animal Holding Rooms: Ventilated Racks	2	C		Pressure relationship is dependent on project. If ventilated racks with rack mounted fan packs are utilized, room air change rates must be as listed for static rack rooms.
Animal Procedure Rooms	2	C		Pressure relationship is dependent on project.
Animal Holding Rooms: Static Racks		C		ACH typically 10 occupied, 10 unoccupied. Pressure relationship is dependent on project.
Chemistry Teaching Labs	3	V	N	
Pharmacy Teaching Labs	3	V	N	
Synthetic Chemistry Labs	4	V	N	
Nano-Labs	4	V	N	
Chemotherapy Labs	4	V	N	
CDC Risk Group 3 Biological Agents or Select Agents	4	V	N	
Laboratories affecting Patient Care in U-M Hospital & Health Center Facilities				See “Minimum Design Standards for Health Care Facilities in Michigan.”

Table Key: LMVR: Lab minimum ventilation rate **C:** Constant Volume **V:** Variable Volume **N:** Negative **A:** Adjustable **P**: Positive

Table Notes:

Table 1 indicates the LMVR, method of air flow control, and room pressurization relative to adjacent spaces, for typical laboratory and vivarium spaces at U-M. The above table is a guide only; requirements must always be validated for the specific project. Air flow control refers to typical control of supply air to the space and is a generalization; the project must determine the appropriate air flow control for the space.

For variable volume systems, the <u>minimum</u> setting of terminal units (TAUs)shall provide the room air changes per hour (ACH) value indicated by the LMVR designator, or as required by code (ASHRAE 62.1) or governing standard, whichever is higher . Indicate this minimum (CFM) setting on the drawings. The maximum settings, which shall also be indicated on the drawings, shall be as required to account for sensible and latent loads, and for exhaust make-up. Where a unoccupied ACH is permitted by the LMVR designation, such spaces shall, if meeting a 8 year simple payback criteria (SID-D), be provided with methods (e.g. occupancy sensors, etc.) to allow un-occupied setback to the minimum ACH. See the LMVR narrative, above, for additional requirements.

All rooms where bio-hazardous research is conducted shall be designed to provide negative pressure relative to adjacent spaces, and shall include visual pressure indication. Bio-hazardous research is defined as:

A. Recombinant research at BSL 2, 2+, or 3, as classified by the NIH office of Recombinant DNA Activities.
B. Infectious disease research at BSL 2 or 3, as classified by CDC/NIH Biosafety Guideline.

   Offices contained within lab areas shall operate as positive with respect to the lab.

Appendix B

Perchloric Acid Fume Hood Systems

Perchloric acid fume hood designs shall be reviewed and approved by U-M Occupational Safety and Environmental Health Department (OSEH). The following are general guidelines. The designer should also adhere to the perchloric hood requirements found in NFPA 45.

Exhaust System:

Provide a dedicated exhaust system for perchloric exhaust. Do not manifold with other exhaust systems (e.g. toilet exhaust, particulate exhaust, etc.).

Terminate vertical stacks no less than 100 feet from an air intake.

Equip the ventilation system with a built-in water wash-down system. Automatic wash-down systems are normally recommended and should be reviewed with the U-M Design Manager and U-M OSEH. Ensure that the system will adequately spray all interior surfaces of the duct, plenum, fan, fan stack, and hood. Additionally, perchloric acid fume hoods shall be provided with wash down nozzles for rinsing the area behind the baffle. Service fitting controls for internal outlets and for the wash-down system shall be external to the hood. Drain(s) shall be provided to catch the wash-down water. The point of drain discharge shall be approved by U-M OSEH. Drain material shall be polypropylene. A backflow preventer shall be provided on the cold water supply to the wash-down system. Provide a frost proof hydrant near the fan/fan stack to allow manual wash-down.

Duct:

Route via the shortest and straightest route possible to the outside, with no offsets or horizontal runs. Provide positive drain back to the hood. Indicate clearly on the design drawings that the contractor may not modify the duct design without written approval from the engineer.

Duct material: acid resistant, non-reactive materials selected for the specific chemical use in the hood; typically shall be all welded 316 stainless steel. For final connections where welded joints are not possible, specify gaskets and sealants that are non-reactive and resistant to perchloric acid. Require 316 stainless steel fasteners or fasteners with corrosion resistance equivalent to the selected duct material. Specify that all duct shall be watertight.

Flexible connections shall not be used.

Provide access to permit visual inspection of duct internals.

Labeling:

Require duct, fans and stacks to be marked as follows:

EXPLOSION HAZARD

Do no service work or inspection on this duct without prior approval from U-M Occupational Safety and Environmental Health Department.

Locate markers near points where ductwork originates or continues into shafts, floors or walls, and at maximum 5' intervals along duct runs.

Fans:

Eductor type fans systems shall normally be used in lieu of conventional fan arrangements.

Specify acid resistant, non-reactive fan materials selected for the specific chemical use in the hood. Teflon or PVC coated blades can typically be used.

Specify Type A spark proof fans.

Specify fan types with fan motors located outside the duct work. Drive belts shall be non-spark conductive type and shall not be located within the ductwork.

Appendix C

Definitions

For definitions of various laboratory chemical fume hood types, refer to U-M Master Specification 115313 Laboratory Chemical Fume Hoods.

Capture Velocity

The air velocity at the hood face or capture device necessary to overcome opposing air currents, and to contain contaminated air within that device.

Face Velocity

Speed of air moving into fume hood entrance or working access opening, usually expressed in feet per minute (FPM).

Hood - Laboratory Chemical Fume

A ventilated, enclosed work space intended to capture, contain and exhaust fumes, vapors and particulate matter generated inside the enclosure. Biological Safety Cabinets are not fume hoods and the two are not interchangeable.

Hood - Auxiliary Air Chemical Fume

A fume hood typically using "raw" outside air for make-up air; should not be used at U-M except by special permission from the U-M Design Manager.

Main (duct) Lateral

Large duct main running on a lab floor with multiple fume hood and general exhaust duct connections such that the large proportion of general exhaust connections is expected to result in a very dilute exhaust air stream.

Make-Up Air (Once-Through Air)

The supply of outdoor air to a building replacing air removed by exhaust ventilation systems.

Seal Welded Duct Joints

Both the longitudinal and transverse duct joints are continuously welded to form a 100% air and water tight seal.

Vivarium

A cluster of animal housing areas and support facilities. Fume hood and other exhaust accessories are often included as part of the design for these facilities, and therefore require special system design considerations.