Laboratory Modeling Guideline Using ASHRAE 90.1-2019 APPENDIX G

International Institute for Sustainable Laboratories®

JULY 2020

Purpose of This Guideline

The following is a guideline for energy modeling of laboratory spaces in a building in accordance with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2019 *Energy Standard for Buildings Except Low-Rise Residential Buildings*, Appendix G Performance Rating Method. The intent of this guideline is to clarify application of Appendix G requirements to the baseline energy model, offer some improved model input assumptions for situations when specific information is not available, and to provide a recommended approach to addressing inconsistencies between the requirements of ASHRAE 90.1 Appendix G and the prescriptive requirements of the standard to improve its applicability to laboratories.

The specific focus of this document is on the Appendix G Baseline Building Energy Model which reflects the minimum energy performance required by the standard. This document is **not** a design guide for laboratories; high-performance laboratory design is covered extensively by other documents in the I²SL library and elsewhere.

Modifications to ASHRAE 90.1 recommended in previous versions of this guideline were subsequently adopted by ASHRAE through the efforts of engineers submitting recommended changes using ASHRAE's continuous maintenance process. These modifications were included in the standard and 90.1 User's Manual into the 2013 editions. Inconsistencies between the prescriptive requirements of the standard and Appendix G were created when addendum bm to ASHRAE 90.1-2013 was approved reverting most of Appendix G to the requirements of ASHRAE 90.1-2004 thus undoing previous clarifications. ASHRAE continues to modify the standard through the continuous maintenance process and at the time of initial publication of this guideline, there was a proposed addendum i attempting to correct the inconsistency in the requirements for energy recovery between the prescriptive and Appendix G sections of the standard. The recommended resolution presented in the proposed addendum was consistent with this guideline. On October 30, 2020, ASHRAE approved addendum i exempting laboratory systems greater than 15,000 cfm from the requirement for enthalpy energy recovery in Appendix G baseline systems. Since the ASHRAE revision does not address systems between 5,000 cfm and 15,000 cfm, it is recommended that modelers use the recommendations in this guide as additional clarification. Clarifications include recommended application of the Typical Use and High Use plug load diversity profiles included in the User's Manual, a recommended approach to determining baseline system airflow rates and modification of the fume hood diversity profile also included in the User's Manual.

A secondary intent in publishing this guideline is to allow certification reviewers, e.g. U.S. Green Building Council (USGBC), to acknowledge the inconsistencies in ASHRAE 90.1 and to consider the proposed modifications until ASHRAE otherwise resolves the conflict through the continuous maintenance process. Users of this guideline should be aware that certification reviewers may reject use of this guideline even with the inconsistencies highlighted. Users may want to request an interpretation from the reviewing certification group (e.g. USGBC for LEED) before proceeding with use of these recommendations.

Intended Users of This Guideline

This document is intended for use by energy modelers tasked with modeling laboratory buildings using Appendix G methodology as well as design engineers. Common use cases include modeling for LEED New Construction or for demonstrating compliance with local ordinances such as stretch energy codes.

Applicability of This Guideline

The provisions of this guideline are limited to systems serving laboratory spaces. This guideline follows OSHA 1910-1450 in defining laboratory space as follows:

> "Laboratory means a facility where the 'laboratory use of hazardous chemicals' occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis. Laboratory scale means work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. 'Laboratory scale' excludes those workplaces whose function is to produce commercial quantities of materials."

However, laboratories are an extremely diverse space type and some specialized space types may not be fully addressed by this guide; examples include, but are not limited to clean rooms and laser labs.

Summary of Contents

This guideline recommends several modifications to ASHRAE 90.1, as well as providing additional guidance and discussion of default diversity schedules for typical laboratory buildings. The contents of the guideline are summarized in the table below and are described in detail on the following pages. Illustrative examples are provided in the text.

#	Guideline Area	90.1-2019 Section Adressed	Type of Change
1	Modeling load diversity and reheat energy impacts	Table G3.1 12 Receptacles and Other Loads	Modification
2	Baseline exhaust energy recovery requirements	G3.1.2.10 Exhaust Air Energy Recovery	Modification
3	Determination of baseline building design airflow rates	G3.1.2.8 Design Airflow Rates	Additional Guidance
4	Occupied Airflow in Laboratories	6.5.7.3 Laboratory Exhaust Systems	Modification
5	Ventilation airflow in baseline and proposed design models	G3.1.2.5 Ventilation	Additional Guidance
6	Unoccupied Airflow in Laboratories	Exception to G3.1.3.13 VAV Minimum Flow Set Points (Systems 5 and 7)	Modification
A	Typical schedules for lab occupancy and equipment	Table G3.1 Schedules shall be typical of the proposed building type as determined by the designer and approved by the rating authority	Guidance

All other sections should be followed as defined in the standard.

For energy efficiency measures that are not explicitly addressed by the standard or by this guideline and cannot be modeled directly in approved software, modelers should follow Section G.2.5, Exceptional Calculation Methods. This guideline does not cover the details of such calculation methods.

1. Modeling Load Diversity and Reheat Load Impacts

Table G.3.1 No.12 Receptacles and Other Loads

Model the equipment loads in each laboratory space in a manner that reflects realistic variation in load between spaces instead of using an average across all spaces. The 2016 ASHRAE 90.1 User's Manual Table G-N "Laboratory Occupancy" provides sample schedules developed in earlier versions of this I^{2}SL Guideline that may be used to simulate equipment, lighting, occupancy, and fume hood diversity. The ASHRAE User's Manual does not however include direction on how to distribute equipment/plug load diversity factors between columns titled "Schedule for Equipment - Percent of Maximum Load Typical Use" and "Schedule for Equipment—Percent of Maximum Load High Use." For modeling purposes, use "Typical Use" profile for 90 percent of lab spaces and use "High Use" profile for 10 percent of lab spaces (by area).

Note on Formatting

The following pages include excerpts from ASHRAE 90.1-2019. The modifications to the sections of the standard are indicated through additions (underline) and ~~deletions~~ (strikethrough). The rationale for the recommended modifications is *italicized*.

For fume hood driven laboratories, model fume hood airflow diversity in accordance with the schedule in Appendix A of this Guide. This profile should be applied only where design fume hood exhaust is greater than or equal to 1.5 times the minimum occupied ventilation requirement.

Alternatively, schedules based on observed load patterns may be used.

Rationale: Equipment loads

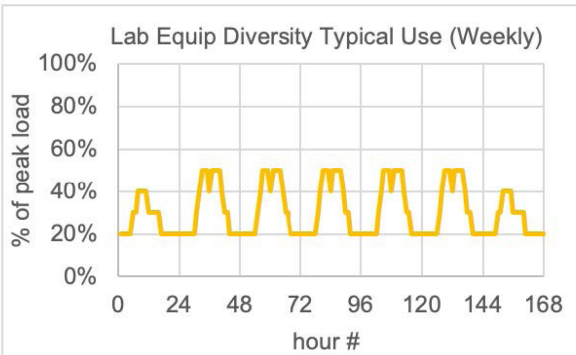
It is important to consider the variation of internal equipment loads from one space to the next. This variation can have a substantial impact on energy use, especially reheat energy. To capture this effect, and reward designs that reduce reheat, equipment load variation should be modeled. Note that the variation should be modeled identically in the baseline and proposed designs.

Based on analysis of energy model results versus actual building energy use, it was found that reheat energy use was being underpredicted in many instances. It was determined that when models used average laboratory plug load diversity schedules in all spaces, credit for supply air temperature reset was significantly overestimated. To address this issue, it is recommended that laboratory spaces be broken into two separate groups operating at different diversity schedules. 10 percent of the lab spaces (by area) are assigned the high equipment use schedule (100 percent load, 24/7), while the remaining 90 percent of the lab spaces are modeled with a typical use variable plug load schedule. This recommendation is intended to reflect a small fraction of rooms being at higher load than others and NOT to suggest that there are constant load spaces which should be addressed separately from variable load spaces. The use of these separate schedules on plug loads produces results that better reflect overall building average plug load usage while providing more realistic estimates of building reheat energy use.

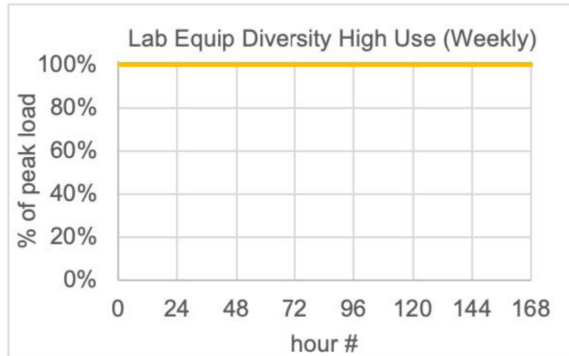
Example

A building contains 10,000 sf of lab space with design plug load of 4 W/sf. Using the guidance in Appendix A:

9,000 sf of lab space receives low-use schedule:



1,000 sf of lab space receives high-use schedule:



Rationale: Fume hood diversity

In addition to equipment, lighting, and occupancy diversity schedules, the ASHRAE 90.1-2016 User's Manual includes a fume hood airflow diversity schedule developed in earlier versions of this I²SL Guideline. It has been found this original schedule was somewhat conservative as it was based strictly on occupancy, i.e. by assuming that fume hood use is directly proportional only to the number of people in the lab. A less conservative approach is now recommended for energy modeling purposes, based on a combination of occupancy and equipment plug load use diversity factors. An updated fume hood diversity profile table is included in Appendix A.

This profile should be applied to fume hood driven laboratory spaces only when design fume hood exhaust is greater than or equal to 1.5 times the minimum occupied ventilation requirements of the space (see example airflow tables below). It was found when analyzing diversified fume hood airflow versus minimum ventilation airflow rates, that when the design fume hood exhaust airflow is less than the above value, the diversified space airflow becomes driven by the space minimum ventilation rate (ACH) in both the occupied and unoccupied periods.

2. Baseline Exhaust Energy Recovery Requirements

G3.1.2.10 Exhaust Air Energy Recovery

Individual fan systems that have both a design supply air capacity of 5,000 cfm or greater and have a minimum design outdoor air supply of 70 percent or greater shall have an energy recovery system with at least 50 percent enthalpy recovery ratio. Fifty percent enthalpy recovery ratio shall mean a change in the enthalpy of the outdoor air supply equal to 50 percent of the difference between the outdoor air and return air at design conditions. Provision shall be made to bypass or control the heat recovery system to permit air economizer operation, where applicable.

Exception to G3.1.2.10

If any of these exceptions apply, exhaust air energy recovery shall not be included in the baseline building design:

1. Systems serving spaces that are not cooled and that are heated to less than 60°F.
2. Systems exhausting toxic, flammable, or corrosive fumes or paint or dust. This exception shall only be used if exhaust air energy recovery is not used in the proposed design.
3. Commercial kitchen hoods (grease) classified as Type 1 by NFPA 96. This exception shall only be used if exhaust air energy recovery is not used in the proposed design.
4. Heating systems in Climate Zones 0 through 3.
5. Cooling systems in Climate Zones 3C, 4C, 5B, 5C, 6B, 7, and 8.
6. Where the largest exhaust source is less than 75 percent of the design outdoor airflow. This exception shall only be used if exhaust air energy recovery is not used in the proposed design.
7. Systems requiring dehumidification that employ energy recovery in series with the cooling coil. This exception shall only be used if exhaust air energy recovery and series-style energy recovery coils are not used in the proposed design.
8. ~~Systems serving laboratory HVAC zones with a total laboratory exhaust volume greater than 15,000 cfm (7100 L/s) [10/30/2020 addendum i].~~ Laboratory exhaust systems complying with Section 6.5.7.3 exception b.

Rationale

The requirement for energy recovery in any system is dictated by ASHRAE 90.1-2019 Section 6.5.6.1, which includes an exception for laboratory systems meeting Section 6.5.7.3. Section 6.5.7.3 permits the laboratory space to meet the standard via either sensible heat recovery or VAV operation (or a combination of both).

It appears that the intent of Appendix G is that baseline building laboratory spaces comply via the VAV operation path (see G3.1.3.13), and so it makes sense to reinstate the laboratory-specific energy recovery exception here to avoid inconsistency between Section 6 and Appendix G, rather than following ASHRAE addendum i that limits the laboratory exception to systems greater than 15,000 cfm.

Note that prior to 2016, Appendix G included the laboratory energy recovery exception in Appendix G and was consistent with the prescriptive requirements of Section 6. Further, it is generally understood that the "toxic, flammable, or corrosive fumes" exception does not relate to laboratory exhaust.

Because the above change brings Appendix G back into alignment with Section 6.5.7.3.b of ASHRAE 90.1-2019, the amended version results in a reasonable code compliant baseline system for modeling purposes.

3. Determination of Baseline Building Design Airflow Rates

G3.1.2.8 Design Airflow Rates

G3.1.2.8.1 Baseline All System Types Except System Types 9 and 10: System design supply airflow rates for the baseline building design shall be based on a supply-air-to-room temperature set-point difference of

20°F or the minimum outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is greater. For systems with multiple zone thermostat set points, use the design set point that will result in the lowest supply air cooling set point or highest supply air heating set point. If return or relief fans are specified in the proposed design, the baseline building design shall also be modeled with fans serving the same functions and sized for the baseline system supply fan air quantity less the minimum outdoor air, or 90 percent of the supply fan air quantity, whichever is larger.

Exception to G3.1.2.8.1

1. For systems serving laboratory spaces, airflow rate shall be based on a supply-air-to-room temperature set-point difference of 17°F or the required ventilation air or makeup air, whichever is greater. Refer to guideline recommendations in Section "G3.1.2.5 Ventilation" below for determination of baseline laboratory ventilation airflow rates.

2. If the proposed design HVAC system airflow rate based on latent loads is greater than the design airflow rate based on sensible loads, then the same supply-air-to-room-air humidity ratio difference (gr/lb) used to calculate the proposed design airflow shall be used to calculate design airflow rates for the baseline building design.

Rationale

The intent of the original Exception 1 above is to assign the baseline total design supply airflow rate based on industry standard practice. The use of 17°F delta T to determine supply airflow rates is based on a typical laboratory room temperature (72°F) and a common practice supply air condition (55°F).

The additional language refers the user to new language in Section G3.1.2.5, described in "5. Ventilation Airflow in Baseline and Proposed Design Models" below, which provides expanded guidance on assigning the baseline ventilation rates referenced in this section.

4. Occupied Airflow in Laboratories

6.5.7.3 Laboratory Exhaust Systems

Buildings with laboratory exhaust systems having a total exhaust rate greater than 5000 cfm shall include at least one of the following features:

[…]

b. VAV laboratory exhaust and room supply systems that are required to have minimum circulation rates to comply with code or accreditation standards shall be capable of and configured to reduce zone exhaust and makeup airflow rates to the greater of the design minimum exhaust makeup airflow (exhaust devices at minimum operating airflow), code or standard ~~regulated~~ minimum circulation values or the minimum required to maintain pressurization relationship requirements during both occupied and unoccupied periods. ~~Systems serving nonregulated zones shall be capable of and configured to reduce exhaust and makeup airflow rates to 50% of the zone design values or the minimum required to maintain pressurization relationship requirements.~~

Rationale

To prevent wasted reheat energy, ASHRAE 90.1-2019 requires cooling load-driven spaces to reduce airflow to a minimum before allowing reheat. The reduced occupied airflow for laboratories is dictated by paragraph 6.5.7.3.b for systems without energy recovery. Essentially this section requires VAV operation and reduction in airflow to the required makeup airflow or to the code (or applicable standard) minimum occupied or minimum unoccupied ventilation rate before allowing reheat.

The original intent of the standard appears to have been to require at least a 50 percent setback from peak design airflow before reheating. As with Section G3.1.3.13 below, this section was originally intended to apply to constant volume labs that would set back to at least 50 percent of design when unoccupied. Because this standard has been updated to require reduction in airflow to the minimum ventilation rates required to meet code or applicable standards in both occupied and unoccupied periods before reheating, it is recommended the requirement in the last sentence of the original language be eliminated for modeling purposes.

5. Ventilation Airflow in Baseline and Proposed Design Models

G3.1.2.5 Ventilation

Minimum ventilation system outdoor air intake flow shall be the same for the proposed design and baseline building design.

Exception to G3.1.2.5:

1. When modeling demand control ventilation in the proposed design in systems with outdoor air capacity less than or equal to 3000 cfm serving areas with an average design capacity of 100 people per 1000 ft2 or less.

2. When designing systems in accordance with Standard 62.1, Section 6.2, “Ventilation Rate Procedure,” reduced ventilation airflow rates may be calculated for each HVAC zone in the proposed design with a zone air distribution effectiveness (Ez) > 1.0 as defined by Standard 62.1, Table 6-2. Baseline ventilation airflow rates in those zones shall be calculated using the proposed design Ventilation Rate Procedure calculation with the following change only. Zone air distribution effectiveness shall be changed to (Ez) = 1.0 in each zone having a zone air distribution effectiveness (Ez) > 1.0. Proposed design and baseline building design Ventilation Rate Procedure calculations, as described in Standard 62.1, shall be submitted to the rating authority to claim credit for this exception.

3. Where the minimum outdoor air intake flow in the proposed design is provided in excess of the amount required by the building code or the rating authority, the baseline building design shall be modeled to reflect the greater of that required by either the rating authority or the building code and will be less than the proposed design.

4. For baseline systems serving only laboratory spaces that are prohibited from recirculating return air by code or accreditation standards, the baseline system shall be modeled as 100 percent outdoor air. Minimum occupied ventilation rate for the baseline system shall be taken to be the **greater** of the following:

a. Prescriptive requirements of applicable Mechanical Code.

b. Where Mechanical Code ventilation requirements do not apply directly:

i. Occupied condition: 1 cfm/sf exhaust airflow or 6 air changes per hour, whichever is larger.

ii. Unoccupied condition: 0.67 cfm/sf or 4 air changes per hour, whichever is larger.

c. Ventilation rate based on 2018 ASHRAE Classification of Laboratory Ventilation Design Levels (2018), or other qualified professional's assessment of required ventilation rate.

d. Makeup air required for exhaust devices (e.g. fume hoods) when devices are operating at minimum design airflow.

e. For fume hood driven laboratories where makeup for maximum fume hood exhaust is **less than** (1.5) times the space occupied minimum ventilation rate, laboratories shall be modelled as air change driven spaces meeting above ventilation criteria for both occupied and unoccupied periods.

f. For fume hood driven laboratories where makeup for maximum fume hood exhaust is **greater than** (1.5) times the space occupied minimum ventilation rate, the hourly ventilation airflow shall be determined based on the peak fume hood makeup and airflow diversity schedule in Appendix A.

For the proposed system, in laboratory spaces for which a qualified professional has deemed that reduced minimum outdoor airflow rates (below those required by code or industry standard practice) are appropriate and have been approved by the Authority Having Jurisdiction, the proposed system shall be modeled with the minimum occupied and unoccupied ventilation airflow (outdoor air) levels as designed. The baseline system minimum occupied and unoccupied ventilation rates shall remain as described above.

Rationale: Baseline building required ventilation airflow

The intent of the added language in Exception 4 above is to provide a method for assigning the baseline ventilation rate based on industry standard practice, so that high-performance practices, which often incorporate reductions in supply airflow given appropriate conditions, may be recognized.

Two further motivations are simplification and consistency. Determining the required outdoor air ventilation rates for laboratory spaces can be complicated, and its determination should not fall to the energy modeler. In a significant fraction of laboratory space types, no direct prescriptive code ventilation requirements apply. The modifications above are intended to simplify the process for creating baseline models and to standardize the approach across the modeling industry.

Where code minimum ventilation rates apply and are available, they should be used as baseline building minimum occupied ventilation rate requirements. Where qualified professional assessments recommend ventilation rates in excess of the other options, they should be used as baseline ventilation rate requirements. Otherwise, the default occupied, and unoccupied minimum ventilation rates introduced above should be used.

The suggested occupied mode minimum ventilation rate condition is based on ASHRAE 62.1-2019 and the current International Mechanical Code exhaust airflow requirement for Educational Science Laboratories, which is the closest space type for laboratories using chemicals (ASHRAE 62.1-2019 currently includes only two lab types - Educational Science Labs and Computer Labs).

The rate selected is also consistent with most of the many lab types covered in the 2018 ASHRAE Classification of Laboratory Ventilation Design Levels guideline. This condition is therefore considered a reasonable reflection of industry standard practice for new construction lab facilities.

For unoccupied conditions, the source of the minimum ventilation rate condition is the non-mandatory commentary of ANSI/AIHA Z9.5-2012, the 2018 ASHRAE Classification of Laboratory Ventilation Design Levels guideline, and Appendix A of National Fire Protection Association (NFPA) Standard 45-2019 (Standard on Fire Protection for Laboratories Using Chemicals).

See modifications to Exception to G3.1.3.13 below for additional information.

Rationale: Reduction below baseline ventilation rates - proposed system only:

Under appropriate conditions, a qualified professional can design systems for laboratories that allow the use of outdoor airflow rates below prescriptive code requirements and/or industry standard practice. When approved by the Authority Having Jurisdiction, reduced outdoor airflow rates can safely deliver significant energy savings. Depending on the nature of the laboratory, this reduction can be static (such as a reduction in the design outdoor airflow rates, based on the outcome of a hazard assessment) or dynamic (such as through the implementation of demand-controlled ventilation). Ventilation effectiveness, defined as "the system's ability to remove the contaminants from the laboratory space", is an important design consideration in this context.

Energy savings enabled by appropriate reduction in outdoor airflow rates for laboratory spaces should be captured and rewarded under Appendix G. Capturing these savings, where present, is the intent of the added language after the exceptions to "G3.1.2.5 Ventilation" section above.

6. Unoccupied Airflow in Laboratories

G3.1.3.13 VAV Minimum Flow Set Points (Systems 5 and 7):

Minimum volume set points for VAV reheat boxes shall be 30 percent of zone peak airflow, the minimum outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is larger.

Exception to G3.1.3.13

Systems serving laboratory spaces shall reduce the exhaust and makeup air volume during unoccupied periods to the largest of: 50 percent of zone minimum occupied ~~peak~~ airflow, the exhaust device minimum makeup airflow, the minimum unoccupied ventilation ~~outdoor~~ airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards.

Rationale

The intent of the original exception language was to require a reduction in laboratory airflow to 50 percent of peak value during unoccupied periods based on laboratories operating at constant peak airflow during occupied periods. Updates to the standard now require reduction in occupied airflow to the minimum *occupied ventilation rate when not needed for cooling or makeup air. The modification above clarifies the intent for reduction in airflow from the minimum occupied ventilation rate during unoccupied periods and clarifies the need to maintain makeup air for exhaust devices like fume hoods.*

The "minimum unoccupied ventilation airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards" should be taken from the baseline building requirements described above.

Examples

The following tables provide illustrative examples of airflow analyses used to determine peak baseline airflow rates and minimum baseline and proposed airflow rates for cooling-driven, ventilation-driven and fume hood-driven applications.

The examples assume that a detailed hazard analysis has shown that appropriate minimum ventilation rates are roughly 4 ACH occupied / 2 ACH unoccupied, a reduction from industry standard practice values of 6 ACH occupied / 4 ACH unoccupied. The example fume hood exhaust rates are based on a standard 100 cfm face velocity at 18-inch sash height, with minimum airflow of 40 percent of peak (roughly 375 ACH).

Example: Baseline design occupied airflow determination for four sample 1,000-sf laboratory spaces:

Lab Space Description	Peak Cooling Airflow at 17°F Delta-T (cfm)	Required Ventilation Airflow (cfm)	Makeup for Fume Hood Exhaust (cfm)	Use for Baseline System Peak Supply (cfm)
Cooling-Driven Lab	3,900	1,000	0	3,900
Ventilation-Driven Lab (Low Cooling Load)	365	1,000	0	1,000
Fume Hood-Driven Lab FH Exh < 1.5 x Occupied Ventilation	365	1,000	1,200	1,200
Fume Hood-Driven Lab FH Exh ≥ 1.5 x Occupied Ventilation	365	1,000	2,400	2,400

Note: The above example assumes a neutral-pressure lab. Adjustments must be made to address room pressurization.

Example: Baseline and Proposed design minimum occupied airflow analysis for four representative 1,000-sf lab spaces:

Lab Space Description	Minimum Occupied Cooling Airflow (cfm)	Occupied Ventilation Airflow Using Exception 4b Guidance (cfm)	Fume Hood Minimum Exhaust (cfm)	Occupied Ventilation Airflow Using Detailed Hazard Analysis (cfm)	Use for Baseline Minimum Occupied Supply (cfm)	Use for Proposed Design Minimum Occupied Supply (cfm)
Cooling-Driven Lab	0	1,000	0	670	1,000	670 (or as-designed min cfm if higher)
Ventilation-Driven Lab (Low Cooling Load)	0	1,000	0	670	1,000	670 (or as-designed min cfm if higher)
Fume Hood-Driven Lab -- FH Exh < 1.5 x Occupied Ventilation	0	1,000	570	670	1,000	670 (or as-designed min cfm if higher)
Fume Hood-Driven Lab -- FH Exh ≥ 1.5 x Occupied Ventilation	0	1,000	1,130	670	1,000	1,130 (or as-designed min cfm if higher)*

**Use fume hood diversity schedule for hourly min flow ratio*

Example: Baseline and Proposed Design minimum unoccupied airflow analysis for four representative 1,000-sf lab spaces:

Lab Space Description	Minimum Unoccupied Cooling Airflow (cfm)	Unoccupied Ventilation Airflow Using Exception 4 Guidance (cfm)	Fume Hood Minimum Exhaust (cfm)	Unoccupied Ventilation Airflow Using Detailed Hazard Analysis (cfm)	Use for Baseline Minimum Unoccupied Supply (cfm)	Use for Proposed Design Minimum Unoccupied Supply (cfm)
Cooling-Driven Lab	0	670	0	340	670	340 (or as-designed min cfm if higher)
Ventilation-Driven Lab (Low Cooling Load)	0	670	0	340	670	340 (or as-designed min cfm if higher)
Fume Hood-Driven Lab -- FH Exh < 1.5 x Occupied Ventilation	0	670	570	340	670	570 (or as-designed min cfm if higher)
Fume Hood-Driven Lab -- FH Exh ≥ 1.5 x Occupied Ventilation	0	670	1,130	340	1,130	1,130 (or as-designed min cfm if higher)*

**Use fume hood diversity schedule for hourly min flow ratio*

References

American Society of Heating, Refrigeration, and Air-Conditioning Engineers. *ASHRAE 90.1-2019 Energy Standard for Buildings Except Low-Rise Residential Buildings*. 2019. Atlanta, GA: ASHRAE.

American Society of Heating, Refrigeration, and Air-Conditioning Engineers. *ASHRAE Standard 90.1 User's Manual Based on ASHRAE Standard 90.1-2016 Energy Standard for Buildings Except Low-Rise Residential Buildings*. 2017. Atlanta, GA: ASHRAE.

American Society of Heating, Refrigeration, and Air-Conditioning Engineers. *ASHRAE Laboratory Design Guide: Planning and Operation of Laboratory HVAC Systems*. Second edition. 2015. Atlanta, GA: ASHRAE.

National Fire Protection Association. *NFPA 45-2019 Standard on Fire Protection for Laboratories Using Chemicals*. 2019. Quincy, MA: NFPA.

American Society of Safety Professional (ASSP replaced American Industrial Hygiene Association - AIHA as Secretariat of Z9.5 Committee). *ANSI/AIHA Standard Z9.5-2012 Laboratory Ventilation*. 2012. Park Ridge, IL: ASSP.

I²SL Best Practices

These best practice guides and technical bulletins provide information on the design, construction, and operation of specific technologies that contribute to energy efficiency and sustainability in laboratories. https://www.i2sl.org/resources/bpg.html.

Acknowledgements

This guideline was originally developed in 2005 by a committee of laboratory modelers and designers convened by the Labs for the 21st Century program. This update was carried out by I²SL in 2020 and reflects current design practices and changes to ASHRAE 90.1. I²SL would like to thank all participants for volunteering their time and expertise.

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I[2]SL Modeling Guideline APPENDIX A

Schedules provided in the 2016 ASHRAE 90.1 User's Manual are based on assumption that the laboratory will operate continuously with heaviest usage between 8am and 5pm. Fans are assumed to be on 24 hours throughout the day. If the laboratory operates on a seasonal schedule, such as a school schedule, and has lower usage during one season, adjust the schedules. Guidance is provided above on how to break down laboratory area into typical and high use equipment load spaces for plug load scheduling since this was not included in the ASHRAE 90.1-2016 User's Manual.

VAV Fume Hood Airflow Diversity Schedule - Update

The schedules in this section should be used for research laboratories whose airflow rates are fume hood driven (i.e. not driven by required space ventilation rates or internal loads) and where the standard fume hood face velocity of 100 fpm and an 18-inch sash height is used. Adjust schedules for teaching labs where diversity during classes is limited. Adjust schedules to reflect design case energy savings for high performance fume hoods (which use reduced face velocity and/or reduced standby airflow setpoints), for occupancy-based face velocity setbacks, or for automatic sash closers.

Note: These schedules are based on the premise that fume hood use is directly related to occupancy and other equipment use diversity of the laboratories. Assumptions include hood airflow at 100 percent of design airflow using 100 fpm face velocity/18" inch restricted sash height opening when in use and 40 percent airflow (roughly 375 ACH per ANSI/AIHA Z9.5-2012) when sash is closed. This results in baseline building airflow for fume hood-driven labs that complies with the requirements of G3.1.3.13 (less than 50% airflow when unoccupied).

Sample Calculation of Fume Hood Diversity

Like equipment plug load diversity discussed above, to determine a reasonable average usage factor for fume hoods the above schedules assume 10 percent of fume hoods at constant full flow while remaining 90 percent reflect a variable fume hood use.

Fume Hood Diversity—Weekday

Period Start - End (Hour)	% Diversity (% of max fume hood airflow
1 (12 to 1 am)	47
2 (1 to 2 am)	47
3 (2 to 3 am)	47
4 (3 to 4 am)	47
5 (4 to 5 am)	47
6 (5 to 6 am)	47
7 (6 to 7 am)	47
8 (7 to 8 am)	48
9 (8 to 9 am)	50
10 (9 to 10 am)	70
11 (10 to 11 am)	70
12 (11 am to 12 pm)	58**
13 (12 - 1 pm)	56
14 (1 - 2 pm)	70
15 (2 - 3 pm)	70
16 (3 - 4 pm)	70
17 (4 - 5 pm)	51
18 (5 - 6 pm)	48
19 (6 - 7 pm)	47
20 (7 - 8 pm)	47
21 (8 - 9 pm)	47
22 (9 - 10 pm)	47
23 (10 - 11 pm)	47
24 (11 pm - 12 am)	47

** See sample calculation below for this hour

Fume Hood Diversity—Weekend	
Period Start - End (Hour)	% Diversity (% of max fume hood airflow
1 (12 to 1 am)	47
2 (1 to 2 am)	47
3 (2 to 3 am)	47
4 (3 to 4 am)	47
5 (4 to 5 am)	47
6 (5 to 6 am)	47
7 (6 to 7 am)	48
8 (7 to 8 am)	48
9 (8 to 9 am)	52
10 (9 to 10 am)	52
11 (10 to 11 am)	52
12 (11 am to 12 pm)	51
13 (12 - 1 pm)	48
14 (1 - 2 pm)	48
15 (2 - 3 pm)	48
16 (3 - 4 pm)	48
17 (4 - 5 pm)	47
18 (5 - 6 pm)	47
19 (6 - 7 pm)	47
20 (7 - 8 pm)	47
21 (8 - 9 pm)	47
22 (9 - 10 pm)	47
23 (10 - 11 pm)	47
24 (11 pm - 12 am)	47

Example calculation of overall fume hood diversity for 11:00 am on a weekday:

- Constant Hood Use: 100 percent hoods in use.
- Variable Hood Use: 45 percent Occupancy Diversity x 50 percent Typical Equipment Use = 22 percent of hoods in use.
    - 78 percent Hoods at 40 percent flow + 22 percent Hoods at 100 percent Flow = 54 percent diversity from full flow in variable fume hood use labs.
- Overall fume hood exhaust system diversity:
    - 10 percent fume hoods at 100 percent flow + 90 percent fume hoods at 54 percent flow = 58 percent diversity.