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Labs21 Laboratory Modeling Guidelines using ASHRAE 90.1-1999

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Laboratory Modeling Guidelines using ASHRAE 90.1-1999

Introduction

The following is a guideline for energy modeling of laboratory spaces in a building in accordance with the Energy Cost Budget method described in ASHRAE 90.1-1999 Energy Standard for Buildings Except Low-Rise Residential Buildings. For the purposes of this document, a laboratory is defined as any space requiring once through ventilation systems (recirculation of air to other spaces in a building is not allowed). To accomplish this, ventilation systems in laboratories typically provide 100% outside air to the occupied space.

The guideline is structured similarly to the ASHRAE 90.1-99 standard. Only those sections being clarified or modified are discussed in the guideline; all other sections should be followed as defined in the standard. Specifically, those sections that are affected include the following:

- 6.3.3.1 – Fan Power Limitation (modification)
- 6.3.7.2 – Fume Hoods (modification)
- 11.3.11 – Schedules (modification)
- 11.4.3 – HVAC Systems (clarification)
- 11.4.3 (h) Budget Supply-Air-to-Room Air Temperature Difference (modification)
- 11.4.3(i) – Fan system efficiency (modification)
- Table 11.4.3A – Budget System Descriptions (modification)

For energy efficiency measures that are not explicitly addressed by the standard, we recommend application of Section 11.5, Exceptional Calculation Methods. This guideline does not cover the details of such calculation methods.

6.3.3.1 Fan Power Limitation

Fan systems must not exceed the maximum allowable fan power given in 6.3.3.1. There are pressure and relief fan credits for filtering systems, heat recovery, etc.; however, even with these credits, laboratory fan systems typically exceed the fan limitations in 6.3.3.1.

This guideline proposes changes to the fan requirements in the standard to better address laboratory fan systems and promote more efficient designs. The following table lists the fan power limitations ONLY for systems serving laboratories.

Fan Power Limitations for Laboratory Applications

Supply Air Volume	Allowable Nameplate Motor Power	
	Constant Volume	Variable Volume
<20,000 cfm	2.2 hp/1000 cfm	3.1 hp/1000 cfm
>20,000 cfm	2.0 hp/1000 cfm	2.8 hp/1000 cfm

Note: The laboratory fan power limitations are calculated using a static pressure ratio of 9.15” w.g./5” w.g.

The static pressure drop is based on a combined pressure drop (supply plus return and exhaust), for a typical laboratory system equal to 9.15” w.g. (See Appendix B for the breakdown of how this allowance was determined.)

For fan systems with components complying under 6.3.3.1(b), the allowable fan system power may be adjusted if the Energy Cost Budget Method is not used to demonstrate compliance. (For details on the Energy Cost Budget Method see section 11.) Those components listed in Appendix B that have been included in the calculation of the fan power above do not qualify for these credits.

6.3.7.2 Fume Hoods

Buildings with design supply flow rates of 5,000 cfm or greater and fume hood systems, shall include at least one of the following features:

a) VAV system capable of reducing exhaust air and make-up air volume to individual space by at least 50% of design values or 4 ACH, whichever is greater. (Assume the exhaust fan is constant volume with bypass air control to allow variable exhaust flow from the building, while maintaining a constant discharge velocity from the exhaust stack.)

b) Direct makeup air supply equal to at least 75% of the exhaust rate, heated no warmer than 2 F below room set point, cooled to no lower than 3F above room set point, no humidification added, and no simultaneous heating and cooling used for dehumidification control. (Note that this option is rarely used in laboratory design.)

c) Energy recovery systems to precondition makeup air from fume hood exhaust in accordance with 6.3.6.1 (Exhaust Air Energy Recovery) without using any exception.

11.3.11 Schedules

In modeling laboratory spaces, scheduling occupancy, lighting and equipment loads clearly affects energy use in the spaces. Appendix A includes sample schedules that may be used; alternatively, schedules based on observed load patterns could be used. Documentation of proposed schedules by the designer and approval of the authority having jurisdiction is required by ASHRAE 90.1-1999 paragraph 11.3.11. The typical schedules are based on ASHRAE 90.1-1989 for office occupancy except as noted (laboratories classified as office in ASHRAE 90.1).

It is important to consider the diversity of internal equipment loads from one space to the next. The variation in internal equipment loads can have a substantial impact on energy use, especially reheat requirements. To capture this effect, and reward designs that reduce reheat, equipment load diversity should be modeled as follows:

> Create a “high use” internal equipment load schedule and assign it to 10-15% of the area served by an air handler. An example of a “high use” schedule is included in Appendix A. Remaining spaces should be modeled with the typical internal equipment load schedule for the project. Note that the equipment schedules and the spaces to which these schedules apply must be identical in the Energy Cost Budget Model and the Design Energy Cost Model.

11.4.3 HVAC Systems

The budget building shall be based on a variable air volume supply system . The VAV system shall be temperature controlled with the flow varying between the maximum flow rate and an occupied minimum flow rate. When unoccupied, the airflow shall be further reduced to the minimum. The design supply flow, i.e. maximum flow, shall assume 18” sash height and 100 fpm for the fume hoods. The minimum flow shall be equal to the greater of 50% of design value, NFPA 45-2000 recommended 4 air changes per hour, airflow make-up air for exhaust devices or project-required health and safety minimum ventilation rate. These recommendations are made since they result in similar airflow reductions required by ASHRAE 90.1-1999 paragraph 6.3.7.2 (a) for fume hood systems.

If ventilation requirements make the system operate such that it does not comply with 6.3.7.2a or b, then the Energy Cost Budget Model must include energy recovery that meets the provisions of 6.3.6.1 (i.e., 50% total recovery effectiveness), per the requirement of 6.3.7.2c.

A fume hood diversity schedule is included in Appendix A and may be used to simulate the use of fume hoods in fume hood driven laboratories.

11.4.3 (h) Budget Supply-Air-to-Room Air Temperature Difference

For the laboratory budget system, use a supply-air-to-room-air temperature difference of 17 deg F in lieu of the 20 deg F value listed in ASHRAE 90.1-1999. The minimum airflow rates in typical commercial buildings are much lower than those required in laboratory occupancies. The higher minimum airflow rates warrant a smaller temperature difference to avoid excessive reheat.

11.4.3 (i) Fan system power

The fan system brake horsepower shall be modeled at the limits prescribed in 6.3.3.1 based upon the system supply airflow for the energy cost budget model. The allowable fan system power may be adjusted in accordance with 6.3.3.1(b) for components that would be present in the budget and proposed fan systems. Adjustments for components that are only in the proposed design, such as heat recovery coils, should not be included in the energy cost budget model. (If heat recovery coils are included in the energy cost budget model then an adjustment may be made.)

Table 11.4.3A Budget System Descriptions

Note 2: Budget system VAV minimum airflow setpoint should meet requirements described above in lieu of compliance with note 2 of Table 11.4.3.A. System supply air temperature reset should not be modeled since the “High Use” lab equipment schedule recommended above would eliminate any time where reset can occur (10 to 15% of spaces require full cooling airflow 24 hours per day).

Note 4: Budget system should not be modeled with static pressure reset. Systems modeled as described above and specifically the “High Use” lab equipment schedule recommended above would eliminate any time where reset can occur (10 to 15% of spaces require full cooling airflow 24 hours per day).

APPENDIX A

The schedules are based on ASHRAE 90.1-1989 for office occupancy except as noted (laboratories classified as office in ASHRAE 90.1). The schedules assume heavier loads during more typical working hours, 8am-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 as needed.

<u>Lab Occupancy Schedule</u>

Starting Month: January Starting Daytype: Monday	Ending Month: December Ending Daytype: Friday
Period: Start - End (Hour)	% Diversity
0 - 7	5 (see note)
7 - 8	10
8 - 9	20
9 - 11	90
11 - 13	45
13 - 18	90
18 - 19	30
19 - 22	10
22 - 24	5 (see note)

Starting Month: January Starting Daytype: Saturday, Sunday	Ending Month: December Ending Daytype: Holiday
Period: Start – End (Hour)	% Diversity
0 - 7	5 (see note)
7- 9	10
9 -13	30
13 - 18	10
18 - 24	5 (see note)

Note: Minimal occupancy added to reflect laboratory operation.

Lab Lighting Schedule

Starting Month: January Starting Daytype: Monday	Ending Month: December Ending Daytype: Friday
Period: Start - End (Hour)	% Diversity
0 - 6	20(see note)
6 - 7	30(see note)
7 - 8	50(see note)
8 - 12	90
12 - 13	80
13 - 17	90
17 - 18	90
18 - 20	50
20 - 22	30(see note)
22 - 24	20 (see note)

Starting Month: January Starting Daytype: Saturday, Sunday	Ending Month: December Ending Daytype: Holiday
Period: Start – End (Hour)	% Diversity
0 - 6	10 (see note)
6 - 8	10 (see note)
8 -12	40 (see note)
12 - 17	20 (see note)
17 - 24	10 (see note)

Note: Lighting loads added to reflect 24-hour laboratory operation.

Lab Equipment Schedule
The schedules for internal equipment loads have been modified from the ASHRAE 90.1-89 equipment schedules that are identical to the lighting schedules. These schedules are based on default equipment schedules for labs used in eQuest software.

Lab Equipment Load Schedule – Typical

Starting Month: January Starting Daytype: Monday	Ending Month: December Ending Daytype: Friday
Period: Start - End (Hour)	% Diversity
0 - 7	20
7 - 8	30
8 - 9	40
9 - 12	50
12 - 13	40
13 - 17	50
17 - 18	40
18 - 20	30
20 - 24	20

Starting Month: January Starting Daytype: Saturday, Sunday	Ending Month: December Ending Daytype: Holiday
Period: Start – End (Hour)	% Diversity
0 - 6	20
6 - 8	30
8 -12	40
12 – 17	30
17 – 24	20

Lab Equipment Load Schedule – High use

Starting Month: January Starting Daytype: Monday	Ending Month: December Ending Daytype: Friday
Period: Start - End (Hour)	% Diversity
0 - 24	100

Starting Month: January Starting Daytype: Saturday, Sunday	Ending Month: December Ending Daytype: Holiday
Period: Start – End (Hour)	% Diversity
0 - 24	100

<u>Fume Hood Diversity Schedule</u> – Use only for laboratories that are fume hood driven. For internally load driven laboratories, no fumehood diversity schedules are necessary.

Starting Month: January Starting Daytype: Monday	Ending Month: December Ending Daytype: Friday
Period: Start – End (Hour)	% Diversity
0 - 7	53
7 - 8	55
8 - 9	60
9 - 12	98
12 - 13	73
13 - 17	98
17 - 18	65
18 - 20	55
20 - 24	53

Note: Schedule based on premise that fume hood use is directly related to occupancy of the laboratories. Using the laboratory occupancy schedule above and 100% hood airflow when in use and 50% airflow when not in use (assumes 18" operating sash height and minimum flow of 25 cfm/SF of hood work surface per NFPA 45).

Starting Month: January Starting Daytype: Saturday, Sunday	Ending Month: December Ending Daytype: Holiday
Period: Start – End (Hour)	% Diversity
0 – 7	53
7 – 9	55
9 –13	65
13 – 18	55
18 – 24	53

Note: Schedule based on premise that fume hood use is directly related to occupancy of the laboratories. Using the laboratory occupancy schedule above and 100% hood airflow when in use and 50% airflow when not in use (assumes 18" operating sash height and minimum flow of 25 cfm/SF of hood work surface per NFPA 45 – see fume hood design criteria standard).

APPENDIX B

The following table B1 is intended to provide guidance for establishing a “budget” fan horsepower limit for laboratory buildings. The intent is to allow users to establish a fan energy limit more appropriate for research facilities than the limits listed in ASHRAE 90.1-1999 which are believed to be intended only for commercial buildings (i.e. offices, retail). Since with fixed design airflow the operating fan horsepower is directly proportional to the operating fan pressures, the table identifies typical pressure losses that would be used to determine a budget fan horsepower.

For comparison purposes, the table includes a column containing a list of typical components found in a commercial variable air volume duct system. No specific information on how the ASHRAE fan energy budget was established is included in the 1999 edition of the standard, so the list was established to determine typical components that would result in a fan horsepower similar to the limit listed in ASHRAE. Review of the original ASHRAE 90.1-1989 edition identified that for a budget built up central station VAV system, the static pressures used to determine the fan horsepower limits was 4” w.g. on the supply and 1” w.g. on the return (see ASHRAE 90.1-1989, page 114, System type 5). These values and the component values are not intended as recommended design criteria, but only as an example of components that may have gone into the ASHRAE fan energy budget. The laboratory column then identifies how these systems differ from the commercial system listed. The laboratory static pressure requirements were then used to establish the fan energy limit for the budget building systems listed in the modeling guide.

Since programmatic requirements may vary, components that may be required but are not considered typical have been provided in a second table B2. Where appropriate, the static pressure loss of these or other additional components necessary for the project are to be added to the total budget static pressure listed and a new fan power limit established for the budget building. The pressure losses used would be the same in both the budget and proposed cases systems (thus raising the budget by the same value as the proposed). This was done to ensure where components are necessary to meet local codes or standards, such as system intake sound levels, the addition of a component (i.e. intake sound attenuator) can be addressed by these guidelines. The establishment of a more appropriate baseline will also allow for credit when low duct pressure drop systems or component are included (i.e. low pressure drop coils).

TABLE B1 - System Static Pressure Allowance – Budget Laboratory Building					
Component	**Commercial Application Budget**	**Laboratory Application Budget**	**Difference**	**Criteria for Selection/Sizing**	**Comments**
Supply System					
Intake Louvers	0.15” w.g.	0.15” w.g.		2001 ASHRAE Fundamentals, Chapter 34, Figure 15 and SMACNA Duct Design Table 9-8. Pressure drop is maximum typical value.	Based on 400 fpm over gross louver area, 800 fpm over net lover area. Design recommendation based on limiting water intake.
Intake Damper	0.07” w.g.	0.07” w.g.		1500 fpm – pressure drop from ASHRAE DFDB @ 1500 fpm	Typical design practice for selection of control dampers.
Prefilter	0.32” w.g.	0.32” w.g.		500 fpm – Clean pressure drop listed from manufacturer data, typical 24”x24” filter (Farr 30/30)	Filter Velocity: 2001 ASHRAE Fundamentals states duct velocity for low efficiency extended-surface. Typical AHU casing velocity = 500 fpm. Also see SMACNA Duct Design Table 9-8 Filter Type: 2000 ASHRAE Equipment, Chapter 24, Table 2 25% to 40% Dust Sport Efficiency Filters
Final Filter	N/A	0.55” w.g.	0.55” w.g.	500 fpm – Clean pressure drop from manufacturers data, typical 24”x24” filter (Farr Riga-flow 100)	Filter Velocity: 2001 ASHRAE Fundamentals states up to 750 fpm, but in practice, typically matches prefilter velocity. Also see SMACNA Duct Design Table 9-8. Filter Type: ASHRAE 2000 Equipment, Chapter 24, Table 2 - 80% - 85% extended surface bag or cartridge filter.
Preheat Coil - Steam	0.18” w.g. per ASHRAE DFDB at 800 fpm 1-row coil	0.38” w.g. per ASHRAE DFDB at 800 fpm 2-row coil	0.20” w.g.	800 fpm	2000 ASHRAE Equipment Chapter 24 states 200 to 1500 fpm. Must review part load operation. 800 fpm selected will allow VAV airflow reduction to 40% (or 320 fpm) while remaining within the ARI 410 rating range of 200 fpm to 1500 fpm. 800 fpm is found by experience to prevent excessive coil capacity and maintain proper airside temperature control. Tube velocities in smaller coils are also higher allowing setback while maintaining control.

TABLE B1 - System Static Pressure Allowance – Budget Laboratory Building					
Component	**Commercial Application Budget**	**Laboratory Application Budget**	**Difference**	**Criteria for Selection/Sizing**	**Comments**
Humidifier	0.00” w.g.	0.06” w.g.	0.06” w.g.	With 100% outside air in drier climates, a humidifier is required to meet ASHRAE Standard 55 for minimum humidity levels. Pressure drop from mfr. data (Dri-Steem Ultrasorb with 3” tube spacing @ 800 fpm)	Select to match velocity of upstream or downstream component. Allow space for air to transition. Use SMACNA transition angles to determine spacing.
Cooling Coil	0.75” – Sample selection for typical office occupancy 25% OA (Aerofin)	1.3” - Sample selection for typical lab occupancy 100% OA (Aerofin)	0.55”wc	500 fpm	2000 ASHRAE Equipment Chapter 24 states 200 to 800 fpm. Must review part load operation. 500 fpm selected will allow VAV airflow reduction to 40% (or 200 fpm) while remaining within the ARI 410 rating range of 200 fpm to 800 fpm. 500 fpm is found by experience to provide reasonable balance between pressure drop, cost and space
Unit Discharge Damper	0.13” w.g. per ASHRAE DFDB @ 2000 fpm	0.13” w.g. per ASHRAE DFDB @ 2000 fpm		1500 fpm.	Typical design practice for selection of control dampers. Smoke damper where applicable.
Ductwork AHU to Terminal Box < 6000 cfm	1.28” w.g. including fittings	1.28” w.g. including fittings		0.25” w.g. pressure drop per 100 ft	Allowance to match ASHRAE total. Typical loss per 100 ft, no guidelines from ASHRAE or SMACNA
Ductwork AHU to Terminal Box >/= 6000 cfm				2000 fpm	1991 ASHRAE Practical Guide to Noise and Vibration Control (velocity) and 2003 ASHRAE Applications. Based on typical standard radius elbows and a room NC=45. NC 45 selected ad mid range of research labs.
Ductwork Terminal Box to Space < 6000 cfm	0.1” w.g. including fittings	0.1” w.g. including fittings		0.10” w.g. pressure drop per 100 ft	Typical practice, no guidelines from ASHRAE or SMACNA
Ductwork Terminal Box to Space >/= 6000 cfm				2000 fpm	1991 ASHRAE Practical Guide to Noise and Vibration Control (velocity) and 2003 ASHRAE Applications. Based on typical standard radius elbows and a room NC=45. NC 45 selected at mid range of research labs.

TABLE B1 - System Static Pressure Allowance – Budget Laboratory Building					
Component	**Commercial Application Budget**	**Laboratory Application Budget**	**Difference**	**Criteria for Selection/Sizing**	**Comments**
Fire Dampers	0.03” w.g.	0.03” w.g.		C=0.12 - Pressure drop from ASHRAE DFDB @ 2000 fpm	ASHRAE Duct Fitting Database
Terminal Box – Supply without Reheat Coil	0.94” w.g. total per ASHRAE DFDB @ 2000 fpm inlet velocity – includes 0.42” w.g. for HW coil	0.6” valve only	0.38” w.g.		ASHRAE data for commercial. Manufacturer data for laboratories. Based on Phoenix Controls venturi valve.
Duct Mounted Reheat Coil		0.42” w.g. (same as commercial)			Velocity to match low pressure duct system See criteria above.
Terminal Box Sound Attenuators		0.3” w.g. – estimate			Velocity to match low pressure duct system See criteria above.
Diffusers Registers and Grilles	0.05 “ w.g. per 1981 SMACNA duct design for square diffuser	0.10” w.g. – manufacturer data for radial pattern diffuser (Titus Tri-Tec)	0.05” w.g.	500 fpm	Based on velocity and selection at 5 NC below design conditions per recommendation from acoustical consultant. NC 45 selected at mid range of research labs.
Total Supply	4.0” w.g. Commercial	5.79” w.g. Laboratory	1.79”w.g. Difference		
Exhaust					
Registers and Grilles	0.20” w.g. per 1981 SMACNA duct design Table 9-7.	Use fume hood	0.55” w.g.	600 fpm	Based on velocity and selection at 5 NC below design conditions per recommendation from acoustical consultant. NC 45 selected at mid range of research labs.
Fume Hoods	N/A	0.75”wc		0.75” w.g.	Typical maximum hood loss per ANSI/AIHA Z9.5-2003 page 55.
Ductwork Terminal Box to Exhaust Fan < 6000 cfm	0.38” w.g.	1.28”wc – Use same as supply VAV duct allowance	0.9” w.g.	0.25” w.g. pressure drop per 100 ft	Allowance for commercial to match ASHRAE total. For labs, use same as supply duct allowance. Typical loss per 100 ft , no guidelines from ASHRAE or SMACNA
Ductwork Terminal Box to Exhaust Fan >/= 6000 cfm				2000 fpm	1991 ASHRAE Practical Guide to Noise and Vibration Control (velocity) and 2003 ASHRAE Applications. Based on typical standard radius elbows and a room NC=45. NC 45 selected ad mid range for typical research labs.
Ductwork Space to Terminal Box < 6000 cfm	0.10” w.g.	0.1” w.g.		0.10” w.g. pressure drop per 100 ft	Typical practice, no guidelines from ASHRAE or SMACNA

TABLE B1 - System Static Pressure Allowance – Budget Laboratory Building					
Component	**Commercial Application Budget**	**Laboratory Application Budget**	**Difference**	**Criteria for Selection/Sizing**	**Comments**
Ductwork Space to Terminal Box >/= 6000 cfm				2000 fpm	1991 ASHRAE Practical Guide to Noise and Vibration Control (velocity) and 2003 ASHRAE Applications. Based on typical standard radius elbows and a room NC=45. NC 45 selected ad mid range for typical research labs.
Terminal Box – Exhaust	0.0” w.g.	0.6” w.g.	0.6” w.g.	0.6”w.g.	Manufacturers design data Based on Phoenix Controls venturi valve.
Intake Damper	0.07” w.g.	0.07” w.g.		1500 fpm – pressure drop from ASHRAE DFDB @ 1500 fpm	Typical design practice for selection of control dampers.
Exhaust Discharge Stack	N/A	0.56”wc	0.31” w.g.	3000 fpm	3000 fpm from ANSI/AIHA Z9.5-2003 page 48. Pressure loss from ASHRAE Duct Fitting Database Co=1.0
Exhaust Louver – toilet and general exhaust systems only	0.25” w.g.	N/A		0.25” w.g.	2001 ASHRAE Fundamentals, Chapter 34, Figure 15 and SMACNA Duct Design Table 9-8 Based on 400 fpm over gross louver area, 800 fpm over net lover area.
Total Exhaust	1” w.g. Commercial	3.36” w.g. Laboratory	2.36” w.g. Difference		
Total System – Supply + Exhaust	**5” w.g. Commercial**	**9.15” w.g. Laboratory**	**4.15”w.g. Difference**		

TABLE B2- Examples of Additional Components to be added to Static Pressure Allowance Where Appropriate					
Component	**Commercial Application Budget**	**Laboratory Application Budget**	**Difference**	**Criteria for Selection/Sizing**	**Comments**
Supply System					
Snow Melt Screen/Coil				Project Specific	Select for minimum pressure drop. Where applicable. Needed in some locations to prevent buildup of light snow on filters and associated inefficiency, added maintenance and additional pressure drop.
AHU Intake Sound Attenuator		0.03" w.g. per ASHRAE DFDB @ 500 fpm		500 fpm Select to match velocity of upstream or downstream component. Allow space for air to transition. Use SMACNA transition angles to determine spacing.	May be required to meet local ambient noise levels.
Preheat Coil – Hot Water & Glycol				500 fpm	Typical practice. If a hot water coil is used remove the pressure drop for the stream preheat coil
AHU Discharge Sound Attenuator		0.68" w.g. per ASHRAE DFDB @ 2000 fpm		Project Specific	Size to match supply duct. See velocity criteria above.
Exhaust System					
Biosafety Cabinets – Class II Type A2				0.1" w.g.	Manufacturers design data.
Biosafety Cabinets – Class II Type B2				3" w.g.	Manufacturers design data.
Terminal Box Sound Attenuators				Project Specific	Velocity to match low pressure duct system See criteria above.
HEPA Filters					Required for Biocontainment Laboratories – Project Specific.