# Tech Report One

## ASHRAE Standard 62.1 - 2007 and Standard 90.1 - 2007 Analysis

# Biobehavioral Health Building

The Pennsylvania State University | Biobehavioral Health Building | University Park, PA | Mechanical | Ling | Jake Copley

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# Tech Report One

## Executive Summary

The purpose of this report is to determine if the Biobehavioral Health Building is in compliance with both ASHRAE Standard 62.1 - 2007 and Standard 90.1 - 2007.

When analyzing Standard 62.1-2007, all equipment and systems called out in the following sections are in compliance with ASHRAE standards. There were only a handful of items that have not yet been specified for the project and were considered not in compliance or not applicable. Concluding the minimum ventilation rate calculations, it was determined that all but one air handling unit are in compliance with ASHRAE Standard 62.1 minimum ventilation standards. A probable cause for this could be due to the assumption in occupancy density for the various spaces. The zones with the largest occupancies were the zones where there was the greatest discrepancy. All controls and filtration specifications for the project were in compliance with ASHRAE 62.1

After analysis of BBH most building components and controls were within the requirements specified by ASHRAE Standard 90.1-2007. It is a requirement by PSU, that all new construction must be LEED certified at a minimum. With this goal in mind, the over all design was up to par with current energy standards. The only area that was not within compliance were the motors. Not all motors were within the minimum efficiency requirements specified by the minimum motor power requirements. A majority of the motors used in the building were less than the minimum nameplate hp provided in Table 10.8 (Appendix A) therefore could not be compared with the standard. Most of the items that were not in compliance with ASHRAE minimum energy design standards can be considered negligible due to the small effect the component has on the system. Many items were not capable of being compared with ASHRAE standards due to the components small size, such as the small motor sizes seen in the Motor Efficiency Calculations.

In conclusion, Biobehavioral Health was determined to be mostly compliant with minimum ventilation and energy design requirement specified by ASHRAE Standard 62.1 and 90.1. All detailed calculations can be found in Appendix B.

## Building Overview

The Biobehavioral Health Building (BBH) is a 93,500 square foot new construction building located at The Pennsylvania State University Main Campus, in University Park, PA and a overall project cost of $48.1 million. There are four floors above ground, one below and a mechanical penthouse. The site was originally home to a parking lot and an existing 12,000 square foot Henderson Bridge Building, which was building in 1958. The new Biobehavioral Health Building is located south of the Henderson North Building between the Old Main lawn and the HUB lawn (Figure 1). It's expected completion date is November of 2012.

***Figure 1.1:*** *Arial view from Bing.com showing location.*

**Occupant**

Biobehavioral Health, from the College of Health and Human Development, will occupy the majority of the first floor and the entire second floor. On the third floor is space allocated for The Prevention Research Center. The Center for Aging and the Center for Human Development and Family Research in Diverse Contexts share the fourth floor. Each floor consists of a mix of offices, projects and research spaces. The ground floor contains a 200 seat lecture hall and the first floor has two 35 seat general purpose classrooms.

**Primary Project Team**

| | | |
|---|---|---|
| **Owner** | The Pennsylvania State University | www.opp.psu.edu |
| **Architect** | Bohlin Cywinski Jackson | www.bcj.com |
| **CM** | Massaro CM Services | www.massarocorporation.com |
| **MEP/Fire Protection** | Bruce E. Brooks Associates | www.brucebrooks.com |
| **Structural Engineer** | Robert Silman Associates | www.rsapc.com |
| **Civil Engineer** | Gannett Fleming, Inc. | www.gannettfleming.com |
| **Landscape Architect** | Michael Vergason | www.vergason.net |
| **Geotech Consultant** | CMT Laboratories, Inc. | www.cmtlaboratories.com |
| **GC** | L.S. Fiore | www.lsfiore.com |

**Architecture**

Due to the historic nature of Henderson North, built in 1933, the BBH was designed to be aesthetically complimentary to Henderson North. The differences between the two buildings are responses to the growth of sustainable design and the need for student activities. The building is served with main double loaded corridors down the middle of the building connecting the three main entrances on the east and west sides of the building. General purpose classrooms are located on the ground and first floor for ease of access for students. Offices, project and research spaces are located on the upper floors.

***Figure 1.2:*** *West entrance off Old Main lawn.*

***Figure 1.3:*** *Entrance off the HUB lawn.*

***Figure 1.4:*** *Southeast entrance.*

Limestone and brick clad the building paying their respects to Henderson North. The limestone veneer wraps into the main entry ways on both the east and west entrances. All three entrances are located on heavy cross campus traffic areas. The West entrance is off the Old Main lawn (Figure 2). Another entrance is located on the HUB lawn (Figure 3) on the Northeast corner of the building along with the third entrance on the Southeast corner (Figure 4). Salvaged Elm wood from the Penn State Campus can be seen as accent pieces, benches and cabinetry throughout the building.

BBH has two main sustainable features. The first is a green roof that covers approximately fifty percent of the roof area. Second, complimenting the green roof, is a cistern that collects rainwater runoff to be used for landscape maintenance. The use of a cistern makes BBH one of the first buildings on campus to use the concept in order to reduce storm runoff into the storm system reducing the stress on the system during a heavy rain storm. BBH is located in the University Planned District (UPD). Per Pennsylvania State University standards, Penn State requires all future buildings on the Penn State Campuses must be LEED Certified. To help improve energy efficiency, BBH has been design to be in conformance with the International Energy Conservation Code.

The facade is very similar to Henderson North with limestone veneer up to the second floor followed by brick on the remaining floors. There are also limestone accent pieces around the building again in similar fashion to Henderson North. On the northeast and southeast corners of the building there are glass curtain walls surrounding the main stairwell and entrances.

## Mechanical System Overview

The mechanical system of the Biobehavioral Health Building is composed of six variable air volume air handling units with economizers. The air handlers are divided by zone, AHU-1 and 5 service the core of the building, AHU-2 serves the classrooms, AHU-3 and 4 serve the south and north offices respectively and finally AHU-6 serves the conference rooms. BBH also uses perimeter steam based radiator heating.

BBH is fed off the campus steam and chilled water, supplied from central campus steam and chilled water plants, which provide all heating and cooling needs along with domestic hot water requirements. Steam from the campus loop is fed through a plate heat exchanger which transfers heat to the building hot water loops.

### Section 5 Analysis

This section is an analysis of Section 5 of ASHRAE Standard 62.1. This will verify if BBH is in compliance with minimum ventilation requirements specified by ASHRAE.

**5.1 Natural Ventilation**

> *Use of natural ventilation systems designed in accordance with this section shall be permitted in lieu of or in conjunction with mechanical ventilation systems.*

•The building is ventilated mechanically, natural ventilation is not used. Section 5.1 does not apply.

**5.2 Ventilation Air Distribution**

> *Ventilating systems shall be designed in accordance with the following.*
>
> *Designing for Air Balancing. The ventilation air distribution system shall be provided with means to adjust the system achieve at least the minimum ventilation airflow as required by section 6 under any load condition.*

•Plenums are not used in the building.

•The mechanical system is a variable air volume system. The system can be adjusted to achieve airflows required by section 6. This complies with section 5.2.1.

•The building design documents specify the requirements for testing, adjusting and balancing for HVAC equipment. This complies with section 5.2.3.

**5.3 Exhaust Duct Locations**

> *Exhaust ducts that convey potentially harmful contaminants shall be negatively pressurized relative to spaces through which they pass, so that exhaust air cannot leak into occupied spaces; supply, return or outdoor air ducts or plenums.*

•The building exhaust air louvers are located on the south side of the penthouse (opposite from intake louvers on the north side).

•Exhaust systems are negatively pressurized relative to the space which duct work passes, with fans at the discharge of the system.

**5.4 Ventilation System Controls**

*Mechanical ventilation systems shall included controls, manual or automatic, that enable the fan system to operate whenever the spaces served are occupied.*

•For occupied spaces (janitor rooms, toilet/shower and copy rooms), exhaust fans will operate continuously when HVAC zone is occupied. See sequence of operations for scheduled exhaust fans. This complies with section 5.4.

**5.5 Airstream Surfaces**

*All airstream surfaces in equipment and ducts in the heating, ventilating and air conditioning systems shall be design and construction in accordance with the following requirements.*

*Material surfaces shall be determined to be resistant to mold growth and erosion.*

*Exception: Metal surfaces and metal fasteners.*

•Sheet metal and metal fasteners are used throughout the building. Section 23 31 13 states that surfaces in contact with the airstream shall comply with ASHRAE 62.1. This complies with section 5.5.

**5.6 Outdoor Air Intakes**

*Outdoor air intakes, including doors and windows that are required as part of a natural ventilation system, shall be located such that the shortest distance from the intake to any specific potential outdoor contaminant source shall be equal or greater than separation distance listed in Table 5.1 (Appendix A)*

*Outdoor air intakes that are part of the mechanical ventilation system shall be design to manage rain entrainment.*

*Air-handling and distribution equipment mounted outdoors shall be designed to prevent rain intrusion into the airstream when tested at design airflow and with no airflow, using the rain test apparatus described in Section 58 of UL 1995.*

•Intake louvers are located the appropriate minimum distances away from significantly contaminated exhaust (approximately 23', min of 15') and surfaces directly below intake (approximately 3', min of 1'). This complies with section 5.6.1.

•Drainable blade louvers have been specified for the project with a point of beginning water penetration at not less than 900 FPM.

•No air-handling or distribution equipment is mounted outdoors. This complies with section 5.6.3.

**5.7 Local Capture of Contaminants**

*The discharge from non-combustion equipment that captures the contaminants generated by the equipment shall be ducted directly to the outdoors.*

•All discharge from non-combustion equipment is directed to the outside. There is no indoor exhaust discharge. This complies with section 5.7.

**5.8 Combustion**

*Fuel burning appliances, both vented and unvented, shall be provided with sufficient air for combustion and adequate removal of combustion products, in accordance with manufacturer instructions. Products of combustion from vented appliances shall be vented directly outdoors.*

•With campus steam, no fuel-burning appliances are used in the building. Section 5.8 does not apply.

**5.9 Particulate Matter Removal**

*Particulate matter filters or air cleaners having a minimum efficiency reporting value (MERV) of not less than 6 when rated in accordance with ASHRAE Standard 52.2 shall be provided upstream of all cooling coils or other devices with wetted surfaces through with air is supplied to an occupiable space.*

•Particulate matter filters in the air handling units throughout the building have a minimum of MERV 8 for the pre-filter and MERV 13 for the main filter. This complies with section 5.9. Filters must comply with NFPA 90A and ASHRAE Standard 52.1.

**5.10 Dehumidification Systems**

*Mechanical air-conditioning systems with dehumidification capability shall be designed to comply with the following.*

*Occupied space relative humidity shall be limited to 65% or less when system performance is analyzed with outdoor air at the dehumidification design condition.*

•Based on the entering air temperatures into the cooling coils of the 6 air handling units, all humidity levels are below 55% relative humidity which is less that the prescribed 65%. This complies with section 5.10.1.

**5.11 Drain Pans**

*Pans intended to collect and drain liquid water shall be sloped at least 0.125 inches per foot.*

*Drain pan outlet shall be located at the lowest point on the drain pan and shall be of sufficient diameter to preclude drain pan overflow under any normally expected operating condition.*

*For configurations that result in negative static pressure at the drain pan relative to the drain outlet, the drain line shall include a P-trap or other sealing device designed to maintain a seal against ingestion of ambient air while allowing complete drainage of drain pan.*

*The drain pan shall be located under the water-producing device. Drain pan width shall be sufficient to collect water droplets across the entire width of the water-producing device or assembly.*

•According to section 23 82 19 and submittal 23 73 13 - 00001 of the building specifications main and auxiliary drain pans will be removable plastic that comply with ASHRAE 62.1. This complies with sections 5.11.1, 5.11.2.

•Traps are included on all drain pans see details per submittal 23 73 13 - 00001. This complies with section 5.11.3.

•Drain pans are full width of cooling coil and extend a minimum 6" downstream of last coil section. Intermediate drain pans are used for cooling coils with finned heights greater than 48". This complies with section 5.11.4.

**5.12 Finned-Tube Coils and Heat Exchangers**

> *Individual finned-tube coils or multiple finned-tube coils in series without adequate intervening access space of at least 18 inches shall be selected to result in no more than 0.75 in w.c. combined pressure drop when dry coil face velocity is 500 fpm.*

•Drain pans are supplied beneath each cooling coil and condensate producing heat exchanger per spec section 23 82 19. This complies with section 5.12.1.

•No specification for 18" clearance between coils.

**5.13 Humidifiers and Water-Spray Systems**

•The Biobehavioral Health Building does not use a humidification systems. Section 5.13 does not apply.

**5.14 Access for Inspection, Cleaning and Maintenance**

> *Ventilation equipment shall be installed with sufficient working space for inspection and routine maintenance.*
>
> *Access doors, panels or other means shall be provided and sized to allow convenient and unobstructed access sufficient to inspect, maintain and calibrate all ventilation system components for which routine inspection, maintenance or calibration is necessary.*

•Double wall access doors provide access to mechanical equipment parts with 180 per submittal 23 73 13 - 00001. This is in compliance with ASHRAE section 5.14.2.

**5.15 Building Envelope and Interior Space Surfaces**

> *A weather barrier or other means shall be provided to prevent liquid water penetration into the envelope.*
>
> *An appropriately placed vapor retarder or other means shall be provided to limit water vapor diffusion to prevent condensation on cold surfaces within the envelope.*
>
> *Exterior joints, seams or penetrations in the building envelope that are pathways for air leakage shall be caulked, gasketed, weather-stripped, provided with continuous air barrier.*

•Below grade, a self adhered waterproofing membrane is used to prevent liquid water penetration into the building is in compliance with section 5.15.1. Details can be seen below in Figure 1.5.

•Above grade, a fluid applied air barrier is use over rigid insulation to create an air tight barrier and is in compliance with section 5.15.1. Details can be seen below in Figure 1.5.

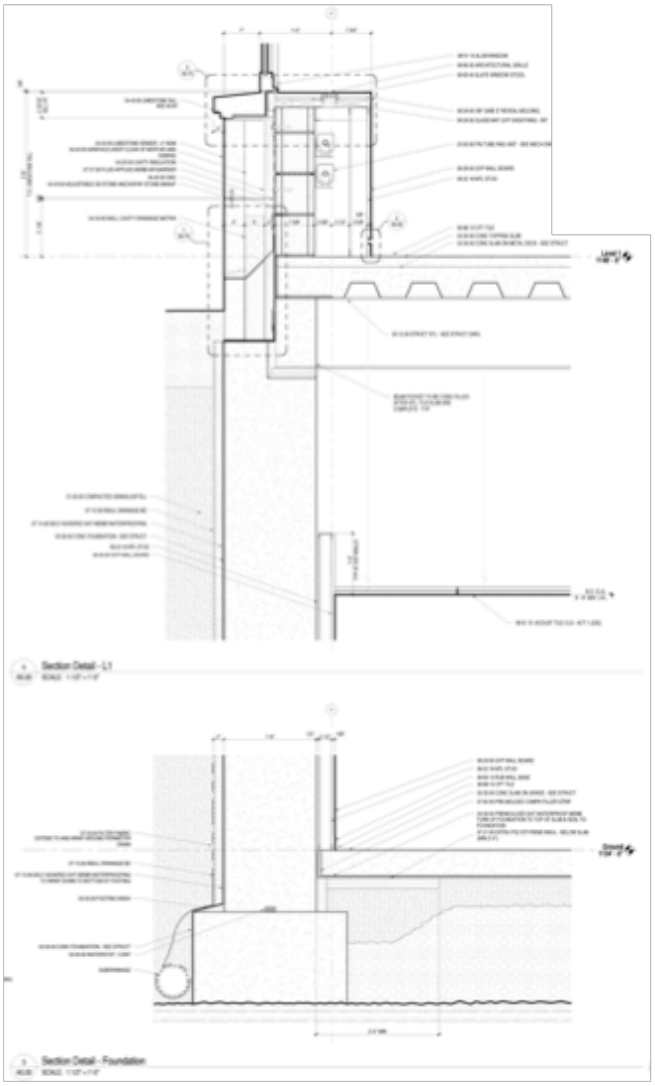

***Figure 1.5:*** *Wall Detail*

•All pipes and ducts that have the potential to fall below the local dew point are insulation to prevent the formation of condensation. This is in compliance with section 5.15.2.

**5.16 Buildings with Attached Parking Garages**

•No parking garage is attached to the Biobehavioral Health Building.  Section 5.16 does not apply.

**5.17 Air Classification and Recirculation**

> *Air shall be classified and its recirculation shall be limited in accordance with the following sections.*
>
> *Air (return, transfer or exhaust air) leaving each space or location shall be designated at an expected air-quality classification not less than that show in Tables 5.2 or 6.1 (Appendix A) or as approved by the authority having jurisdiction.*

•Each floor can be generalized as spaces with Air Class 1. This allows the air to be freely recirculated within other spaces in the zone with out excessive air cleaning. This complies with section 5.17.

**5.18 Requirements for Buildings Containing ETS Areas and ETS-Free Areas**

> *The requirements of this section must be met when a building contains both ETS areas and ETS-free areas.*

•The Biobehavioral Health Building is applying for LEED certification and will provide a non-smoking environment. Section 5.18 does not apply.

## Section 6 Analysis

*Ventilation Rate Procedure*

> *The is a prescriptive procedure in which outdoor air intake rates are determined based on space type/application, occupancy level and floor area. All tables and equations in this section are referenced from ASHRAE Standard 62.1 - 2007*

Breathing Zone Outdoor Airflow ($V_{bz}$)

> *The design outdoor airflow required in the breathing zone of the occupiable space or spaces in a zone.*

$$V_{bz}=R_p \cdot P_z + R_a \cdot A_z \quad \text{(Eq 6.1)}$$

Where,

$A_z$ = zone floor area ($ft^2$)

$P_z$ = zone population, the largest number of people expected to occupy the zone during typical usage. (Estimated values found in Table 6.1 (Appendix A))

$R_p$ = outdoor airflow rate required per person as determine from Table 6.1 (Appendix A)

$R_a$ = outdoor airflow rate required per unit area as determined from Table 6.1 (Appendix A)

Zone Outdoor Airflow ($V_{oz}$)

> *The design zone outdoor airflow ($V_{oz}$), the outdoor airflow that must be provided to the zone by the supply air distribution system. $E_z$ is determined using Table 6-2 (Appendix A)*

$$V_{oz} = V_{bz}/E_z \quad \text{(Eq 6.2)}$$

Primary Outdoor Air Fraction ($Z_p$)

> *When Table 6-3 (Appendix A) is used to determine system ventilation efficiency, the zone primary outdoor air fraction ($Z_p$) shall be determined in accordance with Equation 6.5.*

$$Z_p = V_{oz}/V_{pz} \quad \text{(Eq 6.5)}$$

$V_{pz}$ = minimum expected primary airflow

System Ventilation Efficiency ($E_v$)

> *The system ventilation efficiency ($E_v$) shall be determined using Table 6.3 (Appendix A).*

Uncorrected Outdoor Air Intake ($V_{ou}$)

*The design uncorrected outdoor air intake ($V_{ou}$) shall be determined in accordance with Equation 6.6.*

$$V_{ou} = D * \sum_{all\ zones}(R_p * P_z) + \sum_{all\ zones}(R_a * A_z) \quad \text{(Eq 6.6)}$$

Occupant Diversity (D)

$$D = P_s / \sum_{all\ zones} P_z \quad \text{(Eq 6.7)}$$

$P_s$ = system population

Outdoor Air Intake ($V_{ot}$)

*The design outdoor air intake flow ($V_{ot}$) shall be determined in accordance with Equation 6.8.*

$$V_{ot} = V_{ou} / E_v \quad \text{(Eq 6.8)}$$

**Table 1.1: Minimum Ventilation**

| AHU | Design Min OA CFM | ASHRAE 62.1 OA CFM | Compliance (Y/N) |
|---|---|---|---|
| 1 (Core Offices) | 4500 | 3476 | Y |
| 2 (Classrooms) | 2750 | 3484 | N |
| 3 (South Offices) | 4750 | 993 | Y |
| 4 (North Offices) | 3150 | 962 | Y |
| 5 (Core) | 5000 | 2041 | Y |
| 6 (Conference) | 2700 | 2075 | Y |

Six air handling units were analyzed since they make up the majority of the ventilation system. In conclusion, it was determined that two of the air handling units comply with the minimum ventilation specified by ASHRAE Standard 62.1-2007 as seen above in Table 1. A possible reason for this is due to the variation in occupancy values use for the specified spaces. AHU-4, 5, 6 are not severely under the ASHRAE minimum ventilation requirement. AHU-2 (Classrooms) was the air handling unit with the largest difference. This could be due to the size of the space and occupancy density use. A reduced occupant density of 35 persons/1000sf was used in lieu of 150 persons/1000sf, an estimate of the occupancy of the lecture hall is know to be around 205 people. Likewise the occupant density of classrooms 102 and 102a were increased to 45 persons/1000sf from 35 persons/1000sf. The capacity of the classrooms 102 and 102a is know to be around 35 people. Given the areas of these spaces, these occupant densities more accurately modeled the ventilation requirements for these spaces.

For all air handling units the nominal outside air ($\sum V_{oz}$) was less than the require outside air ($V_{ot}$). This is because the nominal outside air does not take into account the system ventilation efficiency. Low system ventilation efficiencies cause the required outside air value to increase to account for the inadequate distribution of ventilation air.

## ASHRAE Standard 62.1 - 2007 Summary

In conclusion, most mechanical components called out in section 5 are in compliance with ASHRAE standards. There were only a handful of items that have not yet been specified for the project and were considered compliant or not applicable.

Concluding the minimum ventilation rates it was determined that all but one air handling unit is in compliance with ASHRAE minimum ventilation standards. A probable cause for this could be due to the assumption in occupancy density for the various spaces. The zones with the largest occupancies were the zones where there was the greatest discrepancy.

Improvement could be seen by using different design values for the minimum ventilation rates for some of the more heavily occupied spaces. One of these spaces is quite large and consists of a decent size lobby type of space which does not need the ventilation rates required for a lecture hall. So, slightly reduced ventilation rates could easily place the remaining air handling unit in compliance with Standard 62.1 and still provide adequate ventilation to the space.

# ASHRAE Standard 90.1 - 2007 Analysis

## Section 5 - Building Envelope

### 5.1.4 Climate Zone

•Location in University Park, PA, which lies in zone 5A. Zone 5A is described as a cool humid climate. This climate zone was determined using Figure 5 from ASHRAE Standard 90.1 - 2007.

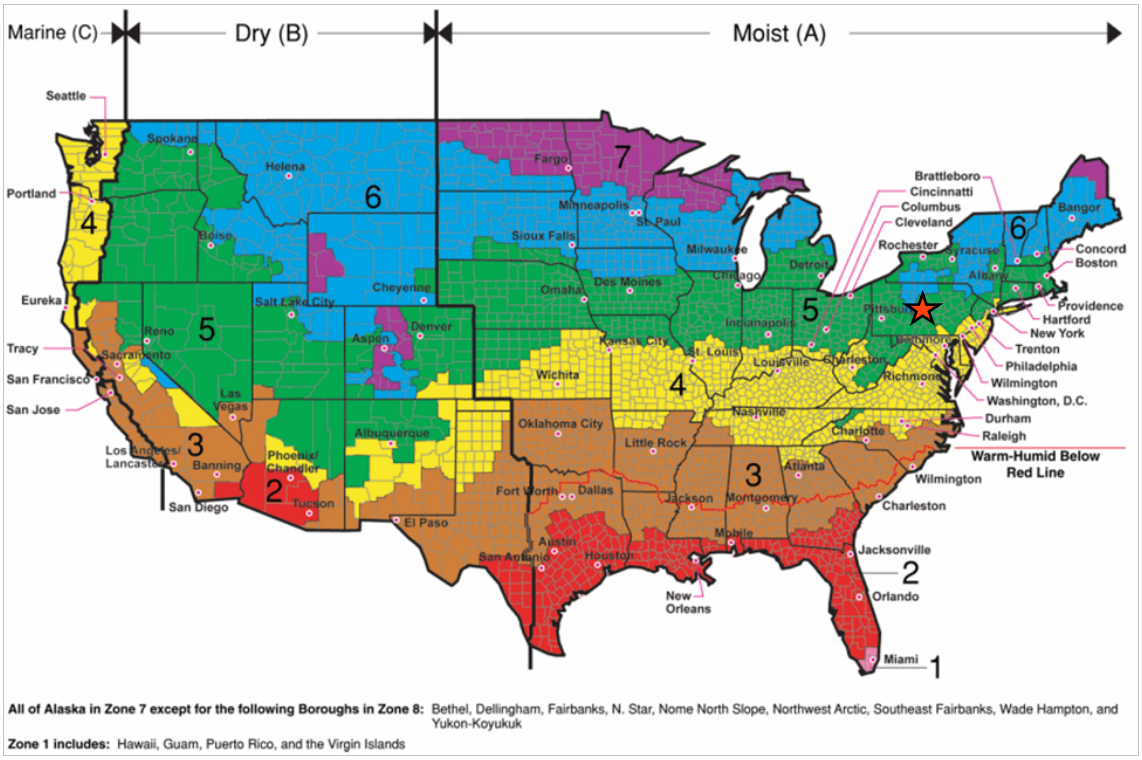


***Figure 1.6:*** *Climate zones for United States locations.*

### 5.4 Mandatory Provisions

*All fenestration and openings in building envelope shall be sealed.*

•Construction documents call for exterior doors to be weatherstripped and fenestrations to be sealed to prevent air leakage. This complies with section 5.4.3.1.

•All building entrances that separate conditioned space from the exterior are provide with a vestibule to create an air lock between the exterior and interior. This complies with section 5.4.3.4.

### 5.5 Prescriptive Building Envelope

*See Table 5.5-5 (Appendix A) for Building Envelope Requirements for Climate Zone 5 (A,B,C).*

*The total vertical fenestration area shall be less than 40% of the gross wall area.*

•The total vertical fenestration area is less then 40% of the gross wall area. BBH complies with section 5.5.4.2.1, see Table 2 below.

| Table 1.2: Glazing Area | | | | |
|---|---|---|---|---|
| | Glazing Area ($ft^2$) | Wall Area ($ft^2$) | Percent Glazing | ASHRAE 90.1 Compliance (Y/N) |
| Biobehavioral Health Building | 12033 | 41469 | 30% | Y |

•The building envelope must meet minimum requirements according to its climate zone. Most envelope sections of BBH met the building envelope requirements as shown in Table 3 below.

| Table 1.3: Building Envelope Requirements for Climate Zone 5A | | | | | | |
|---|---|---|---|---|---|---|
| Element | Element Construction | Element Maximum | Element Insulation Min | Assembly Maximum | Assembly Insulation Min | ASHRAE 90.1 Compliance (Y/N) |
| Roof | Insulation Entirely above Deck | U-0.048 | R-20 | U-0.047 | R-21 | Y |
| Walls Above Grade | Mass | U-0.090 | R-11.4 | U-0.081 | R-12.22 | Y |
| Walls Below Grade | Below Grade Wall | C-0.119 | R-7.5 | C-0.088 | R-11.35 | Y |
| Slab On Grade Floors | Heated | F-0.860 | R-15 for 24 in | NR | NR | N |

## Section 6 - Heating, Ventilating and Air Conditioning

### 6.3 The Simplified Approach Option for HVAC Systems

*The simplified building approach is an optional path for compliance when the following conditions are met.*

- *Building is two stories or fewer in height.*
- *Gross floor area is less than 25,000 sf.*
- *Each HVAC system in the building complies with the requirements listed in section 6.3.2*

•BBH does not meet the requirements of the Simplified Approach Option.

### 6.4 Mandatory Provisions

*The supply of heating and cooling energy to each zone shall be individually controlled by thermostatic controls responding to temperature within the zone.*

*All supply and return ducts and plenums installed as part of a HVAC air distribution system shall be thermally insulation in accordance with Table 6.8.2B.*

*Ductwork and plenums shall be sealed in accordance with Table 6.4.4.2A.*

•The supply heating and cooling for each zone is individually controlled by thermostatic controls responding to temperature within the zone. The system also uses demand based ventilation $CO_2$ control. This complies with section 6.4.3.1.1.

•HVAC systems have unoccupied mode where fluctuations occur to prevent equipment from running continuously. This complies with section 6.4.3.3.

•Duct insulation requirements are met for ductwork in unconditioned space, concealed ductwork does not meet the requirements as shown below in Table 4.

**Table 1.4: Duct Insulation Schedule**

| Duct Location | Insulation Material | |
|---|---|---|
| | Mineral Fiber Blanket | Mineral Fiber Board |
| Concealed | ~ R-1 | NA |
| Exposed | NA | ~ R-6 |

•Duct sealing is specified in the construction documents.

### 6.5 Prescriptive Path

*Each cooling system that has a fan shall include either an air or water economizer.*

*All air economizers shall be capable of automatically reducing outdoor air intake to the design minimum outdoor quantity when outdoor air intake will no longer reduce cooling energy use.*

*Each HVAC system at fan system design conditions shall not exceed the allowable fan system motor nameplate hp or fan system bhp as shown in Table 6.5.3.1.1A.*

*Radiant heating systems that are used as primary or supplemental enclosed space heating must be in conformance with the governing provisions of the standard.*

•Radiant heating panels used in conjunction with other systems such as VAV or thermal storage systems.

•Each AHU in Biobehavioral Health use air economizers. High limit shutoff for economizers are used with temperature and enthalpy control. Economizers are control so to not increase heating energy use during normal operation. This complies with section 6.5.1.

| Table 1.5: Fan Power Limitations: Option 1 - Fan System Motor Nameplate hp (hp<CFMs*0.0015) | | | | |
|---|---|---|---|---|
| Unit | CFMs | CFMs*0.0015 | Nameplate hp | ASHRAE 90.1 Compliant (Y/N) |
| AHU-1 | 16500 | 24.75 | 20 | Y |
| AHU-2 | 9500 | 14.25 | 15 | N |
| AHU-3 | 13300 | 19.95 | 15 | Y |
| AHU-4 | 7100 | 10.65 | 15 | N |
| AHU-5 | 14300 | 21.45 | 15 | Y |
| AHU-6 | 9200 | 13.8 | 10 | Y |

•BBH complies with ASHRAE 90.1 Fan System Power Limitations as shown above in Table 5.

•All AHU's use variable frequency drives to control the fan speed. All AHU fans can be controlled from 10% to 100% of motor's 60Hz speed. This complies with section 6.5.5.2.

•BBH uses a combination of VAV systems and radiant hydronic convectors to heat enclosed spaces. This complies with section 5.6.8.2.

**6.7 Submittals**

> *Construction documents shall require that, within 90 days after the date of system acceptance record drawings of the actual installation be provided to the building owner or the designated representation of the building owner. Record drawings shall include, as a minimum, the location and performance data on each piece of equipment, general configuration of duct and pipe distribution system including sizes and the terminal air and water design flow rates. It is also required that an operating manual and a maintenance manual be provided to the building owner. These manuals shall be in accordance with industry accepted standards.*

•The owner will receive all as builts and manuals after construction has been completed.

## Section 7 - Service Water Heating (Domestic Hot Water)

•Insulation is specified on chilled water, hot water, domestic water, steam and steam condensate pipes. This complies with section 7.4.3.

## Section 8 - Power

> *Feeder conductors shall be sized for a maximum voltage drop of 2% at design load.*
>
> *Branch circuit conductors shall be sized for a maximum voltage drop of 3% at design load.*

•Voltage drop is specified to not be greater than 3% which is outside the tolerances of ASHRAE Standard 90.1 section 8.4.1.

## Section 9 - Lighting

**9.4 Mandatory Provisions**

*Interior lighting in building larger than 5000 sf shall be controlled with an automatic control device to shut off building lighting in all spaces.*

•BBH uses occupancy sensors along with manual switches are specific locations in general purpose classrooms. This complies with section 9.4.1.

**9.5 Building Area Method Compliance Path**

*Use the following steps to determine the interior lighting power allowance by the building area method.*

- *Determine the appropriate building area type from Table 9.5.1 (Appendix A) and the allowance LPD.*
- *Determine the gross lighted floor area of the building area type.*
- *Multiply the gross lighting floor areas of the building area types times the LPD.*

•The building area being lit is approximately 93,500 sf. An LPD of 1.2 W/sf was chosen for school/ university building area type.

•After completing a lighting take off it was determined that the building is lit using approximately 0.8W/sf which complies with section 9.5.

## Section 10 - Other Equipment

*Electric motors shall comply with the requirements of the Energy Policy of 1992 where applicable as shown in Table 10.8 (Appendix A)*

•Seven motors comply with the minimum efficiencies shown in Table 10.8. The remaining motors do not comply with section 10.4.1.

## ASHRAE Standard 90.1 - 2007 Summary

After analysis of BBH most building components and controls were within the requirements specified by ASHRAE Standard 90.1-2007. It is a requirement for PSU, that all new construction must be LEED certified at a minimum. With this goal in mind, the over all design was up to par with current energy standards. The two areas that were not within compliance were the motors and voltage drop. Not all motors were within the minimum efficiency requirements specified by the minimum motor power requirements. A majority of the motors used in the building were less than the minimum nameplate hp provided in Table 10.8 (Appendix A).

## References

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Bruce E. Brooks & Associates. Electrical Construction Documents. Philadelphia, PA.

Bruce E. Brooks & Associates. Mechanical Construction Documents. Philadelphia, PA.

ASHRAE. (2007). *Standard 62.1 - 2007, Ventilation for Acceptable Indoor Air Quality.* Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ASHRAE. (2007). *Standard 90.1 - 2007, Energy Standard for Buildings Except Low-Rise Residential Buildings.* Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

# Appendix A

### Table 5.1 Air Intake Minimum Separation Distance

| Object | Minimum Distance, ft (m) |
|---|---|
| Significantly contaminated exhaust (Note 1) | 15 (5) |
| Noxious or dangerous exhaust (Notes 2 and 3) | 30 (10) |
| Vents, chimneys, and flues from combustion appliances and equipment (Note 4) | 15 (5) |
| Garage entry, automobile loading area, or drive-in queue (Note 5) | 15 (5) |
| Truck loading area or dock, bus parking/idling area (Note 5) | 25 (7.5) |
| Driveway, street, or parking place (Note 5) | 5 (1.5) |
| Thoroughfare with high traffic volume | 25 (7.5) |
| Roof, landscaped grade, or other surface directly below intake (Notes 6 and 7) | 1 (0.30) |
| Garbage storage/pick-up area, dumpsters | 15 (5) |
| Cooling tower intake or basin | 15 (5) |
| Cooling tower exhaust | 25 (7.5) |

## Table 5.5-5 Building Envelope Requirements for Climate Zone 5 (A,B,C)

| Opaque Elements | Nonresidential | | Residential | | Semiheated | |
|---|---|---|---|---|---|---|
| | Assembly Maximum | Insulation Min. R-Value | Assembly Maximum | Insulation Min. R-Value | Assembly Maximum | Insulation Min. R-Value |
| *Roofs* | | | | | | |
| Insulation Entirely above Deck | U-0.048 | R-20.0 c.i. | U-0.048 | R-20.0 c.i. | U-0.119 | R-7.6 c.i. |
| Metal Building | U-0.065 | R-19.0 | U-0.065 | R-19.0 | U-0.097 | R-10.0 |
| Attic and Other | U-0.027 | R-38.0 | U-0.027 | R-38.0 | U-0.053 | R-19.0 |
| *Walls, Above-Grade* | | | | | | |
| Mass | U-0.090 | R-11.4 c.i. | U-0.080 | R-13.3 c.i. | U-0.151[a] | R-5.7 c.i.[a] |
| Metal Building | U-0.113 | R-13.0 | U-0.057 | R-13.0 + R-13.0 | U-0.123 | R-11.0 |
| Steel-Framed | U-0.064 | R-13.0 + R-7.5 c.i. | U-0.064 | R-13.0 + R-7.5 c.i. | U-0.124 | R-13.0 |
| Wood-Framed and Other | U-0.064 | R-13.0 + R-3.8 c.i. | U-0.051 | R-13.0 + R-7.5 c.i. | U-0.089 | R-13.0 |
| *Walls, Below-Grade* | | | | | | |
| Below-Grade Wall | C-0.119 | R-7.5 c.i. | C-0.119 | R-7.5 c.i. | C-1.140 | NR |
| *Floors* | | | | | | |
| Mass | U-0.074 | R-10.4 c.i. | U-0.064 | R-12.5 c.i. | U-0.137 | R-4.2 c.i. |
| Steel-Joist | U-0.038 | R-30.0 | U-0.038 | R-30.0 | U-0.052 | R-19.0 |
| Wood-Framed and Other | U-0.033 | R-30.0 | U-0.033 | R-30.0 | U-0.051 | R-19.0 |
| *Slab-On-Grade Floors* | | | | | | |
| Unheated | F-0.730 | NR | F-0.540 | R-10 for 24 in. | F-0.730 | NR |
| Heated | F-0.860 | R-15 for 24 in. | F-0.860 | R-15 for 24 in. | F-1.020 | R-7.5 for 12 in. |
| *Opaque Doors* | | | | | | |
| Swinging | U-0.700 | | U-0.500 | | U-0.700 | |
| Nonswinging | U-0.500 | | U-0.500 | | U-1.450 | |
| **Fenestration** | **Assembly Max. U** | **Assembly Max. SHGC** | **Assembly Max. U** | **Assembly Max. SHGC** | **Assembly Max. U** | **Assembly Max. SHGC** |
| *Vertical Glazing, % of Wall* | | | | | | |
| Nonmetal framing (all)[b] | U-0.35 | | U-0.35 | | U-1.20 | |
| Metal framing (curtainwall/storefront)[c] | U-0.45 | SHGC-0.40 all | U-0.45 | SHGC-0.40 all | U-1.20 | SHGC-NR all |
| Metal framing (entrance door)[c] | U-0.80 | | U-0.80 | | U-1.20 | |
| Metal framing (all other)[c] | U-0.55 | | U-0.55 | | U-1.20 | |
| *Skylight with Curb, Glass, % of Roof* | | | | | | |
| 0%–2.0% | $U_{all}$-1.17 | $SHGC_{all}$-0.49 | $U_{all}$-1.17 | $SHGC_{all}$-0.49 | $U_{all}$-1.98 | $SHGC_{all}$-NR |
| 2.1%–5.0% | $U_{all}$-1.17 | $SHGC_{all}$-0.39 | $U_{all}$-1.17 | $SHGC_{all}$-0.39 | $U_{all}$-1.98 | $SHGC_{all}$-NR |
| *Skylight with Curb, Plastic, % of Roof* | | | | | | |
| 0%–2.0% | $U_{all}$-1.10 | $SHGC_{all}$-0.77 | $U_{all}$-1.10 | $SHGC_{all}$-0.77 | $U_{all}$-1.90 | $SHGC_{all}$-NR |
| 2.1%–5.0% | $U_{all}$-1.10 | $SHGC_{all}$-0.62 | $U_{all}$-1.10 | $SHGC_{all}$-0.62 | $U_{all}$-1.90 | $SHGC_{all}$-NR |
| *Skylight without Curb, All, % of Roof* | | | | | | |
| 0%–2.0% | $U_{all}$-0.69 | $SHGC_{all}$-0.49 | $U_{all}$-0.69 | $SHGC_{all}$-0.49 | $U_{all}$-1.36 | $SHGC_{all}$-NR |
| 2.1%–5.0% | $U_{all}$-0.69 | $SHGC_{all}$-0.39 | $U_{all}$-0.69 | $SHGC_{all}$-0.39 | $U_{all}$-1.36 | $SHGC_{all}$-NR |

[a] The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[a] Exception to Section A3.1.3.1 applies.
[b] Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c] Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance doors.

## Table 6.1 Minimum Ventilation Rates in Breathing Zone

| Occupancy Category | People Outdoor Air Rate $R_p$ | | Area Outdoor Air Rate $R_a$ | | Notes | Default Values | | | Air Class |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Occupant Density (see Note 4) | Combined Outdoor Air Rate (see Note 5) | | |
| | cfm/person | L/s-person | cfm/ft$^2$ | L/s-m$^2$ | | #/1000 ft$^2$ or #/100 m$^2$ | cfm/person | L/s-person | |
| **Correctional Facilities** | | | | | | | | | |
| Cell | 5 | 2.5 | 0.12 | 0.6 | | 25 | 10 | 4.9 | 2 |
| Dayroom | 5 | 2.5 | 0.06 | 0.3 | | 30 | 7 | 3.5 | 1 |
| Guard stations | 5 | 2.5 | 0.06 | 0.3 | | 15 | 9 | 4.5 | 1 |
| Booking/waiting | 7.5 | 3.8 | 0.06 | 0.3 | | 50 | 9 | 4.4 | 2 |
| **Educational Facilities** | | | | | | | | | |
| Daycare (through age 4) | 10 | 5 | 0.18 | 0.9 | | 25 | 17 | 8.6 | 2 |
| Daycare sickroom | 10 | 5 | 0.18 | 0.9 | | 25 | 17 | 8.6 | 3 |
| Classrooms (ages 5–8) | 10 | 5 | 0.12 | 0.6 | | 25 | 15 | 7.4 | 1 |
| Classrooms (age 9 plus) | 10 | 5 | 0.12 | 0.6 | | 35 | 13 | 6.7 | 1 |
| Lecture classroom | 7.5 | 3.8 | 0.06 | 0.3 | | 65 | 8 | 4.3 | 1 |
| Lecture hall (fixed seats) | 7.5 | 3.8 | 0.06 | 0.3 | | 150 | 8 | 4.0 | 1 |
| Art classroom | 10 | 5 | 0.18 | 0.9 | | 20 | 19 | 9.5 | 2 |
| Science laboratories | 10 | 5 | 0.18 | 0.9 | | 25 | 17 | 8.6 | 2 |
| University/college laboratories | 10 | 5 | 0.18 | 0.9 | | 25 | 17 | 8.6 | 2 |
| Wood/metal shop | 10 | 5 | 0.18 | 0.9 | | 20 | 19 | 9.5 | 2 |
| Computer lab | 10 | 5 | 0.12 | 0.6 | | 25 | 15 | 7.4 | 1 |
| Media center | 10 | 5 | 0.12 | 0.6 | A | 25 | 15 | 7.4 | 1 |
| Music/theater/dance | 10 | 5 | 0.06 | 0.3 | | 35 | 12 | 5.9 | 1 |
| Multi-use assembly | 7.5 | 3.8 | 0.06 | 0.3 | | 100 | 8 | 4.1 | 1 |
| **Food and Beverage Service** | | | | | | | | | |
| Restaurant dining rooms | 7.5 | 3.8 | 0.18 | 0.9 | | 70 | 10 | 5.1 | 2 |
| Cafeteria/fast-food dining | 7.5 | 3.8 | 0.18 | 0.9 | | 100 | 9 | 4.7 | 2 |
| Bars, cocktail lounges | 7.5 | 3.8 | 0.18 | 0.9 | | 100 | 9 | 4.7 | 2 |
| **General** | | | | | | | | | |
| Break rooms | 5 | 2.5 | 0.06 | 0.3 | | 25 | 10 | 5.1 | 1 |
| Coffee stations | 5 | 2.5 | 0.06 | 0.3 | | 20 | 11 | 5.5 | 1 |
| Conference/meeting | 5 | 2.5 | 0.06 | 0.3 | | 50 | 6 | 3.1 | 1 |
| Corridors | – | – | 0.06 | 0.3 | | – | | | 1 |
| Storage rooms | – | – | 0.12 | 0.6 | B | – | | | 1 |
| **Hotels, Motels, Resorts, Dormitories** | | | | | | | | | |
| Bedroom/living room | 5 | 2.5 | 0.06 | 0.3 | | 10 | 11 | 5.5 | 1 |
| Barracks sleeping areas | 5 | 2.5 | 0.06 | 0.3 | | 20 | 8 | 4.0 | 1 |
| Laundry rooms, central | 5 | 2.5 | 0.12 | 0.6 | | 10 | 17 | 8.5 | 2 |
| Laundry rooms within dwelling units | 5 | 2.5 | 0.12 | 0.6 | | 10 | 17 | 8.5 | 1 |
| Lobbies/prefunction | 7.5 | 3.8 | 0.06 | 0.3 | | 30 | 10 | 4.8 | 1 |
| Multipurpose assembly | 5 | 2.5 | 0.06 | 0.3 | | 120 | 6 | 2.8 | 1 |

| Occupancy Category | People Outdoor Air Rate $R_p$ | | Area Outdoor Air Rate $R_a$ | | Notes | Default Values | | | Air Class |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Occupant Density (see Note 4) | Combined Outdoor Air Rate (see Note 5) | | |
| | cfm/person | L/s-person | cfm/ft$^2$ | L/s-m$^2$ | | #/1000 ft$^2$ or #/100 m$^2$ | cfm/person | L/s-person | |
| **Office Buildings** | | | | | | | | | |
| Office space | 5 | 2.5 | 0.06 | 0.3 | | 5 | 17 | 8.5 | 1 |
| Reception areas | 5 | 2.5 | 0.06 | 0.3 | | 30 | 7 | 3.5 | 1 |
| Telephone/data entry | 5 | 2.5 | 0.06 | 0.3 | | 60 | 6 | 3.0 | 1 |
| Main entry lobbies | 5 | 2.5 | 0.06 | 0.3 | | 10 | 11 | 5.5 | 1 |
| **Miscellaneous Spaces** | | | | | | | | | |
| Bank vaults/safe deposit | 5 | 2.5 | 0.06 | 0.3 | | 5 | 17 | 8.5 | 2 |
| Computer (not printing) | 5 | 2.5 | 0.06 | 0.3 | | 4 | 20 | 10.0 | 1 |
| Electrical equipment rooms | – | – | 0.06 | 0.3 | B | – | | | 1 |
| Elevator machine rooms | – | – | 0.12 | 0.6 | B | – | | | 1 |
| Pharmacy (prep. area) | 5 | 2.5 | 0.18 | 0.9 | | 10 | 23 | 11.5 | 2 |
| Photo studios | 5 | 2.5 | 0.12 | 0.6 | | 10 | 17 | 8.5 | 1 |
| Shipping/receiving | – | – | 0.12 | 0.6 | B | – | | | 1 |
| Telephone closets | – | – | 0.00 | 0.0 | | – | | | 1 |
| Transportation waiting | 7.5 | 3.8 | 0.06 | 0.3 | | 100 | 8 | 4.1 | 1 |
| Warehouses | – | – | 0.06 | 0.3 | B | – | | | 2 |
| **Public Assembly Spaces** | | | | | | | | | |
| Auditorium seating area | 5 | 2.5 | 0.06 | 0.3 | | 150 | 5 | 2.7 | 1 |
| Places of religious worship | 5 | 2.5 | 0.06 | 0.3 | | 120 | 6 | 2.8 | 1 |
| Courtrooms | 5 | 2.5 | 0.06 | 0.3 | | 70 | 6 | 2.9 | 1 |
| Legislative chambers | 5 | 2.5 | 0.06 | 0.3 | | 50 | 6 | 3.1 | 1 |
| Libraries | 5 | 2.5 | 0.12 | 0.6 | | 10 | 17 | 8.5 | 1 |
| Lobbies | 5 | 2.5 | 0.06 | 0.3 | | 150 | 5 | 2.7 | 1 |
| Museums (children's) | 7.5 | 3.8 | 0.12 | 0.6 | | 40 | 11 | 5.3 | 1 |
| Museums/galleries | 7.5 | 3.8 | 0.06 | 0.3 | | 40 | 9 | 4.6 | 1 |
| **Residential** | | | | | | | | | |
| Dwelling unit | 5 | 2.5 | 0.06 | 0.3 | F,G | F | | | 1 |
| Common corridors | – | – | 0.06 | 0.3 | | | | | 1 |
| **Retail** | | | | | | | | | |
| Sales (except as below) | 7.5 | 3.8 | 0.12 | 0.6 | | 15 | 16 | 7.8 | 2 |
| Mall common areas | 7.5 | 3.8 | 0.06 | 0.3 | | 40 | 9 | 4.6 | 1 |
| Barbershop | 7.5 | 3.8 | 0.06 | 0.3 | | 25 | 10 | 5.0 | 2 |
| Beauty and nail salons | 20 | 10 | 0.12 | 0.6 | | 25 | 25 | 12.4 | 2 |
| Pet shops (animal areas) | 7.5 | 3.8 | 0.18 | 0.9 | | 10 | 26 | 12.8 | 2 |
| Supermarket | 7.5 | 3.8 | 0.06 | 0.3 | | 8 | 15 | 7.6 | 1 |
| Coin-operated laundries | 7.5 | 3.8 | 0.06 | 0.3 | | 20 | 11 | 5.3 | 2 |

| Occupancy Category | People Outdoor Air Rate $R_p$ | | Area Outdoor Air Rate $R_a$ | | Notes | Default Values | | | Air Class |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Occupant Density (see Note 4) | Combined Outdoor Air Rate (see Note 5) | | |
| | cfm/person | L/s·person | cfm/ft$^2$ | L/s·m$^2$ | | #/1000 ft$^2$ or #/100 m$^2$ | cfm/person | L/s·person | |
| **Sports and Entertainment** | | | | | | | | | |
| Sports arena (play area) | – | – | 0.30 | 1.5 | E | – | | | 1 |
| Gym, stadium (play area) | – | – | 0.30 | 1.5 | | 30 | | | 2 |
| Spectator areas | 7.5 | 3.8 | 0.06 | 0.3 | | 150 | 8 | 4.0 | 1 |
| Swimming (pool & deck) | – | – | 0.48 | 2.4 | C | – | | | 2 |
| Disco/dance floors | 20 | 10 | 0.06 | 0.3 | | 100 | 21 | 10.3 | 1 |
| Health club/aerobics room | 20 | 10 | 0.06 | 0.3 | | 40 | 22 | 10.8 | 2 |
| Health club/weight rooms | 20 | 10 | 0.06 | 0.3 | | 10 | 26 | 13.0 | 2 |
| Bowling alley (seating) | 10 | 5 | 0.12 | 0.6 | | 40 | 13 | 6.5 | 1 |
| Gambling casinos | 7.5 | 3.8 | 0.18 | 0.9 | | 120 | 9 | 4.6 | 1 |
| Game arcades | 7.5 | 3.8 | 0.18 | 0.9 | | 20 | 17 | 8.3 | 1 |
| Stages, studios | 10 | 5 | 0.06 | 0.3 | D | 70 | 11 | 5.4 | 1 |

GENERAL NOTES FOR TABLE 6-1

1 **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
2 **Smoking:** This table applies to no-smoking areas. Rates for smoking-permitted spaces must be determined using other methods. See Section 6.2.9 for ventilation requirements in smoking areas.
3 **Air density:** Volumetric airflow rates are based on an air density of 0.075 $lb_{da}/ft^3$ (1.2 $kg_{da}/m^3$), which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.
4 **Default occupant density:** The default occupant density shall be used when actual occupant density is not known.
5 **Default combined outdoor air rate (per person):** This rate is based on the default occupant density.
6 **Unlisted occupancies:** If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.
7 **Health-care facilities:** Rates shall be determined in accordance with Appendix E.

## Table 6.2 Zone Air Distribution Effectiveness

| Air Distribution Configuration | $E_z$ |
|---|---|
| Ceiling supply of cool air. | 1.0 |
| Ceiling supply of warm air and floor return. | 1.0 |
| Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return. | 0.8 |
| Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level. ***Note:*** For lower velocity supply air, $E_z = 0.8$. | 1.0 |
| Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply jet reaches 4.5 ft (1.4 m) or more above the floor. ***Note:*** Most underfloor air distribution systems comply with this proviso. | 1.0 |
| Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification. | 1.2 |
| Floor supply of warm air and floor return. | 1.0 |
| Floor supply of warm air and ceiling return. | 0.7 |
| Makeup supply drawn in on the opposite side of the room from the exhaust and/or return. | 0.8 |
| Makeup supply drawn in near to the exhaust and/or return location. | 0.5 |

1. "Cool air" is air cooler than space temperature.
2. "Warm air" is air warmer than space temperature.
3. "Ceiling" includes any point above the *breathing zone*.
4. "Floor" includes any point below the *breathing zone*.
5. As an alternative to using the above values, $E_z$ may be regarded as equal to air change effectiveness determined in accordance with ANSI/ASHRAE Standard 129[16] for all air distribution configurations except unidirectional flow.

## Table 6.3 System Ventilation Efficiency

| Max ($Z_p$) | $E_v$ |
|---|---|
| ≤0.15 | 1.0 |
| ≤0.25 | 0.9 |
| ≤0.35 | 0.8 |
| ≤0.45 | 0.7 |
| ≤0.55 | 0.6 |
| >0.55 | Use Appendix A |

1. "Max $Z_p$" refers to the largest value of $Z_p$, calculated using Equation 6-5, among all the zones served by the system.
2. For values of $Z_p$ between 0.15 and 0.55, one may determine the corresponding value of $E_v$ by interpolating the values in the table.
3. The values of $E_v$ in this table are based on a 0.15 average outdoor air fraction for the system (i.e., the ratio of the *uncorrected outdoor air intake* $V_{ou}$ to the total *zone primary airflow* for all the zones served by the air handler). For systems with higher values of the average outdoor air fraction, this table may result in unrealistically low values of $E_v$ and the use of Appendix A may yield more practical results.

## Table 6.4.4.2A Minimum Duct Seal Level

| Duct Location | Duct Type | | | |
|---|---|---|---|---|
| | Supply | | Exhaust | Return |
| | ≤2 in. w.c.[b] | >2 in. w.c.[b] | | |
| Outdoor | A | A | C | A |
| Unconditioned spaces | B | A | C | B |
| Conditioned spaces[c] | C | B | B | C |

[a] See Table 6.4.4.2B description of seal level.
[b] Duct design static pressure classification.
[c] Includes indirectly conditioned spaces such as return air plenums.

## Table 6.5.3.1.1A Fan Power Limitation

| | Limit | Constant Volume | Variable Volume |
|---|---|---|---|
| Option 1: Fan System Motor Nameplate hp | Allowable Nameplate Motor hp | hp ≤ $CFM_S \cdot 0.0011$ | hp ≤ $CFM_S \cdot 0.0015$ |
| Option 2: Fan System bhp | Allowable Fan System bhp | bhp ≤ $CFM_S \cdot 0.00094 + A$ | bhp ≤ $CFM_S \cdot 0.0013 + A$ |

[a] where
$CFM_S$ = the maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute
hp = the maximum combined motor nameplate horsepower
bhp = the maximum combined fan brake horsepower
$A$ = sum of ($PD \times CFM_D$/4131)
where
$PD$ = each applicable pressure drop adjustment from Table 6.5.3.1.1B in in. w.c.
$CFM_D$ = the design airflow through each applicable device from Table 6.5.3.1.1B in cubic feet per minute

## Table 6.8.2B Minimum Duct Insulation R-Value, Combined Heating and Cooling Supply Ducts and Return Ducts

| Climate Zone | Duct Location | | | | | | |
|---|---|---|---|---|---|---|---|
| | Exterior | Ventilated Attic | Unvented Attic Above Insulated Ceiling | Unvented Attic with Roof Insulation[a] | Unconditioned Space[b] | Indirectly Conditioned Space[c] | Buried |
| | | | | **Supply Ducts** | | | |
| 1 | R-6 | R-6 | R-8 | R-3.5 | R-3.5 | none | R-3.5 |
| 2 | R-6 | R-6 | R-6 | R-3.5 | R-3.5 | none | R-3.5 |
| 3 | R-6 | R-6 | R-6 | R-3.5 | R-3.5 | none | R-3.5 |
| 4 | R-6 | R-6 | R-6 | R-3.5 | R-3.5 | none | R-3.5 |
| 5 | R-6 | R-6 | R-6 | R-1.9 | R-3.5 | none | R-3.5 |
| 6 | R-8 | R-6 | R-6 | R-1.9 | R-3.5 | none | R-3.5 |
| 7 | R-8 | R-6 | R-6 | R-1.9 | R-3.5 | none | R-3.5 |
| 8 | R-8 | R-8 | R-8 | R-1.9 | R-6 | none | R-6 |
| | | | | **Return Ducts** | | | |
| 1 to 8 | R-3.5 | R-3.5 | R-3.5 | none | none | none | none |

[a] Insulation R-values, measured in (h·ft²·°F)/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of Section 6.4.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75°F at the installed thickness.
[b] Includes crawlspaces, both ventilated and nonventilated.
[c] Includes return air plenums with or without exposed roofs above.

## Table 9.5.1 Lighting Power Densities Using the Building Area Method

| Building Area Type[a] | *LPD* (W/ft$^2$) |
|---|---|
| Automotive facility | 0.9 |
| Convention center | 1.2 |
| Courthouse | 1.2 |
| Dining: bar lounge/leisure | 1.3 |
| Dining: cafeteria/fast food | 1.4 |
| Dining: family | 1.6 |
| Dormitory | 1.0 |
| Exercise center | 1.0 |
| Gymnasium | 1.1 |
| Health-care clinic | 1.0 |
| Hospital | 1.2 |
| Hotel | 1.0 |
| Library | 1.3 |
| Manufacturing facility | 1.3 |
| Motel | 1.0 |
| Motion picture theater | 1.2 |
| Multifamily | 0.7 |
| Museum | 1.1 |
| Office | 1.0 |
| Parking garage | 0.3 |
| Penitentiary | 1.0 |
| Performing arts theater | 1.6 |
| Police/fire station | 1.0 |
| Post office | 1.1 |
| Religious building | 1.3 |
| Retail | 1.5 |
| School/university | 1.2 |
| Sports arena | 1.1 |
| Town hall | 1.1 |
| Transportation | 1.0 |
| Warehouse | 0.8 |
| Workshop | 1.4 |

[a] In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

## Table 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors

| | Minimum Nominal Full-Load Efficiency (%) | | | | | |
|---|---|---|---|---|---|---|
| | Open Motors | | | Enclosed Motors | | |
| Number of Poles ⇒ | 2 | 4 | 6 | 2 | 4 | 6 |
| Synchronous Speed (RPM) ⇒ | 3600 | 1800 | 1200 | 3600 | 1800 | 1200 |
| Motor Horsepower | | | | | | |
| 1 | — | 82.5 | 80.0 | 75.5 | 82.5 | 80.0 |
| 1.5 | 82.5 | 84.0 | 84.0 | 82.5 | 84.0 | 85.5 |
| 2 | 84.0 | 84.0 | 85.5 | 84.0 | 84.0 | 86.5 |
| 3 | 84.0 | 86.5 | 86.5 | 85.5 | 87.5 | 87.5 |
| 5 | 85.5 | 87.5 | 87.5 | 87.5 | 87.5 | 87.5 |
| 7.5 | 87.5 | 88.5 | 88.5 | 88.5 | 89.5 | 89.5 |
| 10 | 88.5 | 89.5 | 90.2 | 89.5 | 89.5 | 89.5 |
| 15 | 89.5 | 91.0 | 90.2 | 90.2 | 91.0 | 90.2 |
| 20 | 90.2 | 91.0 | 91.0 | 90.2 | 91.0 | 90.2 |
| 25 | 91.0 | 91.7 | 91.7 | 91.0 | 92.4 | 91.7 |
| 30 | 91.0 | 92.4 | 92.4 | 91.0 | 92.4 | 91.7 |
| 40 | 91.7 | 93.0 | 93.0 | 91.7 | 93.0 | 93.0 |
| 50 | 92.4 | 93.0 | 93.0 | 92.4 | 93.0 | 93.0 |
| 60 | 93.0 | 93.6 | 93.6 | 93.0 | 93.6 | 93.6 |
| 75 | 93.0 | 94.1 | 93.6 | 93.0 | 94.1 | 93.6 |
| 100 | 93.0 | 94.1 | 94.1 | 93.6 | 94.5 | 94.1 |
| 125 | 93.6 | 94.5 | 94.1 | 94.5 | 94.5 | 94.1 |
| 150 | 93.6 | 95.0 | 94.5 | 94.5 | 95.0 | 95.0 |
| 200 | 94.5 | 95.0 | 94.5 | 95.0 | 95.0 | 95.0 |

[a] Nominal efficiencies shall be established in accordance with NEMA Standard MG1. Design A and Design B are National Electric Manufacturers Association (NEMA) design class designations for fixed-frequency small and medium AC squirrel-cage induction motors.

# Appendix B

### Table 6: Motor Efficiency

| Motor | HP | BHP | FLA | WATTS | V | RPM | EFFICIENCY | Minimum Efficiency | ASHRAE 90.1 Compliant ( |
|---|---|---|---|---|---|---|---|---|---|
| **RAF-1** | 7.5 | 6 | 11 | 8764 | 460 | 515 | 51.1 | | 2 |
| **CRP-1** | | | | 0 | | | | | |
| **CWP-1** | 5 | 5 | 7.6 | 6055 | 460 | 1750 | 61.6 | 87.5 | 1 |
| **CWP-2** | 5 | 5 | 7.6 | 6055 | 460 | 1750 | 61.6 | 87.5 | 1 |
| **CWP-3** | 0.75 | 0.75 | 1.6 | 1275 | 460 | 1750 | 43.9 | | 2 |
| **HWP-4** | 5 | 5 | 7.6 | 6055 | 460 | 1750 | 61.6 | 87.5 | 1 |
| **HWP-5** | 5 | 5 | 7.6 | 6055 | 460 | 1750 | 61.6 | 87.5 | 1 |
| **EFN-1** | 1.5 | 1.18 | 3 | 2390 | 460 | 1375 | 36.8 | 84 | 1 |
| **SFN-2** | 2 | 2.04 | 3.4 | 2709 | 460 | 1381 | 56.2 | 84 | 1 |
| **EFN-3** | 0.75 | 0.71 | 1.6 | 1275 | 460 | 1575 | 41.5 | | 2 |
| **EFN-4** | 0.75 | 0.65 | 1.6 | 1275 | 460 | 2075 | 38.0 | | 2 |
| **EFN-5** | 1 | 1.07 | 2.1 | 1673 | 460 | 1333 | 47.7 | 82.5 | 1 |
| **EFN-6** | 0.5 | 0.4 | 9.8 | 1176 | 120 | 1775 | 25.4 | | 2 |
| **EFN-7** | 39W | 39W | 0.5 | 39 | 120 | 1550 | | | |
| **FCU-034** | 0.75 | 0.66 | 12 | 9561 | 460 | 1000 | 5.1 | | 2 |
| **FCU-102F** | 0.75 | 0.73 | 12 | 9561 | 460 | 1000 | 5.7 | | 2 |
| **FCU-105F** | 0.33 | 0.21 | 5.8 | 667 | 115 | 1000 | 23.5 | | 2 |
| **FCU-217T** | 0.16 | 0.16 | 4.4 | 506 | 115 | 1000 | 23.6 | | 2 |
| **FCU-401Z** | 0.17 | 0.17 | 4.4 | 506 | 115 | 1000 | 25.1 | | 2 |
| **FCU-402Z** | 0.17 | 0.17 | 4.4 | 506 | 115 | 1000 | 25.1 | | 2 |
| **ACU-034** | 1.5 | 0.47 | 6.8 | 2450 | 208 | 1000 | 14.3 | 84 | 1 |
| **ACU-217T** | 0.25 | 0.25 | 1.4 | 504 | 208 | 1000 | 37.0 | | 2 |

See the following spreadsheets for detail ventilation calculations.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Building** | Biobehavioral Health Building | | | | | | | | | | |
| **System Name** | AHU-1 (Core Offices) | | | | | | | | | | |
| **Operating Condition Description** | Design Peak Cooling Load Condition | | | | | | | | | | |
| **Units** | IP | | | | | | | | | | |
| **Inputs for System** | **Name** | **Equation** | **Units** | **System** | | | | | | | |
| **Floor area served by system** | As | | sf | 20883 | | | | | | | |
| **Population of area served by system** | Ps | | P | 132 | | | | | | | |
| **Design primary supply fan airflow rate** | Vbs | | cfm | 2083 | | | | | | | |
| **OA required per unit area for system** | Ras | | cfm | 1422 | | | | | | | |
| **OA required per person for system area** | Rps | | cfm | 661 | | | | | | | |
| **Outdoor Airflow** | Vos | Vbs/Ez | | | | | | | | | |
| **Primary OA Fraction** | Zp | VosVpz | | | | | | | | | |
| **OA Intake** | Vot | Vou/Ev | cfm | 3476 | | | | | | | |
| **Uncorrected OA Intake** | Vou | Dsum(RpPz)+sum(RaAz) | | 2083 | | | | | | | |
| **System Ventilation Efficiency** | Ev | | | 0.60 | | | | | | | |
| **Inputs for Potentially Critical Zones** | | | | | | | | | | | |
| **Zone Name** | | | | | **Offices, Corrido** | **Lobby, Corrido** | **Offices** | **Corridor, restrooms, offic** | **Office, storage** | **Lab, Office** | |
| **Zone Tag** | | | | | 1 | 001F | 5 | 006Q | 7 | 12 | |
| **Floor Area** | Az | | sf | | 1309 | 1213 | 366 | 808 | 489 | 382 | |
| **Occupant Density** | Pz | | P/1000sf | | 5 | 10 | 5 | 0 | 5 | 5 | |
| **Design population of zone** | Pz | | P | | 7 | 12 | 2 | 0 | 2 | 2 | |
| **Area OA Rate** | Raz | | cfm/sf | | 0.06 | 0.06 | 0.06 | 0.06 | 0.12 | 0.06 | |
| **OA required per unit area for zone** | | | cfm | | 79 | 73 | 22 | 48 | 59 | 23 | |
| **Person OA Rate** | Rpz | | cfm/person | | 5 | 5 | 5 | 5 | 5 | 5 | |
| **OA required per person for zone** | | | cfm | | 33 | 61 | 9 | 0 | 12 | 10 | |
| **Breathing Zone Outdoor Airflow** | Vbz | Rpz*Pz+Raz*Az | | | 111 | 133 | 31 | 48 | 71 | 32 | |
| **Zone Outdoor Airflow** | Voz | Vbz/Ez | | | 111 | 133 | 31 | 48 | 71 | 32 | |
| **Primary OAFraction** | Zp | Voz/Vpz | | 0.73 | 0.40 | 0.33 | 0.31 | 0.15 | 0.34 | 0.23 | |
| **Minimum Expected Primary Airflow** | Vpz | | cfm | | 280 | 410 | 100 | 330 | 210 | 140 | |
| **Primary Air Fraction** | Ep | Vpz/Vdz | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction of Secondary Recirculated Air to Zone** | Er | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| **Zone Air Distribution Effectiveness** | Ez | | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction SA to Zone from Sources Outside the Zone** | Fa | Ep+(1-Ep)Er | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction SA to Zone from Fully Mixed Primary Air** | Fb | Ep | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction OA to Zone from Sources Outside the Zone** | Fc | 1-(1-Ez)(1-Er)(1-Ep) | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Zone Discharge Airflow** | Vdz | | | | 280 | 410 | 100 | 330 | 210 | 140 | |
| **Zone Primary Airflow** | Vpz | | | | 280 | 410 | 100 | 330 | 210 | 140 | |
| **Average OA Fraction** | Xs | Vou/Vps | | | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | |
| **Discharge OA Fraction** | Zd | Voz/Vdz | | | 0.40 | 0.33 | 0.31 | 0.15 | 0.34 | 0.23 | |
| **Zone Ventilation Efficiency** | Evz | (Fa+XsFb-ZdFc)/Fa | | | 0.93 | 1.00 | 1.01 | 1.18 | 0.99 | 1.09 | |
| **System Primary Airflow** | Vps | sum(Vpz) | | | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | |
| **Occupant Diversity** | D | Ps/sum(Pz) | | | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | |

| Building | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| System Name | | | | | | | | | | | | | | | | | | | |
| Operating Condition Description | | | | | | | | | | | | | | | | | | | |
| Units | | | | | | | | | | | | | | | | | | | |
| Inputs for System | | | | | | | | | | | | | | | | | | | |
| Floor area served by system | | | | | | | | | | | | | | | | | | | |
| Population of area served by system | | | | | | | | | | | | | | | | | | | |
| Design primary supply fan airflow rate | | | | | | | | | | | | | | | | | | | |
| OA required per unit area for system | | | | | | | | | | | | | | | | | | | |
| OA required per person for system area | | | | | | | | | | | | | | | | | | | |
| Outdoor Airflow | | | | | | | | | | | | | | | | | | | |
| Primary OA Fraction | | | | | | | | | | | | | | | | | | | |
| OA Intake | | | | | | | | | | | | | | | | | | | |
| Uncorrected OA Intake | | | | | | | | | | | | | | | | | | | |
| System Ventilation Efficiency | | | | | | | | | | | | | | | | | | | |
| Inputs for Potentially Critical Zones | | | | | | | | | | | | | | | | | | | |
| Zone Name | Office | Corridor, Offic | Offices, Corrido | Offices | Office, Storage | Office | Office | Office | Office | Office, Reception | Office | Office | Office | Office, electrica | Office, Storage | Corridor | Office | Office, Lobby | |
| Zone Tag | 14 | 15 | 23 | 27 | 30 | 118 | 202 | 207 | 213 | 219C | 219D | 219E | 230 | 301 | 308 | 309 | 310 | 314 | |
| Floor Area | 392 | 774 | 426 | 451 | 1415 | 986 | 243 | 444 | 447 | 969 | 359 | 129 | 906 | 775 | 911 | 353 | 1065 | 660 | |
| Occupant Density | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 30 | 5 | 5 | 5 | 5 | 5 | 0 | 5 | 10 | |
| Design population of zone | 2 | 4 | 2 | 2 | 7 | 5 | 1 | 2 | 2 | 29 | 2 | 1 | 5 | 4 | 5 | 0 | 5 | 7 | |
| Area OA Rate | 0.06 | 0.06 | 0.06 | 0.06 | 0.12 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.12 | 0.06 | 0.06 | 0.06 | |
| OA required per unit area for zone | 24 | 46 | 26 | 27 | 170 | 59 | 15 | 27 | 27 | 58 | 22 | 8 | 54 | 47 | 109 | 21 | 64 | 40 | |
| Person OA Rate | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| OA required per person for zone | 10 | 19 | 11 | 11 | 35 | 25 | 6 | 11 | 11 | 145 | 9 | 3 | 23 | 19 | 23 | 0 | 27 | 33 | |
| Breathing Zone Outdoor Airflow | 33 | 66 | 36 | 38 | 205 | 84 | 21 | 38 | 38 | 203 | 31 | 11 | 77 | 66 | 132 | 21 | 91 | 73 | |
| Zone Outdoor Airflow | 33 | 66 | 36 | 38 | 205 | 84 | 21 | 38 | 38 | 203 | 31 | 11 | 77 | 66 | 132 | 21 | 91 | 73 | |
| Primary OAFraction | 0.30 | 0.30 | 0.21 | 0.26 | 0.46 | 0.23 | 0.23 | 0.31 | 0.35 | 0.73 | 0.20 | 0.18 | 0.26 | 0.47 | 0.60 | 0.15 | 0.30 | 0.45 | |
| Minimum Expected Primary Airflow | 110 | 220 | 170 | 150 | 450 | 360 | 90 | 120 | 110 | 280 | 150 | 60 | 300 | 140 | 220 | 140 | 300 | 160 | |
| Primary Air Fraction | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Fraction of Secondary Recirculated Air to Zone | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Zone Air Distribution Effectiveness | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Fraction SA to Zone from Sources Outside the Zone | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Fraction SA to Zone from Fully Mixed Primary Air | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Fraction OA to Zone from Sources Outside the Zone | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Zone Discharge Airflow | 110 | 220 | 170 | 150 | 450 | 360 | 90 | 120 | 110 | 280 | 150 | 60 | 300 | 140 | 220 | 140 | 300 | 160 | |
| Zone Primary Airflow | 110 | 220 | 170 | 150 | 450 | 360 | 90 | 120 | 110 | 280 | 150 | 60 | 300 | 140 | 220 | 140 | 300 | 160 | |
| Average OA Fraction | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | |
| Discharge OA Fraction | 0.30 | 0.30 | 0.21 | 0.26 | 0.46 | 0.23 | 0.23 | 0.31 | 0.35 | 0.73 | 0.20 | 0.18 | 0.26 | 0.47 | 0.60 | 0.15 | 0.30 | 0.45 | |
| Zone Ventilation Efficiency | 1.02 | 1.03 | 1.11 | 1.07 | 0.87 | 1.09 | 1.10 | 1.01 | 0.98 | 0.60 | 1.12 | 1.14 | 1.07 | 0.86 | 0.73 | 1.17 | 1.02 | 0.87 | |
| System Primary Airflow | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | |
| Occupant Diversity | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Building** | | | | | | | | |
| **System Name** | | | | | | | | |
| **Operating Condition Description** | | | | | | | | |
| **Units** | | | | | | | | |
| **Inputs for System** | | | | | | | | |
| **Floor area served by system** | | | | | | | | |
| **Population of area served by system** | | | | | | | | |
| **Design primary supply fan airflow rate** | | | | | | | | |
| **OA required per unit area for system** | | | | | | | | |
| **OA required per person for system area** | | | | | | | | |
| **Outdoor Airflow** | | | | | | | | |
| **Primary OA Fraction** | | | | | | | | |
| **OA Intake** | | | | | | | | |
| **Uncorrected OA Intake** | | | | | | | | |
| **System Ventilation Efficiency** | | | | | | | | |
| **Inputs for Potentially Critical Zones** | | | | | | | | |
| **Zone Name** | **Office** | **Office, corrido** | **Office, corrido** | **Office** | **Office** | **Office** | **Office** | **Office** |
| **Zone Tag** | 316 | 320 | 405 | 413 | 414 | 415 | 417 | 421 |
| **Floor Area** | 819 | 1347 | 618 | 496 | 131 | 348 | 401 | 451 |
| **Occupant Density** | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| **Design population of zone** | 4 | 7 | 3 | 2 | 1 | 2 | 2 | 2 |
| **Area OA Rate** | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **OA required per unit area for zone** | 49 | 81 | 37 | 30 | 8 | 21 | 24 | 27 |
| **Person OA Rate** | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| **OA required per person for zone** | 20 | 34 | 15 | 12 | 3 | 9 | 10 | 11 |
| **Breathing Zone Outdoor Airflow** | 70 | 114 | 53 | 42 | 11 | 30 | 34 | 38 |
| **Zone Outdoor Airflow** | 70 | 114 | 53 | 42 | 11 | 30 | 34 | 38 |
| **Primary OAFraction** | 0.32 | 0.27 | 0.40 | 0.30 | 0.19 | 0.18 | 0.24 | 0.32 |
| **Minimum Expected Primary Airflow** | 220 | 420 | 130 | 140 | 60 | 160 | 140 | 120 |
| **Primary Air Fraction** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Fraction of Secondary Recirculated Air to Zone** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Zone Air Distribution Effectiveness** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Fraction SA to Zone from Sources Outside the Zone** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Fraction SA to Zone from Fully Mixed Primary Air** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Fraction OA to Zone from Sources Outside the Zone** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Zone Discharge Airflow** | 220 | 420 | 130 | 140 | 60 | 160 | 140 | 120 |
| **Zone Primary Airflow** | 220 | 420 | 130 | 140 | 60 | 160 | 140 | 120 |
| **Average OA Fraction** | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| **Discharge OA Fraction** | 0.32 | 0.27 | 0.40 | 0.30 | 0.19 | 0.18 | 0.24 | 0.32 |
| **Zone Ventilation Efficiency** | 1.01 | 1.05 | 0.92 | 1.02 | 1.14 | 1.14 | 1.08 | 1.01 |
| **System Primary Airflow** | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 | 6390 |
| **Occupant Diversity** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Building** | Biobehavioral Health Building | | | | | | | | | | |
| **System Name** | AHU-2 (Classrooms) | | | | | | | | | | |
| **Operating Condition Description** | Design Peak Cooling Load Condition | | | | | | | | | | |
| **Units** | IP | | | | | | | | | | |
| **Inputs for System** | **Name** | **Equation** | **Units** | **System** | | | | | | | |
| **Floor area served by system** | As | | sf | 10526 | | | | | | | |
| **Population of area served by system** | Ps | | P | 318 | | | | | | | |
| **Design primary supply fan airflow rate** | Vbs | | cfm | 2903 | | | | | | | |
| **OA required per unit area for system** | Ras | | cfm | 632 | | | | | | | |
| **OA required per person for system area** | Rps | | cfm | 2272 | | | | | | | |
| **Outdoor Airflow** | Vos | Vbs/Ez | | | | | | | | | |
| **Primary OA Fraction** | Zp | VosVpz | | | | | | | | | |
| **OA Intake** | Vot | Vou/Ev | cfm | 3484 | | | | | | | |
| **Uncorrected OA Intake** | Vou | Dsum(RpPz)+sum(RaAz) | | 2903 | | | | | | | |
| **System Ventilation Efficiency** | Ev | | | 0.83 | | | | | | | |
| **Inputs for Potentially Critical Zones** | | | | | | | | | | | |
| **Zone Name** | | | | | **Lobby** | **Lecture Hall** | **Lecture Hall** | **Classroom** | **Classroom** | **Conference Room** | |
| **Zone Tag** | | | | | 002F | 022_1 | 022_2 | 102 | 102A | 412 | |
| **Floor Area** | Az | | sf | | 1618 | 2530 | 4289 | 774 | 761 | 554 | |
| **Occupant Density** | Pz | | P/1000sf | | 10 | 30 | 30 | 45 | 45 | 50 | |
| **Design population of zone** | Pz | | P | | 16 | 76 | 129 | 35 | 34 | 28 | |
| **Area OA Rate** | Raz | | cfm/sf | | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | |
| **OA required per unit area for zone** | | | cfm | | 97 | 152 | 257 | 46 | 46 | 33 | |
| **Person OA Rate** | Rpz | | cfm/person | | 5 | 7.5 | 7.5 | 7.5 | 7.5 | 5 | |
| **OA required per person for zone** | | | cfm | | 81 | 569 | 965 | 261 | 257 | 139 | |
| **Breathing Zone Outdoor Airflow** | Vbz | Rpz*Pz+Raz*Az | | | 178 | 721 | 1222 | 308 | 302 | 172 | |
| **Zone Outdoor Airflow** | Voz | Vbz/Ez | | 2903 | 178 | 721 | 1222 | 308 | 302 | 172 | |
| **Primary OAFraction** | Zp | Voz/Vpz | | 0.79 | 0.44 | 0.79 | 0.72 | 0.77 | 0.76 | 0.20 | |
| **Minimum Expected Primary Airflow** | Vpz | | cfm | | 400 | 910 | 1690 | 400 | 400 | 840 | |
| **Primary Air Fraction** | Ep | Vpz/Vdz | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction of Secondary Recirculated Air to Zone** | Er | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| **Zone Air Distribution Effectiveness** | Ez | | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction SA to Zone from Sources Outside the Zone** | Fa | Ep+(1-Ep)Er | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction SA to Zone from Fully Mixed Primary Air** | Fb | Ep | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction OA to Zone from Sources Outside the Zone** | Fc | 1-(1-Ez)(1-Er)(1-Ep) | | | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Zone Discharge Airflow** | Vdz | | | | 400 | 910 | 1690 | 400 | 400 | 840 | |
| **Zone Primary Airflow** | Vpz | | | | 400 | 910 | 1690 | 400 | 400 | 840 | |
| **Average OA Fraction** | Xs | Vou/Vps | | | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | |
| **Discharge OA Fraction** | Zd | Voz/Vdz | | | 0.44 | 0.79 | 0.72 | 0.77 | 0.76 | 0.20 | |
| **Zone Ventilation Efficiency** | Evz | (Fa+XsFb-ZdFc)/Fa | | | 1.18 | 0.83 | 0.90 | 0.86 | 0.87 | 1.42 | |
| **System Primary Airflow** | Vps | sum(Vpz) | | | 4640 | 4640 | 4640 | 4640 | 4640 | 4640 | |
| **Occupant Diversity** | D | Ps/sum(Pz) | | | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | |

| | |
|---|---|
| **Building** | Biobehavioral Health Building |
| **System Name** | AHU-3 (South Offices) |
| **Operating Condition Description** | Design Peak Cooling Load Condition |
| **Units** | IP |

| **Inputs for System** | **Name** | **Equation** | **Units** | **System** |
|---|---|---|---|---|
| **Floor area served by system** | As | | sf | 8420 |
| **Population of area served by system** | Ps | | P | 42.1 |
| **Design primary supply fan airflow rate** | Vbs | | cfm | 733 |
| **OA required per unit area for system** | Ras | | cfm | 523 |
| **OA required per person for system area** | Rps | | cfm | 211 |
| **Outdoor Airflow** | Vos | Vbs/Ez | | |
| **Primary OA Fraction** | Zp | VosVpz | | |
| **OA Intake** | Vot | Vou/Ev | cfm | 993 |
| **Uncorrected OA Intake** | Vou | Dsum(RpPz)+sum(RaAz) | | 733 |
| **System Ventilation Efficiency** | Ev | | | 0.74 |

| **Inputs for Potentially Critical Zones** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Zone Name** | | | | | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** |
| **Zone Tag** | | | | | 101 | 103 | 105 | 106 | 107 | 109 | 112 | 201 | 205 | 206 | 210 | 214 | 302 |
| **Floor Area** | Az | | sf | | 300 | 107 | 312 | 291 | 292 | 438 | 439 | 287 | 317 | 443 | 287 | 297 | 429 |
| **Occupant Density** | Pz | | P/1000sf | | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| **Design population of zone** | Pz | | P | | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 2 |
| **Area OA Rate** | Raz | | cfm/sf | | 0.06 | 0.06 | 0.06 | 0.06 | 0.12 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **OA required per unit area for zone** | | | cfm | | 18 | 6 | 19 | 17 | 35 | 26 | 26 | 17 | 19 | 27 | 17 | 18 | 26 |
| **Person OA Rate** | Rpz | | cfm/person | | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| **OA required per person for zone** | | | cfm | | 8 | 3 | 8 | 7 | 7 | 11 | 11 | 7 | 8 | 11 | 7 | 7 | 11 |
| **Breathing Zone Outdoor Airflow** | Vbz | Rpz*Pz+Raz*Az | | | 26 | 9 | 27 | 25 | 42 | 37 | 37 | 24 | 27 | 38 | 24 | 25 | 36 |
| **Zone Outdoor Airflow** | Voz | Vbz/Ez | | | 26 | 9 | 27 | 25 | 42 | 37 | 37 | 24 | 27 | 38 | 24 | 25 | 36 |
| **Primary OAFraction** | Zp | Voz/Vpz | | 0.40 | 0.14 | 0.15 | 0.14 | 0.14 | 0.24 | 0.14 | 0.14 | 0.17 | 0.14 | 0.11 | 0.14 | 0.10 | 0.17 |
| **Minimum Expected Primary Airflow** | Vpz | | cfm | | 180 | 60 | 190 | 180 | 180 | 260 | 270 | 140 | 190 | 340 | 180 | 260 | 210 |
| **Primary Air Fraction** | Ep | Vpz/Vdz | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Fraction of Secondary Recirculated Air to Zone** | Er | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Zone Air Distribution Effectiveness** | Ez | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Fraction SA to Zone from Sources Outside the Zone** | Fa | Ep+(1-Ep)Er | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Fraction SA to Zone from Fully Mixed Primary Air** | Fb | Ep | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Fraction OA to Zone from Sources Outside the Zone** | Fc | 1-(1-Ez)(1-Er)(1-Ep) | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Zone Discharge Airflow** | Vdz | | | | 180 | 60 | 190 | 180 | 180 | 260 | 270 | 140 | 190 | 340 | 180 | 260 | 210 |
| **Zone Primary Airflow** | Vpz | | | | 180 | 60 | 190 | 180 | 180 | 260 | 270 | 140 | 190 | 340 | 180 | 260 | 210 |
| **Average OA Fraction** | Xs | Vou/Vps | | | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| **Discharge OA Fraction** | Zd | Voz/Vdz | | | 0.14 | 0.15 | 0.14 | 0.14 | 0.24 | 0.14 | 0.14 | 0.17 | 0.14 | 0.11 | 0.14 | 0.10 | 0.17 |
| **Zone Ventilation Efficiency** | Evz | (Fa+XsFb-ZdFc)/Fa | | | 1.00 | 0.99 | 1.00 | 1.00 | 0.91 | 1.00 | 1.00 | 0.97 | 1.00 | 1.03 | 1.01 | 1.05 | 0.97 |
| **System Primary Airflow** | Vps | sum(Vpz) | | | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 |
| **Occupant Diversity** | D | Ps/sum(Pz) | | | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Building** | | | | | | | | | | | | | | |
| **System Name** | | | | | | | | | | | | | | |
| **Operating Condition Description** | | | | | | | | | | | | | | |
| **Units** | | | | | | | | | | | | | | |
| **Inputs for System** | | | | | | | | | | | | | | |
| **Floor area served by system** | | | | | | | | | | | | | | |
| **Population of area served by system** | | | | | | | | | | | | | | |
| **Design primary supply fan airflow rate** | | | | | | | | | | | | | | |
| **OA required per unit area for system** | | | | | | | | | | | | | | |
| **OA required per person for system area** | | | | | | | | | | | | | | |
| **Outdoor Airflow** | | | | | | | | | | | | | | |
| **Primary OA Fraction** | | | | | | | | | | | | | | |
| **OA Intake** | | | | | | | | | | | | | | |
| **Uncorrected OA Intake** | | | | | | | | | | | | | | |
| **System Ventilation Efficiency** | | | | | | | | | | | | | | |
| **Inputs for Potentially Critical Zones** | | | | | | | | | | | | | | |
| **Zone Name** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | |
| **Zone Tag** | 303 | 306 | 308A | 308C | 310A | 310D | 401 | 402 | 403 | 406 | 407 | 408 | 410 | |
| **Floor Area** | 348 | 300 | 323 | 422 | 443 | 444 | 285 | 100 | 348 | 356 | 297 | 177 | 338 | |
| **Occupant Density** | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| **Design population of zone** | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | |
| **Area OA Rate** | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | |
| **OA required per unit area for zone** | 21 | 18 | 19 | 25 | 27 | 27 | 17 | 6 | 21 | 21 | 18 | 11 | 20 | |
| **Person OA Rate** | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| **OA required per person for zone** | 9 | 8 | 8 | 11 | 11 | 11 | 7 | 3 | 9 | 9 | 7 | 4 | 8 | |
| **Breathing Zone Outdoor Airflow** | 30 | 26 | 27 | 36 | 38 | 38 | 24 | 9 | 30 | 30 | 25 | 15 | 29 | |
| **Zone Outdoor Airflow** | 30 | 26 | 27 | 36 | 38 | 38 | 24 | 9 | 30 | 30 | 25 | 15 | 29 | |
| **Primary OAFraction** | 0.16 | 0.12 | 0.11 | 0.14 | 0.14 | 0.21 | 0.40 | 0.04 | 0.14 | 0.19 | 0.25 | 0.08 | 0.13 | |
| **Minimum Expected Primary Airflow** | 180 | 220 | 260 | 260 | 260 | 180 | 60 | 200 | 210 | 160 | 100 | 200 | 220 | |
| **Primary Air Fraction** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction of Secondary Recirculated Air to Zone** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **Zone Air Distribution Effectiveness** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction SA to Zone from Sources Outside the Zone** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction SA to Zone from Fully Mixed Primary Air** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction OA to Zone from Sources Outside the Zone** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Zone Discharge Airflow** | 180 | 220 | 260 | 260 | 260 | 180 | 60 | 200 | 210 | 160 | 100 | 200 | 220 | |
| **Zone Primary Airflow** | 180 | 220 | 260 | 260 | 260 | 180 | 60 | 200 | 210 | 160 | 100 | 200 | 220 | |
| **Average OA Fraction** | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | |
| **Discharge OA Fraction** | 0.16 | 0.12 | 0.11 | 0.14 | 0.14 | 0.21 | 0.40 | 0.04 | 0.14 | 0.19 | 0.25 | 0.08 | 0.13 | |
| **Zone Ventilation Efficiency** | 0.98 | 1.03 | 1.04 | 1.00 | 1.00 | 0.93 | 0.74 | 1.10 | 1.00 | 0.95 | 0.89 | 1.07 | 1.01 | |
| **System Primary Airflow** | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | 5150 | |
| **Occupant Diversity** | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Building** | Biobehavioral Health Building | | | | | | | | | | | |
| **System Name** | AHU-4 (North Offices) | | | | | | | | | | | |
| **Operating Condition Description** | Design Peak Cooling Load Condition | | | | | | | | | | | |
| **Units** | IP | | | | | | | | | | | |
| **Inputs for System** | **Name** | **Equation** | **Units** | **System** | | | | | | | | |
| **Floor area served by system** | As | | sf | 6516 | | | | | | | | |
| **Population of area served by system** | Ps | | P | 32.58 | | | | | | | | |
| **Design primary supply fan airflow rate** | Vbs | | cfm | 695 | | | | | | | | |
| **OA required per unit area for system** | Ras | | cfm | 391 | | | | | | | | |
| **OA required per person for system area** | Rps | | cfm | 304 | | | | | | | | |
| **Outdoor Airflow** | Vos | Vbs/Ez | | | | | | | | | | |
| **Primary OA Fraction** | Zp | VosVpz | | | | | | | | | | |
| **OA Intake** | Vot | Vou/Ev | cfm | 962 | | | | | | | | |
| **Uncorrected OA Intake** | Vou | Dsum(RpPz)+sum(RaAz) | | 554 | | | | | | | | |
| **System Ventilation Efficiency** | Ev | | | 0.58 | | | | | | | | |
| **Inputs for Potentially Critical Zones** | | | | | | | | | | | | |
| **Zone Name** | | | | | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | |
| **Zone Tag** | | | | | 119 | 120 | 122 | 124 | 129 | 130 | 222 | |
| **Floor Area** | Az | | sf | | 150 | 292 | 292 | 438 | 316 | 367 | 309 | |
| **Occupant Density** | Pz | | P/1000sf | | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| **Design population of zone** | Pz | | P | | 1 | 1 | 1 | 2 | 2 | 2 | 2 | |
| **Area OA Rate** | Raz | | cfm/sf | | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | |
| **OA required per unit area for zone** | | | cfm | | 9 | 18 | 18 | 26 | 19 | 22 | 19 | |
| **Person OA Rate** | Rpz | | cfm/person | | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| **OA required per person for zone** | | | cfm | | 4 | 7 | 7 | 11 | 8 | 9 | 8 | |
| **Breathing Zone Outdoor Airflow** | Vbz | Rpz*Pz+Raz*Az | | | 13 | 25 | 25 | 37 | 27 | 31 | 26 | |
| **Zone Outdoor Airflow** | Voz | Vbz/Ez | | 695 | 13 | 25 | 25 | 37 | 27 | 31 | 26 | |
| **Primary OAFraction** | Zp | Voz/Vpz | | 0.62 | 0.18 | 0.21 | 0.21 | 0.19 | 0.21 | 0.21 | 0.22 | |
| **Minimum Expected Primary Airflow** | Vpz | | cfm | | 70 | 120 | 120 | 200 | 130 | 150 | 120 | |
| **Primary Air Fraction** | Ep | Vpz/Vdz | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction of Secondary Recirculated Air to Zone** | Er | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **Zone Air Distribution Effectiveness** | Ez | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction SA to Zone from Sources Outside the Zone** | Fa | Ep+(1-Ep)Er | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction SA to Zone from Fully Mixed Primary Air** | Fb | Ep | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Fraction OA to Zone from Sources Outside the Zone** | Fc | 1-(1-Ez)(1-Er)(1-Ep) | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Zone Discharge Airflow** | Vdz | | | | 70 | 120 | 120 | 200 | 130 | 150 | 120 | |
| **Zone Primary Airflow** | Vpz | | | | 70 | 120 | 120 | 200 | 130 | 150 | 120 | |
| **Average OA Fraction** | Xs | Vou/Vps | | | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | |
| **Discharge OA Fraction** | Zd | Voz/Vdz | | | 0.18 | 0.21 | 0.21 | 0.19 | 0.21 | 0.21 | 0.22 | |
| **Zone Ventilation Efficiency** | Evz | (Fa+XsFb-ZdFc)/Fa | | | 1.02 | 0.99 | 0.99 | 1.01 | 0.99 | 0.99 | 0.98 | |
| **System Primary Airflow** | Vps | sum(Vpz) | | | 2760 | 2760 | 2760 | 2760 | 2760 | 2760 | 2760 | |
| **Occupant Diversity** | D | Ps/sum(Pz) | | | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Building** | | | | | | | | | | | | | | | |
| **System Name** | | | | | | | | | | | | | | | |
| **Operating Condition Description** | | | | | | | | | | | | | | | |
| **Units** | | | | | | | | | | | | | | | |
| **Inputs for System** | | | | | | | | | | | | | | | |
| **Floor area served by system** | | | | | | | | | | | | | | | |
| **Population of area served by system** | | | | | | | | | | | | | | | |
| **Design primary supply fan airflow rate** | | | | | | | | | | | | | | | |
| **OA required per unit area for system** | | | | | | | | | | | | | | | |
| **OA required per person for system area** | | | | | | | | | | | | | | | |
| **Outdoor Airflow** | | | | | | | | | | | | | | | |
| **Primary OA Fraction** | | | | | | | | | | | | | | | |
| **OA Intake** | | | | | | | | | | | | | | | |
| **Uncorrected OA Intake** | | | | | | | | | | | | | | | |
| **System Ventilation Efficiency** | | | | | | | | | | | | | | | |
| **Inputs for Potentially Critical Zones** | | | | | | | | | | | | | | | |
| **Zone Name** | **Office** | **Office** | **Office** | **Conference** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Office** | **Conference** | | **Total # People** | |
| **Zone Tag** | 223 | 227 | 231 | 232 | 316A | 316C | 316E | 320C | 320F | 320H | 430 | 434 | | | |
| **Floor Area** | 445 | 445 | 312 | 367 | 150 | 445 | 290 | 430 | 188 | 280 | 738 | 262 | | | |
| **Occupant Density** | 5 | 5 | 5 | 50 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 50 | | | |
| **Design population of zone** | 2 | 2 | 2 | 18 | 1 | 2 | 1 | 2 | 1 | 1 | 4 | 13 | | | |
| **Area OA Rate** | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | | 0.06 | |
| **OA required per unit area for zone** | 27 | 27 | 19 | 22 | 9 | 27 | 17 | 26 | 11 | 17 | 44 | 16 | | | |
| **Person OA Rate** | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 5 | |
| **OA required per person for zone** | 11 | 11 | 8 | 92 | 4 | 11 | 7 | 11 | 5 | 7 | 18 | 66 | | | |
| **Breathing Zone Outdoor Airflow** | 38 | 38 | 27 | 114 | 13 | 38 | 25 | 37 | 16 | 24 | 63 | 81 | | | |
| **Zone Outdoor Airflow** | 38 | 38 | 27 | 114 | 13 | 38 | 25 | 37 | 16 | 24 | 63 | 81 | | | |
| **Primary OAFraction** | 0.21 | 0.21 | 0.20 | 0.57 | 0.18 | 0.21 | 0.21 | 0.20 | 0.18 | 0.18 | 0.24 | 0.62 | | | |
| **Minimum Expected Primary Airflow** | 180 | 180 | 130 | 200 | 70 | 180 | 120 | 180 | 90 | 130 | 260 | 130 | | | |
| **Primary Air Fraction** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Fraction of Secondary Recirculated Air to Zone** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| **Zone Air Distribution Effectiveness** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Fraction SA to Zone from Sources Outside the Zone** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Fraction SA to Zone from Fully Mixed Primary Air** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Fraction OA to Zone from Sources Outside the Zone** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Zone Discharge Airflow** | 180 | 180 | 130 | 200 | 70 | 180 | 120 | 180 | 90 | 130 | 260 | 130 | | | |
| **Zone Primary Airflow** | 180 | 180 | 130 | 200 | 70 | 180 | 120 | 180 | 90 | 130 | 260 | 130 | | | |
| **Average OA Fraction** | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | | | |
| **Discharge OA Fraction** | 0.21 | 0.21 | 0.20 | 0.57 | 0.18 | 0.21 | 0.21 | 0.20 | 0.18 | 0.18 | 0.24 | 0.62 | | | |
| **Zone Ventilation Efficiency** | 0.99 | 0.99 | 1.00 | 0.63 | 1.02 | 0.99 | 1.00 | 1.00 | 1.02 | 1.02 | 0.96 | 0.58 | | | |
| **System Primary Airflow** | 2760 | 2760 | 2760 | 2760 | 2760 | 2760 | 2760 | 2760 | 2760 | 2760 | 2760 | 2760 | | | |
| **Occupant Diversity** | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | | | |

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|---|---|---|---|---|---|---|---|---|---|
| **Building** | Biobehavioral Health Building | | | | | | | | |
| **System Name** | AHU-5 (Core) | | | | | | | | |
| **Operating Condition Description** | Design Peak Cooling Load Condition | | | | | | | | |
| **Units** | IP | | | | | | | | |
| **Inputs for System** | **Name** | **Equation** | **Units** | **System** | | | | | |
| **Floor area served by system** | As | | sf | 15989 | | | | | |
| **Population of area served by system** | Ps | | P | 79.945 | | | | | |
| **Design primary supply fan airflow rate** | Vbs | | cfm | 1145 | | | | | |
| **OA required per unit area for system** | Ras | | cfm | 959 | | | | | |
| **OA required per person for system area** | Rps | | cfm | 186 | | | | | |
| **Outdoor Airflow** | Vos | Vbs/Ez | | | | | | | |
| **Primary OA Fraction** | Zp | VosVpz | | | | | | | |
| **OA Intake** | Vot | Vou/Ev | cfm | 2460 | | | | | |
| **Uncorrected OA Intake** | Vou | Dsum(RpPz)+sum(RaAz) | | 1359 | | | | | |
| **System Ventilation Efficiency** | Ev | | | 0.55 | | | | | |
| **Inputs for Potentially Critical Zones** | | | | | | | | | |
| **Zone Name** | | | | | **Lobby** | **Corridor** | **Corridor** | **Corridor** | **Corridor and Elec** |
| **Zone Tag** | | | | | 101F | 104F | 106Q | 204Q | 206Q |
| **Floor Area** | Az | | sf | | 520 | 2008 | 2851 | 1844 | 721 |
| **Occupant Density** | Pz | | P/1000sf | | 10 | 0 | 0 | 0 | 0 |
| **Design population of zone** | Pz | | P | | 5 | 0 | 0 | 0 | 0 |
| **Area OA Rate** | Raz | | cfm/sf | | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **OA required per unit area for zone** | | | cfm | | 31 | 120 | 171 | 111 | 43 |
| **Person OA Rate** | Rpz | | cfm/person | | 5 | 0 | 0 | 0 | 0 |
| **OA required per person for zone** | | | cfm | | 26 | 0 | 0 | 0 | 0 |
| **Breathing Zone Outdoor Airflow** | Vbz | Rpz*Pz+Raz*Az | | | 57 | 120 | 171 | 111 | 43 |
| **Zone Outdoor Airflow** | Voz | Vbz/Ez | | 1145 | 57 | 120 | 171 | 111 | 43 |
| **Primary OAFraction** | Zp | Voz/Vpz | | 0.56 | 0.10 | 0.16 | 0.23 | 0.16 | 0.09 |
| **Minimum Expected Primary Airflow** | Vpz | | cfm | | 560 | 760 | 730 | 700 | 460 |
| **Primary Air Fraction** | Ep | Vpz/Vdz | | | 1 | 1 | 1 | 1 | 1 |
| **Fraction of Secondary Recirculated Air to Zone** | Er | | | | 0 | 0 | 0 | 0 | 0 |
| **Zone Air Distribution Effectiveness** | Ez | | | | 1 | 1 | 1 | 1 | 1 |
| **Fraction SA to Zone from Sources Outside the Zone** | Fa | Ep+(1-Ep)Er | | | 1 | 1 | 1 | 1 | 1 |
| **Fraction SA to Zone from Fully Mixed Primary Air** | Fb | Ep | | | 1 | 1 | 1 | 1 | 1 |
| **Fraction OA to Zone from Sources Outside the Zone** | Fc | 1-(1-Ez)(1-Er)(1-Ep) | | | 1 | 1 | 1 | 1 | 1 |
| **Zone Discharge Airflow** | Vdz | | | | 560 | 760 | 730 | 700 | 460 |
| **Zone Primary Airflow** | Vpz | | | | 560 | 760 | 730 | 700 | 460 |
| **Average OA Fraction** | Xs | Vou/Vps | | | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| **Discharge OA Fraction** | Zd | Voz/Vdz | | | 0.10 | 0.16 | 0.23 | 0.16 | 0.09 |
| **Zone Ventilation Efficiency** | Evz | (Fa+XsFb-ZdFc)/Fa | | | 1.01 | 0.95 | 0.88 | 0.96 | 1.02 |
| **System Primary Airflow** | Vps | sum(Vpz) | | | 12000 | 12000 | 12000 | 12000 | 12000 |
| **Occupant Diversity** | D | Ps/sum(Pz) | | | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 |

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|---|---|---|---|---|---|---|---|---|---|---|
| **Building** | | | | | | | | | | |
| **System Name** | | | | | | | | | | |
| **Operating Condition Description** | | | | | | | | | | |
| **Units** | | | | | | | | | | |
| **Inputs for System** | | | | | | | | | | |
| **Floor area served by system** | | | | | | | | | | |
| **Population of area served by system** | | | | | | | | | | |
| **Design primary supply fan airflow rate** | | | | | | | | | | |
| **OA required per unit area for system** | | | | | | | | | | |
| **OA required per person for system area** | | | | | | | | | | |
| **Outdoor Airflow** | | | | | | | | | | |
| **Primary OA Fraction** | | | | | | | | | | |
| **OA Intake** | | | | | | | | | | |
| **Uncorrected OA Intake** | | | | | | | | | | |
| **System Ventilation Efficiency** | | | | | | | | | | |
| **Inputs for Potentially Critical Zones** | | | | | | | | | | |
| **Zone Name** | **Corridor and Office** | **Corridor and Restroom** | **Corridor** | **Corridor** | **Corridor, Elec, Storage** | **Corridor** | **Restrooms, Storage, Kitchen** | | **Total # Peopl** | |
| **Zone Tag** | 221 | 307Q | 321F | 401F | 401Q | 418 | 422 | | | |
| **Floor Area** | 1101 | 818 | 1774 | 1205 | 791 | 1386 | 970 | | | |
| **Occupant Density** | 7 | 0 | 0 | 0 | 0 | 0 | 25 | | | |
| **Design population of zone** | 8 | 0 | 0 | 0 | 0 | 0 | 24 | | | |
| **Area OA Rate** | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | | 0.06 | |
| **OA required per unit area for zone** | 66 | 49 | 106 | 72 | 47 | 83 | 58 | | | |
| **Person OA Rate** | 5 | 0 | 0 | 0 | 0 | 0 | 5 | | 1 | |
| **OA required per person for zone** | 39 | 0 | 0 | 0 | 0 | 0 | 121 | | | |
| **Breathing Zone Outdoor Airflow** | 105 | 49 | 106 | 72 | 47 | 83 | 179 | | | |
| **Zone Outdoor Airflow** | 105 | 49 | 106 | 72 | 47 | 83 | 179 | | | |
| **Primary OAFraction** | 0.29 | 0.25 | 0.18 | 0.30 | 0.26 | 0.09 | 0.56 | | | |
| **Minimum Expected Primary Airflow** | 360 | 200 | 600 | 240 | 180 | 890 | 320 | | 6000 | |
| **Primary Air Fraction** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Fraction of Secondary Recirculated Air to Zone** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| **Zone Air Distribution Effectiveness** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Fraction SA to Zone from Sources Outside the Zone** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Fraction SA to Zone from Fully Mixed Primary Air** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Fraction OA to Zone from Sources Outside the Zone** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| **Zone Discharge Airflow** | 360 | 200 | 600 | 240 | 180 | 890 | 320 | | | |
| **Zone Primary Airflow** | 360 | 200 | 600 | 240 | 180 | 890 | 320 | | | |
| **Average OA Fraction** | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | | | |
| **Discharge OA Fraction** | 0.29 | 0.25 | 0.18 | 0.30 | 0.26 | 0.09 | 0.56 | | | |
| **Zone Ventilation Efficiency** | 0.82 | 0.87 | 0.94 | 0.81 | 0.85 | 1.02 | 0.55 | | | |
| **System Primary Airflow** | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | | | |
| **Occupant Diversity** | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 | 2.15 | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Building** | Biobehavioral Health Building | | | | | | | |
| **System Name** | AHU-6 (Conference) | | | | | | | |
| **Operating Condition Description** | Design Peak Cooling Load Condition | | | | | | | |
| **Units** | IP | | | | | | | |
| **Inputs for System** | **Name** | **Equation** | **Units** | **System** | | | | |
| **Floor area served by system** | As | | sf | 3516 | | | | |
| **Population of area served by system** | Ps | | P | 170 | | | | |
| **Design primary supply fan airflow rate** | Vbs | | cfm | 1171 | | | | |
| **OA required per unit area for system** | Ras | | cfm | 251 | | | | |
| **OA required per person for system area** | Rps | | cfm | 920 | | | | |
| **Outdoor Airflow** | Vos | Vbs/Ez | | | | | | |
| **Primary OA Fraction** | Zp | VosVpz | | | | | | |
| **OA Intake** | Vot | Vou/Ev | cfm | 3454 | | | | |
| **Uncorrected OA Intake** | Vou | Dsum(RpPz)+sum(RaAz) | | 1171 | | | | |
| **System Ventilation Efficiency** | Ev | | | 0.34 | | | | |
| **Inputs for Potentially Critical Zones** | | | | | | | | |
| **Zone Name** | | | | | **Multipurpose** | **Conference** | **Conference** | **Conference** |
| **Zone Tag** | | | | | 17 | 116 | 218 | 311 |
| **Floor Area** | Az | | sf | | 583 | 728 | 551 | 551 |
| **Occupant Density** | Pz | | P/1000sf | | 40 | 50 | 50 | 50 |
| **Design population of zone** | Pz | | P | | 23 | 36 | 28 | 28 |
| **Area OA Rate** | Raz | | cfm/sf | | 0.06 | 0.06 | 0.06 | 0.06 |
| **OA required per unit area for zone** | | | cfm | | 35 | 44 | 33 | 33 |
| **Person OA Rate** | Rpz | | cfm/person | | 8 | 5 | 5 | 5 |
| **OA required per person for zone** | | | cfm | | 187 | 182 | 138 | 138 |
| **Breathing Zone Outdoor Airflow** | Vbz | Rpz*Pz+Raz*Az | | | 222 | 226 | 171 | 171 |
| **Zone Outdoor Airflow** | Voz | Vbz/Ez | | 1171 | 222 | 226 | 171 | 171 |
| **Primary OAFraction** | Zp | Voz/Vpz | | 0.89 | 0.89 | 0.51 | 0.26 | 0.26 |
| **Minimum Expected Primary Airflow** | Vpz | | cfm | | 250 | 440 | 660 | 660 |
| **Primary Air Fraction** | Ep | Vpz/Vdz | | | 1 | 1 | 1 | 1 |
| **Fraction of Secondary Recirculated Air to Zone** | Er | | | | 0 | 0 | 0 | 0 |
| **Zone Air Distribution Effectiveness** | Ez | | | | 1 | 1 | 1 | 1 |
| **Fraction SA to Zone from Sources Outside the Zone** | Fa | Ep+(1-Ep)Er | | | 1 | 1 | 1 | 1 |
| **Fraction SA to Zone from Fully Mixed Primary Air** | Fb | Ep | | | 1 | 1 | 1 | 1 |
| **Fraction OA to Zone from Sources Outside the Zone** | Fc | 1-(1-Ez)(1-Er)(1-Ep) | | | 1 | 1 | 1 | 1 |
| **Zone Discharge Airflow** | Vdz | | | | 250 | 440 | 660 | 660 |
| **Zone Primary Airflow** | Vpz | | | | 250 | 440 | 660 | 660 |
| **Average OA Fraction** | Xs | Vou/Vps | | | 0.23 | 0.23 | 0.23 | 0.23 |
| **Discharge OA Fraction** | Zd | Voz/Vdz | | | 0.89 | 0.51 | 0.26 | 0.26 |
| **Zone Ventilation Efficiency** | Evz | (Fa+XsFb-ZdFc)/Fa | | | 0.34 | 0.71 | 0.97 | 0.97 |
| **System Primary Airflow** | Vps | sum(Vpz) | | | 5200 | 5200 | 5200 | 5200 |
| **Occupant Diversity** | D | Ps/sum(Pz) | | | 1.00 | 1.00 | 1.00 | 1.00 |

| | | | |
|---|---|---|---|
| Building | | | |
| System Name | | | |
| Operating Condition Description | | | |
| Units | | | |
| Inputs for System | | | |
| Floor area served by system | | | |
| Population of area served by system | | | |
| Design primary supply fan airflow rate | | | |
| OA required per unit area for system | | | |
| OA required per person for system area | | | |
| Outdoor Airflow | | | |
| Primary OA Fraction | | | |
| OA Intake | | | |
| Uncorrected OA Intake | | | |
| System Ventilation Efficiency | | | |
| Inputs for Potentially Critical Zones | | | |
| Zone Name | Conference | Conference | Total |
| Zone Tag | 312 | 419 | |
| Floor Area | 669 | 434 | |
| Occupant Density | 50 | 50 | |
| Design population of zone | 33 | 22 | |
| Area OA Rate | 0.12 | 0.06 | 0.07 |
| OA required per unit area for zone | 80 | 26 | |
| Person OA Rate | 5 | 5 | 6 |
| OA required per person for zone | 167 | 109 | |
| Breathing Zone Outdoor Airflow | 248 | 135 | |
| Zone Outdoor Airflow | 248 | 135 | |
| Primary OAFraction | 0.69 | 0.58 | |
| Minimum Expected Primary Airflow | 360 | 230 | 2600 |
| Primary Air Fraction | 1 | 1 | |
| Fraction of Secondary Recirculated Air to Zone | 0 | 0 | |
| Zone Air Distribution Effectiveness | 1 | 1 | |
| Fraction SA to Zone from Sources Outside the Zone | 1 | 1 | |
| Fraction SA to Zone from Fully Mixed Primary Air | 1 | 1 | |
| Fraction OA to Zone from Sources Outside the Zone | 1 | 1 | |
| Zone Discharge Airflow | 360 | 230 | |
| Zone Primary Airflow | 360 | 230 | |
| Average OA Fraction | 0.23 | 0.45 | |
| Discharge OA Fraction | 0.69 | 0.58 | |
| Zone Ventilation Efficiency | 0.54 | 0.87 | |
| System Primary Airflow | 5200 | 2600 | |
| Occupant Diversity | 1.00 | 1.00 | |