September 18, 2014

TECHNICAL REPORT ONE: ASHRAE STANDARDS 62.1 AND 90.1 EVALUATION

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DR. JAMES FREIJHAUT NEOMED Research and Graduate Education Building

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Executive Summary

This Report is an evaluation of the NEOMED Research and Graduate Education and Comparable Medical Unit with respect to ASHRAE Standards 62.1 and 90.1. The Project is located on the Northeast Ohio Medical University campus, at 4209 Ohio 44, Rootstown, Ohio. The facility is used for graduate-level research and education in the medical field, with laboratories, operating rooms, a vivarium, and numerous biological support spaces. The project was completed in August 2013.

Through investigation of the standards, The RGE and CMU addition are generally up to code. However, there are a number of opportunities to improve efficiency concerning ventilation rates for non-research areas and energy recovery from exhaust.

Building Overview

The project is comprised of three additions to the NEOMED campus. The main addition is the Research and Graduate Education Center, a four-story 63,000 square foot biomedical research building. The first three floors are fully built out with laboratories, support rooms, and offices, while the top floor is shelled in and will be built out as the research program grows. There is a 6,000 square foot basement to house stand-alone utilities.

The second component is a 14,500 square foot addition to the Comparable Medical Unit, which provides animal care services. Lastly, several existing laboratories in Building D were renovated.

Mechanical Systems Overview

Campus Utilities will not be utilized for this project; there is a stand-alone system of chillers, medium pressure steam generators, and hot water boilers located in the basement area of the addition. The RGE Building has two 100% outside air handling units each sized at 50,000 CFM respectively and a smaller 28,000 CFM office unit with return air. The CMU has its own 35,000 CFM 100% outdoor air unit as well.

ASHRAE Standard 62.1-2013 Evaluation

ASHRAE 62.1 Section 5: Systems and Equipment

5.1 Ventilation Air Distribution

The RGE, CMU and Building D are all in compliance with Section 5.1. The laboratories, support rooms, vivarium, and other such rooms are supplied with 100% outdoor air, therefore the airflow needed for proper conditioning easily exceeds ventilation requirements. The design documents all have appropriate information for balancing and minimum airflow allowed.

5.2 Exhaust Duct Location

Documents indicate that all exhaust duct runs are negatively pressurized relative to the supply duct runs in each room. The lab exhaust runs through two custom air handling units each at 50,000 CFM. Smaller exhaust fans are located above the office wings, and space is allotted for exhaust fans to be placed for future expansion.

5.3 Ventilation System Controls

The RGE building and the CMU addition each have an independent direct digital control systems interfaced with existing campus network. The system accomplishes all sensing and controlling via electronic actuation of all valves and dampers.

5.4 Air Stream Surfaces

All airstream surfaces are comprised of sheet metal ductwork with metal fasteners to comply with requirements for resistance to mold growth and erosion.

5.5 Outdoor Air Intakes

Outdoor air intake for office end of the RGE building is located on the east face of AHU-3. The outdoor air intake of the laboratory air handlers is located on the north face of the supply air tunnel. All outdoor air intakes are well outside of the required distances; the exhaust stacks for the lab exhaust are 25 feet high per 62.1 Table 5.5.1, giving plenty of distance for the class 4 air to discharge. In addition, each inlet is protected by a mesh screen and louvers to protect from rain, snow, and birds. All AHU’s on the project are equipped with access doors for maintenance purposes.

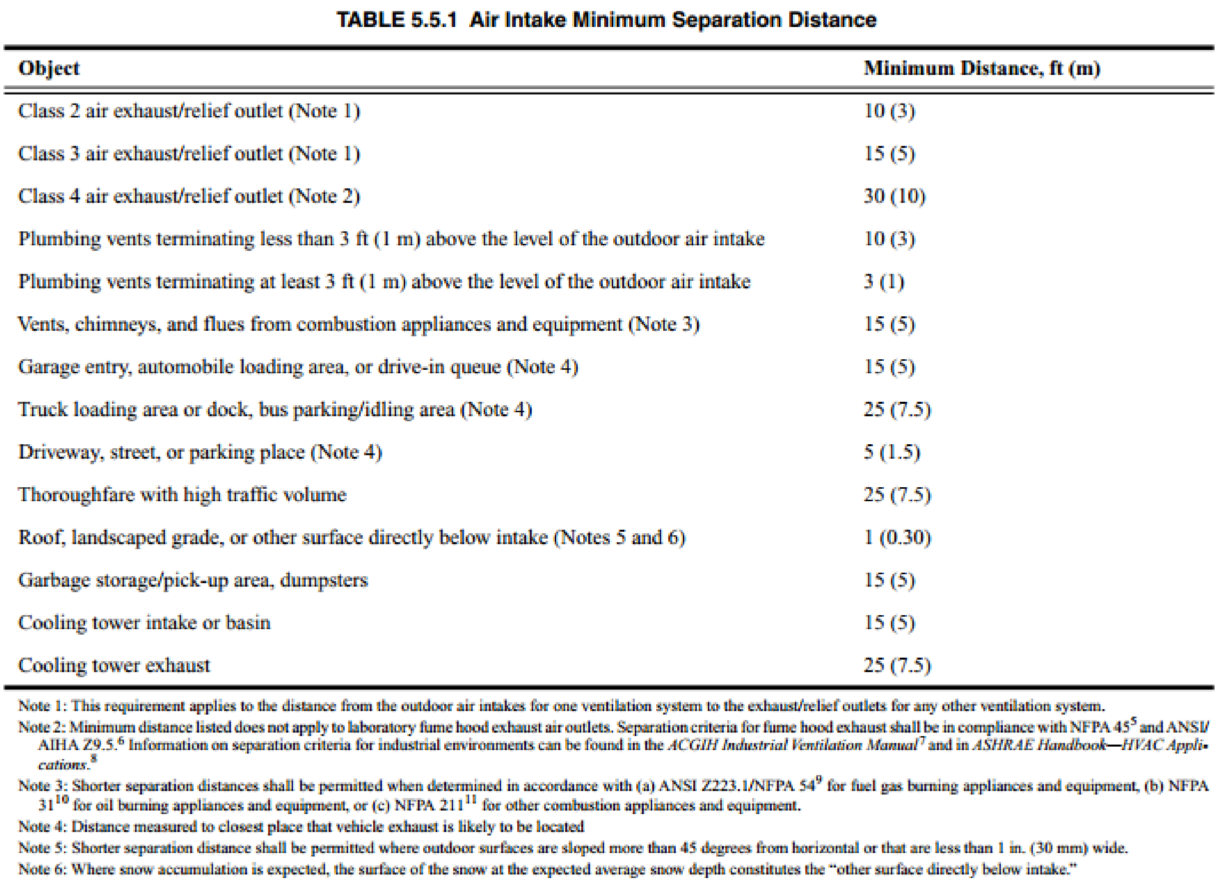

TABLE 5.5.1 Air Intake Minimum Separation Distance

Object	Minimum Distance, ft (m)
Class 2 air exhaust/relief outlet (Note 1)	10 (3)
Class 3 air exhaust/relief outlet (Note 1)	15 (5)
Class 4 air exhaust/relief outlet (Note 2)	30 (10)
Plumbing vents terminating less than 3 ft (1 m) above the level of the outdoor air intake	10 (3)
Plumbing vents terminating at least 3 ft (1 m) above the level of the outdoor air intake	3 (1)
Vents, chimneys, and flues from combustion appliances and equipment (Note 3)	15 (5)
Garage entry, automobile loading area, or drive-in queue (Note 4)	15 (5)
Truck loading area or dock, bus parking/idling area (Note 4)	25 (7.5)
Driveway, street, or parking place (Note 4)	5 (1.5)
Thoroughfare with high traffic volume	25 (7.5)
Roof, landscaped grade, or other surface directly below intake (Notes 5 and 6)	1 (0.30)
Garbage storage/pick-up area, dumpsters	15 (5)
Cooling tower intake or basin	15 (5)
Cooling tower exhaust	25 (7.5)

Note 1: This requirement applies to the distance from the outdoor air intakes for one ventilation system to the exhaust/relief outlets for any other ventilation system.

Note 2: Minimum distance listed does not apply to laboratory fume hood exhaust air outlets. Separation criteria for fume hood exhaust shall be in compliance with NFPA 45[5] and ANSI/AIHA Z9.5.[6] Information on separation criteria for industrial environments can be found in the *ACGIH Industrial Ventilation Manual*[7] and in *ASHRAE Handbook—HVAC Applications*.[8]

Note 3: Shorter separation distances shall be permitted when determined in accordance with (a) ANSI Z223.1/NFPA 54[9] for fuel gas burning appliances and equipment, (b) NFPA 31[10] for oil burning appliances and equipment, or (c) NFPA 211[11] for other combustion appliances and equipment.

Note 4: Distance measured to closest place that vehicle exhaust is likely to be located

Note 5: Shorter separation distance shall be permitted where outdoor surfaces are sloped more than 45 degrees from horizontal or that are less than 1 in. (30 mm) wide.

Note 6: Where snow accumulation is expected, the surface of the snow at the expected average snow depth constitutes the "other surface directly below intake."

Figure 1 (Source: ASHRAE 62.1-2013)

5.6 Local Capture of Contaminants

All areas with equipment that generate contaminates, such as labs and restrooms, have exhaust to capture contaminates and direct outdoors away from any intake openings.

5.7 Combustion Air

All laboratory spaces are equipped with fume hoods for removal of any potential combustion products.

5.8 Particulate Matter Removal

Supply air tunnels have a MERV-9 pre-filter and a MERV-14 after-filter within each air handler. Heat recovery coils within exhaust tunnels have MERV-9 pre-filters. Also, room-side replaceable "filter grilles" are used for exhaust of the animal holding room in the CMU. All of these meet the minimum ASHRAE standard of MERV-8 filtration.

5.9 Dehumidification Systems

Lab and support spaces are designed at 35% humidity in winter and 50% humidity in summer. The vivarium is designed at 30-40% winter humidity and 50% summer humidity. These are all less than the required 65% maximum. Regarding section 5.9.2, the RGE has two custom air handling units, with both supply and exhaust at 37,500 CFM for 100% outdoor air intake. The CMU addition has an 85,000 CFM supply and exhaust in a similar fashion.

5.10 Drain Pans

No mention of drain pans is given in the specifications

5.11 Finned-Tube Coils and Heat Exchangers

Plate and frame heat exchangers are utilized on this project rather than finned-tube heat exchangers

5.12 Humidifiers and Water-Spray Systems

The project utilizes Nortec NH series electrode steam humidifiers which are specified to use potable water and drain pans per ASHRAE standard.

5.13 Access for Inspection, Cleaning, and Maintenance

Sufficient access to HVAC equipment has been designed.

5.14 Building Envelope and Interior Surfaces

Architectural wall sections such as Figure 2 indicate a building envelope with rigid insulation, moisture barriers, and batt insulation between studs.

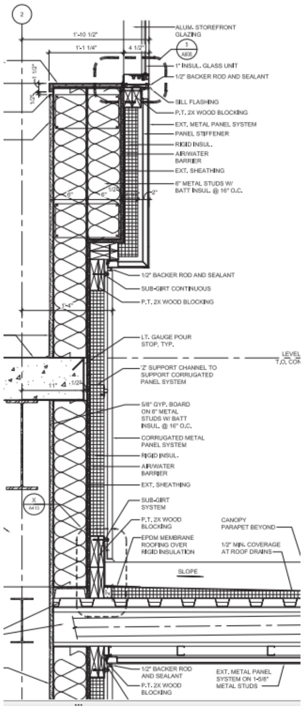

Figure 2: architectural wall section

5.15 Buildings with Attached Parking Garages

Building has no attached parking garages, therefore section 5.15 does not apply.

5.16 Air Classification and Recirculation

The laboratories, animal operating rooms, and various technical support spaces are all Class 2 air per Table 6.2.2.1. However, it is important to note that the airstreams from any of the fume hoods is Class 4 as stated by Table 5.16.1. All other areas such as conference rooms and offices are Class 1 air. As stated before, the laboratory and animal care areas are operating on 100% outdoor air with no recirculation. The Class 1 rooms all recirculate air via return ducts. It is also important to note that the biosafety cabinet fume hoods shall recirculate 100% back into the procedure rooms.

5.17 ETS Air

Smoking is not allowed in any part of the building; 5.17 does not apply.

Conclusion

The Buildings are in compliance with all ventilation requirements prescribed by ASHRAE Standard 62.1.5-2013. This is not surprising given the majority of zones require 100% outdoor air and sensitive humidity control due to the research activities conducted within them.

ASHRAE 62.1 Section 6: Procedures

6.1 General

The site’s outdoor air has no contamination issues and is deemed acceptable for ventilation purposes. Proper ventilation rates are hereby calculated via the prescriptive Ventilation Rate Procedure and the Exhaust Rate Procedure and compared to the existing design specifications. No natural ventilation strategies are used in the design.

6.2 Ventilation Rate Procedure

A preconfigured excel spreadsheet was used to calculate ventilation needed for the offices and conference rooms to the east end of the RGE building, covered by AHU-3. In this project, this was the only air handler configuration that was not configured for 100% outdoor air intake. The breakdown from the spreadsheet calculations is located in Appendix A.

First, breathing zone outdoor air flow rates are calculated with Equation 6-1 from ASHRA 62.1-2013 for each room

$$V_{bz} = R_p*P_z + R_a*A_z$$

Where R_p is outdoor airflow rate per person, P_z is zone population by occupancy class, R_a is outdoor airflow rater per area, and A_z is the area covered by the zone. Table 6-1 of ASHRAE Standard 62.1-2013 contains values for both R_p and R_a, and is referenced by the spreadsheet.

The next step is to find and factor in the zone air distribution effectiveness E_z, found in Table 6-2. In all instances examined, supply air was delivered via ceiling diffusers at cooling temperature, so E_z was 1.0 all around. These values are also referenced in the spreadsheet in Appendix A.

After entering area and airflow data from the drawings, the total supply airflow amounted to roughly 19,600 CFM. This is slightly less than the design value for AHU-3 of 28,000 CFM. Table 1 below gives a breakdown of total system ventilation.

Results								
	Ventilation System Efficiency	Ev						**0.80**
	Outdoor air intake required for system	Vot	cfm					**1609**
	Outdoor air per unit floor area	Vot/As	cfm/sf					**0.17**
	Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p					**12.1**
	Outdoor air as a % of design primary supply air	Ypd	cfm					**8%**

Table 1:AHU-3 Ventilation Breakdown

Also, tallying up the individual zones indicates a surplus of 1294 CFM of unneeded outdoor air and a maximum Z_p value of .26. This could present an opportunity for energy savings.

Conclusion

As a science and research facility, the RGE and CMU buildings by necessity have large turnover in airflow. The analysis shows that even in the minority of non-research zones there are moderate energy savings to be had. There are likely even greater savings to be had if one examines the heat recovery methods used for the rest of the project.

ASHRAE Standard 90.1-2013 Evaluation

Section 5: Building Envelope

5.1 General

As shown by Figure B1-1 in ASHRAE Standard 90.1-2013 Section 5.1.4, the project's location in Rootstown, Ohio places it in the 5A Climate Zone, a relatively cool, moist region.

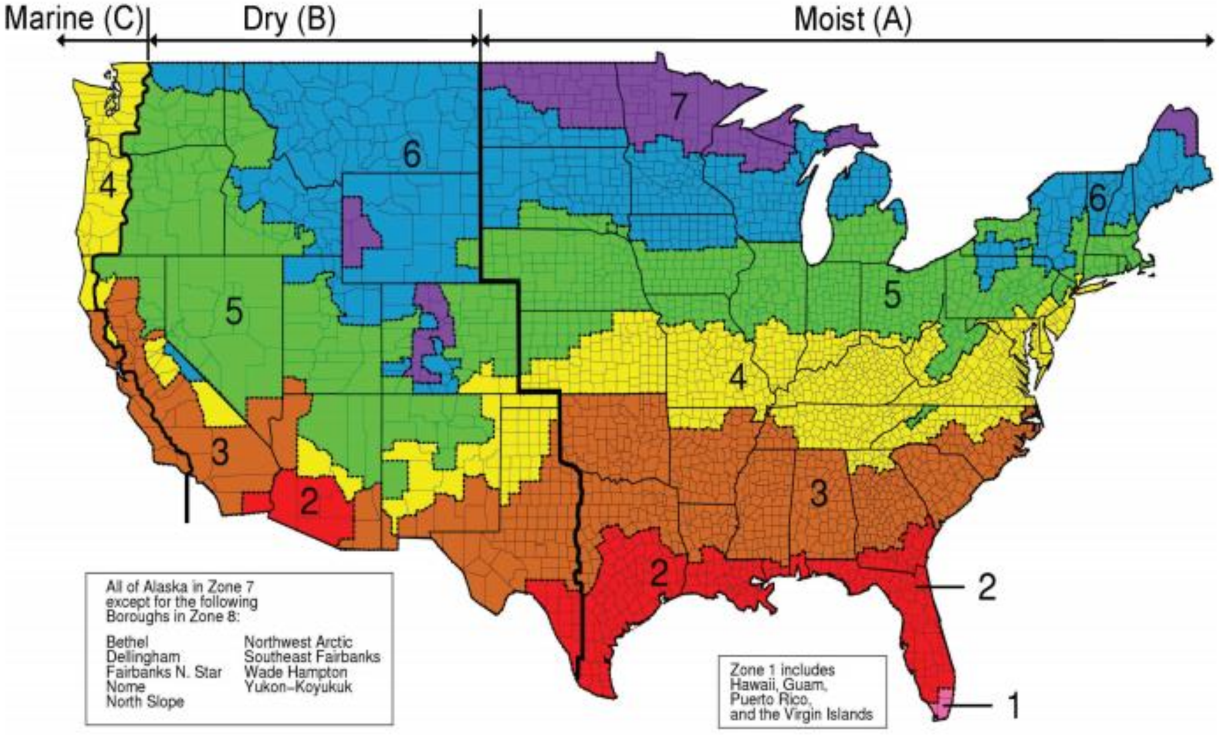

Figure B1-1 U.S. climate zone map (*ASHRAE Transactions*, Briggs et al., 2003).

5.2 Compliance Paths

Here we will elect to use the prescriptive evaluation for the building envelope outline in Section 5.5 of the code.

5.4 Mandatory Provisions

The building is constructed with a continuous air and water membrane throughout the entirety of the envelope. In addition, the entrances to the RGE and CMU have vestibules per section 5.4.3.4 of the code.

5.5 Prescriptive Building Envelope Option

Insulation values for the envelope are not available, making the envelope difficult to access. More information finding will be required.

Section 6: Heating, Ventilation, and Air Conditioning

6.4 Mandatory Provisions

The prescriptive path outlined in Section 6.4 of Standard 90.1-2013 shall be followed as the building project does not meet the size criteria for the simplified approach outlined in Section 6.3. All equipment meets efficiency standards outlined in the tables of Section 6.8 and load calculations were conducted in the program Chvac 7 in accordance with ASHRAE Standards. The DDC system mentioned in the Standard 62.1.5.3-2013 controls all equipment in accordance with Standard 6.4.3.

6.5 Prescriptive Path

AHU-3 is outfitted with an economizer in accordance with code Section 6.5.1. The automatic temperature control system governs the zone controls via digital sensors and actuators. Also, given the data presented in the analysis of Standard 62.1.6.2 the amount of outdoor air utilized by the office air handler is less than the amount needed to require energy recovery equipment. However, the two AHU's feeding the labs of the RGE and the AHU feeding the CMU expansion use heat pipes with refrigerant to transfer heat from the exhaust stream to the supply stream during heating season, and vice versa during the cooling season.

Section 7: Service Water Heating

Domestic water service is piped through water softeners with a duplex water system to provide adequate pressure for lab fixtures. Hot water will be provided via duplex 250 gallon condensing water heaters. This equipment is of proper efficiency per standard 7.8.

Section 8: Power

This project has a new main electrical service made up of a single ended normal power switchboard, diesel emergency generator, branch automatic transfers and an optional standby distribution system. Feeders are sized within the required voltage drop of 2% and branch circuits are sized to no more that 3% voltage drop.

Section 9: Lighting

All lighting on the project is automatically switched off via low voltage relays or occupancy sensors. Multi-level switch control is provided in perimeter areas to reduce intensity of light during daylight hours.

Section 10: Other Equipment

None of the equipment mentioned in Section 10 applies to the project.

Conclusion

The Research and Graduate Education Building and the expansion of the Comparable Medical Unit are up to energy code. This is not surprising, given the fact that the building was completed only one year ago to this report and is a very advanced technical project.

References

ANSI/ASHRAE. (2013). *Standard 62.1-2013, Ventilation for Acceptable Indoor Air Quality.* Atlanta, Georgia: American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.

ANSI/ASHRAE/IES. (2013). *Standard 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P edition).* Atlanta, Georgia: American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.

Scheeser Buckley Mayfield LLC. Mechanical, Electrical, Plumbing, and Fire Protection Construction Documents. Scheeser Buckley Mayfield, Uniontown, Ohio

Bard, Rao + Athanas Consulting Engineers, LLC. MEP Schematic Narratives. BR+A, Boston, MA

Ellenzweig Architects. Architectural Construction Documents. Ellenzweig, Boston, MA

TC Architects Inc. Architectural Construction Documents. TC Architects, Akron, Ohio

Appendix

Building:	**NEOMED Research and Graduate Education Center**												
System Tag/Name:	**AHU-3**												
Operating Condition Description:	**Max Cooling Day**												
Units (select from pull-down list)	**IP**												
Inputs for System	**Name**	**Units**				**System**							
Floor area served by system	As	sf				9671							
Population of area served by system (including diversity)	Ps	P		100% diversity		132							
Design primary supply fan airflow rate	Vpsd	cfm				19,600							
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf				0.06							
OA req'd per person for system area (Weighted average)	Rps	cfm/p				5.3							
Inputs for Potentially Critical zones													
Zone Name	*Zone title turns purple italic for critical zone(s)*						**offices**	**offices**	**copy room**	**Conference**	**Office**	**IMS Director**	**open office reception**
Zone Tag							**362**	**363**	**364**	**365**	**366**	**367**	**369**
Space type		Select from pull-down list					**Office space**	**Office space**	**Office space**	**Conference/meeting**	**Office space**	**Office space**	**Reception areas**
Floor Area of zone	Az	sf					426	426	155	100	142	174	155
Design population of zone	Pz	P		(default value listed; may be overridden)			2.13	2.13	0.775	5	0.71	0.87	4.65
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm					675	600	275	150	375	275	225
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A					ITU	ITU	ITU	ITU	ITU	ITU	ITU
Local recirc. air % representative of ave system return air	Er						75%	75%	75%	75%	75%	75%	75%
Inputs for Operating Condition Analyzed													
Percent of total design airflow rate at conditioned analyzed	Ds	%				100%	100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list					CS	CS	CS	CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez						1.00	1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep						100%	100%	100%	100%	100%	100%	100%
Results													
Ventilation System Efficiency	Ev					**0.80**							
Outdoor air intake required for system	Vot	cfm				**1609**							
Outdoor air per unit floor area	Vot/As	cfm/sf				**0.17**							
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p				**12.1**							
Outdoor air as a % of design primary supply air	Ypd	cfm				**8%**							
Detailed Calculations													
Initial Calculations for the System as a whole													
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	19600							
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	1294							
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.07							
Initial Calculations for individual zones													
OA rate per unit area for zone	Raz	cfm/sf					0.06	0.06	0.06	0.06	0.06	0.06	0.06
OA rate per person	Rpz	cfm/p					5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm					675	600	275	150	375	275	225
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=		36.2	36.2	13.2	31.0	12.1	14.8	32.6
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=		36	36	13	31	12	15	33
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	Fc		=	1-(1-Ez)(1-Ep)(1-Er)	=		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=		0.05	0.06	0.05	0.21	0.03	0.05	0.14
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=		0.05	0.06	0.05	0.21	0.03	0.05	0.14
System Ventilation Efficiency													
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=		1.01	1.01	1.02	0.86	1.03	1.01	0.92
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.80**							
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.89							
Minimum outdoor air intake airflow													
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**1609**							
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.08**							
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	1457	**152.21**						
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.07	**0.09**						
OA Temp at which Min OA provides all cooling													
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrf	=	-135							

Building:	NEOMED Research and Graduate Education Center
System Tag/Name:	AHU-3
Operating Condition Description:	Max Cooling Day
Units (select from pull-down list)	IP

Inputs for System	**Name**	**Units**		**System**							
Floor area served by system	As	sf		9671							
Population of area served by system (including diversity)	Ps	P	100% diversity	132							
Design primary supply fan airflow rate	Vpsd	cfm		19,600							
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf		0.06							
OA req'd per person for system area (Weighted average)	Rps	cfm/p		5.3							
Inputs for Potentially Critical zones											
Zone Name					**Office**	**Office**	**Break/Meeting**	**offices**	**offices**	**copy workroom**	**conference**
		Zone title turns purple italic for critical zone(s)									
Zone Tag					**370**	**371**	**373**	**260**	**261**	**262**	**263**
Space type		Select from pull-down list			**Office space**	**Office space**	**Break rooms**	**Office space**	**Office space**	**Office space**	**Conference/meeting**
Floor Area of zone	Az	sf			142	142	381	426	426	155	100
Design population of zone	Pz	P	(default value listed; may be overridden)		0.71	0.71	9.525	2.13	2.13	0.775	5
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm			300	725	1225	675	600	275	250
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A			ITU	ITU	ITU	ITU	ITU	ITU	ITU
Local recirc. air % representative of ave system return air	Er				75%	75%	75%	75%	75%	75%	75%
Inputs for Operating Condition Analyzed											
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list			CS	CS	CS	CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00	1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep				100%	100%	100%	100%	100%	100%	100%
Results											
Ventilation System Efficiency	Ev			**0.80**							
Outdoor air intake required for system	Vot	cfm		**1609**							
Outdoor air per unit floor area	Vot/As	cfm/sf		**0.17**							
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p		**12.1**							
Outdoor air as a % of design primary supply air	Ypd	cfm		**8%**							
Detailed Calculations											
Initial Calculations for the System as a whole											
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= VpdDs =	19600							
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As =	1294							
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps =	0.07							
Initial Calculations for individual zones											
OA rate per unit area for zone	Raz	cfm/sf			0.06	0.06	0.06	0.06	0.06	0.06	0.06
OA rate per person	Rpz	cfm/p			5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm			300	725	1225	675	600	275	250
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az =		12.1	12.1	70.5	36.2	36.2	13.2	31.0
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez =		12	12	70	36	36	13	31
Fraction of zone supply not directly recirc. from zone	Fa		= Ep + (1-Ep)Er =		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	Fb		= Ep =		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er) =		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	Zd		= Voz / Vdz =		0.04	0.02	0.06	0.05	0.06	0.05	0.12
Unused OA fraction required in primary air to zone	Zp		= Voz / Vpz =		0.04	0.02	0.06	0.05	0.06	0.05	0.12
System Ventilation Efficiency											
Zone Ventilation Efficiency (App A Method)	Evz		= (Fa + FbXs - FcZ) / Fa =		1.03	1.05	1.01	1.01	1.01	1.02	0.94
System Ventilation Efficiency (App A Method)	Ev		= min (Evz) =	**0.80**							
Ventilation System Efficiency (Table 6.3 Method)	Ev		= Value from Table 6.3 =	0.89							
Minimum outdoor air intake airflow											
Outdoor Air Intake Flow required to System	Vot	cfm	= Vou / Ev =	**1609**							
OA intake req'd as a fraction of primary SA	Y		= Vot / Vps =	**0.08**							
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	= Vou / Ev =	1457							
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		= Vot / Vps =	0.07							
OA Temp at which Min OA provides all cooling											
OAT below which OA Intake flow is @ minimum		Deg F	= {(Tp-dTsf)-(1-Y)*(Tr+dTrf =	-135							

Building:	NEOMED Research and Graduate Education Center
System Tag/Name:	AHU-3
Operating Condition Description:	Max Cooling Day
Units (select from pull-down list)	IP

Inputs for System	**Name**	**Units**				**System**							
Floor area served by system	As	sf				9671							
Population of area served by system (including diversity)	Ps	P		100% diversity		132							
Design primary supply fan airflow rate	Vpsd	cfm				19,600							
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf				0.06							
OA req'd per person for system area (Weighted average)	Rps	cfm/p				5.3							
Inputs for Potentially Critical zones							**Potentially Critical Zones**						
Zone Name				*Zone title turns purple italic for critical zone(s)*			**Office space**	**unassig director**	**open office reception**	**Office space**	**Office space**	**break meeting room**	**connecting bridge**
Zone Tag							**264**	**265**	**266**	**267**	**269**	**271**	**1 & 2**
Space type		Select from pull-down list					**Office space**	**Office space**	**Reception areas**	**Office space**	**Office space**	**Office space**	**Corridors**
Floor Area of zone	Az	sf					142	174	155	142	142	388	884
Design population of zone	Pz	P		(default value listed; may be overridden)			0.71	0.87	4.65	0.71	0.71	1.94	0
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm					375	275	275	300	325	775	2825
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A					ITU	ITU	ITU	ITU	ITU	ITU	ITU
Local recirc. air % representative of ave system return air	Er						75%	75%	75%	75%	75%	75%	75%
Inputs for Operating Condition Analyzed													
Percent of total design airflow rate at conditioned analyzed	Ds	%				100%	100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list					CS	CS	CS	CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez						1.00	1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep						100%	100%	100%	100%	100%	100%	100%
Results													
Ventilation System Efficiency	Ev					**0.80**							
Outdoor air intake required for system	Vot	cfm				**1609**							
Outdoor air per unit floor area	Vot/As	cfm/sf				**0.17**							
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p				**12.1**							
Outdoor air as a % of design primary supply air	Ypd	cfm				**8%**							
Detailed Calculations													
Initial Calculations for the System as a whole													
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	19600							
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	1294							
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.07							
Initial Calculations for individual zones													
OA rate per unit area for zone	Raz	cfm/sf					0.06	0.06	0.06	0.06	0.06	0.06	0.06
OA rate per person	Rpz	cfm/p					5.00	5.00	5.00	5.00	5.00	5.00	0.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm					375	275	275	300	325	775	2825
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=		12.1	14.8	32.6	12.1	12.1	33.0	53.0
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=		12	15	33	12	12	33	53
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	Fc		=	1-(1-Ez)(1-Ep)(1-Er)	=		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=		0.03	0.05	0.12	0.04	0.04	0.04	0.02
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=		0.03	0.05	0.12	0.04	0.04	0.04	0.02
System Ventilation Efficiency													
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=		1.03	1.01	0.95	1.03	1.03	1.02	1.05
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.80**							
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.89							
Minimum outdoor air intake airflow													
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**1609**							
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.08**							
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	1457							
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.07							
OA Temp at which Min OA provides all cooling													
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrf	=	-135							

Building:	**NEOMED Research and Graduate Education Center**
System Tag/Name:	**AHU-3**
Operating Condition Description:	**Max Cooling Day**
Units (select from pull-down list)	**IP**

Inputs for System	**Name**	**Units**				**System**							
Floor area served by system	As	sf				9671							
Population of area served by system (including diversity)	Ps	P		100% diversity		132							
Design primary supply fan airflow rate	Vpsd	cfm				19,600							
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf				0.06							
OA req'd per person for system area (Weighted average)	Rps	cfm/p				5.3							
Inputs for Potentially Critical zones													
Zone Name				*Zone title turns purple italic for critical zone(s)*			**open office reception**	**service closets**	**lobby**	**offices**	**offices**	**AV Room**	**conference/ seminar**
Zone Tag							**153**	**152**	**151**	**154**	**155**	**156**	**165 & 163**
Space type		Select from pull-down list					**Reception areas**	**Telephone closets**	**Main entry lobbies**	**Office space**	**Office space**	**Storage rooms**	**Conference/meeting**
Floor Area of zone	Az	sf					221	200	877	426	426	50	762
Design population of zone	Pz	P		(default value listed; may be overridden)			6.63	0	8.77	2.13	2.13	0	38.1
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm					250	150	500	725	600	50	1800
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A					ITU	ITU	ITU	ITU	ITU	ITU	ITU
Local recirc. air % representative of ave system return air	Er						75%	75%	75%	75%	75%	75%	75%
Inputs for Operating Condition Analyzed													
Percent of total design airflow rate at conditioned analyzed	Ds	%				100%	100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list					CS	CS	CS	CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez						1.00	1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep						100%	100%	100%	100%	100%	100%	100%
Results													
Ventilation System Efficiency	Ev					**0.80**							
Outdoor air intake required for system	Vot	cfm				**1609**							
Outdoor air per unit floor area	Vot/As	cfm/sf				**0.17**							
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p				**12.1**							
Outdoor air as a % of design primary supply air	Ypd	cfm				**8%**							
Detailed Calculations													
Initial Calculations for the System as a whole													
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	19600							
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	1294							
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.07							
Initial Calculations for individual zones													
OA rate per unit area for zone	Raz	cfm/sf					0.06	0.00	0.06	0.06	0.06	0.12	0.06
OA rate per person	Rpz	cfm/p					5.00	0.00	5.00	5.00	5.00	0.00	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm					250	150	500	725	600	50	1800
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=		46.4	0.0	96.5	36.2	36.2	6.0	236.2
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=		46	0	96	36	36	6	236
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	Fc		=	1-(1-Ez)(1-Ep)(1-Er)	=		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=		0.19	0.00	0.19	0.05	0.06	0.12	0.13
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=		0.19	0.00	0.19	0.05	0.06	0.12	0.13
System Ventilation Efficiency													
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=		0.88	1.07	0.87	1.02	1.01	0.95	0.93
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.80**							
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.89							
Minimum outdoor air intake airflow													
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**1609**							
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.08**							
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	1457							
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.07							
OA Temp at which Min OA provides all cooling													
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrf	=	-135							

Building:	NEOMED Research and Graduate Education Center
System Tag/Name:	AHU-3
Operating Condition Description:	Max Cooling Day
Units (select from pull-down list)	IP

Inputs for System

	Name	Units		System
Floor area served by system	As	sf		9671
Population of area served by system (including diversity)	Ps	P	100% diversity	132
Design primary supply fan airflow rate	Vpsd	cfm		19,600
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf		0.06
OA req'd per person for system area (Weighted average)	Rps	cfm/p		5.3

Inputs for Potentially Critical zones

Zone Name			*Zone title turns purple italic for critical zone(s)*	***kitchen***	**copy room**	**Office space**	**Office space**	**conference room**	**Office space**	**Office space**
Zone Tag				**162**	**157**	**158**	**159**	**160**	**161**	**166**
Space type		Select from pull-down list		**Cafeteria/fast-food dining**	**Office space**	**Office space**	**Office space**	**Conference/meeting**	**Office space**	**Office space**
Floor Area of zone	Az	sf		162	130	142	142	130	142	142
Design population of zone	Pz	P	(default value listed; may be overridden)	16.2	0.65	0.71	0.71	6.5	0.71	0.71
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm		575	275	475	275	250	300	400
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A		ITU	ITU	ITU	ITU	ITU	ITU	ITU
Local recirc. air % representative of ave system return air	Er			75%	75%	75%	75%	75%	75%	75%

Inputs for Operating Condition Analyzed

Percent of total design airflow rate at conditioned analyzed	Ds	%	100%	100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list		CS	CS	CS	CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez			1.00	1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep			100%	100%	100%	100%	100%	100%	100%

Results

Ventilation System Efficiency	Ev		**0.80**
Outdoor air intake required for system	Vot	cfm	**1609**
Outdoor air per unit floor area	Vot/As	cfm/sf	**0.17**
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p	**12.1**
Outdoor air as a % of design primary supply air	Ypd	cfm	**8%**

Detailed Calculations

Initial Calculations for the System as a whole

Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	19600
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	1294
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.07

Initial Calculations for individual zones

OA rate per unit area for zone	Raz	cfm/sf				0.18	0.06	0.06	0.06	0.06	0.06	0.06
OA rate per person	Rpz	cfm/p				7.50	5.00	5.00	5.00	5.00	5.00	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm				575	275	475	275	250	300	400
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=	150.7	11.1	12.1	12.1	40.3	12.1	12.1
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=	151	11	12	12	40	12	12
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	Fc		=	1-(1-Ez)(1-Ep)(1-Er)	=	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=	0.26	0.04	0.03	0.04	0.16	0.04	0.03
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=	0.26	0.04	0.03	0.04	0.16	0.04	0.03

System Ventilation Efficiency

Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=		0.80	1.03	1.04	1.02	0.90	1.03	1.04
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.80**							
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.89							

Minimum outdoor air intake airflow

Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**1609**
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.08**
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	1457
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.07

OA Temp at which Min OA provides all cooling

OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrf	=	-135

Building:	**NEOMED Research and Graduate Education Center**
System Tag/Name:	**AHU-3**
Operating Condition Description:	**Max Cooling Day**
Units (select from pull-down list)	**IP**

Inputs for System	**Name**	**Units**		**System**
Floor area served by system	As	sf		9671
Population of area served by system (including diversity)	Ps	P	100% diversity	132
Design primary supply fan airflow rate	Vpsd	cfm		19,600
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf		0.06
OA req'd per person for system area (Weighted average)	Rps	cfm/p		5.3

Inputs for Potentially Critical zones				
Zone Name			*Zone title turns purple italic for critical zone(s)*	**offices**
Zone Tag				**168**
Space type		Select from pull-down list		**Office space**
Floor Area of zone	Az	sf		342
Design population of zone	Pz	P	(default value listed; may be overridden)	1.71
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm		1200
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A		ITU
Local recirc. air % representative of ave system return air	Er			75%

Inputs for Operating Condition Analyzed					
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list			CS
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00
Primary air fraction of supply air at conditioned analyzed	Ep				100%

Results			
Ventilation System Efficiency	Ev		**0.80**
Outdoor air intake required for system	Vot	cfm	**1609**
Outdoor air per unit floor area	Vot/As	cfm/sf	**0.17**
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p	**12.1**
Outdoor air as a % of design primary supply air	Ypd	cfm	**8%**

Detailed Calculations							
Initial Calculations for the System as a whole							
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	19600	
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	1294	
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.07	
Initial Calculations for individual zones							
OA rate per unit area for zone	Raz	cfm/sf					0.06
OA rate per person	Rpz	cfm/p					5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm					1200
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=		29.1
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=		29
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=		1.00
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=		1.00
Fraction of zone OA not directly recirc. from zone	Fc		=	1-(1-Ez)(1-Ep)(1-Er)	=		1.00
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=		0.02
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=		0.02
System Ventilation Efficiency							
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=		1.04
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.80**	
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.89	
Minimum outdoor air intake airflow							
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**1609**	
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.08**	
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	1457	
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.07	
OA Temp at which Min OA provides all cooling							
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrf	=	-135	