Technical Report One

ASHRAE Standard 62.1 Ventilation and Standard 90.1 Energy Design Evaluations

National Rural Utilities Cooperative Finance Corporation (NRUCFC) Headquarters Building
Sterling, VA

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Executive Summary

The purpose of Technical Assignment One is to determine if the National Rural Utilities Cooperative Finance (NRUCFC) Headquarters Building is in compliance with ASHRAE Standard 62.1-2007 and Standard 90.1-2007. The new headquarters building is 120,000 square foot office building that will also house a fitness center, café, and executive lounge. The three-story above grade building is located on a 42-acre lot in Sterling, VA, about 10 miles north of the Dulles International Airport, at the intersection of Route 28 & 7. The headquarters is LEED® Gold certified.

ASHRAE Standard 62.1-2007—Ventilation for Acceptable Indoor Air Quality—specifies the qualifications and procedures to reach acceptable indoor air quality. The systems and equipment as well as ventilation rates were found to be in compliance with this standard.

ASHRAE Standard 90.1-2007—Energy Standard for Buildings except Low-Rise Residential Buildings—specifies minimum equipment efficiencies and building insulation values meant to increase energy efficiency of the building. The fenestration ratio and insulation values were unknown at time of print. The pump motor efficiencies were found to be non-compliant with this standard, while the power distribution and lighting power densities were found to be compliant.

Mechanical Systems Overview

Primary Cooling

Two 210 ton electric centrifugal chillers are located in the first floor central plant. They incorporate oil-free compressors to increase part-load efficiency. Six "ice on coil" storage tanks will circulate 25% ethylene glycol solution through the chillers. Two induced draft cooling towers are located on the roof. The central plant and piping has been configured to allow for future expansion and serve as the central plant for other buildings.

Primary Heating

Two high efficiency natural gas-fired condensing boilers are located in the mechanical penthouse and serve as the primary heating source. They will circulate water to the terminal units with a hot water heat feature. The heating plant is also configured for future expansion.

Atrium Heating and Cooling

A combination of radiant flooring and ventilation units serve as the heating and cooling for the three story atrium. A water to water heat pump serves the radiant flooring while three ground source heat pumps ventilate the space. Both systems are connected to the geothermal well located in the parking lot.

Office Space Heating and Cooling

Four central air handling units, located on the roof, serve as the heating and cooling for the office spaces, supplying to the zones shown in Figure 1. The perimeter spaces are ventilated by fan powered boxes with a hot water coil. Interior spaces are ventilated by VAV boxes.

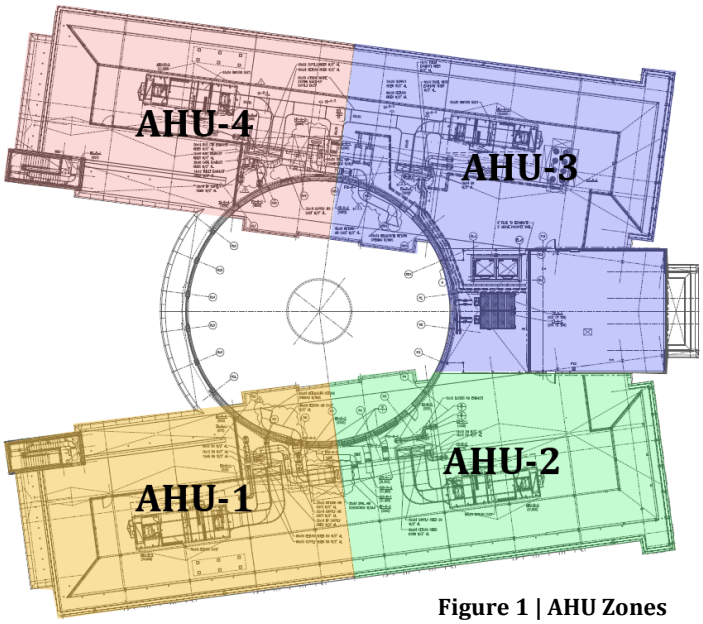

Figure 1 | AHU Zones

ASHRAE Standard 62.1-2007 Ventilation Evaluation

62.1 | Section 5 | Systems and Equipment | Evaluation

62.1 | Section 5.1 | Natural Ventilation

Windows are non-operable and all spaces are ventilated mechanically; therefore natural ventilation is not used as a mean of ventilation.

62.1 | Section 5.2 | Ventilation Air Distribution

A minimum air flow rate through each terminal unit is specified in the construction documents and complies with Section 6 as discussed later in the report.

62.1 | Section 5.3 | Exhaust Duct Location

Exhaust ducts are all negatively pressurized relative to the spaces through which they pass.

62.1 | Section 5.4 | Ventilation System Controls

A fully integrated Building Management and Control System (BMCS) incorporating direct digital control (DDC) is used to control and monitor the HVAC system. During Occupied mode the AHUs will maintain setpoint. During Unoccupied mode, the AHUs will start intermittently in cool-down mode when predefined quantities of associated zones call for cooling.

62.1 | Section 5.5 | Air Stream Surfaces

All general ductwork is to be constructed in accordance with HVAC Construction Standards-Metal and Flexible, Second Edition, 1995 published by SMACNA, which is in compliance with this section.

62.1 | Section 5.6 | Outdoor Air Intakes

All outdoor air intakes are in compliance with Section 5.6.1, where as they are located at the minimum separation distance. The outdoor units' intake louver are specified to be tested in accordance with AMCA 500-L99 to with stand wind driven rain water entrainment as well as withstand rain intrusion. Removable bird screens are provided for each louver. See Section 5.11 for Drain Pan compliance.

62.1 | Section 5.7 | Local Capture of Contaminants

Exhaust fans are located in areas where contaminates are produced, such as the main electrical and mechanical room, the kitchen, and restrooms. These areas are ducted directly to the outdoors.

62.1 | Section 5.8 | Combustion

Emergency generators are located in a separate enclosure on the project site. Two 60kW Microturbines are located on the roof and vents directly to the outdoors. Natural gas boilers are located in the penthouse, which is served by its own heating and ventilating unit.

62.1 | Section 5.9 |Particulate Matter Removal

Filters have a minimum efficiency reporting value (MERV) of 8 and are in accordance with ASHRAE Standard 52.

62.1 | Section 5.10 |Dehumidification Systems

The building will be positively pressurized in the summer and neutral during the winter months. It is specified that the new headquarters building will maintain a maximum of 65% relative humidity, therefore complying with this section.

62.1 | Section 5.11 | Drain Pans

The drains pans are of double walled construction, with a minimum slope of no less than .25 inches in one foot. All cooling coils are specified to have drain pans made of stainless steel.

62.1 | Section 5.12 | Finned-Tube Coils and Heat Exchangers

A plate and frame heat exchanger is used and does not have finned-tube coils.

62.1 | Section 5.13 | Humidifiers and Water-Spray Systems

NRUCFC Headquarters does not utilize humidifiers or water-spray systems; therefore this section does not apply.

62.1 | Section 5.14 | Access for Inspection, Cleaning, and Maintenance

Proper clearances are provided on the plans to be able to remove any necessary components. All ventilation equipment has panels provided to access any components that need to be changed or maintained. The AHUs' access panels will have an 8"x10" sealed glass and wire view window. Terminal units have access panels as well.

62.1 | Section 5.15 | Building Envelope and Interior Surfaces

A combination of a bentonite and crystalline waterproofing is used on the footing and slab on grade foundation. An air-barrier system is used to retard water penetration from the exterior. Pipes and ducts will be properly insulated if their temperature has to the potential to drop below the dew point.

62.1 | Section 5.16 | Buildings with Attached Parking Garages

There is no attached parking garage; therefore this section does not apply.

62.1 | Section 5.17 | Air Classification and Recirculation

A majority of the building is office space therefore is Class 1 air. The air in the fitness center, café, restrooms, and mechanical/electrical rooms is Class 2 air and the exhaust is ducted directly to the outdoors so that it does not recirculate with the Class 1 air.

62.1 | Section 5.18 | Requirements for Buildings Containing ETS Areas and ETS-Free Areas

NRUCFC Headquarters is a LEED® Gold and meets the prerequisite of ETS Control.

62.1 | Section 6 Evaluation

The four air handling units that serve the two wings of the building and three heat pumps that serve the atrium and lobby were selected for analysis. Each air handler severs a zone on each of the three floors. The spaces within the zones have similar purposes and therefore were able to be analyzed as one zone. The equations that are used in the following analysis are from ASHRAE Standard 62.1-2007 Section 6.

Ventilation Rate Procedure Analysis

Breathing Zone Outdoor Airflow (V_{bz})

$$V_{bz} = (R_{p+} * P_z) + (R_a * A_z) \quad \text{(Eqn. 6-1)}$$

Where | A_z = Zone Floor Area
P_z = Zone Population
R_p = Outdoor Airflow Rate per Person (cfm/person)
R_a = Outdoor Airflow Rate per Unit Area (cfm/ft^2)

Zone Air Distribution Effectiveness (E_z)

$$E_z = 1 \quad \text{(From Table 6-2)}$$

Zone Outdoor Airflow (V_{oz})

$$V_{oz} = V_{bz}/ E_z \quad \text{(Eqn. 6-2)}$$

Primary Outdoor Air Fraction (Z_p)

$$Z_p = V_{oz}/ V_{pz} \quad \text{(Eqn. 6-5)}$$

Where | V_{pz}=Zone Primary Airflow

System Ventilation Efficiency (E_v)

$$E_v = 1 \quad \text{(From Table 6.3)}$$

Uncorrected Outdoor Air Intake (V_{ou})

$$V_{ou} = D * \Sigma_{\text{all zones}}(R_p * P_z) + \Sigma_{\text{all zones}}(R_a * A_z) \quad \text{(Eqn. 6-6)}$$

Occupant Diversity (D)

$$D = P_s/ \Sigma_{\text{all zones}} P_z \quad \text{(Eqn. 6-7)}$$

Where | P_s = System Population

Outdoor Air Intake (V_{ot})

$$V_{ot} = V_{ou}/E_v \quad \text{(Eqn. 6-8)}$$

The results of the Ventilation Rate Procedures show that NRUCFC Headquarters supplies sufficient outdoor air to its spaces based on occupancy and room area. The occupancy for the zones was known and not calculated based on ASHRAE Standard 62.1. Because the areas of individual spaces were unknown, spaces such as the café and fitness center were grouped with general office space. These spaces require more outdoor air, but because they are a small fraction of the zone area and the design outdoor air quantity well exceeds the minimum, they can be assumed to be in compliance. A summary of the Ventilation Rate Procedure is shown in Table 1 below.

Ventilation Rate Summary			
System	**Design Outdoor Air Quantity (CFM)**	**Minimum Outdoor Air Intake Required (CFM)**	**Compliance**
AHU-1	4500	1818	**Y**
AHU-2	4050	1895	**Y**
AHU-3	4610	2045	**Y**
AHU-4	4000	1879	**Y**
HP 1-3	2710	1158	**Y**

Table 1 | Ventilation Rate Summary

ASHRAE Standard 62.1-2007 Summary

The NRUCFC Headquarters complies will all applicable sub-sections of Section 5. As discussed earlier in the report, the new headquarters building is also in compliance with Section 6. The four air handling units as well as three heat pumps are able to supply ample amounts of outside air to the two wings of the building, the atrium, and the lobby.

ASHRAE Standard 90.1-2007 Energy Design Evaluation

90.1 | Section 5 | Building Envelope

90.1 | Section 5.1.4 | Climate

As shown in Figure 2 below, the NRUCFC Headquarters is located Sterling, VA (Northern Virginia) and is classified as Climate Zone 4-A. Zone 4-A is defined as being Mixed-Humid climate meaning the region has mixed weather condition with periods of high humidity.

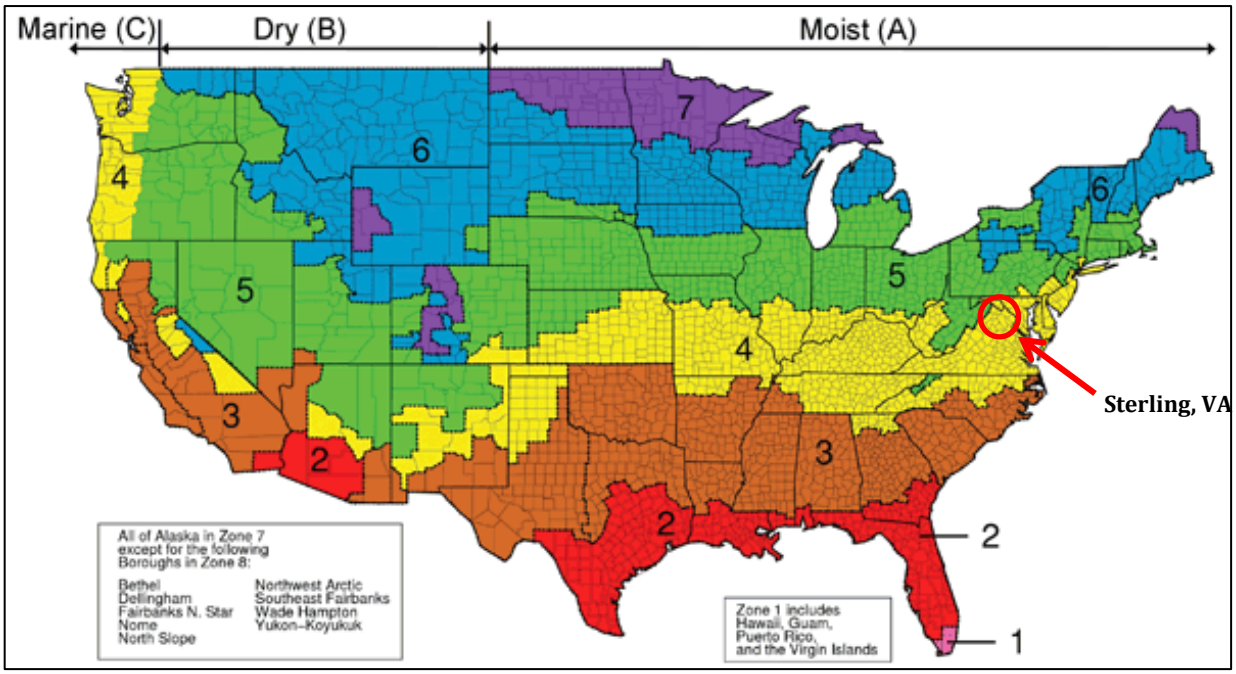

Figure 2 | Climate Zones for United States Location | ASHRAE 90.1-2007

90.1 | Section 5.4 | Mandatory Provisions

The building envelope is specified to be sealed at any opening to minimized air leakage. Air leakage through fenestration and doors shall not exceed .01 cfm per square foot for a complete module or bay. All fenestration must comply with North American Fenestration Standard Voluntary Performance Specification for Windows, Skylights and Glass Doors. Vestibules in the new headquarters building comply with the minimum distance of 7 feet between the interior and exterior door in the closed position.

90.1 | Section 5.5 | Prescriptive Building Envelope Option

The U and R values for the exterior walls, roof, and slab-on-grade were not found on the construction drawings. An inquiry has been sent to the architect but at this time, no response has been received.

Exact information on fenestration is unknown at this time. Upon a visual inspection, the glazing looks to exceed the maximum of 40% of the wall area however shading devices are used on the areas with the largest amount of fenestration, therefore allowing the NRUCFC Headquarters to comply with Section 5.5.

90.1 | Section 6 | Heating, Ventilation, and Air Conditioning

90.1 | Section 6.2 | Compliance Paths

Compliance with Section 6 can be achieved through either the Simplified Approach for HVAC Systems (Section 6.3) or Mandatory Provisions (Section 6.4) and Prescriptive Path (Section 6.5).

90.1 | Section 6.3 | Simplified Approach Option for HVAC Systems

To use the simplified approach, the project must be two stories or less and have a gross floor area less than 25,000 square feet. The new headquarters building is three stories and is approximately 120,000 square feet; therefore the simplified approach may not be used.

90.1 | Section 6.4 | Mandatory Provisions

The terminal units are controlled by temperature sensors in each zone and are responsible for both heating and cooling. CO_2 sensors accompany the temperature sensors so that when the space is not occupied, the minimum air flow is delivered and when occupied more outdoor air can be brought to the space. The cooling coil and heating coil modulate in sequence to maintain a set point of 55 degrees Fahrenheit. During unoccupied hours, the AHUs will start intermittently in cool-down mode when a zone calls for cooling with a night setback or a temporary occupancy override.

In the case of a fire emergency, all isolation and fire/smoke dampers in the exhaust ductwork opens and a rooftop exhaust fan activates.

90.1 | Section 6.5 | Prescriptive Path

There is no economizer requirement for climate zone 4A. The heating and cooling controls don't allow for simultaneous heating and cooling of the same zone.

The controls for hydronic heat pumps are specified to comply with the standards set forth in Section 6.5.2.2.3 of Standard 90.1-2007.

The supply and return fans on the four AHU's are in compliance with Section 5. The atrium smoke exhaust fans are not in compliance. The fan exhausting the fire pump room and the locker room is also not in compliance as shown in Table 2 below.

Fan Compliance				
Unit	**HP**	**CFM**	**CFM*0.0015**	**Compliance(Y/N)**
ASX-R-1	50	21400	32.10	**N**
ASX-R-2	50	21400	32.10	**N**
ASX-R-3	50	21400	32.10	**N**
EX-1-1	0.75	650	0.98	**Y**
EX-1-3	5	6500	9.75	**Y**
EX-1-4	0.75	600	0.90	**Y**
EX-1-5	0.75	400	0.60	**N**
EX-R-1	0.5	530	0.80	**Y**
EX-R-2	1.5	825	1.24	**N**

EX-R-3	0.46	500	0.75	**Y**
EX-R-4	0.5	580	0.87	**Y**
EX-R-5	1.5	2330	3.50	**Y**
EX-R-6	0.75	800	1.20	**Y**
EX-R-7	2	4800	7.20	**Y**
EX-R-8	2	3500	5.25	**Y**
TX-1-1	-	100	0.15	**Y**
TX-R-1	0.25	975	1.46	**Y**
TX-R-2	0.75	1800	2.70	**Y**
TX-R-3	0.25	975	1.46	**Y**
TX-R-4	0.25	1050	1.58	**Y**
KX-R-1	1	1330	2.00	**Y**
TF-1-1	0.25	200	0.30	**Y**
TF-2-1	0.25	250	0.38	**Y**
RF-R-2	3	5400	8.10	**Y**
RF-R-3	3	4500	6.75	**Y**
AHU-1 Supply	30	24000	36.00	**Y**
AHU-1 Return	20	24000	36.00	**Y**
AHU-2 Supply	30	21000	31.50	**Y**
AHU-2 Return	15	21000	31.50	**Y**
AHU-3 Supply	25	18000	27.00	**Y**
AHU-3 Return	15	18000	27.00	**Y**
AHU-4 Supply	30	21000	31.50	**Y**
AHU-4 Return	15	21000	31.50	**Y**

Table 2 | Fan HP Compliance

90.1 | Section 7 | Service Water Heating

The two hot water boilers located in the mechanical penthouse have an efficiency of 90%. The minimum efficiency for a gas boiler is 80%; therefore the headquarters building is in compliance with this section.

90.1 | Section 8 | Power

The new headquarters building electrical system complies with the voltage drop provisions of less than 2% for feeders and less than 3% for branch circuits. Power plans and riser diagrams are provided with the construction drawings.

90.1 | Section 9 | Lighting

To determine lighting power compliance with Section 9, the Building Area Method was used. NRUCFC Headquarters can be classified as an office building and cannot exceed a lighting power density (LPD) of 1.0 Watts/square foot. The calculated LPD is 0.93 W/ft^2, complying with this section. A table of lighting fixtures and their power densities can be found in Appendix B. Each office space contains an occupancy sensor to control the lighting and save energy by turning the lights off when the space is not occupied.

90.1 | Section 10 | Other Equipment

None of the pump motor efficiency's complies with Section 10. All pumps listed in Table 3 utilize variable frequency drives.

Pump Motor Efficiency Compliance						
Pump	**Service**	**RPM**	**HP**	**Efficiency (%)**	**Min. Efficiency (%)**	**Compliance (Y/N)**
GWP-1-1	Primary Glycol Water	1800	10	74.14	89.5	N
GWP-1-2	Primary Glycol Water	1800	10	74.14	89.5	N
GWP-1-3	Primary Glycol Water	1800	10	74.14	89.5	N
GWP-1-4	Secondary Glycol	1800	10	70.31	89.5	N
GWP-1-5	Secondary Glycol	1800	10	70.31	89.5	N
GWP-1-6	Secondary Glycol	1800	10	70.31	89.5	N
CWP-1-1	Condenser Water	1800	15	78.92	91.0	N
CWP-1-2	Condenser Water	1800	15	78.92	91.0	N
CWP-1-3	Condenser Water	1800	15	78.92	91.0	N
HWP-P-1	Hot Water System	1800	7.5	60.05	88.5	N
HWP-P-2	Hot Water System	1800	7.5	60.05	88.5	N
HWP-P-3	Hot Water System	1800	7.5	60.05	88.5	N
CHWP-P-1	Chilled Water System	1800	7.5	66.66	88.5	N
CHWP-P-2	Chilled Water System	1800	7.5	66.66	88.5	N
GTWP-1-1	Geothermal Primary	1800	7.5	67.14	88.5	N
GTWP-1-2	Geothermal Primary	1800	7.5	67.14	88.5	N
GTWP-1-3	Geothermal Secondary	1800	5	70.72	87.5	N
GTWP-1-4	Geothermal Secondary	1800	5	70.72	87.5	N
HXWP-1-1	WTR to WTR HP to PFHPX-1-1	1800	5	46	87.5	N
HXWP-1-2	WTR to WTR HP to PFHPX-1-2	1800	5	46	87.5	N

Table 3 | Pump Motor Efficiency

ASHRAE Standard 90.1-2007 Summary

NRUCFC Headquarters complies with most sections of Standard 90.1-2007. The fan HP in the headquarters building doesn't comply with Section 6.5.3. The atrium smoke fans and the exhaust fans for the fire pump room and locker room require too much horsepower. None of the pump motor efficiencies are compliant with Section 10. Because NRUCFC Headquarters is not compliant with these sections, it is not in compliance with Standard 90.1-2007.

Appendices

Appendix A | Ventilation Rate Procedure Calculations

Building:	NRUCFC Hsadquaters										
System Tag/Name:	AHU-1										
Operating Condition Description:											
Units (select from pull-down list)	IP										
Inputs for System	**Name**	**Units**					**System**				
Floor area served by system	As	sf					23534				
Population of area served by system (including diversity)	Ps	P	100%	diversity			75				
Design primary supply fan airflow rate	Vpsd	cfm					9,200				
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					5.0				
Inputs for Potentially Critical zones								Potentially Critical Zones			
Zone Name	*Zone title turns purple italic for critical zone(s)*							First Floor South	Second Floor Offices	*Third Floor Offices*	
Zone Tag								FPB-1-1, 2, 3, 4 , 5, 6, 8, 9; VAV-VAV-1-1, 2	FPB-2-1, 2, 3, 4, 5, 7, 9; VAV-2-2, 3, 19, 20	FPB-3-1, 2, 3, 4, 5, 6, 7;VAV-3-1,2	
Space type		Select from pull-down list						Office space	Office space	Office space	
Floor Area of zone	Az	sf						7,575	7872	8087	
Design population of zone	Pz	P	(default value listed; may be overridden)					25	25	25	
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm						2,820	3495	2885	
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A									
Local recirc. air % representative of ave system return air	Er										
Inputs for Operating Condition Analyzed											
Percent of total design airflow rate at conditioned analyzed	Ds	%					100%	100%	100%	100%	
Air distribution type at conditioned analyzed		Select from pull-down list						CS	CS	CS	
Zone air distribution effectiveness at conditioned analyzed	Ez							1.00	1.00	1.00	
Primary air fraction of supply air at conditioned analyzed	Ep										
Results											
Ventilation System Efficiency	Ev						**0.98**				
Outdoor air intake required for system	Vot	cfm					**1818**				
Outdoor air per unit floor area	Vot/As	cfm/sf					**0.08**				
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p					**24.2**				
Outdoor air as a % of design primary supply air	Ypd	cfm					**20%**				
Detailed Calculations											
Initial Calculations for the System as a whole											
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	9200					
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	1787					
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.19					
Initial Calculations for individual zones											
OA rate per unit area for zone	Raz	cfm/sf						0.06	0.06	0.06	
OA rate per person	Rpz	cfm/p						5.00	5.00	5.00	
Total supply air to zone (at condition being analyzed)	Vdz	cfm						2820	3495	2885	
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=			579.5	597.3	610.2	
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=			580	597	610	
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=			1.00	1.00	1.00	
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=			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	
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=			0.21	0.17	0.21	
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=			0.21	0.17	0.21	
System Ventilation Efficiency											
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=			0.99	1.02	0.98	
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.98**					
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.94					
Minimum outdoor air intake airflow											
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**1818**					
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.20**					
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	1904					
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.21					
OA Temp at which Min OA provides all cooling											
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrl	=	-14					

Building:	NRUCFC Headquarters										
System Tag/Name:	AHU-2										
Operating Condition Description:											
Units (select from pull-down list)	IP										
Inputs for System	**Name**	**Units**					**System**				
Floor area served by system	As	sf					23534				
Population of area served by system (including diversity)	Ps	P	100%	diversity			75				
Design primary supply fan airflow rate	Vpsd	cfm					8,555				
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					5.0				
Inputs for Potentially Critical zones								**Potentially Critical Zones**			
Zone Name			*Zone title turns purple italic for critical zone(s)*					***First Floor South***	**Second Floor Offices**	**Third Floor Offices**	
Zone Tag								**FPB-1-7, 10, 11, 12, 13; VAV-1-3, 4, 5**	**FPB-2-11, 13, 14, 15, 16; VAV-2-4, 5, 6, 7, 8**	**FPB-3-8, 9, 10, 11, 12, 29;VAV-3-4, 5, 13, 14, 15**	
Space type		Select from pull-down list						**Office space**	**Office space**	**Office space**	
Floor Area of zone	Az	sf						7,575	7872	8087	
Design population of zone	Pz	P	(default value listed; may be overridden)					25	25	25	
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm						2,715	2810	3030	
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A									
Local recirc. air % representative of ave system return air	Er										
Inputs for Operating Condition Analyzed											
Percent of total design airflow rate at conditioned analyzed	Ds	%					100%	100%	100%	100%	
Air distribution type at conditioned analyzed		Select from pull-down list						CS	CS	CS	
Zone air distribution effectiveness at conditioned analyzed	Ez							1.00	1.00	1.00	
Primary air fraction of supply air at conditioned analyzed	Ep										
Results											
Ventilation System Efficiency	Ev						**1.00**				
Outdoor air intake required for system	Vot	cfm					**1795**				
Outdoor air per unit floor area	Vot/As	cfm/sf					**0.08**				
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p					**23.9**				
Outdoor air as a % of design primary supply air	Ypd	cfm					**21%**				
Detailed Calculations											
Initial Calculations for the System as a whole											
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	8555					
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	1787					
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.21					
Initial Calculations for individual zones											
OA rate per unit area for zone	Raz	cfm/sf						0.06	0.06	0.06	
OA rate per person	Rpz	cfm/p						5.00	5.00	5.00	
Total supply air to zone (at condition being analyzed)	Vdz	cfm						2715	2810	3030	
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=			579.5	597.3	610.2	
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=			580	597	610	
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=			1.00	1.00	1.00	
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=			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	
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=			0.21	0.21	0.20	
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=			0.21	0.21	0.20	
System Ventilation Efficiency											
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=			1.00	1.00	1.01	
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**1.00**					
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.94					
Minimum outdoor air intake airflow											
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**1795**					
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.21**					
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	1908					
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.22					
OA Temp at which Min OA provides all cooling											
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrl	=	-9					

Building:	NRUCFC Hsadquaters									
System Tag/Name:	AHU-3									
Operating Condition Description:										
Units (select from pull-down list)	IP									
Inputs for System	**Name**	**Units**				**System**				
Floor area served by system	As	sf				22602				
Population of area served by system (including diversity)	Ps	P	100%	diversity		60				
Design primary supply fan airflow rate	Vpsd	cfm				8,810				
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				5.0				
Inputs for Potentially Critical zones							**Potentially Critical Zones**			
Zone Name							***First Floor Offices***	**Second Floor Offices**	**Thrid Floor Offices**	
							FPB-1-14, 15; VAV-1-6, 7	**FPB-2-27, 30, 31, 32, 33, 34, 35; VAV-2-12, 13, 14, 15, 16, 17, 18**	**FPB-3-13, 14, 15, 16, 17, 18, 19, 28, 30, 31;VAV-3-6, 7, 8, 12, 16, 17**	
Zone Tag										
Space type		Select from pull-down list					**Office space**	**Office space**	**Office space**	
Floor Area of zone	Az	sf					6,643	7872	8087	
Design population of zone	Pz	P	(default value listed; may be overridden)				30	15	15	
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm					1,450	3630	3730	
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A								
Local recirc. air % representative of ave system return air	Er									
Inputs for Operating Condition Analyzed										
Percent of total design airflow rate at conditioned analyzed	Ds	%				100%	100%	100%	100%	
Air distribution type at conditioned analyzed		Select from pull-down list					CS	CS	CS	
Zone air distribution effectiveness at conditioned analyzed	Ez						1.00	1.00	1.00	
Primary air fraction of supply air at conditioned analyzed	Ep									
Results										
Ventilation System Efficiency	Ev					**0.81**				
Outdoor air intake required for system	Vot	cfm				**2045**				
Outdoor air per unit floor area	Vot/As	cfm/sf				**0.09**				
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p				**34.1**				
Outdoor air as a % of design primary supply air	Ypd	cfm				**23%**				
Detailed Calculations										
Initial Calculations for the System as a whole										
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	8810				
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	1656				
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.19				
Initial Calculations for individual zones										
OA rate per unit area for zone	Raz	cfm/sf					0.06	0.06	0.06	
OA rate per person	Rpz	cfm/p					5.00	5.00	5.00	
Total supply air to zone (at condition being analyzed)	Vdz	cfm					1450	3630	3730	
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=		548.6	547.3	560.2	
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=		549	547	560	
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=		1.00	1.00	1.00	
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=		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	
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=		0.38	0.15	0.15	
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=		0.38	0.15	0.15	
System Ventilation Efficiency										
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=		0.81	1.04	1.04	
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.81**				
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.77				
Minimum outdoor air intake airflow										
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**2045**				
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.23**				
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	2146				
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.24				
OA Temp at which Min OA provides all cooling										
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrl	=	-1				

Building:	NRUCFC Hsadquaters											
System Tag/Name:	AHU-4											
Operating Condition Description:												
Units (select from pull-down list)	IP											
Inputs for System	**Name**	**Units**					**System**					
Floor area served by system	As	sf					22602					
Population of area served by system (including diversity)	Ps	P		100%	diversity		75					
Design primary supply fan airflow rate	Vpsd	cfm					8,810					
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					5.0					
Inputs for Potentially Critical zones								**Potentially Critical Zones**				
Zone Name								*First Floor North Offices &Corridors*	Second Floor Offices	Thrid Floor Offices		
	Zone title turns purple italic for critical zone(s)											
Zone Tag								FPB-1-16, 17, 18, 19, 20, 21; VAV-1-14, 15, 16, 17, 18, 19	FPB-2-17, 18, 19, 20, 21, 22, 24, 25, 36; VAV-2-9, 10, 11	FPB-3-20, 21, 22, 23, 24, 25, 26, 34;VAV-3-9, 10, 11, 19		
Space type		Select from pull-down list						Office space	Office space	Office space		
Floor Area of zone	Az	sf						4,563	7872	8087		
Design population of zone	Pz	P		(default value listed; may be overridden)				25	25	25		
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm						1,450	3630	3730		
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A										
Local recirc. air % representative of ave system return air	Er											
Inputs for Operating Condition Analyzed												
Percent of total design airflow rate at conditioned analyzed	Ds	%					100%	100%	100%	100%		
Air distribution type at conditioned analyzed		Select from pull-down list						CS	CS	CS		
Zone air distribution effectiveness at conditioned analyzed	Ez							1.00	1.00	1.00		
Primary air fraction of supply air at conditioned analyzed	Ep											
Results												
Ventilation System Efficiency	Ev						**0.92**					
Outdoor air intake required for system	Vot	cfm					**1879**					
Outdoor air per unit floor area	Vot/As	cfm/sf					**0.08**					
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p					**25.0**					
Outdoor air as a % of design primary supply air	Ypd	cfm					**21%**					
Detailed Calculations												
Initial Calculations for the System as a whole												
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	8810						
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	1731						
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.20						
Initial Calculations for individual zones												
OA rate per unit area for zone	Raz	cfm/sf						0.06	0.06	0.06		
OA rate per person	Rpz	cfm/p						5.00	5.00	5.00		
Total supply air to zone (at condition being analyzed)	Vdz	cfm						1450	3630	3730		
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=			398.8	597.3	610.2		
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=			399	597	610		
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=			1.00	1.00	1.00		
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=			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		
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=			0.28	0.16	0.16		
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=			0.28	0.16	0.16		
System Ventilation Efficiency												
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=			0.92	1.03	1.03		
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.92**						
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.87						
Minimum outdoor air intake airflow												
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**1879**						
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.21**						
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	1978						
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.22						
OA Temp at which Min OA provides all cooling												
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrl	=	-8						

Building:	NRUCFC Headquarters											
System Tag/Name:	Heat Pumps 1-3											
Operating Condition Description:												
Units (select from pull-down list)	IP											
Inputs for System	**Name**	**Units**					**System**					
Floor area served by system	As	sf					8556					
Population of area served by system (including diversity)	Ps	P	100%	diversity			60					
Design primary supply fan airflow rate	Vpsd	cfm					5,080					
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					5.0					
Inputs for Potentially Critical zones								**Potentially Critical Zones**				
Zone Name								*First Floor Atrium & Atrium Bridges*	Second Floor Lobby			
		Zone title turns purple italic for critical zone(s)										
Zone Tag												
Space type		Select from pull-down list						Lobbies	Lobbies			
Floor Area of zone	Az	sf						6,900	1656			
Design population of zone	Pz	P	(default value listed; may be overridden)					50	10			
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm						1,450	3630			
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A										
Local recirc. air % representative of ave system return air	Er											
Inputs for Operating Condition Analyzed												
Percent of total design airflow rate at conditioned analyzed	Ds	%					100%	100%	100%			
Air distribution type at conditioned analyzed		Select from pull-down list						CS	CS			
Zone air distribution effectiveness at conditioned analyzed	Ez							1.00	1.00			
Primary air fraction of supply air at conditioned analyzed	Ep											
Results												
Ventilation System Efficiency	Ev						**0.70**					
Outdoor air intake required for system	Vot	cfm					**1158**					
Outdoor air per unit floor area	Vot/As	cfm/sf					**0.14**					
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p					**19.3**					
Outdoor air as a % of design primary supply air	Ypd	cfm					**23%**					
Detailed Calculations												
Initial Calculations for the System as a whole												
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	=	5080						
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	813						
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.16						
Initial Calculations for individual zones												
OA rate per unit area for zone	Raz	cfm/sf						0.06	0.06			
OA rate per person	Rpz	cfm/p						5.00	5.00			
Total supply air to zone (at condition being analyzed)	Vdz	cfm						1450	3630			
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=			664.0	149.4			
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=			664	149			
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=			1.00	1.00			
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=			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			
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=			0.46	0.04			
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=			0.46	0.04			
System Ventilation Efficiency												
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=			0.70	1.12			
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.70**						
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.69						
Minimum outdoor air intake airflow												
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**1158**						
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	=	**0.23**						
Outdoor Air Intake Flow required to System (Table 6.3 Method)	Vot	cfm	=	Vou / Ev	=	1175						
OA intake req'd as a fraction of primary SA (Table 6.3 Method)	Y		=	Vot / Vps	=	0.23						
OA Temp at which Min OA provides all cooling												
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+dTrl	=	-3						

Appendix B | Lighting Power Density Calculations

Lighting Power Allowance						
Fixture	**W/fixture**	**1st**	**2nd**	**3rd**	**Penthouse**	**Total W**
AR1	280		3			840
CF2	72	6				432
PC3	104		1			104
PF1	108	5	43	50		10584
PF2	216	5	30	22		12312
PF3	432		4	14		7776
PF4a	171		8	16		4104
PF4b	342		1			342
PF5	164		20	20		6560
PF6	28		3			84
PV1	104	1				104
PV2	26	6				156
PV4	60		3	6		540
RB1	28		48	48		2688
RB2	28	4		6		280
RB2e	56	6				336
RB3	28	26				728
RC1	32	4	42	46		2944
RC1a	26	33				858
RC2	32	42	34	18		3008
RC3a	32	55	87	92		7488
RC3b	32	36	66	58		5120
RC4	32	49	20	16		2720
RC5	32		5	10		480
RC6	32	12				384
RC8	32		32	32		2048
RF1	54	4	4			432
RF2	54	130	16			7884
RF2d	56	20				1120
RF3a	98	33				3234
RF3c	98	2	6	12		1960
RF4b	112	6				672
RF6b	238	2				476
RF6d	70			3		210
RF7a	63	9				567
RF8	126		6	16		2772
RM3	39	4	13			663
RM4	39		9			351

RM5	125			9		1125
RR1	50	4	28	10		2100
RR2	100	2	12	18		3200
RR3	50	10				500
SC2	28	3				84
SF1	54	5				270
SF2	39	5				195
SF4a	35	26	14	12		1820
WF1	108	1				108
WF1a	54	1				54
WF4	54	8	8	8		1296
WF5	63	12	8	8		1764
A	64	38	8	8	34	5632
B	32			2		64
					Total Watts	**111,573**
					Total Area	**120,000**
					W/sq. ft.	**0.93**