NASA Langley Research Center – Administration Office Building One

Hampton, VA

TECHNICAL REPORT 1

ASHRAE Standard 62.1 Ventilation and Standard 90.1 Energy Design Evaluations

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Executive Summary

The purpose of this report is to evaluate the NASA Langley Research Center Administrative Building One compliance to the ASHRAE Standard 62.1-2013, Ventilation for Acceptable Indoor Air Quality, and Standard 90.1-2013, Energy Standard for Buildings Except Low Rise Residential. The NASA Langley Research Center Administrative Building One, which will be known as AOB1 in the remainder of this report, is an office building located in Hampton, VA and comprises primarily of open office space, private offices, small teaming rooms, and large conference rooms. The building has an under the floor air distribution system (UFAD) and a curtainwall system enclosure around most of the building.

After investigating AOB1's compliance with ASHRAE 62.1-2013, it was found that AHU-4 does not meet outdoor air requirements of Section 5.1, calculated from the process described in Section 6. This is due to a change in zone population between the original calculation and the final architectural layout. Because of this, AOB1 does not comply with Section 5.3, which calls for the equipment to maintain the proper outdoor air setpoint, even though the equipment is designed to do so. Additionally, Section 5.8 requires that the air handling units be equipped with MERV 8 filters. The building was designed to comply with the 2004 Standard, which required MERV 6 filters. The schedule calls for the use of MERV 7, which would have met compliance with the 2004 Standard but does not meet compliance with the 2013 Standard.

The investigation into AOB1's compliance with ASHRAE 90.1-2013 Sections 5-9 and 10.4.1 found that the building envelope did not comply with the current standard. The original U-values required by the 2004 Standard that was used at the time of design had higher allowances for roof and walls that are no longer compliant to the 2013 Standard. Additionally, the vertical fenestration surpassed the maximum 40% wall area required by the Standard. An in depth calculation using Normative Appendix C of ASHRAE 90.1-2013 would determine if the trade-off option for vertical fenestration is acceptable in this case and if the glazing is compliant.

In conclusion, AOB1 met compliance of most sections of ASHRAE 62.1 and 90.1-2013 Standards. Most cases for which compliance was not met was due to changes in the code between the year used in design and the current 2013 Standard.

Building Overview

NASA LANGLEY

The NASA Langley Research Center was founded in 1917 as the first civil aeronautical research laboratory, and currently has approximately 110 buildings that were constructed over 50 years ago. NASA decided to implement a five-phase revitalization program, which would replace existing buildings with newer, more efficient ones. Their goals for these new buildings were sustainability/efficiency, functionality of the interior environment, pedestrian friendly, and curb appeal. The revitalization program is known as the New Town program, and the first phase consisted of the construction of AOB1.

NEW TOWN PHASE 1

AOB1 is the new headquarters building for NASA's Langley Research Center. The project broke ground in July of 2009 and occupancy began in May 2011. The three story building is approximately 79,000 square feet, with a mechanical penthouse. The building was designed to give viewers a perception of flight. The image below, a rendering from the bridging drawings created by AECOM, demonstrates this original concept, with the glass curtainwall and metal paneling façade and parallelogram footprint with the overhanging upper floors.

Figure 1 – South façade rendering from AECOM Bridging Drawings

The exterior form matches the interior function, with the vertical form towards the center of the building indicating the location of the elevators and lobby. This vertical section also helps to separate the first floor into two sections: employee offices, with a glass façade providing adequate daylighting matching the rest of the building, and large conference rooms for hosting events with its stone façade and windows that are more practical for visual presentations (3)(4).

Mechanical Systems Overview

The air distribution system in AOB1 consists of five air handling units and one dedicated outdoor air unit with a heat recovery wheel. The primary air distribution system in the building is an under floor air distribution system (UFAD). The system serves all office spaces and teaming areas on all three floors. Each floor has an air handling unit (AHU-1, 2, 3) located on that floor which ducts into an open floor plenum that distributes to diffusers for the interior spaces and fan powered boxes (FPB) at the perimeter. There is ceiling return, where air is either recirculated to the air handling unit or relieved to the roof, where it goes through the enthalpy wheel at the dedicated outdoor air handling unit (DOAS) that provides pre-conditioned outdoor air for the building. This unit contains heating, cooling and reheat coils, and is set-up for dehumidification. There are four VAV's located in the penthouse that control the amount of OA distributed to each respective AHU. Figure 2 shows the mechanical system breakdown of the second floor.

- AHU-5 serves the large conference rooms (such as those in pink in Figure 2) of the upper floors separate of the UFAD system and is located in the penthouse.
- AHU-4 is located on the first floor and serves the large conference rooms on the first floor. It has its own OA louver and is not supplied by the DOAS unit.
- Blower coil units (BCU) serve the atrium and lobby spaces
- Fan coil units (FCU) are used for the IT room on each floor

All areas in white are not directly supplied, which include spaces such as stairwells, elevators, restrooms, kitchenettes, mechanical rooms and electrical rooms.

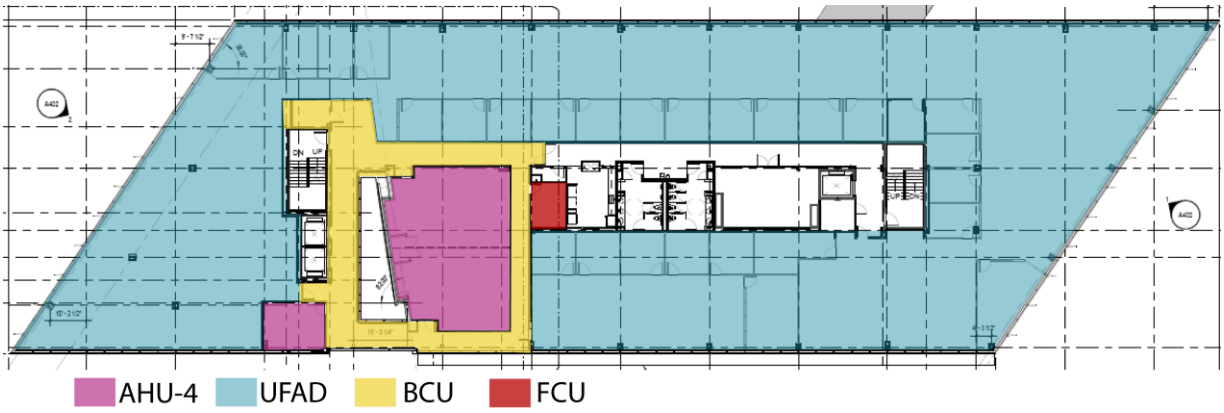

Figure 2 - Second Floor Mechanical System Overview

A geothermal transfer field handles the entire heating and cooling load of the building, with 90 boreholes that are six inches in diameter and 500 feet deep. The well field is connected to six water

to water heat pumps (WWHP) with scroll compressors and two sets of three-way control valves that allow the heat pumps to switch between cooling and heating operating, located in the penthouse. The WWHP's have an EER of fourteen and a heating COP of 3.25. Two geothermal water loop circulation pumps with variable frequency drives control the geothermal water loop.

ASHRAE Standard 62.1-2013 Section 5 Compliance

This section of the report evaluates the compliance of AOB1 with ASHRAE Standard 62.1-2013 Section 5. The building was originally designed to comply with the 2004 Standard. Information used to evaluate this compliance comes from the mechanical narrative, specifications, equipment submittals and construction drawings.

5.1 VENTILATION AIR DISTRIBUTION

AOB1 was designed to comply with ASHRAE 62.1-2014. The narrative provided by the mechanical engineer indicates that the ventilation requirements of section 6 of ASHRAE 62.1-2004 was met. A calculation was done to check compliance to the 2013 standard, the details of which can be found in APPENDIX B1. The design calls for separate plenums for supply and return and is anticipated to supply the correct amount of ventilation air to each floor-mounted terminal unit. The design documents specify 18% OA for AHU's serving the UFAD system and 30% OA for units serving the conference rooms. AHU-1, 2, 3, and 5, which are part of the DOAS unit, met compliance. However, AHU-4 did not meet compliance. See the Section 6 compliance section of this report for more information.

5.2 EXHAUST DUCT LOCATION

Exhaust air ducts for potentially harmful contaminants equipped with an exhaust fan and motorized damper that activates any time the air handling unit for that floor is on.

5.3 VENTILATION SYSTEM CONTROLS

The DOAS unit is equipped with a controller that modulates the damper on the penthouse VAV terminal units that supply OA to each AHU to maintain each units OA setpoint. However, the OA setpoint for AHU-4 does not comply with Section 6.

5.4 AIRSTREAM SURFACES

All ducts are made of sheet metal and comply with section 5.4.1 and 5.4.2 for mold and erosion control, and all equipment was specified to comply with these requirements. Compliance of the open air plenum is unknown.

5.5 OUTDOOR AIR INTAKES

The OA intake for the penthouse DOAS unit is located at least 60 feet away from any contaminant sources, well beyond the minimum distance required in Table 5.5.1, shown below. All other OA intakes also comply with these requirements. OA louvers are designed in such a way to ensure drainage from the center to the sides of the duct through the build-up of insulation to prevent rain entrainment. The mechanical narrative specifies that OA intakes are located a minimum of eight inches above the snow line and that snow drifts have been taken into account. No bird screening devices were specified.

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 3 - From ASHRAE 62.1-2013

5.6 LOCAL CAPTURE OF CONTAMINANTS

Any contaminants produced by noncombustion equipment is properly vented outdoors.

5.7 COMBUSION AIR

There are no fuel-burning appliances in AOB1, therefore ASHRAE 62.1 Section 5.7 does not apply.

5.8 PARTICULTE MATTER REMOVAL

AOB1 does not comply ASHRAE 62.1-2013 Section 5.8. The DOAS unit is scheduled for a MERV 8 filter, but all other air handling units are scheduled with MERV 7 filters. However, ASHRAE 62.1-2004, which is what AOB1 was designed for, only called for MERV 6 filters and would have therefore complied.

5.9 DEHUMIDIFICATION SYSTEMS

The space was designed for a relative humidity of 58% in the summer and the air handling units control sequence is to start dehumidification measures if the relative humidity exceeds 65%. Additionally, the DOAS unit and associated exhaust fan are designed for the same CFM, therefore AOB1 complies with section 5.9.

5.10 DRAIN PANS

Per specifications section 237433, drain plans are sloped 2%, or 0.25 in/ft, a slope greater than the minimum 0.125 in/ft required by section 5.10. This specification also states that the length was designed to comply with ASHRAE 62.1. All other drain pans listed in the specifications are also stated to comply with ASHRAE 62.1.

5.11 FINNED TUBE COILS AND HEAT EXCHANGERS

Drain pans are provided for all dehumidifying cooling coil assemblies in compliance with section 5.10. All air handling units comply with either the minimum 18 inch access door or have a pressure drop of less than 0.75 in wg across the coil.

5.12 HUMIDIFIERS AND WATER-SPRAY SYSTEMS

There are no humidifiers or water-spray systems in AOB1, therefore ASHRAE 62.1-2013 Section 5.12 does not apply.

5.13 VENTILATION EQUIPMENT ACCESS

Product brochures for the submitted air handling units and fan coil units discusses appropriate accessibility and serviceability of equipment components. The raised floor system covering the

supply air plenum was designed for easy removal of floor panels to access equipment and air distribution system beneath, so compliance with section 5.13.3 is met.

5.14 BUILDING ENVELOPE AND INTERIOR SURFACES

AOB1's building envelope was designed for a continuous vapor barrier, horizontally and vertically, as called-out in Figure 4. Figure 5 further demonstrates this vapor barrier design and shows an area that required sealant and slope for water mitigation away from the wall. Additionally, duct insulation is detailed in specification section 230713, equipment in 230716, and piping insulation in 230719.

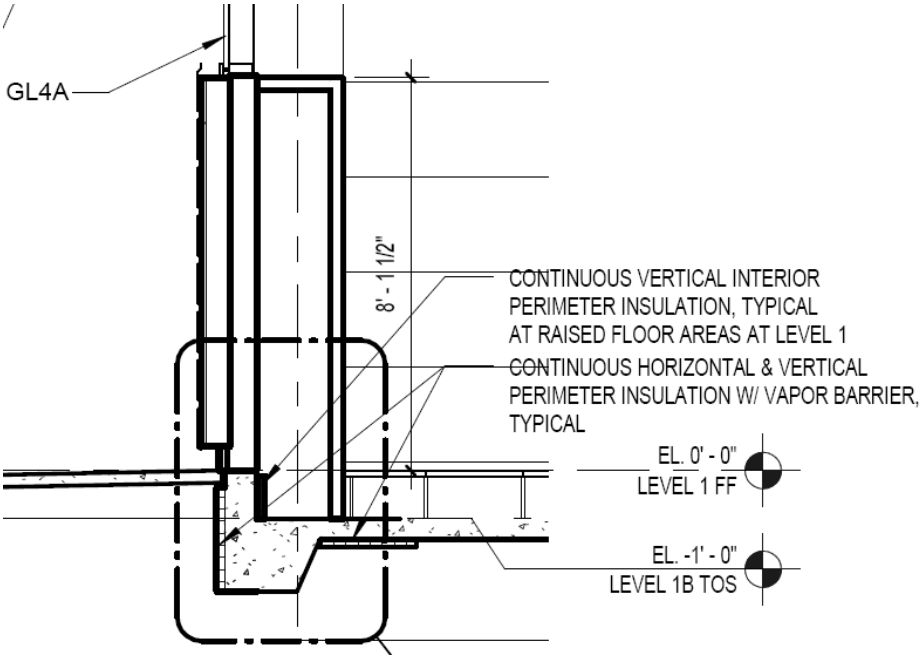

Figure 4 - West Facade Wall Section – Detail 2 on Drawing A502

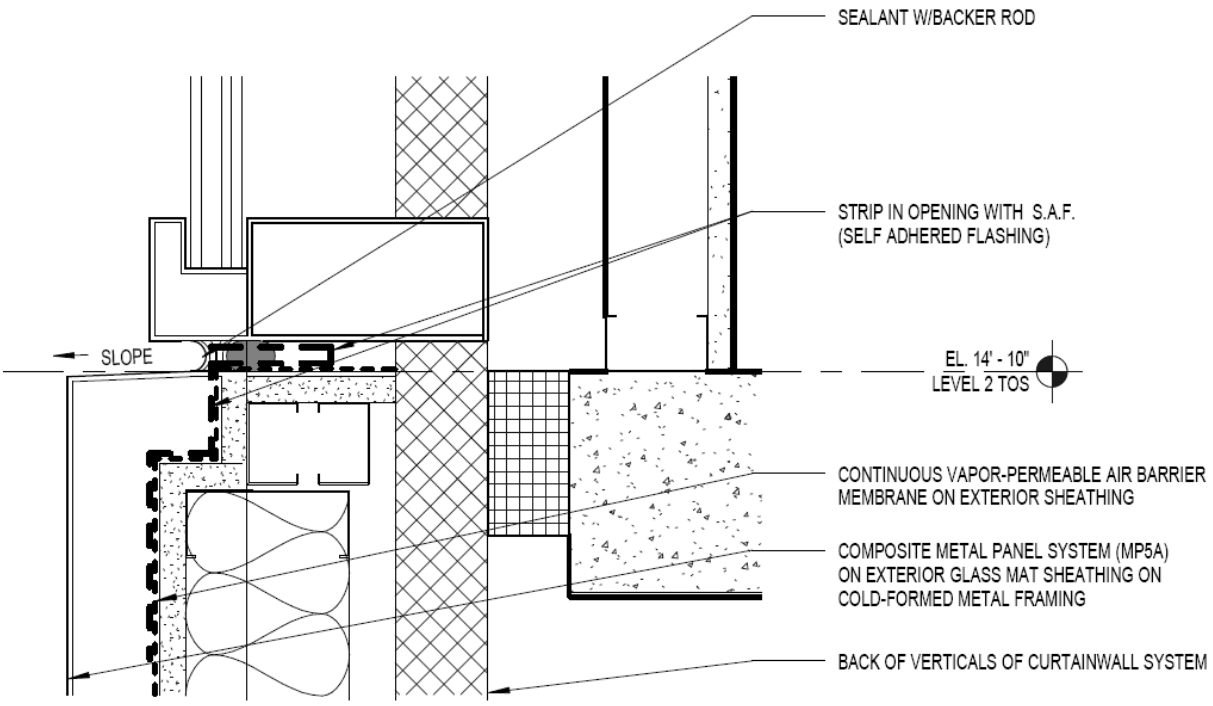

Figure 5 - Detail Section of Sill @ Second Floor - Detail 3 on Drawing A550

5.15 BUILDINGS WITH ATTACHED PARKING GARAGES

AOB1 does not contain an attached parking garage, therefore ASHRAE 62.1 Section 5.15 does not comply.

5.16 AIR CLASSIFICATION AND RECIRCULATION

According to Table 6.2.2.1, which is provided below, the majority of spaces in AOB1, such as offices and conference rooms, are air class 1 and can therefore be recirculated together and used to transfer to all areas of the building, such as unsupplied corridors and toilet exhaust make-up. Areas that do not fall into air class 1, such as toilet rooms and janitors closets, are directly exhausted.

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone *(Continued)*
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

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	
Coffee stations	5	2.5	0.06	0.3		20	8	4	1
Conference/meeting	5	2.5	0.06	0.3		50	6	3.1	1
Corridors	—	—	0.06	0.3		—			1
Occupiable storage rooms for liquids or gels	5	2.5	0.12	0.6	B	2	65	32.5	2
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
Office Buildings									
Breakrooms	5	2.5	0.12	0.6		50	7	3.5	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3		2	35	17.5	1
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
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Banks or bank lobbies	7.5	3.8	0.06	0.3		15	12	6.0	1
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1

GENERAL NOTES FOR TABLE 6.2.2.1

1 **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
2 **Environmental Tobacco Smoke:** This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free 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.

Figure 6 - From ASHRAE 62.1-2013

5.17 REQUIREMENTS FOR BUILDINGS CONTAINING ETS AREAS AND ETS-FREE AREAS

AOB1 is a smoke-free building, therefore ASHRAE 62.1-2013 Section 5.17 does not apply. Additionally, the outdoor air intake for the DOAS unit is located on the roof, sufficiently away from any smoking areas located outside the building.

ASHRAE Standard 62.1-2013 Section 6 Compliance

ASHRAE Standard 62.1-2013 Section 6 evaluates the building outdoor air requirements. A calculation was performed for all spaces served by the air handling units, including the DOAS system which contains AHU-1, 2, 3 and 5, and AHU-4, which has its own individual OA intake.

6.2 VENTILATION RATE PROCEDURE

The first step in calculating the amount of outdoor air that must be distributed by the air handling units is to determine the outdoor airflow required in the breathing zone. This is determined by the following equation:

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

Where P_z is the design zone population and A_z is the area of the zone. R_p and R_a are the airflow rate per person and per unit area, respectively, required for the space type. Table 6.2.2.1 of the Standard lists these rates, and can be found in APPENDIX A.

All areas of the building are classified as a Multiple-Zone Recirculating System and therefore require further calculation to determine the outdoor air intake requirements. The outdoor airflow required for the zone, V_{oz}, is affected by the air distribution effectiveness, E_z. This value represents the effectiveness of the air supply system configuration to distribute air to the breathing zone and is determined from Table 6.2.2.2 of the Standard, shown below.

$$V_{oz} = \frac{V_{bz}}{E_z}$$

The primary outdoor air fraction is the ratio of outdoor air required in the zone to the total airflow being supplied, V_{pz},, including return air. It is represented by Z_{pz}. The zone with the lowest primary outdoor air fraction determines the system ventilation efficiency, E_z, for the calculation. This value can be found using the Table 6.2.5.2 or Appendix A of the Standard. The Appendix A calculation was used for this analysis for all zones and should be referenced for further information on this process.

Table 1 - From ASHRAE 62.1-2013

TABLE 6.2.2.2 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	1.0
Note: For lower velocity supply air, $E_z = 0.8$.	
Floor supply of cool air and ceiling return, provided that the vertical throw is greater than 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) or more above the floor	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification, or underfloor air distribution systems where the vertical throw is less than or equal to 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor	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 supply" includes any point above the breathing zone.
4. "Floor supply" 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 ASHRAE Standard 129[17] for all air distribution configurations except unidirectional flow.

The uncorrected outdoor air intake, V_{ou}, is the amount of outdoor air required for all the zones, with total system population taken into account.

$$V_{ou} = D \sum (R_p * P_z) + \sum (R_a + A_z)$$

For this calculation, a diversity of 100% was used to account for spaces that may be occupied by more people than the original design anticipated, in response to data obtained from the MEP firm that suggests this may occur, particularly for zones served by AHU-4. The final design for the conference rooms served by AHU-4 called for an occupancy of 64 people, which was used for the calculation; however it is reported that an over seat count of up to 28 people could be anticipated, but is not designed for such.

Finally, the outdoor air intake flow, V_{ot}, is the ratio of the uncorrected outdoor air intake to the ventilation system effectiveness:

$$V_{ot} = V_{ou}/E_v$$

This is the outdoor air flow required at each air handling unit. A full calculation is displayed in APPENDIX B1. The OA values from the design schedules and the results from this analysis are found in Table 2.

Table 2 - OA Calculation Results

	EQUIPMENT	DESIGN CFM	OA CALC RESULTS	COMPLIANCE
DOAS	AHU-1	3060	1605	YES
	AHU-2	3060	2019	YES
	AHU-3	3060	1804	YES
	AHU-5	1950	1395	YES
	DOAS:	11000	6823	YES
	AHU-4	780	837	NO

All AHU's connected to the DOAS system met compliance. However, AHU-4 did not meet compliance. Through comparison of the calculation for AHU-4 from the original design, which can also be found in APPENDIX B2, it was found that the population for the two conference rooms was set at 58 people. The final design of the space called for 64 seats, and this was the value used in the new calculation that created a higher OA requirement than the AHU was designed for, causing AHU-4 to not meet compliance.

6.5 EXHAUST VENTILATION

An exhaust ventilation calculation was also performed for the pantries and restrooms. The exhaust rates required for these spaces are found in ASHRAE 62.1-2013 Table 6.5 and can be found in APPENDIX C. Through this calculation it was discovered that the second and third floor public restrooms do not meet ventilation requirements by a deficit of 50 CFM per room. Specific information for this calculation can be found in Table 3. All other spaces were found to comply.

Table 3 - Exhaust Ventilation

ZONE	OCCUPANCY CATEGORY	EXHAUST RATE (CFM/UNIT)	# UNITS	AREA (SF)	REQUIRED EXHAUST RATE	DESIGN EXHAUST RATE
109	toilets - public	50 CFM/UNIT	6	360	300	300
110	toilets - public	50 CFM/UNIT	6	360	300	300

111	kitchenettes	0.3 CFM/SF	-	250	75	250
209	toilets - public	50 CFM/UNIT	4	225	200	150
210	toilets - public	50 CFM/UNIT	4	225	200	150
211	kitchenettes	0.3 CFM/SF	-	250	75	250
309	toilets - public	50 CFM/UNIT	4	225	200	150
310	toilets - public	50 CFM/UNIT	4	225	200	150
311	kitchenettes	0.3 CFM/SF	-	250	75	250
324	kitchenettes	0.3 CFM/SF	-	120	36	75
325	toilets-private	25 CFM/UNIT	1	93	25	75

ASHRAE 62.1 CONCLUSION

The main air distribution system used in AOB1 consists of four air handling units, AHU-1, 2, 3, 5, which are fed by a dedicated outdoor air unit for ventilation air. All four units associated with this DOAS unit comply with the outdoor airflow requirements obtained by the ASHRAE 62.1-2013 Section 6 procedure. Another air handling unit, AHU-4, supplies the conference rooms on the first floor and has its own outdoor air intake. Due to a change in zone population between the original design calculation and the final furniture layout, this unit does not comply with the outdoor air requirements. This causes AOB1 to be non-compliant with ASHRAE 62.1-2013 Section 5.1 and 5.3. Additionally, the building was designed to meet the 2004 standard, which required MERV 6 filters on the units, and this was exceeded by the scheduling of MERV 7 filters. However, the 2013 standard requires MERV 8 filters and therefore AOB1 does not comply with ASHRAE 62.1-2013 Section 5.8.

As for exhaust ventilation, the ASHRAE 62.1-2013 Standard specifies a rate of 50 CFM/unit for public toilets per Table 6.5 of the Standard. This would have required 200 CFM of exhaust from each public toilet room on the second and third floor. Only 150 CFM exhaust was designed for these rooms, therefore the building does not comply with ASHRAE 62.1-2013 Section 6.5.

ASHRAE Standard 90.1-2013 Compliance

This section of the report evaluates the compliance of AOB1 with ASHRAE Standard 90.1-2013. The building was originally designed to comply with the 2004 Standard.

BUILDING ENVELOPE – SECTION 5

AOB1 falls into climate zone 4A, as stated in Table B1-1 in Appendix B, and the building is classified as nonresidential.

SECTION 5.2

Section 5.2 requires compliance with sections 5.1, 5.4, 5.7 and 5.8 and either 5.5 or 5.6.

SECTION 5.4

The building envelope contains a continuous air barrier, in accordance with ASTM E 2178. There are two main building entries, connecting into the lobby, and they are both separated from the exterior by vestibules. These vestibules have a distance of ten feet between doors, which exceeds the minimum seven foot requirement.

SECTION 5.5

According to Table 5.5-4 in the Standard, which can be found in APPENDIX D, vertical fenestration is to be limited to 40% of the building, and the skylight is limited to 3% of the roof area. The skylight does comply with this limit. As shown in Table 4, the area of vertical fenestration exceeds the 40% limit. Normative Appendix C provides instructions for determining if the Trade-Off option of 5.6 applies. For the purpose of this report, it is assumed that, being a LEED Platinum building, the fenestration meets compliance.

Table 4 - Fenestration and Doors Percentage

	NORTH	SOUTH	EAST	WEST	ROOF
Surface area (SF)	12585	12450	5020	4950	22500
Fenestration area (SF)	5839	6613	2590	2025	585
% Fenestration	46	53	51.5	41	2.6

Additionally, this section requires that all assembly U values for the building envelope comply with those values provided in Table 5.5-4 of the standard, which is summarized below in Table 5:

Table 5 - Assembly U-Values

	2013 U-VALUE	U-VALUED INSTALLED	COMPLIANT?	2004 U-VALUE
Roof:	0.037	0.063	NO	0.063
Walls, above grade:	0.060	0.113	NO	0.113
Vertical fenestration:	0.420	0.37	YES	For 40-50%: 0.46
Skylight:	0.500	0.46	YES	1.17

The roof and walls are not complaint with the 2013 Standard, but they were complaint with the 2004 Standard that the building was designed for. For Table 5.5-4 of the Standard for both years, see APPENDIX D. In addition to those U-values, a max SHGC of 0.400 is required for both vertical fenestration and skylights. Both requirements are met, at 0.252 and 0.340, respectively.

HEATING, VENTILATING AND AIR CONDITIONING: SECTION 6

Section 6 of ASHRAE 62.1-2013 covers compliance of the HVAC system design. The simplified approach option is not applicable to AOB1. Therefore, Section 6.3 does not apply and Section 6.4 compliance must be evaluated.

SECTION 6.4

Compliance with this section requires that equipment listed in Table 6.8.1-1 through 6.8.1-13 of the Standard meet the minimum efficiency listed. This equipment requires the water to water, water loop (cooling mode) systems have a minimum of 10.6 EER and a heating mode minimum of 3.7 COP_h, which are both compliant.

HVAC controls requirements of Section 5.4.3 are also met. Because open plenums are used throughout the building with short duct run distances through conditioned spaces, the insulation R-value requirements listed in Table 6.8.2-1 and Table 6.8.2-2 of the Standard do not apply or require no specific R-value.

The hot water system in the building is designed for 100-140^{0}F and the chilled water system is designed for 55-65^{0}F. The thermal conductivity of the specified insulation is 0.24, which complies with the values found in Table 6.8.3-1 and 6.8.3-2 of the Standard.

SECTION 6.5

According to Table 6.5.1-1 of the Standard, an economizer should be required; however, there does not appear to be a control sequence for an economizer on the air handling units or dedicated outdoor air unit and therefore does not comply with ASHRAE 90.1-2013 Section 6.5.1.

Table 6 - Fan Power Limitation Requirements

	HP	CFM	CFM*0.0015	COMPLAINT?
AHU-1, 2, 3	20	17000	25.5	YES
AHU-4	3	2600	3.9	YES
AHU-5	7.5	6500	9.75	YES
DOAS	15	11000	16.5	YES

Table 6 summarizes the fan power limitation compliance of Section 6.5.3.1.1, from Table 6.5.3.1-1 for variable volume flow rates. All air handling units are compliant.

Section 6.5.6 covers energy recovery. Because the ventilation system is 100% OA during all operating hours, there is no requirement for the design supply fan airflow rate.

SERVICE WATER HEATING: SECTION 7

Section 7 of ASHRAE 62.1-2013 covers compliance of the service water heating. The service water for heating comes from the ground field loop through the water to water heat exchangers. All piping insulation meets minimum requirements. The building contains no boilers or water heaters for the HVAC hot water system.

POWER: SECTION 8

Compliance for Section 8: Power requires compliance to sections 8.1, 8.4 and 8.7. A 6600 volt, 1200 amp high voltage feeder supplies the building from a nearby existing substation. It connects to a 1500 kVA 6600 volt primary 480Y/277 volt secondary substation unit. A 100 amp, 480 volt automatic transfer switch serves the emergency systems. Additionally, a 250 kW, 480Y/277 volt diesel generator and two photovoltaic systems that provide solar power to the electrical system are used in the building. An energy management control system remotely monitors the energy use of the building.

The building has a three-phase 75 kVA, low-voltage transformer. Table 8.4.4 from the Standard, shown below, requires that a 75 kVA transformer be 98% efficient. According to the electrical submittals for division 262200, the transformer complies.

TABLE 8.4.4 Minimum Nominal Efficiency Levels for 10 CFR 431 Low-Voltage Dry-Type Distribution Transformers[a]

Single-Phase Transformers		Three-Phase Transformers	
kVA[b]	Efficiency,%[c]	kVA[b]	Efficiency,%[c]
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
		750	98.8
		1000	98.9

a. A low-voltage distribution transformer is a transformer that is air-cooled, does not use oil as a coolant, has an input voltage ≤600 V, and is rated for operation at a frequency of 60 Hz.
b. Kilovolt-ampere rating.
c. Nominal efficiencies shall be established in accordance with the 10 CFR 431 test procedure for low-voltage dry-type transformers.

Figure 7- From ASHRAE 90.1-2013

LIGHTING: SECTION 9

The Building Area Method of Section 9.5 was used for the lighting calculations of this analysis.

SECTION 9.4

The lighting control system for the building consists of daylight sensors in the open office areas, occupancy sensor switches in the private offices and small conference rooms, and separate occupancy sensors in the larger meeting rooms.

SECTION 9.5

AOB1 is classified as having an office building area type, with a LPD of 0.82 W/ft^2. The building grow lighted floor area is about 70,000 square feet.

$$Lighting\ power\ allowance = LPD * Area$$

The lighting power allowance of the building is approximately 57,400 W. The lighting calculations performed by the electrical engineer estimate that 62,272 W were designed. According to this calculation, the ASHRAE 90.1-2007 LPD were higher than the 2013 Standard, making it compliant with the 2007 Standard but not the 2013 Standard. Figure 8 is the table from the lighting calculation document obtained from H.F. Lenz, dated for April of 2010.

Floor Level	Room Area (Square Feet)	Allowable Lighting Power Density as per ASHRAE 90.1-2007 (W/ft2)	Allowable Power as per ASHRAE 90.1-2007 (Watts)	Design Lighting Power Density as per H.F. Lenz Design (W/ft2)	Design Power as per H.F. Lenz Design (Watts)
Level 1	21,501	1.13	24,268	0.88	18,972.80
Level 2	23,809	1.10	26,247	0.93	22,026.80
Level 3	23,023	1.11	25,659	0.92	21,272.20

Figure 8 - LPD, from H.F. Lenz Interior Lighting Calculations

OTHER EQUIPMENT: SECTION 10

ASHRAE 90.1-2010 Section 10 outlines compliance requirements for other equipment. Section 10.4.1 Electric Motors is the section to be analyzed for this report.

This section states that motors with a power rating of at least 1 hp and less than 200 hp must comply with the Energy Independence and Security Act of 2007. Table 10.8-1 and 10.8-2 of the Standard shows these requirements and can be found in APPENDIX E. The Energy Independence and Security Act of 2007 requirements are defined by NEMA MG 1, which is referenced in specification 230513 – common motor requirements for HVAC equipment. Therefore, AOB1 meets the requirements of ASHRAE 90.1-2010 Section 10.4.1.

ASHRAE 90.1 CONCLUSION

AOB1 complies with Sections 6-9 and 10.4.1 of the ASHRAE 90.1-2013 Standard. However, it does not comply with all requirements of Section 5, building envelope. The vertical fenestration exceeded the limit of <40% of the building area. An in depth calculation must be done to determine if the building trade-off option of Normative Appendix C would be suitable to meet compliance, but is not done for this analysis. Additionally, the roof and wall U-values, which complied with the 2004 Standard, do not comply with the 2013 Standard. Therefore, AOB1 does not comply with ASHRAE 90.1-2013 Standard Section 5 for building envelope.

Resources

1. ANSI/ASHRAE. (2013). Standard 62.1-2013, *Ventilation for Acceptable Indoor Air Quality*. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.
2. ANSI/ASHRAE. (2013). Standard 90.1-2013, *Energy Standard for Buildings Except Low Rise Residential Buildings*. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.
3. Flynn, J. (2008, January 1). Visualizing the Future of NASA Langley Research Center. Retrieved September 12, 2014, from http://proceedings.esri.com/library/userconf/feduc08/papers/feduc.pdf
4. Quinville, T. (2009, September 16). New Town NASA Langley Research Center's Revitalization Initiative Report to Hampton Roads SAME Chapter. Retrieved September 12, 2014, from http://posts.same.org/hamptonroads/NASANewTownSep2009.pdf

Renderings from AECOM bridging documents: www.aecom.com

APPENDIX A

ASHRAE 62.1-2013 Table 6.2.2.1 Minimum Ventilation Rates in Breathing Zone

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

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
Multiuse 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
Kitchen (cooking)	7.5	3.8	0.12	0.6		20	14	7.0	2
General									
Break rooms	5	2.5	0.06	0.3		25	7	3.5	1

GENERAL NOTES FOR TABLE 6.2.2.1

1 Related requirements: The rates in this table are based on all other applicable requirements of this standard being met.

2 Environmental Tobacco Smoke: This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free 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.

ITEM-SPECIFIC NOTES FOR TABLE 6.2.2.1

A For high-school and college libraries, use values shown for Public Assembly Spaces—Libraries.

B Rate may not be sufficient when stored materials include those having potentially harmful emissions.

C Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture. "Deck area" refers to the area surrounding the pool that would be expected to be wetted during normal pool use, i.e., when the pool is occupied. Deck area that is not expected to be wetted shall be designated as a space type (for example, "spectator area").

D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.

E When combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation and/or source control shall be provided.

F Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.

G Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone *(Continued)*
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

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	
Coffee stations	5	2.5	0.06	0.3		20	8	4	1
Conference/meeting	5	2.5	0.06	0.3		50	6	3.1	1
Corridors	—	—	0.06	0.3		—			1
Occupiable storage rooms for liquids or gels	5	2.5	0.12	0.6	B	2	65	32.5	2
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
Office Buildings									
Breakrooms	5	2.5	0.12	0.6		50	7	3.5	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3		2	35	17.5	1
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
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Banks or bank lobbies	7.5	3.8	0.06	0.3		15	12	6.0	1
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1

GENERAL NOTES FOR TABLE 6.2.2.1

1 **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.

2 **Environmental Tobacco Smoke:** This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free 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.

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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.

ITEM-SPECIFIC NOTES FOR TABLE 6.2.2.1

A For high-school and college libraries, use values shown for Public Assembly Spaces—Libraries.

B Rate may not be sufficient when stored materials include those having potentially harmful emissions.

C Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture. "Deck area" refers to the area surrounding the pool that would be expected to be wetted during normal pool use, i.e., when the pool is occupied. Deck area that is not expected to be wetted shall be designated as a space type (for example, "spectator area").

D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.

E When combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation and/or source control shall be provided.

F Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.

G Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone *(Continued)*
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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	
Freezer and refrigerated spaces (<50°F)	10	5	0	0	E	0	0	0	2
General manufacturing (excludes heavy industrial and processes using chemicals)	10	5.0	0.18	0.9		7	36	18	3
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	10	5	0.12	0.6	B	2	70	35	2
Sorting, packing, light assembly	7.5	3.8	0.12	0.6		7	25	12.5	2
Telephone closets	—	—	0.00	0.0		—			1
Transportation waiting	7.5	3.8	0.06	0.3		100	8	4.1	1
Warehouses	10	5	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

GENERAL NOTES FOR TABLE 6.2.2.1

1 Related requirements: The rates in this table are based on all other applicable requirements of this standard being met.

2 Environmental Tobacco Smoke: This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free 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.

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						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	
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	0.12	0.6		20	14	7.0	2
Sports and Entertainment									
Gym, sports arena (play area)	20	10	0.18	0.9	E	7	45	23	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	2
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 6.2.2.1

1 **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.

2 **Environmental Tobacco Smoke:** This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free 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.

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D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.

E When combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation and/or source control shall be provided.

F Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.

G Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

vided such value is the product of the net occupiable area of the ventilation zone and the default occupant density listed in Table 6.2.2.1.

6.2.2.2 Zone Air Distribution Effectiveness. The zone air distribution effectiveness (E_z) shall be no greater than the default value determined using Table 6.2.2.2.

Note: For some configurations, the default value depends upon space and supply air temperature.

6.2.2.3 Zone Outdoor Airflow. The zone outdoor airflow (V_{oz}), i.e., the outdoor airflow rate that must be provided to the ventilation zone by the supply air distribution system, shall be determined in accordance with Equation 6.2.2.3.

$$V_{oz} = V_{bz}/E_z \qquad (6.2.2.3)$$

6.2.3 Single-Zone Systems. For ventilation systems wherein one or more air handlers supply a mixture of outdoor air and recirculated air to only one ventilation zone, the

APPENDIX B1

ASHRAE 62.1-2013 OA Calculation for AOB1

DOAS: 6823

AHU-1 **1605**

Equip.	Zone:	Floor Area (Az)	Zone Population (Pz)	Space type	Rp	Ra	Rp*Pz	Ra*Az	Vbz	Ez	Voz	Vpz	Zpz	Ev	Vps	Vot	D	Vou	Xs	Evz
AHU-1	1st floor UFAD	15780	119	office space	5	0.06	595	946.8	1542	0.7	2203	17000	0.130	0.961	17000	1604	1	1542	0.091	0.961
		Total Pz:	119			Total:	595	946.8	1542		2203			Total:	17000				Ev system:	0.961
	Ps=	119																		

AHU-2 **2019**

Equip.	Zone:	Floor Area (Az)	Zone Population (Pz)	Space type	Rp	Ra	Rp*Pz	Ra*Az	Vbz	Ez	Voz	Vpz	Zpz	Ev	Vps	Vot	D	Vou	Xs	Evz
AHU-2	2nd floor UFAD	19685	148	office space	5	0.06	740	1181.1	1921	0.7	2744	17000	0.161	0.952	17000	2019	1	1921	0.113	0.952
		Total Pz:	148			Total:	740	1181.1	1921		2744			Total:	17000				Ev system:	0.952
	Ps=	148																		

AHU-3 **1804**

Equip.	Zone:	Floor Area (Az)	Zone Population (Pz)	Space type	Rp	Ra	Rp*Pz	Ra*Az	Vbz	Ez	Voz	Vpz	Zpz	Ev	Vps	Vot	D	Vou	Xs	Evz
AHU-3	3nd floor UFAD	18750	120	office space	5	0.06	600	1125	1725	0.7	2464	17000	0.145	0.957	17000	1803	1	1725	0.101	0.957
		Total Pz:	120			Total:	600	1125	1725		2464			Total:	17000				Ev system:	0.957
	Ps=	120																		

AHU-5 **1395**

Equip.	Zone:	Floor Area (Az)	Zone Population (Pz)	Space type	Rp	Ra	Rp*Pz	Ra*Az	Vbz	Ez	Voz	Vpz	Zpz	Ev	Vps	Vot	D	Vou	Xs	Evz
FPB-219, 220	conference room	1460	62	conference/meeting	5	0.06	310	87.6	398	0.7	568	740	0.768	0.742	2030	1394	1	1035	0.510	0.742
FPB-221	215 conference r	230	10	conference/meeting	5	0.06	50	13.8	64	0.7	91	125	0.729	1.967	610	526	1	1035	1.696	1.967
FPB-323	318 conference r	635	18	conference/meeting	5	0.06	90	38.1	128	0.7	183	305	0.600	1.489	950	695	1	1035	1.089	1.489
FPB-321	314 conference	1500	54	conference/meeting	5	0.06	270	90	360	0.7	514	700	0.735	0.796	1950	1300	1	1035	0.531	0.796
FPB-322	315 conference r	250	14	conference/meeting	5	0.06	70	15	85	0.7	121	150	0.810	1.648	710	628	1	1035	1.457	1.648
		Total Pz:	158			Total:	790	244.5	1035		1478			Total:	6250				Ev system:	0.742
	Ps=	158																		

AHU-4 **837**

Equip.	Zone:	Floor Area (Az)	Zone Population (Pz)	Space type	Rp	Ra	Rp*Pz	Ra*Az	Vbz	Ez	Voz	Vpz	Zpz	Ev	Vps	Vot	D	Vou	Xs	Evz
AHU-4	117A & 117B	1460	64	conference/meeting	5	0.06	320	87.6	408	0.8	510	765	0.666	0.493	2590	836	1	413	0.159	0.493
		Total Pz:	64			Total:	320	87.6											Ev system:	0.493
	Ps=	65																		

APPENDIX B2

ASHRAE 62.1-2004 OA Calculation from H.F. Lenz original design

H.F. LENZ COMPANY

Subject NASA AOB1 **Date:** Jan-2010

HFL #:. 2009-0185.01 **Calculated by:** CBH

ANSI/ASHRAE Standard 62.1-2004

Ventilation for Acceptable Indoor Air Quality

Ventilation Rate Procedure (VRP)

AHU-4

Zones served by system	Space type	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Ez	Voz	Vpz	Vpzm %	Vpzm	Zp	
105A Conference Room	Conference / meeting	800	30.0	6.5	0.078	195	62.4	0.8	322	1365	30	410	0.79	
105B Conference Room	Conference / meeting	690	28.0	6.5	0.078	182	53.8	0.8	295	1235	30	371	0.80	*
										2,600				

Ps	System population, maximum simultaneious # of occupants of space served by system	64.00
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/SPz	0.91
SRp	Summation of Rp Values	377.00
SRa	Summation of Ra Values	116.22
Vou	Uncorrected outdoor air intake, = D*SRp*Pz +SRa*Az, cfm	457.88

SYSTEM EFFICIENCY

Max Zp	Max Zp	0.80		
Ev	System ventilation efficiency, Table 6.3 based on maxZp	0.60		
			Percent outdoor air intake	
Vot	Minimum outdoor air intake, Vou/Ev, cfm	763.13 CFM	**29%**	= Vot/Sum of Vpz

LEGEND

Az	Floor area of zone, ft2
Pz	Zone population, largest # of people expected to occupy zone
Rp	Area outdoor air rate from Table 6.1, cfm/ft2
Ra	People outdoor air rate from Table 6.1, cfm/person
Ez	Zone air distribution effectiveness, Table 6.2
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm
Vpz	Primary airflow to zone from air handler. **In VAV systems, use the design value.** cfm
Vpzm	The minimum value of the primary airflow to zone from air handler. **In CAV systems, Vpzm = Vpz.** cfm
Zp	Primary outdoor air fraction, Voz/Vpzm

APPENDIX C

ASHRAE 62.1-2013 Table 6.5 Minimum Exhaust Rates

TABLE 6.5 Minimum Exhaust Rates

Occupancy Category	Exhaust Rate, cfm/unit	Exhaust Rate, cfm/ft^2	Notes	Exhaust Rate, L/s·unit	Exhaust Rate, L/s·m^2	Air Class
Arenas	—	0.50	B	—	—	1
Art classrooms	—	0.70		—	3.5	2
Auto repair rooms	—	1.50	A	—	7.5	2
Barber shops	—	0.50		—	2.5	2
Beauty and nail salons	—	0.60		—	3.0	2
Cells with toilet	—	1.00		—	5.0	2
Copy, printing rooms	—	0.50		—	2.5	2
Darkrooms	—	1.00		—	5.0	2
Educational science laboratories	—	1.00		—	5.0	2
Janitor closets, trash rooms, recycling	—	1.00		—	5.0	3
Kitchenettes	—	0.30		—	1.5	2
Kitchens—commercial	—	0.70		—	3.5	2
Locker/dressing rooms	—	0.25		—	1.25	2
Locker rooms	—	0.50		—	2.5	2
Paint spray booths	—	—	F	—	—	4
Parking garages	—	0.75	C	—	3.7	2
Pet shops (animal areas)	—	0.90		—	4.5	2
Refrigerating machinery rooms	—	—	F	—	—	3
Residential kitchens	50/100	—	G	25/50	—	2
Soiled laundry storage rooms	—	1.00	F	—	5.0	3
Storage rooms, chemical	—	1.50	F	—	7.5	4
Toilets—private	25/50	—	E, H	12.5/25	—	2
Toilets—public	50/70	—	D, H	25/35	—	2
Woodwork shop/classrooms	—	0.50		—	2.5	2

NOTES:

A Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.

B When combustion equipment is intended to be used on the playing surface additional dilution ventilation and/or source control shall be provided.

C Exhaust not required if two or more sides comprise walls that are at least 50% open to the outside.

D Rate is per water closet and/or urinal. Provide the higher rate where periods of heavy use are expected to occur, e.g., toilets in theatres, schools, and sports facilities. The lower rate may be used otherwise.

E Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during normal hours of use, the lower rate may be used. Otherwise use the higher rate.

F See other applicable standards for exhaust rate.

G For continuous system operation, the lower rate may be used. Otherwise use the higher rate.

H Exhaust air that has been cleaned to meet Class 1 criteria from Section 5.16.1 shall be permitted to be recirculated.

6.4.3 Control and Accessibility. The means to open required operable openings shall be readily accessible to building occupants whenever the space is occupied. Controls shall be designed to properly coordinate operation of the natural and mechanical ventilation systems.

6.5 Exhaust Ventilation. The Prescriptive Compliance Path or the Performance Compliance Path shall be used to meet the requirements of this section. Exhaust makeup air may be any combination of outdoor air, recirculated air, and transfer air.

6.5.1 Prescriptive Compliance Path. The design exhaust airflow shall be determined in accordance with the requirements in Table 6.5.

6.5.2 Performance Compliance Path. The exhaust airflow shall be determined in accordance with the following subsections.

6.5.2.1 Contaminant Sources. Contaminants or mixtures of concern for purposes of the design shall be identified. For each contaminant or mixture of concern, indoor sources

APPENDIX D

ASHRAE 90.1-2013 and 2007 Table 5.5-4 Building Envelope Requirements for Climate Zone 4 (A, B, C)

Table 5.5-4 Building Envelope Requirements for Climate Zone 4 (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-0.032	R-30 c.i.	U-0.032	R-30 c.i.	U-0.093	R-10 c.i.
Metal Building[a]	U-0.037	R-19 + R-11 Ls or R-25 + R-8 Ls	U-0.037	R-19 + R-11 Ls or R-25 + R-8 Ls	U-0.082	R-19
Attic and Other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
Walls, above Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal Building	U-0.060	R-0 + R-15.8 c.i.	U-0.050	R-0 + R-19 c.i.	U-0.162	R-13
Steel Framed	U-0.064	R-13 + R-7.5 c.i.	U-0.064	R-13 + R-7.5 c.i	U-0.124	R-13
Wood Framed and Other	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.089	R-13
Wall, below Grade						
Below Grade Wall	C-0.119	R-7.5 c.i.	C-0.092	R-10 c.i.	C-1.140	NR
Floors						
Mass	U-0.057	R-14.6 c.i.	U-0.051	R-16.7 c.i.	U-0.107	R-6.3 c.i.
Steel Joist	U-0.038	R-30	U-0.038	R-30	U-0.052	R-19
Wood Framed and Other	U-0.033	R-30	U-0.033	R-30	U-0.051	R-19
Slab-on-Grade Floors						
Unheated	F-0.520	R-15 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.843	R-20 for 24 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10 for 24 in.
Opaque Doors						
Swinging	U-0.500		U-0.500		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC
Vertical Fenestration, 0%–40% of Wall		(for all frame types)			(for all frame types)			(for all frame types)	
Nonmetal framing, all	U-0.35			U-0.35			U-0.51		
Metal framing, fixed	U-0.42			U-0.42			U-0.73		
Metal framing, operable	U-0.50	SHGC-0.40	1.10	U-0.50	SHGC-0.40	1.10	U-0.81	NR	NR
Metal framing, entrance door	U-0.77			U-0.68			U-0.77		
Skylight, 0%–3% of Roof									
All types	U-0.50	SHGC-0.40	NR	U-0.50	SHGC-0.40	NR	U-1.15	NR	NR

* The following definitions apply: c.i. = continuous insulation (see Section 3.2), FC = filled cavity (see Section A2.3.2.5), Ls = liner system (see Section A2.3.2.4), NR = no (insulation) requirement.

a. When using the R-value compliance method for metal building roofs, a thermal spacer block is required (see Section A2.3.2).

TABLE 5.5-4 Building Envelope Requirements For Climate Zone 4 (A,B,C)

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maxi-mum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.063	R-15.0 ci	U-0.218	R-3.8 ci
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.081	R-13.0
Walls, Above-Grade						
Mass	U-0.151[a]	R-5.7 ci[a]	U-0.104	R-9.5 ci	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.134	R-10.0
Steel-Framed	U-0.124	R-13.0	U-0.064	R-13.0 + R-7.5 ci	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Wall, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.107	R-6.3 ci	U-0.087	R-8.3 ci	U-0.322	NR
Steel-Joist	U-0.052	R-19.0	U-0.038	R-30.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.051	R-19.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-0.950	R-7.5 for 24 in.	F-0.840	R-10 for 36 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Non-Swinging	U-1.450		U-0.500		U-1.450	
Fenestration	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Opera-ble)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**
Vertical Glazing,% of Wall						
0-10.0%	U_{fixed}-0.57 U_{oper}-0.67	$SHGC_{all}$-0.39 $SHGC_{north}$-0.49	U_{fixed}-0.57 U_{oper}-0.67	$SHGC_{all}$-0.39 $SHGC_{north}$-0.49	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-NR $SHGC_{north}$NR
10.1-20.0%	U_{fixed}-0.57 U_{oper}-0.67	$SHGC_{all}$-0.39 $SHGC_{north}$-0.49	U_{fixed}-0.57 U_{oper}-0.67	$SHGC_{all}$-0.39 $SHGC_{north}$-0.49	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-NR $SHGC_{north}$NR
20.1-30.0%	U_{fixed}-0.57 U_{oper}-0.67	$SHGC_{all}$-0.39 $SHGC_{north}$-0.49	U_{fixed}-0.57 U_{oper}-0.67	$SHGC_{all}$-0.39 $SHGC_{north}$-0.49	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-NR $SHGC_{north}$NR
30.1-40.0%	U_{fixed}-0.57 U_{oper}-0.67	$SHGC_{all}$-0.39 $SHGC_{north}$-0.49	U_{fixed}-0.57 U_{oper}-0.67	$SHGC_{all}$-0.39 $SHGC_{north}$-0.49	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-NR $SHGC_{north}$NR
40.1-50.0%	U_{fixed}-0.46 U_{oper}-0.47	$SHGC_{all}$-0.25 $SHGC_{north}$-0.36	U_{fixed}-0.46 U_{oper}-0.47	$SHGC_{all}$-0.25 $SHGC_{north}$-0.36	U_{fixed}-0.98 U_{oper}-1.02	$SHGC_{all}$-NR $SHGC_{north}$NR
Skylight with Curb, Glass,% of Roof						
0-2.0%	U_{all}-1.17	$SHGC_{all}$-0.49	U_{all}-0.98	$SHGC_{all}$-0.36	U_{all}-1.98	$SHGC_{all}$-NR
2.1-5.0%	U_{all}-1.17	$SHGC_{all}$-0.39	U_{all}-0.98	$SHGC_{all}$-0.19	U_{all}-1.98	$SHGC_{all}$-NR
Skylight with Curb, Plastic,% of Roof						
0-2.0%	U_{all}-1.30	$SHGC_{all}$-0.65	U_{all}-1.30	$SHGC_{all}$-0.62	U_{all}-1.90	$SHGC_{all}$-NR
2.1-5.0%	U_{all}-1.30	$SHGC_{all}$-0.34	U_{all}-1.30	$SHGC_{all}$-0.27	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}-0.58	$SHGC_{all}$-0.36	U_{all}-1.36	$SHGC_{all}$-NR
2.1-5.0%	U_{all}-0.69	$SHGC_{all}$-0.39	U_{all}-0.58	$SHGC_{all}$-0.19	U_{all}-1.36	$SHGC_{all}$-NR

[a]Exception to A3.1.3.1 applies.

APPENDIX E

ASHRAE 90.1-2013

Table 10.8-1 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype I) Except Fire-Pump Electric Motors

Table 10.8-2 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype II), Except Fire-Pump Electric Motors

TABLE 10.8-1 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype I), Except Fire-Pump Electric Motors[a]

	Full-Load Efficiency, %					
	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
Number of Poles ⇒	2	4	6	2	4	6
Synchronous Speed (RPM) ⇒	3600	1800	1200	3600	1800	1200
Motor Horsepower						
1	77.0	85.5	82.5	77.0	85.5	82.5
1.5	84.0	86.5	86.5	84.0	86.5	87.5
2	85.5	86.5	87.5	85.5	86.5	88.5
3	85.5	89.5	88.5	86.5	89.5	89.5
5	86.5	89.5	89.5	88.5	89.5	89.5
7.5	88.5	91.0	90.2	89.5	91.7	91.0
10	89.5	91.7	91.7	90.2	91.7	91.0
15	90.2	93.0	91.7	91.0	92.4	91.7
20	91.0	93.0	92.4	91.0	93.0	91.7
25	91.7	93.6	93.0	91.7	93.6	93.0
30	91.7	94.1	93.6	91.7	93.6	93.0
40	92.4	94.1	94.1	92.4	94.1	94.1
50	93.0	94.5	94.1	93.0	94.5	94.1
60	93.6	95.0	94.5	93.6	95.0	94.5
75	93.6	95.0	94.5	93.6	95.4	94.5
100	93.6	95.4	95.0	94.1	95.4	95.0
125	94.1	95.4	95.0	95.0	95.4	95.0
150	94.1	95.8	95.4	95.0	95.8	95.8
200	95.0	95.8	95.4	95.4	96.2	95.8

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.

TABLE 10.8-2 Minimum Nominal Full-Load Efficiency for General Purpose Electric Motors (Subtype II), Except Fire-Pump Electric Motors[a]

Full-Load Efficiency, %								
	Open Drip-Proof Motors				Totally Enclosed Fan-Cooled Motors			
Number of Poles ⇒	2	4	6	8	2	4	6	8
Synchronous Speed (RPM) ⇒	3600	1800	1200	900	3600	1800	1200	900
Motor Horsepower								
1	NR	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.
NR—No requirement