TECHNICAL REPORT I



Water Bottling Facility

Mid-Atlantic, US

ASHRAE Standard 62.1 Ventilation & Standard 90.1 Energy Design Evaluation

The Pennsylvania State University
Architectural Engineering
Mechanical Option

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TABLE OF CONTENTS

Executive Summary

The main objective of Technical Report I is to assess the Water Bottling Facility's compliance or failure to adhere to the building requirements found in ASHRAE Standard 62.1-2007 and ASHRAE Standard 90.1. These standards assess the quality of construction by examining the building's systems and equipment as well as the building procedures that were implemented. These requirements can vary depending on building location, occupancy type, and pre-engineered components.

Analysis of ASHRAE Standard 62.1-2007 indicated full compliance with sections 5. This section looked at how air is moved though the building by way of natural ventilation, ventilation air distribution, exhaust duct location, and ventilation system control. It looks at the quality of air by examining air stream surfaces, outdoor air intakes, local capture of contaminants, combustion air, particulate matter removal, and dehumidification systems. It considers the cleanliness of the mechanical systems by considering drain pans, finned-tube coils and heat exchangers, humidifiers and water-spray systems, and access for inspection, cleaning, and maintenance. It considers how the building interacts with its surroundings through building envelope and interior surfaces, attached parking garages, air classification and recirculation, requirements for buildings containing ETS areas and ETS-Free Areas.

ASHRAE Standard 62.1-2007 section 6 required detailed calculations of building ventilation rate. For this analysis only the administrative offices were considered because the load in the spaces associated with the offices are mainly human. The loads on the production and warehouse are mainly environmental and equipment. There are so few people in such a large area that they do not contribute to the load in a large enough level to make an apparent difference.

Within the building specifications and notes associated with the Water Bottling Facility, a specific desire for the building to adhere to the standards specified in ASHRAE Standard 90.1-2007 is made. This standard accounts for the Energy Standard of a building. This is important in the case of this facility because of the push for LEED Gold. Although the majority of the standards were met, others did not quite comply. This lack of compliance is likely due to lack of information not actually noncompliance.

After considering compliance with both, ASHRAE Standard 62.1-2007 and 90.1-2007, it was found that in the majority of instances the Water Bottling Facility meets the criteria of these standards. Because of its compliance, this combination purpose building is properly ventilated and follows current energy standards.

General Information

The facility analyzed in Technical Report I has three major faculties: office, production, and warehouse. All of these components are combined in one building using walls and visual indicators to separate the different use zones. In Figure 1, below, the green section represents the warehouse, the blue production, and the orange office space.

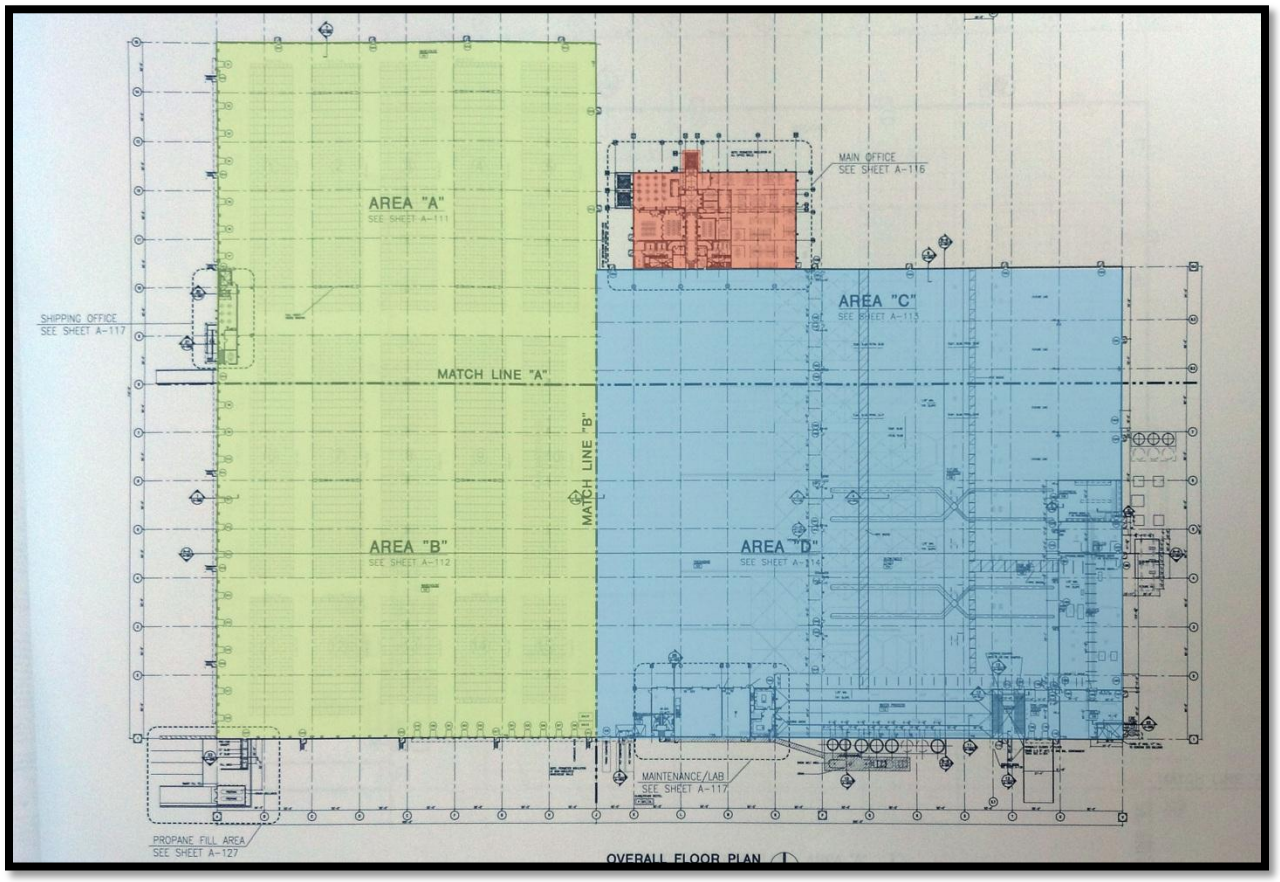

Figure 1: Facility Spaces

ASHRAE Standard 62.1 – 2007 Evaluation

Section 5 – Systems and Equipment

5.1 Natural Ventilation

Natural ventilation is not used in any of the areas that comprise the water bottling facility. The manufacturing and warehouse portions of the building do not have any windows, and the windows in the offices and quality control lab are inoperable.

5.2 Ventilation Air Distribution

The ventilation system within the Water Bottling Facility was balanced after insulation to achieve the proper amount of airflow into each space. A CO_2 monitoring system is utilized in the office spaces of the facility to ensure adequate ventilation for highest productivity level. A further analysis of the ventilation of the building is calculated in ASHRAE Standard 90.1-2007 section 6.

5.3 Exhaust Duct Location

Ductwork in the Water Bottling Facility is required to meet or exceed SMACNA HVAC Duct Construction Standards. Therefore, the requirements of this section are met.

5.4 Ventilation System Controls

All controls are digital and microprocessor-based. The VAV boxes, which are located in the office areas, are operated by thermostats in the spaces. The office area RTUs will modulate the damper's position based on CO_2 content of the space. The HVAC units supplying the Blow Mold/Filler Room use a microprocessor to control both temperature and humidity. The PLC will send signals to the digital controller based on the CIP of the Fillers. Failure Alarms will also output to the PLC.

5.5 Airstream Surfaces

Louvers, fans, piping, vents, and flues are caulked to block moisture and to be air tight. Ducts are composed entirely of sheet metal surfaces and metal fasteners therefore are resistant to mold growth and erosion.

5.6 Outdoor Air intakes

All outdoor air intakes for the Water Bottling Facility fulfill the requirements listed in Table 5-1 from ASHRAE standard 62.1, which can be seen below in Table 1.

Because a large portion of the facility functions as warehouse and shipping docks it was important to consider the flow of traffic when placing the air intakes. They are located at a distance even greater than recommended to ensure to harmful fumes are brought into the building.

Roof air intakes are all elevated on curbs to provide proper distancing from the roof membrane. Within the specifications for building the Water Bottling Facility, it was stressed that each of these curbs be level with the horizon regardless of roof pitch to be sure that the shortest side meets the height requirements.

TABLE 5-1 Air Intake Minimum Separation Distance

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

Note 1: Significantly contaminated exhaust is exhaust air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor.
Note 2: Laboratory fume hood exhaust air outlets shall be in compliance with NFPA 45-1991[3] and ANSI/AIHA Z9.5-1992.[4]
Note 3: Noxious or dangerous exhaust is exhaust air with highly objectionable fumes or gases and/or exhaust air with potentially dangerous particles, bioaerosols, or gases at concentrations high enough to be considered harmful. Information on separation criteria for industrial environments can be found in the ACGIH Industrial Ventilation Manual[5] and in the *ASHRAE Handbook—HVAC Applications*.[6]
Note 4: Shorter separation distances are permitted when determined in accordance with (a) Chapter 7 of ANSI Z223.1/NFPA 54-2002[7] for fuel gas burning appliances and equipment, (b) Chapter 6 of NFPA 31-2001[8] for oil burning appliances and equipment, or (c) Chapter 7 of NFPA 211-2003[9] for other combustion appliances and equipment.
Note 5: Distance measured to closest place that vehicle exhaust is likely to be located.
Note 6: No minimum separation distance applies to surfaces that are sloped more than 45 degrees from horizontal or that are less than 1 in. (3 cm) wide.
Note 7: Where snow accumulation is expected, distance listed shall be increased by the expected average snow depth.

Table 1: Distance from Outdoor Air Intakes

5.7 Local Capture of Contaminants

All exhaust fans in the mechanical room, chemical storage, maintenance office, and quality lab are ducted directly to the outdoors.

5.8 Combustion Air

All fuel-burning equipment is provided a sufficient amount of air and is adequately vented. Gas unit heaters have a flue to relieve combustion air from the space.

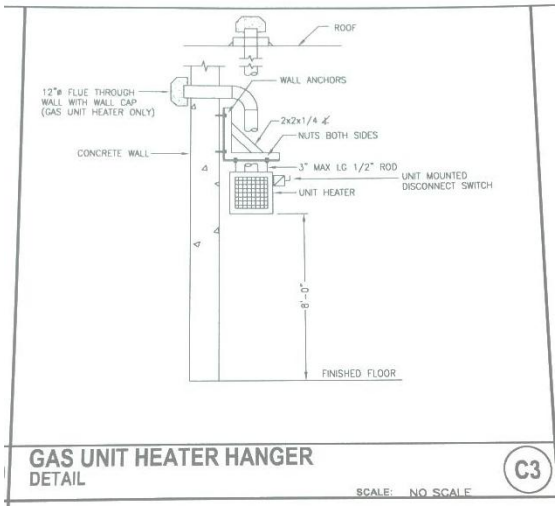

Figure 2: Flue for Gas Unit Heater

5.9 Particulate Matter Removal

All RTUs on the facility are designed to have pre-filters with a 2" – TA. RTUs 1, 4, 5, and 6 are designed to have MERV 13 filters. RTU 3 is designed to have a 90% HEPA filter. Because RTU 2 is only providing conditioning for the LAN room, it is not filtered. Due to the size of the building and the volume of air going through each of the units, further analysis is going into determining how often these filters should be replaced. The maintenance department has determined that in order to ensure that no particulate matter enters the building multiple filters should be used and they should be replaced more often than recommended by the manufacturer.

5.10 Dehumidification Systems

All cooled spaces are designed for a RH of about 50%. This is less than the maximum described in the specifications. The table below indicates that the minimum air intake is greater than the maximum exhaust airflow during dehumidification satisfying the exfiltration requirements.

Air Handling Units	Minimum Outdoor Air (cfm)	Maximum Exhaust Air (cfm)	Exhaust Fans
RTU-1	6,930	820	**EF-11**
RTU-2	-	2,000	**EF-13**
RTU-3	300	5,100	**EF-14**
RTU-4	710	450	**EF-15**
RTU-5	8,330	2,500	**EF-21**
RTU-6	8,330	710	**EF-22**
Total	24,600	11,580	**Total**

Table 2: Air Intake vs. Exhaust Air

5.11 Drain Pans

All condensate is drained to the sanitary sewer. This is done through hub drains and air gaps. The building specifications state that the drain pan set up must fulfill the code requirements.

5.12 Finned-Tube Coils and Heat Exchangers

No information has been provided in regards to finned-tube radiation or heat exchangers. Upon visual inspection of the site and examination of the mechanical room, it can be assumed that the instillation of these devices was done properly. Drainage was not an issue and spacing was more than adequate to examine all equipment

5.13 Humidifiers and Water-Spray Systems

A humidifier is used to maintain the humidity of the Quality Control Room. The water used in the humidification system comes directly from a potable water source (the city water source). The air flows through vanes downstream of the humidifier. Turning vanes are only used when there are elbows of 90°.

5.14 Access for inspection, Cleaning, and Maintenance

Access to ceilings and ductwork is required for balancing and maintenance for all mechanical equipment.

5.15 Building Envelope and Interior Surfaces

The tilt-up panels used to construct the building are engineered to prevent water penetration and incidental condensation. All Joints, seams, and openings are sealed with caulk to provide a water and vapor barrier.

5.16 Buildings with Attached Parking Garages

This section of the standard does not apply because there is no attached parking garage associated with the Water Bottling Facility.

5.17 Air Classification and Recirculation

All air with the potential for moderate to high contaminant concentration is exhausted out of the building. Office spaces are considered to be Class 1 and therefore have the option of recirculating the air to the same space or to spaces with a higher classification such as the lunchroom or restrooms, which have moderate to high contaminant concentrations.

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

The Water Bottling Facility is considered an ETS-Free building. Since the amount of air supplied to the building is greater than the amount of air exhausted, a positive pressurization of the building is created. Because of this positive pressurization, smoke is unable to enter the building, therefore adhering to the standard.

Section 6 - Procedures

6.2 Ventilation Rate Procedure

The equations listed below were used to calculate the current HVAC system to see if proper ventilation was achieved. These can be found in the ASHRAE Standard 62.1-2007. Appendix A of the same standard is a spreadsheet which helps calculate the compliance. Values were derived by using floor area, occupancy, zones, and supply air volume in this spreadsheet.

Breathing Zone Outdoor Airflow:

$$V_{bz} = R_p * P_z + R_a * A_z \qquad \text{(Equation 6-1)}$$

V_{bz} = Breathing Zone Outdoor Airflow (cfm)
A_z = Zone Floor Area (ft^2)
P_z = Zone Population (people)
R_p = Outdoor Airflow Rate (cfm/person)
R_a = Outdoor Airflow Rate (cfm/ft^2)

Zone Air Distribution Effectiveness:

$$E_z = 1.0 \qquad \text{(Table 6-2)}$$

Zone Outdoor Airflow:

$$V_{oz} = {}^{V_{bz}}/_{E_z} \qquad \text{(Equation 6-2)}$$

Primary Outdoor Air Fraction:

$$Z_p = {}^{V_{oz}}/_{V_{pz}} \qquad \text{(Equation 6-5)}$$

Z_p =Zone Primary Outdoor Flow
V_{oz} = Zones Outdoor Airflow
V_{pz} = Zone Primary Airflow

Uncorrected Outdoor Air Intake:

$$V_{ou} = D \sum_{all\ zones}(R_p + P_z) + \sum_{all\ zones}(R_a + A_z) \qquad \text{(Equation 6-6)}$$

Occupant Diversity:

$$D = {}^{P_s}/_{\sum_{all\ zones} P_z} \qquad \text{(Equation 6-7)}$$

P_s = Total Population Being Served

Outdoor Air Intake:

$$V_{ot} = {}^{V_{ou}}/_{E_v} \qquad \text{(Equation 6-8)}$$

ASHRAE 62.1 – 2007 Summary

Section 5 Compliance

Compliance has been found based on the assessment of the Water Bottling Facility's specifications and construction documents compared to ASHRAE Standard 62.1-2007 Section 5. Not all cases had detailed information regarding their compliance to the section but based on the compliance to other portions assumptions could be made in favor of compliance.

Section 6 Compliance

The ventilation rate for the office space of the Water Bottling Facility complies with the requirements set by ASHRAE Standard 62.1-2007 Section 6. Using the equations found in the standard and data found in the mechanical drawings it was discovered that RTU-1 exceeds the minimum requirements for ventilating the space based on occupancy. The unit provides 14,000 cfm while only about 3,500 cfm is required for the people in the space. Other loads that would influence the higher ventilation rate include computers, projectors, vending machines, and refrigerators.

ASHRAE Standard 90.1 – 2007 Evaluation

Section 5 – Building Envelope

5.1.4 Climate

The Water Bottling Facility is located in ASHRAE climate zone 5A. This was determined by reverencing the building's location on the map below and Table B-1 in the ASHRAE Standard 90.1 – 2007.

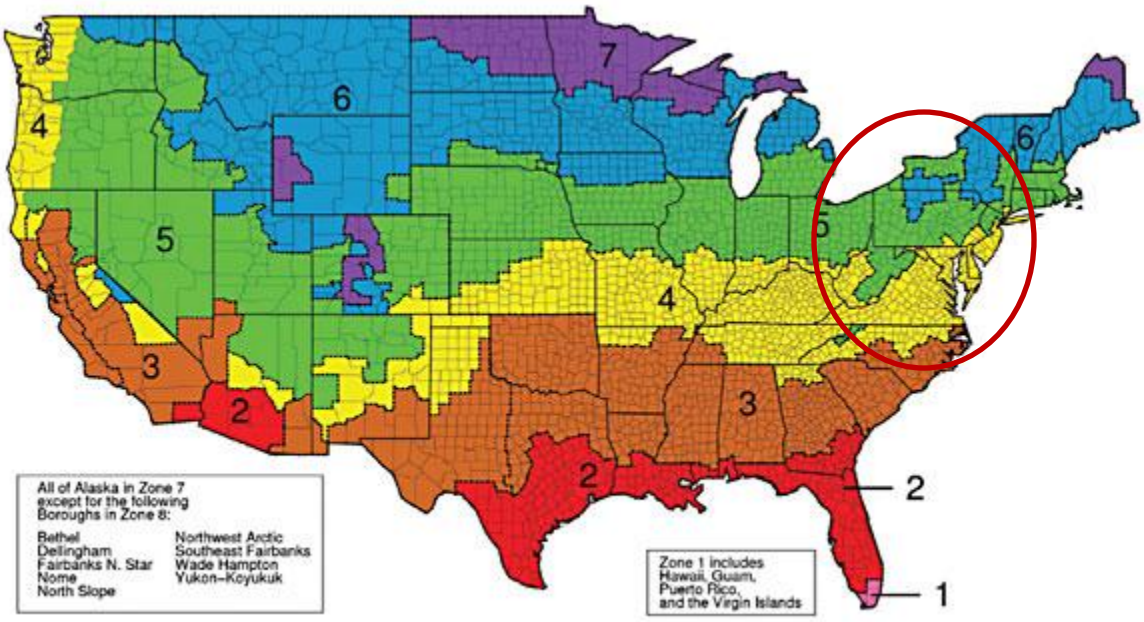

Figure 3: ASHRAE Climate Zones

5.5 Prescriptive Building Envelope Option

To determine the compliance of the building envelope with the ASHRE standard a comparison of the required insulation versus that installed can be seen in Table 3. This table shows that the exterior walls do not comply with the standard desired for this region of the United States although it can be argued that the wall itself could increase the overall R-Value of the wall. Within the project specifications, only the value for the insulation was given not the entire assembly. Combining these two values would produce a number that would prove to be greater than the 11.4 minimum required. In addition to the roof having more than enough insulation to prevent heat loss, it has a white membrane to reduce solar load.

Elements	ASHRAE Assembly Min R-Value	Designed Assembly Min R-Value	Compliance
Exterior Office Walls	11.4 c.i.	11	No
Roof	19.0	25	Yes
Floor Slab	NR	NR	Yes

Table 3: Insulation R-Value Comparison

An analysis of the percent glazing was done in Table-4. This analysis looks at the glazing to wall ratio of the building. The maximum vertical fenestration on a building can comprise only 40% of its surface area. The Water Bottling Facility complies with the fenestration requirements beyond what is seen in Table-4 because that only accounts for the surface of the walls on the office. There are no windows on the other portions of the building resulting in a much lower overall ratio.

Fenestration Area (ft^2)	Wall Area (ft^2)	Percent Glazing	Compliance
2414	7485	32.25%	Yes

Table 4: Percent Glazing

Section 6 – Heating, Ventilation, and Air Conditioning

6.3 Simplified Approach Option for HVAC Systems

The simplified approach cannot be used on the Water Bottling Facility because, although it is under two stories in height, it has an area much larger than the maximum 25,000 ft^2 with an area of 580,000 ft^2.

6.4 Mandatory Provisions

All mechanical equipment must have a manufacturer's label that states the requirements of ASHRAE Standard 90.1-2007 are met. Terminal units are all associated with a single zone. No zone overlap is found even when considering perimeter units. All HVAC systems are connected to the emergency system for emergency shutdown. Gravity Hoods are equipped with motorized dampers to meet requirements based on height. Ducts are insulated as sealed to meet requirements of section 6.4.

6.5 Prescriptive Path

The economizer is initiated when indoor enthalpy is greater than that of outside. During this cycle the exhaust fan in connection with RTU-1 sill operate at variable speeds. The fan within the RTU will be off at this time.

6.7 Submittals

Information about the building was presented to the proper authorities before and after construction. Each team associated with the installation of mechanical equipment must teach the employees of the Water Bottling Facility to run the equipment for a minimum of one 8 hour session.

Section 7 – Service Water Heating

Boilers in the building are associated with production equipment and there for do not need to comply with ASHRAE Standard 90.1-2007.

Section 8 – Power

Feeders and branch circuits associated with the Water Bottling Facility experience a 2% and 3% voltage drop respectively which follows the standard maximums. Building specifications indicate that in addition to meeting these requirements the building must follow NEC standards that are applicable to building type

Section 9 – Lighting

A minimum of 1 ft-candle is required for all exterior concrete and paved surfaces. In the production areas of the facility 50 ft-candles are required and in the warehouse 35ft-candles are needed.

Section 10 – Other Equipment

Since this is a manufacturing facility there are numerous pieces of equipment that are associated with creating the bottles, filling them with water, and packaging them. All of these machines were built within the past 10 years. Therefore it can be assumed that their motors follow the rules implemented by the Energy Policy Act of 1992.

Section 11 – Energy Cost Budget Method

Energy cost budget is an important aspect of a buildings scope. Analysis of this portion will take place in Technical Report II.

ASHRAE 90.1 – 2007 Summary

Within the mechanical drawings a note was made about the importance of the Water Bottling Facility adhering to the AHSRAE 90.1-2007 Standards. The achievement of these standards can be seen though the analysis above. Few cases indicated noncompliance, which could have been caused by missing information. Further analysis of the building in Technical Report II will expose whether these incidences are accurately portrayed in a more simple analysis or if they need to be examined more closely.

References

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

ANSI/ASHRAE (2007), Standard 90.1-2007, Energy Standard for Building Except Low Rise Residential Buildings. American Society of Heating Refrigeration, and air Conditioning Engineers, Inc., Atlanta, GA, 2007.

Haskel Architects and Engineers Engineering Reports

Water Bottling Facility Specifications and Images

Appendix A – Minimum Ventilation Calculations

Building:	Water Bottling Facility											
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					17450					
Population of area served by system (including diversity)	Ps	P	100%	diversity			359					
Design primary supply fan airflow rate	Vpsd	cfm					17,055					
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					5.5					
Inputs for Potentially Critical zones								Potentially Critical Zones				
Zone Name		*Zone title turns purple italic for critical zone(s)*						Open Office	*Locker Rooms*	Storage/Admin	Bussiness	
Zone Tag								1st	1st	1st	1st	
Space type		Select from pull-down list						Office space	Health club/weight rooms	Office space	Office space	
Floor Area of zone	Az	sf						3,768	685	310	12687	
Design population of zone	Pz	P	(default value listed; may be overridden)					215	13	1	130	
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm						6,925	945	600	8585	
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A						ITU	ITU	ITU	ITU	
Local recirc. air % representative of ave system return air	Er							75%	75%	75%	75%	
Inputs for Operating Condition Analyzed												
Percent of total design airflow rate at conditioned analyzed	Ds	%					100%	100%	100%	100%	100%	
Air distribution type at conditioned analyzed		Select from pull-down list						CS	CS	CS	CS	
Zone air distribution effectiveness at conditioned analyzed	Ez							1.00	1.00	1.00	1.00	
Primary air fraction of supply air at conditioned analyzed	Ep							100%	100%	100%	100%	
Results												
Ventilation System Efficiency	Ev						**0.86**					
Outdoor air intake required for system	Vot	cfm					**3534**					
Outdoor air per unit floor area	Vot/As	cfm/sf					**0.20**					
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p					**9.8**					
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	=	17055						
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	=	3037						
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	=	0.18						
Initial Calculations for individual zones												
OA rate per unit area for zone	Raz	cfm/sf						0.06	0.06	0.06	0.06	
OA rate per person	Rpz	cfm/p						5.00	20.00	5.00	5.00	
Total supply air to zone (at condition being analyzed)	Vdz	cfm						6925	945	600	8585	
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az	=		1301.1	301.1	23.6	1411.2		
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez	=		1301	301	24	1411		
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er	=		1.00	1.00	1.00	1.00		
Fraction of zone supply from fully mixed primary air	Fb		=	Ep	=		1.00	1.00	1.00	1.00		
Fraction of zone OA not directly recirc. from zone	Fc		=	1-(1-Ez)(1-Ep)(1-Er)	=		1.00	1.00	1.00	1.00		
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz	=		0.19	0.32	0.04	0.16		
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz	=		0.19	0.32	0.04	0.16		
System Ventilation Efficiency												
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa	=		0.99	0.86	1.14	1.01		
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	=	**0.86**						
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	=	0.83						
Minimum outdoor air intake airflow												
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	=	**3534**						
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	=	3653						
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+dTrf)	=	-10						

Appendix B – Building Envelope Requirements Table

TABLE 5.5-5 Building Envelope Requirements For Climate Zone 5 (A, B, C)*

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

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