The

Gaige

Technology and Business
Innovation Building
Penn State Berks, Reading, PA

Technical Report One

AHSRAE Standards 62.1 and 90.1 Evaluations

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Technical Report One

Executive Summary

The purpose of this thesis technical assignment is to analyze the Gaige Building's compliance with ASHRAE Standards 62.1 and 90.1. The Gaige Building is a classroom, lab, and office building located on the Penn State University's Berks commonwealth campus in Reading, PA. The building's construction began in April of 2010 and was completed in November of 2011.

First, the Gaige Building was evaluated based upon its compliance with sections five and six of ASHRAE Standard 62.1. Section five of standard 62.1 contains a variety of information and requirements, all relating to potential building issues such as mold growth, locating building exhaust system, supply air system efficiencies, filtering contaminants from air, and draining condensate. After the complete analysis of the Gaige Building under section five of standard 62.1, it was found to be completely compliant. This is not a surprising result, for the Gaige Building is a LEED Gold rated construction, which requires all of these compliances. The only potential non-compliance with this section is the placement of the exhaust outlet for the kitchen hoods. It appears that the hoods are exhausted through one of the RTUs, which is located next to the outdoor air intake for the same unit.

Next, the Gaige Building was analyzed as to whether or not it was compliant with the Ventilation Rate Procedure of standard 62.1, section six. After a complete calculation of the ventilation requirements for each space along with the outdoor air intake for each unit, it was found that the current design of the Gaige Building was not compliant with the ventilation requirements found in this report in the two largest roof top units. The large difference was found to be a result of a difference in the calculation of the system ventilation

efficiency. It is clear that the large difference should be analyzed in further work, to determine if the design assumptions in the calculation of the building's ventilation requirements were proper or if there is a flaw in the current outside air design specifications for the building.

The next goal of this technical assignment is to analyze the Gaige Building's compliance with ASHRAE Standard 90.1. In this report, the Gaige Building was analyzed based upon its compliance with sections five through ten of the standard. Overall, the building was found to be compliant with all major aspects of 90.1. The non-compliant parts came from some underperforming efficiency qualifications of two water heaters, and three fans that did not meet fan power limitations. By simply making minor changes in equipment selection, all of these problems could be remedied.

The other finding that was significant from the 90.1 analysis was the extreme over-compliance of the glazing chosen for the Gaige Building. Although required to have a U-value of 0.45, the curtain wall system for the Gaige Building had a U-value of 0.075. It appears that this selection was made to allow for compliance with Penn State's requirement of a 30% reduction in energy consumption from the limitations specified in ASHRAE Standard 90.1 The decision looks to have been made simply to meet an energy requirement, with no significant cost consideration. Further analysis should look into the initial cost of this system, versus the saving that will be experienced over the lifetime of the building with decreased energy consumption. If it doesn't pay off, another glazing option should be considered, with additional methods to reduce the energy consumption to the 30% requirement. A further analysis of the building's energy consumption will be conducted in the second technical assignment.

Project Background

The Gaige Technology and Business Innovation Building is a 64,000 SF building located in Reading, PA, on the Berks commonwealth campus of Penn State University. The Gaige Building is a host of many functions, but primarily, it is used as classroom, office, and lab space for the college's engineering, business, and hotel and restaurant management programs.

The Gaige Building is three stories tall, and it was constructed between April 2010 and November 2011. It was operated on a design-bid-build project delivery method, and had a full range of consulting services, from cost-estimating to A-V consulting. Functionally, the first floor contains classroom and lab spaces primarily, with a large area for studying and relaxing called the Learning Loft. Once you move to the second floor, you see the same classroom and lab emphasis, but a corridor on the east-west wing of the building provides a large amount of conference and office space.

Once you move to the third floor, the east-west wing of the building is capped off at two stories, but the north-sound wing continues up to three stories to accommodate one more classroom space and ample office and conference space. The exterior of the building consists of weather-resistant terracotta panel, metal framed exterior glazing and curtain wall systems, and precast concrete panels. Together, all of these building elements provide an aesthetically pleasing, but sealed and energy efficient building façade and enclosure. More information on the architecture of the building can be found in the building statistics report performed on the Gaige Building through this same thesis project.

Mechanical System Overview

The Gaige Building has three main root top units (RTU-1, RTU-2, and RTU-3) that provide ventilation, conditioning, and exhaust for the majority of the spaces within the building's design. The units are sized to 20,500 CFM, 14,000 CFM, and 12,500 CFM respectively. Each of these units serve a variety of spaces within the first, second, and third floors of the building. Air is supplied from the roof top units at a supply temperature of 55 degrees, and it is ducted throughout the building.

At the individual spaces, variable air volume boxes are provided for each zone. The VAV box takes the 55 degree air, and varies the volume of air being supplied to the space to meet the cooling requirement of the space at the current time. The load is monitored by a thermostat located in each of the zones separately. CO2 and occupancy sensors also are coordinated with the VAV boxes to allow for a reduction in outside air required to be supplied to each space. A minimum set point prevents the VAV box from supplying air less than the minimum outside air requirement for the space. A reheat coil prevents from overcooling the space when providing minimum outside air at a time when cooling requirements are reduced.

Two 1300 MBH boilers provide the hot water service for the building and all mechanical heating requirements. Four split system air conditioners are required to provide individual space cooling for the telecom/data rooms in the building, and one computer room air conditioner is required for the IT storage and equipment room, also supplied with an air-cooled chiller. Unit heaters are provided throughout the building as needed in semi-heated spaces, such as the vestibules at the building entrances.

Finally, the heating loads for the building are met by radiant-heating panels and fin-tube heat exchangers placed at exterior walls of spaces that don't experience a year round cooling load. This allows for simultaneous heating and cooling throughout the building in spaces that contain these heating elements. Although it provides poor energy efficiency, the VAV boxes are equipped with reheat coils, so some heating in spaces without panes or fin-tubes could potentially have some heating capacity, but that is not the primary design intent.

ASHRAE Standard 62.1: The Building's Compliance

In this part of the report, The Gaige Building will be reviewed to test its compliance with ASHRAE Standard 62.1, section five and section six. First, *Section 5: Systems and Equipment* will overview how the building's current design compares with the systems and equipment requirements set in place by the standard. Then, in *Section 6: Procedures-Ventilation Rate Procedure Analysis,* the building will be analyzed to determine its compliance with ASHRAE Standard 62.1 section six. In section six, design minimum required ventilation and exhaust rates are specified based upon a building's occupancy types, populations, areas, and the airflow system's designed type and efficiency. The Ventilation Rate Calculation Procedure will be used to determine the Gaige Building's compliance with the standard. The numbers used for the Gaige Building will be the design specified airflow rates in the mechanical construction documents, and are not actual airflow measurements from the building.

Section 5: Systems and Equipment

The following sections provide a summary of what is contained in each part of section five of ASHRAE Standard 62.1, and provide information relating to the Gaige Building and its compliance with ASHRAE Standard 62.1.

5.1: Ventilation Air Distribution

This building, being a LEED Gold building, has been properly inspected and the HVAC system was balanced to ensure minimum ventilation air is delivered to each space. This also means that since ceiling plenums are used in its design, it meets the requirement of delivering the minimum outside air to each space where these are present. Along with LEED certification, adequate and proper documentation is required, which was provided for proper balancing of the system post construction.

5.2: Exhaust Duct Location

The exhaust ductwork system for the building is negatively pressurized, so that air is transferred into spaces that will require exhausting, and then the air is exhausted from those spaces. The exhaust ductwork that passes through non-exhausted spaces is properly sealed to prevent leakage and contamination of those spaces. This ensures adequate indoor air quality in the space.

5.3: Ventilation System Controls

The mechanical system in the Gaige Building, since it is a variable air volume system, has controls that will vary the amount of air needed in a space based upon the present occupancy of the space. Also, it controls the outside air intake based upon the occupancy of the building. Carbon Dioxide sensors are used in spaces that have a large and more variable occupancy to control the airflow. In smaller spaces, like faculty offices for instance, such sensors are not used, but for system continuity, VAV boxes are still provided. All VAV boxes have been set to at least provide the minimum amount of ventilation air required.

5.4: Airstream Surfaces

For the Gaige Building's air distribution system, metal ductwork is used throughout, allowing resistance to mold growth and other contaminants. Also, due to the use of sheet metal ductwork, it will be able to prevent any erosion, cracking, or damage that other kinds of ductwork might experience.

5.5: Outdoor Air Intakes

The class two air sources present in the Gaige Building are the kitchen for the Bits Bytes Café, Bathrooms, and some of the science laboratories. According to table 5-1 in Standard 62.1, there must be at least a ten foot spacing between these exhaust locations and outdoor air intakes. This distance is respected, except on the roof top units. Refer to table 5-2 below:

TABLE 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 requirements 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 the *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. (3 cm) 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."

On these units, the exhaust air is relieved right next to the outside air intake, but the air is vented in perpendicular directions. This is not ideal, and does not specifically comply with standard 62.1, but the directional aspects of the intake and exhaust outlet could potentially be argued to prevent contamination. Proper consideration has also been given to prevent rain or snow intrusion into the roof top units. Bird screen is also placed over the air intakes and exhaust systems on the outside of the building.

The kitchen hood for the kitchen area are commercial kitchen grease hoods, which are considered class four air, and must be vented directly to the outside. This is done for all of the hoods in the kitchen, and the air is directly exhausted to the outside. This air is exhausted on the roof, and the separation distance is not met for classifying this type of air.

5.6: Local Capture of Contaminants

In the Gaige Building, either the equipment's exhaust containing contaminants is ducted directly outdoors, or the equipment is designed to have exhaust indoors. Since either of these cases are observed throughout the buildings, the Gaige Building is compliant.

5.7: Combustion Air

The combustion equipment in the Gaige Building, or the three boilers, are all compliant with this section. Each boiler is provided first with adequate air intake to attain near complete combustion, and the combustions chamber is sealed properly. As well, the boilers are all directly vented, taking contaminants and products of combustion and directly venting them to the outdoors.

5.8: Particulate Matter Removal

Three air handling units are used in the Gaige Building, and all three contain 8 pre-filters upstream of the cooling coil. These filters are MERV-7 rated, exceeding the rating of MERV-6 required by ASHRAE Standard 90.1 section 5.8.

5.9: Dehumidification Systems

In the design, the air handling units first run the outside air through an energy recovery wheel, and after that, the outside air is precooled for dehumidification purposes. Once dehumidified, the outside air is mixed with the return air, and conditioned further to be sent out to the VAV boxes. Since the VAV boxes are equipped with reheat coils, the air-handling unit can precool to provide dehumidification, and the VAV boxes can prevent the potential for overcooling in the spaces. Also, the building's outside air intake is controlled to exceed its exhaust air rate, providing positive pressurization and preventing exfiltration.

5.10: Drain Pans

All condensing equipment in the Gaige Building is provided with a drain pan that meets specification laid out in section 5.10. The pans are all adequately sloped, have drains located at the lowest point in the pan, and they are properly sealed to prevent the intrusion of air from the fan. As well, they are located underneath the water-condensing equipment, and the pans are ensured to be of adequate size.

5.11: Finned-Tube Coils and Heat Exchangers

As stated in the previous section, drain pans are provided underneath all dehumidifying units and coils. Also, cleaning access for upstream and downstream surfaces is provided for all upstream and downstream surfaces, meeting requirements for section 5.11.

5.12: Humidifiers and Water-Spray Systems

No humidifiers or water-spray systems are used in the design or construction of the Gaige Building, so this section does not apply.

5.13: Access for Inspection, Cleaning, and Maintenance

All primary ventilation equipment is located on the roof or in mechanical rooms within the building. With these locations, rooftop access and access to mechanical rooms is readily accessible. This provides for access for inspection, cleaning, maintenance, calibration, etc. Also, secondary equipment like VAV boxes, and mechanical system ductwork is all accessible through the ceiling of buildings. Most all spaces contain a drop-ceiling system to allow for easy access in case of maintenance.

5.14: Building Envelope and Interior Surfaces

On the exterior envelope of the building, the requirements have been considered and met. Frist, a weather barrier is used continuously throughout the building exterior. This barrier mainly consists of the weather resistant terracotta tiles used on the façade, and glazing, and the precast concrete panels.

Also, throughout the building envelope's construction, a continuous vapor barrier is placed on the warm side of the insulation. Finally, all joints between building façade materials are properly caulked or gasketed to prevent any infiltration, and interior building surfaces that fall below dew point are properly insulated to prevent condensation.

5.15: Buildings with Attached Parking Garages

This building does not have an attached parking garage, so this section does not apply. The parking for this building is provided in adjacent parking lots and throughout the Penn State Berks Campus.

5.16: Air Classification and Recirculation

In the Gaige building, all spaces are given air classification, and all of these air classes, except for the kitchen hood exhaust, are class two or class one. With class two air, it is allowed to be recirculated within class one air sources, so the return air system meets this recirculation requirement. The spaces that are not class one or two air sources, such as mechanical rooms, bathrooms, kitchen hoods, etc. are all directly exhausted to the outside of the building.

5.17: Requirements for Buildings Containing ETS and ETS-Free Areas

The Gaige Building is a smoke-free facility, so therefore, this section does not apply, for no ETS areas are in the building.

Section 6: Procedures-Ventilation Rate Procedure Analysis

In the section below, the Gaige Building will be analyzed to determine whether or not it is in compliance with ventilation requirements set out in section six of ASHRAE Standard 62.1. For this analysis, the ventilation rate procedure will be used. Below, the ventilation rate procedure is first described generally. Then, an overview of how this procedure was setup and conducted for the Gaige Building is provided. Finally, a summary of the Gaige Building's compliance is provided.

The Ventilation Rate Procedure

For the Gaige Building, the Ventilation Rate Procedure was applied to ensure that adequate ventilation air is distributed to all building spaces and zones. Based upon each space's area, occupancy, type, and the air distribution system within the building, a minimum requirement of outdoor air intake is specified for the building's ventilation equipment and a minimum outdoor airflow is specified to each space.

First, a calculation is required to determine the amount of outside air that is required in each space in the breathing zone. This calculation for V_{bs} is shown below:

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

Where,

A_z is the zone floor area: the net occupiable floor area of the ventilation zone (SF)

P_z is the zone population: the number of people in the ventilation zone during typical usage

R_p is the outdoor airflow rate required per person as specified in table 6-1 in ASHRAE Standard 62.1

R_a is the outdoor airflow rate required per unit area as specified in table 6-1 in ASHRAE Standard 62.1

Next, a zone air distribution effectiveness (E_z) is determined based upon the air distribution system to the space. From table 6-2 in Standard 62.1, you can determine a value for E_z for the zone in which the air is being calculated. Once E_z is determined, then the zone outdoor airflow (V_{oz}) can be calculated based upon the equation below:

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

After calculating the zone outdoor airflow, in order to calculate the outdoor air intake flow (V_{ot}) for the building or the particular unit serving a part of a building, you must choose whether or not your system is a single-zone system, 100% outside air system, or multiple-zone recirculating system. For the Gaige Building, it consists of three multiple-zone recirculating systems, so that procedure will be outlined below.

In order to calculate V_{ot} for a multiple-zone recirculating system, we first must find a system ventilation efficiency value (E_v). An intermediate step in calculating E_v is the calculation of the primary outdoor air fraction (Z_{pz}) as shown below:

$$Z_{pz} = \frac{V_{oz}}{V_{pz}}$$

Where, V_{oz} is the outdoor airflow to the zone (CFM)
Z_{pz} is the zone primary airflow, or the primary airflow from the air handling unit, which includes both outdoor air and recirculated air.

Once a value for Z_{pz} is found, you then can determine you system ventilation efficiency (E_v) using table 6-3 in Standard 62.1 (shown below). If Z_{pz} values fall between categories in this table, then interpolation can be used to determine E_v. Otherwise, if Z_p is greater than 0.55, Appendix A of ASHREA Standard 62.1 should be used to find an appropriate value for E_v.

TABLE 6-3 System Ventilation Efficiency

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

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

The final step before calculating the outdoor air intake is to find the uncorrected outdoor air intake (V_{ou}). This value is calculated like the ventilation air in the breathing zone, but a diversity factor based upon population differences between individual spaces and the overall system population can be taken into account. The equations to calculate V_{ou} are outlined below:

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

And,

$$D = \frac{P_s}{\sum_{all\ zones} P_z}$$

Where, V_{ou} is the uncorrected outdoor air intake flow (CFM)
D is the occupant diversity ratio
P_s is the system population

Finally to calculate V_{ot} for a multiple zone system with recirculating air, use the equation below, using the value for E_z already determined from table 6-3 above.

$$V_{ot} = \frac{V_{ou}}{E_v}$$

The overall findings for the ventilation rate calculation procedure for the Gaige Building are shown and summarized in the next section.

Selection of Systems Calculation Procedure

For the Gaige Building, three primary rooftop units are used to condition the building, so the ventilation calculations have been performed separately for each RTU. This partitions each RTU into a separate system containing multiple zones for each unit, all having recirculating air. The details of the space characteristics, areas, occupancies, zone outside air requirements, and Z_p values can be found in Appendix A. For the calculations, population values, and some E_v values for which the Appendix A calculation procedure was used were provided by H.F. Lenz Company, but all calculation were performed individually for this report. As well, primary supply airflow rates were extracted from the calculations and design documents of H.F. Lenz Company. A diversity value of 100% was used in the design of the building, so that same factor has been applied for these calculations as well. Below is table one-A, summarizing the results of these calculations:

Ventilation Calculation Summary			
Unit	Required V_{ot}	Design V_{ot}	Comply?
RTU-1	11993	9020	No
RTU-2	7133	5040	No
RTU-3	1848	4375	Yes

Table 1A: Summary of the ventilation calculations performed for the Gaige Building's three RTUs

Summary of ASHRAE Standard 62.1 Compliance

In section five of ASHRAE Standard 62.1, the Gaige Building is 100% compliant. This is not a surprise, for in order to achieve a rating of LEED Gold certification, this must be accomplished. The only potential issue that has to be further looked into is the placement of the exhaust for the kitchen hoods. It should be determined if other consideration was taken for this issue, or if there is in fact, a non-compliance with section five in Standard 62.1.

In section six, there are non-compliances found in the ventilation calculations between the results performed in this report and the report by H. F. Lenz Company. On further analysis of the data, different methods of determining E_v was used for each method. H. F. Lenz's calculation used appendix A of Standard 62.1 to calculate all E_v values, and those changes resulted in higher E_v values, and therefore, a lower requirement for indoor air intake. This I believe caused a significant change in calculation process. Further analysis needs to be done in what the details of the design ventilation calculation might reveal, and if assumptions made in the calculation of E_v were valid assumptions.

It should be looked into whether or not the assumptions made for design values using the appendix A method of calculation E_v were valid, since the results varied quite significantly. For this report, E_v was calculated using table 6-3, and when appendix A was necessary, H. F. Lenz's data was consulted for an E_v value based upon their design assumptions. This was not required for many spaces though, for most fell within the ranges of table 6-3. As stated, further analysis should be done to check the two different findings and the non-compliant results.

ASHRAE Standard 90.1: The Building's Compliance

Below, a summary of relevant prescriptive compliance requirements are given from ASHRAE Standard 90.1. First, the sections are given, outlined, and the Gaige Building's compliance with each section is discussed. Once all of the relevant sections have been discussed, the overall compliance of the Gaige Building is discussed.

Section 5: Building Envelope

5.1: General

Section 5.1.4: Climate

From ASHRAE Standard 90.1 section five, either Figure B-1 or table B-1 can be used to determine the climate region where a building is located. The Gaige Building, located in Reading, PA, is in Berks County. According to Figure B-1 from ASHRAE Standard 90.1 (shown below), Berks County is in climate zone five.

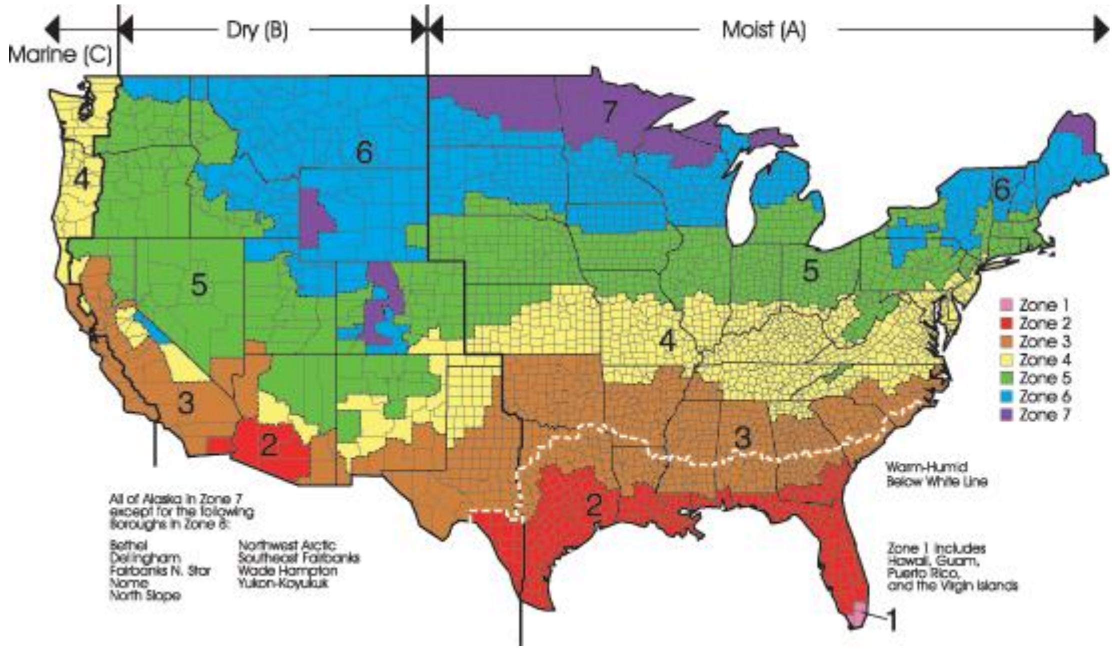

Figure B-1: ASHRAE climate zone map, from commercialwindows.org

5.2: Compliance Paths

For the Gaige Building, the Prescriptive Building Envelope option was chosen to pursue compliance with section five. With this, compliance with sections 5.1, 5.2, 5.4, 5.5, 5.7, and 5.8 is required.

5.4: Mandatory Provisions

In the exterior building envelope of the Gaige Building, a continuous air barrier is provided throughout the building envelope. The air barrier will also resist pressures from wind, and all joints and interruptions in this barrier from lights etc. are detailed with proper caulking and gasketing in the construction documents. 5/8" gypsum sheathing is provided throughout the exterior wall construction to provide this barrier.

For air leakage at fenestration and doors, the Gaige Building is also compliant. It has an air seal at its loading dock door to prevent infiltration. For all main building entrances, exceeding 1000 SF in area, a vestibule is provided to protect the building from excessive air infiltration. Also, every exterior door is equipped with an automatic self-closing device to ensure minimal air infiltration from entering and exiting of the building.

5.5: Prescriptive Building Envelope

The Gaige Building, being a university classroom/lab space, contains non-residential, conditioned spaces. From the table for zone five in section 5.5, the requirements for the Gaige Building were found and represented in table one-B below. The Gaige Building contains no skylights or below grade walls, so those are not included in the provided tables. Table one-B below also summarizes the compliance of the Gaige Building with this section of ASHRAE 90.1.

Buidling Envelope Requirements: Climate Zone 5				
Building Element	Required U-Value	Additional Req.	The Gaige Building	Comply?
Opaque				
Exterior Walls	U-0.064	min R=13+7.5 c.i.	0.042 (R = 23.0)	Yes
Roof	U-0.048	R-20.0 c.i.	0.042 (R = 21.0)	Yes
Floors	U-0.074	R-10.4 c.i.	R = 14.0	Yes
Doors	U-0.500		0.3	Yes
Fenestration				
Curtain Wall	U-0.45	max SHGC = 0.4	0.075 (SHGC = 0.35)	Yes
Entrance Doors	U-0.80	max SHGC = 0.4	0.3	Yes

Table 1B: Summary of building materials in the Gaige Building and their compliance with section 5.5

Façade Materials Summary			
	Area (SF)	% of Total	Comply?
North			
Opaque Area	6962	70.5%	Yes
Glazing Area	2910	29.5%	
East			
Opaque Area	4420	64.2%	Yes
Glazing Area	2464	35.8%	
South			
Opaque Area	4700	48.0%	No
Glazing Area	5087	52.0%	
West			
Opaque Area	3860	63.2%	Yes
Glazing Area	2251	36.8%	
Overall			
Opaque Area	19942	61.0%	Yes
Glazing Area	12772	39.0%	

Table 2: A table summarizing the percentage of glazing on each exterior wall, and overall, and its compliance with section 5

Section 5.5.4: Fenestration

Along with meeting U-value and solar heat gain coefficient requirements, according to ASHRAE Standard 90.1, the maximum percentage of a building's envelope that can consist of glazing is 40%. The Gaige Building comes close to this requirement, but overall, it is compliant, coming in at 39% glazing. The building is broken down into glazing on each four wall orientation to show how the glazing is distributed throughout the building in table two above.

Section 6: Heating, Ventilating, and Air Conditioning

6.2: Compliance Path

Since the Gaige Building is three stories, sections 6.4 and 6.5 must be complied with, and the Simplified Approach Option for HVAC Systems cannot be used. As well, the Gaige Building is also 64,036 SF, which is much greater than the 25,000 SF limit of the simplified approach. Also, many requirements in section 6.3.2 are not met as well.

6.4: Mandatory Provisions

Below is table three, showing all of the minimum efficiently values needed for the equipment used in the Gaige Building. Each type of equipment is listed, and then, the minimum performance values from tables 6.8.1A to 6.8.1K in standard 90.1 are provided. Then, the values for the Gaige Buildings design are given, as well as a statement of compliance.

Equipment Minimum Efficiencies			
Equipment Type	Required Performance	The Gaige Building	Comply?
Roof-Top Units			
RTU-1	9.2 EER w/ Economizer	9.40 EER and Economizer	Yes
RTU-2	9.5 EER w/ Economizer	10.5 EER and Economizer	Yes
RTU-3	9.5 EER w/ Economizer	12.2 EER and Economizer	Yes
Gas-Fired Boilers			
BLR-1	0.75	0.94	Yes
BLR-2	0.75	0.94	Yes
Air-Conditioning Unit			
ACU-1	12.0 SEER	13.8 SEER	Yes
ACU-2	12.0 SEER	13.8 SEER	Yes
ACU-3	12.0 SEER	13.8 SEER	Yes
ACU-4	12.0 SEER	13.8 SEER	Yes
Computer Room ACU			
CRAC-1	12.0 SEER	12.5 SEER	Yes
Cabinet Unit Heaters			
CUH-1	None		Yes
CUH-2	None		Yes
CUH-3 (2 total)	None		Yes
CUH-4	None		Yes
Water Heaters			
WHTR-1 (2 total)	0.9 EF	0.89 EF	No
WHTR-2	0.9 EF	0.89 EF	No
WHTR-3 (2 total)	0.9 EF	0.95 EF	Yes
WHTR-4	0.8 EF	0.89 EF	Yes
WHTR-5 (2 total)	0.9 EF	0.95 EF	Yes

Table 3: Equipment used in the Gaige Building and their minimum compliance values for ASHRAE 90.1 Section 6.4

Each zone in the Gaige Building has individual zone thermostat control, and each thermostat is connected to a separate variable air volume terminal unit that controls the airflow to the zone. Each variable air volume box modulates flow to provide conditioning for the current load on the room, with a minimum set point based upon the ventilation requirements of the space. Occupancy sensors are provided in all occupied spaces with a fairly consistent occupancy or population when occupied. In larger rooms with a more variable occupancy, CO2 sensors are provided to control not only space conditioning requirements, but outside air requirements as well.

The controls of the building has a cooling set point of 79 degrees, and a heating set point of 66 degrees when occupied. When unoccupied, the set points widen to a cooling set point of 84 degrees and a heating set point of 56 degrees. This allows for energy saving during unoccupied building times, but the system still maintains the indoor building temperatures at normal operation values. All ductwork in the Gaige building has been designed to comply with requirements set out to seal and adequately fire-stop all connections in ductwork. As well, all ductwork and piping is properly insulated according to ASHRAE Standard 90.1.

6.5: Prescriptive Path

For the Gaige Building, each of the RTU's in the design are equipped with an economizer, meeting the requirements set forth for this type of equipment. Outside air dampers are modulated with the exhaust air and return air dampers, and all fan speed are monitored and adjusted accordingly. As well, the CO2 sensors along with the VAV boxes communicate back the current outdoor air requirement to provide ventilation air only when it is needed.

Simultaneous heating and cooling is provided by radiant panel and fin-tube heaters in locations that require heating. Air is supplied to the VAV boxes at 55 degrees, and flow and then temperature are modulated to accommodate for space conditioning needs.

Finally, below is table four, summarizing the fan power limitations set forth by ASHRAE standard 90.1. Each fan used in the design of this building is presented, and whether or not it is compliant with the standard is stated.

Fan Power Limitations				
Equipment Name	Horse Power	CFM	CFM * 0.0015	Comply?
RTU-1				
Supply Fan	20.00	20500	30.75	Yes
Exhasut Fan	10.00	20500	30.75	Yes
RTU-2				
Supply Fan	20.00	14000	21.00	Yes
Exhasut Fan	5.00	14000	21.00	Yes
RTU-3				
Supply Fan	20.00	12500	18.75	No
Exhasut Fan	5.00	12500	18.75	Yes
Exhaust Fans				
EFN-1	0.75	2700	4.05	Yes
EFN-2	0.17	300	0.45	Yes
EFN-3	0.07	75	0.11	Yes
EFN-4	0.50	1500	2.25	Yes
EFN-5	0.25	300	0.45	Yes
EFN-6	0.33	1500	2.25	Yes
EFN-7	0.75	600	0.90	Yes
EFN-8	0.33	80	0.12	No
EFN-9	0.33	80	0.12	No
CRAC-1	0.50	885	1.33	Yes
Cabinet Unit Heaters				
CUH-1	0.10	430	0.65	Yes
CUH-2	0.07	335	0.50	Yes
CUH-3	0.10	630	0.95	Yes
CUH-4	0.07	230	0.35	Yes

Table 4: A summary of the equipment used in the Gaige Building and its compliance with ASHRAE Standard 90.1

6.7: Submittals

Complete design documents and construction specification were given for construction of the building, and since this building has achieved LEED Gold certification, it has been properly documented and analyzed according to ASHRAE Standard 90.1.

Section 7: Service Water Heating

7.4: Mandatory Provisions

The Gaige Building contains two boilers in its design, both gas fired and sized at 1300 MBH. As well, each boiler is 94% efficient. Table 7.8 requires that efficiencies be at least 80%, so the Gaige building meets these requirements. Hot water piping is properly insulated according to table 6.8.3 in standard 90.1, as shown below. Controls are also provided in compliance with section 7.

TABLE 6.8.3A Minimum Pipe Insulation Thickness Heating and Hot Water Systems[a,b,c,d]
(Steam, Steam Condensate, Hot Water Heating and Domestic Water Systems)

Fluid Operating Temperature Range (°F) and Usage	Insulation Conductivity		Nominal Pipe or Tube Size (in)				
	Conductivity Btu·in./(h·ft²·°F)	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness (in)				
>350 °F	0.32–0.34	250	4.5	5.0	5.0	5.0	5.0
251°F–350°F	0.29–0.32	200	3.0	4.0	4.5	4.5	4.5
201°F–250°F	0.27–0.30	150	2.5	2.5	2.5	3.0	3.0
141°F–200°F	0.25–0.29	125	1.5	1.5	2.0	2.0	2.0
105°F–140°F	0.22–0.28	100	1.0	1.0	1.5	1.5	1.5

a For insulation outside the stated conductivity range, the minimum thickness (*T*) shall be determined as follows: $T = r\{(1 + t/r)^{K/k} - 1\}$ where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu·in./h·ft2·°F); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

b These thicknesses are based on energy *efficiency* considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.

c For piping smaller than 1½" and located in partitions within *conditioned spaces*, reduction of these thicknesses by 1" shall be permitted (before thickness adjustment required in footnote a) but not to thicknesses below 1".

d For direct-buried heating and hot water *system* piping, reduction of these thicknesses by 1.5" shall be permitted (before thickness adjustment required in footnote a) but not to thicknesses below 1".

e The table is based on steel pipe. Non-metallic pipes schedule 80 thickness or less shall use the table values. For other non-metallic pipes having *thermal resistance* greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.

7.5: Prescriptive Path

Space heating in the Gaige Building is performed by radiant heating panels and fin-tube units, so space heating water-based equipment is not a requirement for this particular building.

Section 8: Power

8.2: Mandatory Provisions

The electrical system in the Gaige Building is first run from the utility to a 1200 A main distribution switchboard, supplying the building with power at 480/277 Volts. From this system, 480/277 V panel boards supply power to services like the mechanical equipment and other larger building systems. Also, a transformer is provided to step the power system down to a 208/120 V system to supply power to lighting panels, receptacle panels, etc. The Gaige building is in compliance with the 2006 National Electric Code, and all of its power requirements are met, along with the additional requirements set forth is section 8 of ASHRAE Standard 90.1. All required documentation of the building system design and equipment manuals have been provided as well.

Section 9: Lighting

9.2: Compliance Path

For the lighting calculations, the lighting power density calculations were performed using the Building Area Method, and the chosen building type was School/University.

9.4: Mandatory Provisions

In the Gaige Building, CO2 sensors and occupancy sensors are provided not only to help reduce mechanical system efficiency, but to control the lighting system as well. The sensors are set to automatically shut off the lighting after a period of time when a space is unoccupied. The range of time before shut off is an adjustable setting. Overall, the lighting design is compliant with the mandatory provisions stated in section 9 of ASHRAE Standard 90.1.

9.5: Building Area Method Compliance Path

For the Building Area Method, the School/University building type was chosen. With this, the allowable LPD for a school/university building is 0.99 Watts/SF. Given this information, and the total occupiable SF of the Gaige Building, the total allowable lighting watts used in the building comes out to be 63395 Watts. The calculation is summarized below:

$$Total\ Alowable\ Watts = 64{,}036\ SF * 0.99\ \frac{W}{SF} = 63395.6\ Watts$$

When calculated on a fixture by fixture basis, the total wattage used by interior lighting in the building comes out to be 53,604 Watts, which is less than the 63395 Watts allowed by Standard 90.1. So yes, the Gaige Building does comply with the maximum interior wattage requirements.

Section 10: Other Equipment

10.4: Mandatory Provisions

Section ten describes mandatory provisions, outlined in section 10.4. The relevant section of this part can be found below under section 10.4.1, Electric Motors.

10.4.1: Electric Motors

In ASHRAE Standard 90.1, minimum efficiencies are set for electric motors. The rating provided is based upon motor type, motor horsepower, the number of poles, and the synchronous speed of the motor. Since built before 2010, the motors in the Gaige Building are required to comply with the Energy Policy Act of 1992.

In the building specification of the Gaige Building, the specifications for energy efficiency of hydronic pump motors can be found. In the specification, in section *232123: hydronic pumps, 2.2: General Pump requirements*, it is stated that all pump efficiencies shall be compliant with the Energy Policy Act. Thus, with this statement, all pump in the Gaige Building have been designed and are compliant with this requirement set forth.

Summary of Compliance with ASHRAE 90.1

Overall, the Gaige Building, as it is LEED Gold certified, is extremely compliant with ASHRAE Standard 90.1. It meets requirements set forth on all exterior building envelope materials. Some small non-compliances, as well as some over-compliances are discussed below. Overall, it is mainly compliant with ASHRAE Standard 90.1.

Discussion of Non-Compliant Systems

Overall, only minor non-compliant elements were found. First, two water heaters were found to have efficiency values of 0.89 when the requirement for compliance with section 6 was a value of 0.9. This would simply require a different equipment selection, probably another model of the same brand and style (like the other products used on this project). Also, some of the fans were found to not comply with the fan power limitations set forth in section six as well. With a lower HP option chosen, these limitation would be satisfied.

These limitations are only exceeded when extremely small flow rates create very strict power limitations. Again, a simply change in fan selection would rectify this problem and allow full compliance with ASHRAE Standard 90.1.

Discussion of Over-Compliant Systems

Although the building is compliant, some of the exterior building materials, such as the extremely high performing windows, can be called into question. Although the high performance windows were required to meet PSU's reduction from ASHRAE Standard 90.1 of 30%, they accomplished this by using extremely high performance windows. Whether or not the cost of buying such high performing windows was weighed out based upon the savings from utility costs in unclear. Potentially, it could easily be seen that this glazing system was simply installed to 'meet a requirement' as opposed to cost-effectively reducing the energy consumption of the building without drastically increasing the initial costs of the building. There is potential for analysis of this fact in further study.

References

ANSI/ASHRAE. (2010). Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ANSI/ASHRAE. (2010). Standard 90.1-2007, Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

RMJM Hillier Architects. Architectural Construction Documents. RMJM/Hillier Architecture, New York,

H. F. Lenz Company, LLP. Electrical, Mechanical, and Plumbing Construction Documents. H. F. Lenz Company, Johnstown, PA

Appendix A

Ventilation Air CalculationsL: RTU-1														
Space	Space Type	A_z (SF)	P_z (people)	R_a (CFM/SF)	R_a*A_z (CFM)	R_p (CFM/person)	R_p*P_z (CFM)	V_{bz} (CFM)	E_z	V_{oz} (CFM)	V_{pz} (CFM)	Z_{pz}	E_v (zone)
Learning Loft Q206	Lounge	1499	30	0.18	269.82	7.5	225	495	0.8	619	2000	0.31	0.84
Resource Q205	Office	205	2	0.06	12.3	5	10	22	0.8	28	220	0.13	1.00
Classroom 244	Classroom	902	28	0.12	108.24	10	280	388	0.8	485	1200	0.40	0.75
Classroom 245	Classroom	856	31	0.12	102.72	10	310	413	0.8	516	1230	0.42	0.73
Classroom 246	Classroom	1269	58	0.12	152.28	10	580	732	0.8	915	1600	0.57	0.76
Classroom 247	Classroom	1010	46	0.12	121.2	10	460	581	0.8	727	1500	0.48	0.67
Classroom 248	Classroom	764	31	0.12	91.68	10	310	402	0.8	502	920	0.55	0.60
Classroom 249	Classroom	789	25	0.12	94.68	10	250	345	0.8	431	820	0.53	0.62
Learning Loft Q102	Lobby	2612	30	0.06	156.72	5	150	307	0.8	383	920	0.42	0.73
Corridor Q103	Corridor	478	0	0.06	28.68	0	0	29	0.8	36	100	0.36	0.79
Classroom 120	Classroom	805	31	0.12	96.6	10	310	407	0.8	508	1150	0.44	0.71
Classroom 121	Classroom	1587	60	0.12	190.44	10	600	790	0.8	988	1750	0.56	0.77
Seminar Classroom 122	Classroom	406	20	0.12	48.72	10	200	249	0.8	311	580	0.54	0.61
Bits & Bytes Café 123	Cafeteria	740	20	0.18	133.2	7.5	150	283	0.8	354	1200	0.30	0.86
HRIM Lab Kitchen 123A	Kitchen	492	2	0.12	59.04	7.5	15	74	0.8	93	260	0.36	0.79
Retail 123B	Cafeteria	191	2	0.12	22.92	10	20	43	0.8	54	270	0.20	0.95
Lobby F102	Lobby	635	5	0.06	38.1	5	25	63	0.8	79	500	0.16	0.99
Electrical Lab 116	Laboratory	804	21	0.18	144.72	10	210	355	0.8	443	780	0.57	0.84
Super/Assistant 115	Office	169	1	0.06	10.14	5	5	15	0.8	19	120	0.16	0.99
Equipment Storage 115A	Storage	307	0	0.12	36.84	0	0	37	0.8	46	150	0.31	0.84
Engineering Automation 114	Laboratory	1007	20	0.18	181.26	10	200	381	0.8	477	920	0.52	0.63
Electronics Lab 113	Laboratory	750	20	0.18	135	10	200	335	0.8	419	800	0.52	0.63
Learning Resource Center 111	Classroom	394	5	0.12	47.28	10	50	97	0.8	122	540	0.23	0.92
Lounge 111A	Lounge	315	5	0.18	56.7	7.5	37.5	94	0.8	118	500	0.24	0.91
Seminar Classroom 112	Classroom	501	25	0.12	60.12	10	250	310	0.8	388	700	0.55	0.78
	Totals:		518		2399		4847.5						

Summary for RTU-1	
Diversity (D):	100%
V_{ou} (CFM):	7247
Overall Ev (minimum):	0.60
Final V_{ot} (CFM):	11993

Ventilation Air CalculationsL: RTU-2														
Space	Space Type	A_z (SF)	P_z (people)	R_a (CFM/SF)	R_a*A_z (CFM)	R_p (CFM/person)	R_p*P_z (CFM)	V_{bz} (CFM)	E_z	V_{oz} (CFM)	V_{pz} (CFM)	Z_{pz}	E_v (zone)
Open Source Computer Lab 209	Computer Lab	712	17	0.12	85.44	10	170	255	0.8	319	740	0.43	0.72
Lobby F201	Lobby	444	5	0.06	26.64	5	25	52	0.8	65	120	0.54	0.61
Department Resource Q207	Lobby	288	0	0.06	17.28	5	0	17	0.8	22	50	0.43	0.72
Lobby F204	Lobby	87	0	0.06	5.22	5	0	5	0.8	7	30	0.22	0.93
Networking Computer Lab 208	Computer Lab	701	17	0.12	84.12	10	170	254	0.8	318	800	0.40	0.75
Server Room 207/IT Storage 207A	Storage	325	0	0.12	39	0	0	39	0.8	49	320	0.15	1.00
IT Storage 203	Storage	376	0	0.12	45.12	0	0	45	0.8	56	140	0.40	0.75
General Purpose Computer Lab 204	Computer Lab	1024	35	0.12	122.88	10	350	473	0.8	591	1200	0.49	0.66
Emerging Technology Lab 206	Laboratory	696	17	0.18	125.28	10	170	295	0.8	369	800	0.46	0.69
Corridor Q201	Corridor	980	0	0.06	58.8	0	0	59	0.8	74	260	0.28	0.87
General Purpose Computer Lab 205	Computer Lab	856	29	0.12	102.72	10	290	393	0.8	491	1320	0.37	0.78
Corridor Q101	Corridor	900	0	0.06	54	0	0	54	0.8	68	200	0.34	0.81
Corridor Q104	Corridor	310	0	0.06	18.6	0	0	19	0.8	23	90	0.26	0.89
Super/Assist Office 107	Office	102	1	0.06	6.12	5	5	11	0.8	14	70	0.20	0.95
Lobby F103	Lobby	465	5	0.06	27.9	5	25	53	0.8	66	140	0.47	0.68
Lobby F104	Lobby	105	0	0.06	6.3	5	0	6	0.8	8	30	0.26	0.89
Lobby F105	Lobby	106	0	0.06	6.36	5	0	6	0.8	8	30	0.27	0.89
Prototype Lab 108	Laboratory	1534	50	0.18	276.12	10	500	776	0.8	970	1750	0.5544	0.82
Receiving 109/Storage 109A	Shipping/Receiving	425	0	0.12	51	10	0	51	0.8	64	420	0.15	1.00
Design Lab 103	Laboratory	785	24	0.18	141.3	10	240	381	0.8	477	1000	0.48	0.67
Projects Lab 106	Laboratory	956	24	0.18	172.08	10	240	412	0.8	515	1000	0.52	0.63
Research Lab 104	Laboratory	518	20	0.18	93.24	10	200	293	0.8	367	690	0.53	0.62
Measurement Lab 105	Laboratory	975	24	0.18	175.5	10	240	416	0.8	519	1410	0.37	0.78
	Totals:		268		1741.02		2625						

Summary for RTU-3	
Diversity (D):	100%
V_{ou} (CFM):	**4366**
Overall Ev (minimum):	0.61
Final V_{ot} (CFM):	**7133**

Ventilation Air CalculationsL: RTU-3														
Space	Space Type	A_z (SF)	P_z (people)	R_a (CFM/SF)	R_a*A_z (CFM)	R_p (CFM/person)	R_p*P_z (CFM)	V_{bz} (CFM)	E_z	V_{oz} (CFM)	V_{pz} (CFM)	Z_{pz}	E_v (zone)
Faculty Office 336 & Q304	Office	509	1	0.06	30.5	5	5	35.5	1.0	35.5	155	0.23	0.92
Department Resource 328	Corridor	116	0	0.06	7.0	0	0	7.0	1.0	7.0	70	0.10	1.00
Faculty Office 333, 334 & 335	Office	277	3	0.06	16.6	5	15	31.6	1.0	31.6	330	0.10	1.00
Faculty Office 330, 331 & 332	Office	273	3	0.06	16.4	5	15	31.4	1.0	31.4	330	0.10	1.00
Faculty Office 329	Office	123	1	0.06	7.4	5	5	12.4	1.0	12.4	280	0.04	1.00
Conference 325	Conference	154	3	0.06	9.2	5	15	24.2	1.0	24.2	140	0.17	0.98
Faculty Office 324, 326 & 327	Office	294	5	0.06	17.6	5	25	42.6	1.0	42.6	360	0.12	1.00
Corridor Q303	Corridor	621	0	0.06	37.3	0	0	37.3	1.0	37.3	200	0.19	0.96
Lobby F301	Lobby	456	0	0.06	27.4	5	0	27.4	1.0	27.4	450	0.06	1.00
Lobby F304	Lobby	97	0	0.06	5.8	5	0	5.8	1.0	5.8	50	0.12	1.00
Corridor Q305	Corridor	99	0	0.06	5.9	0	0	5.9	1.0	5.9	50	0.12	1.00
Copy/Fax/Printer 322	Office	95	1	0.06	5.7	5	5	10.7	1.0	10.7	130	0.08	1.00
Faculty Office 319	Office	131	1	0.06	7.9	5	5	12.9	1.0	12.9	120	0.11	1.00
Corridor Q301	Corridor	800	0	0.06	48.0	0	0	48.0	1.0	48.0	240	0.20	0.95
Corridor Q306	Corridor	48	0	0.06	2.9	0	0	2.9	1.0	2.9	20	0.14	1.00
Corridor Q307A	Corridor	95	0	0.06	5.7	0	0	5.7	1.0	5.7	30	0.19	0.96
Faculty Office 320, 321, & 323	Office	299	3	0.06	17.9	5	15	32.9	1.0	32.9	360	0.09	1.00
Faculty Office 304	Office	114	1	0.06	6.8	5	5	11.8	1.0	11.8	110	0.11	1.00
Faculty Office 305 & 306	Office	221	2	0.06	13.3	5	10	23.3	1.0	23.3	320	0.07	1.00
Conference 317	Conference	150	3	0.06	9.0	5	15	24.0	1.0	24.0	120	0.20	0.95
PT Faculty Office 313	Office	133	1	0.06	8.0	5	5	13.0	1.0	13.0	100	0.13	1.00
Faculty Office 303 & 303A	Office	244	1	0.06	14.6	5	5	19.6	1.0	19.6	230	0.09	1.00
Conference 311A	Conference	150	3	0.06	9.0	5	15	24.0	1.0	24.0	120	0.20	0.95
Admin. Assistant 307A	Office	133	1	0.06	8.0	5	5	13.0	1.0	13.0	160	0.08	1.00
Chancellors Office 307B	Office	321	1	0.06	19.3	5	5	24.3	1.0	24.3	440	0.06	1.00
Reception 307	Reception Areas	476	4	0.06	28.6	5	20	48.6	1.0	48.6	330	0.15	1.00
Conference 311	Conference	205	4	0.06	12.3	5	20	32.3	1.0	32.3	200	0.16	0.99
Faculty Offices 315, 316, 318	Corridor	295	3	0.06	17.7	0	0	17.7	1.0	17.7	360	0.05	1.00
Faculty Office 310, 312 & 314	Corridor	285	3	0.06	17.1	0	0	17.1	1.0	17.1	360	0.05	1.00
Corridor Q202	Corridor	1307	0	0.06	78.4	0	0	78.4	1.0	78.4	220	0.36	0.79
Faculty Office 309	Office	115	1	0.06	6.9	5	5	11.9	1.0	11.9	165	0.07	1.00
Seminar Classroom 308	Classroom	634	25	0.12	76.1	10	250	326.1	1.0	326.1	1500	0.22	0.93
Storage 209A	Computer	100	1	0.06	6.0	5	5	11.0	1.0	11.0	150	0.07	1.00

Ventilation Air CalculationsL: RTU-3-continued														
Space	Space Type	A_z (SF)	P_z (people)	R_a (CFM/SF)	R_a*A_z (CFM)	R_p (CFM/person)	R_p*P_z (CFM)	V_{bz} (CFM)	E_z	V_{oz} (CFM)	V_{pz} (CFM)	Z_{pz}	E_v (zone)
Storage 210A	Storage	180	0	0.12	21.6	0	0	21.6	1.0	21.6	220	0.10	1.00
Admin. Assistant 210B	Office	182	1	0.06	10.9	5	5	15.9	1.0	15.9	220	0.07	1.00
Directors Office 210	Office	201	1	0.06	12.1	5	5	17.1	1.0	17.1	390	0.04	1.00
Faculty Office 211, 212 & 213	Office	260	3	0.06	15.6	5	15	30.6	1.0	30.6	330	0.09	1.00
Faculty Office 214, 215, & 216	Office	263	3	0.06	15.8	5	15	30.8	1.0	30.8	330	0.09	1.00
Faculty Office 219, 218 & 217	Office	261	3	0.06	15.7	5	15	30.7	1.0	30.7	420	0.07	1.00
Faculty Office 221, 223 & 224	Office	264	3	0.06	15.8	5	15	30.8	1.0	30.8	330	0.09	1.00
Faculty Office 220	Office	95	1	0.06	5.7	5	5	10.7	1.0	10.7	120	0.09	1.00
Mail Support 222	Shipping/Receiving	130	1	0.12	15.6	10	10	25.6	1.0	25.6	110	0.23	0.92
Faculty Office 226, 228 & 225	Office	277	3	0.06	16.6	5	15	31.6	1.0	31.6	330	0.10	1.00
PT Faculty Lounge 229	Lounge	292	1	0.18	0.0	7.5	7.5	60.1	1.0	60.1	440	0.14	1.00
Faculty Office 232, 233 & 230	Office	271	3	0.06	16.3	5	15	31.3	1.0	31.3	330	0.09	1.00
Conference 231	Conference	155	3	0.06	9.3	5	15	24.3	1.0	24.3	140	0.17	0.98
Faculty Office 236, 238, & 235	Office	262	3	0.06	15.7	5	15	30.7	1.0	30.7	330	0.09	1.00
Faculty Office 237, 239, & 241	Office	360	3	0.06	21.6	5	15	36.6	1.0	36.6	260	0.14	1.00
Faculty Office 242 & 240	Office	172	2	0.06	10.3	5	10	20.3	1.0	20.3	220	0.09	1.00
	Totals:		**109**		**818.8**		**647.5**						

Summary for RTU-3	
Diversity (D):	100%
V_{ou} (CFM):	**1466**
Overall Ev (minimum):	0.79
Final V_{ot} (CFM):	**1848**

Appendix B

Inerior Lighting Power Density Summary			
Fixture Designation	# of Fixtures	Fixture Watts	Total Watts
LA	439	33	14487
LA-1	30	58	1740
LA-2	95	33	3135
LA-4	28	38	1064
LA-6	14	40	560
LB	90	33	2970
LB-1	119	33	3927
LC	30	65	1950
LC-1	6	33	198
LD	68	65	4420
LE	36	36	1296
LG	17	90	1530
L J	2	64	128
L J-2	3	49	147
L J-3	2	48	96
LK	2	85	170
LK-1	14	65	910
LK-2	15	101	1515
LK-3	25	36	900
LK-4	5	166	830
LK-5	9	65	585
LK-6	2	65	130
LK-7	11	66	726
LK-8	2	29	58
LM	9	90	810
LN	9	8	72
LP	34	36	1224
LP-1	10	67	670
LT	26	36	936
LV	4	17	68
LAA	15	85	1275
LBB	8	33	264
LCC	4	4	16

LDD	1	32	32	
LEE	2	20	40	
LGG	5	100	500	
A	8	65	520	
C	39	65	2535	
D	8	65	520	
E	10	65	650	
		Total:	**53604**	**Watts**
		Allowable Watts:	**63395**	**Watts**
		Compliant?:	**Yes**	