Technology and Engineering Development (TED) Building

Thomas Jefferson National Accelerator Facility

Newport News, VA

Tech Report I

ASHRAE Std. 62.1-2007 and Std. 90.1-2007 Compliance Report

10/4/2010

David Blum | Mechanical Option

Dr. James Freihaut | Adviser

Architectural Engineering | The Pennsylvania State University

Table of Contents

List of Tables and Figures

Executive Summary

The Technology and Engineering Development (TED) Building is a 67,000 ft^2 building designed to provide technical support to the Continuous Electron Beam Accelerator Facility at the Thomas Jefferson National Accelerator Facility. It is a two story building with technical workspaces on the first floor, open office and administrative spaces on the second floor, and an adjacent two story high bay assembly area. This report analyzes the compliance of the TED mechanical system with ASHRAE Std. 62.1-2007 and ASHRAE Std. 90.1-2007.

Std. 62.1 sets requirements relating to indoor air quality, environmental provisions (Section 5), and ventilation requirements (Section 6). The two air systems in the TED serve very different occupancy types; one serving workshop space and the other serving office space. Therefore, both were analyzed for compliance with Std. 62.1. The TED is found to be compliant with sections 5 and 6 of this standard.

Std. 90.1 concentrates on the energy efficiency of the building and sets maximum energy usage or minimum efficiency values for various components of the mechanical system. The TED does not fully comply with every prescriptive requirement listed by the standard. However, instances in which the design does not comply are shown to be irrelevant or negligible when compared to the overall energy efficiency for the entire system. Overall, the design requires significantly less energy use than the design described by the prescriptive methods of Std. 90.1.

Conditioned air is supplied to the TED through two 32,000 CFM air handling units; the first serving the first floor and high bay and the second serving the second floor office space. Each AHU is attached to a total energy recovery unit that uses exhaust air to precondition incoming outdoor air. A hybrid geothermal heat pump system, containing a closed-loop cooling tower and gas fired condensing boiler, supply hot and chilled water to each AHU as well as individual water-cooled air-conditioning units and cabinet unit heaters. A DDC building automation system controls all of the components of the mechanical system.

ASHRAE Std. 62.1-2007 Compliance Analysis

Section 5 Systems and Equipment

5.1 Natural Ventilation

Natural ventilation is not relied on to provide proper ventilation to the spaces. No analysis is completed.

5.2 Ventilation Air Distribution

Compliance is detailed in section 6.

5.3 Exhaust Duct Location

All rectangular ductwork, including exhaust ductwork, is specified to comply with SMACNA Seal Class A, exempting compliance with section 5.3. However, compliance would still be achieved because potentially contaminated air from toilet rooms, mechanical rooms, and a fume hood (located in a fabrication shop) is exhausted from the roof by exhaust fans and through dedicated ductwork. The exhaust ductwork is specified to be 2 in wg negative.

5.4 Ventilation System Control

A programmable occupancy schedule included in the DDC system automatically signals the outdoor air unit supply fans, air handling unit supply fans, fan powered boxes, and variable air volume boxes to energize or de-energize accordingly. An unoccupied override button located on the temperature sensor corresponding to each terminal box can enable the air system serving that zone for two hours. In addition, CO_2 sensors monitor the occupancy in conference rooms to automatically modify air requirements for low usage. These controls allow the ventilation system to operate whenever the spaces are occupied, satisfying section 5.4 requirements.

5.5 Airstream Surfaces

All rectangular ductwork is specified to be minimum 24 gauge sheet metal, exempting compliance with section 5.5 requirements. Flexible duct and connectors are specified to be listed under UL-181, complying with section 5.5.1 Mold Growth and 5.5.2 Corrosion requirements.

Air handling and outside air units are to be constructed of 18 to 22 gauge galvanized steel sheet metal, exempting compliance with section 5.5.1 Mold Growth and 5.5.2 Corrosion requirements. The total energy wheel within the outside air unit is specified to be aluminum with a corrosion resistant coating. This complies with section 5.5.2 Corrosion requirements; however, no specified reference is found for compliance with section 5.5.1 Mold Growth.

5.6 Outdoor Air Intakes

Outdoor air intakes for the supply of outside air preconditioning units and air handling unit economizer sections meet all distance requirements located in Table 5-1 of Std. 90.1 for their proximity to locations with harmfully low air qualities. These locations include some exhaust openings, loading docks, or cooling towers.

All AHUs and OAUs are specified to be constructed for outdoor conditions, including weather tight sealing. In addition, 0.5 in square mesh bird screens constructed of 0.063 in metal wire are located on all intakes and openings. These outdoor environment specifications comply with section 5.6.

5.7 Local Capture of Contaminants

Contaminants from the fume hood located in the fabrication shop are ducted directly to the roof and expelled to the outdoors 10 ft above the roof via an exhaust fan. This complies with section 5.7.

5.8 Combustion Air

The boiler has a separate combustion air intake and flue exhaust ducts with openings each located on the roof. In the high bay area, a welding fume extraction system is used to exhaust welding fumes directly to the outdoors through a side wall penetration. These systems are in compliance with section 5.8.

5.9 Particulate Matter Removal

MERV rated 8/13 (30%/85%) are located upstream of the cooling coil in each air handling unit. This is in compliance of section 5.9.

5.10 Dehumidification System

With a cooling supply air set point of 52 F WB and a space cooling set point of 75 F, the building automation system is to keep the spaces at approximately 50% relative humidity. The design minimum outdoor air intake is 14,300 CFM and the design maximum exhaust airflow is 12,000 CFM. The net building positive pressure reduces infiltration of untreated outside air. The relative humidity set point and >1 ratio of minimum outdoor to maximum exhaust air comply with section 5.10.

5.11 Drain Pans

Drain pan fabrication and installation are specified to be compliant with Std. 62.1. They are to be insulated, double walled, sloped, and located under the air handling unit cooling coils and humidifiers. This is assumed to be compliant with section 5.11.

5.12 Finned-Tube Coils and Heat Exchangers

Air handling unit cooling coils contain drain pans as discussed in section 5.11 above. Access doors are provided between AHU pre-heating and cooling coils for maintenance and cleaning. These measures comply with section 5.12.

5.13 Humidifiers and Water Spray Systems

The source of the humidifier water is potable domestic water. There is a straight and uninterrupted duct length of 3ft downstream of the humidifier. The humidifier location and water source are compliant with section 5.13.

5.14 Access for Inspection, Cleaning, and Maintenance

Appropriate access doors and clearances have been specified for air handlers, outside air precondition units, and ductwork that provide the ability to inspect, clean, and maintain these components of the ventilation system. This is in compliance with section 5.14.

5.15 Building Envelope

Air and vapor barriers are specified to fully enclose and seal exterior walls. All penetrations through AVBs are sealed with vapor retarding tape that produces an air tight seal. All foundation walls, elevator pits, and slabs on grade are sealed using a bentonite polymer alloy water proofing system. Exterior joints are sealed using electrometric sealants classified as watertight and airtight. All weather barriers and seals comply with section 5.15.

5.16 Buildings with Attached Parking Garages

There is no attached parking garage to the TED. No analysis is completed.

5.17 Air Classification and Recirculation

Air class designations for each space are provided in Table A-1 and Table A-2 located in Appendix A. Zone air designated as Class 2 that is recirculated through the return air system and used as a proportion of supply air can be reclassified as Class 1 upon recirculation air due to the presence of MERV 8/13 filers located in each air handler. Air from toilet and mechanical rooms is exhausted directly out of the building. It passes through an energy recovery unit and exchanges energy with incoming outside air through a total energy wheel; air streams are not mixed. Class 4 air from the boiler flue and welding workshop in the high bay is exhausted directly out of the building. These exhaust and recirculation measures comply with section 5.17.

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

Smoking is prohibited inside the building or within 25 ft of entrances and openings.

Section 6 Procedures

Section 6 of ASHRAE Std. 62.1-2007 describes the ventilation rate procedure by which necessary outdoor air ventilation airflows are calculated for each space. Table A-1 and Table A-2 in Appendix A summarize the results of this procedure for both analyzed systems. These tables were used to determine compliance with section 6 of the standard. The procedure is outlined as follows with Std. 62.1 equations and table numbers referenced along the right margin:

The required outdoor airflow for each zone is determined by:

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

Where V_{bz} *= Required outdoor airflow for zone (cfm)*

R_p *= Outdoor airflow rate required per person (cfm / person)* Table 6-1

P_z *= Zone population (people)*

R_a *= Outdoor airflow rate required per square foot (cfm / ft*^{2}*)* Table 6-1

A_z *= Zone floor area (ft*^{2}*)*

The required outdoor airflow for each zone is corrected by a zone air distribution effectiveness to give the design outdoor airflow for each zone as determined by:

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

Where V_{oz} *= Design outdoor airflow for zone (cfm)*

E_z *= Zone air distribution effectiveness* Table 6-2

The ratio of the design outdoor airflow rate to the total primary airflow rate to each zone is determined by:

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

Where Z_p *= Zone primary outdoor air fraction*

V_{pz} *= Minimum expected primary airflow to zone including outdoor and recirculation air (cfm)*

The total outdoor air intake for the system, modified by occupant diversity but uncorrected for system ventilation efficiency, is determined by:

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

Where V_{ou} *= Design uncorrected outdoor air intake (cfm)*

The occupant diversity for Equation 6-6 is determined by:

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

Where D = Occupant Diversity

P_s *= System Population (people)*

The final design outdoor air intake flow rate, corrected by the system ventilation efficiency, is determined by:

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

Where V_{ot} *= Design outdoor air intake flow (cfm)*

E_v *= System ventilation efficiency using max* Z_p Table 6-3

The final calculated design outdoor air intake flow rate is compared to the design outdoor air intake to determine compliance with section 6 of ASHRAE Std. 62.1-2007. Table 1-6-1 below shows the final results of this analysis.

Table 1-6-1: Outdoor Air Compliance

System	Required (cfm)	Design (cfm)	Compliance
AHU 1	6369	7500	Yes
AHU 2	3748	6800	Yes

Std. 62.1 Conclusion

The TED achieves compliance with each section in Std. 62.1 as analyzed above. This is to be expected when considering the nature of work performed in the TED, specifically on the first floor. The scientific and engineering support that the TED is designed to give to the Thomas Jefferson National Accelerator Facility is vital to its successful research advances. The quality of the material fabricated and stored on this floor can be severely impacted by improper moisture or particulate levels in the air.

Striving for LEED v2.2 Gold Certification has added extra motivation to going above and beyond the requirements of Std. 62.1. Two LEED credits obtained that impact compliance with Std. 62.1 are the use of low emitting materials, including adhesives, sealants, paints, coatings, and carpets, and increased ventilation. These credits contribute to significant improvements of indoor air quality in the TED.

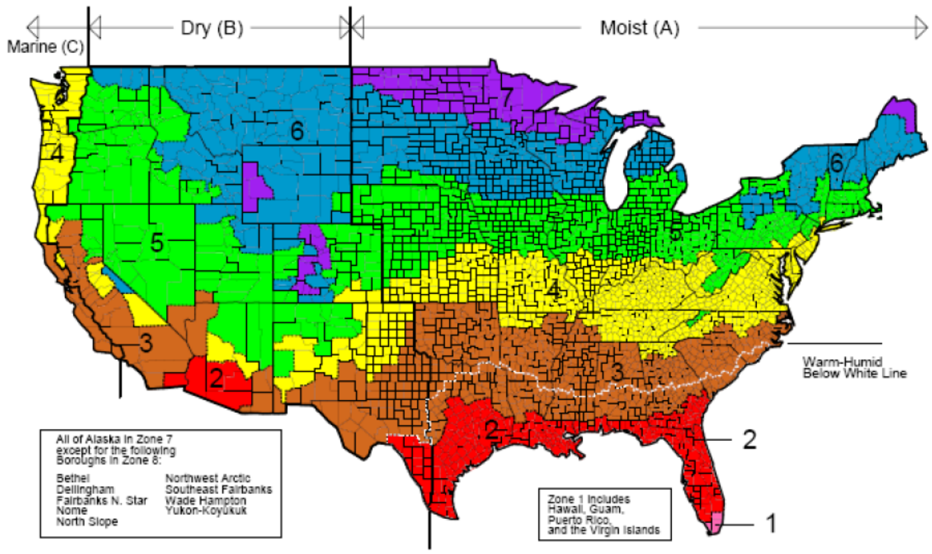
ASHRAE Std. 90.1-2007 Compliance Analysis

Section 5 Building Envelope

5.1 General

The TED is categorized as a nonresidential conditioned space and is located in climate zone 4A, based on the location of Newport News, VA on figure B-1 and Table B-1 in appendix B from Std. 90.1. Figure 2-5-1, below, shows the climate zone map with climate zone 4A shaded in yellow.

Figure 2-5-1: Climate Zone Map from ASHRAE Std. 90.1, Figure B-1



5.4 Mandatory Provisions

Air leakage is minimized by the use of sealants in all required joint locations. The sealants specified also qualify for LEED credits MR 4.1 and MR 4.2 for recycled content, and EQ 4.1 for low emitting materials. Aluminum framed entrances and storefronts and glazed aluminum curtain walls are specified to have air leakage rates of up to 0.06 cfm/ft^2, less than the required 0.4 cfm/ft^2. Overhead loading dock doors are sealed as required by containing weather-stripping gaskets fitted along the top and bottom The vestibule comprising the main entrance to the building is 8 ½ ft wide between the two sets of doors; greater than the required 7 ft width for compliance. The TED complies with section 5.4.

5.5 Prescriptive Building Envelope Option

Vertical fenestration makes up approximately 18% of the total wall area. The second floor, containing primarily open office space, accounts for 65% of all fenestration in the building. This is to maximize the amount of natural light entering the open office areas, decreasing the amount of artificial lighting needed for the space. In addition, second floor fenestration is sputtered to control the amount of heat gain through the glass.

Section 5.5 compliance can be analyzed using the Prescriptive Building Envelope Option because the total amount of vertical fenestration accounts for less than 40% of the total building wall area. Table 2-5-1, shown below, summarizes compliance with section 5.5. Required values were taken from Table 5.5.4 of Std. 90.1.

Table 2-5-1: Prescriptive Building Envelope Compliance for Climate Zone 4A

Assembly	Required		Design		Compliance
Roof	R = 20 Min		R = 30		Yes
Masonry Cavity Wall	R = 9.5 Min		R = 15		Yes
Metal Wall Panels	R = 13 Min		R = 14		Yes
Below Grade Wall	NR		NR		Yes
Slab On Grade (unheated)	NR		NR		Yes
Glazed Aluminum Curtain Wall	U = 0.50 Max	SHGC = 0.40 Max	U = 0.46	SHGC = 0.38	Yes
Aluminum Framed Entrances and Store Fronts	U = 0.50 Max	SHGC = 0.40 Max	U = 0.40	SHGC = 0.28	Yes
Skylight w/ Curb <2% Roof Area	U = 1.17 Max	SHGC = 0.49 Max	U = 0.28	SHGC = 0.37	Yes

Section 6 Heating, Ventilation, and Air Conditioning

6.4 Mandatory Provisions

See section 6.8 for minimum equipment efficiency compliance analysis.

Temperature in each zone is controlled by motorized dampers located on the terminal box for each zone. A decrease in temperature sensed by temperature sensors located in each zone will modulate the damper until its minimum position; upon which a further decrease in temperature will activate the modulation of a reheat coil to maintain space temperature set points.

For each system, a reprogrammable schedule will include occupied and unoccupied hours. During unoccupied hours, the DDC de-energizes the air handling unit, attached outside air unit, and associated terminal boxes, shutting down fans and closing intake and exhaust dampers. The AHU and associated terminal boxes are energized intermittently during this time to maintain reprogrammable setback zone temperatures. Temporary occupancy start-up while in unoccupied mode by manual push buttons on temperature sensors located in zones will energize the zone's associated AHU, OAU, and terminal box for two hours. During warm up or cool down time, the OAU remains de-energized, while the AHU and terminal boxes begin to operate as per occupied hours. The time given for this period is calculated based on outdoor and indoor temperatures.

Preheat coil pumps are energized when the outdoor air temperature is below 36 F and heat trace coils are energized below a reprogrammable set point from 30 F to 50 F. Large conference or meeting rooms utilize CO_2 sensors for demand controlled ventilation. These HVAC system control measures comply with section 6.4.

All rectangular ducts are specified to be class A sealed, meeting all duct sealing requirements in section 6.4 for supply, return, and exhaust ductwork.

6.5 Prescriptive Path

Each air handler utilizes an economizer, though the standard does not require that of systems in climate zone 4A. Economizer control is sequenced with air temperature; modulating the return and outside air dampers, and closing the cooling coil valve.

Fan system power limitations are met by all system fans except for the supply fans for AHU 1 and AHU 2. These fans each use 2 more horsepower than the standard limitations allow. For a more detailed summary of this analysis, please see Table B-1 in Appendix B.

Hydronic system pumps, including two for chilled water, two for hot water, and three for condenser water, utilize staged variable speed drives to modulate water flow for varying load conditions. This hydronic system control strategy complies with section 6.5.

6.7 Submittals

Individual specification sections are dedicated to testing, adjusting, and balancing for HVAC systems and to detailed commissioning guidelines; complying with section 6.7.

6.8 Minimum Equipment Efficiency

Equipment efficiencies were analyzed and compared to minimum values set by Std. 90.1 Tables 6.8.1A through 6.8.1G. An analysis was completed for twelve water to water geothermal water source heat pumps (all one type), one closed circuit cooler, one gas fired condensing boiler, and three water cooled air conditioning units (all one type). The analysis found that all equipment complied with Std. 90.1 minimum efficiencies except the water cooled air conditioning units, where a design EER equal to 6.2 was calculated compared to the allowable minimum EER of 12.1. A summary of all equipment efficiency results can be found in Tables B-2 through B-5 in Appendix B.

Section 7 Service Water Heating

7.4 Mandatory Provisions

Service hot water is supplied by a gas fired storage type water heater, rated at 150,000 Btu/hr input and 100 gallon storage capacity. No specific information for standby losses is obtained; therefore no quantitative analysis comparable to Table 7.8 can be performed. However, the specifications for the gas fired water heater require of manufacturers that the water heater complies with minimum efficiency standards listed in ASHRAE 90.1.

The water heater includes controls that regulate the supply of gas to the main burner, allowing water storage temperature to be adjusted as needed. A mixing valve regulates the outlet temperature by sensing the temperature of each inlet flow and controlling the proportions of each flow to produce an outlet flow with the set point temperature. The water heater exit temperature is maintained at 15 F above the set point temperature to allow for mixing of return water. These hot water system control measures are in compliance with section 7.4.

Section 8 Power

8.4 Mandatory Provisions

The electrical engineer's basis of design reports that voltage drop for branch circuits do not exceed 3%. It also states that the combination of both feeder and branch circuits do not exceed 3%. This does not specifically comply with a maximum of 2% voltage drop for feeders, as required by section 8.4. However, this significantly exceeds the NEC 2008 requirement of the combination voltage drop of branch and feeder circuits being maximum 5%; therefore, compliance with section 8.4 can be inferred.

Section 9 Lighting

9.4 Mandatory Provisions

TED lighting is controlled by a combination of manual switches, time switches, occupancy sensors, and photoelectric sensors. Time switches are capable of up to 8 on-off set points in a 24-hour period. In addition, they include reprogrammable annual holiday schedules that override daily set points. Occupancy switches use a combination of passive infrared and ultrasonic technology to properly sense occupant presence. When unoccupied, lights are turned off after a set time limit that is reprogrammable between 1 and 15 minutes.

Interior photoelectric switches monitor and control the amount of light in an area and lights are switched off when natural daylight levels are sufficient. A reprogrammable 5 to 300 second time delay and adjustable dead band are included to prevent cycling. Exterior photoelectric switches monitor and control the light levels of exterior spaces during operation hours with a 15 second time delay to prevent false switching. These interior and exterior lighting control measures comply with section 9.4.

9.5 Building Area Method Compliance

The Building Area Method was used to determine compliance with section 9.5. This method calculates the Lighting Power Density (W / ft^2) for the entire building. Allowable LPD values are from Table 9.5.1 if Std. 90.1. The results of the analysis show the TED is compliant with section 9.5 and are summarized in Table 2-9-2 below. A more detailed spreadsheet of the analysis can be found in Table C-1 of Appendix C.

Table 2-9-1: Building Area Method Compliance

Space	Classification	Area (ft^2)	Power (W)	Allowable LPD (W/ft^2)	Design LPD (W/ft^2)	Compliance
Floor 1	Workshop	36131	46918	1.40	1.30	Yes
Floor 2	Office	30662	21748	1.00	0.71	Yes
Total Building	Mix	66793	68666	1.20	1.03	Yes

Std. 90.1 Conclusion

The TED generally complies with the prescriptive method set forth by Std. 90.1. The two areas where compliance is not met are fan limitation requirements and water-cooled air conditioner efficiency requirements. The power used for the air handling unit supply fans is 4.2% greater than the allowable power for the given air flow. However, these supply fans include variable frequency drives that significantly reduce energy use at part loads when compared to constant volume fans of the same size and power. Therefore, though the prescriptive energy requirement specific to Std. 90.1 is not met, there is still a sizeable energy reduction present.

The other instance that does not comply with Std. 90.1 is the calculated EER values of the water cooled air-conditioning equipment located in computer server rooms. The design EER of the air-conditioners is equal to 6.2 while the required minimum EER is 12.1. This difference is large, however, must be analyzed in the context of the entire system. There are three of these types of air-conditioners used in the TED; each using a total of 3.8 hp (2.8 kW). The total electrical energy used by all three units (11.4 hp) accounts for only 3% of the total electrical energy used by all system fans and pumps (371 hp). There is significantly more potential for energy reduction in other parts of the system.

The negligible effect of the two non-compliance instances mentioned above is confirmed by the designer's use of the Performance Rating Method found in Appendix G of Std. 90.1. This method compares the designed building to a Std. 90.1 compliant base building of the same characteristics and using the same system modeling program. Results of this analysis showed that the TED is designed to use 45% of the total yearly energy (electric and gas) used by the comparable Std. 90.1 base building. This reduction in energy use can be attributed to the design and control strategies that were analyzed in this report.

References

ASHRAE Std. 62.1-2007

ASHRAE Std. 90.1-2007

NEC 2008

EwingCole Construction Drawings and Specifications: Mechanical, Electrical, Plumbing, and Architectural

Appendix A

Table A-1: ASHRAE Std. 62.1.6 AHU 1

ASHRAE Std. 62.1-2007 Compliance_AHU1								Calculated Outdoor Airflow for zone	Table 6-2	Design Outdoor Airflow for zone	Design Primary Airflow (outdoor+recirc air)				Population Served by System		Diversity	Total Vbz for System	Table 6-3	Total Outdoor Air for system	Outdoor Air Fraction of Design Primary Air
Terminal Box	Zone Name	A_z (ft^2)	Occupancy Type	Air Class	P_z (ppl)	R_z (cfm/per)	R_a (cfm/ft^2)	V_{bz} (cfm)	E_z	V_{oz} (cfm)	V_{pz} (cfm)	Z_p	P_z x R_z (cfm)	A_z x R_a (cfm)	P_s (ppl)	ΣP_z (ppl)	D	V_{ou} (cfm)	E_v	V_{ot} (cfm)	$V_{ot}/\Sigma V_{Pz}$
TD-FPB-1-01	1511 Break Room	380	Break Rooms	1	16	5	0.06	102.8	1	102.8	880	0.12	80	22.8	100	209	0.48	5095	0.8	6369	0.19
TD-FPB-1-02	1553 Vacuumn Assembly Shop	1500	Wood/Metal Shop	2	7	10	0.18	340	1	340	1440	0.24	70	270							
TD-FPB-1-03, 04	1546 Hall B Techs	1150	Office Space	1	13	5	0.06	134	1	134	2075	0.06	65	69							
TD-FPB-1-05 - 012	1605 Machine Shop	10225	Wood/Metal Shop	2	35	10	0.18	2190.5	1	2190.5	9755	0.22	350	1840.5							
VAV-1-01	1516 S/R Office	240	Office Space	1	2	5	0.06	24.4	1	24.4	140	0.17	10	14.4							
VAV-1-02	1501 Lobby	1015	Main Entry Lobbies	1	12	5	0.06	120.9	1	120.9	880	0.14	60	60.9							
VAV-1-03	1502 Vestibule	541	Office Space	1	3	5	0.06	47.46	1	47.46	680	0.07	15	32.46							
VAV-1-04	1526 Elec Fab Shop	1160	Wood/Metal Shop	2	5	10	0.18	258.8	1	258.8	840	0.31	50	208.8							
VAV-1-05	1551 Gen. Purpose Test Area	1585	Computer Labs	1	18	10	0.12	370.2	1	370.2	1385	0.27	180	190.2							
VAV-1-06	1552 LPTS LLRF	945	Computer Labs	1	9	10	0.12	203.4	1	203.4	760	0.27	90	113.4							
VAV-1-07	1546 Hall A/D Techs	1530	Office Space	1	15	5	0.06	166.8	1	166.8	1110	0.15	75	91.8							
VAV-1-08	1545 Hall A Elec Storage	850	Storage Rooms	1	0	0	0.12	102	1	102	600	0.17	0	102							
VAV-1-09	1538, 1539 Installation Techs	420	Office Space	1	6	5	0.06	55.2	1	55.2	360	0.15	30	25.2							
VAV-1-10	NOT USED								1												
VAV-1-11	1519 HPTS Klystron	690	Computer Labs	1	5	10	0.12	132.8	1	132.8	1280	0.10	50	82.8							
VAV-1-12	1521 HPTS DC OPS	760	Computer Labs	1	5	10	0.12	141.2	1	141.2	1785	0.08	50	91.2							
VAV-1-13	1522 HPTS Projects	480	Computer Labs	1	5	10	0.12	107.6	1	107.6	1725	0.06	50	57.6							
VAV-1-14, 15	1525 LPTS Mech	5835	Computer Labs	1	33	10	0.12	1030.2	1	1030.2	3200	0.32	330	700.2							
VAV-1-16	1501 Lobby	375	Corridors	1	0	0	0.12	45	1	45	375	0.12	0	45							
VAV-1-17	8 Open Stair	330	Corridors	1	0	0	0.06	19.8	1	19.8	340	0.06	0	19.8							
VAV-1-18	1510 Corridor	640	Corridors	1	0	0	0.06	38.4	1	38.4	600	0.06	0	38.4							
VAV-1-19	1554 Clean Storage	550	Storage Rooms	1	0	0	0.12	66	1	66	360	0.18	0	66							
VAV-1-20	1520 Service Corridor	810	Corridors	1	0	0	0.06	48.6	1	48.6	750	0.06	0	48.6							
VAV-1-21	1535 Vac Pump Repair	955	Office Space	1	2	5	0.06	67.3	1	67.3	600	0.11	10	57.3							
VAV-1-22	1533 Cryo Break Room	490	Break Rooms	1	16	5	0.06	109.4	1	109.4	870	0.13	80	29.4							
VAV-1-23	1544 Hall C Elec Lab	320	Office Space	1	2	5	0.06	29.2	1	29.2	270	0.11	10	19.2							
VAV-1-24	1508 Elev Mach Room	50	Elevator Machine Room	1	0	0	0.12	6	1	6	550	0.01	0	6							
	Floor 1 Totals	**33451**			**209**			**5957.96**			**33610**	**0.32**	**1655**	**4302.96**							

Table A-2: ASHRAE Std. 62.1.6 AHU 2

ASHRAE Std. 62.1-2007 Compliance_AHU2								Calculated Outdoor Airflow for zone	Table 6-2	Design Outdoor Airflow for zone	Design Primary Airflow (outdoor+recirc air)				Population Served by System		Diversity	Total Vbz for System	Table 6-3	Total Outdoor Air for system	Outdoor Air Fraction of Design Primary Air
Terminal Box	Zone Name	A_z (ft^2)	Occupancy Type	Air Class	P_z (ppl)	R_z (cfm/per)	R_a (cfm/ft^2)	V_{bz} (cfm)	E_z	V_{oz} (cfm)	V_{pz} (cfm)	Z_p	P_z x R_z (cfm)	A_z x R_a (cfm)	P_s (ppl)	ΣP_z (ppl)	D	V_{ou} (cfm)	E_v	V_{ot} (cfm)	$V_{ot}/\Sigma V_{pz}$
TD-FPB-2-01	2562 Collaborative Space	450	Conference/Meeting	1	12	5	0.06	87	1	87	1510	0.06	60	27	175	280	0.63	2998	0.8	3748	0.12
TD-FPB-2-02	2561 Large Conference	280	Conference/Meeting	1	12	5	0.06	76.8	1	76.8	440	0.17	60	16.8							
TD-FPB-2-03	2561 Large Conference	280	Conference/Meeting	1	12	5	0.06	76.8	1	76.8	440	0.17	60	16.8							
TD-FPB-2-04	2559 Large Conference	290	Conference/Meeting	1	12	5	0.06	77.4	1	77.4	440	0.18	60	17.4							
TD-FPB-2-05, 07, 27, 30-31	2500 Corridor	2722	Corridors	1	0	0	0.06	163.32	1	163.32	4160	0.04	0	163.32							
TD-FPB-2-06	2558 Fitness	930	Health Club/Weight Room	2	20	20	0.06	455.8	1	455.8	1750	0.26	400	55.8							
TD-FPB-2-08, 09, 26	2502 Café	1760	Break Room	1	42	5	0.06	315.6	1	315.6	3055	0.10	210	105.6							
TD-FPB-2-10	2590 Corridor	290	Corridors	1	0	0	0.06	17.4	1	17.4	800	0.02	0	17.4							
TD-FPB-2-11 - 14	2544 Mech Open Office	5465	Office Space	1	19	5	0.06	422.9	1	422.9	4745	0.09	95	327.9							
TD-FPB-2-15	2508, 2509, 2511, 2512 Offices	620	Office Space	1	4	5	0.06	57.2	1	57.2	1250	0.05	20	37.2							
TD-FPB-2-16	2505, 2506, 2507 Offices	465	Office Space	1	3	5	0.06	42.9	1	42.9	930	0.05	15	27.9							
TD-FPB-2-17	2504 Conference	260	Conference/Meeting	1	12	5	0.06	75.6	1	75.6	650	0.12	60	15.6							
VAV-2-01 - 09, 11-16, 19, 21-24, 28-29	V&I Open Office	14240	Office Space	1	114	5	0.06	1424.4	1	1424.4	9105	0.16	570	854.4							
VAV-2-06	2542, 2543 Conference	200	Conference/Meeting	1	8	5	0.06	52	1	52	180	0.29	40	12							
VAV-2-10	2519 Phone Booth	615	Corridors	1	0	0	0.06	36.9	1	36.9	295	0.13	0	36.9							
VAV-2-17	2525 DOC Control	850	Storage Rooms	1	0	0	0.12	102	1	102	450	0.23	0	102							
VAV-2-18	2552 Corridor	835	Corridors	1	0	0	0.06	50.1	1	50.1	275	0.18	0	50.1							
VAV-2-19	2547 Elec Library	180	Libraries	1	2	5	0.12	31.6	1	31.6	150	0.21	10	21.6							
VAV-2-20	2553 , 2546 Conference	210	Conference/Meeting	1	8	5	0.06	52.6	1	52.6	180	0.29	40	12.6							
VAV-2-25	ST08 Open Stair	290	Corridors	1	0	0	0.06	17.4	1	17.4	345	0.05	0	17.4							
	Floor 2 Totals	**31232**			**280**			**3635.72**			**31150**	**0.29**									

Appendix B

Table B-1: Fan Power Limitation

Fan	Type	CFM	Allowable Power (hp)	Design Power (hp)	Difference (hp)	Compliance
AHU 1 Supply	VAV	32000	48.00	50.00	-2.00	No
AHU 1 Return	VAV	32000	48.00	30.00	18.00	Yes
AHU 2 Supply	VAV	32000	48.00	50.00	-2.00	No
AHU 2 Return	VAV	32000	48.00	30.00	18.00	Yes
OAU 1 Supply	VAV	7500	11.25	7.50	3.75	Yes
OAU 1 Exhaust	VAV	6000	9.00	5.00	4.00	Yes
OAU 2 Supply	VAV	6800	10.20	5.00	5.20	Yes
OAU 2 Exhaust	VAV	6000	9.00	5.00	4.00	Yes
Computer Room AC Unit 1-1	VAV	750	1.13	0.16	0.97	Yes
Computer Room AC Unit 1-2	VAV	750	1.13	0.16	0.97	Yes
Computer Room AC Unit 2-1	VAV	750	1.13	0.16	0.97	Yes
Exhaust Fan 1-1	VAV	270	0.41	0.25	0.16	Yes
Exhaust Fan 1-2	VAV	800	1.20	0.75	0.45	Yes
Exhaust Fan 2-1	VAV	465	0.70	0.25	0.45	Yes
Cabinet Unit Heater-1	CAV	222	0.24	0.08	0.16	Yes
Cabinet Unit Heater-2	CAV	222	0.24	0.08	0.16	Yes
TD-FPB 1-01	VAV	880	1.32	0.33	0.99	Yes
TD-FPB 1-02	VAV	1440	2.16	0.50	1.66	Yes
TD-FPB 1-03	VAV	465	0.70	0.33	0.37	Yes
TD-FPB 1-04	VAV	1610	2.42	0.75	1.67	Yes
TD-FPB 1-05	VAV	830	1.25	0.33	0.92	Yes
TD-FPB 1-06	VAV	1525	2.29	0.50	1.79	Yes
TD-FPB 1-07	VAV	1250	1.88	0.50	1.38	Yes
TD-FPB 1-08	VAV	1250	1.88	0.50	1.38	Yes
TD-FPB 1-09	VAV	1525	2.29	0.50	1.79	Yes
TD-FPB 1-10	VAV	1125	1.69	0.50	1.19	Yes
TD-FPB 1-11	VAV	1125	1.69	0.50	1.19	Yes
TD-FPB 1-12	VAV	1125	1.69	0.50	1.19	Yes
TD-FPB 2-01	VAV	1510	2.27	0.50	1.77	Yes
TD-FPB 2-02	VAV	440	0.66	0.33	0.33	Yes
TD-FPB 2-03	VAV	440	0.66	0.33	0.33	Yes
TD-FPB 2-04	VAV	440	0.66	0.33	0.33	Yes
TD-FPB 2-05	VAV	1350	2.03	0.50	1.53	Yes
TD-FPB 2-06	VAV	1750	2.63	0.50	2.13	Yes
TD-FPB 2-07	VAV	960	1.44	0.30	1.14	Yes
TD-FPB 2-08	VAV	1075	1.61	0.50	1.11	Yes
TD-FPB 2-09	VAV	1000	1.50	0.50	1.00	Yes
TD-FPB 2-10	VAV	800	1.20	0.30	0.90	Yes
TD-FPB 2-11	VAV	1425	2.14	0.50	1.64	Yes
TD-FPB 2-12	VAV	1425	2.14	0.50	1.64	Yes
TD-FPB 2-13	VAV	895	1.34	0.30	1.04	Yes
TD-FPB 2-14	VAV	1000	1.50	0.50	1.00	Yes
TD-FPB 2-15	VAV	1250	1.88	0.50	1.38	Yes
TD-FPB 2-16	VAV	930	1.40	0.30	1.10	Yes
TD-FPB 2-17	VAV	650	0.98	0.30	0.68	Yes

Table B-2: Water to Water Geothermal Heat Pump

	Cooling		Heating		
Name	Min Efficiency	Design Efficiency	Min COP	Design COP	Compliance
TD-WWHP-1 to 12	12	14	4.2	4.3	Yes

Table B-3: Closed Circuit Cooler

Name	Fan Type	Min gpm/hp	Design gpm	Design hp	Design gpm/hp	Compliance
TD-CCC-1	Centrifugal	20	270	30	9	Yes

Table B-4: Gas Fired Condensing Boiler

Name	Min Efficiency	Input (MBH)	Gross Output (MBH)	Efficiency	Compliance
TD-B-1	0.75	1400	1200	0.86	Yes

Table B-5: Water Cooled Room Air-Conditioner

Name	Min EER	Capacity (Btu/h)	Power Consumption (W)	EER	Compliance
TD-CRU	12.1	17400	2819	6.17	No

Appendix C

Table C-1: Lighting Power Density Calculation

LPD Calculation							
Luminaire Type	Number	Power / Lamp (W)	Number Lamps	Total Power / Luminaire (W)	Total Power (W)		
1st Floor A							
A11F	5	28	1	28	140		
A16	16	28	3	84	1344		
A7	14	28	2	56	784		
A8	4	28	2	56	224		
B1	103	54	2	108	11124		
B2	13	28	2	56	728		
C1	6	26	2	52	312		
C10	15	26	1	26	390		
C3	10	32	2	64	640		
C5	3	26	2	52	156		
C8	10	32	1	32	320		
C9	15	32	1	32	480		
T1	7	28	2	56	392		
1st Floor B							
A10	5	24	2	48	240		
A7	21	28	2	56	1176		
A8	12	28	2	56	672		
A9	5	28	3	84	420		
B1	105	54	2	108	11340		
B2	18	28	2	56	1008		
C1	6	26	2	52	312		
C5	17	26	2	52	884		
D1	4	28	2	56	224		
T1	12	28	2	56	672		
1st Floor C							
D2	10	28	2	56	560		
T2	30	54	6	324	9720		
1st Floor D							
C5	15	26	2	52	780		
C6	14	26	2	52	728		
C7	16	32	1	32	512		
D1	3	28	2	56	168		
Z2	12	39	1	39	468		
						Floor 1 Area (ft^2)	LPD1
1st Total	**526**	**927**	**60**	**1937**	**46918**	**36131**	**1.30**
2nd Floor A							
A11F	26	28	1	28	728		
A4	30	28	2	56	1680		
A5	28	28	3	84	2352		
A6	8	40	2	80	640		
C1	54	26	2	52	2808		
C10	11	26	1	26	286		
C11	4	26	1	26	104		
C12	8	26	1	26	208		
C4	2	18	1	18	36		
J1	4						
P2	48	28	1	28	1344		
P5	2	28	1	28	56		
T1	4	28	2	56	224		
2nd Floor B							
A4	3	28	2	56	168		
A5	23	28	3	84	1932		
A6	8	40	2	80	640		
A7	2	28	2	56	112		
C1	39	26	2	52	2028		
D1	4	28	2	56	224		
P2	96	28	1	28	2688		
T1	15	28	2	56	840		
2nd Floor D							
A11	9	28	1	28	252		
A11F	2	28	1	28	56		
A12F	3	21	1	21	63		
A17	2	28	1	28	56		
A18	2	21	1	21	42		
A19	1	17	1	17	17		
A4	17	28	2	56	952		
C1	19	26	2	52	988		
D1	4	28	2	56	224		
						Floor 2 Area (ft^2)	LPD2
2nd Total	**478**	**789**	**46**	**1283**	**21748**	**30662**	**0.71**
						Total Building Area (ft^2)	LPD Total
Building Total	**1004**	**1716**	**106**	**3220**	**68666**	**66793**	**1.03**