Gallaudet University
Sorenson Language and Communication Center

TECHNICAL REPORT 2

BUILDING ENERGY ANALYSIS

COMPLIANCE WITH ASHRAE STANDARD 90.1-2004 & LEED-NC V2.2

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Senior Thesis

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EXECUTIVE SUMMARY

ASHRAE Standard 90.1-2004: Energy Standard for Buildings sets forth a series of building design criteria regarding building envelope, lighting, HVAC system efficiency, and more. Its goal is to provide acceptable "to provide minimum requirements for the energy-efficient design of buildings." Furthermore, the U.S. Green Building Council has established building design criteria for sustainability and high performance. These standards attempt to reduce the massive impact that building energy use has on the environment. In fact, according to the U.S. Department of Energy, "buildings in the United States consume more than 30% of our total energy and 60% of our electricity annually." The purpose of this report is to evaluate the Gallaudet University Sorenson Language and Communication Center (SLCC) for its compliance with these standards.

The SLCC is an 87,700 SF education facility on the campus of Gallaudet University in the heart of Washington, DC. The building is served by six (6) Trane M-Series Climate Changer Air Handing Units. Each unit serves a distinct zone within the facility that is unique in use and occupation schedule. The spaces served include classrooms, offices, conference rooms, computer labs, media studios, therapy rooms, audiology labs, and typical support spaces. In total, the AHUs are designed to provide 72,875 CFM of conditioned air to 142 terminal VAV units. 21,360 CFM – or about 30% – of this supply is outdoor air. Chilled water service is provided from the Gallaudet Campus Chiller Plant, and hot water is produced from steam service to a plate-and-frame heat exchanger.

The building envelope and lighting power density requirements explained in ASHRAE Std. 90.1 Sections 5 and 9 were used to evaluate the design of the SLCC. The LEED-NC V2.2 and V2.1 Reference Guides were also used to compare the design of the SLCC for its compliance with each standard. Finally, Carrier's Hourly Analysis Program (HAP) 4.2 was used to build an energy model of the building for analysis. Additional analyses for lost "rentable" space and mechanical system first cost were conducted. The input numbers were derived from mechanical drawings, narratives, and calculations provided by the primary architects and MEP engineers at SmithGroup.

The calculations and evaluations performed in this report show that the design for the SLCC meets the criteria for ASHRAE Std. 90.1-2004 compliance. Also, the building's design would be able to garner a LEED Certified Rating.

All assumptions, procedures, calculations, analyses and conclusions regarding the design of the SLCC mechanical system may be found within this report.

ASSUMPTIONS

BUILDING ENERGY ANALYSIS

Because of the unique functions of this one-of-a-kind facility, several assumptions were made relating design spaces to those included in ASHRAE Standard 90.1-2004. The compilation of these assumptions and information derived from contract documents provided the inputs used in Carrier's Hourly Analysis Program (HAP) energy model. These assumptions include:

- The average metabolic rate or building occupants was based on "sedentary work." The motivating factor for this assumption is that the primary mode of communication for occupants is American Sign Language (ASL), which requires additional body movement. This is relative to the "office work" activity rate that would have been assumed otherwise.
- Data such as room floor area, outdoor air requirements, lighting wattage, occupancy, wall area and orientation, and glazing type and area was derived from building drawings, schedules, and calculations performed by the mechanical engineer.
- Since multiple wall types were not able to be included in HAP, the envelope load was calculated as one wall type with a total area such that the difference in u-value was accounted for.
- Room occupancy and equipment usage schedules were assumed to be a typical office/class day. The media studio, however, was assumed to be utilized for a fraction of the day and a maximum of 60% of the total studio lighting would be used at anyone time.
- The outdoor air quality was assumed to be worse than HAP's default of 400ppm of CO_2 because the building is located in the metropolitan Washington, DC area. The input CO_2 ratio was instead 500ppm.
- Air handling unit (AHU) inputs including cooling/heating coil type, fan data, zone assignments, diversity factor, etc. were derived from schedules in the contract documents.
- Any information not derived from drawings was assumed to be the default value in HAP.
- Electricity rates determined from Pepco – the primary electricity provider for the District of Columbia – time metered primary service schedule "GT-3A."

LEED COMPLIANCE:

The Sorenson Language and Communication Center (SLCC) has had a LEED-NC V2.1 Certified Rating as its design goal. For this report, analysis of the SLCC overall design was compared to LEED-NC V2.2. Assumptions include:

- A preliminary LEED Scorecard was completed near the end of the CD phase. A comparison of the expected and possible points earned according to V2.1 was conducted versus V2.2 requirements. The criteria used to evaluate points earned for V2.1 was used against the V2.2 standards to compare, rather than an in depth analysis of the building design.
- Energy and Atmosphere Prerequisite 2 depends on compliance with both the mandatory and prescriptive provisions of ASHRAE Std. 90.1-2004 rather than ASHRAE Std. 90.1-1999. The results of this report will influence this compliance for LEED V2.2, but it is assumed that the design meets ASHRAE 90.1-1999 and therefore LEED V2.1 requirements.
- Energy and Atmosphere Credit 1 – "Optimize Energy Performance" – is evaluated based on the HAP energy model.

MECHANICAL SYSTEM OVERVIEW

Gallaudet University's future Soreson Language and Communication Center will be served by six AHUs that serve distinct zones within the building (see figure 1) based on occupancy schedules and space types. These AHUs are served by hot water heating coils and chilled water cooling coils. Chilled water service is to be provided from the campus chiller plant while hot water is produced by a plate and frame heat exchanger served by campus steam. With the exception of AHU-2, the air handlers serve VAV terminal units with and without hot water reheat. AHU-2 serves the atrium, however, and provides a constant volume air supply to the large, open space. All return air is directed back to the air handler via transfer ducts and plenum returns. Several support spaces above grade are served by fan coil units (FCUs) and the computer server room (3224) is served by a computer room air conditioning unit (CRAC). Below grade, unit heaters and a FCUs condition mechanical spaces. Secondary direct digital controls (DDCs) direct operation of VAVs, FCUs, and other equipment.

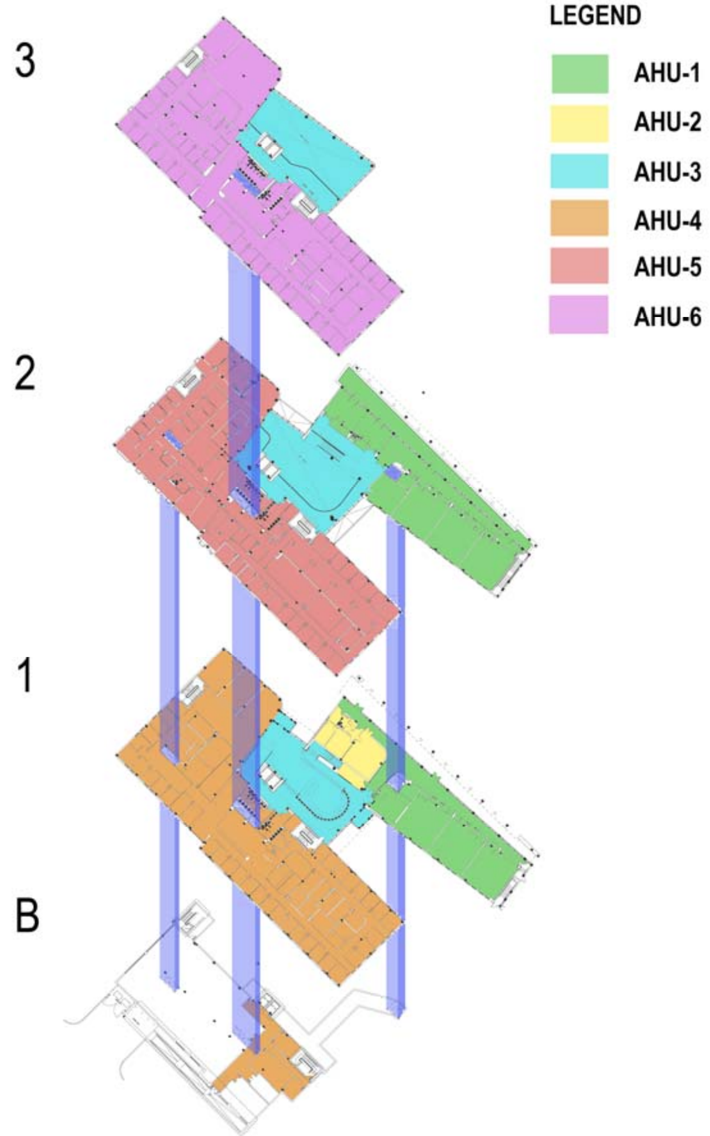


Figure 1: SLCC air handling unit service zones and shaft space.

ASHRAE Std. 90.1-2004 COMPLIANCE

LIGHTING PERFORMANCE

ASHRAE Standard 90.1 is written through a partnership with the Illuminating Engineers Society of North America (IESNA) in order to integrate the mechanical and electrical design disciplines. The goal is to coordinate their standards to optimize energy performance and occupant comfort. One of the major changes in the 2004 version of this standard is the reduction of allowable lighting power densities (LPD) from previous versions.

The SLCC, however, was designed versus the 1999 version of ASHRAE Standard 90.1 in order to comply with LEED-NC V2.1. Therefore many spaces within the SLCC do not meet the space-by-space allowable LPD per ASHRAE 90.1-2004. It should be noted, however, that the SLCC meets criteria for the building area method LPD calculation in ASHRAE 90.1-2004. See the figures 2-3 and Appendix A.

Additionally, the SLCC meets the ASHRAE 90.1-2004 requirement for occupancy sensors for space lighting control.

Space-by-Space Method:

		Design		ASHRAE Std. 90.1		
System	Area [SF]	Actual Area Weighted Power Density [W/SF]	Actual Lighting Power [W]	Allowable Area Weighted Power Density [W/SF]	Allowable Lighting Power [W]	Meets 90.1 Requirements
AHU-1	13185	1.23	16203	1.03	13546	NO
AHU-2	1311	0.91	1188	0.51	667	NO
AHU-3	7990	1.08	8652	0.65	5210	NO
AHU-4	15285	0.89	13536	1.03	15778	YES
AHU-5	15061	0.94	14230	0.97	14684	YES
AHU-6	15146	1.00	15199	1.09	16522	YES
Total:	67978	6.05	69008	5.29	66406	NO

Area Weighted Avg:	1.02		0.98		NO

Design-to-Std. Ratio: 103.9%

Figure 2: Space-by-space method calculation for LPD compliance with ASHRAE 90.1-2004.

Building Area Method:
(Assume "School/University" Building Type)

		Design		ASHRAE Std. 90.1		
System	Area [SF]	Actual Area Weighted Power Density [W/SF]	Actual Lighting Power [W]	Allowable Area Weighted Power Density [W/SF]	Allowable Lighting Power [W]	Meets 90.1 Requirements
1-6	67978	1.02	69008	1.20	81574	YES

Figure 3: Building area method calculation for LPD compliance with ASHRAE 90.1-2004.

BUILDING ENVELOPE PERFORMANCE

The walls, fenestration, and roofs that comprise the building envelope have a major impact on the energy use of a building. Heat transfer through a wall, solar radiation gain, and infiltration are the primary forms of thermal energy transfer through the envelope that the mechanical system must compensate for. Section 5 of ASHRAE Standard 90.1-2004 addresses these thermal loads and sets criteria that each component of the envelope must meet. Furthermore, LEED-NC V2.2 offers Sustainable Sites Credit 7.1 to minimize heat island effects by utilizing a highly reflective roof. This minimizes both local outdoor heat islands and the thermal load gain within the building.

The design of the Sorenson Language and Communication Center addresses these standards by minimizing glazing area exposed to sunlight, using a highly reflective coating on the roof, and employing thermally efficient wall constructions. First, the total vertical glazing area is 13,740 SF, or approximately 35.5% of the total wall area. This design already meets the ASHRAE 90.1 maximum of 50% glazed wall area, but goes further by orienting approximately 52% of that glazing area north (see figures 4, 6-9). This minimizes solar radiation gain inside the building. Also, all doors to the exterior either open from non-conditioned spaces or have vestibules. Next, the roofs of the SLCC are covered with an Energy Star compliant, high reflectance, high emmisivity roofing membrane. This light colored material reflects much more solar radiation than traditional roofing membranes while performing traditional bulk water management. As a result, the building absorbs much less solar energy and emits less thermal radiation to the surroundings. Finally, walls are constructed to have a total u-value that meets or exceeds ASHRAE 90.1 maximums for the climate in Washington, DC (see figure 5). The SLCC is enclosed with three four typical wall constructions: a brick cavity wall, a zinc sided barrier wall, and a glass and aluminum curtain wall. The curtain wall is assumed to be constructed with insulating glazing units (IGUs) with the same u-value as typical windows in the SLCC.

In addition to these design elements, the envelope of the SLCC is specified to be sealed in accordance with ASHRAE Standard 90.1 Section 5.4.3.1.

An analysis of the glazing area and wall thermal efficiencies can be found below.

Glazing-to-Wall Area Ratio				
Wall Type	Total Wall Area [SF]	Total Glazing Area [SF]	Glazing Area Facing North[SF]	Percent Glazed Total Façade
Masonry Façade	22804.0			11.3%
Glazing in Masonry		2582.0		
Zinc Sided Façade	4318.0		594	13.6%
Glazing in Zinc Sided		588.0		
Curtain Wall Façade	10838.0		6396	95.0%
Curtain Wall Glazing		10300.0		
Total	37960	13470	6990	35.5%

Figure 4: Analysis of glazing area-to-total wall area ratio.

Envelope Construction U-Values					ASHRAE 90.1-2004	
Wall Type	Total Wall Area [SF]	Percent Total Envelope Area	R-Value	U-Value	Maximum U-Value	Meets ASHRAE 90.1-2004?
Roof	33624.0	47.0%	17.17	0.058	0.063	YES
Masonry Façade	22804.0	31.9%	22.25	0.045	0.124	YES
Zinc Sided Façade	4318.0	6.0%	21.01	0.05	0.124	YES
Curtain Wall/Glazing	10838.0	15.1%	2.89	0.35	0.570	YES

Figure 5: Analysis of envelope construction.

Figure 6: North Elevation of SLCC.

Figure 7: South Elevation of SLCC.

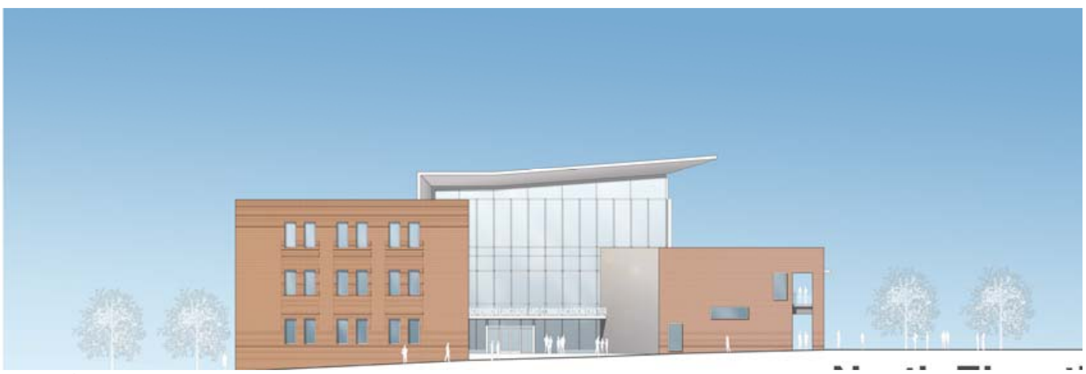


Figure 8: East Elevation of SLCC.

Figure 9: West Elevation of SLCC.

DESIGN LOAD AND ENERGY ANALYSIS

Carrier's HAP 4.2 was used to create an energy model of the SLCC. Inputs came from information taken from building drawings, specs, and calculations if known, and from general assumptions and program defaults if unknown. The system load sizing summary provides values within the expected range, while the annual cost data (figure 10) does not. Further investigation and manipulation of the model will be necessary to calculate proper outputs.

Annual Energy Cost Analysis		
Component	Annual Cost [$]	Annual Cost per Sq. Ft.[$/SF]
Air System Fans	2,348	0.034
Cooling	0	0.000
Heating	627	0.009
Pumps	0	0.000
Cooling Tower Fans	0	0.000
HVAC Sub-Total	2,975	0.044
Lights	5,102	0.075
Electric Equipment	3,870	0.057
Misc. Electric	0	0.000
Misc. Fuel Use	0	0.000
Non-HVAC Sub-Total	8,972	0.132
Total	11,946	0.175

Figure 10: Total system thermal loads.

Total System Thermal Loads								
	Location	Floor Area [SF]	Maximum CFM	CFM/SF	Sensible Cooling Coil Load [Tons]	Latent Cooling Coil Load [Tons]	Total Cooling Coil Load [Tons]	Total Heating Coil Load [Tons]
AHU-1	B200	13185	12000	0.91	26.09	20.38	46.48	7.02
AHU-2	B200	1311	2250	1.72	6.23	40.25	46.48	0.08
AHU-3	B200	7990	3946	0.49	16.65	11.20	27.85	20.38
AHU-4	B200	15291	47250	3.09	30.74	24.13	54.87	2.98
AHU-5	B200	15165	39900	2.63	25.40	19.94	45.34	2.07
AHU-6	B200	15282	42000	2.75	31.90	25.04	56.94	6.12
Total		68224	147346	2.16	137.01	140.94	277.95	38.63

Figure 11: Total system thermal loads.

As figure 11 illustrates, the greatest thermal load on the SLCC is during peak cooling. This is not surprising since the building is located in Washington, DC. Much of the heating load is offset by the heat generation from people and equipment within the building. Figures 12 through 15 demonstrate this discrepancy. These figures also show the proportion of total load each source accounts for.

Design Cooling Loads By Source							
Source	AHU-1 [BTU/hr]	AHU-2 [BTU/hr]	AHU-3 [BTU/hr]	AHU-4 [BTU/hr]	AHU-5 [BTU/hr]	AHU-6 [BTU/hr]	Total [Tons]
Window & Skylight Solar Loads	36155	0	1019	47788	39784	46383	14.26075
Wall Transmission	22871	354	26072	5856	5545	5588	5.523833
Roof Transmission	5007	0	9139	0	0	12641	2.23225
Window Transmission	3547	0	244	6449	5355	6395	1.8325
Floor Transmission	0	0	0	0	0	0	0
Partitions	0	0	0	0	0	0	0
Ceiling	0	0	0	0	0	0	0
Overhead Lighting	34014	27669	17692	25011	26474	27319	13.18158
Task Lighting	0	0	0	0	0	0	0
Electric Equipment	25184	9867	0	55700	31521	53201	14.62275
People	47235	4329	36451	47061	46102	50445	19.30192
Infiltration	0	0	0	0	0	0	0
Miscellaneous	0	0	0	0	0	0	0
Total [Tons]	14.50108	3.51825	7.551417	15.65542	12.89842	16.831	0.005913

Figure 12: Cooling loads by source.

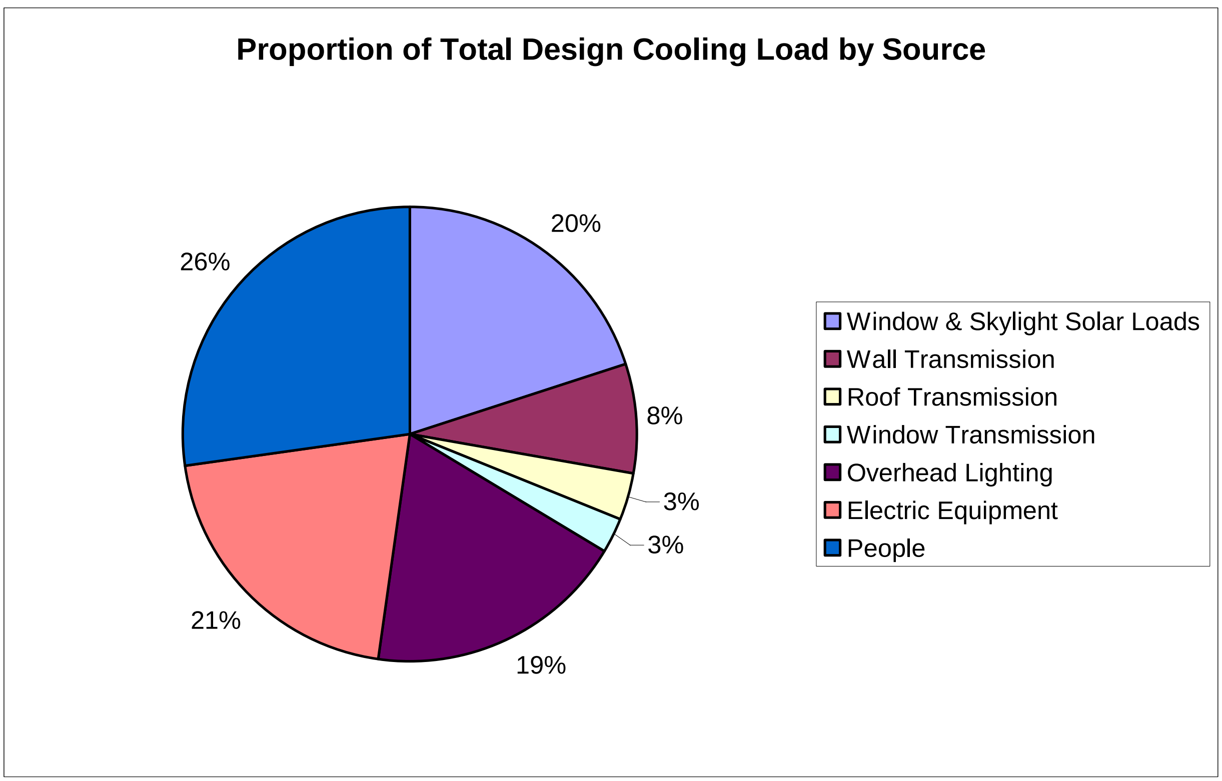


Figure 13: Cooling loads by source comparison.

Design Heating Loads By Source							
Source	AHU-1 [BTU/hr]	AHU-2 [BTU/hr]	AHU-3 [BTU/hr]	AHU-4 [BTU/hr]	AHU-5 [BTU/hr]	AHU-6 [BTU/hr]	Total [Tons]
Window & Skylight Solar Loads	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wall Transmission	62871	720	98947	14431	13825	13995	17.06575
Roof Transmission	19084	0	20577	0	0	48875	7.378
Window Transmission	11319	0	809	20790	17267	20617	5.900167
Floor Transmission	8140	541	2054	7194	0	0	1.494083
Partitions	0	0	0	0	0	0	0
Ceiling	0	0	0	0	0	0	0
Overhead Lighting	0	0	0	0	0	0	0
Task Lighting	0	0	0	0	0	0	0
Electric Equipment	0	0	0	0	0	0	0
People	0	0	0	0	0	0	0
Infiltration	0	0	0	0	0	0	0
Miscellaneous	0	0	0	0	0	0	0
Total [Tons]	8.451167	0.105083	10.19892	3.534583	2.591	6.95725	31.838

Figure 14: Heating loads by source.

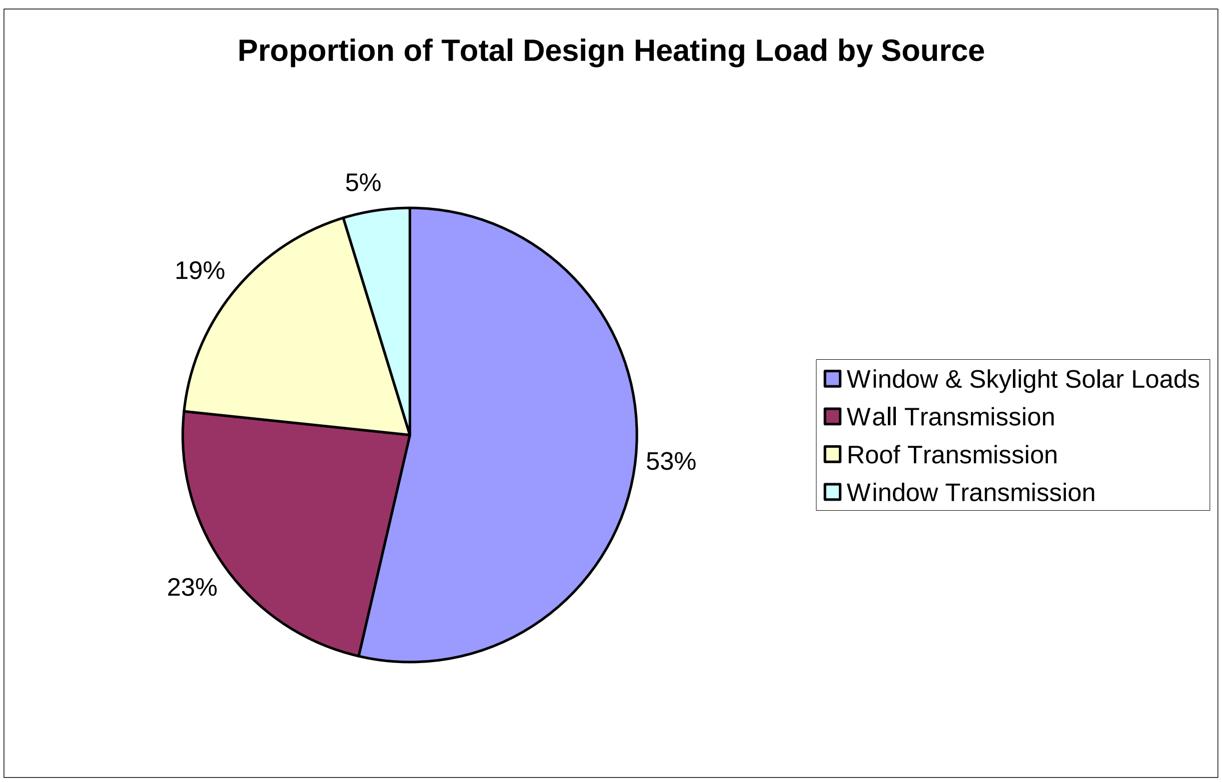


Figure 15: Heating loads by source.

LEED RATING COMPLIANCE

LEED-NC V2.1 COMPLIANCE

From the beginning of the design process SmithGroup architects and engineers worked towards the ultimate goal of designing a unique and world-class facility for Gallaudet University that would achieve U.S. Green Building Council LEED Certification. Several prerequisites for the design needed to be met to achieve this certification, including meeting ASHRAE Standard 90.1 requirements. Because the design process started in early 2005 the SLCC is designed to meet LEED-NC V2.1 requirements. According to the LEED-NC V2.1 Scorecard completed towards the end of the contract documents phase, a total of twenty-six (26) points are expected to be earned with a potential for six (6) more. This would likely garner a LEED Certified Rating (27-32 points), or at best a LEED Silver Rating (33-38 points).

Design elements of the SLCC intended to gain LEED points include reducing the heat island effect, a water use reduction of over 30%, and selective material use and construction. For example, a highly reflective roofing membrane and minimal building footprint reduce the solar energy absorption and thermal mass of the building. In order to gain four water efficiency credits, storm water will be captured to irrigate water efficient landscaping, while waterless urinals, dual-flush toilets, and faucet automatic sensors reduce sanitary water use. Recycled materials and locally produced products will be used for construction and finishes.

With regard to the mechanical system, all Energy and Atmosphere Prerequisites are expected to be met. Beyond that, a possible two (2) of ten (10) points for optimal energy performance could be earned. This leaves at least eight (8) points available to secure a higher LEED rating. Since no refrigerants will be used in this building and the campus chiller plant uses CFC-free HFC-134A as a refrigerant, EA Credit 4 would be earned for minimizing ozone depletion. Additional commissioning would garner one (1) more EA point. Indoor air quality would be optimized with the installation of low-emitting adhesives, paints, carpets, and woods and a construction IAQ management plan, thus gaining another six (6) points. Housekeeping and copy rooms would be exhausted to provide indoor chemical and pollutant source control, thus gaining another point.

LEED-NC V2.2 COMPLIANCE

An analysis of the SLCC design versus LEED-NC V2.2 was conducted for this report based on the V2.1 analysis provided by the architects. If a design element met both V2.1 and V2.2 criteria, it was assumed to gain its respective point. Some slight differences in the credit content actually provided an additional LEED point with V2.2. The SLCC would likely gain the Sustainable Sites Credit 2: Development Density & Community Connectivity for its location in the urban core of the District of Columbia and the services it can provide the community. Any points gained from EA Credit 1: Optimize Energy Performance are determined from the building energy model in this report.

See below for the LEED-NC V2.2 checklist for likely points earned by the SLCC. A total of twenty-eight (28) points are expected, with a possibility for six (6) more, thus earning a LEED Certified Rating.

LEED-NC

LEED-NC Version 2.2 Registered Project Checklist

Gallaudet University SLCC
Washington, DC

Yes	?	No			
8	1	5		**Sustainable Sites**	**14** Points
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
1			Credit 1	**Site Selection**	1
1			Credit 2	**Development Density & Community Connectivity**	1
		1	Credit 3	**Brownfield Redevelopment**	1
1			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
		1	Credit 4.3	**Alternative Transportation**, Low-Emitting and Fuel-Efficient Vehicles	1
	1		Credit 4.4	**Alternative Transportation**, Parking Capacity	1
		1	Credit 5.1	**Site Development,** Protect or Restore Habitat	1
1			Credit 5.2	**Site Development,** Maximize Open Space	1
		1	Credit 6.1	**Stormwater Design,** Quantity Control	1
1			Credit 6.2	**Stormwater Design,** Quality Control	1
1			Credit 7.1	**Heat Island Effect,** Non-Roof	1
1			Credit 7.2	**Heat Island Effect,** Roof	1
		1	Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
4		1		**Water Efficiency**	**5** Points
1			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
1			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
		1	Credit 2	**Innovative Wastewater Technologies**	1
1			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
1			Credit 3.2	**Water Use Reduction**, 30% Reduction	1

Yes	?	No			
2	3	15		**Energy & Atmosphere**	**17** Points
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required
	2	8	Credit 1	**Optimize Energy Performance**	1 to 10
		6	Credit 2	**On-Site Renewable Energy**	1 to 3
1			Credit 3	**Enhanced Commissioning**	1
1			Credit 4	**Enhanced Refrigerant Management**	1
		1	Credit 5	**Measurement & Verification**	1
	1		Credit 6	**Green Power**	1

continued…

Figure 16.1: LEED-NC V2.2 Checklist for SLCC.

LEED-NC

LEED-NC Version 2.2 Registered Project Checklist

Gallaudet University SLCC
Washington, DC

Yes	?	No			
6	1	6		**Materials & Resources**	**13** Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
		1	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
		1	Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roof	1
		1	Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1
1			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
1			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
		1	Credit 3.1	**Materials Reuse**, 5%	1
		1	Credit 3.2	**Materials Reuse**,10%	1
1			Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
1			Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
1			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regior	1
1			Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regior	1
		1	Credit 6	**Rapidly Renewable Materials**	1
	1		Credit 7	**Certified Wood**	1

Yes	?	No			
6	1	8		**Indoor Environmental Quality**	**15** Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
		1	Credit 1	**Outdoor Air Delivery Monitoring**	1
		1	Credit 2	**Increased Ventilation**	1
1			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
	1		Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1			Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
1			Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
1			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
1			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
		1	Credit 6.1	**Controllability of Systems**, Lighting	1
		1	Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
		1	Credit 7.1	**Thermal Comfort**, Design	1
		1	Credit 7.2	**Thermal Comfort**, Verification	1
		1	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
		1	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Figure 16.2: LEED-NC V2.2 Checklist for SLCC.

LEED-NC

LEED-NC Version 2.2 Registered Project Checklist

Gallaudet University SLCC
Washington, DC

Yes	?	No			
2		3	**Innovation & Design Process**		**5** Points
1			Credit 1.1	**Innovation in Design**: Educational Case Study	1
		1	Credit 1.2	**Innovation in Design**: Provide Specific Title	1
		1	Credit 1.3	**Innovation in Design**: Provide Specific Title	1
		1	Credit 1.4	**Innovation in Design**: Provide Specific Title	1
1			Credit 2	**LEED® Accredited Professional**	1
Yes	?	No			
28	6	38	**Project Totals** (pre-certification estimates)		**69** Points

Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points

Figure 16.3: LEED-NC V2.2 Checklist for SLCC.

MECHANICAL SYSTEM DISCUSSION

An analysis by the primary MEP engineers at SmithGroup found that two possible EA Credit 1: Optimum Energy Performance points could be earned. Below are their results (figure 17). This leaves an opportunity to gain up to eight points and improve the LEED rating of the SLCC.

Energy & Cost Summary by Fuel	DEC'' Use [10^3 Btu]	DEC'' Cost [$]	ECB' Use [10^3 Btu]	ECB' Cost [$]	DEC'' / ECB' Energy %	DEC'' / ECB' Cost %
Electricity	3,358,728	$88,989	4,266,915	$113,051	78.7%	78.7%
Oil	624,921	$8,655	1,057,210	$14,642	59.1%	59.1%
Total	**3,983,649**	**$97,644**	**5,324,125**	**$127,693**		

Percent Savings = 100 x (ECB' $ - DEC'' $) / ECB' $ = 23.5%

Credit 1 Points Earned = 2

Figure 17: Design energy use versus Energy Cost Budget of SLCC.

LOST "RENTABLE" SPACE

The goal of major new construction on a college campus is to provide state-of-the-art facilities to advance learning and research. Unlike a business such as a realtor or property manager, no profit is expected from occupancy of the building. Still, mechanical space is minimized above grade in order to maximize "useable" space. Instead, mechanical spaces are congregated either below grade or on the roof.

The SLCC follows this basic building design principle while addressing specific design goals. All AHUs are located in the basement, as are the emergency generator, switchboard, etc. Mechanical space on higher floors is limited to three shafts, a handful of closets, and plenum space between floors. With two lounges on the third floor of the atrium overlooking the classroom wing roof, no equipment is permitted on that roof. Instead, exhaust fans are hidden in a portico. Exhaust fans on the third floor roof are also hidden from view on the ground or from within the building.

As a result the total lost "rentable" space in the SLCC is 12900 SF, or 14.7% of the building area. However, the vast majority of this space is located in the basement. Lost "rentable" space above grade counts for only 1048 SF, or 1.2% of above grade floor area.

Total Lost "Rentable" Space		
Space Type	Area [SF]	% Building Area
Entire Building	87704	100.0%
Mech./Elec. Equipment Space	12108	13.8%
Shaft Space	792	0.9%
Total	12900	14.7%

FIGURE 18: The proportions of mechanical space versus total building area.

Lost "Rentable" Space Above Grade		
Space Type	Area [SF]	% Building Area
Entire Building	72655	100.0%
Mech./Elec. Equipment Space	256	0.3%
Shaft Space	792	0.9%
Total	1048	1.2%

FIGURE 19: The proportions of mechanical space versus building area on main floors.

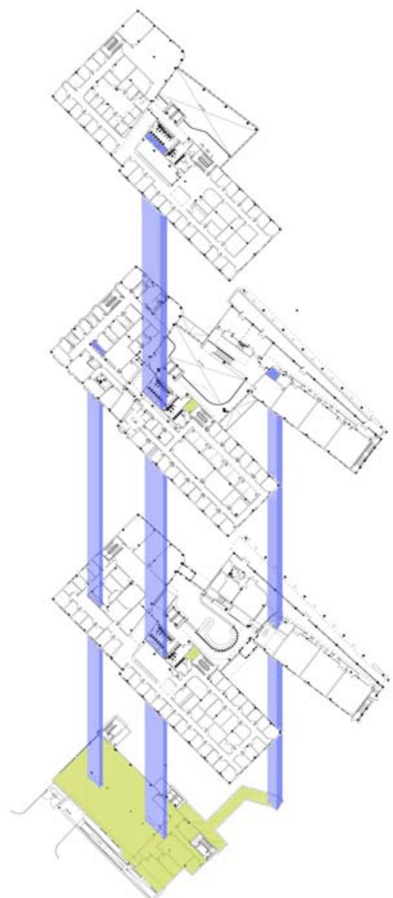


FIGURE 20: Orientation of mechanical space in the SLCC.

MECHANICAL SYSTEM COST ANALYSIS

The construction documents phase of the SLCC design completed in September, 2006 when the project was opened for bidding. The total first cost estimates for the design have not been procured for the bids or 100% CDs. However, full estimates were performed at the 60% CD Submission by Heery International – Construction Manager for SLCC – and International Consultants (ICI).

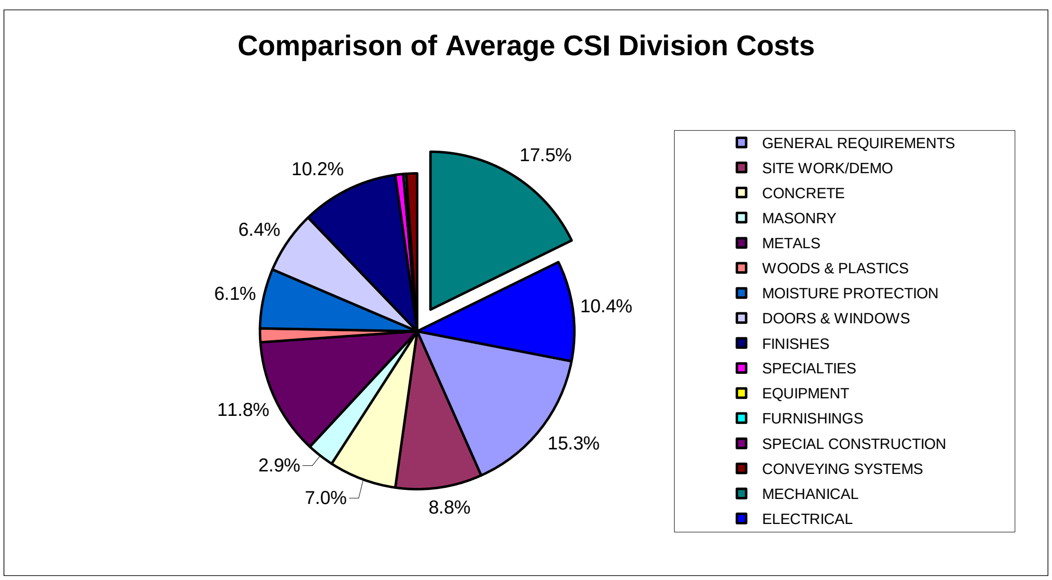
The total project costs range from $22.95M to $24.05M, with the CSI Division 15 costs ranging from $3.48M to $3.87M. The average mechanical system cost for the SLCC is approximately 17.5% of the total cost.

These 60% estimates are based on total building areas greater than the actual SLCC design area. It is likely that the 100% estimates would be less than the 60% estimates.

Gallaudet University SLCC 60% Construction Document Cost Estimate Comparison

Division	Description	ICI† Cost/SF *88,432*	ICI† Amount	Heery‡ Cost/SF *87,704*	Heery‡ Amount	Average Cost/SF	Average Cost	Average Portion of Total Cost
1	GENERAL REQUIREMENTS	37.15	3,284,919	35.70	3,130,654	38.64	3,207,787	15.3%
2	SITE WORK/DEMO	21.02	1,858,674	20.76	1,820,980	22.16	1,839,827	8.8%
3	CONCRETE	16.86	1,490,948	16.30	1,429,608	17.59	1,460,278	7.0%
4	MASONRY	7.52	665,232	6.45	565,746	7.41	615,489	2.9%
5	METALS	29.98	2,651,078	26.41	2,316,251	29.91	2,483,665	11.8%
6	WOODS & PLASTICS	3.20	282,609	3.00	263,121	3.29	272,865	1.3%
7	MOISTURE PROTECTION	15.39	1,361,003	13.84	1,213,656	15.50	1,287,330	6.1%
8	DOORS & WINDOWS	16.20	1,432,475	14.24	1,249,024	16.15	1,340,750	6.4%
9	FINISHES	21.95	1,941,193	26.76	2,347,035	25.82	2,144,114	10.2%
10	SPECIALTIES	1.81	159,935	1.83	160,236	1.93	160,086	0.8%
11	EQUIPMENT	0.08	7,450	0.27	23,500	0.19	15,475	0.1%
12	FURNISHINGS		0	0.51	44,648	0.27	22,324	0.1%
13	SPECIAL CONSTRUCTION		0		0	0.00	0	0.0%
14	CONVEYING SYSTEMS	3.05	270,000	3.08	270,000	3.25	270,000	1.3%
15	MECHANICAL	43.81	3,874,102	39.71	3,483,011	44.31	3,678,557	17.5%
16	ELECTRICAL	25.50	2,254,854	24.10	2,113,331	26.31	2,184,093	10.4%

	ICI		Heery		Average	
Subtotal		21,534,472		20,430,801		20,982,637
Contingency	5%	1,076,724	5%	1,021,540	5%	1,049,132
Subtotal		22,611,196		21,452,341		22,031,768
Escalation	6.7%	1,442,810	7%	1,501,664	7%	1,542,224
Total	**272.01**	**24,054,006**	**261.72**	**22,954,005**	**267.6794**	**23,573,992**



FIGURES 21: Mechanical first cost versus total building construction cost.

CONCLUSION

The calculations in this report find that the Gallaudet University Sorenson Language and Communication Center meets the minimum requirements from ASHRAE Std. 90.1-2004 for building envelope and lighting efficiency. Also the SLCC design would earn enough points to gain a LEED Certified Rating. The design of the SLCC was based on previous ASHRAE and LEED standards but still complies with the most recent versions used for this report. The calculated values in this report will be essential as a base case to compare different design options in the second half of this thesis.

Clearly the SLCC has been designed with sustainability in mind. Many design elements are derived from LEED credits for water efficiency, sustainable sites, materials and resources, and indoor environmental quality. However, the mechanical and electrical systems are only expected to gain a possible two of ten energy and efficiency points. This offers an opportunity to earn the SLCC a LEED Silver Rating through innovative design elements to enhance energy efficiency. In the end, though, the goal should not be to chase LEED points, but to provide an optimal and efficient environment for the occupants.

RESOURCES

2005 ASHRAE Handbook – *HVAC Applications*. ASHRAE, Inc. Atlanta, GA. 2005.

ANSI/ASHRAE Standard 90.1-2004 – *Energy Standard for Buildings*. ASHRAE, Inc. Atlanta, GA. 2004.

Colorado Energy, "R-Values Table." 21 Mar. 2005. Visited 25 Oct. 2006. http://www.coloradoenergy.org/procorner/stuff/r-values.htm

LEED-NC V2.2 – *Reference Guide For New Construction and Major Renovations.* U.S. Green Building Council, Washington, DC. 2005.

Pepco, "Rate Schedules for Electric Service in the District of Columbia." 1 Jan. 2005. Visited 28 Oct. 2006. http://www.pepco.com/_res/documents/dc_rate-schedules.pdf

APPENDIX A

ASHRAE 90.1-2004 LIGHTING COMPLIANCE

ASHRAE Standard 90.1-2004 Table 9.6.1: Lighitng Power Densities Using the Space-by-Space Method		
	Space Type	LPD [W/SF]
1	Atrium	0.6
2	Classroom	1.4
3	Conference	1.3
5	Cooridor	0.5
6	Laboratory	1.4
7	Library	1.2
8	Lounge	1.2
9	Computer Lab	1.1
10	Office	1.1
11	Reception	1.3
12	Storage	0.8
13	Restroom	0.9
14	Stairs/Support	0.6

ASHRAE Standard 90.1-2004 Table 9.6.1: Lighitng Power Densities Using the Building Area Method		
	Building Type	LPD [W/SF]
1	School / University	1.2

Space-By-Space Method (AHU-1)

Room No.	Room Type	Floor Area [SF]	Overhead Lighting [W]	Task Lighting [W/SF]	Lighting Power Density	Allowable Lighting Power Density [W/SF]	Meets 90.1 Requirements
B202	HOUSEKEEP	225	112	0	0.50	0.6	YES
B290-292	CORRIDOR	979	728	0	0.74	0.5	NO
B203	STORAGE	484	168	0	0.35	0.8	YES
B274	TELECOM	141	112	0	0.79	0.8	YES
1375	AV CLOSET	95	112	0	1.18	0.8	NO
1302A	AV CLOSET	30	21	0	0.70	0.8	YES
1303A	AV CLOSET	28	21	0	0.75	0.8	YES
1304A	AV CLOSET	28	21	0	0.75	0.8	YES
1304	CLASSROOM	916	1500	0	1.64	1.4	NO
1303	CLASSROOM	932	1500	0	1.61	1.4	NO
1302	CLASSROOM	932	1500	0	1.61	1.4	NO
1301	LOUNGE	504	504	0	1.00	1.2	YES
1392	CORRIDOR	1913	1680	0	0.88	0.5	NO
2300BA	AV CLOSET	55	112	0	2.04	0.8	NO
2300AA	STORAGE	99	112	0	1.13	0.8	NO
2375	AV CLOSET	95	112	0	1.18	0.8	NO
2302A	AV CLOSET	38	56	0	1.47	0.8	NO
2303A	AV CLOSET	28	56	0	2.00	0.8	NO
2304A	AV CLOSET	28	56	0	2.00	0.8	NO
2304	CLASSROOM	926	1500	0	1.62	1.4	NO
2303	CLASSROOM	934	1500	0	1.61	1.4	NO
2302	CLASSROOM	934	1500	0	1.61	1.4	NO
2301	CLASSROOM	508	420	0	0.83	1.4	YES
2391	CORRIDOR	1384	1512	0	1.09	0.5	NO
2300B	CONFERENCE	440	616	0	1.40	1.3	YES
2300A	CONFERENCE	509	672	0	1.32	1.3	YES

Space-By-Space Method (AHU-2)

Room No.	Room Type	Floor Area [SF]	Overhead Lighting [W]	Task Lighting [W]	Lighting Power Density	Allowable Lighting Power Density [W/SF]	Meets 90.1 Requirements
1300A	MEDIA STUDIO	636	3016	19844	35.94	1.1	NOT INCL.
1300B	MEDIA CONTRL	265	536	0	2.02	1.1	NO
1375	AV CLOSET	82	112	0	1.37	0.8	NO
1300BA	OFFICE	173	168	0	0.97	1.1	YES
1300C	WC	62	84	0	1.35	0.9	NO
1300	CORRIDOR	50	224	0	4.48	0.5	NO
1300CA	WC	43	64	0	1.49	0.9	NO

Space-By-Space Method (AHU-3)

Room No.	Room Type	Floor Area [SF]	Overhead Lighting [W]	Task Lighting [W/SF]	Lighting Power Density	Allowable Lighting Power Density [W/SF]	Meets 90.1 Requirements
1000	ATRIUM	4271	6104	0	1.43	0.6	NO
2390	CORRIDOR	1018	476	0	0.47	0.5	YES
2090	CORRIDOR	791	448	0	0.57	0.5	NO
2091	LOUNGE	191	336	0	1.76	1.2	NO
2092	LOUNGE	240	616	0	2.57	1.2	NO
2390	LOUNGE	318	0	0	0.00	1.2	YES
3090	CORRIDOR	784	504	0	0.64	0.5	NO
3091	LOUNGE	113	112	0	0.99	1.2	YES
3092	LOUNGE	264	56	0	0.21	1.2	YES

Space-By-Space Method (AHU-4)

Room No.	Room Type	Floor Area [SF]	Overhead Lighting [W]	Task Lighting [W/SF]	Lighting Power Density	Allowable Lighting Power Density [W/SF]	Meets 90.1 Requirements
1121	OFFICE	118	112	0.00	0.95	1.1	YES
1120	OFFICE	111	112	0.00	1.01	1.1	YES
1119	OFFICE	111	112	0.00	1.01	1.1	YES
1118	OFFICE	110	112	0.00	1.02	1.1	YES
1117	OFFICE	113	112	0.00	0.99	1.1	YES
1116	OFFICE	154	224	0.00	1.45	1.1	NO
1115	OFFICE	113	112	0.00	0.99	1.1	YES
1114	OFFICE	114	112	0.00	0.98	1.1	YES
1113	OFFICE	114	112	0.00	0.98	1.1	YES
1112	OFFICE	114	112	0.00	0.98	1.1	YES
1111	OFFICE	146	168	0.00	1.15	1.1	YES
1110	OFFICE	150	168	0.00	1.12	1.1	YES
1200	RECEPTION	478	560	0.00	1.17	1.3	YES
1290	LOUNGE	218	252	0.00	1.16	1.2	YES
1201	OFFICE	112	112	0.00	1.00	1.1	YES
1202	OFFICE	109	112	0.00	1.03	1.1	YES
1203	OFFICE	109	112	0.00	1.03	1.1	YES
1204	OFFICE	109	112	0.00	1.03	1.1	YES
1205	OFFICE	109	112	0.00	1.03	1.1	YES
1206	OFFICE	109	112	0.00	1.03	1.1	YES
1207	OFFICE	109	112	0.00	1.03	1.1	YES
1208	OFFICE	109	112	0.00	1.03	1.1	YES
1209	OFFICE	109	112	0.00	1.03	1.1	YES
1210	OFFICE	109	112	0.00	1.03	1.1	YES
1211	OFFICE	109	112	0.00	1.03	1.1	YES
1212	OFFICE	109	112	0.00	1.03	1.1	YES
1213	OFFICE	109	112	0.00	1.03	1.1	YES
1214	OFFICE	135	112	0.00	0.83	1.1	YES
1215	OFFICE	121	112	0.00	0.93	1.1	YES
1216	OFFICE	116	112	0.00	0.97	1.1	YES
1217	OFFICE	121	112	0.00	0.93	1.1	YES
1293	CORRIDOR	333	224	0.00	0.67	0.5	NO

Space-By-Space Method (AHU-4) Continued

Room No.	Room Type	Floor Area [SF]	Overhead Lighting [W]	Task Lighting [W/SF]	Lighting Power Density	Allowable Lighting Power Density [W/SF]	Meets 90.1 Requirements
1218	OFFICE	139	112	0.00	0.81	1.1	YES
1219	OFFICE	113	112	0.00	0.99	1.1	YES
1220	OFFICE	113	112	0.00	0.99	1.1	YES
1221	OFFICE	113	112	0.00	0.99	1.1	YES
1222	OFFICE	113	112	0.00	0.99	1.1	YES
1223	OFFICE	113	112	0.00	0.99	1.1	YES
1224	OFFICE	113	112	0.00	0.99	1.1	YES
1225	OFFICE	110	112	0.00	1.02	1.1	YES
1101	COMP LAB	635	336	0.00	0.53	1.1	YES
1102	WORKROOM	556	448	0.00	0.81	1.1	YES
1103	COMP LAB	559	336	0.00	0.60	1.1	YES
1126	STORAGE	344	252	0.00	0.73	0.8	YES
1104	WORKROOM	1034	504	0.00	0.49	1.1	YES
1105	WORKROOM	200	112	0.00	0.56	1.1	YES
1106	WORKROOM	367	224	0.00	0.61	1.1	YES
1125	CONFERENCE	252	224	0.00	0.89	1.3	YES
1191	CORRIDOR	215	308	0.00	1.43	0.5	NO
1124	OFFICE	632	784	0.00	1.24	1.1	NO
1240	OFFICE	630	231	0.00	0.37	1.1	YES
1292	CORRIDOR	1205	644	0.00	0.53	0.5	YES
1239	OFFICE	254	224	0.00	0.88	1.1	YES
1226	CONFERENCE	243	168	0.00	0.69	1.3	YES
1227	LIBRARY	166	112	0.00	0.67	1.2	YES
1228	RESEARCH LAB	166	112	0.00	0.67	1.4	YES
1229	RESEARCH LAB	166	112	0.00	0.67	1.4	YES
1230	RESEARCH LAB	166	112	0.00	0.67	1.4	YES
1231	VIDEO LAB	148	84	0.00	0.57	0.6	YES
1232	OFFICE	134	84	0.00	0.63	1.1	YES
1234	CONFERENCE	198	168	0.00	0.85	1.3	YES
1235	VIDEO LAB	132	84	0.00	0.64	0.6	YES
1236	VIDEO LAB	132	84	0.00	0.64	0.6	YES
1237	STORAGE	140	112	0.00	0.80	0.8	YES
1238	WORKROOM	172	112	0.00	0.65	1.1	YES
1122	TAP LAB	185	650	0.00	3.51	1.4	NO
1123	TAP LAB	193	650	0.00	3.37	1.4	NO
1122A	STORAGE	50	28	0.00	0.56	0.8	YES
1233	STORAGE	102	84	0.00	0.82	0.8	YES
1273	JC	28	28	0.00	1.00	0.6	NO
1072	WC	312	401	0.00	1.29	0.9	NO
1071	WC	232	320	0.00	1.38	0.9	NO

Space-By-Space Method (AHU-5)

Room No.	Room Type	Floor Area [SF]	Overhead Lighting [W]	Task Lighting [W/SF]	Lighting Power Density	Allowable Lighting Power Density [W/SF]	Meets 90.1 Requirements
2113	OBSERVATION	92	112	0.00	1.22	1.1	NO
2112	THERAPY	92	112	0.00	1.22	1.1	NO
2115	THERAPY	92	168	0.00	1.83	1.1	NO
2118	OBSERVATION	92	112	0.00	1.22	1.1	NO
2117	THERAPY	92	112	0.00	1.22	1.1	NO
2119	THERAPY	92	112	0.00	1.22	1.1	NO
2120	OFFICE	168	168	0.00	1.00	1.1	YES
2121	THERAPY	395	448	0.00	1.13	1.1	YES
2123A	THERAPY	184	168	0.00	0.91	1.1	YES
2123D	THERAPY	236	168	0.00	0.71	1.1	YES
2201	RECEPTION	346	280	0.00	0.81	1.3	YES
2202	RECEPTION	492	672	0.00	1.37	1.3	YES
2203	THERAPY	86	112	0.00	1.30	1.1	NO
2204	WORKROOM	86	112	0.00	1.30	1.1	NO
2205	WORKROOM	114	112	0.00	0.98	1.1	YES
2206	CONFERENCE	145	224	0.00	1.54	1.3	NO
2207	LAB	109	112	0.00	1.03	1.4	YES
2208	LAB	109	112	0.00	1.03	1.4	YES
2209	OFFICE	109	112	0.00	1.03	1.1	YES
2210	OFFICE	109	112	0.00	1.03	1.1	YES
2211	OFFICE	109	112	0.00	1.03	1.1	YES
2212	OFFICE	109	112	0.00	1.03	1.1	YES
2213	OFFICE	109	112	0.00	1.03	1.1	YES
2214	OFFICE	109	112	0.00	1.03	1.1	YES
2215	OFFICE	109	112	0.00	1.03	1.1	YES
2216	OFFICE	109	112	0.00	1.03	1.1	YES
2217	OFFICE	135	112	0.00	0.83	1.1	YES
2293	CORRIDOR	226	196	0.00	0.87	0.5	NO
2218	OFFICE	140	112	0.00	0.80	1.1	YES
2219	OFFICE	114	112	0.00	0.98	1.1	YES
2220	OFFICE	114	112	0.00	0.98	1.1	YES
2221	OFFICE	114	112	0.00	0.98	1.1	YES
2222	OFFICE	114	112	0.00	0.98	1.1	YES
2223	OFFICE	114	112	0.00	0.98	1.1	YES
2224	OFFICE	114	112	0.00	0.98	1.1	YES
2225	OFFICE	109	112	0.00	1.03	1.1	YES
2104	CONFERENCE	449	448	0.00	1.00	1.3	YES
2106	THERAPY	336	168	0.00	0.50	1.1	YES
2107	OBSERVATION	114	112	0.00	0.98	1.1	YES
2108A	STORAGE	23	0	0.00	0.00	0.8	YES
2106D	STORAGE	23	0	0.00	0.00	0.8	YES
2108	THERAPY	238	112	0.00	0.47	1.1	YES
2191	CORRIDOR	925	420	0.00	0.45	0.5	YES
2105	STORAGE	217	112	0.00	0.52	0.8	YES
2110	OBSERVATION	117	168	0.00	1.44	1.1	NO
2109	THERAPY	155	168	0.00	1.08	1.1	YES
2111	THERAPY	154	168	0.00	1.09	1.1	YES
2114	OBSERVATION	104	168	0.00	1.62	1.1	NO
2116	THERAPY	155	112	0.00	0.72	1.1	YES
2123	CORRIDOR	188	168	0.00	0.89	1.1	YES
2192	CORRIDOR	552	504	0.00	0.91	0.5	NO

Space-By-Space Method (AHU-5) Continued

Room No.	Room Type	Floor Area [SF]	Overhead Lighting [W]	Task Lighting [W/SF]	Lighting Power Density	Allowable Lighting Power Density [W/SF]	Meets 90.1 Requirements
2122	OBSERVATION	75	112	0.00	1.49	1.1	NO
2123C	OBSERVATION	73	112	0.00	1.53	1.1	NO
2124	WORKROOM	535	504	0.00	0.94	0.8	NO
2125	RECEPTION	209	168	0.00	0.80	1.3	YES
2200	RECEPTION	480	385	0.00	0.80	1.3	YES
2102	OBSERVATION	90	112	0.00	1.24	1.1	NO
2103	THERAPY	92	112	0.00	1.22	1.1	NO
2101	THERAPY	92	112	0.00	1.22	1.1	NO
2226	AUDIO BOOTH	92	-	0.00	-	1.1	-
2226A	OBSERVATION	83	-	0.00	-	1.1	-
2227	AUDIO BOOTH	92	-	0.00	-	1.1	-
2227A	OBSERVATION	83	-	0.00	-	1.1	-
2228	AUDIO BOOTH	92	-	0.00	-	1.1	-
2228A	OBSERVATION	83	-	0.00	-	1.1	-
2229	AUDIO BOOTH	92	-	0.00	-	1.1	-
2229A	OBSERVATION	83	-	0.00	-	1.1	-
2233	WORKROOM	696	672	0.00	0.97	1.1	YES
2295	CORRIDOR	1641	1988	0.00	1.21	0.5	NO
2232	COMP LAB	438	336	0.00	0.77	1.1	YES
2231	STORAGE	143	168	0.00	1.17	0.8	NO
2230	LAB	193	168	0.00	0.87	1.4	YES
2273	JC	28	56	0.00	2.00	0.6	NO
2106B	WC	50	96	0.00	1.92	0.9	NO
2123B	WC	44	64	0.00	1.45	0.9	NO
2072	WC	312	401	0.00	1.29	0.9	NO
2071	WC	232	320	0.00	1.38	0.9	NO

Space-By-Space Method (AHU-6)

Room No.	Room Type	Floor Area [SF]	Overhead Lighting [W]	Task Lighting [W/SF]	Lighting Power Density	Allowable Lighting Power Density [W/SF]	Meets 90.1 Requirements
3120	OFFICE	109	112	0.00	1.03	1.1	YES
3119	OFFICE	109	112	0.00	1.03	1.1	YES
3118	OFFICE	109	112	0.00	1.03	1.1	YES
3117	OFFICE	132	112	0.00	0.85	1.1	YES
3116	OFFICE	112	112	0.00	1.00	1.1	YES
3115	OFFICE	109	112	0.00	1.03	1.1	YES
3114	OFFICE	109	112	0.00	1.03	1.1	YES
3113	OFFICE	109	112	0.00	1.03	1.1	YES
3112	OFFICE	109	112	0.00	1.03	1.1	YES
3111	OFFICE	109	112	0.00	1.03	1.1	YES
3110	OFFICE	160	224	0.00	1.40	1.1	NO
3290	LOUNGE	166	252	0.00	1.52	1.2	NO
3200	RECEPTION	530	567	0.00	1.07	1.3	YES
3201	OFFICE	153	168	0.00	1.10	1.1	YES
3202	OFFICE	152	168	0.00	1.11	1.1	YES
3203	OFFICE	147	168	0.00	1.14	1.1	YES
3204	OFFICE	109	112	0.00	1.03	1.1	YES
3205	OFFICE	109	112	0.00	1.03	1.1	YES
3206	OFFICE	109	112	0.00	1.03	1.1	YES
3207	OFFICE	109	112	0.00	1.03	1.1	YES
3208	OFFICE	109	112	0.00	1.03	1.1	YES
3209	OFFICE	109	112	0.00	1.03	1.1	YES
3210	OFFICE	224	224	0.00	1.00	1.1	YES
3211	OFFICE	109	112	0.00	1.03	1.1	YES
3212	OFFICE	109	112	0.00	1.03	1.1	YES
3213	OFFICE	135	112	0.00	0.83	1.1	YES
3293	CORRIDOR	272	112	0.00	0.41	0.5	YES
3214	WORKROOM	186	112	0.00	0.60	1.1	YES
3215	OFFICE	135	112	0.00	0.83	1.1	YES
3216	OFFICE	118	112	0.00	0.95	1.1	YES
3217	OFFICE	113	112	0.00	0.99	1.1	YES
3218	OFFICE	113	112	0.00	0.99	1.1	YES
3219	OFFICE	113	112	0.00	0.99	1.1	YES
3220	OFFICE	113	112	0.00	0.99	1.1	YES
3221	OFFICE	113	112	0.00	0.99	1.1	YES
3222	OFFICE	108	112	0.00	1.04	1.1	YES
3102	WORKROOM	1787	1344	0.00	0.75	1.1	YES
3103	COMP LAB	562	448	0.00	0.80	1.1	YES
3121	LAB	302	336	0.00	1.11	1.4	YES
3122B	LAB	92	112	0.00	1.22	1.4	YES
3122C	LAB	86	112	0.00	1.30	1.4	YES
3122A	LAB	124	112	0.00	0.90	1.4	YES
3122E	AUDIO BOOTH	59	56	0.00	0.95	1.1	YES
3122F	AUDIO BOOTH	54	56	0.00	1.04	1.1	YES
3122	LAB	580	280	0.00	0.48	1.4	YES
3122L	LAB	89	112	0.00	1.26	1.4	YES
3122K	LAB	90	112	0.00	1.24	1.4	YES
3122J	LAB	82	112	0.00	1.37	1.4	YES
3122I	LAB	90	112	0.00	1.24	1.4	YES
3122G	AUDIO BOOTH	75	112	0.00	1.49	1.1	NO
3122H	LAB	90	112	0.00	1.24	1.4	YES

Space-By-Space Method (AHU-6) Continued

Room No.	Room Type	Floor Area [SF]	Overhead Lighting [W]	Task Lighting [W/SF]	Lighting Power Density	Allowable Lighting Power Density [W/SF]	Meets 90.1 Requirements
3101	CONFERNCE	290	224	0.00	0.77	1.3	YES
3122D	AUDIO BOOTH	14	21	0.00	1.50	1.1	NO
3122D	AUDIO BOOTH	14	21	0.00	1.50	1.1	NO
3122D	LAB	147	112	0.00	0.76	1.4	YES
3234	WORKROOM	626	336	0.00	0.54	1.1	YES
3292-3296	CORRIDOR	1642	1456	0.00	0.89	0.5	NO
3233	OFFICE	290	336	0.00	1.16	1.1	YES
3232	STORAGE	189	224	0.00	1.19	1.3	YES
3223	WORKROOM	239	224	0.00	0.94	1.1	YES
3225	WORKROOM	184	224	0.00	1.22	1.1	NO
3226	CONFERNCE	259	336	0.00	1.30	1.3	YES
3228	LAB	126	168	0.00	1.33	1.4	YES
3231	STORAGE	107	168	0.00	1.57	0.8	NO
3229	STORAGE	199	210	0.00	1.06	0.8	NO
3227	STORAGE	141	168	0.00	1.19	0.8	NO
3224	STORAGE	189	112	0.00	0.59	0.8	YES
3230	WORKROOM	144	168	0.35	1.52	1.1	NO
3190-3191	CORRIDOR	824	504	0.00	0.61	0.5	NO
3072	WC	31	401	0.00	12.94	0.9	NO
3071	WC	262	320	0.00	1.22	0.9	NO

APPENDIX B

ASHRAE 90.1-2004 BUILDING ENVELOPE COMPLIANCE

Roof (Winter)

	T_{db} (°F)
Exterior	19.4
Plenum	80.0

U Value Actual: 0.06 U Value Max: 0.063

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				80.00
	1	Horiz. Int. Film	0			0.61	-2.15	
b								77.85
	2	Steel Deck	0.125			0.20	-0.71	
c				0.125				77.14
	3	Gypsum	0.625			0.56	-1.98	
d				0.75				75.16
	4	Rigid Insul.	3.00		5.00	15.00	-52.94	
e				3.75				22.22
	5	Cover Board	0.375			0.63	-2.22	
f				4.125				20.00
	6	Ext. Film	0			0.17	-0.60	
g				4.125				19.40
					R Value:	17.17	(ft^2 °F hr)/BTU	
					U Value:	0.06	BTU/(ft^2 °F hr)	
					Heat Loss:	3.53	BTU/(hr ft^2)	

Roof (Summer)

	T_{db} (°F)
Exterior	94.5
Plenum	85.0

U Value Actual: 0.06 U Value Max: 0.063

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				85.00
	1	Horiz. Int. Film	0			0.61	0.34	
b								85.34
	2	Steel Deck	0.125			0.20	0.11	
c				0.125				85.45
	3	Gypsum	0.625			0.56	0.31	
d				0.75				85.76
	4	Rigid Insul.	3.00		5.00	15.00	8.30	
e				3.75				94.06
	5	Cover Board	0.375			0.63	0.35	
f				4.125				94.41
	6	Ext. Film	0			0.17	0.09	
g				4.125				94.50
					R Value:	17.17	(ft^2 °F hr)/BTU	
					U Value:	0.06	BTU/(ft^2 °F hr)	
					Heat Gain:	0.55	BTU/(hr ft^2)	

Masonry Wall Above Grade (Winter)

	T_{db} (°F)
Exterior	19.4
Interior	70.0

U Value Actual: 0.04 U Value Max: 0.127

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				70.00
	1	Int. Film	0			0.68	-1.55	
b								68.45
	2	Gypsum	0.625			0.56	-1.27	
c				0.625				67.18
	3	Batt Insul.	6		3.14	18.84	-42.85	
d				0.625				24.33
	4	Gypsum	0.625			0.56	-1.27	
e				6.625				23.06
	4	Air Space	2.125			1.00	-2.27	
f				8.75				20.79
	5	Brick	3.625			0.44	-1.00	
g				12.375				19.79
	6	Ext. Film	0			0.17	-0.39	
h				12.375				19.40

R Value:	22.25	(ft^2 °F hr)/BTU
U Value:	0.04	BTU/(ft^2 °F hr)
Heat Loss:	2.27	BTU/(hr ft^2)

Masonry Wall Above Grade (Summer)

	T_{db} (°F)
Exterior	94.5
Interior	75.0

U Value Actual: 0.04 U Value Max: 0.127

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				75.00
	1	Int. Film	0			0.68	0.60	
b								75.60
	2	Gypsum	0.625			0.56	0.49	
c				0.625				76.09
	3	Batt Insul.	6		3.14	18.84	16.51	
d				0.625				92.60
	4	Gypsum	0.625			0.56	0.49	
e				6.625				93.09
	4	Air Space	2.125			1.00	0.88	
f				8.75				93.97
	5	Brick	3.625			0.44	0.39	
g				12.375				94.35
	6	Ext. Film	0			0.17	0.15	
h				12.375				94.50

R Value:	22.25	(ft^2 °F hr)/BTU
U Value:	0.04	BTU/(ft^2 °F hr)
Heat Gain:	0.88	BTU/(hr ft^2)

Wall Below Grade (Winter)

Air	T_{db} (°F)
Exterior	19.4
Interior	70.0

Air-to-soil Amplitude [°F]:	16
$T_{sen, soil}$ (°F):	35.4

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				70.00
	1	Int. Film	0			0.68	-1.36	
b								68.64
	2	Gypsum	0.625			0.56	-1.12	
c				0.625				67.51
	3	Polystyrene	3		5	15.00	-30.10	
d				0.625				37.41
	4	Concrete	12		0.08	0.56	-1.12	
f				12.625				36.28
	5	Brick	3.625			0.44	-0.88	
g				16.25				35.40
					R Value:	17.24	(ft^2 °F hr)/BTU	
					U Value:	0.06	BTU/(ft^2 °F hr)	
					Heat Loss:	2.94	BTU/(hr ft^2)	

Wall Below Grade (Summer)

Air	T_{db} (°F)
Exterior	94.5
Interior	75.0

Air-to-soil Amplitude [°F]:	16
$T_{sen, soil}$ (°F):	78.5

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				75.00
	1	Int. Film	0			0.68	0.14	
b							0.00	75.14
	2	Gypsum	0.625			0.56	0.11	
c				0.625			0.00	75.25
	3	Polystyrene	3		5	15.00	3.05	
d				0.625			0.00	78.30
	4	Concrete	12		0.08	0.56	0.11	
f				12.625			0.00	78.41
	5	Brick	3.625			0.44	0.09	
g				16.25				78.50
					R Value:	17.24	(ft^2 °F hr)/BTU	
					U Value:	0.06	BTU/(ft^2 °F hr)	
					Heat Gain:	1.13	BTU/(hr ft^2)	

Zinc Sided Wall (Winter)

	T_{db} (°F)
Exterior	19.4
Interior	70.0

U Value Actual: 0.05 U Value Max: 0.127

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				70.00
	1	Int. Film	0			0.68	-1.64	
b								68.36
	2	Gypsum	0.625			0.56	-1.35	
c				0.625				67.01
	3	Batt Insul.	6		3.14	18.84	-45.37	
d				6.625				21.64
	4	Gypsum	0.625			0.56	-1.35	
e				7.25				20.29
	5	Zinc Siding	0.375			0.20	-0.48	
f				7.625				19.81
	6	Ext. Film	0			0.17	-0.41	
g				7.625				19.40
					R Value:	21.01	(ft^2 °F hr)/BTU	
					U Value:	0.05	BTU/(ft^2 °F hr)	
					Heat Loss:	2.41	BTU/(hr ft^2)	

Zinc Sided Wall (Summer)

	T_{db} (°F)
Exterior	94.5
Interior	75.0

U Value Actual: 0.05 U Value Max: 0.127

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				75.00
	1	Int. Film	0			0.68	0.63	
b								75.63
	2	Gypsum	0.625			0.56	0.52	
c				0.625				76.15
	3	Batt Insul.	6		3.14	18.84	17.49	
d				6.625				93.64
	4	Gypsum	0.625			0.56	0.52	
e				7.25				94.16
	5	Zinc Siding	0.375			0.20	0.19	
f				7.625				94.34
	6	Ext. Film	0			0.17	0.16	
g				7.625				94.50
					R Value:	21.01	(ft^2 °F hr)/BTU	
					U Value:	0.05	BTU/(ft^2 °F hr)	
					Heat Gain:	0.93	BTU/(hr ft^2)	

Glazing (Winter)

	T_{db} (°F)
Exterior	19.4
Interior	70.0

U Value Actual: 0.35 U Value Max: 0.57

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				70.00
	1	Int. Film	0			0.68	-11.91	
b				0				58.09
	2	IGU w/ 1/2" Air Space	1			2.04	-35.72	
c				1				22.38
	3	Ext. Film	0			0.17	-2.98	
d				1				19.40
					R Value:	2.89	(ft^2 °F hr)/BTU	
					U Value:	0.35	BTU/(ft^2 °F hr)	
					Heat Loss:	17.51	BTU/(hr ft^2)	

Glazing (Summer)

	T_{db} (°F)
Exterior	94.5
Interior	75.0

U Value Actual: 0.35 U Value Max: 0.57

Surface	Layer	Material	Material Thickness	Total Thickness	Conductivity [BTU/hr ft^2 °F	R-Value [BTU/hr ft^2 °F]	Delta T [°F]	T [°F]
a				0				75.00
	1	Int. Film	0			0.68	4.59	
b				0				79.59
	2	IGU w/ 1/2" Air Space	1			2.04	13.76	
c				1				93.35
	3	Ext. Film	0			0.17	1.15	
d				1				94.50
					R Value:	2.89	(ft^2 °F hr)/BTU	
					U Value:	0.35	BTU/(ft^2 °F hr)	
					Heat Gain:	6.75	BTU/(hr ft^2)	

APPENDIX C

DETAILED MECHANICAL SYSTEM FIRST COST BREAKDOWN

This first cost analysis was performed by International Consultants (ICI) at 60% CDs.

INTERNATIONAL CONSULTANTS, INC. PHILADELPHIA, PENNSYLVANIA 215 / 923.8888

SMITH GROUP INC.
GALLAUDET UNIVERSITY
SORENSON LANGUAGE & COMMUNICATION CENTER
WASHINGTON, DC

ICI #: 205848-3
Prep: mcf/gel
Date: 6/2/06
Page: 1 of 3
Revised: 6/5/06

SUMMARY - 60% CONSTRUCTION DOCUMENT COST ESTIMATE

15.0	**PLUMBING**				
	Toilet	30	EA	$ 1,050.00	$ 31,500
	Urinal	9	EA	1,005.00	9,045
	Lavatory w/Sensor Operator	36	EA	1,150.00	41,400
	Electric Water Cooler (Hi - Low)	8	EA	1,550.00	12,400
	Shower	1	EA	1,425.00	1,425
	Sink	9	EA	975.00	8,775
	Janitor Sink	4	EA	1,150.00	4,600
	Domestic Hot Water Heater -225 Gallon Capacity	1	EA	16,500.00	16,500
	Sump Pump with Pit - 1/2 HP	1	EA	1,500.00	1,500
	Recirculation Pump (1/8 HP)	1	EA	1,500.00	1,500
	Duplex Booster System (5HP) with Tank	1	LS	7,500.00	7,500
	Wall Hydrant	11	EA	350.00	3,850
	Floor Drain	13	EA	425.00	5,525
	Roof Drain	13	EA	450.00	5,850
	Clean Out	8	EA	325.00	2,600
	Water Piping:				
	- 1/2"-3/4	3,000	LF	19.00	57,000
	- 1"-1 1/2"	1,254	LF	24.00	30,096
	- 2"-2 1/2"	270	LF	30.00	8,100
	- 4"	20	LF	50.00	1,000
	- 6"	30	LF	80.00	2,400
	Miscellaneous Valves/Piping/Accessories	1	LS	15,000.00	15,000
	Sanitary/Storm Piping:				
	- 1 1/2" - 2"	2,223	LF	25.00	55,575
	- 3"	304	LF	30.00	9,120
	- 4"	1,335	LF	36.00	48,060
	- 6"	670	LF	53.00	35,510
	- 8"	154	LF	73.00	11,242
	- 10"	56	LF	100.00	5,600
	Sprinkler System	88,432	SF	3.25	287,404
	Sprinkler System - Tunnel	1,465	SF	3.25	4,761
	Fire Pump (40HP)/Jockey Pump (1.5HP)	1	EA	70,000.00	70,000
	Subtotal				$ 794,838
	Contingency	0%			-
	TOTAL				$ 794,838

INTERNATIONAL CONSULTANTS, INC. PHILADELPHIA, PENNSYLVANIA 215 / 923.8888

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DETAILS - 60% CONSTRUCTION DOCUMENT COST ESTIMATE

Account	Description	Quantity	Unit	Unit Cost	Amount
15.5	**HVAC**				
	Air Handling Units:				
	- 1,500 CFM	1	EA	$ 7,450.00	$ 7,450
	- 11,600-13,900 CFM	4	EA	60,500.00	242,000
	- 17,700 CFM	1	EA	82,500.00	82,500
	Computer Room A/C Unit - 2,500 CFM	1	EA	15,000.00	15,000
	Extend Chilled Water Piping to Building	490	LF	365.00	178,850
	Extend Steam Piping to Building	245	LF	185.00	45,325
	Extend Condensate Return Piping to Building	245	LF	145.00	35,525
	Pump:				
	- 5HP	5	EA	6,200.00	31,000
	- 7.5 HP with VFD	2	EA	7,750.00	15,500
	- 25 HP with VFD	2	EA	12,500.00	25,000
	- Condensate Pump	1	EA	8,500.00	8,500
	Heat Exchanger	1	EA	26,500.00	26,500
	Expansion Tank - 600 Gallon	2	EA	2,000.00	4,000
	Mechanical Piping	88,432	SF	5.00	442,160
	Steam PRV	1	EA	11,500.00	11,500
	Water Treatment	1	LS	10,000.00	10,000
	Ductwork	81,500	LB	8.00	652,000
	Duct Insulation	53,300	SF	3.50	186,550
	Diffuser/Register/Grill	540	EA	225.00	121,500
	Linear Diffuser	640	LF	60.00	38,400
	Transfer Duct	181	EA	450.00	81,450
	Sound Attenuators	19	EA	2,650.00	50,350
	Louver	672	SF	55.00	36,960
	Relief Fan:				
	- 1,200 CFM	1	EA	1,850.00	1,850
	- 8,600-10,800 CFM	4	EA	5,000.00	20,000
	- 15,000 CFM	1	EA	7,500.00	7,500
	- VFD @ Fans	1	LS	15,000.00	15,000
	Exhaust Fan:				
	- 75-150 CFM	5	EA	750.00	3,750
	- 400 CFM	2	EA	900.00	1,800
	- 750-1,050 CFM	2	EA	1,350.00	2,700
	- 1,500 CFM	1	EA	1,850.00	1,850
	- 1,800-2,150 CFM	2	EA	2,300.00	4,600
	- 3,000 CFM	1	EA	2,800.00	2,800
	- 15,000 CFM	3	EA	7,500.00	22,500
	Hot Water Reheat Coil - 2.8-36 Gallon/Min.	4	EA	2,100.00	8,400
	Hot Water Reheat Coil - 11.6 Gallon/Min.	1	EA	3,850.00	3,850
	Cabinet Unit Heater - 260 CFM	6	EA	1,000.00	6,000
	Miscellaneous Unit Heaters	1	LS	7,500.00	7,500
	Fin Tube Radiation	50	LF	120.00	6,000

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DETAILS - 60% CONSTRUCTION DOCUMENT COST ESTIMATE

Account	Description	Quantity	Unit	Unit Cost	Amount
15.5	**HVAC** (continued)				
	Fan Coil Unit:				
	- 281 CFM	3	EA	2,500.00	7,500
	- 695 CFM	3	EA	3,000.00	9,000
	- 1,135 CFM	1	EA	3,300.00	3,300
	VAV Terminal Units:				
	- 0-200 CFM w/o Reheat Coil	20	EA	750.00	15,000
	- 200-350 CFM w/o Reheat Coil	4	EA	775.00	3,100
	- 0-200 CFM	23	EA	1,250.00	28,750
	- 200-350 CFM	40	EA	1,350.00	54,000
	- 350-650 CFM	26	EA	1,500.00	39,000
	- 650-1350 CFM	24	EA	1,850.00	44,400
	- 1,350-1,600 CFM	5	EA	2,150.00	10,750
	- 2,230 CFM	1	EA	2,400.00	2,400
	Testing/Balance/Controls	88,432	SF	4.50	397,944
	Subtotal				$ 3,079,264
	Contingency	0%			-
	TOTAL				$ 3,079,264
	ALTERNATE				
	Open Suppliers of AHU to Other Manufactures besides Trane	(1)	LS	$ 30,000.00	$ (30,000)
	Subtotal				$ (30,000)
	Mark Ups (5% + 18% + 6.7%)	32%			(9,660)
	TOTAL - NET DEDUCT				$ (39,660)