Technical Assignment 1

ASHRAE Standard 62.1 Ventilation and Standard 90.1 Energy Design Evaluations

Compliance Analysis

David H. Koch Institute for Integrative Cancer Research

Massachusetts Institute of Technology

Cambridge, Ma



Table of Contents

Executive Summary

The David H. Koch Institute, currently under construction, is to be a 360,000 GSF Integrative Cancer Research Institute in Cambridge, MA. In the winter of 2010, the Massachusetts Institute of Technology will add the institute to its long list of prestigious institutions. It is designed to become a LEED Gold Certified project, standing seven stories above grade with a basement and penthouse.

This document is the compilation of data, calculations and results that analyze the Koch Institute's compliance with ASHRAE Standard 62.1 (Ventilation) and 90.1 (Energy Design Evaluations). The Koch Institute receives the majority of its conditioned air from a 100% Central VAV Ventilation/ Cooling System located in the facility's penthouse. Therefore, the following report analyzes this system along with the building characteristics for compliance with ASHRAE Standards 62.1 and 90.1.

The sample calculations for Ventilation Rate found on pages 11 and 12 of the report produced values far less than those of the design. It is common for designers to oversize for safety, especially when regarding indoor air quality issues. Also, the Koch Institute contains a large number of laboratory and vivarium spaces. Spaces such as these have very strict design criteria and often times; design is driven by Hourly Air Change Rate requirements.

Throughout the analysis it was quite clear that as a whole, the Koch Institute design complies with ASHRAE Standards 62.1 and 90.1. It is a carefully designed building with intricate supply and exhaust systems. The building envelope is comprised of many different materials, yet they all meet the criteria set forth by ASHRAE Standard 90.1. Due to the complexity of the mechanical systems in the Koch Institute, a brief Mechanical Summary is included on the following pages for further understanding.

Mechanical Summary

Due to the diversity of spaces and individual space requirements, the Koch Institute's mechanical systems are very sophisticated. A central VAV ventilation/cooling system provides fully conditioned 100% outside air, utilizing heat recovery from exhaust fan systems. It is responsible for supplying the laboratory and vivarium spaces. The system is supplemented with terminal fan coil units in problem areas and chilled beam induction cooling in perimeter spaces. The design contains 24 Air Handling Units supplying air to a multitude of spaces. These AHU's span from small to large (3,600-50,000 CFM) and are strategically placed throughout the building.

Unit	Service	CFM	Max MBH	Heating Coil (EWT)	Preheat Coil	Cooling Coil (EWT)
AHU-1	Laboratory Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-2	Laboratory Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-3	Laboratory Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-4	Laboratory Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-5	Vivarium Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-6	Vivarium Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-7	Laboratory Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-8	Laboratory Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-9	Laboratory Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-10	Laboratory Supply	50000	1700	-	Steam @ 2psig	Water at 43°F
AHU-11	(Reserve)	-	-	-	-	-
AHU-12 (a&b)	Electrical Service Room	9000	235	-	-	Water at 55°F
AHU-13	East Stair Htg./Clg.	3600	75	Water at 180°F	-	Water at 52°F
AHU-14	West Stair Htg./Clg.	3600	75	Water at 180°F	-	Water at 52°F
AHU-15	East Stair Htg./Clg.	3600	75	Water at 180°F	-	Water at 52°F
AHU-16	West Stair Htg./Clg.	3600	75	Water at 180°F	-	Water at 52°F
AHU-17 (a&b)	Basement Spot Cooling	6000	187	-	-	Water at 55°F
AHU-18 (a-e)	Penthouse Spot Cooling	6000	187	-	-	Water at 55°F

Table 1 *– Built Up Air Handling Unit Characteristics*

The building is designed as a 100% Outdoor Air system. As can be seen in *Table 1.1*, the majority of air is supplied to the building by AHU's (1-10). These ten large units utilize a heat pipe recovery system for preheating of the entering airstream. The vertical arrangement of the building's air supply is contained within two large main shafts denoted East Shaft and West Shaft, as well as the East & West Stair Shafts. The 50,000 CFM built up air handling units 1-10 are each paired up with an equally sized EAHU, depicted in the following *Table 1.2.*

Unit	Service	CFM	Max MBH
EAHU-1	Laboratory Supply	50000	1700
EAHU-2	Laboratory Supply	50000	1700
EAHU-3	Laboratory Supply	50000	1700
EAHU-4	Laboratory Supply	50000	1700
EAHU-5	Vivarium Supply	50000	1700
EAHU-6	Vivarium Supply	50000	1700
EAHU-7	Laboratory Supply	50000	1700
EAHU-8	Laboratory Supply	50000	1700
EAHU-9	Laboratory Supply	50000	1700
EAHU-10	Laboratory Supply	50000	1700

Table 2 *– Built Up Exhaust Air Handling Unit Characteristics*

Factory Built-Up Air Handling Units

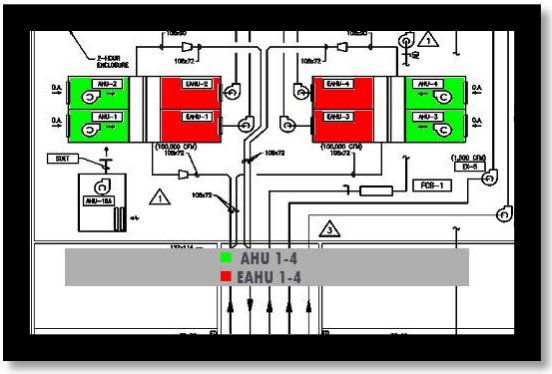

Figure 1 *– AHU 1-4 and EAUH 1-4*

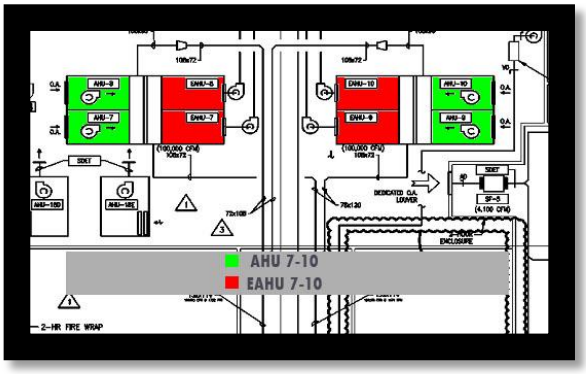

Figure 2 *– AHU 7-10 and EAUH 7-10*

AHU's (1-4) & (7-10)

Located in the Penthouse, AHU 1-4 and AHU 7-10 are grouped together in the West and East sides of the building respectively. AHU 1-4 each feed 50,000 CFM into a common 132" x 114" duct that runs down the West Shaft feeding floors 6-basement. Similarly, AHU 7-10 each feed 50,000 CFM into a common 132" x 114" duct that runs down the East Shaft feeding floors 6-basement. This design provides for easy maintenance of all units due to a reduction in diversity in system components and maintenance requirements.

EAHU's (1-4) & (7-10)

Also located in the penthouse the exhaust air handling units follow a similar design technique as the one described in the previous section. EAHU's 1-4 utilize the West Shaft for ductwork and EAHU's 7-10 utilize the East Shaft for ductwork. Duct Sizes mimic those of the AHU's.

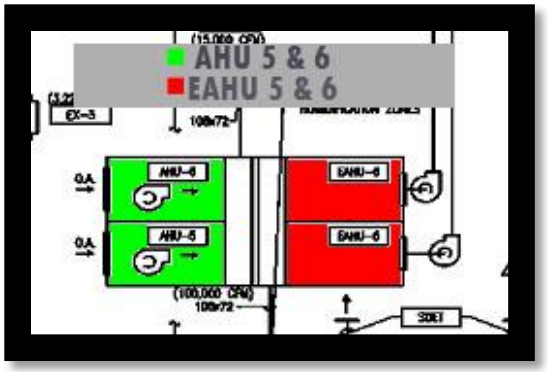

Figure 3 *– AHU 5&6 and EAUH 5&6*

AHU 5 & 6 and EAHU 5 & 6

Located in the center of the Penthouse, AHU 5 & 6 are paired together to serve the vivarium spaces as well as supplemental spaces not yet conditioned. Though these units are also paired with EAHU 5 & 6 they do not follow the design of the previously discussed units. AHU 5 & 6 supply 50,000 CFM each to a common plenum with multiple taps. Ductwork is tapped into the plenum and runs either east or west before dropping down to serve the building. The air that is diverted to the eastern side of the building is humidified and goes on to serve mainly office spaces. Air diverted to the west is sent to a cage wash area as well as a "northwest humidified" area.

Modular Indoor Air Handling Units

AHU 12 (a & b)

Located on the basement level in the electrical service room, AHU 12 a & b work together to provide a total of 18,000 CFM of conditioned air to the electrical room.

AHU 13 & 14 – West Stair Heating and Cooling

Located on the penthouse level, AHU-13 provides 3,600 CFM of conditioned air to the Penthouse – 5th level of the West Stairway. It does so by delivering 900 CFM of conditioned air to each level. Located on the basement level, AHU-14 provides 3,600 CFM of conditioned air to 1st – 4th level of the West Stairway. It does so by delivering 900 CFM of conditioned air to each level.

AHU 15 & 16 – East Stair Heating and Cooling

Located on the penthouse level, AHU-15 provides 3,600 CFM of conditioned air to the Penthouse – 5th level of the East Stairway. It does so by delivering 900 CFM of conditioned air to each level. Located on the basement level, AHU-16 provides 3,600 CFM of conditioned air to 1st – 4th level of the East Stairway. It does so by delivering 900 CFM of conditioned air to each level.

AHU 17 (a & b) and AHU 18 (a-e) – Basement and Penthouse Spot Cooling

These (7) AHU's, all equally sized at 6,000 CFM, provide spot cooling for the basement and penthouse levels.

ASHRAE Standard 62.1-2007 Compliance Analysis

Section 5: Systems and Equipment

Section 5.1 – Natural Ventilation

The building utilizes a mechanical ventilation system therefore natural ventilation is not a ventilation method for the building.

Section 5.2 – Ventilation Air Distribution

All spaces throughout the building meet ventilation requirements set forward by the ASHRAE Standard 62.1. The design documents specify clearly the design air flow throughout each space as well as provide assumptions made throughout the design process.

Section 5.3 – Exhaust Duct Locations

Each exhaust duct is negatively pressured with regards to the spaces they pass through. Located on the penthouse level, the main exhaust air handling units EAHU 1-10 along with all other exhaust fans sufficiently dispose of contaminated exhaust air.

Section 5.4 – Ventilation System Controls

The mechanical system contains controls to enable all pertinent equipment when spaces are occupied to maintain acceptable space conditions. Minimum outdoor air flow is maintained for all spaces satisfying the Section 5.4 requirements.

Section 5.5 – Airstream Surfaces

The majority of the HVAC system is comprised of sheet metal with sound attenuators at the entrance and exits of units and at main duct transitions. Compliant flexible duct is used when necessary at diffusers.

Section 5.6– Outdoor Intakes

Due to the nature of the spaces throughout the building, there is a concern with re-entrainment of contaminated air. After reviewing Table 5-1 of ASHRAE Standard 62.1 it is clear that all categories are compliant. The most eminent threat in this buildings case is the re-entry of exhausted contaminants. Therefore, the below images were further evaluated to check for compliance.

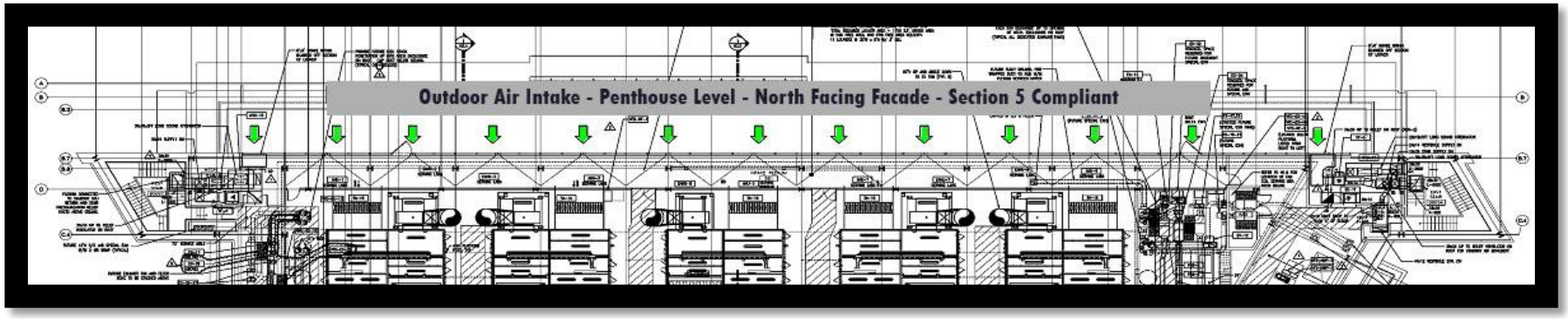

Figure 4 – *Partial view of HVAC Penthouse Plan to show Outdoor Air Intake to large central system*

STACK EXIT CONES

FAN	CFM	STACK SIZE	STACK VELOCITY	EXIT SIZE	EXIT VELOCITY
FUTURE SPECIAL	1000 MAX	12"	1250	12"	NOTE 3
EX-7	1800	18"	1000	14"	1,800
EX-8	1800	18"	1000	14"	1,800
EX-9	675	12"	850	8"	2,200
EX-10	1,800	20"	850	12"	2,200
EX-12	2,400	20"	1,100	14"	2,200
EX-13	800	12"	1,000	8"	2,200
EX-14	475	10"	850	6.5"	2,200
EAHU (TYP)	50,000	60"	2,550	56"	2,900

NOTES:
1. ALL CONES TERMINATE 15' ABOVE ROOF LEVEL w/ TOP OF ARCH ENCLOSURE.

Figure 5 – *Taken from HVAC Roof Plan*

The diagramitic view of the Penhouse Plan shown in ***Figure 4*** shows the major intake of outdoor air by the central VAV ventilation/cooling units. It can be seen in Note 1 of ***Figure 5***, taken from the HVAC Roof Plan, "ALL CONES TERMINATE 15' ABOVE ROOF LEVEL w/ TOP OF ARCH ENCLOSURE", therefore they comply with regulations set by Table 5-1 in ASHRAE Standard 62.1.

Section 5.7 – Local Capture of Contaminants

Exhaust from Laboratory and Vivarium spaces is ducted directly to exhaust fans on the roof. All contaminants are exhausted at high velocities to prevent re-entry.

Section 5.8 – Combustion Air

All combustion processes are provided with sufficient amounts of air according to the manufacturer's requirements. The products of combustion from the emergency generator are vented directly to the outdoors at a minimum of 15'.

Section 5.9 – Particulate Matter Removal

Temporary construction filters with a MERV of 8 have been specified in the Air Quality Requirements for Contractors Dust Control. This meets the requirement of a MERV no less than 6 that is stated in Section 5.9. Once constructed the Pre-Filters and Final-Filters have more than sufficient minimum efficiency reporting values (MERV's).

Unit	Service	Pre-Filter MERV	Final-Filter MERV
AHU-1	Laboratory Supply	8	14
AHU-2	Laboratory Supply	8	14
AHU-3	Laboratory Supply	8	14
AHU-4	Laboratory Supply	8	14
AHU-5	Vivarium Supply	11	18
AHU-6	Vivarium Supply	11	18
AHU-7	Laboratory Supply	8	14
AHU-8	Laboratory Supply	8	14
AHU-9	Laboratory Supply	8	14
AHU-10	Laboratory Supply	8	14
AHU-11	(Reserve)	8	-
AHU-12 (a&b)	Electrical Service Room	8	-
AHU-13	East Stair Htg./Clg.	8	-
AHU-14	West Stair Htg./Clg.	8	-
AHU-15	East Stair Htg./Clg.	8	-
AHU-16	West Stair Htg./Clg.	8	-
AHU-17 (a&b)	Basement Spot Cooling	8	-
AHU-18 (a-e)	Penthouse Spot Cooling	8	-

Table 3 – *Air Handling Unit Filter Schedule (Pre & Final)*

Section 5.10 – Dehumidification Systems

The maximum relative humidity throughout the building is 50% with the exception of the spaces with chilled beam applications. Though certain spaces throughout the design are to be neutral or negative with respect to one another, the net positive intake airflow reduces infiltration. Other fans throughout the building also aid in the building pressurization effort.

Section 5.11 – Drain Pans

All drain pans are specified to have a minimum slope of 1/8 in. per foot from the horizontal. All outlets are located at the bottom of the pan with sufficient size to prevent overflow under any normal expected operating condition. All drain pans will include field installed seal traps ensured to clear the floor, assuming a 5 in. house-keeping pad. In ***Figure 6*** a typical AHU drain pan seal trap is shown and the unit base height is specified as 8", exceeding the requirement.

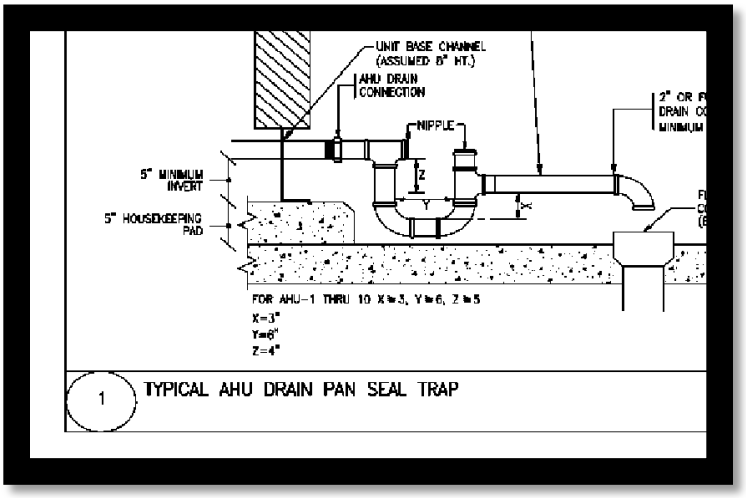

Figure 6 *– Drain Pan Seal Trap*

Section 5.12 – Finned-Tube Coils and Heat Exchangers

The spacing between individual finned-tube coils meets the required minimum access space of 18" as mentioned above. Drain pans are provided beneath each dehumidifying coil assemblies and all condensate-producing heat exchangers.

Section 5.13 – Humidifiers and Water Spray Systems

Humidification is done with low pressure (10psig) steam from softened city water. The ducted humidification on the penthouse level provides ample absorption distance as recommended by the humidifier manufacturer.

Section 5.14 – Access for Inspection, Cleaning, and Maintenance

Access to all mechanical equipment is sufficient providing unobstructed access to inspect. The factory built up air handling units specify access doors sized at a minimum of 12" x 12". The modular indoor air handling units specify access between adjacent coils in series to be sized at a minimum of 20 inches.

Section 5.15 – Building Envelope and Interior Spaces

The building envelope construction includes proper vapor barrier to avoid liquid water penetration into the building. Interior surfaces such as pipes, ducts and relevant equipment are all specified to be insulated, preventing condensation when surface temperatures could drop below the dew-point of the surrounding space conditions.

ASHRAE Standard 62.1-2007 Compliance Analysis

Section 6: Procedures

For the Purpose of these calculations, Factory Built-Up Air Handling Units 1-4 were selected for analysis. These four units are the same size as AHU 7-10 and serve similar spaces; therefore the analysis will give results that are pertinent to the central air distribution system.

Section 6.2 – Ventilation Rate Procedure

The outdoor air at the site is compliant with Section 4.1 – Regional Air Quality and therefore the outdoor airflow required in the breathing zone can be calculated with Equation 6-1.

$$V_{bz} = R_p \times P_z + R_a \times A_z \quad \textbf{(6-1)}$$

A_z = zone floor area: the net occupiable floor area of the zone (ft^2)

P_z = zone population: the largest number of people expected to occupy the zone during typical usage.

R_p = outdoor airflow rate required per person as determined from Table 6-1 (cfm/person)

R_a = outdoor airflow rate required per unit area as determined from Table 6-1 (cfm/ft^2)

Zone Air Distribution Effectiveness (E_z)

The spaces served by AHU 1-4 fit into the category of "ceiling supply of cool air" defined in Table 6-2 Zone Air Distribution Effectiveness. Therefore, for the purpose of these calculations,

$$E_z = 1$$

Zone Outdoor Airflow (V_{oz})

The zone outdoor airflow is calculated using Equation 6-2 from the ASHRAE Standard which is shown below.

$$V_{oz} = V_{bz}/E_z \quad \textbf{(6-2)}$$

With $E_z = 1$ Equation 6-2 is reduced to:

$$V_{oz} = V_{bz}$$

Primary Outdoor Air Fraction

$$Z_p = V_{oz}/V_{pz} \quad \textbf{(6-5)}$$

Uncorrected Outdoor Air Intake

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

$$\text{Where: } D = P_s/\sum_{\text{all zones}} P_z \quad \textbf{(6-7)}$$

Outdoor Air Intake

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

Level 2 was chosen to display a sample of the calculations performed for the spaces using the formulas shown on page 10. The buildings air supply is 100% outdoor air so therefore, the ventilation rate for all spaces is met due to the nature of the system. The West Shaft serves the West Zones of the building. For organizational purposes, the zone is displayed in NW and SW sections on Level 2.

Level 2 NW Zone - Ventilation Rate vs. Design							
Room #	Space Name	A_z	R_a	P_z	R_p	$V_{bz}=V_{oz}$	CFM (Designed)
281D	Electron Micro	134	0.06	17	5	93.04	450
279	Sorting	934	0.18	17	10	338.12	2520
						0	2520
279A	Chiller Storage	83	0.06	0	0	4.98	
286	Lab Support	233	0.18	17	10	211.94	750
284	Lab Support	237	0.18	17	10	212.66	750
287	Eng- Wittrup	530	0.06	25	10	281.8	1450
285	Tissue Culture	255	0.18	17	10	215.9	500
281B	Delta Vision	154	0.06	17	5	94.24	475
281A	Delta Vision	128	0.06	17	5	92.68	400
280F	Spinning Disk Confocal	140	0.18	17	10	195.2	475
281C	Microscopy Office	104	0.06	17	5	91.24	150
281	Biomicroscopy Dry Prep/ Equip Space	64	0.06	17	5	88.84	375
280D	Spinning Disk Confocal	148	0.06	17	5	93.88	475
280	Biomicroscopy Wet Prep/ Equip Space	295	0.06	17	5	102.7	1000
281G	2 Photon Microscope	133	0.06	17	5	92.98	450
281F	Chiller	61	0.06	0	10	3.66	200
200CB	Corridor	776	0.06	0	0	46.56	675
200CBA	Corridor	590	0.06	0	0	35.4	675
280A	Laser Capture	94	0.06	17	5	90.64	325
280B	Flourescence Microscopes	197	0.18	17	5	120.46	650
273B	Office	101	0.06	17	5	91.06	150
280C	Drying & Vacuum	88	0.18	17	10	185.84	300
273A	BL2 + Sorting	252	0.06	17	5	100.12	1100
273	Analyzers	775	0.18	25	10	389.5	3150
251	Tea	430	0.06	100	5	525.8	600
251A	Pantry	204	0.12		5	24.48	275
253G	PI Office	209	0.06	17	5	97.54	275
253	Reception	492	0.06	30	5	179.52	400
253F	PI Office	200	0.06	17	5	97	275
253D	PI Office	198	0.06	17	5	96.88	275
255	Men	225	-	-	-	-	300
257	Women	221	0	-	-	-	300
259	Large Meeting	708	0.06	25	10	292.48	840
268	Chem Waste	146	0.12	5	10	67.52	200
270	Waste	238	0.06	17	0	14.28	225
270E	Elec	182	0.06	5	10	60.92	225
270T	TDCR	169	0.06	5	5	35.14	150
270J	Janitor	75	0.12	5	0	9	100
269	Vestibule	197	0.06	11	5	66.82	275
269A	Vestibule	86	0.06	11	5	60.16	125
Connected Total							24,805

Table 4 *– Level 2 Northwest Ventilation Rate Sample Calculations*

Level 2 SW Zone - Ventilation Rate vs. Design							
Room #	Space Name	A_z	R_a	P_z	R_p	$V_{bz}=V_{oz}$	Total Max (Designed)
289	Write-Up	516	0.06	17	10	200.96	1000
200CBA	Corridor	590	-	-	-	-	675
200CBB	Corridor	719	-	-	-	-	
291	Eng-Wittrup	1399	0.06	17	10	253.94	1755
						0	1170
288	Microscope	50	0.06	5	5	28	175
292	Autoclave	169	0.06	5	5	35.14	800
243	CCR-Chen	1132	0.18	17	5	288.76	575
						0	550
258	Small Meeting	234	0.06	17	5	99.04	300
200LA	Lobby	1444	0.06	11	5	141.64	1000
261	Reception	874	0.06	7	5	87.44	550
261D	PI Office	197	0.06	17	5	96.82	150
261C	PI Office	197	0.06	17	5	96.82	150
261B	PI Office	197	0.06	17	5	96.82	150
261A	PI Office	197	0.06	17	5	96.82	150
261F	Fellow	91	0.06	17	5	90.46	125
261G	Copy Storage	83	0.06	17	5	89.98	100
Connected Total							**9,375**

Table 5 *– Level 2 Southwest Ventilation Rate Sample Calculations*

These calculations result in some numbers that do not completely demonstrate the system accurately. A number of these spaces are designed to meet air change rates because it is a lab and research building. Also, all air that is being supplied to the spaces is 100% outdoor air, and contaminated air is being exhausted. Therefore, the indoor air quality requirements of ASHRAE Standard 62.1 are met throughout the building without an issue.

62.1 Conclusions

The analysis of the designs compliance to ASHRAE Standard 62.1 was an overall success. The Standard is meant to ensure proper ventilation rates and acceptable indoor air quality. In this report, Sections 5 and 6 of the ASHRAE Standard made up the bulk of the analysis.

Section 5 ensures that the systems and equipment are properly designed and located to achieve an acceptable indoor air quality. No areas of this section were found to be inadequate according to the requirements set forth by the ASHRAE Standard. In fact, many areas of the design went above and beyond, aiding in the goal of achieving LEED Gold Certification.

ASHRAE Standard 90.1-2007 Energy Design Evaluations Compliance Analysis

The following section is an analysis of the compliance of the Koch Institute Design with the guidelines set forth by ASHRAE Standard 90.1-2007. The buildings envelope, HVAC systems, service water heating, power, lighting and electric motor efficiency will all be looked at in detail to check for compliance with the Standard.

Section 5: Building Envelope

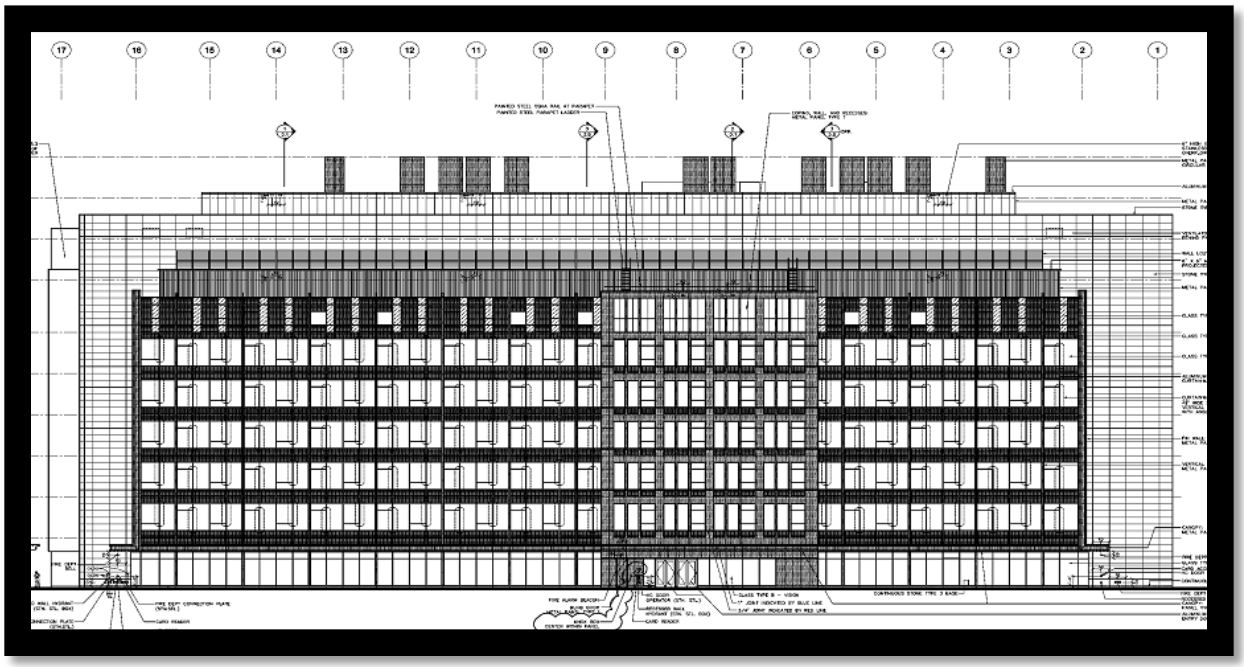

Figure 7 – *Exterior Elevation North*

Section 5.1.4 - Climate

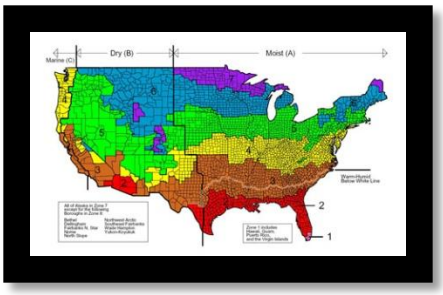

Figure 8 – *ASHRAE Climate Zone Map*

The Koch Institute is located in Cambridge, Ma which is located in Zone 5 on the ASHRAE Climate Zone 5 which is depicted in green in the ***Figure 8*** to the left. The Building Envelope Requirements are checked against the Table 5.5-5 in ASHRAE Standard 90.1 which lists numerous requirements based on roof, walls (above and below grade), floors, slab-on-grade, opaque doors, and different fenestration arrangements.

Section 5.5 – Prescriptive Building Envelope Option

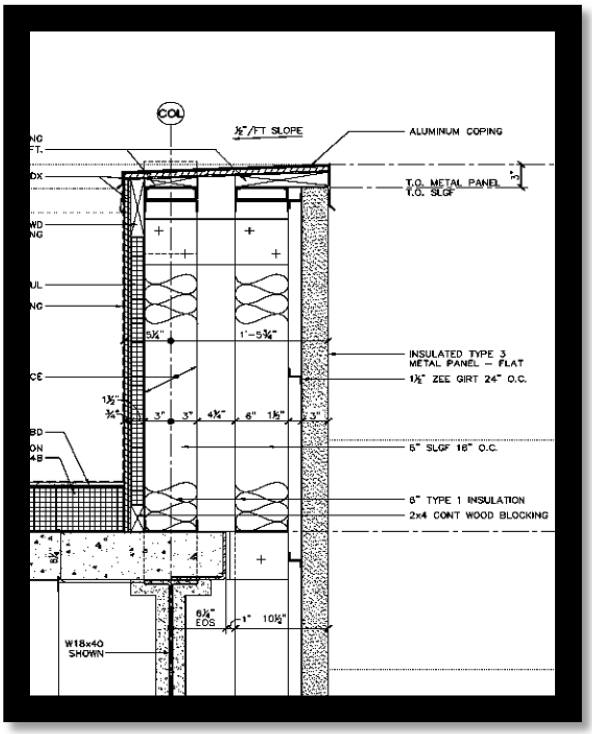

Figure 9 – *Exterior Wall Section (metal paneling)*

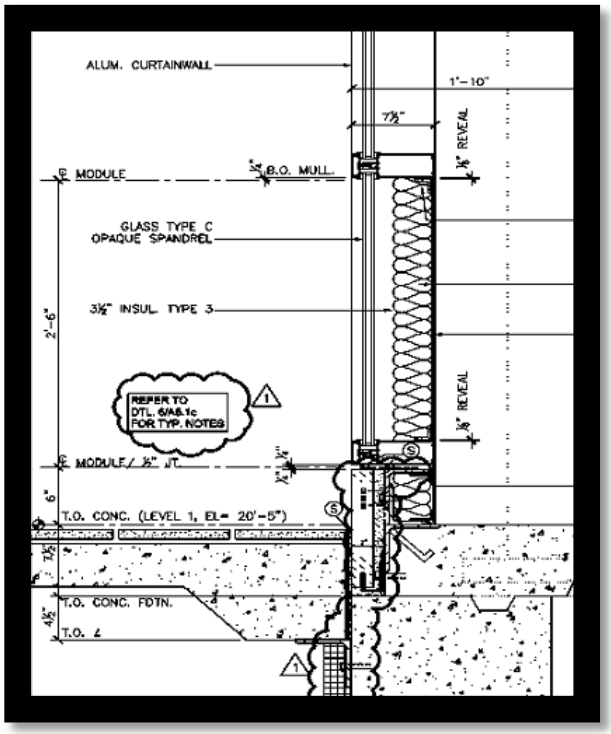

Figure 10 – *Exterior Wall Section (curtain wall)*

The Koch Institute is a non-residential building that was analyzed under the Prescriptive Option of the Standard. The requirements of the building envelope were checked for compliance against Table 5.5-5 Building Envelope Requirements for Climate Zones 5 (A,B,C)

Fenestration Area				
Level	Glass Area (ft^2)	Gross Wall Area (ft^2)	% Glass	Compliant
1st	3,567.73	13,260.00	0.27	YES
2nd	4,022.47	9,855.00	0.41	NO
3rd	4,022.47	9,855.00	0.41	NO
4th	4,022.47	9,855.00	0.41	NO
5th	4,022.47	9,855.00	0.41	NO
6th	4,022.47	9,855.00	0.41	NO
7th	2,358.75	8,295.00	0.28	YES
Total	26,038.82	70,830.00	0.37	YES

Table 6 – *Fenestration Area Compliance Table*

It is stated in Standard 90.1 that the fenestration area shall not exceed 40% of the gross wall area. ***Table-6*** above shows that the design complies with this requirement. It was checked against individual floor areas, and though this is no the requirement, it is only off by 1% in floors 2-6.

Building Envelope Requirements for Climate Zone 5					
	Required		Designed		
Opaque Elements	Assembly Max U-Value	Insulation Min R-Value	Assembly Max U-Value	Insulation Min R-Value	Compliant
Mass	U-.090	R-10.4 c.i.	U-0.091	R-11	YES

Table 7 – *Building Envelope (Opaque Element) Requirements Compliance Table*

For the ASHRAE Climate Zone 5, the requirements for the envelope opaque element assembly are shown above in ***Table-7.*** It is also clear in ***Table-7*** that the design values are within the required range set forth by Standard 90.1.

Building Envelope Requirements for Climate Zone 5					
	Required		Designed		
Fenestration	Assembly Max U-Value	Assembly Max SHGC	Assembly Max U-Value	Assembly Max SHGC	Compliant
Metal Framing	U-0.45	SHGC-0.40	U-0.37	SHGC-0.40	YES

Table 8 – *Building Envelope (Fenestration) Requirements Compliance Table*

For the ASHRAE Climate Zone 5, the requirements for the envelope fenestration assembly are shown above in ***Table-8.*** It is also clear in ***Table-8*** that the design values are within the required range set forth by Standard 90.1.

The Koch Institute's envelope design complies with all of the requirements in this section. The fenestration area ***Table 6*** shows that each floor's fenestration area is only over the prescribed 40% of gross wall area. But as an overall façade the requirement is met by 3%, which is the actual requirement. In ***Appendix B***, at the conclusion of this report, there are more detailed calculations of wall and fenestration area. It is possible that this 1% area could be a result of a miscalculation in those tables.

Table 7 and Table 8 of this section show us that the Koch Institute's envelope also complies with ASHRAE requirements for Climate Zone 5. Therefore, the building is compliant with Section 5 of ASHRAE Standard 90.1 – Energy Design Evaluation.

Section 6: Heating, Ventilation, and Air Conditioning

Section 6.2 – Compliance Paths

For this analysis, ASHRAE provides two different compliance paths for which to compare your design. There is a Simplified Approach given in Section 6.3 and there is a Mandatory Provisions Approach given in Section 6.4. The simplified approach has a limitation of 25,000 ft^2 gross floor area that exceeded by the Koch Institute's 360,000 ft^2 gross floor area. Therefore, this compliance analysis will follow the Mandatory Provisions Approach laid out in Section 6.4.

Section 6.4 – Mandatory Provisions

With the project still under construction, verification of equipment efficiencies and labeling of all mechanical equipment cannot yet be analyzed.

The design does specify that each zone shall be individually controlled by thermostatic controls responding to temperature sensors within each space. The perimeter radiation heating system handling the increase building envelope loads is coupled with the air systems to reach the desired space conditions.

All equipment that handles more than 10,000 CFM is operated with optimum start controls, ensuring that energy consumption is minimized and that space conditions are met.

Section 6.5 – Preventative Path

The Koch Institute uses a combination Variable Air Volume and Constant Air Volume system to maximize zone control while still meeting pressurization requirements for specialty rooms. Therefore, when checking the fans against ASHRAES Fan Power Limitation in Table 6.5.3.1.1A, Constant volume was assumed. To calculate the Allowable Horsepower was calculated as follows:

$$\text{Allowable HP} = \text{CFM} * 0.0011$$

The fan is then compliant if the Allowable HP > Nameplate HP and is given a "YES" or "NO" in the Compliant column. This process was performed for AHU, EAHU, Exhaust, Supply and Return Fans and results are given in the Tables on the following pages.

AHU Fan Compliance				
Unit	hp	CFM	Allowable Horsepower	Compliant
AHU-1	81	50000.00	55.00	NO
AHU-2	81	50000.00	55.00	NO
AHU-3	81	50000.00	55.00	NO
AHU-4	81	50000.00	55.00	NO
AHU-5	81	50000.00	55.00	NO
AHU-6	81	50000.00	55.00	NO
AHU-7	81	50000.00	55.00	NO
AHU-8	81	50000.00	55.00	NO
AHU-9	81	50000.00	55.00	NO
AHU-10	81	50000.00	55.00	NO
EAHU-1	55	50000.00	55.00	YES
EAHU-2	55	50000.00	55.00	YES
EAHU-3	55	50000.00	55.00	YES
EAHU-4	55	50000.00	55.00	YES
EAHU-5	55	50000.00	55.00	YES
EAHU-6	55	50000.00	55.00	YES
EAHU-7	55	50000.00	55.00	YES
EAHU-8	55	50000.00	55.00	YES
EAHU-9	55	50000.00	55.00	YES
EAHU-10	55	50000.00	55.00	YES
AHU-11	-	-	-	-
AHU-12 (a&b	5	9000.00	13.50	YES
AHU-13	3	3600.00	5.40	YES
AHU-14	2.5	3600.00	5.40	YES
AHU-15	2.5	3600.00	5.40	YES
AHU-16	2.5	3600.00	5.40	YES
AHU-17 (a&b	3.2	6000.00	9.00	YES
AHU-18 (a-e)	3.2	6000.00	9.00	YES

Table 9 – *AHU Fan Compliance Table*

Exhaust Fan Compliance Check				
Fan Tag	hp	cfm	Allowable Horsepower	Compliant
EX-1	20.00	20000	22.00	YES
EX-2	7.50	8000	8.80	YES
EX-3	5.00	3900	4.29	NO
EX-4	-	-	-	-
EX-5	3.00	1500	1.65	NO
EX-6	-	-	-	-
EX-7	3.00	1800	1.98	NO
EX-8	3.00	1800	1.98	NO
EX-9	1.00	675	0.74	NO
EX-10	3.00	1800	1.98	NO
EX-11	7.50	6000	6.60	NO
EX-12	5.00	2400	2.64	NO
EX-13	1.50	800	0.88	NO
EX-14	1.00	475	0.52	NO
EX-15	0.33	200	0.22	NO
EX-16	0.33	1000	1.10	YES
EX-17	0.75	3000	3.30	YES
EX-18	0.25	300	0.33	YES

Table 10 – *Exhaust Fan Compliance Table*

Supply Fan Compliance Check				
Fan Tag	hp	cfm	Allowable Horsepower	Compliant
SF-1	15.00	20000	22	YES
SF-2	15.00	18000	19.8	YES
SF-3	15.00	12000	13.2	NO
SF-4	15.00	12000	13.2	NO
SF-5	7.50	4100	4.51	NO
SF-6	10.00	12000	13.2	YES

Table 11 – *Supply Fan Compliance Table*

Return Fan Compliance Check				
Fan Tag	hp	cfm	Allowable Horsepower	Compliant
RF-1	15.00	15000	16.5	YES
RF-2	15.00	15000	16.5	YES

Table 12 – *Return Fan Compliance Table*

Though many of the fans shown in tables above are non-compliant based on the formula, many of them fall into the exception listed in Section 6.5.3.1.2 a. This states that fans less than 6 bhp, where the first available motor larger than the break horsepower has a nameplate rating of within 50% of the bph, the next larger nameplate motor size may be selected. Also, by assuming a constant of 0.0011, the fan compliance was held to a Constant Volume Specification though some may be VAV.

The Exhaust Air Energy Recovery System utilized in the factory built-up AHU and EAHU systems meets the requirements of having 70% or more outdoor air supply have at least 50% recovery effectiveness. The total enthalpy heat wheel recovers 75% of the energy difference to pre-heat and pre-cool the outdoor air stream.

Section 6.7 – Submittals

The Koch Institute is designed to achieve a LEED Gold Certification and therefore submittal of all proper documentation is strictly enforced. The system balancing and system commissioning is to be performed for LEED credits as specified.

Section 7: Service Water Heating

The heating source for the building is steam all year round which is provided from the MIT central energy plant through existing campus underground piping. The campus steam service is designed to be extended from a pre-existing tap at the SE corner of the adjacent State Center.

Section 9: Lighting

The lighting levels in the Koch Institute were designed to conform to the Illuminating Engineering Society's recommended values. Therefore the space breakdown of average lighting levels goes as follows:

- Laboratories: 70 to 80 FC
- Laboratory support: 50 to 60 FC
- Offices: 50 to 60 FC
- Corridors: 20 to 30 FC
- Conference Rooms: 40 to 50 FC
- Toilets: 20 to 30 FC
- Lobbies and Foyers: 20 to 30 FC
- Animal Holding Rooms (Day/Night Cycle): 30 to 35 FC
- Animal Holding Rooms (Working): 60 to 70 FC

The Building Area Method was utilized in this case to analyze the power density of the multiple electrical loads throughout the building. ***Table 13*** and ***Table 14*** provide summaries of the building load and power density as calculated.

BUILDING LOAD SUMMARY			
Service	Load (kVA)		
	Connected	Distribution	Service
Lighting	399	359	323
Elevators	160	144	130
Mechanical	2212	1801	1441
Plumbing	246	214	171
Fire Protection	130	127	101
Environmental Rooms	524	341	341
Research Loads	1840	920	869
Total	**5510**	**3905**	**3376**

Table 13 *– Building Load Summary Table*

BUILDING DENSITY SUMMARY			
Area	SF	Load (kVA)	VA/SF
Lighting	369099	323	0.9
Elevators	369099	130	0.4
Mechanical	369099	1441	3.9
Plumbing	369099	171	0.5
Fire Protection	369099	101	0.3
Environmental Rooms	369099	341	0.9
Research Loads	369099	869	2.4
Total Building	**369099**	**3376**	**9.1**

Table 14 *– Building Density Summary Table*

CONCLUSIONS

The calculations and statements made throughout this analysis most strongly point out the David Koch Institute's success in complying with the ASHRAE Standard 90.1. The design is very energy conscious as well as sophisticated, making this analysis difficult and tedious. It is possible that throughout the analysis something was overlooked or incorrectly assumed. It is also possible that some of these areas of non-compliance have been resolved seeing that the job is still under construction.

That being said there were a number of non-compliant areas. The largest area of non-compliance can be seen in the Fan Power Compliance Section. But, of the 24 failed fans, 10 fall into the exception described in **Section 6.5** and can therefore be considered acceptable.

In conclusion, none of the fore mentioned discrepancies are exceedingly alarming and could be easily re-worked to fully comply with ASHRAE Standard 90.1 – 2007 Energy Design Evaluations.

APPENDIX A

List of Tables and Figures

List of Figures

List of Tables

APPENDIX B

Supplemental Tables

BASEMENT LEVEL - NW ZONE		
Room #	Space Name	CFM
053E	Electrical	450
000CG	Corridor	550
000LA	Lobby	375
063A	Mens Lockers	350
063	Men	375
062J	Janitor Closet	25
061	Women	375
061A	Womens Lockers	350
054	Hot Lab	375
065	Admin Files	150
074	Research Storage	150
078	Research Storage	275
000SC	West Stair	
000CB	Corridor	900
058	Autoclave	
069	Vestibule	600
052	Custodial Team Room	250
056	Break	200
082	Glass Washing	2,310
		390
		1,200
073	Media Prep	425
073A	Media Prep	375
068	Material Handling	
068D	Maintenance Storage	600
068C	E/U Waste	600
068G	Custom Storage	600
068H	Share Wast	
068B	Chem DGM	100
068K	Hot Waste	
097A	Fuel Storage Vault	200
097B	Eject/Sprinkler	150
Connected Total*		**12,700**

LEVEL 1 - NW ZONE		
Room #	Space Name	CFM
181	Gallery	1,450
		1,450
100CB	Corridor	1,365
180	Pathology Consult	100
182A	Office	100
181B	BP Office	100
154	Lactation	200
151	Fire Command	75
157	Women	350
155	Men	350
-		75
182	Histology	750
		750
		725
184	Office	100
186	IT Work Room	100
188B	Office	100
188	Microarray	2,550
		0
169E	Electric	
153T	TDCR	
169	Vestibule	400
169J	Janitor	
169CJ	Janitor	
169C	Servery ORY Storage	175
Connected Total		**11,265**

LEVEL 1 - SW ZONE		
Room #	Space Name	CFM
181A	Prep/Equip	750
		725
185	Proteomics	800
		1,550
189B	BI Office	375
189A	BI Office	150
189D	Proteomics Office	150
189C	BI Office	150
189	Office	300
185A	Data Analysis	275
190	Chem Waiste	575
195C	Equipment	
191	Shared Equipment	
100CBC	Service Vestibule	100
195	Vestibule	350
100CBB	Corridor	400
195B	ES Cell	1,550
195A	Office	200
168	Labs Break	200
166	HQ Reading Room	200
Connected Total		**8,800**

LEVEL 2 - NW ZONE		
Room #	Space Name	CFM
281D	Electron Micro	450
279	Sorting	2520
		2520
279A	Chiller Storage	
286	Lab Support	750
284	Lab Support	750
287	Eng- Wittrup	1450
285	Tissue Culture	500
281B	Delta Vision	475
281A	Delta Vision	400
280F	Spinning Disk Confocal	475
281C	Microscopy Office	150
281	Biomicroscopy Dry Prep/ Equip Space	375
280D	Spinning Disk Confocal	475
280	Biomicroscopy Wet Prep/ Equip Space	1000
281G	2 Photon Microscope	450
281F	Chiller	200
200CB	Corridor	
200CBA	Corridor	675
280A	Laser Capture	325
280B	lourescence Microscope	650
273B	Office	150
280C	Drying & Vacuum	300
273A	BL2 + Sorting	1100
273	Analyzers	3150
251	Tea	600
251A	Pantry	275
253G	PI Office	275
253	Reception	400
253F	PI Office	275
253D	PI Office	275
255	Men	300
257	Women	300
259	Large Meeting	840
268	Chem Waste	
270	Waste	225
270E	Elec	
270T	TDCR	
270J	Janitor	
269	Vestibule	275
269A	Vestibule	125
Connected Total		23,455

LEVEL 2 - SW ZONE		
Room #	Space Name	CFM
289	Write-Up	1000
200CBA	Corridor	675
200CBB	Corridor	
291	Eng-Wittrup	1755
		1170
288	Microscope	175
292	Autoclave	800
243	CCR-Chen	575
		550
258	Small Meeting	300
200LA	Lobby	1000
261	Reception	550
261D	PI Office	150
261C	PI Office	150
261B	PI Office	150
261A	PI Office	150
261F	Fellow	125
261G	Copy Storage	100
Connected Total		9,375

LEVEL 3 - NW ZONE		
Room #	Space Name	CFM
379	Write Up	750
378	LS	525
380	Dewer Storage	
381		
387	ENG- Fellows	1,450
		2,175
384	Tissue Culture	1,900
382	Microscope	325
375	ENG- White	2,175
300CBA	Corridor	700
300CBA	Corridor	
374	Equipment	
372	LS	500
371	ENG-White	1,575
355	Men	300
357	Women	300
368	Copy	200
359	Large Meeting	840
370	Waste	225
370J	Janitor	
370A	Chem Waste	
370E	Electric	
370T	TDCR	
388	Equipment	
369	Vestibule	275
367A	Vestibule	125
351	Tea	600
351A	Pantry	275
353G	PI Office	275
353	Reception	400
353F	PI Office	275
353C	Copy Storage	
353D	PI Office	275
Connected Total		**16,440**

LEVEL 3 - SW ZONE		
Room #	Space Name	CFM
389	Write Up	1,050
300CBA	Corridor	725
300CBB	Corridor	
391	Eng - TBD	1,755
		1,170
392	Autoclave	800
361G	Copy Storage	100
361F	Fellow	125
361D	PI Office	150
361C	PI Office	150
361B	PI Office	150
361A	PI Office	150
361	Reception	550
300LA	Lobby	1,000
358	Small Meeting	300
343	CCR-Hynes	550
		575
340	Lab Support	850
Connected Total		**10,150**

LEVEL 4 - NW ZONE		
Room #	Space Name	CFM
487	ENG- Sasisekharan	1,450
		2,175
484	Tissue Culture	1,800
		800
481	Microscope	700
480	Lab Support	525
479	ENG - BHATIA	1,450
473	ENG - BHATIA	1,250
		1,250
		1,250
400CB	Corridor	
400CBA	Corridor	800
472	Lab Support	500
453D	PI Office	275
453F	PI Office	275
453C	Copy Storage	
453	Reception	400
453G	PI Office	275
451	Tea	600
451A	Pantry	275
455	Men	300
457	Women	300
468	Copy	200
459	Large Meeting	840
470	Waste	225
470A	Chem Waste	
470E	Electric	
470J	Janitor	
470T	TDCR	
474	Equipment	
469	Vestibule	275
469A	Vestibule	125
Connected Total		**18,315**

LEVEL 4 - SW ZONE		
Room #	Space Name	CFM
400CBA	Corridor	775
400CBB	Corridor	
489	Write Up	1,050
492	Autoclave	800
488	Equipment	
491	ENG - Sasisekharan	1,170
		1,755
461F	Fellow	125
461G	Copy Storage	100
461D	Shared Fellow	150
461C	PI Office	150
461B	PI Office	150
461A	PI Office	150
461	Reception	550
400LA	Lobby	1,000
458	Small Meeting	300
443	CCR - Lees/Hopkins	1,100
446	Equipment	
442	Lab Support	450
Connected Total		**9,775**

LEVEL 5 - NW ZONE		
Room #	Space Name	CFM
579	Write Up	1,050
578	Support Room	500
580	Dewer Storage	
587	ENG- Hammond	1,450
		2,175
586	Bacterial Room	500
584	Tissue Culture	850
582	Shared Optical Microscope	325
581	AFM Microscope	525
500CBA	Corridor	1,050
500CB	Corridor	
573	ENG- Hammond	1,250
		1,250
		625
		725
574	Equipment	
572	LS	500
555	Men	300
557	Women	300
568	Copy	200
559	Large Meetings	840
570	Waste	225
570J	Janitor	
570T	TDCR	
570E	Electrical	
570A	Chem Waste	
569	Vestibule	275
569A	Vestibule	125
551	Tea	600
551A	Pantry	275
553G	PI Office	275
553	Reception	400
553F	PI Office	275
553D	PI Office	275
Connected Total		**17,140**

LEVEL 5 - SW ZONE		
Room #	Space Name	CFM
589	Write Up	1,000
500CBA	Corridor	1,025
500CBB	Corridor	
591	ENG - Belcher	1,755
		1,170
590	Equipment	
588	Laser Room	
592	Autoclave	800
546	Lab Support	425
		400
543	CCR - Amon	1,450
558	Small Meeting	300
500LA	Lobby	1,000
561	Reception	550
561A	PI Office	150
561B	PI Office	150
561C	PI Office	150
561D	Shared Fellow	150
561G	Copy Storage	100
561F	Fellow	125
Connected Total		**10,700**

LEVEL 6 - NW ZONE		
Room #	Space Name	CFM
679	Write Up	750
678	LS	525
673	ENG - Cima	1,875
		1,875
680	Dewer Storage	0
681	LS	525
676	LS	350
682	Microscope	325
684	Tissue Culture	1,900
687	ENG - TBA 2	2,610
		1,740
600CBA	Corridor	1,275
		1,250
600CB	Corridor	0
674	Equipment	0
672	LS	750
670	Waste	125
670J	Janitor	0
670T	TDCR	0
670E	Electrical	0
669	Vestibule	400
668	Chem Waste	125
655	Men	300
657	Women	300
659	Large Meeting	840
653C	Copy Storage	0
653D	Langer Lang PI EQ	275
653F	ENG PI	275
653G	ENG PI	275
653	Reception	400
651	Tea	600
651A	Pantry	275
632A	Write Up	300
Connected Total		**20,240**

LEVEL 6 - SW ZONE		
Room #	Space Name	CFM
687A	Write Up	500
694	Write Up	500
691	ENG - Langer - L1	525
		1,000
		525
692	Autoclave	800
688	Equipment	0
661H	Copy Files Storage	275
661G	Langer	150
661F	Langer PI Eq	150
661D	Langer PI Eq	150
661C	Langer PI Eq	150
661	Reception	550
661B	Langer Lab Manager	300
661A	Receiving	150
660	Private Meeting	350
600LA	Lobby	1,000
600CBB	Corridor	
658	Small Meeting	300
646	Write Up	275
644	Write Up	250
Connected Total		**7,900**

Fenestration Area - Floor 1				
Room Name	Glass Area (ft²)	Glass U-Value	Net Wall Area (ft²)	Wall U-Value
West Gallery	763.75	0.37	1,336.26	0.091
East Gallery	891.86	0.37	1,788.14	0.091
Vestibule North				
Vestibule NorthEast				
Vestibule South				
Vestibule NorthWest				
Fire Command	75.00	0.37	205.00	0.091
HR	20.63	0.37	199.38	0.091
Cubicles 1	78.75	0.37	351.25	0.091
Cubicles 2	78.75	0.37	341.25	0.091
Cubicles 3	78.75	0.37	341.25	0.091
FO 1	39.38	0.37	155.63	0.091
FO 2	39.38	0.37	190.63	0.091
Director	52.50	0.37	507.50	0.091
Exec Director	65.63	0.37	234.38	0.091
Dev Director	39.38	0.37	190.63	0.091
Com Office	39.38	0.37	190.63	0.091
Food Service/Cafeteria	354.00	0.37	466.00	0.091
Interaction	108.00	0.37	102.00	0.091
HQ Reading Room	108.00	0.37	207.00	0.091
Core Lab Break Room	234.00	0.37	81.00	0.091
Office	26.25	0.37	178.75	0.091
ES Cell	78.75	0.37	351.25	0.091
Equipment	39.38	0.37	180.63	0.091
Service Vestibule	67.50	0.37	177.50	0.091
BI Office 3	20.63	0.37	194.38	0.091
BI Office 2	20.63	0.37	484.38	0.091
BI Office 1	41.25	0.37	173.75	0.091
Proteomics Office	41.25	0.37	168.75	0.091
Proteomics	123.75	0.37	506.25	0.091
Biopolymers	41.25	0.37	388.75	0.091
1st Floor Total	**3,567.73**		**9,692.27**	

Fenestration Area - Floors 2-6 Typical				
Room Name	Glass Area (ft^2)	Glass U-Value	Net Wall Area (ft^2)	Wall U-Value
CCR Lab 1 (North & West)	205.00	0.37	365.00	0.091
CCR Lab 2-4 (North)	541.66	0.37	403.34	0.091
CCR Lab 5-7 (South & West)	295.00	0.37	755.00	0.091
CCR Lab 8 (South & West)	219.38	0.37	560.63	0.091
CCR Lab 9-11 (West)	298.13	0.37	489.38	0.091
Bio Lab 1-2 (North)	355.83	0.37	274.17	0.091
Bio Lab 3 (North)	273.33	0.37	195.42	0.091
Bio Lab 4 (North)	278.33	0.37	197.92	0.091
Bio Lab 5-6 (North & East)	390.83	0.37	539.17	0.091
Bio Lab 7-8 (South)	266.87	0.37	363.13	0.091
Bio Lab 9-10 (South & East)	246.25	0.37	473.75	0.091
Bio Lab 11-12 (South & SouthEast)	343.75	0.37	773.75	0.091
Bio Lab 13-14 (NorthEast & SouthEast)	308.12	0.37	441.88	0.091
Floors 2-6 Totals	**4,022.47**		**5,832.53**	

Fenestration Area - Floor 7				
Room Name	Glass Area (ft^2)	Glass U-Value	Net Wall Area (ft^2)	Wall U-Value
Animal Holding Room 1 (North & West)	195.00	0.37	685.00	0.091
Animal Holding Room 2 (North)	150.00	0.37	330.00	0.091
Animal Holding Room 3 (North)	198.75	0.37	281.25	0.091
Animal Holding Room 4 (North & East)	247.50	0.37	812.50	0.091
AHR/Procedure 1 (North)	161.25	0.37	318.75	0.091
AHR/Procedure 2 (North)	161.25	0.37	398.75	0.091
AHR/Procedure 3 (North)	146.25	0.37	333.75	0.091
AHR/Procedure 4 (North)	161.25	0.37	318.75	0.091
AHR/Procedure 5 (North)	161.25	0.37	318.75	0.091
AHR/Procedure 6 (North)	161.25	0.37	318.75	0.091
Break Room (South & West)	125.63	0.37	414.38	0.091
Vet Tech Office 1 (South)	67.50	0.37	157.50	0.091
Vet Tech Office 2 (South)	67.50	0.37	127.50	0.091
Veterinarian Office (South & East)	125.63	0.37	414.38	0.091
Janitor 1 (North)	48.75	0.37	106.25	0.091
Janitor 2 (North)	48.75	0.37	106.25	0.091
Janitor 3 (North)	45.00	0.37	110.00	0.091
Storage 1 (North & East)	43.13	0.37	191.88	0.091
Storage 2 (North & West)	43.13	0.37	191.88	0.091
7th Floor Total	**2,358.75**		**5,936.25**	