Mechanical Technical Report Two
Building and Plant Energy Analysis

HITT Contracting Headquarters
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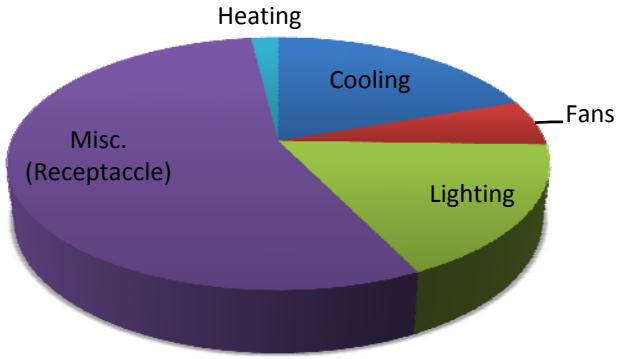
Executive Summary

Energy consumption in buildings has become an increasingly relevant topic in recent times as a trend towards sustainability grows in the United States and around the world. Energy models can be used to benchmark the energy usage of buildings and provide a basis for economic comparisons of systems. This report uses an energy model created in Trane Trace 700 that analyzes building design loads, energy usage and annual energy costs for HITT Contracting Headquarters. All load sources, including Room dimensions, wall areas, wall assemblies, lighting power densities, ventilation rates, occupancy densities, window types, and mechanical equipment details, were all taken from the mechanical design documents provided by the MEP design firm KTA Group.

The cooling loads modeled in the Trace 700 model, were within 10% of the capable cooling load of designed system. The total modeled cooling load was calculated to be 363 Tons, whereas the designed load was 420 Tons. This is a reasonable model, judging by the fact that the designer has to move up slightly in unit size to ensure operation at the desired load.

The total annual energy cost for HITT Contracting Headquarters was estimated by the model to be $340,748. HVAC systems consume a large piece of the total building energy at total of 27.4%. The HVAC design engineer also performed an energy model of their own on the building. The economic results of their model were close to those calculated in the model developed for this paper and had a total annual energy cost of $351,557. The cooling cost per square foot was also determined to be $0.50 per square foot for the model prepared for this paper and $0.57 per square foot for the model prepared by the HVAC engineer. The graph below depicts the breakdown of the total energy consumption between Heating, Cooling, Fan, Lighting, and Miscellaneous (Receptacle) loads for the model created for this report.

Modeled Building Energy Consumption



Design Load Estimation

HITT Contracting Headquarters was analyzed using an energy model created in Trane Trace 700. The energy model is used to estimate heating and cooling loads on the building, which in turn can be used to size equipment in these systems. Comparisons between the actual design loads and Trace 700 modeled loads can be found in the Calculated Loads section on Tables 4 & 5. Load sources considered in the energy model include: room dimensions, wall areas, wall assemblies, lighting loads, ventilation rates, occupancy densities, window types, and mechanical equipment details. This data was taken from the mechanical design documents provided by KTA Group. Load schedules for lights, occupancy, and miscellaneous loads are typical to a low-rise office building and are shown in Appendix B. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) prescribes outdoor design conditions to be used in HVAC system design. The outdoor air design conditions for winter and summer and load calculation assumptions are listed in the Tables 1 & 2 below. See Appendix A for further calculations involving miscellaneous loads. Rated equipment performances were taken from the design documents and are shown in Table 3.

Table 1 - ASHRAE Outdoor Air Conditions

Washington, DC	Temperature °F
Winter Dry Bulb	15
Summer Dry Bulb	95
Summer Wet Bulb	76

Table 2 - Load Calculation Assumptions

Load Type	Loads	
Lighting	1.1	Watts/SF
Misc. Loads	3.46	Watts/SF
People	250	Btu/Person Sensible
	250	Btu/Person Latent
Occupancy Density	114	SF/Person (Office)
	50	SF/Person (Conference)
	20	SF/Person (Fitness)
	50	SF/Person (Cafe)

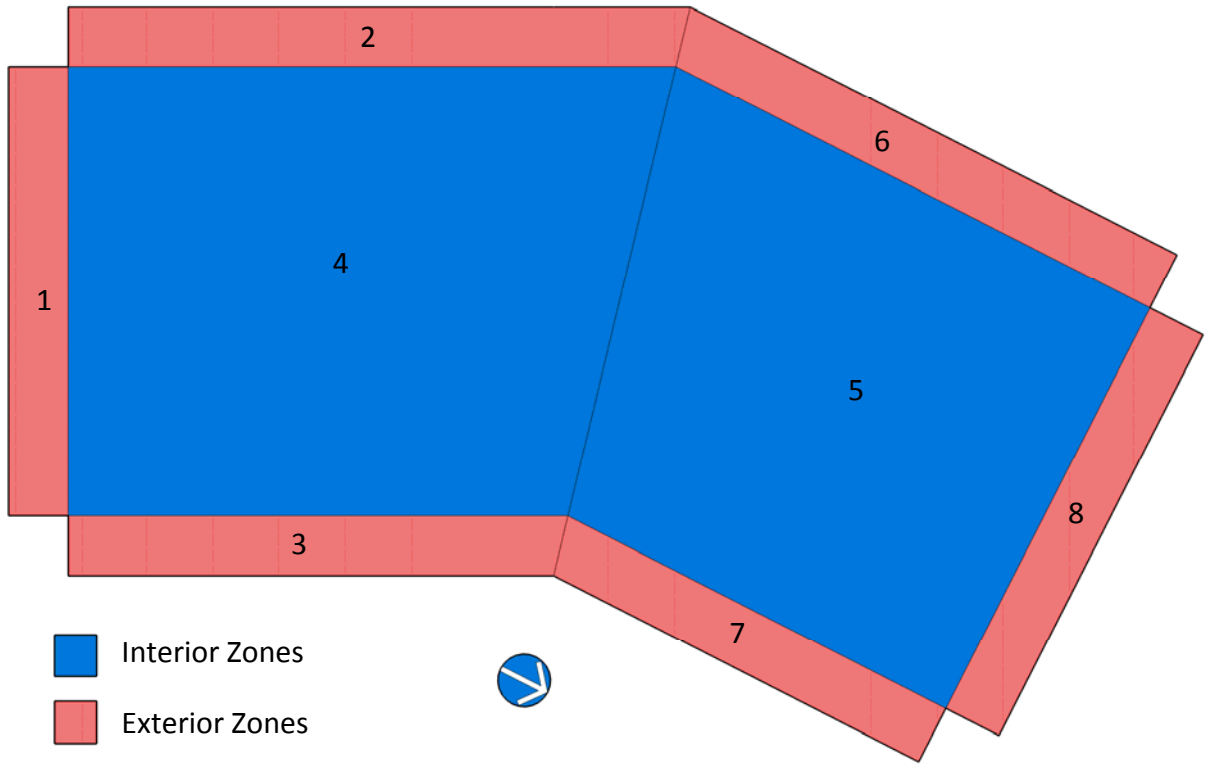
Table 3 – Rated Equipment Performance

Unit	Cooling EER	Heating Efficiency
All RTUs	11.1	100%
AC 3 & 4	12.5	100%
AC 2	12.5	100%

Energy Model Design

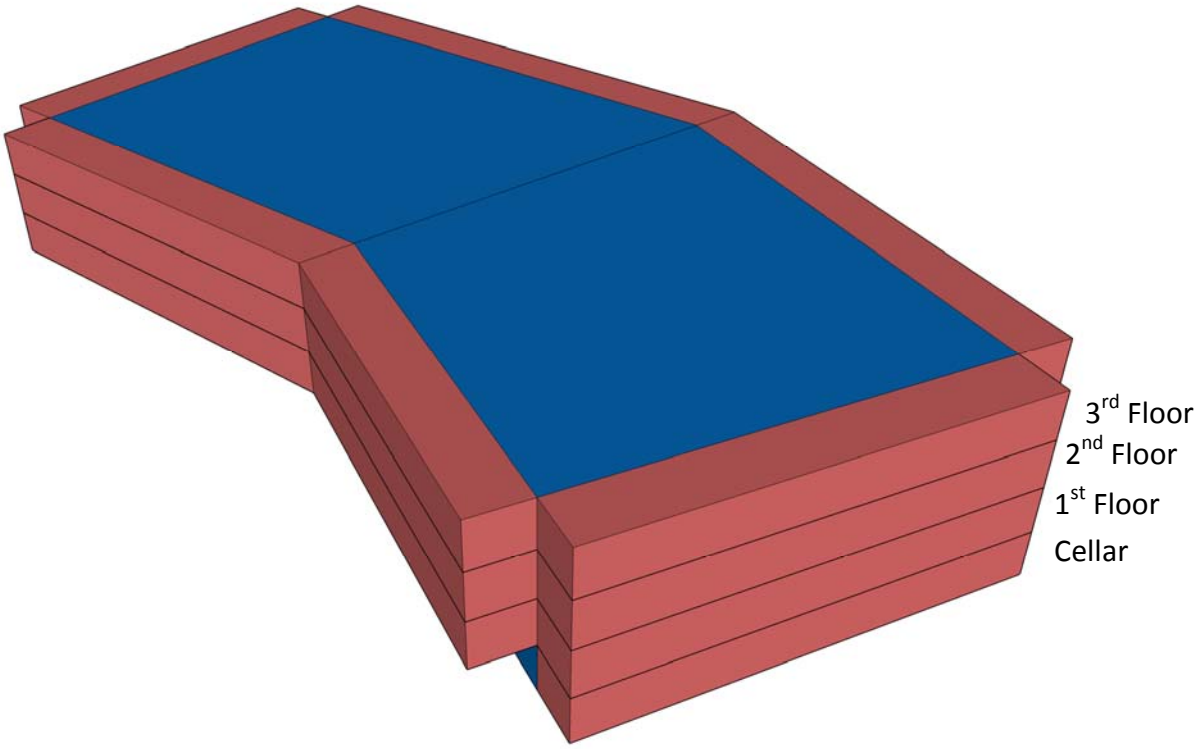
The block load model was formed in Trace 700 by dividing each floor into eight (8) separate zones determined by their direction of exposure, whether they were internal or external, and which system served them. The unique building layout provided extra exposures due to the angle at the center of the building. Since two (2) Rooftop units (RTUs) serve each floor, zones one through four on Figure 1 are served by one RTU and zones five through eight are served by another. See Figure 1 below for a schematic of zone layout. Each floor has slightly different exposures due to the design of the building. The first floor has an exterior floor exposure that covers the integrated parking area, along with the typical exterior wall exposures. The second floor is the most standard with no roof or floor exterior exposures, just the typical exterior wall exposures. The third floor has the roof exposure in addition to the typical wall exposures. Finally the cellar level has a mixture of exterior wall exposures with ground exposures including walls and a slab on grade. See Figure 2 on the next page for view of the zone divisions for each floor. See Appendix C for examples of inputs into Trane Trace 700.

Figure 1 - Zone Layout Schematic, Floors 1-3 (8 Zones, 2 Systems)



The RTUs designed for HITT Contracting Headquarters consisted of air-cooled packaged units with total energy recovery wheels on each unit. The heating system used electric resistance heating in all of the RTUs. The supplemental units (AC 2, 3 & 4) were all designed as split systems with condenser fans on the roof and electric resistance heating. Ventilation rates for each unit were taken from the design documents and are noted in Appendix E.

Figure 2 – Zone Layout Schematic – All Floors



Calculated Loads

All but one of the modeled cooling loads are less than the design cooling loads. This most likely occurs because the building systems were overdesigned when selecting cooling equipment because equipment comes in incremental load steps (i.e. 30, 35, 40, 45, 50 Tons etc) and the load required by the space must be met or exceeded. Table 4 compares the cooling and ventilation requirements of the building on a per square foot basis for both the designed values and modeled values. The Trace 700 model came close to the values that the building was designed to, while being within 10% of the ventilation requirements. ofThe total cooling load for the designed system is 420 Tons and the cooling load estimated in the Trace 700 model is 363 Tons. See Table 5 on the next page for a unit by unit comparison of the designed loads vs. the modeled loads.

Table 4 - Comparison: Energy Model vs Designed			
	Designed	Computed	% Difference
Cooling (ft^2/Ton)	321.6	372.5	16%
Supply Air (CFM/ft^2)	1.17	1.08	-7%
Ventilation (CFM/ft^2)	0.26	0.25	-5%

See Appendix F for full load comparison calculation including cooling & heating.

See Appendix E for full ventilation rate comparison calculation.

Table 5 - Unit Comparison: Energy Model vs Designed			
Unit Name	Designed Cooling(Tons)	Model Cooling(Tons)	% Difference
AHU-C-2	62.2	63.3	2%
AHU-1-1	55.8	52.1	-7%
AHU-1-2	57.0	42.5	-25%
AHU-2-1	55.8	52.1	-7%
AHU-2-2	57.0	39.3	-31%
AHU-3-1	57.1	50.6	-11%
AHU-3-2	56.4	42.0	-26%
AC-2	11.6	10.6	-8%
AC-3	3.6	5.1	42%
AC-4	3.6	5.1	42%
Totals	420	363	-14%

Annual Energy Consumption and Operating Costs

Trace 700 was also used to compute the annual energy consumption and operating costs for HITT Contracting Headquarters. Dominion Virginia Power (DVP) is the provider of electric energy to HITT Contracting Headquarters. The Economic data including On Peak Demand, Off Peak Demand, On Peak Consumption and Off Peak Consumption was obtained from correspondence with the design team at KTA Group and is shown in Table 6.

Table 6 – Dominion Virginia Power Utility Rates		
On Peak Demand	14.488	$/kW Demand
Off Peak Demand	2.926	$/kW Demand
On Peak Consumption	0.0404	$/kWh
Off Peak Consumption	0.0272	$/kWh
Customer Charge(Per Month)	119.8	$/Month

The monthly energy consumption and utility costs as calculated by Trace 700 are displayed in Figures 3 & 4 below and broken down in Appendices G & H. The schedules noted in Appendix B were used for the energy consumption modeling. On peak Demand was set to occur between the hours of 10am – 10pm from June to September and 7am-10pm from October to May. This, along with increased demand to satisfy the cooling loads, accounts for the spike in the off-peak demand during the summer months. The annual electricity consumption and the annual electricity cost for HITT Contracting Headquarters were modeled to be 3,769,755 kWh and $340,748, respectively, as calculated in Table 8.

Figure 3 – Monthly Electricity Consumption

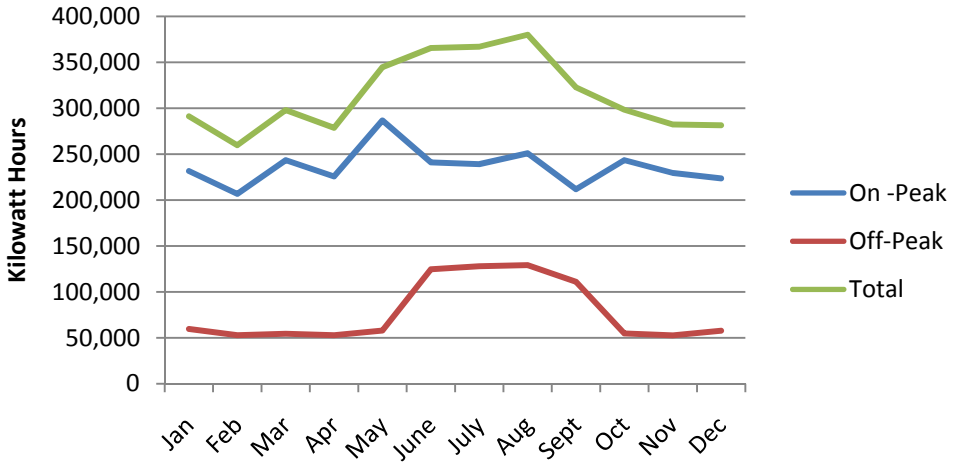
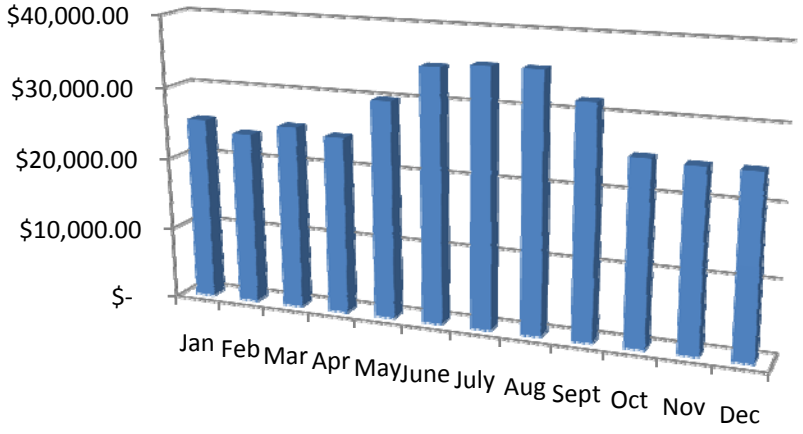


Figure 4 – Monthly Electricity Cost



The annual cooling cost per square foot of the modeled building is $0.50 per square foot as calculated in Table 7 with a building square footage of 135,000 square feet. The designed annual cooling cost per square foot amounted to $0.57 per square foot. A 12% difference is noted between the two.

Table 7 – Cooling Cost Per Square Foot			
	kWh/yr	Cost Per Year	Cost/SF
Modeled	740,440	$66,928	$0.50
Designed	707,169	$77,343	$0.57

Breakdown & Comparison of Annual Operating Costs

A breakdown of the total electrical load is displayed in Table 8, showing that miscellaneous receptacle loads are by far the largest user of energy in the building at 55% of the total building energy usage. An energy analysis was also performed by the mechanical engineer at KTA Group (the MEP design firm for the project) using Trane Trace 700. The load breakdown of Trace 700 energy model developed for this report and the model created by the by the HVAC engineer are very similar. All of the percentages are within 3% of each other. See Table 9 for a breakdown of the HVAC engineer model. The total annual cost of the HVAC engineer model is higher than the model developed for this paper due to more energy required during the expensive on-peak hours.

Table 8 – Breakdown of Annual Equipment Operating Costs			
	kWh/yr	Annual Operating Cost	%Total
Cooling	740,440	$66,928	19.6%
Fans	220,677	$19,947	5.9%
Lighting	651,445	$58,884	17.3%
Misc	2,084,419	$188,411	55.3%
Heating	72,773	$6,578	1.9%
Total	3,769,755	$340,748	100.0%

See Appendix D for Cooling and Fan operating cost calculations.

Table 9 – KTA Model - Annual Equipment Operating Costs			
	kWh/yr	Annual Operating Cost	%Total
Cooling	707,169	$77,343	22%
Fans	225,008	$24,609	7%
Lighting	642,881	$70,311	20%
Misc	1,542,913	$168,747	48%
Heating	96,432	$10,547	3%
Total	3,214,403	$351,557	100%

Figure 5 – Modeled Energy Consumption

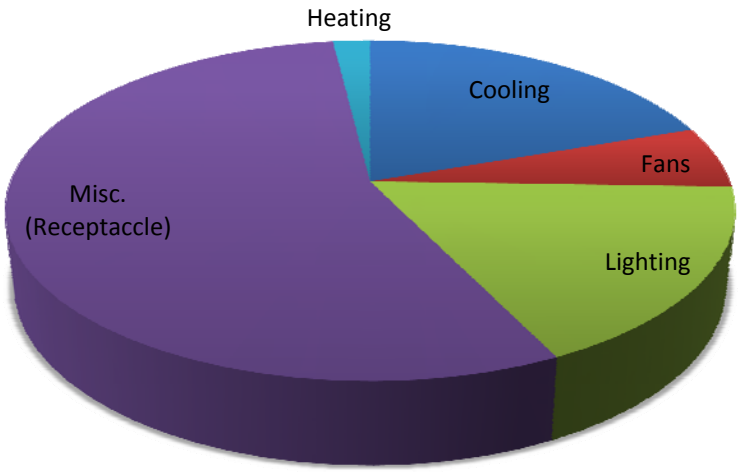
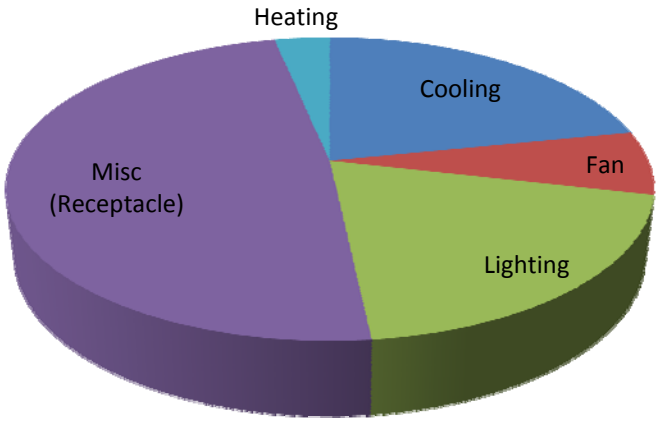


Figure 6 - KTA Modeled Energy Consumption



References

KTA Group, Inc. 2008. Mechanical Construction Documents. KTA Group, Herndon, VA. 2008.

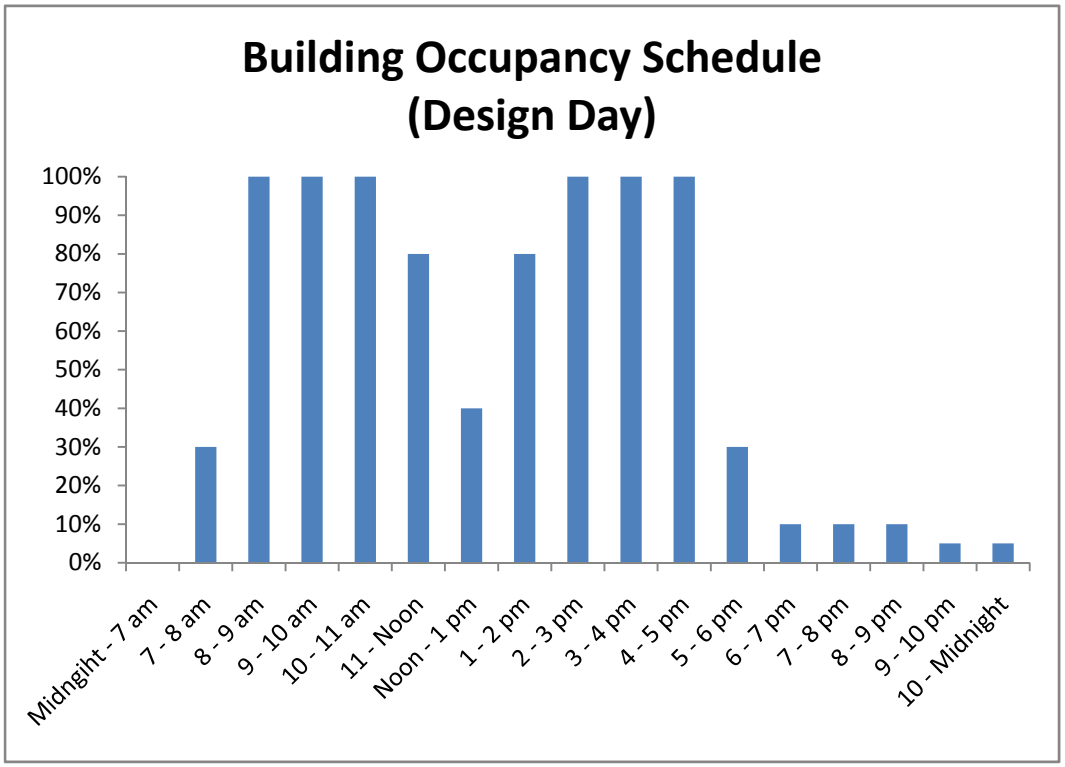
Noritake Associates. 2008. Architectural Construction Documents. Noritake Associates, Alexandria, VA. 2008.

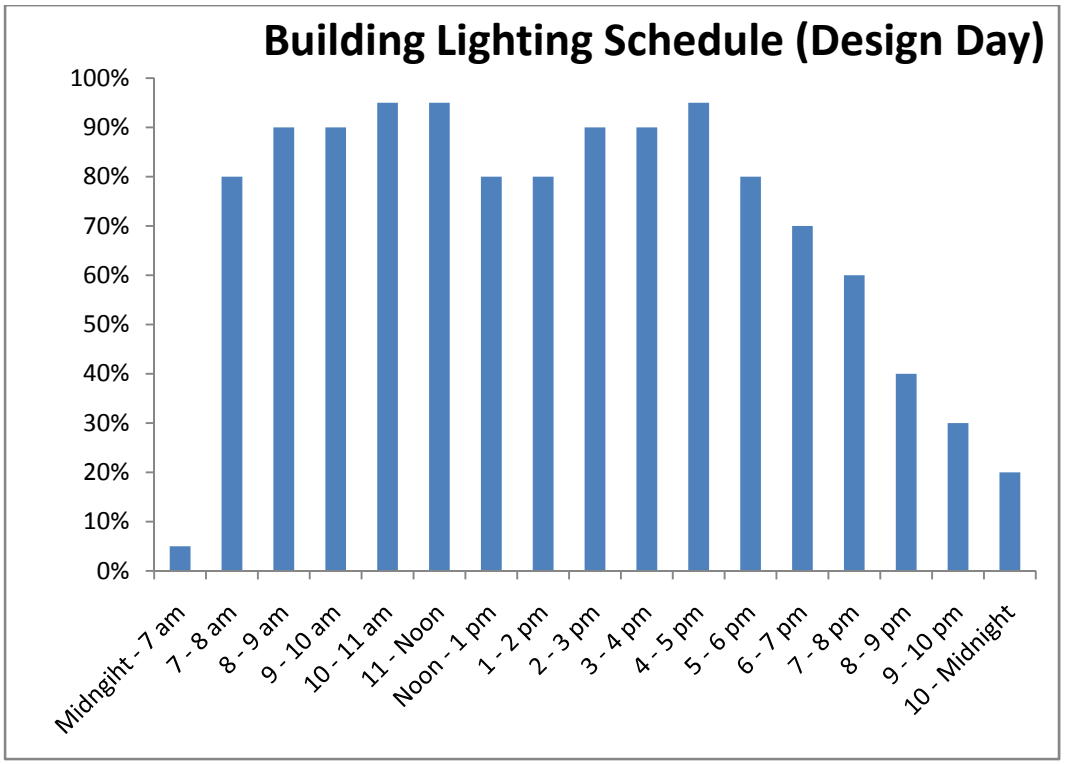
Appendix A – Miscellaneous Loads Calculation

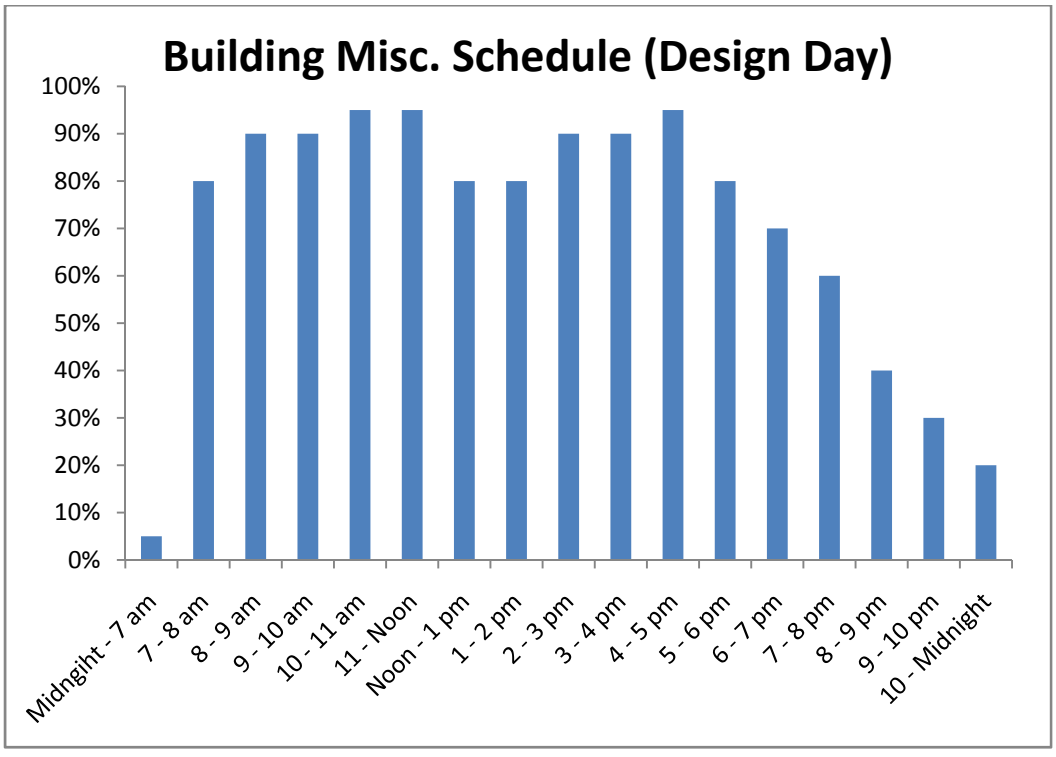
Misc. Load Calculation (W/SF)						
Load Type	kW					
Computers	255					
Receptacle	172					
UPS	40					
Total kW	467	/	135000	=	3.46	Watts/SF
Computer Load	500	Watts/Computer				
# of Computers	510	Computers				
Total Comp. Load	255	kW				

Appendix B – Building Schedules

All schedules reflect a typical Monday to Friday schedule for the respective system. During weekends, the building is assumed to be unoccupied.

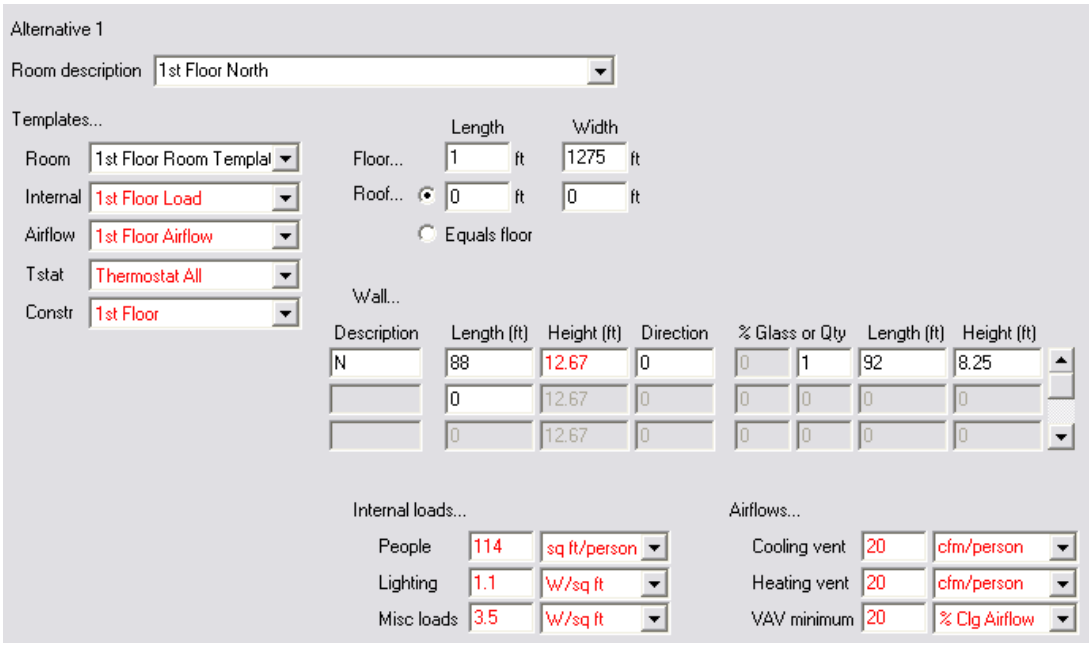



Building Lighting Schedule (Design Day)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Midnight - 7 am
7 - 8 am
8 - 9 am
9 - 10 am
10 - 11 am
11 - Noon
Noon - 1 pm
1 - 2 pm
2 - 3 pm
3 - 4 pm
4 - 5 pm
5 - 6 pm
6 - 7 pm
7 - 8 pm
8 - 9 pm
9 - 10 pm
10 - Midnight

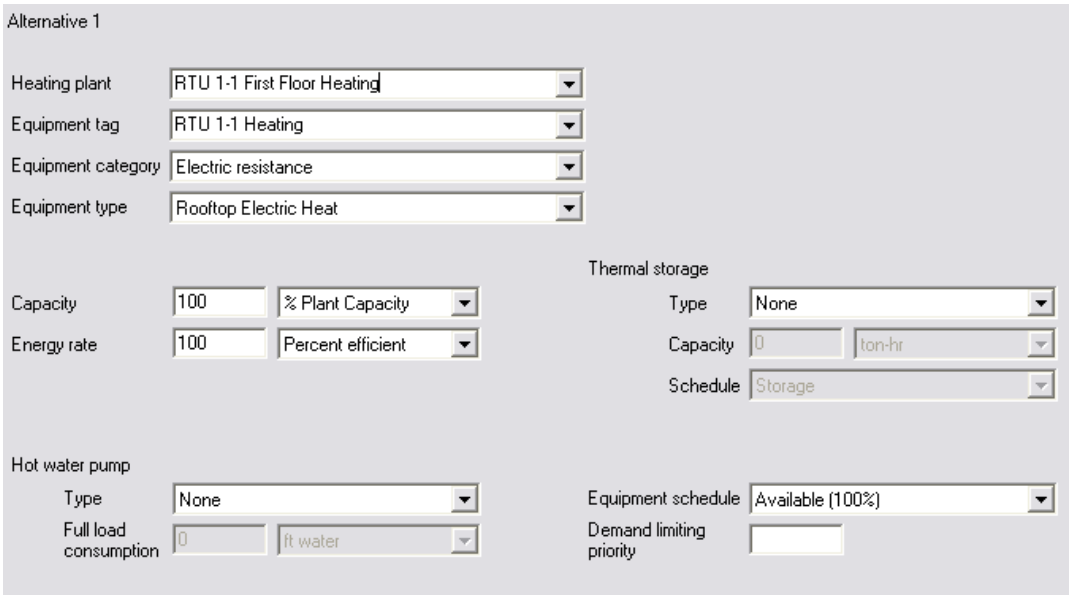

Building Misc. Schedule (Design Day)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Midnight - 7 am
7 - 8 am
8 - 9 am
9 - 10 am
10 - 11 am
11 - Noon
Noon - 1 pm
1 - 2 pm
2 - 3 pm
3 - 4 pm
4 - 5 pm
5 - 6 pm
6 - 7 pm
7 - 8 pm
8 - 9 pm
9 - 10 pm
10 - Midnight

Appendix C – Trane Trace Inputs

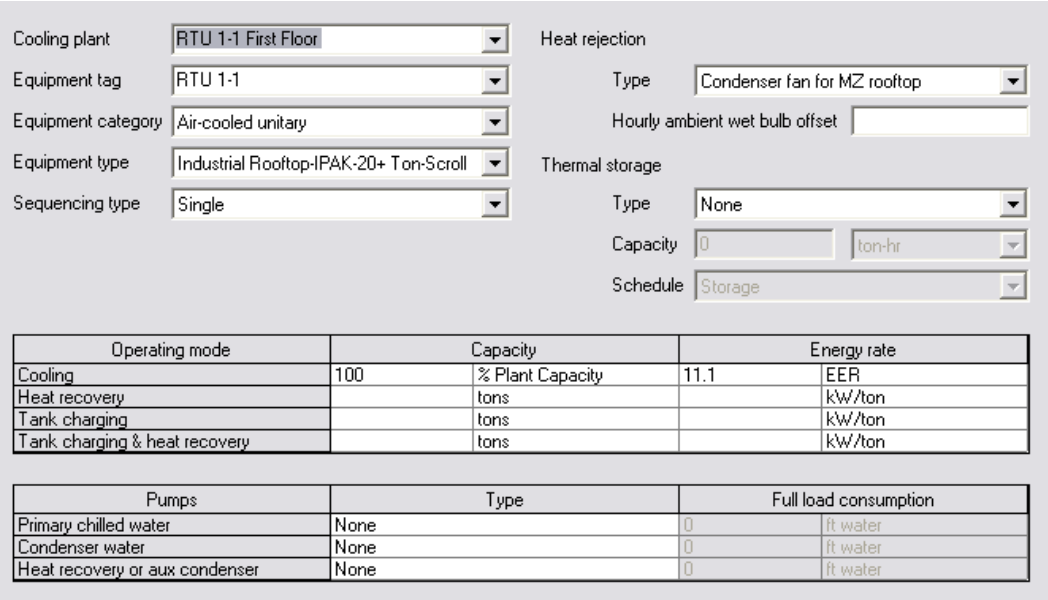
Typical Office Space



Heating Systems



Cooling Systems



Cooling plant	RTU 1-1 First Floor
Equipment tag	RTU 1-1
Equipment category	Air-cooled unitary
Equipment type	Industrial Rooftop-IPAK-20+ Ton-Scroll
Sequencing type	Single

Heat rejection

Type	Condenser fan for MZ rooftop
Hourly ambient wet bulb offset	

Thermal storage

Type	None	
Capacity	0	ton-hr
Schedule	Storage	

Operating mode	Capacity		Energy rate	
Cooling	100	% Plant Capacity	11.1	EER
Heat recovery		tons		kW/ton
Tank charging		tons		kW/ton
Tank charging & heat recovery		tons		kW/ton

Pumps	Type	Full load consumption	
Primary chilled water	None	0	ft water
Condenser water	None	0	ft water
Heat recovery or aux condenser	None	0	ft water

Appendix D – Cooling and Fan System Operating Costs

Cooling System Operating Costs		
	kWh/yr	Annual Operating Cost
AC 3 & 4	10,148	$917
AC 2	32,934	$2,977
RTU 1-1	79,595	$7,195
RTU 1-2	63,870	$5,773
RTU 2-1	79,595	$7,195
RTU 2-2	58,798	$5,315
RTU 3-1	79,887	$7,221
RTU 3-2	66,298	$5,993
RTU C-2	269,315	$24,343
Total	740,440	$66,928

Fan Operating Costs		
	kWh/yr	Annual Operating Cost
AC 3 & 4	5,298	$479
AC 2	19,597	$1,771
RTU 1-1	25,467	$2,302
RTU 1-2	30,752	$2,780
RTU 2-1	25,467	$2,302
RTU 2-2	7,811	$706
RTU 3-1	30,873	$2,791
RTU 3-2	29,900	$2,703
RTU C-2	45,512	$4,114
Total	220,677	$19,947

Appendix E – Ventilation Rate Comparison

Ventilation Comparison: Energy Model vs Designed					
Unit Name	Area (Square Feet)	Designed CFM	Model CFM	Designed OA CFM	Model OA CFM
AHU-C-2	26057	26400	26572	4800	4571
AHU-1-1	19165	19850	20785	4600	3382
AHU-1-2	15725	22000	17470	4800	2759
AHU-2-1	19165	19850	20785	4600	3362
AHU-2-2	15725	22000	17411	4800	2759
AHU-3-1	19165	18300	19461	4600	3362
AHU-3-2	15725	20100	16384	4800	2759
AC-2	2450	4200	3500	875	817
AC-3	978.5	2500	2015	900	975
AC-4	978.5	2500	2015	900	975
Totals	135134	157700	146398	35675	25721

Supply Air Comparison: Energy Model vs Designed		
Unit Name	Designed CFM/FT^2	Model CFM/FT^2
AHU-C-2	1.01	1.02
AHU-1-1	1.04	1.08
AHU-1-2	1.40	1.11
AHU-2-1	1.04	1.08
AHU-2-2	1.40	1.11
AHU-3-1	0.95	1.02
AHU-3-2	1.28	1.04
AC-2	1.71	1.43
AC-3	2.55	2.06
AC-4	2.55	2.06
Totals	1.17	1.08

Ventilation Comparison: Energy Model vs Designed		
Unit Name	Designed OA CFM/FT^2	Model OA CFM/FT^2
AHU-C-2	0.18	0.18
AHU-1-1	0.24	0.18
AHU-1-2	0.31	0.18
AHU-2-1	0.24	0.18
AHU-2-2	0.31	0.18
AHU-3-1	0.24	0.18
AHU-3-2	0.31	0.18
AC-2	0.36	0.33
AC-3	0.92	1.00
AC-4	0.92	1.00
Totals	0.26	0.19

Appendix F – Load Comparison

Load Comparison: Energy Model vs Designed							
Unit Name	Area (Square Feet)	Designed Cooling(MBH)	Model Cooling(MBH)	Designed Heating(MBH)	Model Heating(MBH)	Designed (FT^2/Ton)	Model (FT^2/Ton)
AHU-C-2	26057	746.8	760.1	273.0	128.6	418.70	411.37
AHU-1-1	19165	670.1	625.3	136.5	192.1	343.20	367.79
AHU-1-2	15725	684.1	510.0	273.0	177.8	275.84	370.00
AHU-2-1	19165	670.1	625.3	136.5	192.1	343.20	367.79
AHU-2-2	15725	684.1	471.8	273.0	169.3	275.84	399.96
AHU-3-1	19165	685.2	607.3	273.0	216.3	335.64	378.69
AHU-3-2	15725	677.3	503.7	273.0	192.4	278.61	374.63
AC-2	2450	138.8	127.5	95.6	129.0	211.82	230.59
AC-3	978.5	43.1	61.4	36.1	46.1	272.44	191.24
AC-4	978.5	43.1	61.4	36.1	46.1	272.44	191.24
Totals	135134	5043	4354	1806	1490	321.58	372.46

Load Comparison: Energy Model vs Designed			
Unit Name	Area (Square Feet)	Designed (FT^2/Ton)	Model (FT^2/Ton)
AHU-C-2	26057	418.70	411.37
AHU-1-1	19165	343.20	367.79
AHU-1-2	15725	275.84	370.00
AHU-2-1	19165	343.20	367.79
AHU-2-2	15725	275.84	399.96
AHU-3-1	19165	335.64	378.69
AHU-3-2	15725	278.61	374.63
AC-2	2450	211.82	230.59
AC-3	978.5	272.44	191.24
AC-4	978.5	272.44	191.24
Totals	135134	321.58	372.46

Appendix G – Monthly Electricity Consumption

Monthly Electricity Consumption in kWhrs													
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
On-Peak	231,532	206,633	243,512	225,732	286,709	241,018	239,161	250,935	211,717	243,449	229,428	223,577	2,833,403
Off-Peak	59,743	53,020	54,529	52,984	58,037	124,560	127,857	129,129	111,054	54,846	52,799	57,799	936,355
Total	291,275	259,653	298,041	278,716	344,746	365,578	367,018	380,064	322,771	298,295	282,227	281,376	3,769,758

Appendix H – Monthly Operating Cost (Overall)

Monthly Operating Cost	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
On Peak Consumption	$9,354	$8,348	$9,838	$9,120	$11,583	$9,737	$9,662	$10,138	$8,553	$9,835	$9,269	$9,033	$114,469
Off Peak Consumption	$1,625	$1,442	$1,483	$1,441	$1,579	$3,388	$3,478	$3,512	$3,021	$1,492	$1,436	$1,572	$25,469
On Peak Demand	$12,979	$12,693	$12,801	$12,636	$15,372	$16,671	$16,905	$16,608	$15,451	$12,546	$12,763	$12,819	$170,244
Off Peak Demand	$1,373	$1,336	$1,236	$1,270	$1,381	$5,041	$5,337	$5,132	$4,682	$1,269	$1,248	$1,261	$30,565
Total	$25,332	$23,819	$25,359	$24,466	$29,915	$34,837	$35,382	$35,390	$31,707	$25,142	$24,716	$24,684	$340,748