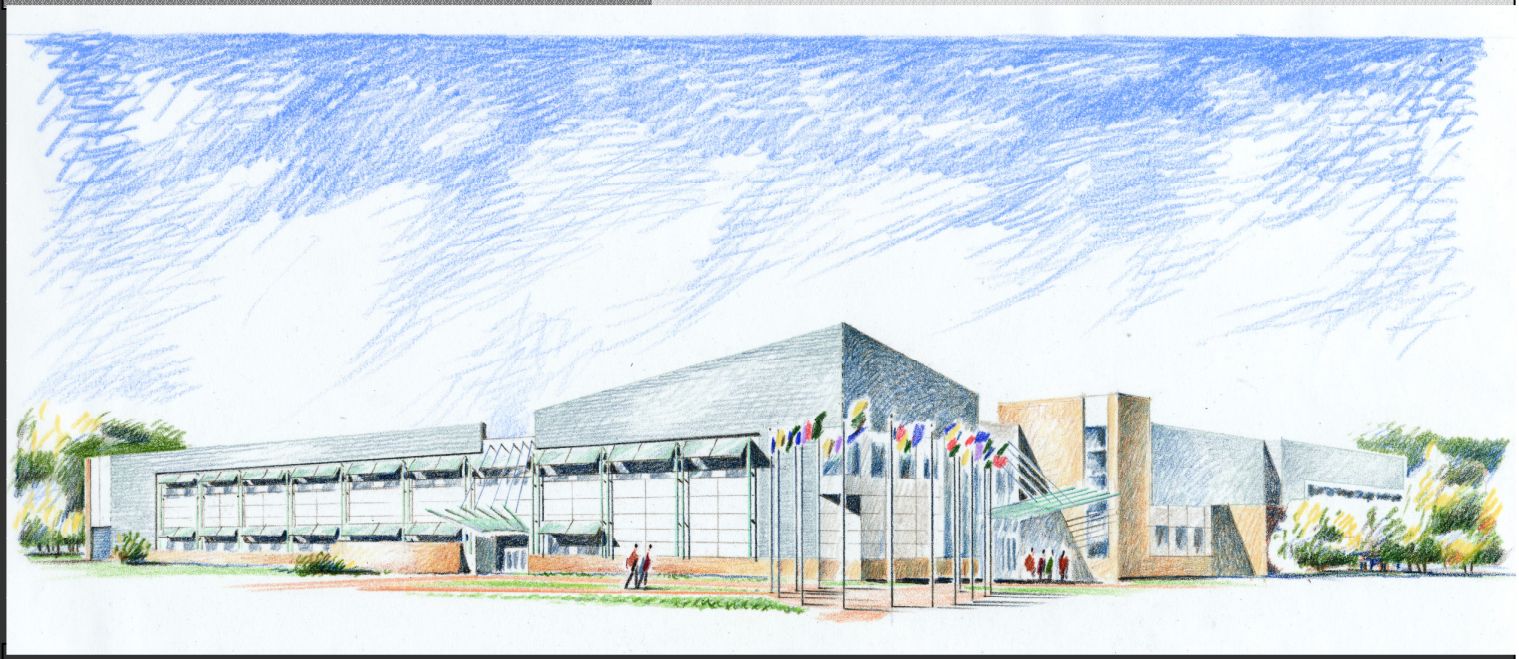
MECHANICAL TECHNICAL ASSIGNMENT 2

Building and Plant Energy Analysis Report



The Regional Learning Alliance at Cranberry Woods

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EXECUTIVE SUMMARY

The Regional Learning Alliance Conference and Learning Center is a 76,000 ft^2, mixed use, educational facility, located in Cranberry Township, PA. The purpose of this report is to analyze the existing building design and annual energy consumption. During the analysis, Trane's TRACE 700 building energy simulation program was used to model the individual spaces, HVAC system components, and cooling/heating plants. In addition, the simulation estimated the annual energy consumption and environmental impacts of the building. Input data needed to complete the analysis was provided by the mechanical design team at Tower Engineering and Renaissance 3 Architect design documents. Where information was not available, default Trace settings were used.

After completing the building energy simulation, the TRACE values for the cooling loads, supply air and ventilation air were compared to those in the design documents. Both air handlers were sufficiently designed, with cooling loads (ft2/ton) and ventilation supplies (CFM/ft2) that exceeded TRACE recommendations.

According to the TRACE model, The Regional Learning Alliance Center has an annual energy consumption of 1,473,690 kWh. Of this 1,473,690 kWh consumed, heating accounts for roughly 36.7%, cooling: 9.3%, fans: 21.4%, pumps: 1.5%, lighting: 17.1% and receptacles: 14.1%. This information, along with local electric and gas rates, was then used to calculate the annual operating cost of the building, which topped out at $118,955. A breakdown of operating costs for each individual component can be found on Page 7. Lastly, the annual cooling cost per square foot was calculated at $0.188/SF of conditioned space.

When comparing the TRACE energy model discussed in this report, to the original HAP model created by Tower Engineering, it was found that the majority of the values (including the total building energy, total source energy, electric costs, natural gas costs, and heating coil loads) varied by only 10-20%. A complete summary of these comparisons can be found in Table 5 on Page 8. While discrepancies occurred in the percentage of energy used for cooling, air system fans and electrical equipment, it is most likely due to the differences between TRACE vs. HAP input information, and is discussed later in this report.

MECHANICAL SYSTEM INITIAL COST

The Regional Learning Alliance Center's HVAC system consists of 2 Air Handling Units and 50 Fan Coil Units. 100% outdoor air is supplied to each fan coil unit from AHU-1, which is located on the facility's rooftop, and is controlled by a variable frequency drive. AHU-2, is a 10,000 CFM constant volume unit that is dedicated to the ventilation of the main lobby and atrium. Stairwells, vestibules, mechanical rooms and electrical rooms are strictly heated, and are served by electric and cabinet unit heaters. IT/Technology rooms are strictly cooled by a separate air conditioning unit located in the space. The building's chiller plant consist of one 75-ton evaporatively cooled chiller, and 2 gas fired hot water boilers. Separate boilers are used for the domestic hot water system, and will not be taken into account when modeling.

The actual initial construction cost of the mechanical system was provided by The Regional Learning Alliance owner representative at $1,855,630. With a total floor area of 76,000 SF, the initial cost per square foot is **$24.40/SF.**

DESIGN LOAD ANALYSIS

Although Tower Engineering initially performed an energy model using Carrier's Hourly Analysis Program, the model was not available for reference. However, they were able to provide output documentation containing the energy consumption and annual cost predictions based off the model. This information is available in APPENDIX F, and will be used for comparison later in this report.

For this report, the design loads and energy usage for The Regional Learning Alliance Center were estimated using Trane's TRACE 700 energy analysis program. All outdoor ventilation rates, design occupancies and electrical loads were taken from documents provided by Tower Engineering and Renaissance 3 Architects. Default weather data for Pittsburgh Pennsylvania was provided by TRACE and used for all computations, while the lighting loads (W/SF) were taken from original ASHRAE 90.1 calculations and can be found in APPENDIX A .

ASSUMPTIONS:

The following assumptions were made while inputting TRACE data. Most assumptions resulted from either a lack of information, or the inability to appropriately model a particular feature.

► No U-value could be located for the atrium curtain wall glazing. Therefore, the U-value that corresponded to the south windows was used.

► Curtain walls were modeled as an exterior wall, with 100% glazing.

► Since the exact Azulite window construction was not an option in TRACE, a construction with similar U-values and shading coefficients was selected. These values can be found in APPENDIX B.

► Where sloped ceilings occurred (lobby/atrium, interaction space, shared reception space, etc), an average height was used for the floor-to-floor input value.

► Door glazing modeled as double clear, ¼", with U factor=0.6

► Standard school equipment loads were used in the Lecture and Discussion Classrooms. Standard office equipment loads were used in tenant offices, and office space where pieces of equipment were not individually listed.

► The building's clearstory windows proved to be difficult to model. While the benefit of their day lighting obviously affects numerous spaces, including the atrium and lobby, the actual windows were modeled on an exterior wall in Corridor 2100. This could have cause for the extra load in the space, and lack thereof in others.

► Where occupancies were not listed, default occupancy values using standard occupancy densities from ASHRAE 62.1 were calculated using corresponding room areas.

► *Typical* exterior wall and roof U-values were used for modeling purposes and can be found in APPENDIX B.

► Due to the lack of information available from the initial model, default "Mid-rise Building" TRACE schedules were used for occupancy, lighting, equipment and ventilation.

► Rooms with occupancy censored lighting (such as offices and lecture rooms) followed the "People-midrise building" schedule, instead of the "Lighting-midrise building" schedules. Refer to APPENDIX D

► Attempted to model windows with exterior shading devices by adding an overhang.

► Infiltration neglected for modeling purposes.

► Space whose areas were not clearly designated on design documents were estimated using CAD.

In attempts to examine the TRACE input information in more detail, APPENDIX B includes typical construction values for the building's exterior walls, roof and windows, APPENDIX C reviews internal load and air flow input information for a typical tenant office, and APPENDIX D provides the default values used for the occupancy, lighting, ventilation and equipment schedules.

After inputting all 112 rooms, 50 fan coil units were modeled in the systems section and matched to the corresponding zone they served. In addition, the DOAS and constant volume air handling unit (serving the atrium and lobby) were also modeled. Components of each system (ie: heating/ cooling coils) were distributed to the heating/cooling plants, which consisted of the 75-ton chiller, and 2 gas fired boilers. APPENDIX E provides all information regarding TRACE input and performance characteristics used during the energy analysis.

CONCLUSIONS:

After completing the model and running the analysis, TRACE cooling loads were referenced from the Design Cooling Output Summary, while the actual design values were calculated by hand. Each unit's scheduled MBH value was converted to tons, and used with the corresponding served area to obtain these results.

Supply air values were calculated by summing up airflows from each individual fan coil unit (either from the TRACE outputs, or design documents), and then dividing by the square footage of conditioned space. This information can be found in the table below.

TABLE 1: SUPPLY AIR CALCULATIONS

	designed sa (CFM)	TRACE sa (CFM)
AHU-1	47,214	42,332
AHU-2	10,000	16,000
Conditioned Area by AHU-1: 59,000 SF		
Conditioned Area by AHU-2: 8,020 SF		
47214/59000=**0.80 CFM/ft2**	42322/59000=**0.717 cfm/ft2**	
10,000/8020=**1.25 CFM/ft2**	16,000/8020=**1.97 cfm/ft2**	

By comparing the TRACE model to the actual design, The Regional Learning Alliance Center's mechanical equipment seems to be adequately designed. Since the majority of the building is served by fan-coil units run off of AHU-1, this cooling load is obviously greater than AHU-2, which primarily serves the atrium/lobby spaces. Table 2 summarizes the differences between TRACE outputs and design data:

TABLE 2: DESIGNED vs. COMPUTED COMPARISONS

	cooling load (ft2/ton)	supply air (CFM/ft2)	ventilation supply (CFM/ft2)
TRACE VALUES			
AHU-1	587	0.717	0.0526
AHU-2	315	1.97	0.258
DESIGNED VALUES			
AHU-1	705	0.8	0.06
AHU-2	436	1.25	0.31

Referencing Table 2, the designed cooling loads for AHU-1 and AHU-2 exceeded Trane TRACE recommendations by 20% and 38%, respectively. The discrepancies in values are most likely due to input errors, which occurred while trying to accurately model the atrium, clear story windows, and curtain wall constructions. In addition, the default schedules only run the loads for weekdays, when in reality, The Regional Learning Alliance Center is opened Saturday morning until 3 p.m. Classes also have the opportunity to meet during evening hours, which could have been another factor that added to the difference in cooling loads.

TRACE ENERGY CONSUMPTION ANALYSIS:

According to the model's energy consumption summary, The Regional Learning Alliance consumes **1,473,680 KWh** of energy annually. Figure 1 and Table 3 break down this energy consumption by building component.

FIGURE 1: ENERGY CONSUMPTION PIE CHART

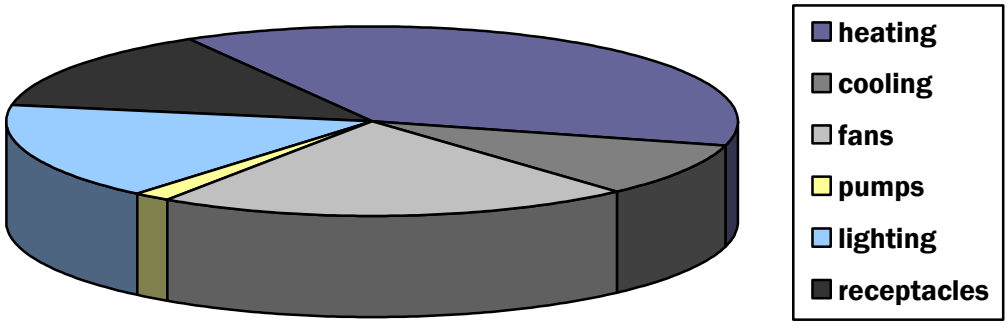


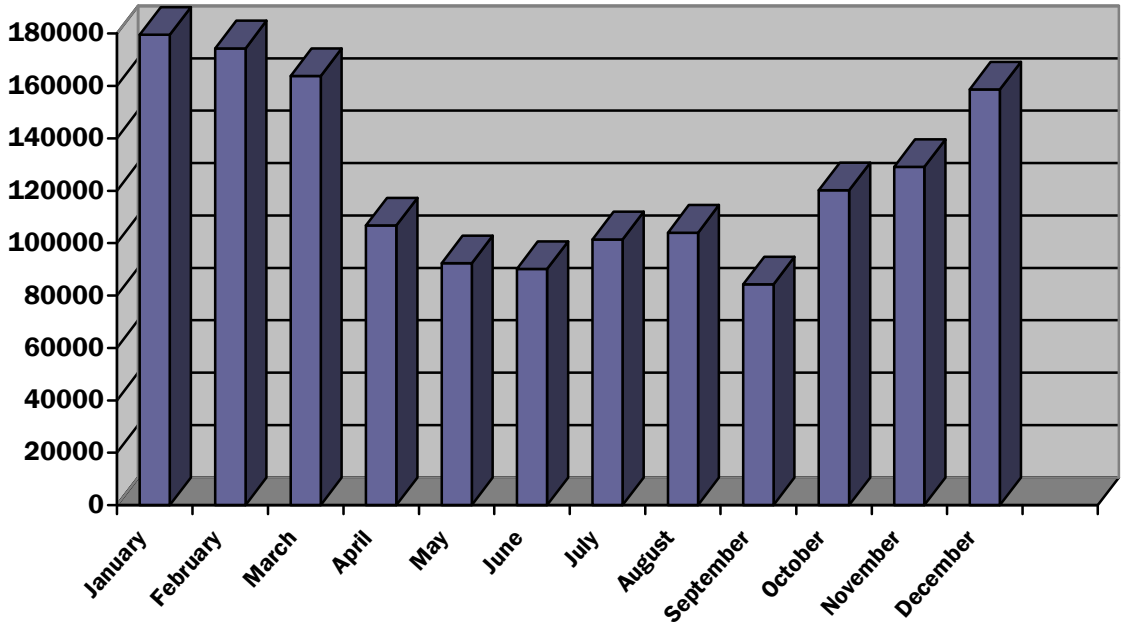
TABLE 3: ENERGY CONSUMPTION PERCENTAGE BREAKDOWN

Component	Percentage of Total Building Energy
heating	36.7
cooling	9.3
fans	21.4
pumps	1.5
lighting	17.1
receptacles	14.1

As shown in Figure 1, and Table 3, The Regional Learning Alliance's energy consumption is dominated primarily by heating and fans, which makes sense since the building's primary ventilation system is composed of 50 fan-coil units. In addition, the building utilizes glass curtainwalls in various zones throughout the building, including the large 2-story atrium and lobby. This immense and open space is most likely what caused such a high percentage of energy to be used for heating.

TRACE output summaries were also used to calculate the building's energy consumption on a monthly basis. This breakdown can be seen in Figure 2.

FIGURE 2: AVERAGE MONTHLY ENERGY USAGE



**Note:* Values on the Y-axis have units of kWh.

Typically, winter months and peak summer months consume the most energy, since the building is most heavily heated and cooled during these times. Figure 2 shows an increase in energy usage during winter months, however, the energy usage during July and August are not as high as suspected (though still noticeably larger than transitional periods). While this could be due to an error in modeling the glazing and sun shading devices used on most windows and curtain walls, further investigation of this issue will need to take place.

COST ANALYSIS:

Knowing the annual (and monthly) energy usages will allow us to perform a building operating cost analysis. During the original estimation performed by Tower Engineering, the following *flat rates* were used:

- Electric: $0.069 / kWh (provided by Penn power)
- Gas: $2.946 / therm (provided by Sprague Energy)

While the syllabus suggests to include demand values, the cost analysis will be performed using the flat rates so that a comparison to the original calculations can be made. Table 4 illustrates the calculations and cost breakdown for each month. Using these values provided from TRACE, the annual energy cost was estimated at $118,955 ($63,873 being electric and $55,082 natural gas).

TABLE 4 : MONTHLY & ANNUAL OPERATING COSTS

MONTH	kWh	Therms	Cost per kWh ($)	Cost per Therm($)	Total cost per Month ($)
January	74,224.00	3,594.00	0.069	2.946	15,709.38
February	67,142.00	3,658.00	0.069	2.946	15,409.27
March	81,196.00	2,817.00	0.069	2.946	13,901.41
April	71,740.00	1,194.00	0.069	2.946	8,467.58
May	81,694.00	364.00	0.069	2.946	6,709.23
June	84,687.00	186.00	0.069	2.946	6,391.36
July	78,577.00	35.00	0.069	2.946	5,524.92
August	87,480.00	255.00	0.069	2.946	6,787.35
September	74,471.00	335.00	0.069	2.946	6,125.41
October	78,633.00	1,416.00	0.069	2.946	9,597.21
November	74,756.00	1,855.00	0.069	2.946	10,622.99
December	71,097.00	2,988.00	0.069	2.946	13,708.34
				TOTAL ANNUAL COST:	118,954.46

Knowing the total annual costs for both heating and electric, as well as the building energy use percentage breakdown, Table 5 can be used to summarize a *rough* estimated annual cost per component.

TABLE 5 : ANNUAL OPERATING COSTS BY COMPONENT

Component	Percentage of Total Building Energy	Rough Estimated Cost/Year ($)
heating	36.7	43,656
cooling	9.3	11,065
fans	21.4	25,456
pumps	1.5	1,784
lighting	17.1	20,341
receptacles	14.1	16,773

From the data estimated in Table 5, an annual cooling cost per square foot was obtained through the following calculation:

$11,065/59,000 SF (of conditioned space)= **$0.188 / SF**

Referring back to Figure 2, it seemed as though the energy consumption for the peak summer months were not quite as high as they should have been. Therefore, it is likely that this price is actually a bit greater than the value calculated above.

TRACE vs. HAP ENERGY ANALYSIS COMPARISON

During the actual design phase, Tower Engineering used Carrier's Hourly Analysis Program to simulate the building and produce an energy report. Although the original HAP model and input information was not available, Tower was able to provide the project's output, which consisted of an estimated annual energy consumption and operating costs. A detailed version of this information can be found in APPENDIX F.

The following table compares the difference in values that occurred between the two models.

TABLE 5 : HAP vs. TRACE MODEL COMPARISON

Information Being Compared	HAP Value	TRACE Value	Percent Difference
Total Building Energy (kBTU/yr)	4,812,695	5,029,124	4.3
Total Source Energy (kBTU/yr)	12,197,073	11,447,279	6.1
Heating Coil Loads (kBTU)	2,029,091	1,869,723	8.5
PECENTAGE OF BUILDING ENERGY (%)			
Cooling	14.10	9.30	50
Heating	40.50	36.70	10
Pumps	3.25	1.50	20
Air System Fans	14.80	21.40	40
Lights	19.22	17.10	10
Electric Equipment	8.10	14.10	70
OPERATING COSTS (4/yr)			
Electric	58,073	63,873	10.0
Natural Gas	57,614	55,082	4.6
Totals	115,687	118,955	2.8

As you can see, the majority of the TRACE values came within 10% of the original values estimated using HAP. Noticeable inconsistencies arise in the percentage of building energy used for cooling, air system fans, and electric equipment. As mentioned previously in this report, the cooling load computed in TRACE seemed relatively low when taken into account

for monthly operating costs. Therefore, the HAP output of 14.1% is most likely closer to the actual value. In addition, the variance in electrical equipment may be due to the fact that miscellaneous equipment was inputted to TRACE on a Watt/SF basis, which could have caused the overcompensation in load.

The 40% and 50% difference in air system fan and cooling energy usage will be further investigated before proceeding to Technical Assignment 3.

ENVIRONMENTAL IMPACT ANALYSIS

In addition to the energy analysis, another important factor to consider is the environmental impact of the building's emissions. Trane's TRACE monthly energy consumption report provided average carbon dioxide, nitrogen oxides, and sulfur dioxide emissions. Table 6 summarizes the estimated emissions profile for The Regional Learning Alliance Center.

TABLE 6 : HAP vs. TRACE MODEL COMPARISON

Emission	Total Amount Produced
CO2	4,139,237 lbm/year
SO2	31,912 gm/year
NOX	9,090 gm/year

APPENDIX A- Lighting Loads (W/SF)

REGIONAL LEARNING ALLIANCE

Lighting Power Allowance Worksheet

Description	Room #	Lighted Floor Area	% Total Floor Area	Design Wattage	Design Watts/ Sq.Ft.	Design Light Level % of Total	Lighting Power Density	Lighting Power Allowance	Base Case Light Level % of Total	Design Wattage/ Allowance
Mechanical Rm.	0100	3,525	0.0526	1508	0.43	0.0225	1.30	4582.5	0.0684	33%
Elevator Machine Rm.	0113	64	0.0010	58	0.91	0.0009	1.30	83.2	0.0012	70%
Stair #3		188	0.0028	58	0.31	0.0009	0.90	169.2	0.0025	34%
Lobby/Atrium	1000	3,023	0.0451	2845	0.94	0.0424	1.30	3929.9	0.0586	72%
Corridor	1100	1,070	0.0160	726	0.68	0.0108	0.70	749.0	0.0112	97%
Corridor	1101	330	0.0049	237	0.72	0.0035	0.70	231.0	0.0034	103%
Corridor	1102	170	0.0025	99	0.58	0.0015	0.70	119.0	0.0018	83%
Corridor	1103-04	1,815	0.0271	1276	0.70	0.0190	0.70	1270.5	0.0190	100%
Kitchen Restroom	1103a	46	0.0007	58	1.26	0.0009	1.00	46.0	0.0007	126%
Kitchen Janitor	1103b	20	0.0003	58	2.90	0.0009	1.10	22.0	0.0003	264%
Electrical Closet	1103c	69	0.0010	58	0.84	0.0009	1.30	89.7	0.0013	65%
Telecom Closet	1103d	67	0.0010	116	1.73	0.0017	1.30	87.1	0.0013	133%
Kitchen Restroom	1103e	46	0.0007	58	1.26	0.0009	1.00	46.0	0.0007	126%
Casual Dining Area & Servery	1110	2,000	0.0298	1575	0.79	0.0235	1.40	2800.0	0.0418	56%
Maintenance Garage	1111	278	0.0041	348	1.25	0.0052	1.30	361.4	0.0054	96%
Kitchen/Scullery/Dish Rm.	1112	1,260	0.0188	1972	1.57	0.0294	2.20	2772.0	0.0413	71%
Dry Storage	1112b	102	0.0015	116	1.14	0.0017	1.10	112.2	0.0017	103%
Kitchen Office	1112f	62	0.0009	116	1.87	0.0017	1.50	93.0	0.0014	125%
Recycle Area	1114	69	0.0010	116	1.68	0.0017	1.10	75.9	0.0011	153%
Janitor's Closet	1115	20	0.0003	58	2.90	0.0009	1.10	22.0	0.0003	264%
Women's Restroom/Entry	1116a-b	276	0.0041	580	2.10	0.0087	1.00	276.0	0.0041	210%
Men's Restroom/Entry	1117a-b	276	0.0041	580	2.10	0.0087	1.00	276.0	0.0041	210%
Storage Staging	1119	644	0.0096	406	0.63	0.0061	1.10	708.4	0.0106	57%
Discussion Classroom	1120	726	0.0108	870	1.20	0.0130	1.60	1161.6	0.0173	75%
Discussion Classroom	1121	726	0.0108	870	1.20	0.0130	1.60	1161.6	0.0173	75%
Discussion Classroom	1122	703	0.0105	870	1.24	0.0130	1.60	1124.8	0.0168	77%

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APPENDIX A- Lighting Loads Cont'd

REGIONAL LEARNING ALLIANCE

Lighting Power Allowance Worksheet

Description	Room #	Lighted Floor Area	% Total Floor Area	Design Wattage	Design Watts/ Sq.Ft.	Design Light Level % of Total	Lighting Power Density	Lighting Power Allowance	Base Case Light Level % of Total	Design Wattage/ Allowance
Conference/Dining Reception	1123-24	3,978	0.0593	1247	3.14	0.1861	1.50	5967.0	0.0890	209%
Corridor/Vestibule	1200	1,319	0.0197	88	0.67	0.0132	0.70	923.3	0.0138	96%
Lobbies	1202-1203	1,954	0.0291	228	1.17	0.0340	1.80	3517.2	0.0525	65%
Vestibule	1210	85	0.0013	11	1.36	0.0017	0.70	59.5	0.0009	195%
Large Meeting Room	1211	2,120	0.0316	293	1.39	0.0438	1.60	3392.0	0.0506	87%
Storage	1211a	223	0.0033	17	0.78	0.0026	1.10	245.3	0.0037	71%
Library/Study	1213	886	0.0132	84	0.96	0.0126	1.40	1240.4	0.0185	68%
Vestibule	1214	118	0.0018	11	0.98	0.0017	0.70	82.6	0.0012	140%
Snack Bar/Cyber Café-prep	1220	300	0.0045	19	0.66	0.0030	2.20	660.0	0.0098	30%
Snack Bar/Cyber Café-dining	1220	350	0.0052	19	0.57	0.0030	1.40	490.0	0.0073	40%
Lecture Classroom	1221	742	0.0111	104	1.41	0.0156	1.60	1187.2	0.0177	88%
Lecture Classroom	1222	742	0.0111	104	1.41	0.0156	1.60	1187.2	0.0177	88%
Lecture Classroom	1223	742	0.0111	104	1.41	0.0156	1.60	1187.2	0.0177	88%
Lecture Classroom	1224	742	0.0111	104	1.41	0.0156	1.60	1187.2	0.0177	88%
Women's Restroom/Entry	1225a-b	331	0.0049	74	2.25	0.0111	1.00	331.0	0.0049	225%
Men's Restroom/Entry	1226a-b	331	0.0049	74	2.25	0.0111	1.00	331.0	0.0049	225%
Child Development Center	1227	1,761	0.0263	197	1.12	0.0294	1.40	2465.4	0.0368	80%
Unisex Restroom	1227b	46	0.0007	5	1.26	0.0009	1.00	46.0	0.0007	126%
Staff Restroom	1227c	45	0.0007	5	1.29	0.0009	1.00	45.0	0.0007	129%
Office	1227d	61	0.0009	5	0.95	0.0009	1.50	91.5	0.0014	63%
Wellness Training Center	1228	2,443	0.0364	313	1.28	0.0467	1.40	3420.2	0.0510	92%
Women's Toilet	1229a-c	186	0.0028	35	1.91	0.0053	1.00	186.0	0.0028	191%
Women's Locker Room	1229b	140	0.0021	9	0.71	0.0015	1.00	140.0	0.0021	71%
Women's Toilet	1230a-c	186	0.0028	35	1.91	0.0053	1.00	186.0	0.0028	191%
Women's Locker Room	1230b	140	0.0021	9	0.71	0.0015	1.00	140.0	0.0021	71%
Specialized Training/Exhibit	1231	1,986	0.0296	374	1.89	0.0558	1.60	3177.6	0.0474	118%

APPENDIX A- Lighting Loads Cont'd

REGIONAL LEARNING ALLIANCE

Lighting Power Allowance Worksheet

Description	Room #	Lighted Floor Area	% Total Floor Area	Design Wattage	Design Watts/ Sq.Ft.	Design Light Level % of Total	Lighting Power Density	Lighting Power Allowance	Base Case Light Level % of Total	Design Wattage/ Allowance
Stair #1		268	0.0040	39	0.15	0.0006	0.90	241.2	0.0036	16%
Stair #3		192	0.0029	97	0.51	0.0014	0.90	172.8	0.0026	56%
Stair #4		177	0.0026	39	0.22	0.0006	0.90	159.3	0.0024	24%
Corridor	2100	1,117	0.0167	264	0.24	0.0039	0.50	558.5	0.0083	47%
Corridor	2101	432	0.0064	309	0.72	0.0046	0.70	302.4	0.0045	102%
Corridor	2102	330	0.0049	165	0.50	0.0025	0.70	231.0	0.0034	71%
Electrical Closet	2103	24	0.0004	58	2.42	0.0009	1.30	31.2	0.0005	186%
Breakout	2103	376	0.0056	408	1.09	0.0061	1.80	676.8	0.0101	60%
Breakout	2104	357	0.0053	408	1.14	0.0061	1.80	642.6	0.0096	63%
Breakout	2105	357	0.0053	408	1.14	0.0061	1.80	642.6	0.0096	63%
Board Room	2110	735	0.0110	606	0.82	0.0090	1.50	1102.5	0.0164	55%
Men's Restroom/Entry	2111	172	0.0026	390	2.27	0.0058	1.00	172.0	0.0026	227%
Women's Restroom/Entry	2112	172	0.0026	390	2.27	0.0058	1.00	172.0	0.0026	227%
Discussion Classroom	2113	730	0.0109	1044	1.43	0.0156	1.60	1168.0	0.0174	89%
Discussion Classroom	2114	730	0.0109	1044	1.43	0.0156	1.60	1168.0	0.0174	89%
Lecture Classroom	2115	618	0.0092	870	1.41	0.0130	1.60	988.8	0.0147	88%
Discussion Classroom	2116	730	0.0109	1044	1.43	0.0156	1.60	1168.0	0.0174	89%
Discussion Classroom	2117	730	0.0109	1044	1.43	0.0156	1.60	1168.0	0.0174	89%
Lecture Classroom	2118	618	0.0092	870	1.41	0.0130	1.60	988.8	0.0147	88%
Discussion Classroom	2119	730	0.0109	1044	1.43	0.0156	1.60	1168.0	0.0174	89%
Discussion Classroom	2120	730	0.0109	1044	1.43	0.0156	1.60	1168.0	0.0174	89%
Seminar Room	2121	349	0.0052	348	1.00	0.0052	1.50	523.5	0.0078	66%
Corridor	2200	1,185	0.0177	812	0.69	0.0121	0.70	829.5	0.0124	98%
Corridor	2201	1,120	0.0167	627	0.56	0.0094	0.70	784.0	0.0117	80%
Interaction Space	2202	751	0.0112	805	1.07	0.0120	1.80	1351.8	0.0202	60%
Waiting Area	2204	686	0.0102	630	0.92	0.0094	1.40	960.4	0.0143	66%

APPENDIX A- Lighting Loads Cont'd

REGIONAL LEARNING ALLIANCE

Lighting Power Allowance Worksheet

Description	Room #	Lighted Floor Area	% Total Floor Area	Design Wattage	Design Watts/ Sq.Ft.	Design Light Level % of Total	Lighting Power Density	Lighting Power Allowance	Base Case Light Level % of Total	Design Wattage/ Allowance
Corridor	2205	735	0.0110	696	0.95	0.0104	0.70	514.5	0.0077	135%
Corridor	2206	160	0.0024	198	1.24	0.0030	0.70	112.0	0.0017	177%
Staff Clerical Area	2210	846	0.0126	1197	1.41	0.0179	1.30	1099.8	0.0164	109%
Storage	2211	87	0.0013	58	0.67	0.0009	1.10	95.7	0.0014	61%
Office	2212	218	0.0033	261	1.20	0.0039	1.50	327.0	0.0049	80%
Office	2213	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Office	2214	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Office	2215	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Technology Center/Server Rm.	2216	541	0.0081	783	1.45	0.0117	1.50	811.5	0.0121	96%
Electrical Closet	2217	18	0.0003	58	3.22	0.0009	1.30	23.4	0.0003	248%
Kitchen/Copy Rm.	2217	228	0.0034	285	1.25	0.0043	1.40	319.2	0.0048	89%
Shared RLA/Tenant Reception	2218	261	0.0039	330	1.26	0.0049	1.80	469.8	0.0070	70%
Seminar Rm.	2219	436	0.0065	546	1.25	0.0081	1.50	654.0	0.0098	83%
Lecture Classroom	2220	592	0.0088	870	1.47	0.0130	1.60	947.2	0.0141	92%
Discussion Classroom	2221	720	0.0107	1044	1.45	0.0156	1.60	1152.0	0.0172	91%
Discussion Classroom	2222	720	0.0107	1044	1.45	0.0156	1.60	1152.0	0.0172	91%
Discussion Classroom	2223	720	0.0107	1044	1.45	0.0156	1.60	1152.0	0.0172	91%
Lecture Classroom	2224	720	0.0107	1044	1.45	0.0156	1.60	1152.0	0.0172	91%
Career/Conference Rm.	2225	194	0.0029	306	1.58	0.0046	1.50	291.0	0.0043	105%
Consult Rm.	2226	180	0.0027	306	1.70	0.0046	1.50	270.0	0.0040	113%
Storage	2227	137	0.0020	116	0.85	0.0017	1.10	150.7	0.0022	77%
Electrical Closet	2227	95	0.0014	116	1.22	0.0017	1.30	123.5	0.0018	94%
Tenant Office	2228	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Tenant Office	2229	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Tenant Office	2230	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Faculty Work Area	2231	816	0.0122	1566	1.92	0.0234	1.30	1060.8	0.0158	148%

APPENDIX A- Lighting Loads Cont'd

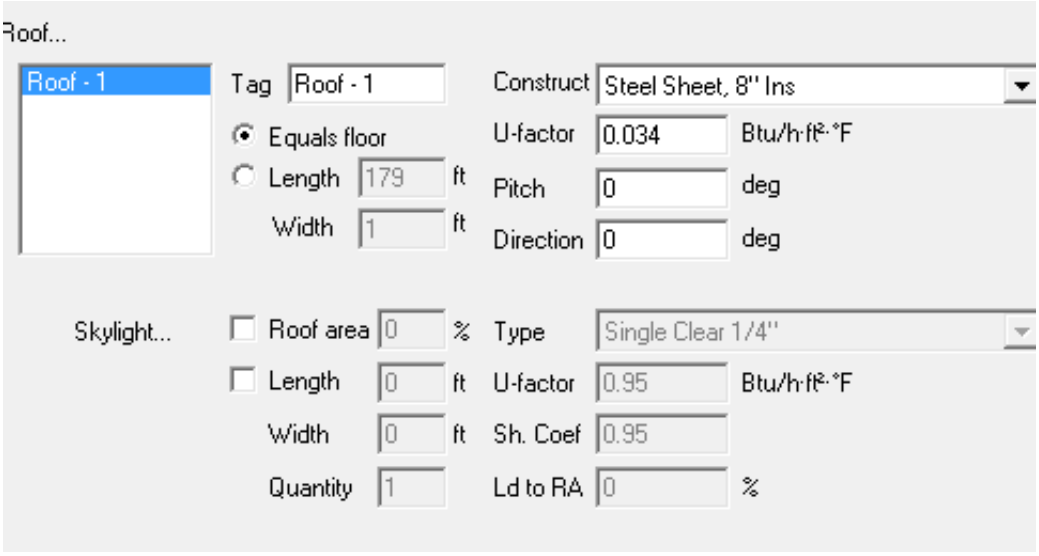
REGIONAL LEARNING ALLIANCE

Lighting Power Allowance Worksheet

Description	Room #	Lighted Floor Area	% Total Floor Area	Design Wattage	Design Watts/ Sq.Ft.	Design Light Level % of Total	Lighting Power Density	Lighting Power Allowance	Base Case Light Level % of Total	Design Wattage/ Allowance
Tenant Office	2232	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Tenant Office	2233	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Tenant Office	2234	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Computer Lab	2235	791	0.0118	1566	1.98	0.0234	1.60	1265.6	0.0189	124%
Tenant Office	2236	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Tenant Office	2237	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Tenant Office	2238	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Tenant Office	2239	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Tenant Office	2240	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Tenant Office	2241	179	0.0027	261	1.46	0.0039	1.50	268.5	0.0040	97%
Women's Restroom/Entry	2250	219	0.0033	506	2.31	0.0075	1.00	219.0	0.0033	231%
Storage	2251	54	0.0008	58	1.07	0.0009	1.10	59.4	0.0009	98%
Janitor's Closet	2252	48	0.0007	58	1.21	0.0009	1.10	52.8	0.0008	110%
Men's Restroom/Entry	2253	219	0.0033	506	2.31	0.0075	1.00	219.0	0.0033	231%
Stair #1		268	0.0040	78	0.29	0.0012	0.90	241.2	0.0036	32%
Stair #3		192	0.0029	78	0.41	0.0012	0.90	172.8	0.0026	45%
Stair #4		192	0.0029	78	0.41	0.0012	0.90	172.8	0.0026	45%
TOTALS		67,040	1.0000	84,978		1.2676		91,104	1.3589	

APPENDIX B- TRACE Construction Input Information

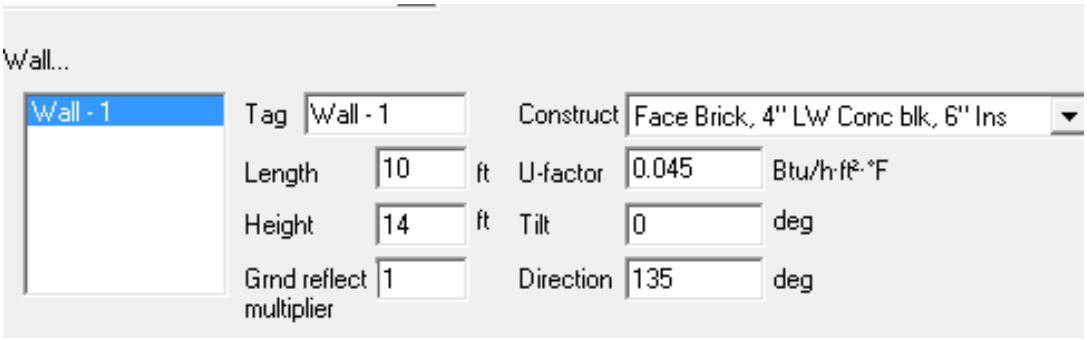
ROOF INPUT VALUES



Majority of the roof is designated as "Built-up roof, steel deck, R-28 insulation" with a U-factor=0.034 BTU/hr-ft2-F.

For modeling purposes, this construction with a similar U-factor was chosen.

WALL INPUT VALUES



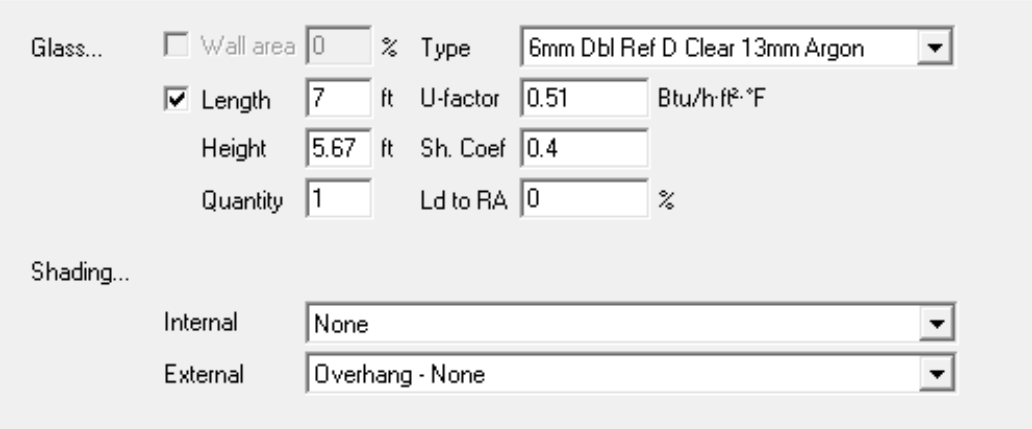
Typical exterior wall composed of 4" face brick, R-19 insulation, 5/8" drywall, and has an overall U-value of 0.045 BTU/ hr-ft2-F.

For modeling purposes, this construction with a similar U-factor was chosen.

The direction of the exterior wall is provided in degrees, with North being designated as zero degrees.

APPENDIX B- TRACE Construction Input Information Cont'd

WINDOW INPUT VALUES



Typical East and West windows are a doube pane assembly, (0.25" Azurlite, 0.625" or 90% Argon fill, 0.25" clear glass), with a low-e film on the third surface and an overall assembly shading coefficient of 0.4.

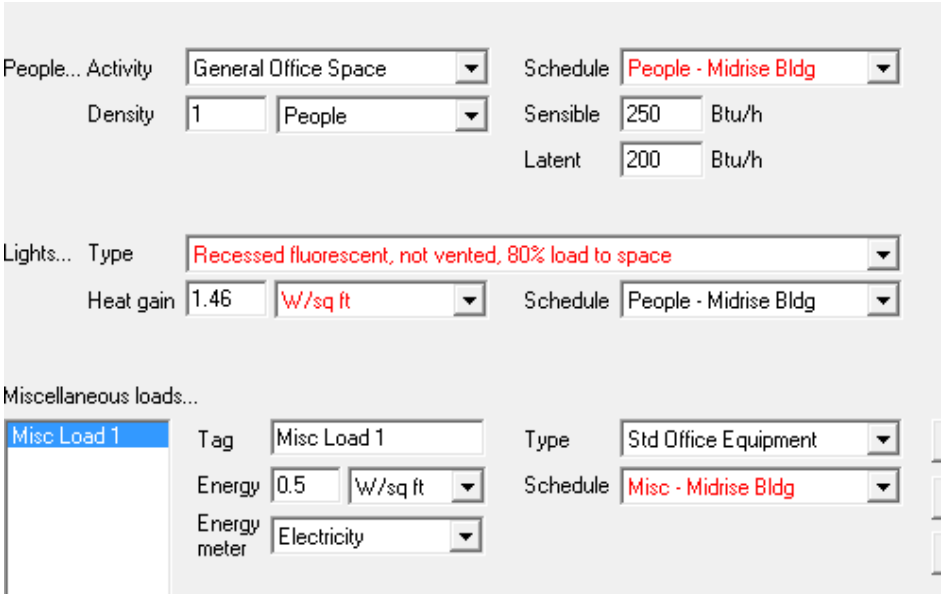
North and South windows have a similar construction, but a shading coefficient of 0.76.

Both windows have an overall assembly U-factor of 0.51 BTU/hr-ft2-F.

Since no construction exactly matched this make up, a default glazing with similar properties was chosen for each window.

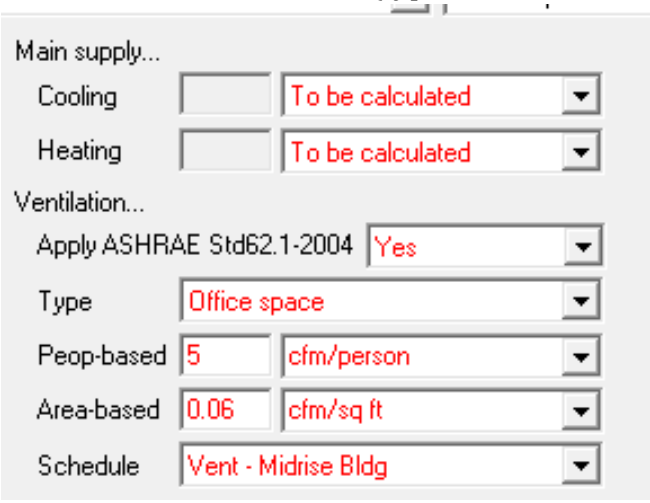
APPENDIX C- TRACE Internal Loads & Airflow Input Information

INTERNAL LOAD INPUT VALUES (typical tenant office)



Note : Where miscellaneous loads were known, each piece of equipment was entered separately with it's corresponding wattage. Miscellaneous loads in the kitchen areas were calculated by adding up all the equipment wattages from the electrical schedules, and inputting an overall wattage/SF value.

AIRFLOW INPUT VALUES (typical tenant office)



Note : ASHRAE Standard 62.1 can be applied during TRACE calculations, or, you can hand enter the outdoor air values from the design documents, as done in this model.

APPENDIX D- TRACE Schedule Input Information

LIGHTING – midrise building

Schedule Definition

	Start	End
Month	January	December
Day type	Cooling design	Weekday

Start time	End time	Percentage
Midnight	6 a.m.	0
6 a.m.	7 a.m.	10
7 a.m.	8 a.m.	50
8 a.m.	5 p.m.	100
5 p.m.	6 p.m.	50
6 p.m.	7 p.m.	10
7 p.m.	Midnight	0

MISC. EQUIPMENT – midrise building

Schedule Definition

	Start	End
Month	January	December
Day type	Cooling design	Weekday

Start time	End time	Percentage
Midnight	6 a.m.	0
6 a.m.	7 a.m.	10
7 a.m.	8 a.m.	30
8 a.m.	11 a.m.	100
11 a.m.	1 p.m.	80
1 p.m.	5 p.m.	100
5 p.m.	6 p.m.	10
6 p.m.	Midnight	0

VENTILATION – midrise building

Schedule Definition

	Start	End
Month	January	December
Day type	Cooling design	Weekday

Start time	End time	Percentage
Midnight	6 a.m.	0
6 a.m.	7 a.m.	50
7 a.m.	5 p.m.	100
5 p.m.	6 p.m.	50
6 p.m.	Midnight	0

PEOPLE – midrise building

Schedule Definition

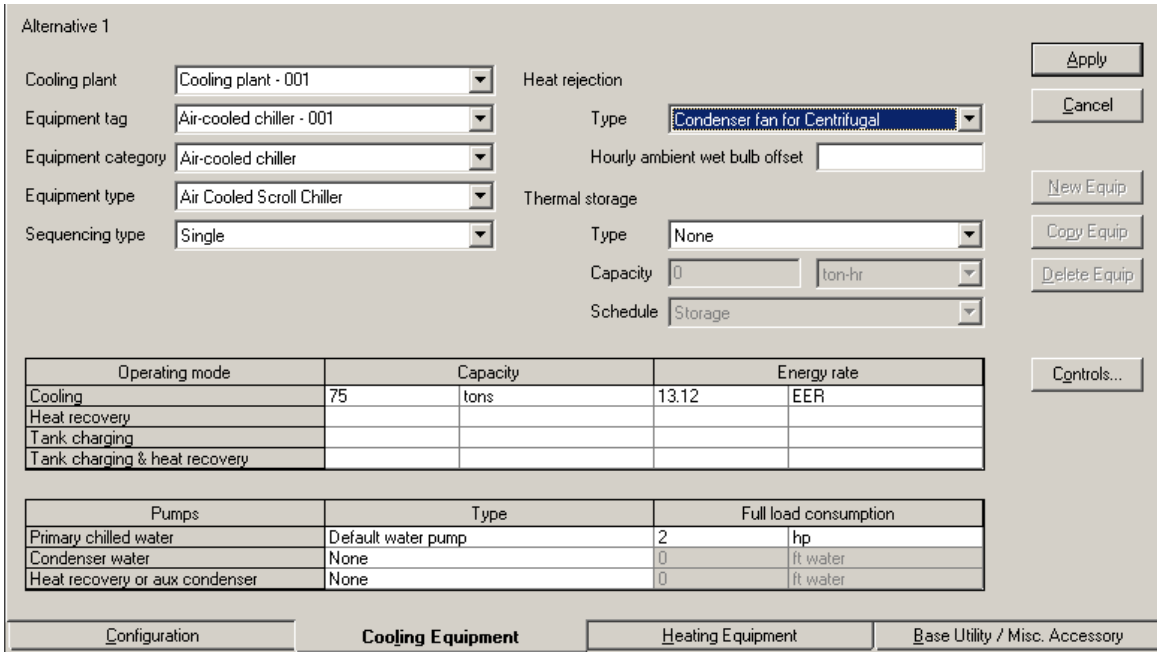
	Start	End
Month	January	December
Day type	Cooling design	Weekday

Start time	End time	Percentage
Midnight	6 a.m.	0
6 a.m.	7 a.m.	10
7 a.m.	8 a.m.	30
8 a.m.	11 a.m.	100
11 a.m.	1 p.m.	80
1 p.m.	5 p.m.	100
5 p.m.	6 p.m.	10
6 p.m.	Midnight	0

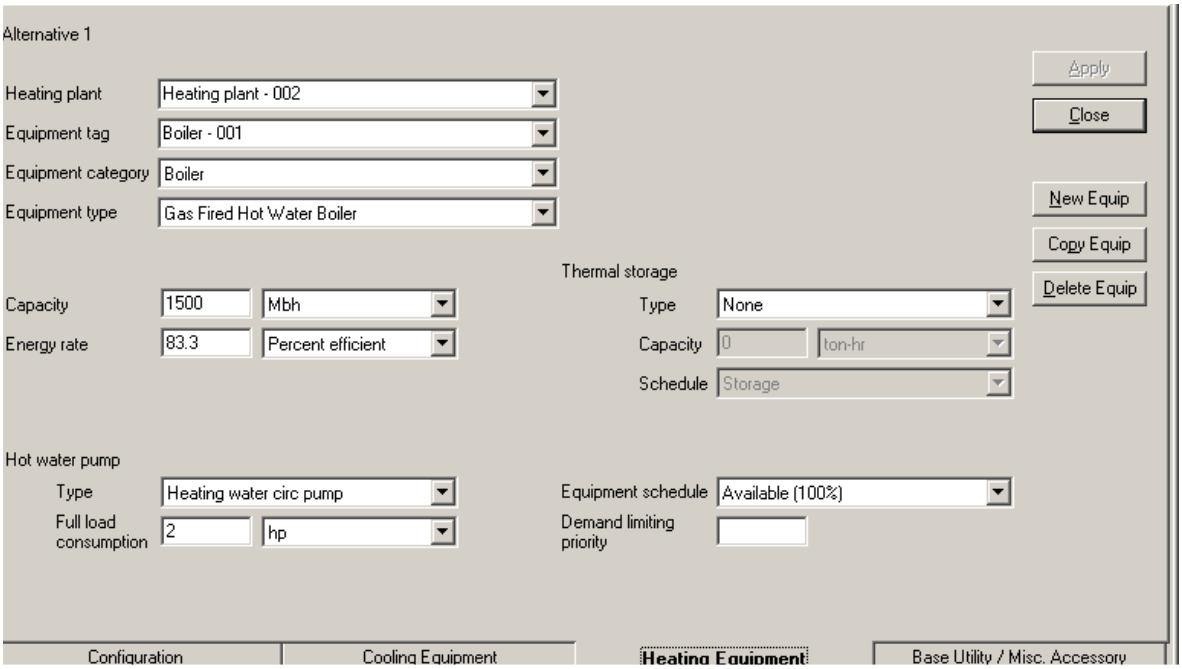
Note : In rooms where lighting is run on occupancy sensors (such as classrooms and office space), the lighting loads were analyzed using the "PEOPLE-midrise building" schedule.

APPENDIX E- TRACE Energy Analysis Input Information

CHILLER (cooling plant input information)

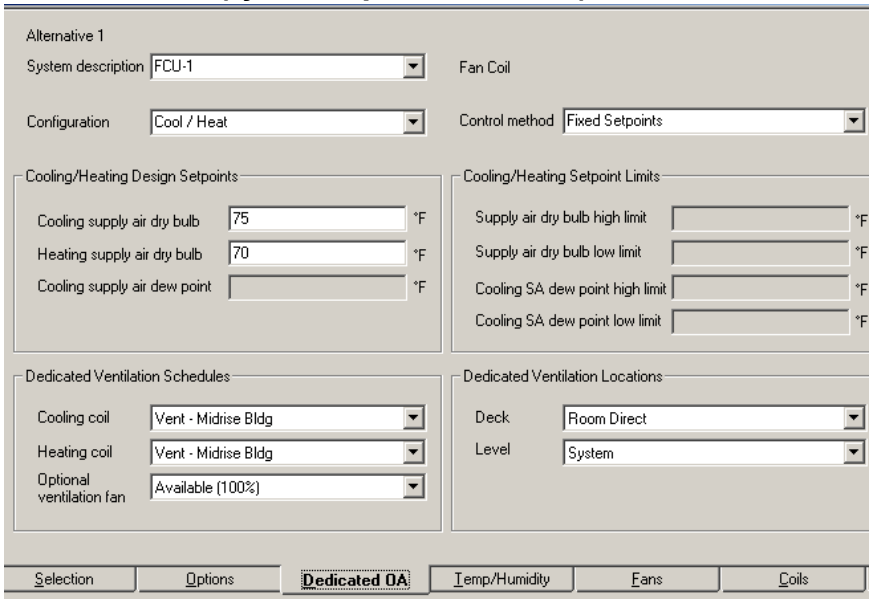


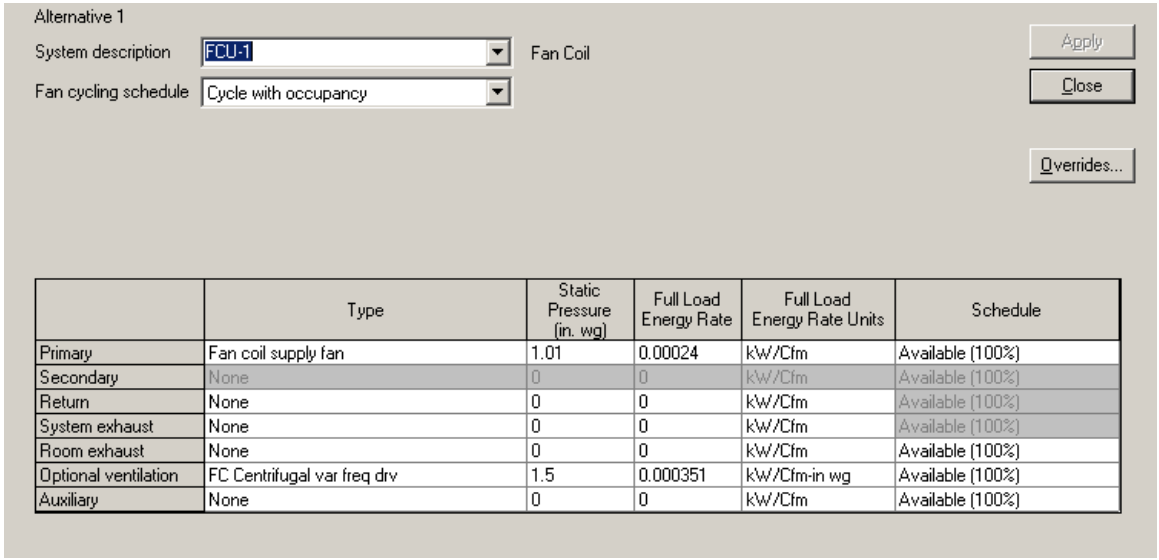
BOILER (heating plant input information)



APPENDIX E- TRACE Energy Analysis Input Information Cont'd

FAN COIL UNIT (system input information)





	Type	Static Pressure (in. wg)	Full Load Energy Rate	Full Load Energy Rate Units	Schedule
Primary	Fan coil supply fan	1.01	0.00024	kW/Cfm	Available (100%)
Secondary	None	0	0	kW/Cfm	Available (100%)
Return	None	0	0	kW/Cfm	Available (100%)
System exhaust	None	0	0	kW/Cfm	Available (100%)
Room exhaust	None	0	0	kW/Cfm	Available (100%)
Optional ventilation	FC Centrifugal var freq drv	1.5	0.000351	kW/Cfm-in wg	Available (100%)
Auxiliary	None	0	0	kW/Cfm	Available (100%)

Note : TRACE's User Manual (page 4-46) was referenced on how to model FCU's with a dedicated outdoor air system. All 50 fan-coil units were inserted as separate systems, using their corresponding static pressures from Mechanical Schedules.

APPENDIX F- ORIGINAL HAP OUTPUT INFORMATION

ANNUAL COST ESTIMATION

Component	Annual Cost ($/yr)	($/ft2)
HVAC COMPONENTS		
Electric	31,507	0.53
Natural Gas	57,614	0.98
SUBTOTALS:	89,121	1.51
NON-HVAC COMPONENTS		
Electric	26,566	0.45
GRAND TOTAL	115,687	2.0

ENERGY CONSUMPTION BY SYSTEM COMPONENT

Component	Site Energy (kBTU)	Site Energy (kBTU/ft2)	Source Energy (kBTU)	Source Energy (kBTU/ft2)
Air System Fans	713,981.0	12.100	2,549,933	43.216
Cooling	678,554.0	11.500	2,423,407	41.072
Heating	1,949,762.0	33.040	1,972,311	33.427
Pumps	156,718.0	2.656	559,706	9.486
HVAC SUBTOTALS	3,499,015.0	59.302	7,505,357	127.201
Lights	925,414.0	15.680	3,305,050	56.014
Electric Equipment	388,266.0	6.580	1,386,666	23.501
NON-HVAC SUBTOTAL	1,313,681.0	22.264	4,691,716	79.515
GRAND TOTALS:	4,812,695.0	81.566	12,197,073	206.717

PERCENTAGE OF ENERGY CONSUMPTION BY SYSTEM COMPONENT

Component	Percentage of Total Building Energy
Air System Fans	14.8
Cooling	14.1
Heating	40.5
Pumps	3.3
Lights	19.2
Electric Equipment	8.1

REFERENCES & WORKS CITED

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