Technical Report Two

Building and Plant Energy Analysis

Defense Information Systems Agency Headquarters Facility

Ft. George G. Meade, MD.

George Slavik III

Mechanical Option

Advisor: Dr. Treado

Table of Contents:

I. - Executive Summary - Pg. 3

II. - Mechanical Systems Revisited – Pg. 4

III. - Design Load Estimation – Pg. 6

IV. – Operations Building Computed Loads – Pg. 9

V. – DISA HQ Total Load Estimation – Pg. 14

VI. – Appendix A- Pg. 17

Executive Summary

In order to better understand the Defense Information Systems Agency (DISA) Headquarters Facility's performance, an energy model simulation run by Trance TRACE 700 software was performed. This simulation helped calculate cooling loads, energy consumption, and various costs to run the building.

The simulation was simplified due to the size of this project (1,000,000 + SF) and time constraints, as this model took the Engineer months to complete. An energy model of the Operations building which is typical office space for the rest of the facility was completed. The energy model yielded results that seemed reasonable. The electricity use was dominated by plug loads, which makes sense when considering the use of the building. The calculated heating and cooling loads were a bit off when compared to the results of the Engineer's energy model. The cooling load had a 35% error, while the heating load had a 17% error. Although the $/SF of the office space is high compared to typical office space, this facility has much more equipment than a typical office building. The estimated annually energy consumption for the DISA HQ was found to be $ 2,814,385.50.

II. Mechanical System Revisited

The DISA HQ includes six integrated buildings organized in a campus layout. The facility is comprised of six connected buildings: Command, Operations, Acquisitions, Lab, Warehouse and Central Plant. The program contains about 70% office spaces, 7% lab spaces, and 10% common spaces.

The air systems served by the Central Utility Plant (CUP) were selected as follows:

Office Space

An Under Floor Air Distribution (UFAD) system to make full use of the 18" raised access floor and provide individual comfort control for the building occupants, and high energy efficiency when coupled with central roof level custom air handling equipment delivering low pressure air. The decision to place the AHU equipment on the roof rather than in AHU rooms is intended to maximize usable program area in the buildings.

Lab

To serve this high load area efficiently, a system of variable volume vertical air flow, Chilled Water (CHW) AHU's designed specifically for use in data centers will be coupled with a direct injection outdoor air system to provide ventilation air at a constant dewpoint for humidity control.

This system best meets the unique needs of what is in effect a data center with high personnel occupancy. The AHU's will be enclosed in a mechanical space to one side of each floor of the lab, in contrast with CRAC units which are typically placed in the space. This will minimize the noise contribution to the space from these units.

Common (Multiuse) Area:

The lower floor contains the Cafeteria, Kitchen and Health/Wellness functions which are not suited for the use of a raised access floor. The HVAC systems for these areas are conventional overhead VAV with roof mounted AHU's. The second floor contains the Conference Center and Training functions which utilize a raised access floor. These areas are also suitable for the use of a UFAD system, to maximize the comfort and energy efficiency of these areas.

Special Use Spaces:

These are mainly high load equipment areas, some without occupancy, some with people and equipment and some with people and normal computer loads. These areas are all on raised access floors and will be handled with chilled water Computer Room Air Conditioning (CRAC) units in

combination with a direct injection outside air system to provide ventilation air at a constant dew point for humidity control; in general, other ventilation methods are also used for some areas.

Mission Critical Spaces:

Certain spaces are Mission Critical; therefore HVAC equipment for these spaces must operate on the generator when required, together with part of the central chilled water plant and key components of the Building Automation System (BAS), to enable the Mission Critical spaces to continue uninterrupted operation. In addition some HVAC equipment is required to be redundant to increase reliability.

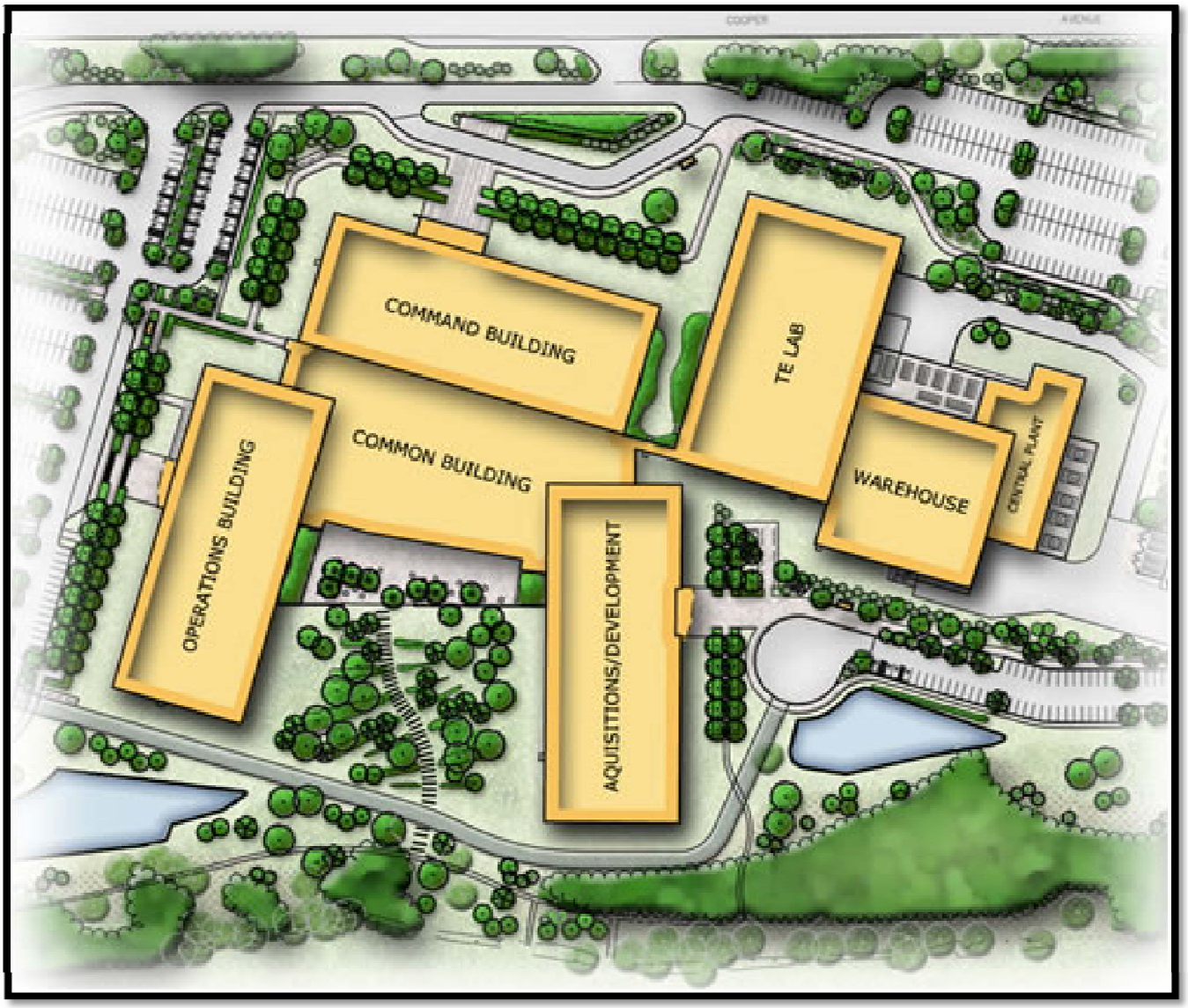

Figure II.1- Site Layout

III. Design Load Estimation

Trane Air Conditioning Economics (TRACE) 700H software was used as the building simulation program to estimate the design loads for the DISA HQ. In order to accurately calculate the design loads, information from the design documents were used.

TRACE takes in account both external and internal loads on the building. The external cooling/heating loads are due to heat gain/loss through the exterior building envelope. The internal loads are generated by Mechanical/Electrical Equipment, lighting, plug loads, and the building's occupants.

Do to the scale of this project (1,040,000 $ft^{2)}$ and time constraints the energy load simulation had to be simplified. The block load calculation was performed for the Operations Building. This was chosen due to the fact that is the larger of the office buildings. The remaining office buildings contain the same Mechanical system, along with similar loads. The special use spaces will be estimated using design documents. The high tech Lab spaces will have extremely high loads (37 W/SF), and do to the secure nature of the space. Not enough information was provided to perform an energy model. This area will also be estimated using the design documents and compared to the energy model used by the design team.

In order to ensure correct data and computer inputs, information was obtained from the design documents.

Building Enclosure Construction

Using the design documents, the building's areas, orientation, ventilation rates, and loads were entered into the simulation program. The table below summarizes the thermal resistive properties of the building.

Building Enclosure Construction			
Building Component	U-Value (Btu/hr-ft^2-°F)	SHGC	SC
Roof	0.034 (R-30 Equivalent)	-	-
Walls	0.08 (R-19 Equivalent)	-	-
Glass	0.46 (Double Glazed)	0.25	0.29

Figure III.1- Building Enclosure Construction

Outdoor Air Ventilation Rates

All outdoor air ventilation rates were taken from the mechanical equipment schedules in the design documents.

				SUPPLY AIR FAN				
ID TAG	MANUFACTURER/MODEL	LOCATION	SERVICE	# FANS	FAN AIRFLOW (cfm)	UNIT AIRFLOW (cfm)	OUTSIDE AIR (cfm)	SA TEMP (°F)
O-AHU-1	BUFFALO	OPERATIONS ROOF	OFFICE UFAD LEFT CORE	1	38,000	38,000	7,030	62
O-AHU-2	BUFFALO	OPERATIONS ROOF	OFFICE UFAD CENTER CORE	2	25,250	50,500	9,345	62
O-AHU-3	BUFFALO	OPERATIONS ROOF	OFFICE UFAD RIGHT CORE	2	22,500	45,000	8,325	62

Figure III.2- Operations Building UFAD AHU Schedule

Internal Loads

The lighting and the electrical equipment loads for the DISA HQ were input on a W/SF basis, and were found in the design documents. The occupancy assumption was based on the RFP. The occupant's load is based on ASHRAE Handbook of Fundamentals 2005- Low Rise Office Buildings.

Internal Load Assumptions	
Load	Assumption
Lighting	0.72 W/SF
Misc. Plug Loads	1.5 W/SF
Occupants	143 SF/Person
Occupants- Sensible	250 BTU/H
Occupants-Latent	200 BTU/H

Figure III.3- Internal Loads

Design Indoor and Outdoor Air Conditions

The design indoor air conditions were specified by the RFP, while the outdoor air conditions were obtained from the ASHRAE Handbook of Fundamentals 2005 and are noted below in Figure III. 4.

Outside Temperature and Humidity Conditions (ASHRAE Fundamentals 2005)	
Outside Design Conditions	**Summer**
Dry bulb and coincident wet bulb - Envelope	93.6°F DB/75.0°F WB
Wet bulb and Coincident dry bulb – 100% OA Coils	77.2°F DB/82.4°F WB
Wet bulb for evaporative heat rejection	78.1°F WB
Outside Design Conditions	**Winter**
Dry bulb and Humidity Ratio (HR)	12.3°F at 4.6 gr/lb

Figure III.4- Design Outdoor Conditions- Baltimore, MD.

Indoor Design Conditions	
Space	**Summer T°F / % RH/ Winter Temp°F**
Open Offices	75/50/72
Private Offices	75/50/72
Server Rooms	65-68/MAX 60/65-68
Lab Areas	65-68/MAX 60/65-68
Ftiness	68/MAX 60/68
Dining	75/MAX 60/72

Figure III.5- Design Indoor Conditions

IV. Computed Loads

An energy analysis was performed by the engineer of the project using Trane TRACE 700. This will be used for comparison and accuracy purposes. This was also used to help estimate the loads for the specialty spaces, and high security lab.

The figures below will show the results of the computed cooling and heating loads as well as energy use summaries for the Operations building. Also included are the related Engineer's calculated building loads which can be used as a comparison.

COOLING LOAD SUMMARY				
AHU	Total Load(Tons)	A/C Area (ft^2)	ft^2/ton	Peak
O-AHU-1	141.2	57,767	409	15-Jul
O-AHU-2	211.2	80,460	381	15-Jul
O-AHU-3	171.8	63,379	369	15-Jul
Total	524.2	201,606	386.3	

Figure IV.1- Calculated Operations Building Cooling Load

COOLING LOAD SUMMARY				
AHU	Total Load(Tons)	A/C Area (ft^2)	ft^2/ton	Peak
O-AHU-1	92.8	57,767	622	15-Jul
O-AHU-2	137.0	80,460	587	15-Jul
O-AHU-3	112.6	63,379	563	15-Jul
Total	342.4	201,606	590.7	

Figure IV.2- Engineer's Calculated Operations Building Cooling Load

COOLING LOAD ERROR			
AHU	Calculated ft^2/ton	Engineer's ft^2/ton	% Error
O-AHU-1	409	622	34%
O-AHU-2	381	587	35%
O-AHU-3	369	563	34%
Total	386.3	590.7	35%

Figure IV.3- Calculated vs. Engineer's calculated %Error

HEATING LOAD SUMMARY			
Building	Total Load(MBH)	A/C Area (ft^2)	BTU/SF
Operations	3012.0	201,606	14.94

Figure IV.4- Calculated Operations Building Heating Load

HEATING LOAD SUMMARY			
Building	Total Load(MBH)	A/C Area (ft^2)	BTU/SF
Operations	2505.0	201,606	12.43

Figure IV.5- Engineer's Calculated Operations Building Heating Load

HEATING LOAD ERROR			
Building	Calculated BTU/SF	Engineer's BTU/SF	% Error
Operations	14.94	12.43	17%

Figure IV.6- Calculated vs. Engineer's Calculated %Error

Utility	Rate
Blended Elec Rate	$0.169/KWH
Blended Gas Rate	$1.367/Therm

Figure IV.7- BGE- Baltimore Gas & Electricity Utility Rates

Load	Source	Energy (10^6 BTU/yr)	% of Total	Cost	% of Total
Lighting	Elec	1369	6%	$34,225	6%
Heating	Gas	1146	5%	**$14,909**	3%
Cooling	Elec	1544	6%	$38,600	7%
Pumps	Elec	561	2%	$14,025	2%
Cooling Towers	Elec	37	0%	$925	0%
Fans	Elec	1697	7%	$42,425	7%
Plugs	Elec	17428	73%	$435,700	75%
TOTALS				**$580,809**	

Figure IV.8- Operations Building Annual Energy Use Summary

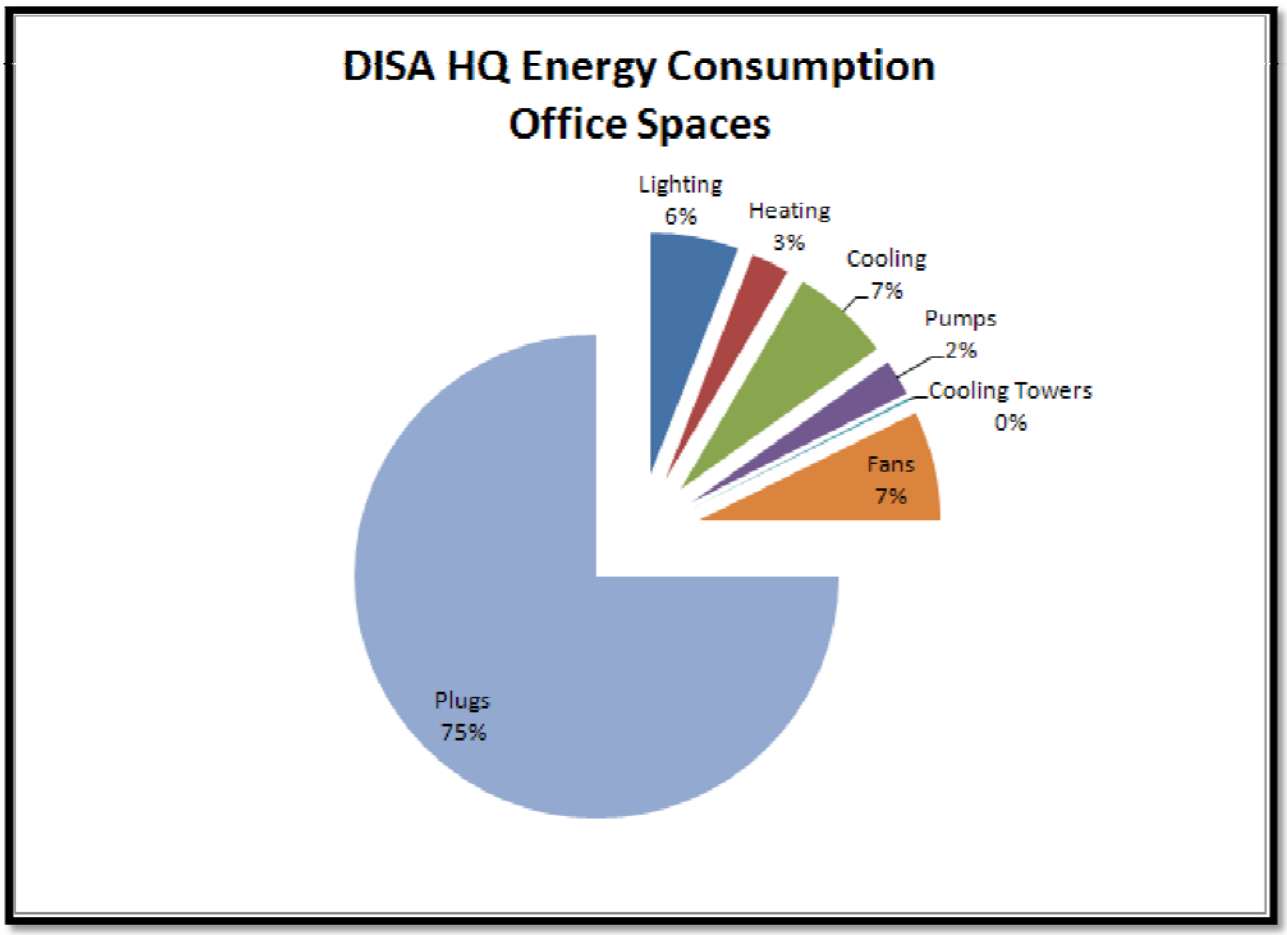

Figure IV.9- Operations Building Annual Energy Use Breakdown

Figure IV.9 above shows that the office space energy consumption is dominated by plug loads. This is due to the nature of the space. The majority of the facility is office space which leads to high plug loads, along with the energy intense TE Lab space (37 W/SF).

Source	Energy (10^6 BTU/yr)	% of Total	Cost
Gas	1146	5%	$14,909
Elec	22636	95%	$565,900

Figure IV.10- Operations Building Annual Energy Expense Summary

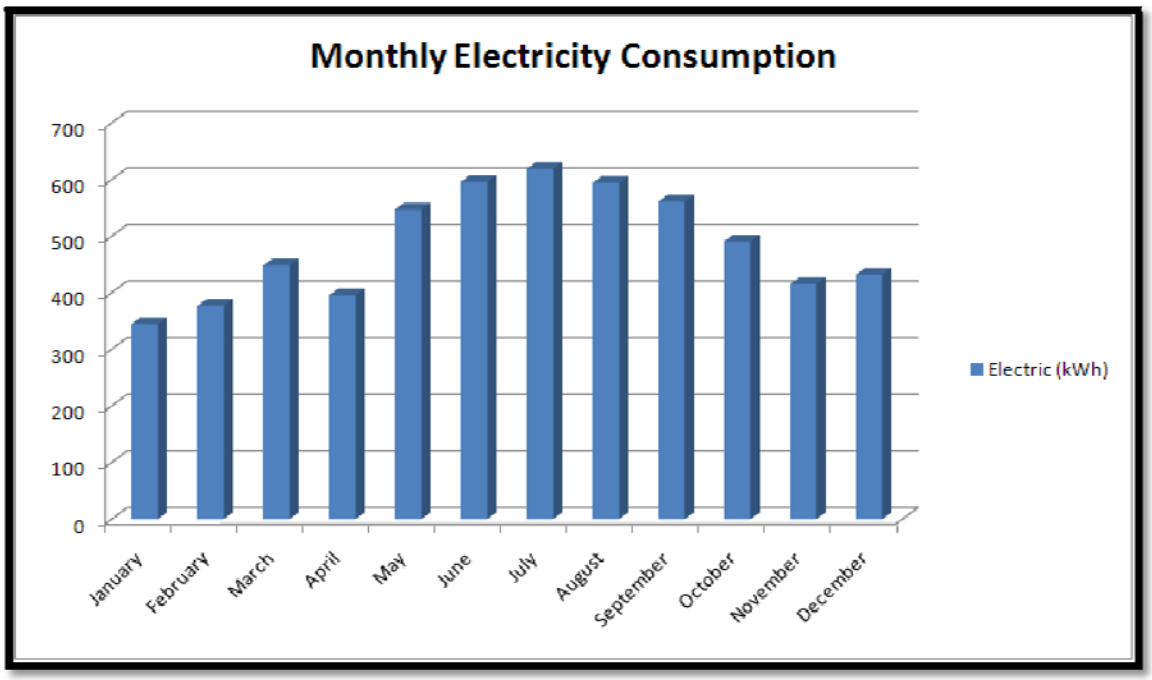

Figure IV.10- Operations Building Monthly Electricity Consumption

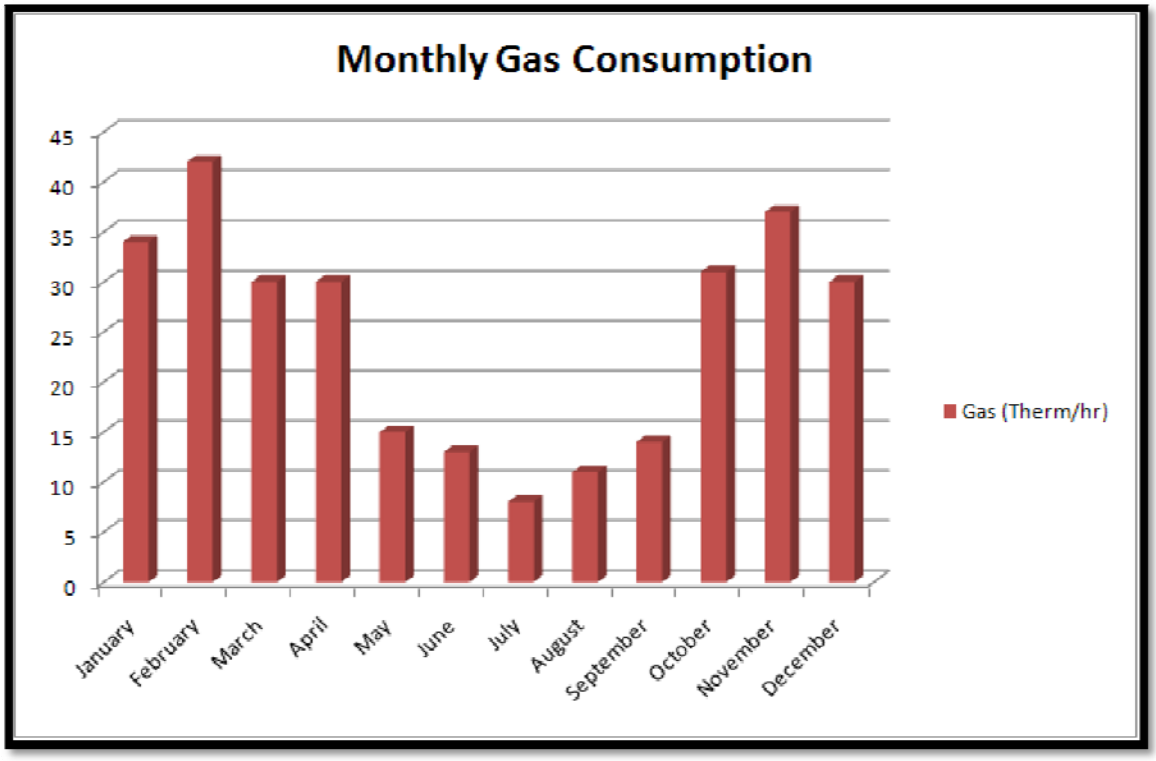

Figure IV.11- Operations Building Monthly Natural Gas Consumption

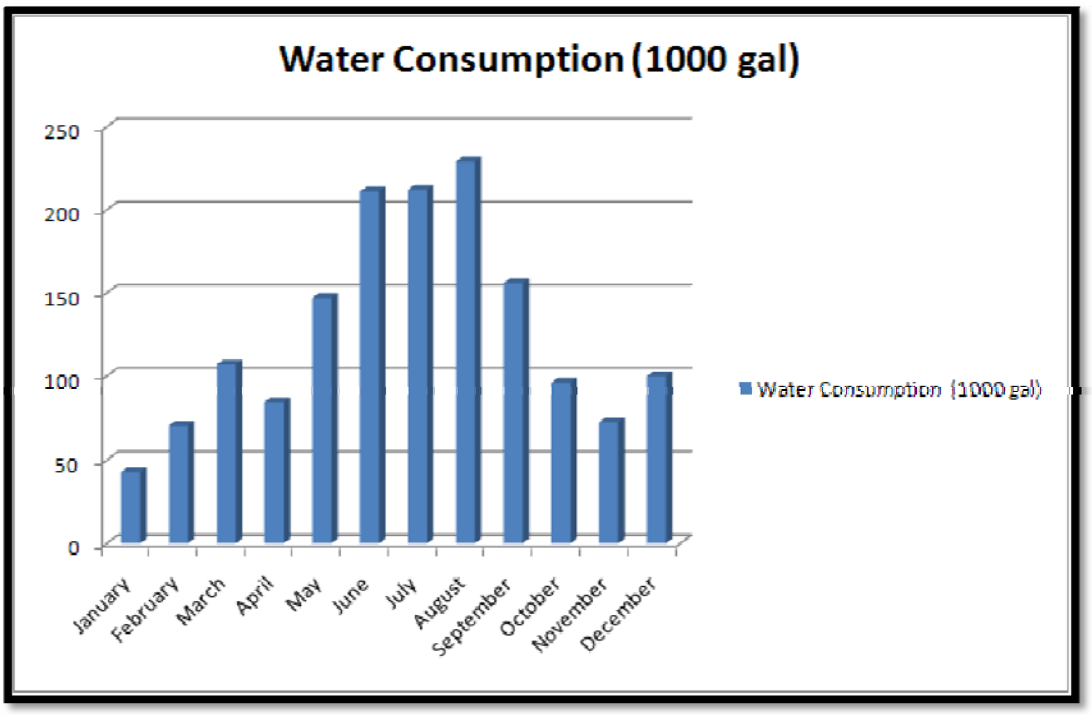

Figure IV.12- Operations Building Monthly Water Consumption

V. DISA HQ Total Load Estimation

As previously discussed, the TRACE energy model was only created for the Operations building. Therefore, an estimation must be made for the rest of the headquarters facility. The most accurate method to compute this estimation was to use the Engineer's TRACE block load summaries for the remaining buildings which were not included in this model. These buildings include Command, Acquisitions, Common, Lab, and Warehouse.

The Operations building was chosen due to the fact that the majority of this facility (70%) is office building very typical to that found in the Operations building. The high-security lab has extremely high cooling loads due to equipment loads.

Space Type	% of Total	Area (Ft^2)
Office	70	728,000
Lab	7	72,800
Common	10	104,000
Circulation/Storage	13	135,200
TOTAL		**1,040,000**

Figure V.1- Program Area Breakdown

Figure V.2 below shows the heating loads for the DISA HQ. The operations building uses the heating load results of the Trane TRACE model constructed. The remaining building's heating loads were found in the design documents. The total heating load was found to be 14, 333 MBH.

HEATING LOAD SUMMARY				
Building	Total Load(MBH)	A/C Area (ft^2)	BTU/SF	Note
Operations	3012.0	201,606	14.9	Calculated
Command	2824.0	231,926	12.2	Design Doc.
Acquisitions	3027.0	267,468	11.3	Design Doc.
Common	3653.0	109,350	33.4	Design Doc.
Lab	1061.0	91,704	11.6	Design Doc.
Warehouse	756.0	14,705	51.4	Design Doc.
TOTAL	**14,333**			

Figure V.2- DISA HQ Heating Load Summary

Figure V.3 below shows the cooling loads for the DISA HQ. The operations building uses the cooling load results of the Trane TRACE model constructed. The remaining building's cooling loads were found in the design documents. The peak cooling load was on 4,160 tons on July 15th.

COOLING LOAD SUMMARY				
Building	Total Load(Tons)	A/C Area (ft^2)	ft^2/ton	Note
Operations	342.4	201,606	590.7	Calculated
Command	1164.0	231,926	199	Design Doc.
Acquisitions	621.0	267,468	431	Design Doc.
Common	467.0	109,350	234	Design Doc.
Lab	1363.0	91,704	67	Design Doc.
Warehouse	32.0	14,705	457	Design Doc.
TOTAL	**3989.4**			

Figure V.3- DISA HQ Cooling Loads

The overall energy cost for the DISA HQ has been estimated, due to the scale of the campus. The office space energy cost was estimated based on the $/SF for the Operations building found in Figure V.4.

Building Area (SF)	**201,606**
$/sf/yr	**$2.88**

Figure V.4- Operations Building Annual Energy Cost Summary

DISA HQ ANNUAL ENERGY COST ESTIMATE				
Building	Area (ft^2)	$/SF	Note	
Operations	201,606	$ 2.88	$ 580,625.28	Calculated
Command	231,926	$ 2.88	$ 667,946.88	Design Doc.
Acquisitions	267,468	$ 2.88	$ 770,307.84	Design Doc.
Common	109,350	$ 2.88	$ 314,928.00	Design Doc.
Lab	91,704	$ 5.00	$ 458,520.00	Design Doc.
Warehouse	14,705	$ 1.50	$ 22,057.50	Design Doc.
TOTAL			**$ 2,814,385.50**	

Figure V.5-DISA HQ Annual Energy Cost Estimate Summary

The estimated annually energy consumption for the DISA HQ is $ 2,814,385.5. The estimated used a $/SF summary to estimate the remaining office areas, along with a rule of thumb for the Lab & Warehouse space.

This estimate was close to the $3,200,000.00 annual energy consumption that the Engineer estimated for this project using TRACE.

The electricity and natural gas used in the DISA HQ will produce pollutants. Listed below in figures V.6 & 7, are the amount of pollutants (lb) that will be added to the atmosphere as a direct result of the energy use at the DISA HQ.

Pollutant	MD (lb/kWh)	Total Pollutants From Electricity
CO_{2e}	1.82E+00	6.07E+07
CO_2	1.71E+00	5.70E+07
CH_4	4.02E-03	1.34E+05
N_2O	3.54E-05	1.18E+03
NO_X	3.10E-03	1.03E+05
SO_X	1.11E-02	3.70E+05
CO	1.19E-03	3.97E+04
TNMOC	7.74E-05	2.58E+03
Lead	1.16E-07	3.87E+00
Mercury	3.56E+08	1.19E+16
PM10	9.25E-05	3.08E+03
Solid Waste	1.69E+01	5.64E+08

Figure V.6- Pollutants Resulting From Electricity Use

Pollutant	MD (lb/kWh)	Total Pollutants From Natural Gas
CO_{2e}	1.23E+02	8.60E+08
CO_2	1.22E+02	8.53E+08
CH_4	2.50E-03	1.75E+04
N_2O	2.50E-03	1.75E+04
NO_X	1.11E-01	7.76E+05
SO_X	6.03E-03	4.22E+04
CO	9.33E-03	6.52E+04

Figure V.7- Pollutants Resulting From Natural Gas Use

APPENDIX A

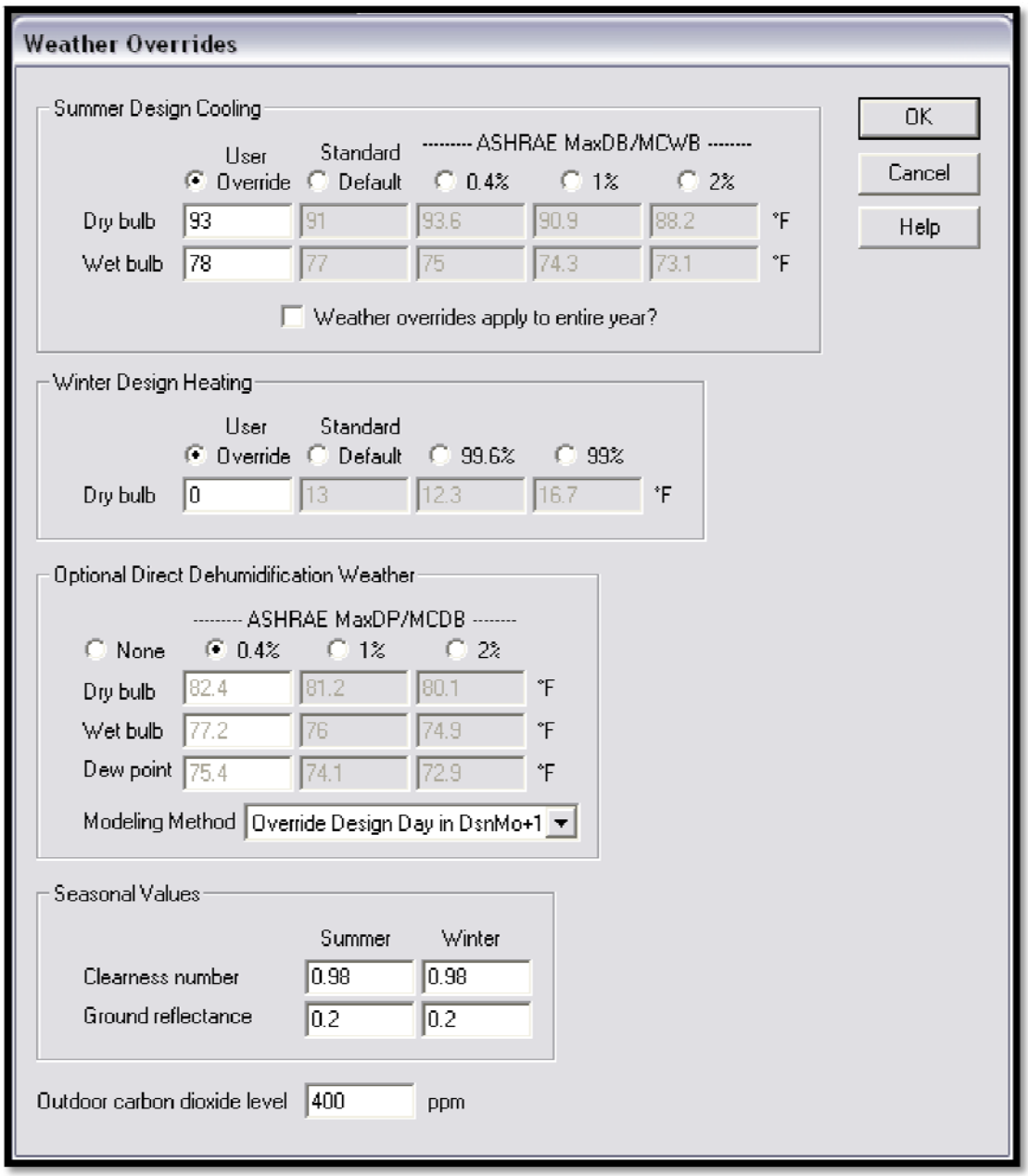

Figure A-1- ASHRAE Weather Data Input

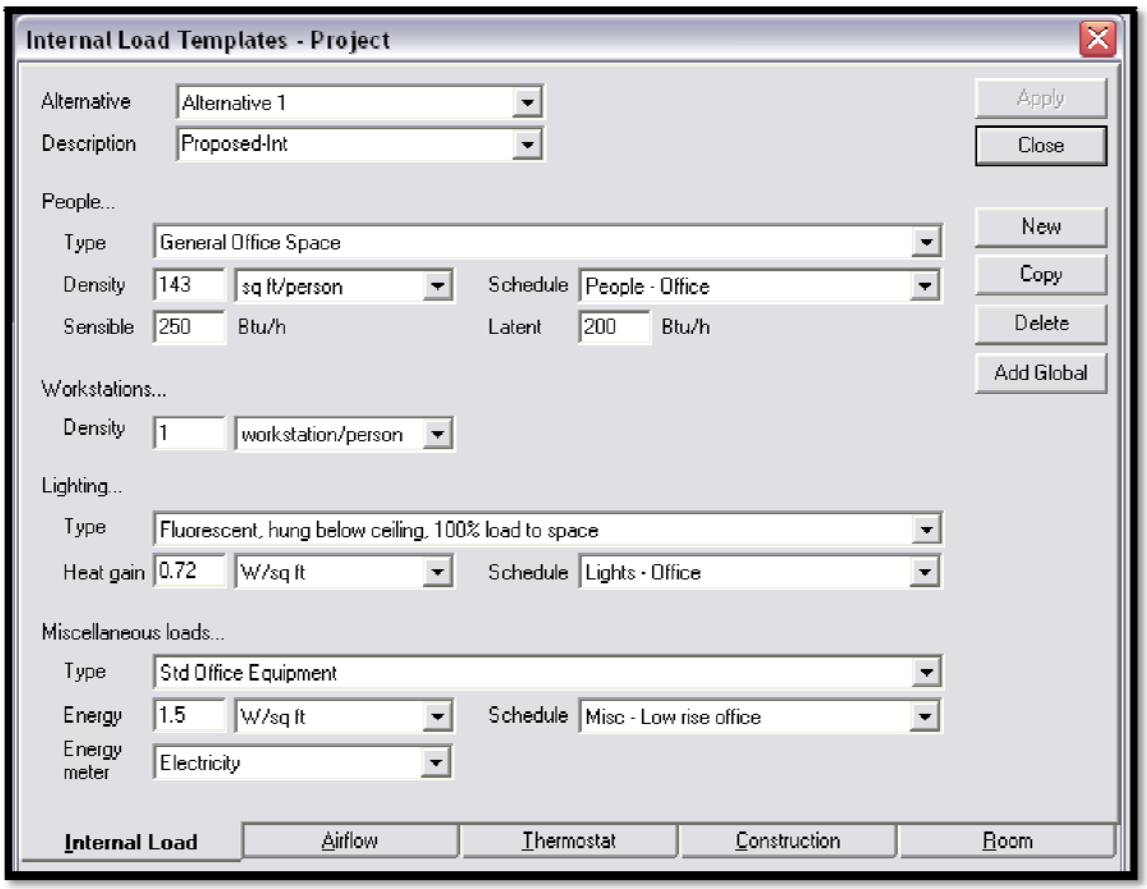

Figure A-2- Typical Office Template Input

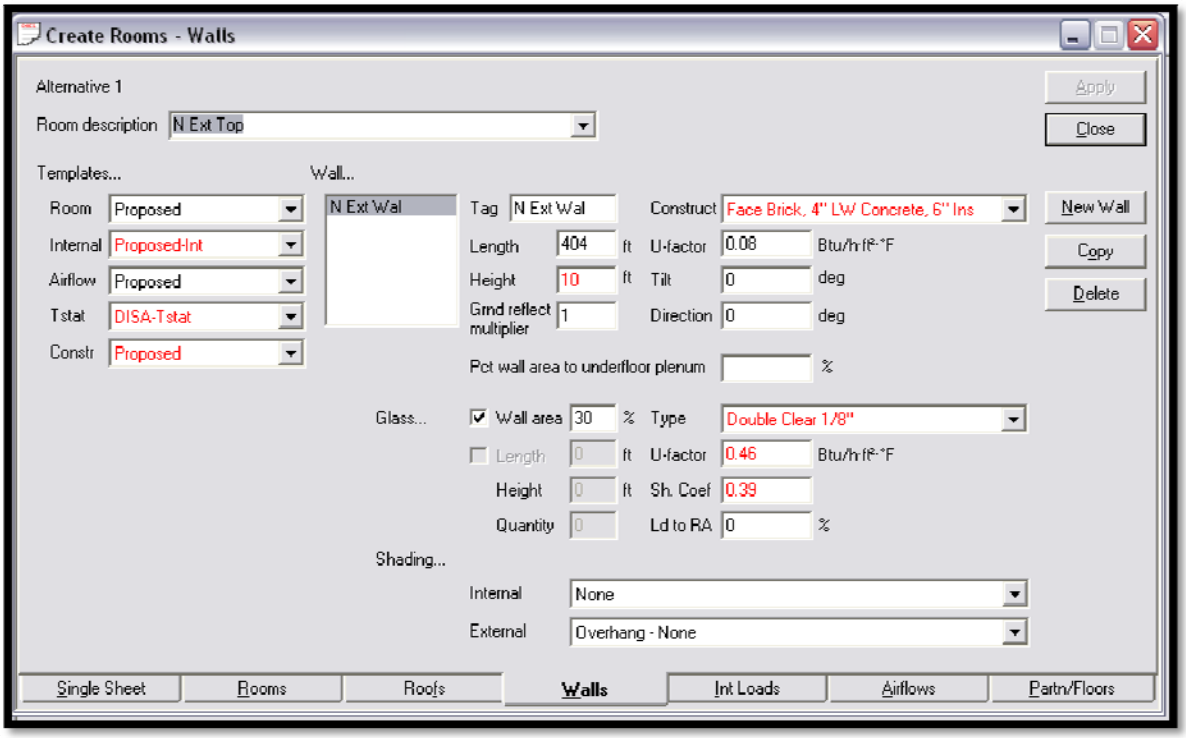

Figure A-3 Typical Wall Construction Input

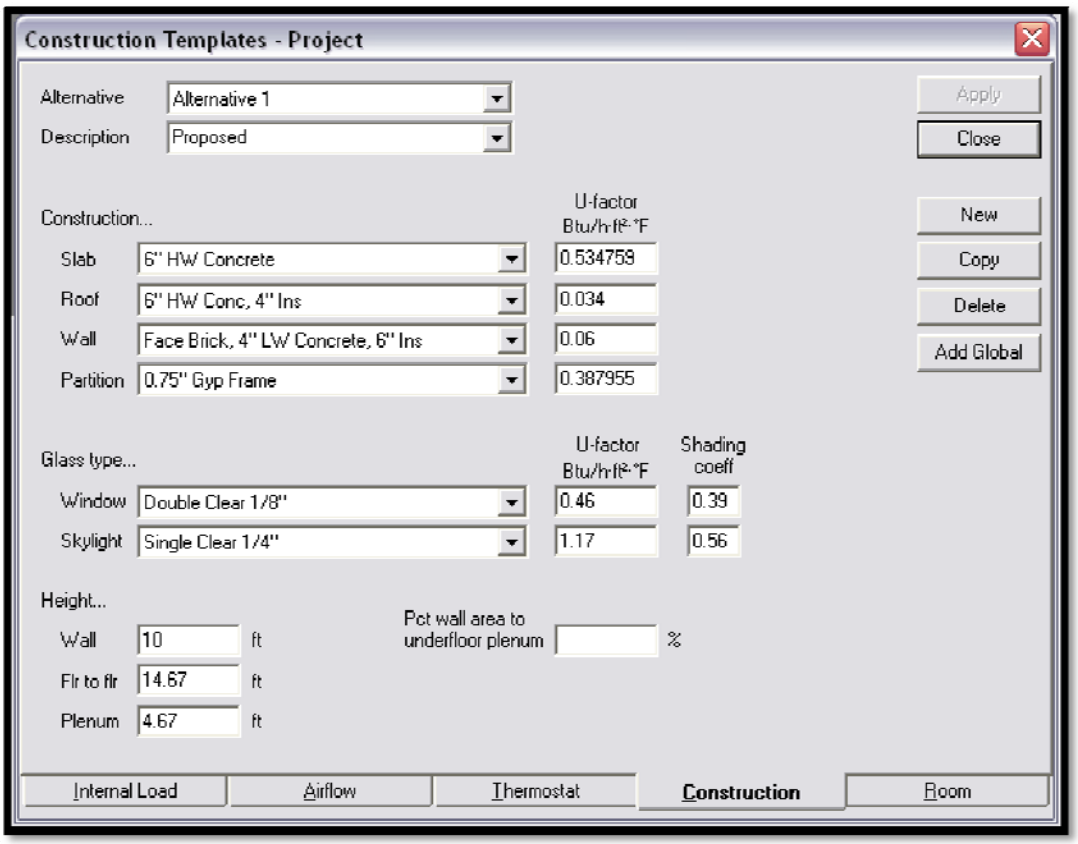

Figure A-4- Typical Construction Material Properties Input

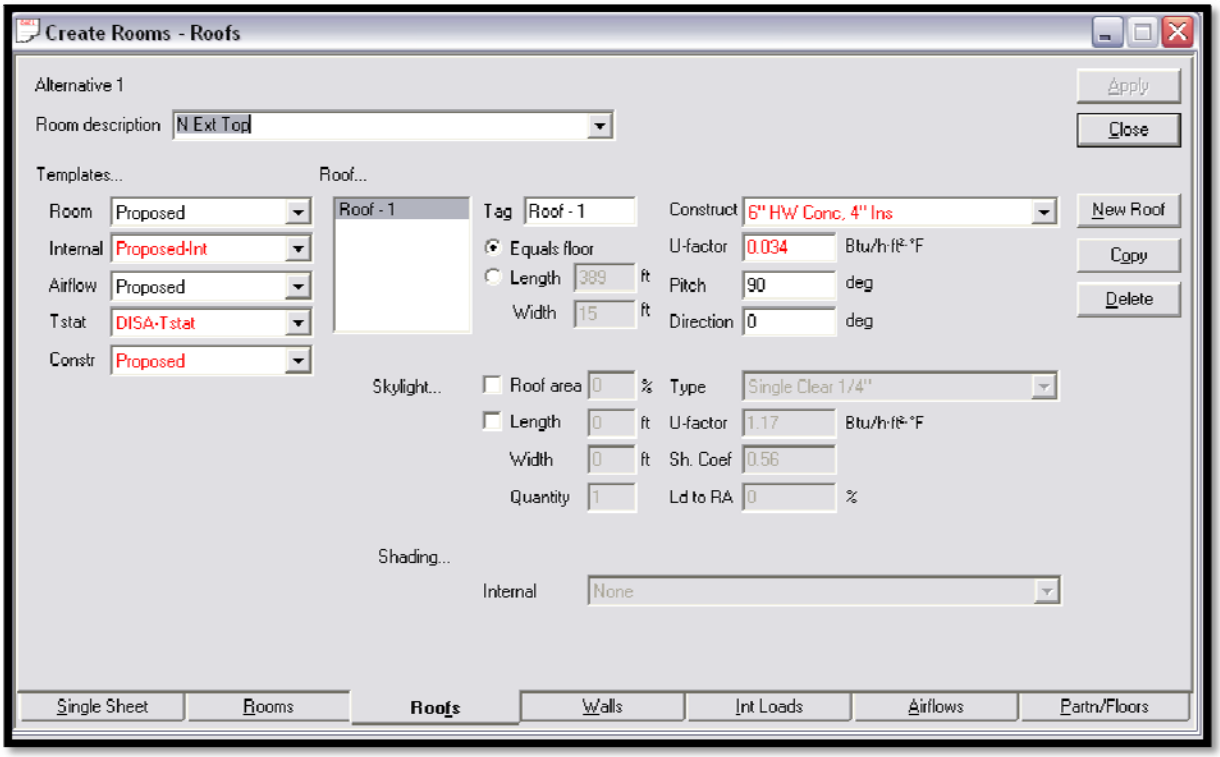

Figure A-5- Typical Roof Material Properties Input

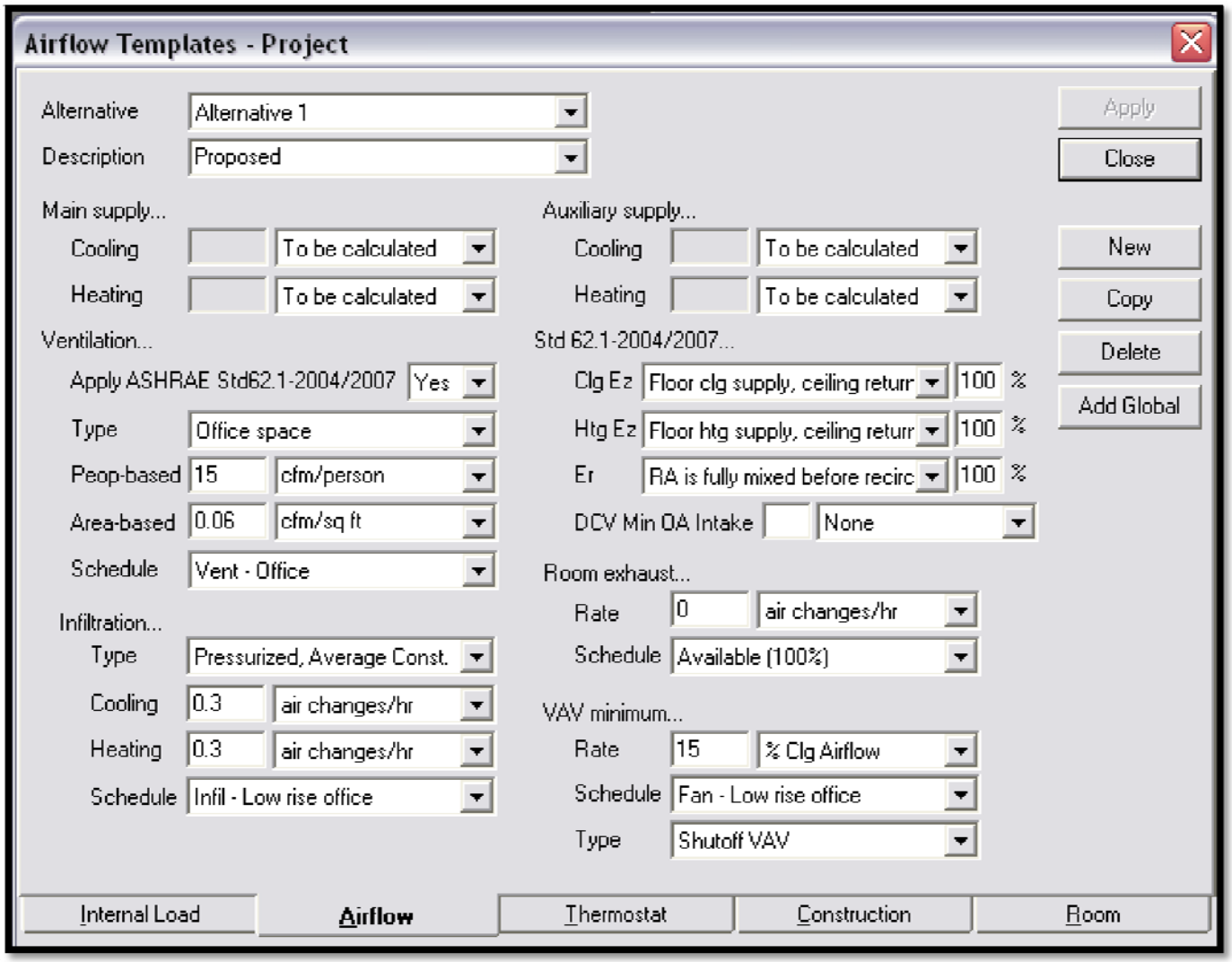

Figure A-6-Typical Room Airflow Input

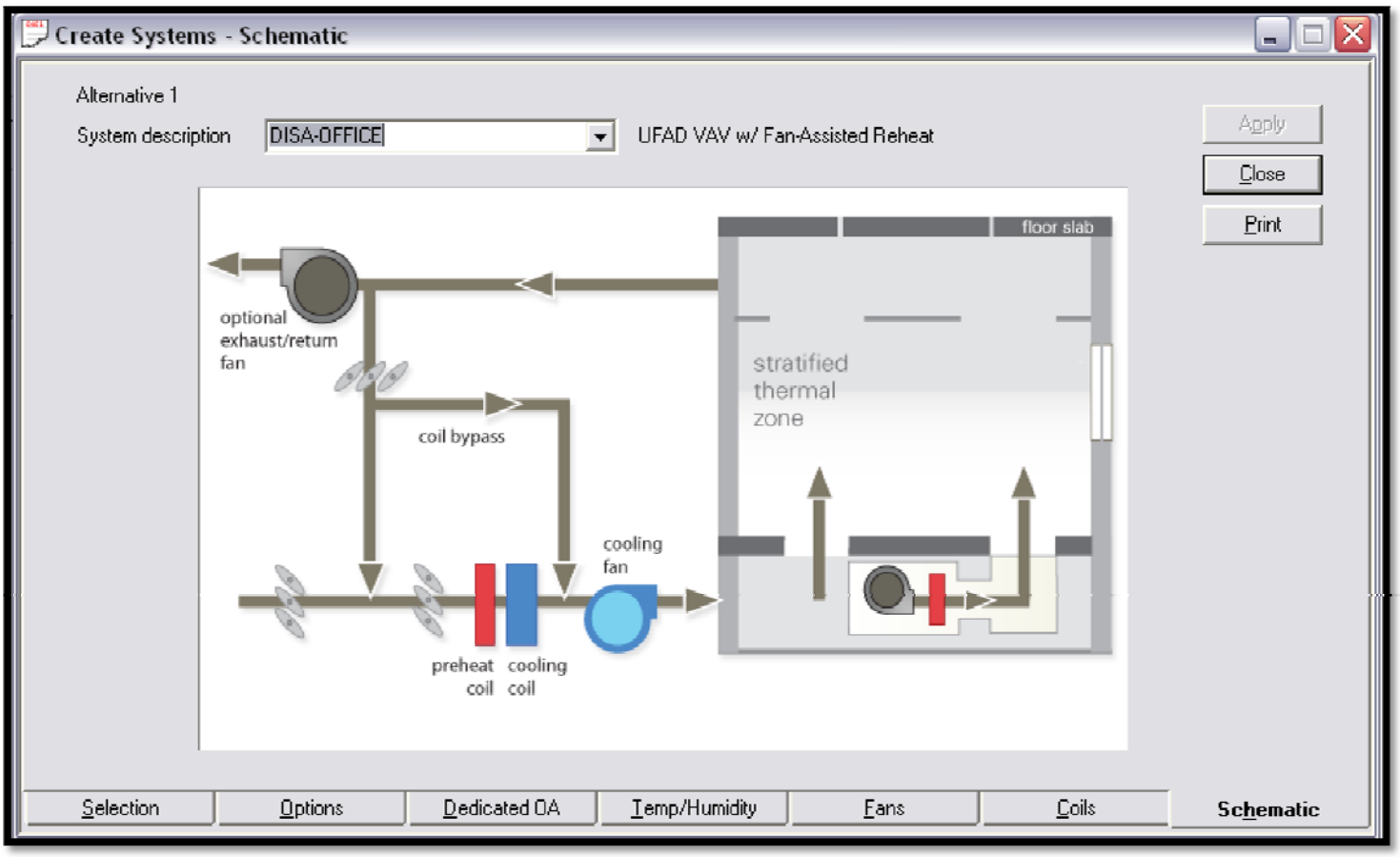

Figure A-7- DISA HQ Operations Building Schematic