COMMERCIAL BUILDING HVAC
ENERGY USAGE IN SEMI-TROPICAL CLIMATES

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ABSTRACT

The design of heating and cooling equipment in semi-tropical climates presents some design considerations and limitations not so prevalent in temperate climates. In some cases, the heating season may be non-existent for all practical purposes. Another consideration is the high ventilation loads due to cooling the moist air prevalent in semi-tropical climates. This paper describes a computer program which assesses all the pertinent variables which comprise the annual heating and cooling energy requirements for commercial buildings. It is then suggested that this computer program would be valuable in determining the changes one could expect in annual energy usage by varying certain building design parameters. Secondly, a small office building actually constructed in Central Florida in which the author designed the Heating and Cooling HVAC system is described. Tradeoffs are presented showing the effects of changes in these building design parameters.

INTRODUCTION

The design of heating and cooling equipment in semi-tropical climates presents some design considerations and limitations not so prevalent in temperate climates. First of all, the average cooling season is increased as compared to temperate climates with a corresponding decrease in the heating season. In some cases, the heating season may be non-existent for all practical purposes. Many older commercial buildings in Central Florida made no provisions whatsoever for heating plants where the normal occupancy is for just an eight hour day. For these conditions, the mechanical designer relied on the "heat of lights" and the heat gain from building occupants to offset the building heat loss during the seasonal cooling months. These designs relied on spot heaters to provide some heat during the cold spells.

Another consideration is the high ventilation loads due to cooling the moist air prevalent in semi-tropical climates, especially coastal areas. This paper examines these effects and the variation in the thermal design parameters for commercial HVAC system design applications.

This paper describes a computer program which assesses all the pertinent variables which comprise the annual heating and cooling energy requirements for commercial buildings. It is then suggested that this computer program would be valuable in determining the changes one could expect in annual energy usage by varying certain building design parameters. Secondly, a small office building actually constructed in Central Florida in which the author designed the Heating and Cooling HVAC system is described. Trade-offs are presented showing the effects of changes in:

a) amount of fresh air ventilation
b) window overhangs, shading and the use of reflective and tinted glass
c) variation in wall insulation
d) changes in space lighting levels
e) building orientation.

Having established the changes in annual energy consumption due to the above variables, the baseline or reference constructed building is examined for other geographical site locations.

This study presents valuable insight into which building design parameters cause the greater change in HVAC annual energy consumption. In essence, the HVAC design engineer can use the program to rapidly look at the effects of varying different parameters in the mechanical design of buildings and also have a rapid means of obtaining cost data for various design concepts. The design engineer can perform "What If?" analysis and look at the effect of different building design concepts on the overall annual energy consumption.

CLIMATIC ZONES

Since the study building was actually constructed according to the basic design parameters in Central Florida, Zone 1 was selected as the primary climate zone for the study. North Latitude 28 degrees extending across Florida as shown in Table 1 and in Figure 1 defines Zone 1.

TABLE 1

SEMI-TROPICAL CLIMATE ZONE 1

28 DEGREES NORTH LATITUDE

LOCATION	LATITUDE	WINTER DB		SUMMER DB/WB		
	degrees	99%	97.5%	1%	2.5%	5%
Cape Kennedy	28 30'	35	38	90/78	88/78	87/88
Lakeland, FL	29	32	35	92/78	90/77	88/77
Orlando, FL	28 30'	35	38	94/76	93/76	91/76
St. Petersburg	28	36	40	92/77	91/77	90/76
Sanford, FL	28 50'	35	38	94/76	93/76	91/76
Tampa, FL	28	36	40	92/77	91/77	90/76
Corpus Christi	27 50'	31	35	95/78	94/78	92/78

Fig. 1 Climatic Zones

A second zone was also defined in this study which extends from Jacksonville, Florida through Tallahassee across the panhandle, through Alabama and Louisiana at North Latitude 30 degrees, as shown in Table 2. This zone has similar climatic conditions: hot humid summer weather and moderate winter conditions as does the Zone 1 Central Florida area. Climatic data also show that the east coast Texas areas also exhibit warm humid summer temperatures. However, the inland summer conditions average approximately 5 degree F higher with almost semi-arid moisture conditions. The zones defined above just touch upon the state of Texas.

TABLE 2

SEMI-TROPICAL CLIMATE ZONE 2

LOCATION	LATITUDE degrees		WINTER DB 99%	97.5%	SUMMER DB/WB 1%	2%	5%
Jacksonville	30	30'	29	32	96/77	94/77	92/76
Panama City	30		29	33	92/78	90/77	89/77
Pensacola, FL	30	30'	25	29	94/77	93/77	91/77
Tallahassee	30	20'	27	30	94/77	92/76	90/76
Baton Rouge	30	30'	25	29	95/77	93/77	92/77
New Orleans	30		29	33	93/78	92/78	90/77
Mobile, AL	30	40'	25	29	95/77	93/77	91/76
Port Arthur	30		27	31	95/79	93/78	91/78
Houston, TX	29	40'	27	32	96/77	94/77	92/77

COMPUTER PROGRAM DESCRIPTION

The computer program developed for this study is essentially a "bin" type energy procedure which calculates the building heat loss and heat gain over an assumed constant three-hour period. These parameters essentially involve the outdoor ambient temperature and, in the case of the wall transmission, a reference "U" value. The procedure for computing the heat gain due to wall transmission is described in the 1981 ASHRAE Handbook of Fundamentals and also in the ASHRAE Cooling and Heating Load Calculation manual (1, 2). This manual employs the Cooling Load Temperature Difference method (CLTD) which includes the thermal capacity of the wall system and accounts for the fact that the peak cooling load may occur some time after the peak instantaneous heat gain. Variation in building orientation is also considered in the program since data for different wall orientations is available in the ASHRAE guides. The permitted wall orientations are for 45 degree increments from true North as shown in Table 3.

TABLE 3

BUILDING ORIENTATION

1	North	Northeast
2	East	Southeast
3	South	Southwest
4	West	Northwest

Wall Area Orientation 1 ? 1220 ft^2
Wall Area Orientation 2 ? 1590 ft^2
Wall Area Orientation 3 ? 660 ft^2
Wall Area Orientation 4 ? 870 ft^2

Total Gross Conditioned Floor Area? 14900 ft^2

Wall U Value ? 0.06 Btu/hr-ft^2-F

Wall Weight per Unit Area ? 16 pounds/ft^2

Is construction lightweight frame or lightweight curtain? Lightweight Frame

Energy Table U Value 0.081 Btu/hr-ft^2-F
Lightweight Frame 0.081 Btu/hr-ft^2-F

This table is an actual representation of the CRT display screen and illustrates the interactive nature of the program. Since the assigned values for orientations 1 through 4 are arbitrary, it is obvious that we can rotate the building through 360 degrees in increments of 45 degrees to determine the effect of building orientation on the heat gain and the annual energy consumption.

Wall transmission is determined by evaluating the Wall Multiplier factors as shown in equation (1).

$$WM_i = \frac{U_i^w (WA)_i}{U_t^w (FA)} \qquad (1)$$

where

U_w = actual wall "U" value

WA = wall area

U_t^w = reference "U" value

FA = total plan floor area

The actual wall "U" value is a weighted average which accounts for the heat transmission through doors and other glass areas which are not accounted for in the fenestration calculation. Namely,

For i = 1 to 4 (Wall Orientation)

$$U_i^w = \frac{U_w A_w + U_g A_g + U_d A_d}{A} \quad (2)$$

where $A = A_w + A_g + A_d$

Wall thermal capacity effects are accounted for by having separate data tables in the program for: lightweight curtain walls, lightweight frame walls, medium weight walls, heavy weight walls, and extra heavy weight walls.

Heat gain through roofs is handled in a similar fashion except that for roofs, eighteen separate and distinct configurations are in the program each with its own reference roof "U" value. The program user is free to vary the "U" value for the actual building configuration. The roof multiplier equation is

$$RM = \frac{U^r(RA)}{U_t^r(RA)} \quad (3)$$

The energy calculation due to solar fenestration is accomplished by matrix multiplication tables in the program for each month of the year. These tables contain the solar heat gain factors as a function of orientation for that particular month. Separate tables are employed for different overhangs and side fins. The solar multiplier factor is

$$SM_i = \frac{(GA)_i(SCM)}{(FA)} \quad (4)$$

For i = 1 to 4 (glass orientation)

GA is the glass area and SCM is essentially the shading coefficient. Similar to its treatment in air conditioning load calculations, the glass conduction load is added together for the four building orientations. The equation accounting for glass condition is

$$GM = \frac{(CM)(X)}{(FA)} \quad (5)$$

Obviously CM in the equation is the overall glass "U" value.

The ventilation parameter is handled by

$$VM = \frac{(Q)}{(FA)} \quad (6)$$

The simplicity of the VM parameter should clearly indicate the nature of the energy usage calculation obtained from the program. Clearly, the ventilation load is the difference between the total enthalpy of the outside air evaluated at the wet bulb temperature. The program uses the three-hour average variation of the outside dry and wet bulb temperature and assumes that the indoor design conditions are dictated by energy code guidelines. It is obvious from these constraints that the program cannot calculate energy usage figures for conditions other than the reference weather data and building occupancy schedule. As previously pointed out, the use of this program is to obtain rapid estimates of changes in annual energy usage as a function of variations in design parameters. Variations in building energy usage, as a function of operating procedures, is beyond the scope of this program.

Lighting loads are program input as total load in watts due to lighting and are factored into the calculation. Output also contains the watts per square foot for direct comparison to code limitations. Each building type by its nature, will have a representative occupancy density; and in addition, the activities of the people in the building will also vary according to the building use. Representative building types available in the program are shown in Table 4. The variation in internal heat gains due to occupants as a function of building usage is immediately obvious if we examine a typical office building, a theatre, and a bowling alley. According to Rudoy and Cuba in (2) one can present data as shown in Table 5. The program contains a data table for each building type which incorporates an average value for the population density and a representative value for the occupancy heat gains as suggested by Table 5. The program user may adjust this value by using a "people multiplier" other than 1.0 which may be inferred as an increase or decrease in occupancy from the suggested value or as a variation in occupancy heat gain from the program value. Clearly, the "people multiplier" can also be thought of as varying both occupancy levels and heat gains from those occupants.

TABLE 4

AVAILABLE BUILDING TYPES

A	Place of Assembly, Auditorium
B	Bank or Savings and Loan
C	Clinic
D	Drug Store
E	School
	1. Classroom
	2. Gymnasium (conditioned)
	3. Office
	4. Laboratory
	5. Auditorium
	6. Dining
	7. Kitchen
G	Supermarket
H	Hotel, Motel
L	Library
M	Mercantile
	1. Strip Shopping Center
	2. Department Store
	3. Mall (conditioned)
	4. Storage
N	Nursing Home
O	Office Building
P	Hospital
	1. Autopsy/Morgue
	2. Central Supply
	3. Operating Suite

4. Emergency Department
5. Intensive Care Unit
6. Laboratory
7. General Patient Care
8. Dining
9. Kitchen
10. Office

R Restaurant
S Storage, Warehouse (conditioned)
T Theater
V Air Terminal
1. Commercial
2. Concourse
3. Storage
4. Dining
5. Kitchen

W Place of Worship
X Bowling Alley
Z Special (Any building not listed above)

TABLE 5

HEAT GAIN FROM OCCUPANTS

(Adjusted Group Total)

	Btu/hr-Person	Persons/1000 ft^2	Heat Gain 1000 ft^2
Office Building	420	10	4,200
Theater	350	150	52,500
Bowling Alley	960	70	67,200

The program will also take into consideration reduced airflow requirements due to venting the return air through the light fixtures. This will be examined and described subsequently in the paper both from the aspect of venting return air to a ceiling plenum, and venting the return air through the ceiling light fixture which is tied to a return air duct system.

Nationally recognized fuel energy program calculation procedures are designed primarily for climates where heating is more important than cooling. This program is based on the Florida Model Energy Code which is climate specific for humid semi-tropical climates. Therefore, some of the assumptions built into the program may not be appropriate for northern temperature climates. It is worth mentioning here that the subsequent building description study and conclusions derived from the study may be appropriate only for humid semi-tropical locations.

In keeping with the above considerations, the program includes a morning heating startup factor for the office buildings even though the buildings will, in all likelihood, require cooling much of the day even in the cool winter months. Startup Heat Energy for Office Buildings in Zone 1 and Zone 2 are as follows:

Zone 1 (28 deg. North Lat.) 1400 Btu/ft^2

Zone 2 (30 deg. North Lat.) 2600 Btu/ft^2

An additional factor which contributes to the overall annual energy usage is the efficiency of the cooling and heating/air conditioning system. Obviously a more efficient mechanical plant, or one that uses a heat pump as opposed to electric strip heat, uses less energy. The bottom line is how much? We can factor this into an economic analysis to determine if the proposed design modifications are cost effective.

The comparisons made and the conclusions arrived at are based on computing the annual energy usage for the building and also the building monthly heat gain. By looking at these parameters side by side, some interesting observations are made concerning the building thermal envelope properties, specifically insulation characteristics.

BUILDING DESCRIPTION & RESULTS

A high energy efficient office building used for this study was recently constructed in Central Florida. Most of the space is utilized for engineering consulting services with the remaining space leased out to other professionals such as attorneys and accountants. As far as the engineering utilization of the space is concerned, the central core on the second and third floor is used for an open bay drafting and design work area. The first floor is used primarily for private executive offices and also provides space for a reception area and the executive staff.

Wall construction consists of 3/4 inch stucco on metal lath with 1/2 inch exterior plywood sheating supported by 2 by 6 wood studs. Insulation consists of a 6 inch batt fiberglass insulation. Interior finish consists of 1/2 inch drywall. Insulation thickness varied somewhat throughout the building; but for purposes of analysis and design, an average wall "U" value of 0.06 Btu/hr-ft^2-F was assumed.

Roof construction consisted of a normal built-up roof over 3 inch lightweight concrete decking. The underside of the decking had a 6 inch foil-backed insulation installed resulting in a reflective air space gap between the insulation and the 5/8 inch gypsum plaster ceiling. This resulted in a "U" value for the roof system of 0.034 Btu/hr-ft^2-F.

Glazing considerations for the building resulted in an average glass to total wall area ratio of 33 percent for the building. Glazing consisted of a 1/4 inch single pane bronze tinted glass throughout with shading coefficient equal to 0.7. These actual building design parameters are fully described in Table 6. Building design occupancy levels were 137 people approximately distributed evenly over the three floors. The design ventilation rate was taken as 5 cfm per person which resulted in a design ventilation rate of 685 cfm for the building.

Each floor is served by a separate air handler with its individual split system condensing unit Air-To-Air Heat Pump installed on the roof. The first floor air handler is installed in a mechanical equipment room so that the return air enters the room and then enters the evaporative coils via a return air filter unit on the side of the air handler. In this specific case the motor as well as the fan is considered to be in the conditioned space. Thus, one must account for the heat generated by the fan horsepower and also the inefficiencies of the electric motor. The second and third floor air handlers are installed in the ceiling plenum space as shown in Figure 2. These systems have a duct return air system, and the design selected results in the fan motors being out of the air stream. Therefore, only the heat dissipation generated by the fan horsepower is considered to be included in the overall building heat gain. A 1/6 horsepower exhaust fan was assumed to operate for the normal eight-hour workday.

TABLE 6

ACTUAL BUILDING DESIGN

Wall Area, Orientation 1	1220 ft^2
Wall Area, Orientation 2	1590 ft^2
Wall Area, Orientation 3	660 ft^2
Wall Area, Orientation 4	870 ft^2
Conditioned Floor Area,	14,900 Square Feet (Gross)
Wall U Value	0.06 Btu/hr-ft^2-F
Roof U Value	0.034 Btu/hr-ft^2-F
Roof Area	4,500 Square Feet
Glass Area, Orientation 1	542 ft^2
Glass Area, Orientation 2	890 ft^2
Glass Area, Orientation 3	494 ft^2
Glass Area, Orientation 4	315 ft^2
Shading Coefficient, Sc	0.7
Conduction Multiplier	1.0
Ventilation Air Rate	685 cfm
People Multiplier	0.919
Lighting	40,230 watts
Fixtures Vented?	Yes
Fixtures Ducted?	Yes
Electrical Heat Dissipation	8.72 Horsepower
Heating System Multiplier	0.38
Cooling System Multiplier	0.45
Exhaust Fan	0.16666 Horsepower
Operating Hours/Day	8 Hours
Electrical Energy Cost	0.05 \$/Kw-hr

The actual design lighting level for the building was taken from typical energy code recommendations as 2.7 watts/ft^2. The only variation presented in this study is to show the annual energy consumption as a function of lighting level. The annual energy budget value dictated by the Florida Energy Code was 42 MBH/Year-ft^2 at the time this study was undertaken. It is of interest to note that this figure has been reduced to 40 MBH/Year-ft^2. Since the building orientation numbering system is arbitrary, it should be noted that the actual building orientation is with 1 being North (Refer to Table 3).

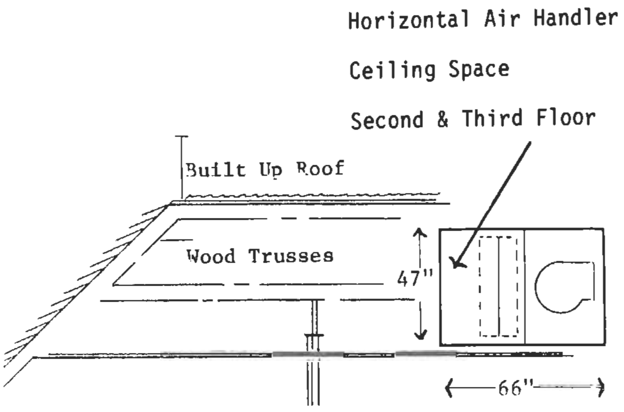

Fig. 2 Air Handler Installation

The results of rotating the building in successive 45 degree increments clockwise is shown in Table 7 for both a geographical Zone 1 and Zone 2 location. Since the building has a fairly uniform glass-to total wall area on all four sides and is well insulated, large variations in annual energy usage as a function of building orientation are not to be expected.

TABLE 7

BUILDING ORIENTATION

(ANNUAL ENERGY USAGE)

AZIMUTH Degrees	Zone 1 MBH/Year-ft^2	Zone 2 MBH/Year-ft^2
0	34.4	34.2
45	34.5	-
90	34.3	34.1
135	34.3	-
180	34.2	33.9
225	34.1	-
270	34.1	33.8
315	34.3	-

Total Variation < 2%

The effect of wall insulation was examined next by arbitrarily varying the "U" value from the design value up to 1.0 Btu/hr-ft^2-F. These results are shown in Table 8. Before trying to explain why such a small unexpected variation in annual energy consumption occurs for such a large variation in wall transmission factors, it may be appropriate to examine the two limiting conditions on a monthly basis. This is shown in Table 9 and explains the apparent anomaly. This table reveals an interesting situation which is substantiated by the computer calculations. The building actually is in the cooling mode during most of the winter months even, though November through February are the coldest design months. The situation comes from the fact that net cooling is required due to the occupancy load and the "heat of lights." The higher "U" values permit a greater heat loss due to transmission which reduces the net cooling load during these months. This condition is indicated by the asterisks in the table. Actually, the higher transmission losses assist in cooling the building during the colder winter months; and hence, the integrated effect over the 12-month period is not as large as one might expect. Table 10 shows the variation in annual energy usage as a function of roof "U" value. A similar argument can be made for the roof thermal conductance to show the net cooling benefit during the cool winter months. It is important to remember that these conclusions are only valid for the case studied in this model for the Zone 1 and Zone 2 region. It is expected that this effect would be nullified in temperate regions slightly north of Zone 2.

TABLE 8

WALL U VALUE - ANNUAL ENERGY USAGE

U VALUE Btu/Hr-ft^2-F	ZONE 1 MBH/Year-ft^2	ZONE 1 MBH/Year-ft^2
0.06	34.4	34.2
0.08	34.5	34.2
0.1	34.5	34.2
0.2	34.6	34.2
0.4	34.8	34.3
0.6	35.1	34.3
0.8	35.3	34.4
1.0	35.5	34.5

Total Variation < 4%

TABLE 9

BUILDING MONTHLY HEAT GAIN (MBH/ft^2)

	ZONE 1		ZONE 2	
	U = 0.06	U = 1.0	U = 0.06	U = 1.0
	Btu/hr-ft^2-F			
January	1.8*	1.1*	1.5*	0.54* plus heat loss
February	2.1*	1.8*	1.8*	1.2*
March	2.4	2.6	2.4*	2.4*
April	2.6	2.9	2.5	2.6
May	2.8	3.2	2.7	3.1
Summer	12.8	15.1	12.7	15.0
October	2.5	2.8	2.4*	2.4*
November	2.4*	2.4*	2.3*	2.2*
December	2.1*	1.8*	1.9*	1.3*

*Indicates those months that wall transmission actually produces a heat loss for at least a part of the daily eight hour period (Morning Period).

TABLE 10

ROOF U VALUE VARIATION FOR ZONE 1

U VALUE Btu/hr-ft^2-F	ANNUAL ENERGY USAGE MBH/Year-ft^2
0.034	34.4
0.09	35.7
0.15	35.8
0.20	35.9
0.40	36.3
0.80	37.1

Glazing considerations gave a more distinct variation in building annual fuel consumption as shown in Table 11. This was one of the significant parameters addressed by the architectural and engineering consultants on the project. The shading coefficient used for each type of glazing is also shown in the table. Although an external venetian-type shading device was never considered on the project, its theoretical value in reducing energy consumption is shown. Maximum energy savings of approximately 3 percent occur by using a 1/4 inch bronze reflective glass when compared to ordinary 1/4 inch clear plate glass. The low savings is due to the deep overhangs on the building resulting in window shading for much of the day. Energy savings are about 7.9 percent by using an external shading device.

TABLE 11

FENESTRATION ANNUAL ENERGY USAGE

GLASS TYPE	MBH/Year-ft^2
1/4 inch clear plate SC = 1.0	35.6
1/4 inch bronze tint SC = 0.7	34.4
1/4 inch bronze reflective SC = 0.43	33.5
External Shading Device SC = 0.25	32.8

A significant parameter, one which greatly affects annual energy usage, is the fresh air ventilation required by the building. This paper will not go into the altruistic virtues of reduced ventilation requirements nor discuss the optional energy conserving alternatives available to the building designer. Needless to say, the 5 cfm/person limitation imposed by the designer is a minimum value at best and should probably be supplemented with high efficiency filtration or the use of charcoal filters. Table 12 shows the rapid increase in annual energy consumption as the ventilation requirement is increased. The calculations did not include the 35 cfm/person value since this exceeded the building's annual energy budget of 42 MBH/Year-ft^2. Note that ASHRAE's 1981 Handbook of Fundamentals (1) recommends a ventilation range of 15 to 25 cfm/person with 15 cfm/person for office buildings as an absolute minimum.

TABLE 12

FRESH AIR VENTILATION (ZONE 1)

VENTILATION cfm/person	ANNUAL ENERGY USAGE MBH/Year-ft^2	% INCREASE
5	34.4	-
6.67	36	4.6
10.0	36.5	6.1
17	37.5	9.0
23	38.5	12
33	40.1	16.6

As previously discussed, venting return air through the ceiling light fixtures will definitely reduce the cooling load to the conditioned space. This will usually result in lower fan operating costs due to reduced supply air flow requirements imposed on the system. The cooling load presented by the lights is still accountable to the mechanical refrigeration plant system. What happens is that this heat load is added to the return air, thus changing the entering coil air conditions. Should the light fixtures be vented, only some of this heat may escape the refrigeration system due to natural or forced ventilation of attic spaces. This conclusion is substantiated by the results shown in Table 13. The results, which show that the situation for fixtures that are neither vented nor ducted is somewhat less, remain a bit obscure. The total variation is less than 2.6 percent. While venting and ducting light fixtures may reduce installed system capacity and may reduce annual energy consumption significantly in certain climatic regions, the significant reductions expected by this consideration were not achieved for this typically semi-tropical office building design.

TABLE 13

RETURN AIR THROUGH FIXTURES (ZONE 1)

INSTALLATION TYPE	ANNUAL ENERGY USAGE MBH/Year-ft^2
Vented and Ducted	34.4
Vented Only	34.0
Neither	33.5

TABLE 14

LIGHTING (ZONE 1)

LIGHTING LOAD (INCLUDING BALLAST)	ANNUAL ENERGY USAGE MBH/Year-ft^2	% INCREASE
2.7	34.4	-
3.0	37.1	7.8
3.5	40.5	17.9
4.0	45.7	33.0

The final parameter investigated in this study was the variation on annual energy usage as more efficient heating and cooling mechanical plants were used in the building design. Table 15 shows the building calculated energy consumption for the design heat pump (COP = 2.6-2.79 and EER = 7.5-7.99). The next variation shows a 2 1/2 percent increase if electric strip heat is used instead of an Air-To-Air Heat Pump. The reason for this is that heating is used so seldom in controlling the thermal environment of the office building. The recurring fact is that the lighting and the occupancy load is used and is sufficient to provide heating for the building in the temperate winter months. This is substantiated by considering that for many years commercial office and light manufacturing plants in Central Florida did not even contain a heating plant. This practice was even more prevalent in the south Florida district. The table also shows the reduced energy consumption as equipment Energy Efficiency Ratios (EER's) are increased. This should not be considered as a panacea since any particular package air conditioner can be made to show an increased EER if the saturated suction temperature is increased. This may not be desirable since, especially in high humidity Zone 1 and 2 regions, occupants would then arbitrarily lower the thermostat settings, thus operating the building at a much lower dry bulb temperature in an attempt to dehumidify. The increased equipment operating times under such conditions would cancel out any savings suggested by the higher EER machine.

TABLE 15

MECHANICAL HVAC EQUIPMENT EFFICIENCY (ZONE 1)

REFERENCE SYSTEM	ANNUAL ENERGY USAGE MBH/Year-ft^2
COP 2.6-2.79 EER 7.5-7.99	34.4
COP 1.0 Electric Strip Heat	35.3 (2.5%)
EER 6.8-6.99	36.0 (4.8%)
EER 8.55-8.99	32.7 (-4.8%)
EER 9.5-9.99	31.4 (-8.7%)
EER 10.5-10.99	30.1 (-12.3%
EER 12 and above	28.8 (-16.3%)

CONCLUSIONS

This study adopted a model energy code calculation procedure for determining the annual usage of a commercial building and demonstrated that the procedure can be used for rapid estimates of building energy usage as various design parameters are changed. The study showed as expected that significant changes in energy consumption occurred as the ventilation and lighting levels were altered. Energy savings from extremely well-insulated walls and ceilings were not as large as expected due to the fact that in semi-tropical climates the occupancy heat gain and the lighting heat gain usually provide more than sufficient heating for the building environmental thermal control. In effect, higher transmission heat losses will provide some free cooling during the cooler winter months in semi-tropical climates.

REFERENCES

1. ASHRAE 1981 - "Handbook of Fundamentals", Atlanta: American Society of Heating, Refrigertion, and Air-Conditioning Engineers, Inc.

2. Rudoy, W. and Cuba, J.F., "Cooling and Heating Load Calculation Manual", ASHRAE GRP 158, American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc.

SYMBOLS

A = Area, ft

CM = Overall Glass "U" Value, Btu/hr-ft^2-F

FA = Total Plan Floor Area, ft^2

GA = Glass Area, ft^2

GM = Glass Conduction Multiplier, Btu/hr-ft^2-F

MBH = 1000 Btu

Q = Building Design Ventilation Rate, cfm

RA = Roof Area, ft^2

RM = Roof Multiplier, Dimensionless

SCM = Glass Shading Coefficient, Dimensionless

SM = Solar Multiplier

U = Overall Heat Transfer Coefficient, Btu/hr-ft^2-F

VM = Ventilation Multiplier, ft/sec

WA = Wall Area, ft^2

WM = Wall Multiplier Factor, Dimensionless

X = Building Total Glass Area, ft^2

SUBSCRIPTS

d = door

g = glass

i = building wall orientation

t = code standard value as dictated by specific wall or roof grouping

w = wall

SUPERSCRIPTS

r = roof value

w = wall value