WC Engineering

A Greener Tomorrow, Today

WC Engineering Inc

4600 Touchton Road,

Building 100, Suite 150

Jacksonville, FL 32246

Attention: Michael Jones

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Subject: HVAC Calculations per elegantcafedwg.pdf

Quote #: QU-51217

Building area is 2,420 sq. ft.

No. of Occupants is 92 people (fire code sign on the entry wall)

Infiltration loss is typically 1 to 2 air changes per hour (assume 2 ACH)

Outdoor Air required is 15 to 25% of ventilation air

Breathing Zone is given as:

- 3 to 72 inches from the floor
- 24 inches from walls or AC equipment

Inside design temperature of 70 to 72˚F (assume 70˚F cooling set point)

Humidity is 30 to 35% (< 20% and > 60% is problematic)

Climatological data for Jacksonville, FL:

- http://cms.ashrae.biz/weatherdata/STATIONS/722060_s.pdf
- Annual Cooling Design Conditions:
  - T_db is 34.8˚C or 94.6˚F (0.4% extreme)
  - Latitude is 30.50 N

Rough Estimation

Using 20 cfm/person (common minimum design standard) and a reheat system the estimated cooling load is 0.25 to 0.35 tons per 100 sq. ft. of total building area.

Q = 2,420 sq. ft. x 0.35 tons / 100 sq. ft. = 8.47 tons

Cooling Load

Q_dot = U x A x (T_i – T_o) or more accurate Q_dot = U x A x (CLTD)

(Cooling Load Temperature Difference gives ~15% error)

- T_i = 70˚F
- T_o = 94.6˚F
- ΔT = 24.6
- U = 1/R

Roof

- 3 feet of air space in attic
- R = 1.79 (1/2” acoustical ceiling tile)
- R = 30 (9-1/4” thick R-19 insulation)

U_total = 1/R_total = 0.03

A = 2,420 ft^2

CLTD = 28 (L- light construction & ΔT ≈ 35˚C since worst case for Jacksonville, FL is 36.6˚C)

Q_roof = 0.03 x 2,420 x 28 = 2,130 Btu/hr

Doors

- Front W facing glass door is treated as a window
- No. of 1-¾ inch insulated metal doors (in E wall) is 2
- A = 80" x 36" = 20 sq. ft.
- U = 0.40 (Btu/hr-ft^2-°F)
- CLTD = 16 (light construction & 35˚C)

Q_doors = U x A x #_doors x CLTD = 0.40 x 20 x 2 x 16 = 1,220 Btu/hr

Concrete Slab

- 4" thick slab = 0.333'
- ΔT = 5˚F
- Slab edge of N & S walls have zero heat transfer since they abut against neighboring business spaces
- U_slab_face = 0.05
- U_ slab_edge = 0.81

A_slab_face = 2,420 sq. ft.

A_ slab_edge = 0.333' x (41' x 2) = 27.33 sq. ft.

Q_slab = (0.05 x 2,420 + 0.81 x 27.33) x 5 = 715 Btu/hr

Exterior Wall

- Zero heat transfer from N & S facing walls since they abut against other business spaces
- E wall height is 128" high and 41' long; made of 12" CMU (concrete masonry unit), ¾" wood, and ½" sheetrock
- W wall is considered a window with the exception of parts which are comprised of 12" CMU, ¾" wood, ½" sheetrock, and 1" stucco

East wall

- R = 0.33 (outside air 7.5 mph wind)

- R = 2.04 – 2.56 (12” CMU- LW block not HW block)
- R = 0.68 – 0.69 (Inside Air)
- R = 1.08 (3/4” plywood)
- R = 2.22 (1/2” sheetrock)
- CLTD = 16 (light construction & 35˚C)
- Area of E wall = 41’ x 128” = 200’

U_total = 1/R_tot = 0.15

A_wall = (12’ x 200’) – A_windows – A_E_door = 2,400 – 80 – 60 = 2,260 sq. ft.

West wall

The same as the east wall except stucco is added

- R = 4.76 (1” stucco)

U_total = 1/R_tot = 0.09

Area of W wall = 24” (above glass window) x 41’ + 16.5” x 104” x 3 (parts between windows) = 82 + 36 = 118 sq. ft.

Q_E_wall = 0.15 x 2,260 x 16 = 5,425 Btu/hr

Q_W_wall = 0.09 x 118 x 16 = 170 Btu/hr

Q_tot = 5,425 + 170 = 5,595 Btu/hr

Windows

Most areas average 3 to 5 hours of peak sun per day

Conduction heat gain through fenestration areas: Q = A x U x CLTD

Solar Radiation through glass:

Q_fes = (A_s x SHGF + A_sh x SHGF_sh) x SC

Q_fs = Q_fes x CLF (space cooling load)

- SHGF = Maximum Solar Heat Gain Factor, Btu/hr-ft^2 (use latitude 32˚N & June)
  https://engineering.dartmouth.edu/~d30345d/courses/engs44/SHGF-daily-totals.pdf
- SHGF_sh = Shaded Solar Heat Gain Factor (use table 5, East/West & May)
  http://personal.cityu.edu.hk/~bsapplec/cooling.htm
- A_s = Unshaded Area of Window Glass, ft^2
  A_sh = Shaded Area of Window Glass, ft^2

SC = Shading Coefficient

SL = Shade Line = Shade Line factor x width of the overhang (the distance shadow falls beneath the edge of an overhang)

SCL = Solar Cooling Load (SCL = SHGF x CLF, where CLF takes into account time lag)

GLF = Glass Load Factor (GLF = SCL x SC)

- Aluminum frame single glass door & windows
- U = 1.27 Btu/hr-ft^2-°F
- Area of door = 72” x 104” = 52 sq. ft.
- Area of window = 66” x 104” = 48 sq. ft.
- No. of windows is 6
- Area_tot = 52 + 48 x 6 = 340 sq. ft.
- CLTD = 16 (light construction & 35˚C)

Q_windows = 1.27 x 16 x 340 = 6,910 Btu/hr (least accurate method)

- Width of overhang = 101”
- SLF = 0.8
- SL = 0.8 x 101” = 81”
- A_s = (1 – (81/104) x 340) = 75 sq. ft.
- A_sh = 340 – 75 = 265 sq. ft.
- SHGF = 1,169 Btu/ft^2-day / 8 hours = 146
- SHGF_sh = 142 W/m^2 x 0.0929 m^2/ft^2 x 3.41 Btu/h-W = 45
- SC = 0.50 (blinds or translucent roller shade for single pane)
- 0.25 for white shades, 1.0 for no shades

  http://personal.cityu.edu.hk/~bsapplec/cooling.htm

Q_windows = (75 x 146 + 265 x 45) x 0.50 = 11,440 Btu/hr

Lighting

Q = 3.41 x W x BF x CLF

- 3.41 – conversion coefficient between Watts and Btu/hr
- W – lighting capacity, Watts
- BF – Ballast Factor (heat loss in the ballasts of fluorescent lights)

- CLF – Cooling Load Factor (heat storage in the lighting fixtures)
- Fluorescent lights
- Quantity of (25) 4'X2' fixtures with (4) 48" lamps of T12 diameter

  W = 32W per bulb, BF = 0.92
- Quantity of (6) 2'X2' fixtures with (2) 24" u-shaped lamps of T12 diameter

  W = 32W per bulb, BF = 0.94
- CLF (1.0 is often used)

Q_lighting = 3.41 x [(25 x 4 x 32W x 0.92 x 1.0) + (6 x 2 x 32W x 0.94 x 1.0)] = 11,270 Btu/hr

Occupants

Qs = qs x n x CLF

Ql = ql x n

- Q_s & Q_l = Sensible and Latent heat gains, Btu/hr
- q_s & q_l = Sensible and Latent heat gains per person, Btu/hr-person
- n = Number of People
- CLF = Cooling Load Factor for people (capacity of a space to absorb and store heat; 0.91 could be used, however 1.0 will be used)
- Activity is office work
- Level is moderate

Sensible heat gain is 250 Btu/hr-person

Latent heat gain is 200 Btu/hr-person

Q_occupants: 450 Btu/hr-person x 92 people = 41,400 Btu/hr

Equipment

- Quantity of 59 computers (21" monitors)
- Running at idle is 30W and continuously is 130W
- Refrigerator (15ft^3) = 300W (there is a small fridge only, so halving this value)
- Laser Printer is 70W
- Coffee maker is 2,590 Btu/hr
- 50" televisions (qty. 2, Westinghouse) = 151.3 kWh/yr
- Any other office equipment = 25% Nameplate (Watts ≈ volts×amps)

- All 59 computers are running

Q = 3.41 x (59 computers x 130W) = 26,150 Btu/hr (21” computers)

Q = 3.41 x (1 computer x 110W) = 375 Btu/hr (15” computer)

Q = 2 x 151.3 kWh/yr x 0.3895 [(Btu/hr) / (kWh/yr)] = 120 Btu/hr (television)

Q = 3.41 x 150W = 510 Btu/hr (refrigerator)

Q = 3.41 x 70W = 240 Btu/hr (laser printer)

Q = 2,590 Btu/hr (coffee maker)

Q = 2,185 Btu/hr (8 head soda fountain machine)

Q_equipment = 32,170 Btu/hr

Q_l+s_r = 9,800 + 2,130 + 1,220 + 715 + 5,595 + 11,440 + 11,270 + 41,400 + 32,170 = 105,740 Btu/hr

Ventilation

Rp (cfm/person)	Pz (No. of People)	Ra (cfm/ft^2)	Az (Floor Area, ft^2)	Ez
5	92	0.06	2,420	1.00

Single Zone and Dedicated OA (outdoor air) Systems (DOAS)

V_bz_dot = Rp x Pz x Ra x Az (ventilation rate, breathing zone outdoor air)

Ez = distribution effectiveness

Voz_dot = V_bz_dot / Ez (zone outdoor airflow)

Voz = (5 x 92 + 0.06 x 2,420) / 1.0 = 605 cfm

Ventilation Air Cooling Load

- http://www.engineeringtoolbox.com/cooling-heating-equations-d_747.html
- Load on the coil due to leakage in return air duct and return air fan is negligible

Sensible heat in a cooling process of air

h_s = 1.08 x V_oz x ΔT

- ρ = 0.075 lbm/ft^3
- T_o = 94.6˚F (dry-bulb)
- T_i = 70˚F (dry-bulb)
- ΔT = (T_o – T_i) = 24.6

h_s = 1.08 x 605 ft^3/min x 24.6 = 16,075 Btu/hr

Latent heat due to moisture in the air, in a humidification process of air

$h\_l = 4,840 \times V\_oz \times dw\_lb$

- dw_lb = humidity ratio difference (lb water/dry air)
- $T\_wb = 25.4^\circ C = 77.7^\circ F$ (mean coincident wet bulb)
- $dw\_lb = 0.0206$

$h\_l = 4,840 \times 605\ ft^3/min \times 0.0206 = 60,320$ Btu/hr

$h\_t = h\_s + h\_l = 16,075 + 60,320 =$ 76,395 Btu/hr

$Q\_t = Q\_l{+}s\_r + h\_t = 105,740 + 76,395 = 182,135$ Btu/hr

$Q\_t = 182,135 / 12,000 =$ 15.18 tons

Alternative method

$h\_t = 4.5 \times V\_oz \times dh$

- $dh = h\_o - h\_i$ (enthalpy difference)
- $h\_o = 45.5$ (using psychrometric chart at $T\_db = 94.6^\circ F$ & $dw\_lb = 0.0206$)
- $h\_i = 22$ (using psychrometric chart at $T\_db = 70^\circ F$ & RH = 30%)

$h\_t = 4.5 \times 605 \times (45.5 - 22) = 63,980$ Btu/hr

$Q\_t = Q\_l{+}s\_r + h\_t = 105,740 + 63,980 = 169,720$ Btu/hr

$Q\_t = 169,720 / 12,000 = 14.14$ tons