Faculty of Engineering and Technology

Department of Mechanical and Mechatronics Engineering

Refrigeration and Air Conditioning

ENME 432

Cooling load calculations

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Indoor Conditions: 24 C, 50% RH and $\omega_{in} = 0.009\, kg/kg$

Outdoor Conditions: 35 C, 40% RH and $\omega_{out} = 0.014\ kg/kg$

Supply Temperature: 13 C.

For the supermarket:

1) **Transmission with solarload:**

- **Northern side:**

$q_{wall} = U_{wall} * A_{wall} * \ CLTD$

$A_{wall} = hieght * \sum wall\ lengths$ = 4*31.24 = 125 m2
$R_{wall} = \ R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166
$U_{wall} = \frac{1}{\sum R_{wall}}$ = 0.49 KW/m2.K
$\Delta T_{wall} = T_\circ - \ T_i$ = 35-24 = 11C.
$CLTD = 12$
$q_{wall} = U_{wall} * A_{wall} * \ CLTD$ = 0.49*125*12 = 735W

- **Western side:**

$A_{wall} = hieght * \sum wall\ lengths$ = 4*31.1 = 124.5 m2
$R_{wall} = \ R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166
$U_{wall} = \frac{1}{\sum R_{wall}}$ = 0.49 KW/m2.K
$\Delta T_{wall} = T_\circ - \ T_i$ = 35-24 = 11C.
$CLTD = 27$
$q_{wall} = U_{wall} * A_{wall} * \ CLTD$ = 0.49*124.5*27 = 1650W

- **Southern side:**

$A_{wall} = hieght * \sum wall\ lengths$ = 4*31.24 = 125 m2
$R_{wall} = \ R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166
$U_{wall} = \frac{1}{\sum R_{wall}}$ = 0.49 KW/m2.K
$\Delta T_{wall} = T_\circ - \ T_i$ = 35-24 = 11C.
$CLTD = 19$
$q_{wall} = U_{wall} * A_{wall} * \ CLTD$ = 0.49*125*19 = 1164W

- **Roof:**

$q_{roof} = U_{roof} * A_{roof} * \ CLTD$

A_{roof} = 31.24*31.1=972 m2
$R_{roof} = \ R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166
$U_{roof} = \frac{1}{\sum R_{roof}}$ = 0.49 KW/m2.K
$\Delta T_{roof} = T_\circ - \ T_i$= 35-24 = 11C.
$CLTD = 21$
$q_{roof} = U_{roof} * A_{roof} * \ CLTD$ = 0.49*972*21 = 10000 W

- **Floor:**

$q_{floor} = U_{floor} * A_{floor} * \ \Delta T_{floor}$

A_{floor} = 972 m2
$R_{floor} = \ R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 1.33
$U_{floor} = \frac{1}{\sum R_{floor}}$ = 0.75 KW/m2.K
$\Delta T_{floor} = T_\circ - \ T_i$ = 35-24 = 11C.

$q_{floor} = U_{floor} * A_{floor} * \ \Delta T_{floor}$ = 0.75*972*11 = 8020 W

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2) Ventilation load:

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \ \Delta T + 3000 * \dot{V}_{vent} * \ \Delta\omega$

$(\#people) = A_s * (occupation)$ = 972 (m2) * 0.08 (people/ m2) = 78 people.

$\dot{V}_{vent}$ = $(air\ requierments/\ person) * (\#people)$ = 8(liters/person)* 78 = 642litres.

$\Delta T = T_i - \ T_\circ$ = 35-24 = 11C.

$\Delta\omega = \omega_i - \ \omega_\circ$ = 0.014-.009 = 0.005.

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \ \Delta T + 3000 * \dot{V}_{vent} * \ \Delta\omega$ = 1.23 *642*11 + 3000*642*.005 = 18316 W.

3) Infiltration load:

$q_{infiltration} = 1.23 * \dot{V}_{infil} * \Delta T + 3000 * \dot{V}_{infil} * \Delta\omega$

$\dot{V}_{infil} = V * (air\ changes\ per\ second)$ = 972*4*(0.5/3600) = 540 litres.

$\Delta T = T_i - T_\circ$ = 35-24 = 11C.

$\Delta\omega = \omega_i - \omega_\circ$ = 0.014-.009 = 0.005.

$q_{infiltration} = 1.23 * \dot{V}_{infil} * \Delta T + 3000 * \dot{V}_{infil} * \Delta\omega$ = 1.23 *540*11 + 3000*540*.005 = 15406 W.

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4) Internal load:

- **Lights**:

$q_{lights} = lamp\ rating * Fu * Fb * CLF$

$lamp\ rating = 25\left(\frac{watt}{m2}\right) * area = 25\left(\frac{watt}{m2}\right) * 972\ m2 = 24300\ W$

$q_{lights} = lamp\ rating * Fu * Fb * CLF = 24300 * .97 * 1 * 1.2$ = 28285 W

- **People**:

$q_{s_{people}} = sensible\ heat\ gain * CLF * \#\ of people$

$q_{l_{people}} = latent\ heat\ gain * CLF * (\#\ of people)$

$(\#people) = A_s * (occupation)$ = 972 (m2) * 0.08 (people/ m2) = 78 people.

$q_{s_{people}} = sensible\ heat\ gain * CLF * \#\ of people$ = 92.5*1*78= 7215 W.

$q_{l_{people}} = latent\ heat\ gain * (\#\ of people)$ = 92.5*78= 7215 W.

q_{people} = 7215 * 2 = 14430 W

- **Equipment:**

3 refrigerators, 1000 watt each = 3*1000 = 3000 W.

$$q_{TOTAL\ room\ load\ of\ the\ supermarket} = q_{Transmission} + q_{Internal} + q_{infiltration}$$

$$= \mathbf{82690\ W}$$

$q_{Snsible\ of\ the\ supermarket}$ = **67375 W**

- **Main Duct #1 for the supermarket:**

$$SHR_1 = \frac{67375}{82690} = 0.814$$

$$h_{S1} = 33.5\ Kj/Kg$$

$$h_i = 47.5\ Kj/Kg$$

$$q_{Room\ of\ Supermarket} = \dot{m}_{S1} \times (h_i - h_{S1})$$

$$\dot{m}_{S1} = \frac{q_{Room\ of the\ Supermarket}}{(h_i - h_{S1})} = \frac{82.690\ KW}{(47.5 - 33.5)} = 5.9\ Kg/s.$$

$$v_{S1} = 0.82\ m^3/Kg$$

$$\dot{V}_{S1} = \dot{m}_{S1} \times v_{S1} = 5.9 \times 0.82 = 4.84\ m^3/s = 10255\ CFM$$

$$\dot{V}_{grill} = \frac{\dot{V}_{S1}}{9}$$

$\dot{V}_{grill} = \frac{4.84}{9}$ = 0.538 m3/s.

$$\text{Throw}_{\text{horizental}} = \frac{\text{L}}{2 * \text{n}}$$

n= 3

$$\text{Throw}_{\text{horizental}} = \frac{31}{2 * 3} = 5.17\text{m}$$

$$\text{Throw}_{\text{vertical}} = \frac{\text{L}}{2 * \text{n}}$$

n= 3

$$\text{Throw}_{\text{vertical}} = \frac{31}{2 * 3} = 5.17\text{m}$$

Longest run = (31-5.17) + (2*10.34) +5.17 = 51.68m

Let $V_{main} = 10m/s$

$\dot{V}_{ab} = 4840\ l/s$

$\frac{\Delta p}{L} = 1.2$

D_{ab} = 800 mm

a = 550mm

b = 1000mm

$\dot{V}_{bc} = 3227\ l/s$

D_{bc} = 720 mm

a = 550mm

b = 800mm

$\dot{V}_{bc} = 1613\ l/s$

D_{bc} = 500 mm

a = 550mm

b = 550mm

$B - 1 = C - 1 = D - 1 = 500mm$

a = 550mm

b = 550mm

For the gym:

1) **Transmission with solar load:**

- **East walls:**

$A_{East\ Walls} = (3 + 3.69 + 0.63 + 2.48 + +3.13 + 3.13 + +1.78) \times 4$

$= 71.36\ m^2.$

U_{walls} was found based on the Table in Example 5-1 (Outside wall):

$U_{walls} = 0.49\ W/m^2\ C.$

$q_{East\ walls} = U_{walls} \times A_{East\ Walls} \times (CLTD)$

$CLTD_{max}$= 21 from Table (4-15) in the book.

$q_{East\ walls} = 0.49 \times 71.36 \times 21 =$ 734.3 W

- **South walls:**

$A_{South\ Walls} = (0.53 + 1.24 + 1.26 + 0.91 + 0.84 + 0.77) \times 4 = 22.2\ m^2$

$CLTD_{max} = 19$ from Table (4-15).

$q_{South\ walls} = 0.49 \times 22.2 \times 19 =$ 206.7 W

- **East windows:**

$q_{glass\ total} = U_g \times A_g \times (T_{out} - T_{in}) + A_g \times (SHGF) \times (S.C) \times (CLF)$

$A_{East\ Windows} = (0.81 + 0.81 + 1.88 + 1.88 + 1.88) \times 4 = 29.04\ m^2.$

$U_g = 3.3\ W/m^2\ C$ for double glass.

$SHGF = 700\ W/m^2$ from Table (4-10).

$S.C.(Shading\ Coefficienct) = 0.4$ for reflective double glass. (Table 4-11).

$CLF = 0.8$ at 8 a.m. facing East from Table (4-12).

$q_{East\ windows} = 3.3 \times 29.04 \times (35 - 24) + 29.04 \times (700) \times (0.4) \times (0.8)$

= 7560 W

- **South windows:**

$A_{South\ Windows} = (4.14 + 3.57 + 3.19 + 3.42 + 2.47) \times 4 = 67.16\ m^2.$

$SHGF = 355\ W/m^2$ from Table (4-10) for May, Aug.

S.C=0.4 reflective double glass.

$CLF = 0.83$ from Table (4-12) at 12 noon facing south.

$q_{South\ Wins.} = 3.3 \times 67.16 \times (35 - 24) + 67.16 \times (355) \times (0.4) \times (0.83)$

= 10353 W

- **Roof:**

$q_{Roof} = U_{Roof} \times A_{Roof} \times (CLTD_{Roof})$

$U_{Roof} = 0.48\ W/m^2C.$

$A_{Roof} = 312\ m^2.$

$CLTD_{Roof} = 21$ From Table (4-14) at 20 solar time with suspended ceiling.

$q_{Roof} = 0.48 \times 312 \times (21)$ = 3145W

- **Floor:**

$q_{Floor} = U_{Floor} \times A_{Floor} \times (T_{out} - T_{in})$

$U_{Floor} = 0.757\ W/m^2C$

$A_{Floor} = 312\ m^2$

$q_{Floor} = 0.757 \times 312 \times (35 - 24)$ = 2600 W

$\boldsymbol{q_{Transmission\ of\ the\ gym}}$ =**24600 W**

2) Internal Loads:

- **People:**
  - **In the Arena**: 75 people.

$q_{People} = (SHG \times CLF \times People) + (LHG \times People)$

$SHG = 35\% \times 300 = 105\ W.$ From Table (4-7).

$LHG = 300 - 105 = 195\ W.$

$CLF = 0.64$ from Table (4-9) for 12 hours in space and 2 hours after each entry.

$q_{People} = (105 \times 0.64 \times 75) + (195 \times 75)$ = 19665 W

  - **In the reception:** 27 people.

$SHG = 60\% \times 100 = 60\ W$

$LHG = 100 - 60 = 40\ W$ from Table (4-7) for seated people.

$CLF = 0.55$ for 12 hours in space and 1 hour after each entry. Table (4-9)

$q_{People} = (60 \times 0.55 \times 27) + (40 \times 27)$ = 1971 W

  - **In the lockers room:** 9 people.

$SHG = 50\% \times 150 = 75\ W$

$LHG = 150 - 75 = 75\ W$ Table (4-7) for standing people.

$CLF = 0.55$ Table (4-9).

$q_{People} = (75 \times 0.55 \times 9) + (75 \times 9)$ = 1046 W

- **Lights:**

$q_{Lights} = Lamp\ Rating \times F_u \times F_b \times CLF$

$Lamp\ Rating = 25\ W/m^2 \times 312 = 7800\ W$

$CLF = 0.97$ for 10 hour operation at fixture Y in Table (4-6).

$q_{Lights} = 7800 \times 1 \times 1.2 \times 0.97$ = 9080 W

- **Equipment:**
  - **Two domestic refrigerators:**

$q_{Sensible} = 2 \times 120 = 240\ kcal/hr = 279\ W$

$q_{Latent} = 2 \times 80 = 160\ kcal/hr = 186\ W$

  - **Electric Coffee Maker (25 L):**

$q_{Sensible} = 1000\ kcal/hr = 1162\ W.$

$q_{Latent} = 1000\ kcal/hr = 1162\ W.$

$\boldsymbol{q_{Sensible\ total}} = 1162 + 279 = 1441\ W.$

$\boldsymbol{q_{Latent\ total}} = 1162 + 186 = 1348\ W.$

q_{Total} = 2789 W

$\boldsymbol{q_{internal\ of\ the\ gym}}$ = **34550 W**

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3) **Ventilation Load**:

$$q_{Ventilation} = 1.23 \times \dot{V}_{vent.} \times (T_{out} - T_{in}) + \left[3000 \times \dot{V}_{vent.} \times (\omega_{out} - \omega_{in})\right]$$

- **Arena:**

$\dot{V}_{vent.} = 750\ L/s$. From previous heating calculations.

$q_{Vent.\ Arena} = 1.23 \times 750 \times (35 - 24) + [3000 \times 750 \times (0.014 - 0.009)]$

= 10150 + 11250 = 21400 W

- **Reception:**

$\dot{V}_{vent.\ Recep.} = 216\ L/s$

$$q_{Vent.\ Recep.} = 1.23 \times 216 \times (35 - 24) + [3000 \times 216 \times (0.014 - 0.009)]$$

= 2922 + 3240 = 6162 W

- **Lockers room:**

$$\dot{V}_{vent.\ Lockers} = 112.5\ L/s.$$

$$q_{Vent.} = 1.23 \times 112.5 \times (35 - 24) + [3000 \times 112.5 \times (0.014 - 0.009)]$$

= 1522 + 1687 = 3209 W

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4) Infiltration Load:

- **Arena**:

$$\dot{V}_{infil} = 415\ L/s$$

$$q_{Infil.} = 1.23 \times 415 \times (35 - 24) + [3000 \times 415 \times (0.014 - 0.009)]$$

= 5615 + 6225 = 11840 W

- **Reception:**

$$\dot{V}_{infil} = 99\ L/s$$

$$q_{Infil.} = 1.23 \times 99 \times (35 - 24) + [3000 \times 99 \times (0.014 - 0.009)]$$

= 1339 + 1485 = 2824 W

- **Lockers room:**

$$\dot{V}_{infil} = 18\ L/s$$

$$q_{Infil.} = 1.23 \times 18 \times (35 - 24) + [3000 \times 18 \times (0.014 - 0.009)]$$

= 243 + 270 = 513 W

$$\boldsymbol{q_{TOTAL\ room\ load\ of\ the\ gym} = q_{Transmission} + q_{Internal} + q_{infiltration}}$$

= **24017 + 31276 + 513 + 2824 + 11840**

= **74325 W**

$q_{Sensible\ of\ the\ gym}$ = **48620 W**

For shop 1:

1) Transmission with solar load:

- **Northern windows:**

$$q_{glass} = U_{glass} * A_{glass} * \Delta T_{glass} + A_{glass} * (SHGF) * (S.C) * (CLF)$$

$A_{glass} = hieght * \sum glass\ lengths$ = 4* 1.3 = 5.2 m2
U_{glass} = 3.3
$\Delta T_{glass} = T_\circ - T_i$ = 35-24 = 11C.

$$q_{glass} = U_{glass} * A_{glass} * \Delta T_{glass} + A_{glass} * (SHGF) * (S.C) * (CLF)$$
= 3.3*5.2*11+5.2*140*.3*.91 = 387 W

- **Northern walls:**

➢ $q_{wall} = U_{wall} * A_{wall} * CLTD$

$A_{wall} = hieght * \sum wall\ lengths$ = 4* 4.76 = 19 m2
$R_{wall} = R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166
$U_{wall} = \frac{1}{\sum R_{wall}}$ = 0.49 KW/m2.K
$\Delta T_{wall} = T_\circ - T_i$ = 35-24 = 11C.

$q_{wall} = U_{wall} * A_{wall} * CLTD$ = 0.49*19*12 = 112W

- **Roof:**

$q_{roof} = U_{roof} * A_{roof} * \ CLTD$

A_{roof} = 27.3 m2
$R_{roof} = \ R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166
$U_{roof} = \frac{1}{\sum R_{roof}}$ = 0.49 KW/m2.K
$\Delta T_{roof} = T_\circ - \ T_i$= 35-24 = 11C.

$q_{roof} = U_{roof} * A_{roof} * \ CLTD$ = 0.49*27.3*21 = 281 W

- **Floor:**

$q_{floor} = U_{floor} * A_{floor} * \ \Delta T_{floor}$

A_{floor} = 27.3 m2
$R_{floor} = \ R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 1.33
$U_{floor} = \frac{1}{\sum R_{floor}}$ = 0.75 KW/m2.K
$\Delta T_{roof} = T_\circ - \ T_i$= 35-24 = 11C.

$q_{floor} = U_{floor} * A_{floor} * \ \Delta T_{floor}$ = 0.75*27.3*11 = 225 W.

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2) Ventilation load:

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \ \Delta T + 3000 * \dot{V}_{vent} * \ \Delta\omega$

$\#\ people$ = 15 people

$\dot{V}_{vent}$ = $(air\ requierments/person) * (\#\ people)$ = 5 (L/s) * 6 = 30 L/s

$\Delta T = T_i - \ T_\circ$ = 35-24 = 11C.

$\Delta\omega = \omega_i - \ \omega_\circ$ = 0.014-.009 = 0.005.

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \ \Delta T + 3000 * \dot{V}_{vent} * \ \Delta\omega$ = 1.23 *30*11 + 3000*30*.005 = 856 W.

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3) Infiltration load:

$q_{infiltration} = 1.23 * \dot{V}_{infil} * \Delta T + 3000 * \dot{V}_{infil} * \Delta\omega$

$\dot{V}_{infil} = V * (air\ changes\ per\ second)$ = 27.3*4*(1/3600) = 30.3 L/s

$\Delta T = T_i - T_\circ$ = 35-24 = 11C.

$\Delta\omega = \omega_i - \omega_\circ$ = 0.014-.009 = 0.005.

$q_{infiltration} = 1.23 * \dot{V}_{vent} * \Delta T + 3000 * \dot{V}_{vent} * \Delta\omega$ = 1.23 *30.3*11 + 3000*30.3*.005 = 865 W.

4) Internal load:

- **Lights**:

$q_{lights} = lamp\ rating * Fu * Fb * CLF$

$lamp\ rating = 25\left(\frac{watt}{m2}\right) * area = 25\left(\frac{watt}{m2}\right) * 27.3m2 = 683\ W$

$q_{lights} = lamp\ rating * Fu * Fb * CLF = 683 * .97 * 1 * 1.2$ = 795 W

- **People**:

$q_{s_{people}} = sensible\ heat\ gain * CLF * \#\ of people$

$q_{l_{people}} = latent\ heat\ gain * CLF * (\#\ of people)$

$(\#people)$ = 6 people.

$q_{s_{people}} = sensible\ heat\ gain * CLF * \#\ of people$ = 92.5*1*6= 555 W.

$q_{l_{people}} = latent\ heat\ gain * (\#\ of people)$ = 92.5*6= 555 W.

q_{people} = 555+555 = 1110 W.

$\boldsymbol{q_{TOTAL\ of\ Shop\ 1} = q_{Transmission} + q_{Internal} + q_{infiltration}}$

= **3775 W**

$q_{Sensible\ of\ Shop\ 1}$ = **2765 W**

For shop 2:

1) **Transmission with solar load:**

- **Northern windows:**

$$q_{glass} = U_{glass} * A_{glass} * \Delta T_{glass} + A_{glass} * (SHGF) * (S.C) * (CLF)$$

$A_{glass} = hieght * \sum glass\ lengths$ = 4* 1.3 = 5.2 m2
U_{glass} = 3.3
$\Delta T_{glass} = T_\circ - T_i$ = 35-24 = 11C.

$$q_{glass} = U_{glass} * A_{glass} * \Delta T_{glass} + A_{glass} * (SHGF) * (S.C) * (CLF)$$
= 3.3*5.2*11+5.2*140*.3*.91 = 387 W

- **Northern walls:**

$q_{wall} = U_{wall} * A_{wall} * CLTD$

$A_{wall} = hieght * \sum wall\ lengths$ = 4* 4.76 = 19 m2
$R_{wall} = R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166
$U_{wall} = \frac{1}{\sum R_{wall}}$ = 0.49 KW/m2.K
$\Delta T_{wall} = T_\circ - T_i$ = 35-24 = 11C.

$q_{wall} = U_{wall} * A_{wall} * CLTD$ = 0.49*19*12 = 112W

- **Roof:**

$q_{roof} = U_{roof} * A_{roof} * \ CLTD$

A_{roof} = 27.3 m2
$R_{roof} = \ R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 2.0166
$U_{roof} = \frac{1}{\sum R_{roof}}$ = 0.49 KW/m2.K
$\Delta T_{roof} = T_\circ - \ T_i$= 35-24 = 11C.

$q_{roof} = U_{roof} * A_{roof} * \ CLTD$ = 0.49*27.3*21 = 281 W

- **Floor:**

$q_{floor} = U_{floor} * A_{floor} * \ \Delta T_{floor}$

A_{floor} = 27.3 m2
$R_{floor} = \ R_\circ + R_{st} + R_c + R_{in} + R_B + R_{plas} + R_i$ = 1.33
$U_{floor} = \frac{1}{\sum R_{floor}}$ = 0.75 KW/m2.K
$\Delta T_{roof} = T_\circ - \ T_i$= 35-24 = 11C.

$q_{floor} = U_{floor} * A_{floor} * \ \Delta T_{floor}$ = 0.75*27.3*11 = 225 W.

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2) Ventilation load:

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \ \Delta T + 3000 * \dot{V}_{vent} * \ \Delta\omega$

$\#\ people$ = 15 people

$\dot{V}_{vent}$ = $(air\ requierments/person) * (\#\ people)$ = 5 (L/s) * 6 = 30 L/s

$\Delta T = T_i - \ T_\circ$ = 35-24 = 11C.

$\Delta\omega = \omega_i - \ \omega_\circ$ = 0.014-.009 = 0.005.

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \ \Delta T + 3000 * \dot{V}_{vent} * \ \Delta\omega$ = 1.23 *30*11 + 3000*30*.005 = 856 W.

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3) Infiltration load:

$q_{infiltration} = 1.23 * \dot{V}_{infil} * \Delta T + 3000 * \dot{V}_{infil} * \Delta\omega$

$\dot{V}_{infil} = V * (air\ changes\ per\ second)$ = 27.3*4*(1/3600) = 30.3 L/s

$\Delta T = T_i - T_\circ$ = 35-24 = 11C.

$\Delta\omega = \omega_i - \omega_\circ$ = 0.014-.009 = 0.005.

$q_{infiltration} = 1.23 * \dot{V}_{vent} * \Delta T + 3000 * \dot{V}_{vent} * \Delta\omega$ = 1.23 *30.3*11 + 3000*30.3*.005 = 865 W.

4) Internal load:

- **Lights**:

$q_{lights} = lamp\ rating * Fu * Fb * CLF$

$lamp\ rating = 25\left(\frac{watt}{m2}\right) * area = 25\left(\frac{watt}{m2}\right) * 27.3m2 = 683\ W$

$q_{lights} = lamp\ rating * Fu * Fb * CLF = 683 * .97 * 1 * 1.2$ = 795 W

- **People**:

$q_{s_{people}} = sensible\ heat\ gain * CLF * \#\ of people$

$q_{l_{people}} = latent\ heat\ gain * CLF * (\#\ of people)$

$(\#people)$ = 6 people.

$q_{s_{people}} = sensible\ heat\ gain * CLF * \#\ of people$ = 92.5*1*6= 555 W.

$q_{l_{people}} = latent\ heat\ gain * CLF * (\#\ of people)$ = 92.5*1*6= 555 W.

q_{people} = 555+555 = 1110 W.

$q_{TOTAL\ of\ Shop\ 2} = q_{Transmission} + q_{Internal} + q_{infiltration}$

= **3775 W**

$q_{Sensible\ of\ Shop\ 2}$ = **2765 W**

$q_{TOTAL\ of\ Gym+Shops} = q_{Transmission} + q_{Internal} + q_{infiltration}$

= **81875 W**

$q_{Sensible\ of\ Gym+Shops} = 2765 + 2765 + 48620$ = **54150 W**

- **Main Duct # 2 (2 shops & gym):**

$$SHR_2 = \frac{54150}{81875} = 0.660$$

$h_{S2} = 31\ Kj/Kg$

$h_i = 47.5\ Kj/Kg$

$q_{TOTAL\ of\ Gym+Shops} = \dot{m}_{S2} \times (h_i - h_{S2})$

$$\dot{m}_{S2} = \frac{q_{TOTAL\ of\ Gym+Shops}}{(h_i - h_{S1})} = \frac{81.875KW}{(47.5 - 31)} = 4.96\ Kg/s.$$

$v_{S2} = 0.82\ m^3/Kg$

$\dot{V}_{S2} = \dot{m}_{S2} \times v_{S2} = 4.96 \times 0.82 = 4.0\ m^3/s = 8622\ CFM$

- **Flow rate for the shops:**

$$\dot{m}_{S\ For\ each\ shop} = \frac{q_{TOTAL\ of\ Shop}}{(h_i - h_{S1})} = \frac{3.775\ KW}{(47.5 - 31)} = 0.228\ Kg/s$$

$\dot{V}_{S\ For\ each\ shop} = \dot{m}_S \times v_{S2} = 0.228 \times 0.82 = 0.187\ m^3/s = 396\ CFM$

- **Flow rate for the gym:**

$\dot{m}_{S\ For\ theGym} = \dot{m}_{S2} - (2 \times \dot{m}_{S\ For\ each\ shop}) = 4.5\ Kg/s$

$\dot{V}_{S\ For\ the\ gym} = \dot{V}_{S2} - (2 \times \dot{V}_{S\ For\ each\ shop}) = 4.0 - 2 \times 0.187 = 3.63\ m^3/s$

$= 8622 - 2 \times 396 = 7830\ CFM$

$\dot{V}_{grill} = \frac{\dot{V}_{S1}}{8}$

$\dot{V}_{grill} = \frac{4.0}{8}$ = 0.5 m3/s.

$\text{Throw}_{\text{horizental}} = \frac{\text{L}}{2 * \text{n}}$

n=

$\text{Throw}_{\text{horizental}} =$

$\text{Throw}_{\text{vertical}} = \frac{\text{L}}{2 * \text{n}}$

n=

$\text{Throw}_{\text{vertical}} =$

Longest run =

Let $V_{main} = 10 m/s$

$\dot{V}_{ab} = 4000\ l/s$

$\frac{\Delta p}{L} = 1.3$

D_{ab} = 715 mm

a =

b =

$\dot{V}_{bc} = 3815\ l/s$

D_{bc} = 690 mm

a = mm

b = mm

$\dot{V}_{cd} = 3625\ l/s$

D_{cd} = 670 mm

a = mm

b = mm

$B - 1 = C - 1 = D - 1 = mm$

a = mm

b = mm

For the cafeteria:

1) **Skylight transmission with solar load:**

$A_{\text{Sky lights}} = 613.739\ m^2$ From previous heating calculations.

$U_{Skylight} = 3.3\ W/m^2C$

$SHGF = 870\ W/m^2$ From Table (4-10) for horizontal glass (Skylight).

$S.C = 0.9$ For a regular sheet double glass (no internal shading) from Table (4-11).

$CLF = 0.85$ From Table (4-12) for horizontal glass at noon.

$q_{Skylight} = U_{Skylight} * A_{Skylight} * \Delta T_{Skylight} + A_{Skylight} * (SHGF) * (S.C) * (CLF)$

$q_{Skylight} = 3.3 * 613.739 * 11 + 613.739 * (870) * (0.2) * (0.85)$

= 113051 W

2) Floor transmission:

$q_{floor} = U_{floor} * A_{floor} * \Delta T_{floor}$

$$A_{floor} = 613.739\ m^2$$
$$U_{floor} = 0.757\ W/m^2C.$$

$q_{floor} = 0.757 * 613.739 * 11$ = 5111 W

3) Ventilation load:

$q_{ventilation} = 1.23 * \dot{V}_{vent} * \Delta T + 3000 * \dot{V}_{vent} * \Delta\omega$

$\#\ people$ = 15 people

$\dot{V}_{vent}$ = $(air\ requierments/person) * (\#\ people)$ = 5 (L/s) * 15 = 75 L/s

$q_{ventilation} = 1.23 * 75 * 11 + 3000 * 75 * 0.005$ = 2140 W

4) Infiltration load:

$q_{infiltration} = 1.23 * \dot{V}_{infil} * \Delta T + 3000 * \dot{V}_{infil} * \Delta\omega$

$\dot{V}_{infil}$ = $V * (air\ changes\ per\ second)$ = 75.7*4*(1/3600) = 84 L/s

$q_{infiltration} = 1.23 * 84 * 11 + 3000 * 84 * 0.005$ = 2396 W

$\boldsymbol{q_{TOTAL\ room\ load\ of\ the\ cafeteria} = q_{Transmission} + q_{Internal} + q_{infiltration}}$

$$= \boxed{120558\ W}$$

$$q_{Sensible\ of\ cafeteria} = \boxed{119298\ W}$$