APPENDIX 1

PROCEDURE FOR CALCULATION OF COOLING LOAD ESTIMATION

1. Heat gain through walls / ceiling

\[ = U \text{ value} \times \text{Area of the wall or ceiling} \times CLTD_{\text{correct}} \]

\[ CLTD_{\text{correct}} = CLTD + LM + (25.5 - T_i) + (T_{o,m} - 29.4) \]

where
\( CLTD \) - Cooling Load Temperature Difference
\( LM \) - Latitude correction factor for the month
\( T_i \) - Indoor design temperature
\( T_{o,m} \) - Outdoor mean temperature = \( (T_{\text{max}} + T_{\text{min}})/2 \)

where \( T_{\text{max}} \) - Maximum outdoor temperature
\( T_{\text{min}} \) - Minimum outdoor temperature

2. Heat gain through window

\[ = \text{SGHF} \times \text{Area of the window} \times SC \times CLF \]

3. Heat gain through door = \( U \text{ value} \times \text{Area of the door} \times \Delta T \)

where \( \Delta T \) = Difference between outdoor temperature and design indoor temperature

4. Heat gain through floor = \( U \text{ value} \times \text{Area of the floor} \times \Delta T \)
5. Sensible heat gain due to infiltration  
   \[ = \text{Air infiltration rate} \times \text{Specific heat of air} \times \Delta T \]

6. Sensible heat gain due to ventilation  
   \[ = \text{Air ventilation rate} \times \text{Specific heat of air} \times \text{No. of persons} \times \Delta T \]

7. Latent heat gain due to infiltration  
   \[ = \text{Air infiltration rate} \times \text{Latent heat of vaporization of water in the air} \times \text{Humidity difference} \]

8. Latent heat gain due to ventilation  
   \[ = \text{Air ventilation rate} \times \text{Latent heat of vaporization of water in the air} \times \text{Humidity difference} \]

10. Heat gain from appliances  
    \[ = \sum_{i=1}^{n} (\text{No. of appliances} \times \text{Heat dissipated by single appliance}) \]

11. Heat gain from lighting equipments  
    \[ = \text{Lighting capacity} \times \text{Ballast factor} \times \text{CLF} \]

13. Sensible heat gain from occupants  
    \[ = \text{Sensible heat gain per person} \times \text{No. of persons} \times \text{CLF} \]

14. Latent heat gain from occupants  
    \[ = \text{Latent heat gain per person} \times \text{No. of persons} \]

Summation of all the above heat gains gives the hourly cooling load requirement with respect to particular time.
DATA CONSIDERED FOR COOLING LOAD ESTIMATION

(i) Area of the Building components

<table>
<thead>
<tr>
<th>Component</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North wall</td>
<td>1219.2</td>
</tr>
<tr>
<td>South wall</td>
<td>1219.2</td>
</tr>
<tr>
<td>East wall</td>
<td>762</td>
</tr>
<tr>
<td>West wall</td>
<td>762</td>
</tr>
<tr>
<td>North doors</td>
<td>548.64</td>
</tr>
<tr>
<td>South windows</td>
<td>243.84</td>
</tr>
<tr>
<td>East windows</td>
<td>152.4</td>
</tr>
<tr>
<td>West windows</td>
<td>152.4</td>
</tr>
<tr>
<td>Ceiling / floor</td>
<td>1000</td>
</tr>
</tbody>
</table>

(ii) Lights

Type: fluorescent light

<table>
<thead>
<tr>
<th>Lighting capacity</th>
<th>40 W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballast factor</td>
<td>1.25</td>
</tr>
<tr>
<td>CLF (cooling load factor for lighting)</td>
<td>1</td>
</tr>
<tr>
<td>No. of lights</td>
<td>1000</td>
</tr>
</tbody>
</table>

(iii) Occupants

<table>
<thead>
<tr>
<th>No. of persons</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latent heat gain per person</td>
<td>61.8 W</td>
</tr>
<tr>
<td>Sensible heat gain per person</td>
<td>77 W</td>
</tr>
<tr>
<td>CLF per person</td>
<td>1</td>
</tr>
</tbody>
</table>
Lighting and Human loads are considered from 8 AM to 7 PM

(iv) Air infiltration and ventilation

Air ventilation rate = 0.008248 kg/s
(for office building)

\[
\text{No. of Air Changes per Hour (ACH)}
\]

\[
\text{for tight fitted windows and doors, weather stripping, no fire place}
\]

\[
= 0.5
\]

Volume flow rate of air infiltration into the building

\[
= \frac{(\text{ACH} \times \text{volume of the building})}{3600}
\]

\[
= \frac{(0.5 \times 30480)/3600}{3} = 4.233 \text{ m}^3/\text{s}
\]

Air Infiltration rate = Density of air × Volume flow rate of air

\[
= 4.931 \text{ kg/s}
\]

(v) Appliances

No. of communications/transmissions = 100

Heat gain from single communication/transmission = 1641 W

No. of microcomputers/word processors = 1000

Heat gain from single microcomputer/word processor = 88 W

No. of computers = 50

Heat gain from single computer = 2200 W

No. of printers = 20

Heat gain from single printer = 733 W
(vi) Sensible heat gain factor for the room temperature of 28°C

<table>
<thead>
<tr>
<th>Months</th>
<th>SHGF(W/m²)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>South</td>
<td>East &amp;West</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>652.8</td>
<td>671.7</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>495.1</td>
<td>728.5</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>296.45</td>
<td>719</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>183</td>
<td>690.7</td>
<td></td>
</tr>
</tbody>
</table>

(vii) Overall heat transfer coefficient (U value) for flat roofs and walls

5 cm heavy weight concrete with 5 cm insulation, without suspended ceiling

\[
= 1.1694 \text{ W/m}^2\text{K}
\]

10 cm face brick, heavyweight concrete block

North wall = 2.356 W/m²K
South wall = 2.356 W/m²K
East wall = 2.356 W/m²K
West wall = 2.356 W/m²K

(viii) Solar radiation through glass

Sensible Heat Gain Factor (SGHF) – South = 137 W/m²
Sensible Heat Gain Factor (SGHF) – East / West = 234 W/m²
Shading Coefficient (SC) = 0.35
(ix) CLF for glass with interior shading

<table>
<thead>
<tr>
<th>Solar time</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>0.04</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
<td>0.09</td>
<td>0.16</td>
<td>0.23</td>
<td>0.38</td>
<td>0.58</td>
<td>0.75</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.47</td>
<td>0.72</td>
<td>0.8</td>
<td>0.76</td>
<td>0.62</td>
<td>0.41</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>0.05</td>
<td>0.05</td>
<td>0.04</td>
<td>0.04</td>
<td>0.03</td>
<td>0.06</td>
<td>0.09</td>
<td>0.11</td>
<td>0.13</td>
<td>0.15</td>
<td>0.16</td>
<td>0.17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solar time</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>0.8</td>
<td>0.68</td>
<td>0.5</td>
<td>0.35</td>
<td>0.27</td>
<td>0.19</td>
<td>0.11</td>
<td>0.09</td>
<td>0.08</td>
<td>0.07</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>East</td>
<td>0.24</td>
<td>0.22</td>
<td>0.2</td>
<td>0.17</td>
<td>0.14</td>
<td>0.11</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>West</td>
<td>0.31</td>
<td>0.53</td>
<td>0.72</td>
<td>0.82</td>
<td>0.81</td>
<td>0.61</td>
<td>0.16</td>
<td>0.12</td>
<td>0.1</td>
<td>0.08</td>
<td>0.07</td>
<td>0.06</td>
</tr>
</tbody>
</table>
APPENDIX 2

CALIBRATION OF TEMPERATURE MEASURING DEVICES

In order to have a valuable and reliable experimental data for each proposed data run, the correction factor for Resistance temperature detector (RTD) had to be determined. The calibration of RTD gives the correction factor for each RTD. These correction factors offset value read by data acquisition system for each temperature measuring devices by a set amount, insuring that the reading is correct according to industry standards.

The RTDs were checked for accuracy and reliability by immersing them in a water bath and checking temperature read by this temperature measuring devices against a temperature read by a previously calibrated RTD, which is used as secondary standards to calibrate the RTDs. The temperature of the water bath was varied from approximately 30°C to just under 100°C in 10 to 20°C increments. The water was stirred between temperature levels to avoid stratification in the water bath, and the temperature measuring device is tapped to dislodge any air bubbles. The RTDs are found to have a precision of ± 0.1°C. These correction factors were entered into data acquisition program to correct the measured temperature data.
APPENDIX 3

ERROR ANALYSIS

General Forms

The errors associated with various measurements, and in calculations of performance parameters are couples in this section. The maximum possible errors in various measured parameters namely temperature, flow rate, time and energy are estimated from the minimum values of output and accuracy of instrument. This method is based on careful specification of the uncertainties in the various experimental measurements.

If an estimated quantity, S depends on independent variables like \((x_1, x_2, x_3, \ldots, x_n)\) then the error in the value of ‘s’ is given by

\[
\frac{\partial s}{s} = \left\{ \left( \frac{\partial x_1}{x_1} \right) + \left( \frac{\partial x_2}{x_2} \right) + \cdots \left( \frac{\partial x_n}{x_n} \right) \right\}
\]

where \(\left( \frac{\partial x_1}{x_1} \right), \left( \frac{\partial x_2}{x_2} \right)\) etc are the errors in the independent variables.

ERRORS IN MEASURED QUANTITIES

Temperature

Resistance Temperature Detectors (RTDs) of type Pt 100 are used to measure the temperature at various state points of the system. The temperatures measured by RTDs are displayed by the digital temperature detector. The maximum possible error in the case of temperature
measurement is calculated from the minimum values of the temperature measured and accuracy of the instrument (RTD with temperature indicator). The errors in temperature measurement are:

\[
\left( \frac{\partial T}{T} \right)_{\text{Exp}} = \left( \left( \frac{\partial T_{\text{RTD}}}{T_{\text{RTD}}} \right)^2 + \left( \frac{\partial T_{\text{ind}}}{T_{\text{ind}}} \right)^2 \right)^{\frac{1}{2}}
\]

\[
\left( \frac{\partial T}{T} \right)_{\text{Exp}} = \left( \left( \frac{0.3^\circ C}{30^\circ C} \right)^2 + \left( \frac{0.1^\circ C}{30^\circ C} \right)^2 \right)^{\frac{1}{2}} = 0.010531 \text{ or } 1.0531\%}
\]