COMPUTATION OF PEAK HEAT LOAD INCLUDING PEAK HEAT LOAD OF TANFED COLD STORAGE AT KOYEMBADU, CHENNAI.

Introduction:
The existing cold storage having 2 (two) chambers is proposed to be converted into multi-commodity cold storage having 8 (eight) chambers with 4 (four) chambers in each tier of 6.90m height. Besides 2 (Two) small chambers have been proposed at corridor. The chambers wise list of commodities to be stored alongwith size of and actual storage capacity of each chamber is furnished hereunder:-

| Bottom Tier: | Chamber No 1 | 15.3m X 10.4m X 6.90m ht. | Apple – 215 mt. |
| Chamber No 2 | 15.3m X 10.4m X 6.90m ht. | Dates – 450 mt. |
| Chamber No 3 | 15.3m X 8.1mX 6.90m ht. | Potato – 275 mt. |
| Chamber No 4 | 13.3m X 8.1m X 6.90m. ht. | Pulses – 300 mt. |

| Top Tier: | Chamber No 5 | 15.3m X 10.4m X 6.90m ht. | Apple – 215 mt. |
| Chamber No 6 | 15.3m X 10.4m X 6.90m ht. | Apple – 215 mt. |
| Chamber No 7 | 15.3m X 8.1mX 6.90m ht. | Dry Chilli – 125 mt. |
| Chamber No 8 | 13.3m X 8.1m X 6.90m. ht. | Dry Chilli – 125 mt. |

| Bottom Tier: | Chamber No 9 | 12.3m X 3m X 4.6m ht. | Dates – 50 mt. |
| Chamber No 10 | 12.3m X 3m X 4.6m ht. | Orange – 35 mt. |

Indian apples are generally loaded from September to December foreign apples are loaded from April to July with peak loading in May. Potatoes are loaded in March. Dry chilli is loaded from March to April Dates are loaded from February to April. Pulses are generally loaded from March to early May. For daily loading of apple, potato, dry chilli, dates pulses, orange d.b.t. of the chamber will have to be maintained at maxm 40°F, 50°F, 55°F, 45°F, 65°F & 45°F prior to next day’s loading operations. The dry bulb temperature & RH to the items will be maintained throughout the storage period as follows.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Item</th>
<th>d.b.t. - 0</th>
<th>Relative humidity (%)</th>
<th>Storage life</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Apple</td>
<td>32 F ± 1°F</td>
<td>95%</td>
<td>6-7 months</td>
</tr>
<tr>
<td>2.</td>
<td>Potato</td>
<td>35 F ± 1°F</td>
<td>90-95%</td>
<td>9 months</td>
</tr>
<tr>
<td>3.</td>
<td>Dry Chilli</td>
<td>45 F ± 1 F</td>
<td>85%</td>
<td>9-10 months</td>
</tr>
<tr>
<td>4.</td>
<td>Dates</td>
<td>36°F ± 1°F</td>
<td>85%</td>
<td>8-9 months</td>
</tr>
<tr>
<td>5.</td>
<td>Pulses</td>
<td>60 F ± 1 F</td>
<td>75-80%</td>
<td>12 months</td>
</tr>
<tr>
<td>6.</td>
<td>Orange</td>
<td>39 F ± 1°F</td>
<td>90%</td>
<td>4 months</td>
</tr>
</tbody>
</table>
PARAMETERS:-
Now, the parameters on the basis of which load calculations will take place are furnished here under.

- Loading generally takes place in early morning and evening hours.
- Loading rate of apple, potato, dry chilli, dates, pulses, orange are taken as 7%, 5%, 5%, 5%, 10% respectively.
- Ambient condition around Chennai during end March and May is maxm 38°C & 42°C respectively during day time and d.b.t. is 26 & 30°C respectively during early morning hours.
- Relative humidity around Chennai during evening /early morning hours remains around 75%, and 80% respectively during end March & May respectively.
- Specific heats of the products are as follows:-

<table>
<thead>
<tr>
<th>Product</th>
<th>Cp for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>0.86 Btu/lb(°F)</td>
</tr>
<tr>
<td>Apple</td>
<td>0.90</td>
</tr>
<tr>
<td>Dry Chilli</td>
<td>0.94</td>
</tr>
<tr>
<td>Dates</td>
<td>0.88</td>
</tr>
<tr>
<td>Pulses</td>
<td>0.85</td>
</tr>
<tr>
<td>Orange</td>
<td>0.90</td>
</tr>
</tbody>
</table>

- Coefficient of heat transfer for ceiling, walls and floors is computed from the following equation:

\[ U = \frac{1}{1/f_o + x_1/k_1 + x_2/k_2 + 1/c + 1/f} \]

Where \( f_o, f \) = outside & inside surface coefficients accounting for convection & radiation.
\( X_1, x_2 = \) thickness of insulating layers.
\( K_1, k_2 = \) thermal conductivities of insulating layers.
\( C = \) conductance of non-homogeneous material i.e. brick wall & plaster from surface to surface.

7) Respiration heat loads of products are as follows.

<table>
<thead>
<tr>
<th>Product</th>
<th>Temperature</th>
<th>Heat Load (Btu/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>32°F</td>
<td>440 to 880 Btu/ton</td>
</tr>
<tr>
<td>Apple</td>
<td>40°F</td>
<td>1100 to 1760 Btu/ton</td>
</tr>
<tr>
<td></td>
<td>70°F</td>
<td>2200 to 3520 Btu/ton</td>
</tr>
<tr>
<td>Orange</td>
<td>32°F</td>
<td>660 to 900 Btu/ton</td>
</tr>
<tr>
<td></td>
<td>40°F</td>
<td>1400 Btu/ton</td>
</tr>
<tr>
<td></td>
<td>60°F</td>
<td>5000 Btu/ton</td>
</tr>
<tr>
<td></td>
<td>80°F</td>
<td>8000 Btu/ton</td>
</tr>
</tbody>
</table>

8) Apple, Potato, Dry chilli, dates, pulses & orange are supposed to take 6 hrs.
6 hrs, 6 hrs, & 4 hrs. 4 hrs. & 4 hrs. respectively for daily loading.
Computation of Peak Heat Load:-

A) Transmission Load:

Coefficient of heat transfer (U) for 150mm thk EPS for ceiling & walls & 125mm thk below floor having 15kg/m3 density is found to be 0.078 Btu/lb(°F) (Sq.ft.) for ceiling, 0.076 Btu/lb (°F) (Sq.ft.) for walls and 0.069 Btu/lb (°F) (Sq.ft.) for floors, temp below floor is taken as 85°F.

Now, \( Q = UA \Delta t \)

When \( A = \) Exposed area is sq.ft.

\( \Delta t = \) Temperature difference between ambient & chamber temperature

& \( U = \) Heat transfer coefficient

For Ceiling for Apple = \( q \times 0.078 \times (3424 \times (108-40)) \) Btu/hr.
\[ = 18160 \text{ Btu/hr.} \]

For Wall for Apple:
\[ = q \times (0.076 \times [5730 \times (108-40)] + 2872 \times (86-40))] \text{Btu/hr.} \]
\[ = 39652 \text{ Btu/hr.} \]

Floor:
\[ q = 0.069 \times 1712 \times (85-40) \text{ Btu/hr.} \]
\[ = 5316 \text{ Btu/hr.} \]

Total Q for Apple = 63,128 Btu/hr.

Potato:

For Wall Potato:
\[ q = 0.076 \times [(1908 \times (108-50)) + (1136 \times (86-50))] \text{Btu/hr.} \]
\[ = 11518 \text{ Btu/hr.} \]

Floor:
\[ q = 0.069 \times 1712 \times (85-50) \text{ Btu/hr.} \]
\[ = 5316 \text{ Btu/hr.} \]

Total Q for Potato = 14,739 Btu/hr.

Dates:

For Wall:
\[ q = 0.078 \times [(1908 \times (108-45)) + (1136 \times (86-45))] \text{Btu/hr.} \]
\[ = 13009 \text{ Btu/hr.} \]

For Floor:
\[ q = 0.069 \times (1908 \times (85-45)) \text{Btu/hr.} \]
\[ = 5266 \text{ Btu/hr.} \]

So, Total Q for dates = 18,275 Btu/hr.

Dry Chilli:

For Ceiling
\[ q = 0.078 \times 2667 \times (108-55) \text{ Btu/hr=11025 Btu/hr.} \]

For Wall
\[ q = 0.076 \times [3475 \times (108-55)] + (1514 \times (86-55)) \text{Btu/hr.} \]
\[ = 17544 \text{ Btu/hr.} \]

So, Total Q for = 28,569 Btu/hr.
Pulses:
For Wall
\[ q = 0.076 \times \{1737 \times (108-65)\} \]
\[ + \{1136 \times (86-65)\} \text{ Btu/hr.} = 7490 \text{ Btu/hr.} \]
For floor, \( Q \)
\[ = 0.069 \times \{1334 \times (85-65)\} \text{ Btu/hr.} = 1841 \text{ Btu/hr.} \]
So, Total \( Q \) for pulses
\[ = 9331 \text{ Btu/hr.} \]

Orange:
For Wall
\[ q = 0.076 \times \{148 \times (108-45)\} \]
\[ + \{148 \times (86-45)\} \text{ Btu/hr.} = 1170 \text{ Btu/hr.} \]
For floor, \( Q \)
\[ = 0.076 \times \{397 \times (86-45)\} \text{ Btu/hr.} = 1237 \text{ Btu/hr.} \]
So, Total \( Q \) for pulses
\[ = 2407 \text{ Btu/hr.} \]

For dates chamber in corridor, \( = q = 2407 \text{ Btu/hr.} \)
Thus, total \( q \) for dates = 20682 Btu/hr.

B) Infiltration load:
Infiltration load is determined from the following equation,
\[ Q = \text{cft (Room Vol.) x air change / hr. x air density x (h_o – h_i)} \text{ Btu/hr.} \]
When, \( h_o \) – total heat content of outside air at ambient conditions.
\( h_i \) = total heat content of air of inside the chamber.

Apple: Considering each chamber
\[ Q = 38768 \times 5.4/24 \times 1/13.4 \times (57.6-15) \text{ Btu/hr.} \]
When for 38,768 cft room Air Change/24 hrs. = 5.4
(Considering heavy usage)
\( h_o \) at 42°C & 85% RH = 57.6 Btu/lb
\( h_i \) at 40°F & 95% RH = 15 Btu/lb
(From Psychometric chart)
\[ = 27731 \text{ Btu/hr.} \]
Thus, for 3 (three) chambers, \( q = 83193 \text{ Btu/hr.} \)

Potato:
\[ q = 30,194 \times 5.4/24 \times 1/13.4 \times (54.4-19.7) \text{ Btu/hr.} \]
Where \( h_o \) at 38°C & 80% RH = 54.4 Btu/lb
\( h_i \) at 10°C & 92% RH = 19.7 Btu/lb (From Psychometric chart)
\[ = 17,593 \text{ Btu/hr.} \]

Dates:
\[ q = [38,768 \times 5.4/24 \times 1/13.4 \times [54.4-16.5]] \]
\[ + \{5994 \times 13/24 \times 1/13.4 \times [54.4 – 16.5]\} \text{ Btu/lb.} \]
Where for 5994 cft corridor room
Air change /24 hrs = 13.0 (Considering heavy usage)
\( h_i \) at 45°F & 85% RH = 16.5 Btu/lb.
(From Psychometric chart)
\[ = 33,944 \text{ Btu/hr.} \]
**Dry Chilli: (For each chamber)**
\[
q = [(30,194 \times 5.4/24 \times 1/13.4 \times [54.4-21.5]) \text{ Btu/lb.}]
\]
Where \( h_o \) at 55\(^\circ\)F & 85% RH = 21.5 Btu/lb = 16,680 Btu/hr.
(From Psychometric chart)
Thus, for 2 (Two) chambers, Total \( q = 33,360 \text{ Btu/hr.} \)

**Pulses:**
\[
q = [(30,194 \times 5.4/24 \times 1/13.4 \times [54.4-26.6]) \text{ Btu/lb.}]
\]
Where \( h_i \) at 65\(^\circ\)F & 75% RH = 26.6 Btu/lb
(From Psychometric chart)
\[= 14,094 \text{ Btu/hr.} \]

**Orange:**
\[
q = [(5,994 \times 13/24 \times 1/13.4 \times [54.4-16.9]) \text{ Btu/lb.}]
\]
Where \( h_i \) at 45\(^\circ\)F & 90% RH = 16.9 Btu/lb \[= 9,086 \text{ Btu/hr.} \]
(From Psychometric chart)

C) **Product Load:**
**Apple:** d.b.t. of around 40 mt Apples in 3 chambers brought down from 32\(^\circ\)C in May (Evening or morning hours) to 4.5\(^\circ\)C in 24-6/2 in 21 hrs.

Sensible heat load
\[
Q = 40 \times 2200 \times 0.90/21 \times (90-40) \text{ Btu/hr.} = 188,571 \text{ Btu/hr.}
\]
Respiration heat load \[= [40 \times 8800/24 + 600 \times 1760/24] \text{ Btu/hr.} \]
\[= 58,667 \text{ Btu/hr.} \]
So, peak product load of Apple \[= 247,238 \text{ Btu/hr.} \]

**Potato:**
D.B.T. of around 14 mt. potato is brought down from 30\(^\circ\)C in end March to 10\(^\circ\)C in 24-6/2 in 21 hrs.

Sensible heat load
\[
Q = 14 \times 2200 \times 0.86/21 \times (86-50) \text{ Btu/hr.} = 45,408 \text{ Btu/hr.}
\]
Respiration heat load \[= [14 \times 3000/24 + 261 \times 2000/24] \text{ Btu/hr.} \]
\[= 23,500 \text{ Btu/hr.} \]
So, peak product load of Potato \[= 68,908 \text{ Btu/hr.} \]

**Dates:**
D.B.T. of around 25 mt. of dates is brought down from 30\(^\circ\)C to 7\(^\circ\)C in 24-4/2 in 22 hrs.

Sensible heat load
\[
Q = 25 \times 2200 \times 0.88/22 \times (86-45) \text{ Btu/hr.} = 90,200 \text{ Btu/hr.} \]
Dry chilli:
d.b.t. of around 12.5 mt. Dry Chilli is daily brought down from 86°F to 55°F in 24-6/2 in 21 hrs.
Sensible heat load

\[ Q = 12.5 \times 2200 \times 0.94/21 \times (86-55) \text{ Btu/hr.} = 38,160 \text{ Btu/hr.} \]

Pulses:
d.b.t. of around 20 mt. Pulses is daily brought down from 86°F to 65°F in 24-4/2 in 22 hrs.
Sensible heat load

\[ Q = 20 \times 2200 \times 0.85/22 \times (86-65) \text{ Btu/hr.} = 35,700 \text{ Btu/hr.} \]

Orange:
d.b.t. of around 3.5 mt. Orange is daily brought down from 86°F to 45°F in 24-4/2 in 22 hrs.
Sensible heat load

\[ Q = 3.5 \times 2200 \times 0.90/22 \times (86-45) \text{ Btu/hr.} = 12,915 \text{ Btu/hr.} \]
Respiration heat load = \([3.5 \times 5500/24 + 32.5 \times 2000/24]\text{ Btu/hr.} = 3510 \text{ Btu/hr.} \]
So, peak product load of Orange = 16,425 Btu/hr.

D) Internal Load:

i) Lighting Apple:
   For 3 Apple chambers CFL Lights worth maxm 2.4 kw to be lit at time So, \( q = 2400 \times 3.4 \text{ Btu/hr.} = 8160 \text{ Btu/hr.} \)

ii) Lighting Potato:
   For Potato chamber CFL Lights maxm 1.0 kw to be lit at time during loading
   So, \( q = 1000 \times 3.4 \text{ Btu/hr.} = 3400 \text{ Btu/hr.} \)

iii) Lighting Dates:
   For Dates chambers CFL Lights maxm 1.25 kw to be lit at time during loading.
   So, \( q = 1250 \times 3.4 \text{ Btu/hr.} = 4250 \text{ Btu/hr.} \)

iv) Lighting Dry Chilli:
   For 2 (Two) Dry Chilli chambers CFL Lights worth maxm 1.8 kw to be lit at time during loading
   So, \( q = 1800 \times 3.4 \text{ Btu/hr.} = 6120 \text{ Btu/hr.} \)
v) **Lighting Pulses:**
   For one Pulse chamber maxm 0.8 kw CFL lamps to be lit at time during loading
   So, \( q = 800 \times 3.4 \text{ Btu/hr.} \)
   = 2720 Btu/hr.

vi) **Lighting Orange:**

vii) **For one Orange chamber maxm. 0.4 kw CFL lamps to be lit at time during loading**
    So, \( q = 400 \times 3.4 \text{ Btu/hr.} \)
    = 13600 Btu/hr.

**Occupancy –**

i) **Apple-** For loading in 3 apple chambers at time maxm 24 people are supposed to be present at a time.
   So, \( q = 24 \times 760 \text{ Btu/hr.} \)
   = 18,240 Btu/hr.

ii) **Potato-** For loading in one chamber maxm 10 (ten) people are supposed to be present at a time.
    So, \( q = 10 \times 760 \text{ Btu/hr.} \)
    = 7600 Btu/hr.

iii) **Dates-** For loading in 2 chambers maxm 15 (fifteen) people are supposed to be present at a time.
    So, \( q = 15 \times 760 \text{ Btu/hr.} \)
    = 11,400 Btu/hr.

iv) **Dry Chilli -** For loading in 2 chambers maxm 16 people are supposed to be present at a time.
    So, \( q = 16 \times 760 \text{ Btu/hr.} \)
    = 12,160 Btu/hr.

v) **Pulse-** For loading in 1 chamber maxm 8 people are supposed to be present at a time.
   So, \( q = 8 \times 760 \text{ Btu/hr.} \)
   = 6,080 Btu/hr.

vi) **Orange -** For loading in 1 chamber maxm 5 people are supposed to be present at a time.
    So, \( q = 5 \times 760 \text{ Btu/hr.} \)
    = 3800 Btu/hr.

Thus, total internal load of :

- Apple = 26,400 Btu/hr.
- Potato = 11,000 Btu/hr.
- Dates = 15,650 Btu/hr.
- Dry Chilli = 18,280 Btu/hr.
- Pulses = 8,800 Btu/hr.
- Orange = 5,160 Btu/hr.
E) Fresh Air load:
   i) Potato:
   During loading 1 (One) air change per day will take place.

   So, $q = 30,194 \times 1/24 \times 1/13.4 \times (44.8-19.7)$ Btu/hr.
   [Where $h_o$ at 30°C & RH 80% = 44.8 Btu/hr.
   $h_i$ at 10°C & RH 92% = 19.7 Btu/hr.
   (From Psychrometric chart)
   \[= 2356 \text{ Btu/hr.}\]

   ii) Dry Chilli:
   There will be 1 (One) air change daily during loading.

   So, $q = 2 \times 30,194 \times 1/24 \times 1/13.4 \times (44.8-21.5)$ Btu/hr.
   [Where $h_o$ at 30°C & RH 80% = 44.8 Btu/hr.
   $h_i$ at 13°C & RH 85% = 21.5 Btu/hr.
   (From Psychrometric chart)
   \[= 4375 \text{ Btu/hr.}\]

   iii) Dates:
   There will be 1 (One) air change daily during loading.

   So, $q = \{38768 \times 1/24 \times 1/13.4 \times (44.8-16.5) + 5994 \times 1/24 \times 1/13.4 \times (44.8-16.5)\}$ Btu/hr.
   $h_i$ at 45°F & RH 85% = 16.5 Btu/hr. (From Psychrometric chart)
   \[= 3940 \text{ Btu/hr.}\]

   iv) Orange:
   There will be 1 (One) air change daily during loading.

   So, $q = 5994 \times 1/24 \times 1/13.4 \times (44.8-16.8)$ Btu/hr.
   $h_i$ at 45°F & RH 85% = 16.9 Btu/hr. (From Psychrometric chart)
   \[= 520 \text{ Btu/hr.}\]

F) Equipment Load:
1) Apple:
   For Apple chambers total kw to be consumed is 4.95 kw.
   So, $q = 4950 \times 3.4 \text{ Btu/hr.}$
   \[= 16,830 \text{ Btu/hr.}\]

2) Potato:
   For Potato total kw to be consumed is 1.5 kw.
   So, $q = 1500 \times 3.4 \text{ Btu/hr.}$
   \[= 5,100 \text{ Btu/hr.}\]

3) Dates:
   For Dates total kw to be consumed is 1.5 kw.
   So, $q = 1500 \times 3.4 \text{ Btu/hr.}$
   \[= 5,100 \text{ Btu/hr.}\]

4) Dry Chilli:
   For Dry chilli total kw to be consumed is 1.5 kw.
   So, $q = 1500 \times 3.4 \text{ Btu/hr.}$
   \[= 5,100 \text{ Btu/hr.}\]
5) Pulse:
   For Pulses, total kw to be consumed is 1.1 kw.
   So, \( q = 1100 \times 3.4 \text{ Btu/hr.} \)
   \[ = 3740 \text{ Btu/hr.} \]

6) Orange:
   For Orange, total kw to be consumed is 0.55 kw.
   So, \( q = 550 \times 3.4 \text{ Btu/hr.} \)
   \[ = 1870 \text{ Btu/hr.} \]

Thus, peak heat load of Apple:
\[ = (A + B + C + D + E + F) = 436,789 \text{ Btu/ht.} = 36.4 \text{ TR (Approx.)} \]
Taking 10% as safety factor, peak heat load of Apple = 40 TR

Peak heat load of Potato = 119,642 Btu/ht. = 10 TR (Around)
Taking 10% as safety factor, Peak heat load of Potato = 11 TR

Peak heat load of Dates = 167,209 Btu/ht. = 13 9 TR (Approx.)
Taking 10% as safety factor, Peak heat load of dates = 15 TR

Peak heat load of Dry Chilli = 124,844 Btu/ht. = 10.65 TR (Approx.)
Taking 10% as safety factor, Peak heat load of Dry Chilli = 12 TR

Peak heat load of Pulses = 71,665 Btu/ht. = 5.96 TR (Approx.)
Taking 10% as safety factor, Peak heat load of Pulses = 6.5 TR

Peak heat load of Orange = 35,468 Btu/hr.
Taking 10% as safety factor, peak heat load of Orange = 3 TR (Approx.)

Peak heat load for apple is encountered is July / August or May when holding load of other products is in vogue.

So, peak heat load = (40 + 25) TR = 65 TR

When 25 TR is the holding load for other products.

Similarly, in end March/early April, Peak Heat Load for Potato, Dates, Dry chilli, Pulses & Orange are encountered when holding load for apple takes place.

So, Peak heat load – 46.5 + 22) TR = 68.5 TR

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