- 1 -
ABSTRACT

Under the global condition of running out of natural resource and domestic condition of no-existing the natural resource, the energy recovery system is being researched frequently. Among them, heat recovery ventilator, as the system which is recovering wasted heat from the residential space, is being studied frequently.

In this paper, the thermodynamic and economic research of heat recovering ventilator are conducted. The using compact heat exchangers-heat transfer area density, 1160 [$m^2/m^3$]- are made of aluminum and engineering plastic individually, have the triangler plane fins, and its purpose is transferring the sensible heat through the its planes. Heat recovering characteristics are studied at the seasonal out air condition, winter (-10~5°C, RH 40%), spring & fall(6~20°C, RH 60%), summer(21~40°C, RH 70%). As a result, the averaged sensible heat effectiveness is 0.82, and total effectiveness are varied at the range of 0.21~0.82. Sensible heat recovery rates are varied at the range of 18.7~772.2[KJ/sec], and total heat recovery rates are varied at the range of 15.1~989.4[KJ/sec] in the aluminum heat exchanger. And in the engineering plastic heat exchanger, averaged sensible effectiveness is 0.84, and total effectiveness are varied at the range of 0.32~0.70. Sensible heat recovery rates are varied at the range of 21.3~785.6[KJ/sec] and total heat recovery rates are varied at the range of 21.2~1027.8[KJ/sec]. Due to the mass transfer of moisture, the sensible heat recovery rates are not same to the total heat recovery rates. Total effectiveness have its maximum value at the condition of minimum latent heat difference between room and out air, and its minimum value at the condition of minimum sensible heat difference between room and out air, because latent heat effectiveness is smaller than sensible heat effectiveness.

The economic study is based on the monthly temperature and humidity condition at seoul in 2000. and as the result, the maximum gain is showed at the maximum sensible heat difference in January and minimum gain is showed in June. The pay back period of aluminum and engineering plastic are 5.6 year sameley. The life cycle savings are 2,780,917[won] in aluminum and 2,744,417 [won] in engineering plastic.
**No me nc lature**

- **A** : Heat Transfer area \[ m^2 \]
- **C** : Heat Capacity rate \[ KW / ℃ \]
- **C_r** : Heat Capacity Ratio \[-\]
- **C_p** : Specific Heat at Constant Pressure \[ KJ / Kg ℃ \]
- **COP** : Coefficient of Performance \[-\]
- **h** : Convective Heat transfer coefficient, Enthalpy \[ W / m^2 ℃ \], \[ KJ / Kg \]
- **h_{fs}** : Boiling Latent Heat \[ KJ / Kg \]
- **K** : Thermal Conductivity \[ W / m ℃ \]
- **LCS** : Life Cycle Saving \[ Won \]
- **M** : Mass \[ Kg \]
- **m'** : Mass Flow Rate \[ Kg/sec \]
- **MFL** : Money for Recovering Latent Heat \[ Won \]
- **MFP** : Money for Pressure Drop \[ Won \]
- **MFS** : Money for Recovering Sensible Heat \[ Won \]
- **MFV** : Money for Ventilator \[ Won \]
- **NTU** : Number of Transfer Unit \[-\]
- **PGM** : Pure Gain Money \[ Won \]
- **Q** : Heat Transfer Rate \[ KW \]
- **T** : Temperature \[ K \]
- **U** : Overall Heat Transfer Coefficient \[ W / m^2 ℃ \]
- **W** : Humidity Ratio \[ Kgw / Kga \]
- **X** : Mole Fraction \[ mol \]
**subscript**

a : Dry air  
c : Cold, Cooling  
f : Fin, Fan  
h : Hot, Heating  
**hum** : Humidifying  
**deh** : Dehumidifying  
**lat** : Latent  
lt : Life Time  
**max** : Maximum  
**min** : Minimum  
**s** : Saturation  
**sen** : Sensible  
**tot** : Total  
**w** : Water Vapor  
**wet** : Wet air
Greek symbols

\( \alpha \) : Increase Rate \hspace{1cm} [%]

\( \varepsilon \) : heat exchanger effectiveness \hspace{1cm} [-]

\( \eta \) : Efficiency \hspace{1cm} [-]

\( \phi \) : Relative Humidity \hspace{1cm} [%]

\( \rho \) : Density \hspace{1cm} [Kg/ m\(^3\)]

\( \mu \) : Degree of Saturation \hspace{1cm} [%]
1-1. 

---

---
\( \text{(Binary Mixture)} \)
<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Re</th>
<th>Pr</th>
<th>Colburn Factor</th>
<th>Friction Coefficient</th>
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<tbody>
<tr>
<td>W. M. Kay</td>
<td></td>
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<tr>
<td>J. M. Chawla</td>
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<td>J. Wang</td>
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<tr>
<td>M. S. Soylemez</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
M. J. Marangin\textsuperscript{5)} Heat Pipe System\textsuperscript{5)} Heat Source\textsuperscript{5)}.

H. Manz\textsuperscript{6)} \textsuperscript{5)} Fin \textsuperscript{5)}.

J. A. Clark\textsuperscript{7)} Module\textsuperscript{2)} \textsuperscript{54)}\textsuperscript{2)} 2 Module\textsuperscript{2)} Module\textsuperscript{2)}.

\textsuperscript{8)} Plate Fin\textsuperscript{2)} 2-Eqation\textsuperscript{2)}.

\textsuperscript{9)} Plate Fin\textsuperscript{2)}.

\textsuperscript{10)} Plate Fin 7%\textsuperscript{2)}.
2-1. エアフロー構成（Air to Air Heat Recovery System）

Process to Process, Process to Comfort, Comfort to Comfort, Process to Process

Comfort to Comfort
Comfort to Comfort (Sensible Heat)

Pressure Drop

Latent Heat

Fan

Compact Heat Exchanger

Paper

Compact Plate and Fin Heat Exchanger

Fig 2-2. Fixed - Plate Cross - flow Heat Exchanger
2-2.  

Hyland and Wexler have shown (Dry air) that the humidity ratio is

\[ W = \frac{M_w}{M_a} \]  

(2-1)

(Wet air) that the relative humidity is

\[ \phi = \frac{X_w}{X_{ws \ T, P = const}} \]  

(2-2)

Threlkeld, J. L. has shown (Degree of Saturation) that the degree of saturation is

\[ \mu = \frac{W}{W_s \ T, P = const} \]  

(2-3)
\( W = 0.62198 \frac{X_w}{X_a} \) \hspace{1cm} (2-4) \\

\[ \mu = \frac{\phi}{1 + \frac{(1 - \phi) W_r}{0.62198}} \] \hspace{1cm} (2-5) \\

(Specific Heat) \[ 1.006 \text{ [KJ/ Kg]} \] \\

\( h_a = 1.006 T \) \hspace{1cm} (2-6) \\

(Specific Heat) \[ 1.805 \text{ [KJ/ Kg K]} \] \\

\( h_g = 2501 + 1.805 T \) \hspace{1cm} (2-7) \\

\( M h_{wet} = M_a h_a + M_g h_g \)

\[ h_{wet} = \frac{M_a}{M} h_a + \frac{M_g}{M} h_g \]

\[ = h_a + Wh_g \]
\[ = 1.006 T + W(2501 + 1.805 T) \]  \hspace{1cm} (2-8)}
2-3. Effectiveness

Log Mean Temperature Difference Method (Log Mean Temperature Difference Method)
(Effectiveness - Number of Transfer Unit Method)

(Heat Capacity Rate)  and  (Number of Transfer Unit)

2-3. 1 (Effectiveness)

Effectiveness

\[ \varepsilon = \frac{Q_{\text{Real}}}{Q_{\text{Max}}} \]  \( (2-9) \)

Phase Change

\[ \varepsilon = \frac{\dot{m}_{\text{min}} (h_{c_2} - h_{c_1})}{\dot{m}_{\text{min}} (h_{h_3} - h_{c_1})} \]  \( (2-10) \)
\[ \varepsilon = \frac{m_{\text{min}} C_p (T_{e_1} - T_{e_2})}{m_{\text{min}} C_p (T_{h_1} - T_{e_1})} = \frac{C_{\text{min}} (T_{e_1} - T_{e_2})}{C_{\text{min}} (T_{h_1} - T_{e_1})} \]

\[ \varepsilon_{\text{sen}} = \frac{(T_{e_1} - T_{e_2})}{(T_{h_1} - T_{e_1})} \]  (2-11)

\[ \varepsilon_{\text{lat}} = \frac{(W_{e_1} - W_{e_2})}{(W_{h_1} - W_{e_1})} \]  (2-13)
(Total Heat Effectiveness), (Latent Heat), (Sensible Heat), (Wet air).

\[ \varepsilon_{\text{tot}} = \frac{(h_{c, \text{tot}} - h_{c, \text{tot}})}{(h_{c, \text{tot}} - h_{c, \text{tot}})} \]  \hspace{1cm} (2-14)

2-3. (Overall Heat Transfer Coefficient)

(Overall Heat Transfer Coefficient), (Convection Heat Transfer Coefficient), (Thermal Conductivity), (Plate - Fin Heat Exchanger).

\[ \frac{1}{UA} = \frac{1}{(\eta_0 hA)_c} + \frac{dt}{KA} + \frac{1}{(\eta_0 hA)_h} \]  \hspace{1cm} (2-15)

\[ \frac{1}{U} = \frac{1}{(\eta_0 h)_c} + \frac{dt}{K} + \frac{1}{(\eta_0 h)_h} \]  \hspace{1cm} (2-16)

\[ U = \frac{K \eta_0 h}{(2k + \eta_0 h dt)} \]  \hspace{1cm} (2-17)
\[ d\theta - \frac{dt}{\theta} = \eta_0 dt \quad (2-18) \] (Overall Surface Efficiency).

\[ \eta_0 = 1 - \frac{A_L}{A} (1 - \eta_f) \quad (2-18) \]

\[ \eta_f = \frac{\tanh (m \ell)}{m \ell} \quad (2-19) \]

\[ m = \left( \frac{2h}{Kt} \right)^{1/2} \quad (2-20) \]

\[ t \] [m], \[ \ell \] [m].

2-3.3. Cross Flow Heat Exchanger

\[ N T U = \frac{U A}{C_{\text{min}}} \quad (2-21) \]

\[ C \] (Heat Capacity Ratio), \[ U \] (Heat Capacity).
\[
C_r = \frac{C_{M_{\text{in}}}}{C_{M_{\text{ax}}}} = \frac{(\dot{m}C_p)_{\text{min}}}{(\dot{m}C_p)_{\text{max}}}
\]  
(2-22)
2-4. 回收显热的收益

2-4. 1. (Gain for Recovering Sensible Heat)

回收显热的收益

(Sensible Heat) $Q_{sen}$ (Latent Heat) $Q_{lat}$

(Sensible Effectiveness) $\varepsilon_{sen}$

$Q_{sen} = C_{min} \varepsilon_{sen} (T_h - T_c)$ (2-24)

$Q_{heat} = \sum_{n=1}^{n=N_h} C_{min} \varepsilon_{sen} (T_r - T_o) t_m$ (2-25)

$Q_{cool} = \sum_{n=1}^{n=N_c} C_{min} \varepsilon_{sen} (T_r - T_o) t_m$ (2-26)

$T_h, T_c, T_r, T_o, t_m, \varepsilon_{sen}, COP$ 注意细节
\[
MFS(Y) = \frac{F_h}{\eta_h} (1 + \alpha_h)^{Y - 1} Q_{\text{heat}} + \frac{F_c}{COP_c} (1 + \alpha_c)^{Y - 1} Q_{\text{cool}} \tag{2-27}
\]

\[
MFS_{\text{tot}} = \int_1^Y MFS(Y) \, dY \tag{2-28}
\]

\[
MFS_{\text{lt}} = \int_1^{Y_{\text{lt}}} MFS(Y) \, dY \tag{2-29}
\]

2.4.2. (Gain for Recovering Latent Heat)

\[Q_{\text{lat}} = \dot{m} h_{f\text{h}} \varepsilon_{\text{lat}} (W_{h1} - W_{c1}) \tag{2-30}\]
\[ Q_{\text{lat, hum}} = \sum_{m=1}^{n=N_{\text{hum}}} \dot{m}_f h_f \varepsilon_{\text{lat}} (W_r - W_o) t_m \]  
\[ (2-31) \]

\[ Q_{\text{lat, deh}} = \sum_{m=1}^{n=N_{\text{deh}}} \dot{m}_f h_f \varepsilon_{\text{lat}} (W_r - W_o) t_m \]  
\[ (2-32) \]

\[ MFL (Y) = \sum_{n=1}^{n=N_{\text{hum}}} \frac{F_{\text{hum}}}{\eta_{\text{hum}}} (1 + \alpha_{\text{hum}})^{y-1} Q_{\text{hum}} - \sum_{n=1}^{n=N_{\text{deh}}} \frac{F_{\text{deh}}}{\eta_{\text{deh}}} (1 + \alpha_{\text{deh}})^{y-1} Q_{\text{deh}} \]  
\[ (2-33) \]

\[ MFL_{\text{tot}} = \int_1^Y MFL (Y) \, dY \]  
\[ (2-34) \]

\[ MFL_{\text{lt}} = \int_1^{t_1} MFL (Y) \, dY \]  
\[ (2-35) \]

2-4. 3. (Loss for Pressure Drop)
\begin{align}
MFP( Y ) &= \frac{F_{fan}}{\eta_{fan}} (1 + \alpha_{fan})^{y-1} P_t, \tag{2-37} \\
MFP_{tot} &= \int_{1}^{Y} \frac{F_{fan}}{\eta_{fan}} (1 + \alpha_{fan})^{y-1} P_t, dY, \tag{2-38} \\
MFP_{lt} &= \int_{1}^{lt} \frac{F_{fan}}{\eta_{fan}} (1 + \alpha_{fan})^{y-1} P_t, dY. \tag{2-39}
\end{align}

2-4. 4. ๐๐๐๐ ๐๐๐๐ ๐๐๐๐ (Pay-Back Period)

MF \ V( Y ) = F_{v}(1 + \alpha_{v})^{Y-1} \quad \tag{2-40}

MF \ V( Y ) = F_{v}(1 + \alpha_{v})^{Y-1} \quad \tag{2-40}

\text{(Pure Gain Money, PGM) } \tag{2-41}
\[ \text{PGM}(Y) = MFL(Y)_{\text{tot}} + MFS(Y)_{\text{tot}} - MFV(Y) - MFV(Y)_{\text{tot}} \quad (2-41) \]

(Pay Back Period)

\[ \text{LCS} = MFS_{lt} + MFL_{lt} - MFV(Y_{lt}) - MFV(Y_{lt}) \quad (2-42) \]
3-1. 图表

Fig 3-1. 模拟室 · 冷却器 · 加热器 · PVC

(\( \phi \ 100\) mm) 模拟室 · 数字温湿度计（DHM200, Testo industries, USA）

数字风速计（Testo400, Testo, German）

(T-Type) 模拟室 · 探头 · 数据 Logger, YOKOGAYA DR-130) PC INTERFACE DATA
1. Thermo Couple  
2. Probe  
3. Ventilator  
4. Heater  
5. Chiller  
6. Duct  
7. Iso-Thermal Chamber  
8. Fan blower  
9. Humidifier  
10. Compact Heat Exchanger  

Fig 3-1. The Schematic Diagram of Experiment
Fig 3-2 The Schematic Figure of Ventilator

Fig 3-4. The Shape of Heat Exchanger
<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isothermal Unit (In door)</td>
<td>650mm × 560mm × 1550mm</td>
</tr>
<tr>
<td>Isothermal Unit (Out door)</td>
<td>530mm × 530mm × 128mm</td>
</tr>
<tr>
<td>Heat Exchanger</td>
<td>140mm × 475mm × 140mm</td>
</tr>
<tr>
<td>Heater</td>
<td>Plate Heater, 600W</td>
</tr>
<tr>
<td>Fan Blower</td>
<td>Sirocco Fan, 180 l/min/hr</td>
</tr>
<tr>
<td>Data Acquisition System</td>
<td>Yokogawa DR 130</td>
</tr>
<tr>
<td>Thermocouple</td>
<td>T-type (Copper-Constantan)</td>
</tr>
<tr>
<td>Thermo controller</td>
<td>Range : -50 ~ 200 °C</td>
</tr>
<tr>
<td>Item</td>
<td>Sample A</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Heat transfer area</td>
<td>10.8 m²</td>
</tr>
<tr>
<td>Material</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Shape</td>
<td>Plate and fin</td>
</tr>
<tr>
<td>Size</td>
<td>140mm x 475mm x 140mm</td>
</tr>
<tr>
<td>Density</td>
<td>1160 kg/m³</td>
</tr>
<tr>
<td>Fin Shape</td>
<td>Triangular Plane Fin</td>
</tr>
<tr>
<td>Fin Area</td>
<td>6.3 m²</td>
</tr>
<tr>
<td>Fin Thickness</td>
<td>0.1mm</td>
</tr>
<tr>
<td>Fin Length</td>
<td>3.1mm</td>
</tr>
<tr>
<td>Number of Plate</td>
<td>228</td>
</tr>
</tbody>
</table>
Sample A, B

Table 3-3

<table>
<thead>
<tr>
<th>Sample</th>
<th>Chamber</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Chamber</td>
</tr>
<tr>
<td>B</td>
<td>Chamber</td>
</tr>
</tbody>
</table>

Steady State

T - Type

OA (Out Air), RA (Room Air), EA (Exhaust Air), SA (Supply Air)

Data

(Yokogawa, DR-130) PC 30°

Digital Hygrometer (DHM200, Testo industries, USA)

Digital velocity meter (Testo400, Testo, German)

Probe

Micro Manometer (FC012, Benbill, England)

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Table 3-3. Conditions of Experiment

<table>
<thead>
<tr>
<th>Test Sample</th>
<th>Seasons</th>
<th>Room air</th>
<th></th>
<th>Out air</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Temp [°C]</td>
<td>Hum [%]</td>
<td>Temp [°C]</td>
<td>Hum [%]</td>
</tr>
<tr>
<td>&quot;A&quot;, &quot;B&quot;</td>
<td>Winter</td>
<td>25</td>
<td>60</td>
<td>-10 ~ 5</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Spring, Fall</td>
<td>25</td>
<td>60</td>
<td>6 ~ 20</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td>25</td>
<td>60</td>
<td>21 ~ 40</td>
<td>70</td>
</tr>
</tbody>
</table>
3-3. Table 3-5. Experimental Result of Air Flow rate and Static Pressure

<table>
<thead>
<tr>
<th>Item</th>
<th>Sample</th>
<th>RA</th>
<th>SA</th>
<th>OA</th>
<th>EA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air flow rate [l/h]</td>
<td>&quot;A&quot;</td>
<td>72.1</td>
<td>80.6</td>
<td>73.5</td>
<td>117.3</td>
</tr>
<tr>
<td></td>
<td>&quot;B&quot;</td>
<td>70.7</td>
<td>80.2</td>
<td>69.3</td>
<td>107.4</td>
</tr>
<tr>
<td>Static Pressure [Pa]</td>
<td>&quot;A&quot;</td>
<td>-36.3</td>
<td>95.6</td>
<td>-27.5</td>
<td>85.3</td>
</tr>
<tr>
<td></td>
<td>&quot;B&quot;</td>
<td>-35.3</td>
<td>94.1</td>
<td>-27.5</td>
<td>84.3</td>
</tr>
</tbody>
</table>
3-3. 2 층 공기 공급기 (Temperature of Supply Air)

- 10°C 사례 "A"의 기온 18.3°C, 사례 "B"의 기온 19°C 

40°C 사례 "A"의 기온 27.6°C, 사례 "B"의 기온 27.1°C 

25°C 사례 "A"의 기온 27.6°C, 사례 "B"의 기온 27.1°C 

다음 표로 나타낸다.
Fig 3-4. Temperature Distribution of Supply air

(a) Winter Condition

(b) Spring & fall Condition

(c) Summer condition
Fig 3-5

- Effectiveness
- Total Heat Effectiveness
- Sensible Heat Effectiveness

Sample 'A':
Sample 'B':
Sample 'B' (Wet air)

25°C

Mixing
Mass Transfer

- 30 -
Fig 3-5. Effectiveness Variation of Ventilator
3-3. 3-6 (Heat Recovery Rate)


Mixing

°ø±âÀǿµµ°¡Áõ°¡Çò°æ°¨¼ÒÇϱ⶧¹®À̺αÙÀǿܱâ½Àµµ°¡½Ç³»ÀǽÀµµ¿Í°¡Àå

25°C

0 2 3 4 5 6 7 8 9 10

3°C

Hyland

Wexler
Fig 3-6. Heat Recovery Rate with respect to Out air Temp

(a) Winter Condition

(b) Spring & Fall Condition

(c) Summer Condition
3- 3. 3-3 (Froast & Condensation)

\[ (\text{Dry air})\]
\[ (\text{Wet air})\]
\[ (\text{Saturation})\]

\[ \text{Mass transfer} \]

Sample "A", "B" 2°C 37°C 38°C
4-1. Table 4-1. Sensible Heat Effectiveness (Sensible Heat Effectiveness) Sample "A", "B" (Sensible Heat Effectiveness) (Air flow rate), (Pressure Drop) (Latent Heat) LNG (Coefficient of Performance) 2.0 (Boiler Efficiency) 0.6, 0.5. Table 4-2. Boiler Efficiency 4.2%.
Table 4-1. Averaged Temperature and Humidity in Seoul

<table>
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<tr>
<th>Month</th>
<th>Temperature [°C]</th>
<th>Relative Humidity [%]</th>
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<tbody>
<tr>
<td>1</td>
<td>-2.1</td>
<td>63.7</td>
</tr>
<tr>
<td>2</td>
<td>-1.7</td>
<td>55.7</td>
</tr>
<tr>
<td>3</td>
<td>6.3</td>
<td>55.2</td>
</tr>
<tr>
<td>4</td>
<td>11.9</td>
<td>55.8</td>
</tr>
<tr>
<td>5</td>
<td>17.5</td>
<td>66.4</td>
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<tr>
<td>6</td>
<td>23.7</td>
<td>65.0</td>
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<td>7</td>
<td>26.8</td>
<td>73.5</td>
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<td>8</td>
<td>26.2</td>
<td>79.9</td>
</tr>
<tr>
<td>9</td>
<td>20.7</td>
<td>70.9</td>
</tr>
<tr>
<td>10</td>
<td>14.9</td>
<td>64.1</td>
</tr>
<tr>
<td>11</td>
<td>7.0</td>
<td>56.9</td>
</tr>
<tr>
<td>12</td>
<td>0.9</td>
<td>57.6</td>
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Table 4-2. Assumed Parameter of Economic Research

<table>
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<tr>
<th>Item</th>
<th>Value</th>
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<tbody>
<tr>
<td>Cost of Ventilator [Won]</td>
<td>1,200,000</td>
</tr>
<tr>
<td>Life Time of Ventilator [Year]</td>
<td>15</td>
</tr>
<tr>
<td>Fuel Cost [Won/KJ]</td>
<td>0.012</td>
</tr>
<tr>
<td>Fuel Cost Increase Rate [%]</td>
<td>4.2</td>
</tr>
<tr>
<td>Electric Cost [Won/KJ]</td>
<td>0.03413</td>
</tr>
<tr>
<td>Electric Cost Increase Rate [%]</td>
<td>4.2</td>
</tr>
<tr>
<td>Boiler Efficiency [-]</td>
<td>0.6</td>
</tr>
<tr>
<td>Coefficient of Performance [-]</td>
<td>2.0</td>
</tr>
<tr>
<td>Fan Efficiency [-]</td>
<td>0.5</td>
</tr>
<tr>
<td>Inflation Rate [%]</td>
<td>4.2</td>
</tr>
<tr>
<td>Bank Interest Rate [%]</td>
<td>1.0</td>
</tr>
</tbody>
</table>
4-2. (Gain for Recovering Sensible Heat & Loss for Pressure Drop)

Fig 4-1. (Sensible Heat Saving) (Pressure Drop Loss) (Net Energy Saving) Sample "A" Sample "B" Sample "A" Sample "A" Sample "A" Sample "B" Sample "B" 214,065 212,711 13,549 21,406 3,662 3,644
(a) Monthly Sensible Heat Saving

(b) Monthly Pressure Drop Energy Loss

(c) Monthly Net Energy Saving

Fig 4-1. Monthly Energy Saving and Loss
(a) Monthly Money for Recovering Sensible Heat

(b) Monthly Money for Pressure Drop

(c) Monthly Net Gain Money

Fig 4-2. Monthly Money Gain and Loss
4-3. /payment-back period and life cycle saving (Pay-Back Period and Life Cycle Saving)

Fig 4-3. `ÀºÈ¯±âÀåÄ¡»ç¿ë¿¡µû¸¥¿¬°£¼Õ½Çºñ¿ë±×À̵æ°ú¾Ð·Â¼Õ½Çºñ¿ëÀ̵æÀº¹°°¡ÀλóÀ² 4.2%. Sample "A" 203,226 ¿øÀ̰íÀ̴¹°°¡ÀÇ»ó½Â¿¡µû¶óÁ¦Ç°¼ö¸í¿¬ÇÑ (Life-Time) 15 ¿øÀÌ 361,517 ¿øÀÌÀ² ¿ë°úȯ±âÀåÄ¡ÀÇ»ç¿ë¿¡µû¸¥ºñ¿ëÀ̵æÀǰü°è¸¦µµ.

Fig 4-4. `Â»ç¿ëÀÚ°¡Áö³ª¸é¼­¾çÀǰª À»°¡Á®ÅõÀÚºñ¿ëȸ¼ö±â°£Àº Sample "A", "B" 5.6. Sample "A", "B" 5.6. Sample "A", "B" (Life Time Saving) Sample "A" 2,750,917 ¿øÀ̰í Sample "B" 2,744,417 ¿øÀÌ ¿øÀ̵ȴÙ.

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Fig 4-3. Annual Saving and Loss

(a) Sample "A"

(b) Sample "B"
Fig 4-4. Total Gain and Loss until its Life Time

(a) Sample "A"

(b) Sample "B"
1. Sample "A"\(\frac{772.2}{15.1}\) [KJ/sec], Sample "B"\(\frac{785.6}{21.2}\) [KJ/sec]. Sample "B" Report sample "A"\(\frac{2,744,417}{2,750,917}\).

2. Report sample "A"\(\frac{270°}{8°}\) and sample "B"\(\frac{270°}{8°}\) report sample "A"\(\frac{270°}{8°}\) and sample "B"\(\frac{270°}{8°}\).

3. Sample "A"\(\frac{772.2}{15.1}\) [KJ/sec], Sample "B"\(\frac{785.6}{21.2}\) [KJ/sec]. Sample "B" Report sample "A"\(\frac{2,744,417}{2,750,917}\).

4. Report sample "A"\(\frac{270°}{8°}\) and sample "B"\(\frac{270°}{8°}\).

5. Report sample "A"\(\frac{5.6}{5.6}\) and sample "B"\(\frac{2.744,417}{2.750,917}\) Sample "B" Report sample "A"\(\frac{2,744,417}{2,750,917}\).


10. ÀÌÃá¿ì. À̱⼺. °íµæ¿ë. ¾öÇѱæ. 2001, ´ë ÇѼ³ºñ°øÇÐȸ³í¹®Áý, pp 512 ~ 516.


