A comparison study on energy savings and fungus growth control using heat recovery devices in a modern tropical operating theatre

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**ABSTRACT**

Fungus growth has always been a problem in hot and humid areas. This particular problem is crucial for operating theatre as it could affect the success rate of operations. Many postoperative fungus infection cases had occurred in the past, and it is generally agreed that air-conditioning system play a very important role in resolving the fungus growth problem. Besides air quality, the energy consumption level of air-conditioning system is also very important. In this study, the operating theatre 3 in Putrajaya Hospital, Malaysia was chosen as the research subject. The air-conditioning system for OT3 was redesigned with the energy recovery wheel, desiccant dehumidifier and heat pipe heat exchanger to achieve the objectives of this study. A computer program called Transient system simulation program (TRNSYS) was utilized for analysis in this research. From the outcome of simulations, it was found that the energy consumption by 57.85%. Moreover, the payback period of the device is only 0.95 years, which is the shortest among all the systems studied. Therefore, applying heat pipe heat exchanger is a good choice to save energy and resolve fungus growth problem in hot and humid areas.

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maximum and maximum of 48.82% and 53.94% respectively. Throughout a year, the amount of coolness recovered by the energy recovery wheel was 16.85 MW h while the latent energy recovered over a year was 129.00 MW h. These values were very close to the system discussed in the previous sub-chapter as the amount of energy recovered depended on the room conditions. On the other hand, the desiccant dehumidifier removed 13.53 MW h of moisture, but added 18.42 MW h of sensible energy into the air stream.

The amount of energy consumed by this system is summarized in Table 4. In comparison to the simple reheat system, this system could reduce energy consumption of the chiller and electric heater by 48.52% and 40.25% respectively. This showed that this system could reduce the need of over-cooling and reheating. The annual energy consumption of this system was 116.72 MW h. It was noticed the desiccant dehumidifier consumed 13.53 MW h of moisture, but added 18.42 MW h of sensible energy into the air stream.

The hourly simulated room conditions were shown in Fig. 16 and it was found that the average room DBT was 23.81 °C, while the maximum and minimum DBT were 27.38 °C and 20.58 °C respectively. The maximum and minimum relative humidity were 57.20% and 43.43% respectively, with an average of 50.62%. These conditions were considered acceptable as the air conditions exceeded the ASHRAE [4] recommended range for only 121 h or 1.38% of a year.

The HPHX that was utilized to recover the coolness from exhaust air managed to recover 12.66 MW h of coolness per annum. The amount of coolness recovered was less than energy recovery wheel due to the lesser effectiveness of the HPHX in comparison to the energy recovery wheel. The pre-cooling process in the first HPHX has brought the relative humidity of the air closer to saturation and resulted in condensation at the evaporator section of the second HPHX. The amount of sensible heat recovered was 27.17 MW h and it enhanced dehumidification that removed 37.86 MW h of moisture from the air stream. This implied that 65.03 MW h of energy was recovered by integrating this system.

The total energy consumption of the HPHX system is summarized in Table 5. It was observed that the main energy consumer within the system was chiller, which consumed 50.48 MW h or 85.98% of the total energy consumption per annum. This HPHX integrated system could reduce the energy consumed by chiller

### Table 4
Energy consumption for energy recovery wheel and desiccant dehumidifier integrated system.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Energy consumption (MW h)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller</td>
<td>33.40</td>
<td>28.62</td>
</tr>
<tr>
<td>Blower</td>
<td>8.10</td>
<td>6.94</td>
</tr>
<tr>
<td>Energy recovery wheel</td>
<td>1.63</td>
<td>1.40</td>
</tr>
<tr>
<td>Desiccant dehumidifier</td>
<td>33.29</td>
<td>28.52</td>
</tr>
<tr>
<td>Electric heater</td>
<td>40.30</td>
<td>34.52</td>
</tr>
<tr>
<td>Total</td>
<td>116.72</td>
<td>100.00</td>
</tr>
</tbody>
</table>

### Table 5
Energy consumption for heat pipe heat exchanges integrated system.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Energy consumption (MW h)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller</td>
<td>50.48</td>
<td>85.98</td>
</tr>
<tr>
<td>Blower</td>
<td>8.23</td>
<td>14.02</td>
</tr>
<tr>
<td>Total</td>
<td>58.71</td>
<td>100.00</td>
</tr>
</tbody>
</table>

### 4.4. Double heat pipe heat exchanger system

The hourly simulated room conditions were shown in Fig. 16 and it was found that the average room DBT was 23.81 °C, while the maximum and minimum DBT were 27.38 °C and 20.58 °C respectively. The maximum and minimum relative humidity were 57.20% and 43.43% respectively, with an average of 50.62%. These conditions were considered acceptable as the air conditions exceeded the ASHRAE [4] recommended range for only 121 h or 1.38% of a year.

The HPHX that was utilized to recover the coolness from exhaust air managed to recover 12.66 MW h of coolness per annum. The amount of coolness recovered was less than energy recovery wheel due to the lesser effectiveness of the HPHX in comparison to the energy recovery wheel. The pre-cooling process in the first HPHX has brought the relative humidity of the air closer to saturation and resulted in condensation at the evaporator section of the second HPHX. The amount of sensible heat recovered was 27.17 MW h and it enhanced dehumidification that removed 37.86 MW h of moisture from the air stream. This implied that 65.03 MW h of energy was recovered by integrating this system.

The total energy consumption of the HPHX system is summarized in Table 5. It was observed that the main energy consumer within the system was chiller, which consumed 50.48 MW h or 83.97% of the total energy consumption per annum. This HPHX integrated system could reduce the energy consumed by chiller...
by 22.19% in comparison to the simple reheat system. Additionally, the main advantage of this system was the energy savings from the electric heaters, attributed to the removal of heater. Nevertheless, the cost of HPHXs was approximately three times higher than the energy recovery wheel; but the payback period for integrating HPHXs was only 0.95 years, as the system is capable of saving significant amount of energy.

5. Concluding summary

In this paper, the hour-by-hour effects on existing and redesigned HVAC systems utilized in a modern tropical operating theatre were investigated empirically for the entire TMY hours. The analyses had been carried out on the performance and economical aspects of the HVAC systems. The simulation results revealed the following:

1. Energy is wasted in over-cooling and reheating processes in the simple reheat system.
2. Recovering dehumidification potential from exhaust air is more desirable as more energy is used to remove moisture than to lower air temperature to comfortable range in hot and humid areas.
3. The energy recovery wheel integrated system is a good choice for its simplicity reasonable payback period.
4. The desiccant dehumidifier system and energy recovery wheel integrated system is less favourable for its increased capital cost of equipments and prolonged payback period.
5. The double heat pipe heat exchanger system excelled in both the energy savings and economical aspects.

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References