HVAC management for the alleviation of the heat shock

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Heat shock

- Heating, ventilating, and air-conditioning (HVAC) systems make discontinuous temperature gaps between temperature-controlled and uncontrolled spaces.
- People exposed to the temperature gaps will suffer thermal stress called "heat shock".
- Heat shock sometimes causes cardiac and cerebrovascular diseases, especially to older people.

![Fig. 1 Heat shock (it includes cold shock)]

HVAC technology

- Using a patent database which covers US and European patents, we reviewed the current HVAC technologies for preventing the heat shock.
- However, there were few solutions to the problem, such as the auxiliary air-conditioning.
- To find various alternatives or variations, we applied TRIZ (Theory of Inventive Problem Solving, which was created by Genrich Altshuller and improved by Darrell Mann) tools, for example, "contradiction matrix", "trends of evolution", "knowledge/effects", "trimming", etc. to the heat shock problem.
- Then we found the following HVAC systems as practical and effective solutions to the problem:
  - Auxiliary air-conditioning system driven by renewable natural energy.
  - Task-ambient air-conditioning system.

![Fig. 2 Number of disease cases in each month (Yamaguchi, Japan)]

Evaluation methods

- Some indices for thermal stress are necessary for evaluating how much people suffer the heat shock and controlling HVAC systems based on the evaluated values.
- We proposed two thermal stress indices for people exposed discontinuous temperature changes.
- The proposed index is:
  - Integral of squared PMV changes.

![Fig. 3 Relationship between air temperature and number of cases (Yamaguchi, Japan)]

Task-ambient AC

- Task-ambient air-conditioning (TAAC) systems:
  - Selectively control microclimate in "task" area.
  - Loosely control microclimate in "ambient" area.
  - Decrease air-conditioning loads.
  - Alleviate temperature gaps.

![SuppFig. 4 Comparison between two types](a) Ordinary air-conditioning system (b) Task-ambient air-conditioning system]

Prevention of heat shock

- We should take a more advanced management policy, under which the discontinuous temperature changes are controlled or moderated.
- We thus examined adequate HVAC technologies and evaluation methods for preventing the heat shock.

![Fig. 5 Temperature distributions at a height of 1.2 m when TAAC system was applied](a) Location A (b) Location B (c) Location of task area and air-conditioners]

PMV

- Predicted mean vote (PMV) is a thermal comfort index.
- Proposed by P. O. Fanger (1967)
- PMV describes the imbalance between the actual heat flow from the human body in a given environment and the heat flow required for optimum comfort at the specified activity.
- PMV is a function of air temperature, velocity, humidity, metabolic activity, insulation provided by the clothing, etc.
- PMV gives thermal-sensation scale shown in Table 1.

<table>
<thead>
<tr>
<th>PMV</th>
<th>Thermal sensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3 hot</td>
<td></td>
</tr>
<tr>
<td>+2 warm</td>
<td></td>
</tr>
<tr>
<td>+1 slightly warm</td>
<td></td>
</tr>
<tr>
<td>0 neutral</td>
<td></td>
</tr>
<tr>
<td>-1 slightly cool</td>
<td></td>
</tr>
<tr>
<td>-2 cool</td>
<td></td>
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<tr>
<td>-3 cold</td>
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</tbody>
</table>

Integral of squared PMV changes

- PMV can be used as a scale of thermal stress.
- Rate of PMV change will indicate heat shock.
- By integrating squared PMV change, we can indicate accumulation of heat shock.
- We name this value heat shock evaluation value and use a symbol E.
- Fig. 6 shows that the value of E is small when the PMV change is moderate.

![Fig. 6 Task-ambient air-conditioning system](E: Integral of squared d(PMV)/dt Heat shock is strong Heat shock is weak]

Table 1 Thermal-sensation Scale

<table>
<thead>
<tr>
<th>PMV</th>
<th>Rapid Change</th>
<th>Moderate Change</th>
</tr>
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<tbody>
<tr>
<td>0 (neutral)</td>
<td></td>
<td></td>
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<tr>
<td>-1 (slightly cool)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td></td>
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</tr>
<tr>
<td>1 sec</td>
<td></td>
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<tr>
<td>4 sec</td>
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E: Integral of squared d(PMV)/dt Heat shock is strong Heat shock is weak