THERMAL COMFORT AT PRODUCTION ROOM OF BUTSUDAN INDUSTRY IN MAKASSAR

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Abstract

The objectives of this study were to discover the butsudan industrial production room temperature at PT Maruki International Indonesia, Makassar then compare it with the thermal comfort standard SNI T-14-1993-03 (warm-comfort 27,1°C and relative humidity 50-60%) and the factors effecting the thermal comfort and how to control it.

The result of thermal condition measurement in the production room, conducted from July 7 to 26, 2006, start from 8 am till 5 pm for 14 days, showed that the average temperature exceeded the warm-comfort standard 27,1°C, it was 31,76°C (4,86°C higher), the relative humidity was at normal condition 50-60%, and the average wind speed through the windows are 0,09 m/s at the south east window and 1,3 m/s at the north west window. The thermal comfort was not achieved due to the wind speed entered the room was slow, whereas the standard in-room wind speed for factory building ranged from 1,0 to 1,5 m/s. The size of ventilation holes are below the minimum standard (200 m²) only 132,2 m² and the windows were to low.

Keywords: Temperature, Humidity, Wind Speed, Ventilation, Butsudan.

Introduction

PT Maruki International Indonesia (PT MII Makassar) is a “Butsudan” industry that produces storing cupboard for cremation ash made form ebony. At this company there are some building units that the roof and wall material are from galvanized iron-sheet, used artificial and natural air conditioner, based on the labors’ feeling, there are several building units that’s hot. According to Stoecker and Jones (1996) the hot temperature will affect the labors work productivity so it will be necessary to create a comfort working environment. Because of that it is important to find out the thermal condition in the production room of butsudan industry, whether it comply with the thermal comfort standard or not, if not, it is necessary to study the causing factors in order to solve it thus the thermal comfort can be achieved.

Theoretical Base

The Indonesian thermal comfort standard SNI T-14-1993-03 consists of:

a. Cool-comfort, 20,5-22,8oC, relative humidity 50-80%.
b. Comfort optimal, 22,8-25,8°C, relative humidity 70-80%.
c. Almost comfort, 25,8-27,1oC, relative humidity 60-70%.

According to Wiranto (1981), thermal comfort standard for mechanical industry building generally are 24-27oC, humidity 50-60% at the hot season and 24oC with humidity 45-50% at the cold season, thus for humidity standard the range 50-60% is used. According to Lippmeier (1995) at effective temperature, 26oC, people start to feel perspire, at 27,1-30oC human body perspire and the working ability decreased. According to Ismail (2000) vertical ventilation system can be used to reduce heat accumulation in room below the roof. Air flow through the side ventilation (wall) will push the hot out through the ventilation hole/jalousie on the building roof (roof ventilation). Satwiko (2003), divided three ventilation levels to push the hot air out, that is: ventilation of the lower part of the wall for damp (heavy) air circulation, ventilation of human body position for air circulation that hit the human body, and ventilation at the upper part of the...
wall for hot (light) air circulation. According to Mangunwijaya (1988), windows area standard are 1/6-1/9 of the floor area.

Proportional plants placement can reduce the AC load as much as 30% (Ball, Erickson, Garbisch in Purnomo, 2002).

According to http://www.lestarindo.com/hal%20cyclone.html (2004), that Automatic Cyclone Turbine Ventilator is a device like exhaust fan or roof fan, used to suck hot air, unhealthy air, floating dust particles, and as air ventilation/circulation device. It work by rotating with the air flow or the existence of different air pressure inside and outside the room, the hot air in the room will flow and push out through the turbine blades and make the device rotate.

Metodology

Time and Location of Study

The study conducted in the production room (Factory 3) “butsudan” industry of PT. Maruki International Indonesia Makassar at July 2004. Measurement was taken for 14 days (July 7-26, 2004), data collection every day start from 8 am till 5 pm WITA.

Instruments of Study

a. Personal Computer.
b. Oregon Weather Station.
e. Anemometer Sensor: measured wind speed and direction.
The main unit connected to the computer (PC) using R532 cable. All sensors connected wireless to the main unit, all data collected from sensors connected to main unit, are recorded to the computer (PC) with a 1 minute interval using the Weather View Software (look Pic. 6) and the instruments installation scheme are:

**Data Collection Techniques**

Data collection was conducted for 9 hours from 8 am till 5 pm WITA a day for 14 days. When the measurement conducted a survey of thermal comfort to the labors is made. Measurement of indoor and outdoor variables was conducted simultaneously at five measurement points: (North West) NW, (North East) NE, (South East) SE, (South West) SW and (Center of the Room) CR, look at the illustration below:
Result and Study

Result of Thermal Condition Survey

Picture 9. Histogram of thermal condition felt by labors at factory room 3

Picture 10. Thermal condition felt by labors of factory 3 based on time

Picture 9 and 10 showed that among labors surveyed most of them felt hot indoor the factory room 3 approximately 82.3% start from a little hot to very hot at 9 am to 4 pm and approximately 79.7% felt hot at 10 am to 3 pm.

Thermal Condition Analysis

Picture 11. Graphic of average temperature in and outdoor factory room 3

Picture 11, showed that generally temperature in and outdoor the room are at the lowest point in the morning then fluctuated across the day and reached the highest point at noon then decreased again in the afternoon.

Temperatures indoor are at the lowest point at NW side 27.0°C at 8 am; NE 26.8°C at 8 am; SE 26.6°C at 8 am; CR 26.4°C at 8 am and at the highest point at NW side 32.2°C at 11.40 am; NE 36.6°C at 9.50 am; SE 32.9°C at 12.20 pm; SW 32.5°C at 11.40 am; and CR 32.5°C at 1.40 pm. The highest temperatures outdoor the room are at NW side 32.4°C at 1 pm; NE 39.4°C
at 9.40 am; SE 36.8°C at 9.30 am; SW 31.3°C at 3.10 pm; and CR 35.1°C at 1.40 pm; and the
lowest temperature at the NW side 26.6°C at 8 am; NE 26.7°C at 8 am; SE 25.9°C at 8 am; SW
25.6°C at 8 am; and CR 26.3°C at 8 am.

The highest humidity indoor at NW side is 70.0% at 8 am; NE 68.7% at 8.10 am; SE
60.3% at 8.20 am; SW 62.7% at 8.50 am; CR 69.0% at 8 am; the lowest humidity at NW side is
54.0% at 1.40 pm; NE 43.3% at 9.50 am; SE 50.7% at 12.30 pm; SW 52.3% at 3 pm; and CR
53.5% at 1.50 pm. The lowest humidity outdoor the room at NW side is 52.7% at 12.50 pm; NE
36.0% at 11.50 am; SE 41.0% at 9.30 am; SW 53.0% at 3 pm; CR 47.0% at 1.50 pm; whilst the
highest at NW side is 74.3% at 8 am; NE 72.0% at 8.10 am, SE 62.3% at 8.10; SW 65.7% at 8.30
am and CR 73.5% at 8 am. The humidity indoor at 5 pm in NW side is 64.7%; NE 57.3%; SE
55.0%; SW 52.3%; CR 58.5%, whilst outdoor NW 71.7%; NE 60.0%; SE 58.7%; SW 56.0% and
CR 60.5%.

Tabel 1. Average temperature and relative humidity condition at every side of factory room 3

<table>
<thead>
<tr>
<th>Position</th>
<th>Temperature</th>
<th>Deviation (In-out)</th>
<th>Humidity</th>
<th>Deviation (In-out)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indoor</td>
<td>Outdoor</td>
<td></td>
<td>Indoor</td>
</tr>
<tr>
<td>NW</td>
<td>31.21</td>
<td>29.87</td>
<td>1.34</td>
<td>60.01</td>
</tr>
<tr>
<td>NE</td>
<td>34.04</td>
<td>36.11</td>
<td>-2.07</td>
<td>52.12</td>
</tr>
<tr>
<td>SE</td>
<td>31.50</td>
<td>31.64</td>
<td>-0.14</td>
<td>56.38</td>
</tr>
<tr>
<td>SW</td>
<td>30.93</td>
<td>29.99</td>
<td>0.94</td>
<td>56.29</td>
</tr>
<tr>
<td>CR</td>
<td>31.11</td>
<td>32.75</td>
<td>-1.64</td>
<td>59.01</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>31.76</strong></td>
<td><strong>32.07</strong></td>
<td><strong>-0.31</strong></td>
<td><strong>56.76</strong></td>
</tr>
</tbody>
</table>

Data Source: Measurement result 2004

The production room temperature conditions of butsudan industry at each side of building
are different and so was the humidity. The temperature differences in and outdoor at NW and SW
side showed that inside temperatures are higher 1,34°C (NW) and 0,94°C (SW), whereas the
outdoor temperature at NE and SE side are higher 2,07°C (NE) and 0,14°C (SE). Similar with the
temperature difference of the center of the room with a fully open outdoor where the outdoor
temperature is higher 1,64°C.

The average temperature indoor, is above the required standard (27.1°C), for the NW side
it’s 4,11°C higher; NE 6,94°C higher; SE 4,40°C higher; SW 3,83°C higher; and CR 4,01°C
higher; thus the temperature of the production room of butsudan industry is considered hot so it
need to be anticipated because this condition can affect the working capacity (Lippsmeier, 1995), and if the temperature is high then it required a little fast wind flow to push out heat from the room so the body temperature stays at normal condition 37°C. Without a decent air flow, the room would easily become saturated and became unhealthy due to the increasing concentration of CO2, and the oxygen will decrease, people in the room will perspire, whereas the perspiration couldn’t evaporate at the saturated condition without air circulation. In the other hand, the air flow will cause heat release from the surface of the skin through evaporation which mean decrease in temperature or cooling process of the skin. The more air flowing indoor the more heat released.

The humidity of each building side is different. The humidity difference in and outdoor, for the NW and SW side the humidity outdoor are higher at 2.80% (NW) and 3.05% (SW), whilst the NE, SE and CR side the humidity indoor are higher each at 4.74% (NE); 1.38% (SE); and 4.94% (CR). The humidity inside the production room of butsudan industry generally still in normal condition between 50-60%, the highest humidity at the NW side that is 60.01%.

<table>
<thead>
<tr>
<th>Position</th>
<th>Wind Speed (m/second)</th>
<th>Wind Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Mean</td>
</tr>
<tr>
<td>NW</td>
<td>0.0</td>
<td>0.37</td>
</tr>
<tr>
<td>NE</td>
<td>0.0</td>
<td>0.21</td>
</tr>
<tr>
<td>SE</td>
<td>0.0</td>
<td>0.18</td>
</tr>
<tr>
<td>SW</td>
<td>0.0</td>
<td>1.30</td>
</tr>
</tbody>
</table>

Data Source: Measurement result 2004

The condition of wind speed are vary between 8 am to 5 pm. Generally the wind speed at 8-9 am is very calm almost no wind, then from 9 am to 5 pm it fluctuated. The wind speed around the building are varied between 0.18-2.97 m/s. this can be seen from Table 2. The highest wind speed at the SW side around 2.97 m/s coming from SE to NW or vice versa with pressure 1008-1013 so it can be made opening at this side to turn the wind flow into the room due to the presence of temperature difference (thermal force ventilation system).

<table>
<thead>
<tr>
<th>Position</th>
<th>Wind Speed (m/s)</th>
<th>Wind Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Mean</td>
</tr>
<tr>
<td>SE side window</td>
<td>0</td>
<td>0.09</td>
</tr>
<tr>
<td>NW side window</td>
<td>0</td>
<td>1.31</td>
</tr>
</tbody>
</table>

Data Source: Measurement result 2004

Wind speed passed the windows are relatively slow especially at the South East (SE) side 0-1.8 m/s with average of 0.09 m/s with pressure 1009-1013. The NW side 0-3.5 m/s with average
1.31 m/s coming from North till West to South and pressure at 1009-1014, clearly can be seen at Table 3. The wind passed through the windows is relatively slow due to the direction of wind are seldom perpendicular with the wall openings and the uncertain wind direction.

**Architecture Elements Analysis**

a. **Roof Shape**
   The roof of factory 3 building are saddle shaped without any vertical ventilation opening at the roof thus heat are accumulated in the room below the roof.

![Hot air accumulation diagram](image1.png)

**Picture 14. Analysis of hot air accumulation below the roof**

b. **Ventilation hole area**
   - Factory 3 floor area = 30 x 60 = 1,800 m²
   - Ventilation area standard (Mangunwijaya, 1988) = 1/9 x floor area
   - Ventilation area necessity = 1/9 x 1,800 = 200 m²
   - Factory 3 ventilation area total = 132.2 m², below the minimal standard.

c. **Building Material**
   Building material used at factory 3 is galvanized iron-sheet for wall and roof without insulation layer, galvanized iron-sheet temperature far above human body temperature thus heat transfer from galvanized iron-sheet to human body through radiation occurred.

![Ventilation diagram](image2.png)

**Picture 15. Layered roof shape (Clerestory Ventilation)**

d. **Heat from Inside the Room**
   Inside source heat caused by lamps, electrical instrument, machines and heat from labors working. Inside the factory room 3 there are averagely 86 people that release calorie 15.480 watt (180 watt/person) and there are machinery and electrical instrument 372.210 watt.

**Thermal Comfort Achievement Alternative**

a. **Using layered roof (clerestory ventilation)**
   Wind came in carried cold air through horizontal ventilation on the wall will be lead up carrying hot air through the vertical ventilation using the pressure difference between the air in and outside the room.
b. Ventilation hole
The ventilation hole was not very effective because the existing ventilation hole did not fulfill the minimal standard suggested thus the diagonal ventilation system applied did not function maximally then the hole ventilation dimension need to be added at the NW and SW side, also by adding opening at the SW and NE side so the wind blow around the building can flow inside the room with the diagonal ventilation or the thermal force ventilation system.

c. Cyclone turbine ventilator automatic
Cyclone turbine ventilator usage above the roof to suck out hot air and dust accumulated under the roof and can force wind to enter the room through ventilation at the building walls.
To maintain room temperature at the minimal outer room temperature condition (30°C), it required air flow:

Factory room 3 volume = 13.725 m³

Formula: \[ N = \frac{H}{0.33V(t_i-t_o)} \]
\[ H = 387.690 \text{ W (machine calorie + human body calorie)}, \]
\[ t_i = 30°C; t_o = 34°C \]
\[ V = 13.725 \text{ m}^3; N = 387690/0.33(13725)(30-34) \approx 82 \text{ m}^2 \]
Thus 80 cm wide capacity air ventilator necessary;

Formula: \[ Q = C_v A V \]
\[ A = 1.3 \text{ m}^2; \quad V = 5 \text{ m/s} \quad C_v = 0.6 \text{ (suck hole effective)} , \]
\[ Q = 0.6 \times 1.3 \times 5 = 3.9 \text{ m}^3 \approx 4 \text{ m}^3 \]
Thus unit ventilator necessary: \( N/Q = 82/4 = 20.5 \approx 20 \) units

d. Outer room arrangement (landscape)
It is necessary to plant some trees around the building especially trees functioned as sun heat protection, noise and air pollution filter, so the air that will enter the room will be cool and comfort after passing the trees.

Conclusion

1. Thermal condition of the butsudan industry production room is averagely 31.76°C, exceed the standard thermal comfort NI T-14-1993-03; cool-comfort (22.8°C), 8.96°C higher; comfort optimal (25.8°C), 5.96°C higher; and warm comfort (27.1°C), 4.66°C higher. Humidity in average are at normal condition between 50-60%, and average wind speed through the window between 0.09 m/s (SE window) and 1.31 m/s (NW window).

2. Factors caused the unachieved thermal comfort of butsudan industry production room are;
   a. The wind speed that enter the room are slow especially at SE window only 0.09 m/s, whilst ideally 1.0-1.5 m/s.
   b. Ventilation hole area are below standard, only 132.2 m², the standard is 1/9 of floor area (200 m²), and the window position is to low.
   c. The building design did not used the roof ventilation system (clerestory ventilation) thus the hot air below the roof and the wall and roof material from galvanized iron-sheet without insulation layer made it faster to be perforated and absorb sun heat radiation into the room.

The air temperature in the butsudan industry production room can be decreased by: using layered roof/roof ventilation (clerestory ventilation) or installation of automatic cyclone turbine ventilator, addition of ventilation hole area at the NW and SE side, and ventilation addition at the NW and SE side, and plantation of trees around the building as protection and can flow cool wind into the room.

References


