Controlling Method of Indoor Environment in Sickroom with Ceiling Induction Diffusers

(Part 2) Indoor Thermal Environment under Cooling Condition in Sickroom with Four Beds

Ying LI* Toshio YAMANAKA* Hisashi KOTANI* Kazunobu SAGARA* Yoshihisa MOMOI* Yun CHEN*

1. Introduction

In recent years, the issue of indoor environment in sickroom attracted widespread attention. In hospital wards, the odor from patients or diapers is often claimed, which can cause the adverse psychological impact on patients or medical workers. Therefore, high quality of indoor environment in sickrooms is essential. In this study, experiments using full scaled model room with four beds were carried out by the tracer gas step-up method and decay method (using carbon dioxide, CO₂), to verify the characteristics of the air-conditioning method with Ceiling Induction Diffusers on the ceiling. (Cooling condition was simulated) The investigation aimed to examine the influence of relevant parameters on the distributions of indoor temperature. At last, how examined parameters affect the indoor environmental quality in sickroom with ceiling induction diffusers.

2. Methodologies

Experiments are conducted in a full scaled model room with four beds on November 2nd, 2015–November 20th, 2015, in the showroom of KIMURA KOHKI Corporation. The size of experimental room is 7.35m(d)×5.35m(w)×2.42m(h), as shown in Fig.1 and Fig.2. The north wall is insulated with polystyrene foam. Two square return louver (275mm×275mm) and four rectangular supply inlets (1200mm×500mm) with induction panel are located on Ceiling above beds (one for each bed). Rigid diffusion fins are installed on each of aluminum inlet plates. Air-conditioning method with ceiling induction diffusers is different from the traditional air-conditioning system. As a result of air pressure,
indoor air is induced and mixed with the primary air. The proportion of indoor air is 60%, by comparison, the primary air accounts for 40% in total mixed air. The mixed air is rectified and blown into the interior, as shown in Fig.3. The exhaust opening is a crevice, which locates under the floor. The size of exhaust is 865mm×7mm.

3. Experiment method

The mannequins with heating-cable is used as human simulators. Heat generation rate of each mannequin is 40W as sensible heat load of patient. Black lamp, which assumed equipment heat was set aside of each bed at the height of 1000mm from floor. The power of each lamp is 90W. There are four pieces of heating carpets used as hot air flow from windows, which are pasted on the both side of polyethylene foam, the thickness of the set is 150mm. The heat generation rate of each is 250W, that is heat flux is 1000W in total. In addition, the calorific value of illumination in the laboratory is 182W, in total.

The tracer gas step-up method and decay method (using carbon dioxide, CO₂) are applied, then 32 cases have been conducted by changing four parameters: dosing positions of tracer gas (simulating contaminant), with or without curtain around beds, airflow rate of outdoor air and with/without two standing person simulators. Experimental conditions of cases mentioned in this paper are shown in Table 1.

CO₂ as tracer gas was emitted from the chest of each heated mannequin. Flow rate of CO₂ is controlled at 1.5L·min⁻¹ by mass flow meter. Wall surface temperature and indoor air temperature were measured after the steady state confirmed. The measurement points of temperature are shown in Fig.4. The wall surface temperature is collected at 3 points vertically (W1-W9), that is 27 points in total, using T-thermocouple. Twelve straight bars were set in the laboratory. And 8 measurement points were set on every bar. The air temperature is measured at 12 points (P1-P12) horizontally and 8 points vertically, i.e. 96 points in total. It is worth mentioning that, on each bar, the temperatures of four heights of 100mm, 600mm, 1100mm and 1700mm were collected using CO₂ recorders, and the rest four points were measured by T-thermocouple. Namely, the temperatures of red circle points on bars were collected by T-thermocouple, and temperatures of green square points were measured by CO₂ recorders. Then every 30 seconds, the instantaneous value was recorded with the two kinds of measuring instruments. The detail information of measurement instruments is shown in Table 2.

<table>
<thead>
<tr>
<th>Instrument name</th>
<th>Manufacturer</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data logger Cadac 3</td>
<td>Etodenki Corporation</td>
<td>4</td>
</tr>
<tr>
<td>CO₂ recorder (TR-576)</td>
<td>T&amp;D Corporation</td>
<td>15</td>
</tr>
<tr>
<td>CO₂ recorder (TR-76Ui)</td>
<td>T&amp;D Corporation</td>
<td>31</td>
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</tbody>
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4. Influence of parameters on vertical temperature distribution

The diagrams (Fig.5-Fig.10) shows the relationship between the vertical profile of temperature and the height. In Fig.5-Fig.10, solid circle and square shows the temperatures at points measured by CO₂ recorders, while hollow circle and square indicates the temperatures at points measured by T-thermocouple, and temperatures of green square points were measured by CO₂ recorders. Then every 30 seconds, the instantaneous value was recorded with the two kinds of measuring instruments. The detail information of measurement instruments is shown in Table 2.

Table 2. Measurement instrument

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4.1 Influence of positions of tracer gas

The cases, in which CO₂ was emitted from the right bed near

Table 3 Airflow rate

<table>
<thead>
<tr>
<th>Airflow rate of outdoor air [l·h⁻¹]</th>
<th>Supply air flow [m³·h⁻¹]</th>
<th>Return air flow [m³·h⁻¹]</th>
<th>Outdoor air flow [m³·h⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>853</td>
<td>653</td>
<td>200</td>
</tr>
<tr>
<td>4</td>
<td>825</td>
<td>417</td>
<td>408</td>
</tr>
</tbody>
</table>
window (we assumed the perimeter side) and the right bed near door (interior side) were conducted, under the condition of air change rate of 2 times·h⁻¹, without curtain around bed and no standing persons (case 2 and case 3). Fig.5 shows the measured results of vertical profile of temperature.

The temperature decreases gradually with the increase of height. The range of variation is from 22°C at the floor to 20°C at the height of 2110mm. Except for P12, the temperature profile is slightly high at the height of 1700mm. It may be caused by apparatus error of measurement instruments. At the height of 2320mm and 2420mm, the temperatures rise to the level which approximates the temperature of the floor. It is also seen that the temperatures of

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Fig. 5 Vertical temperature distribution (contaminant source position: PR and IR, without curtain, without standing persons, air change rate of outdoor air is 2 times·h⁻¹)

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Fig. 6 Vertical temperature distribution (contaminant source position: PR, without curtain, without standing persons, air change rate of outdoor air is 2 times·h⁻¹ and 4 times·h⁻¹)

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Fig. 7 Vertical temperature distribution (contaminant source position: PR, with and without curtain, without standing persons, air change rate of outdoor air is 2 times·h⁻¹)
P4 and P8 are slightly higher than others, which are affected by the influence of heat airflow from windows. Theoretically, there should be no difference of temperature by changing position of tracer gas, as the position of CO\(_2\) generation seems not to have some effect on temperature distribution. Actually, in Fig.5, the values of each relevant position are absolutely same, that is to say, the two curves coincide. This coincidence of temperature shows the accuracy and steady condition of experiments.

4.2 Influence of airflow rate of outdoor air

On the premise of the other three conditions fixed, the experiment was carried out by changing the air change rate of outdoor air from 2 times·h\(^{-1}\) to 4 times·h\(^{-1}\). When the airflow rate of outdoor air is 2 times·h\(^{-1}\) and 4 times·h\(^{-1}\), the volumes of air supply, air return and outdoor air are shown in Table 3. Vertical profile of temperature is shown in Fig.6.

There are similar vertical temperature distributions in both cases (case 2 and case 5). However, it can be found that temperature under the condition of airflow rate of 4 times·h\(^{-1}\) is lower than that of 2 times·h\(^{-1}\). The temperature differential between the two cases is about 2°C.

4.3 Influence of with or without curtain around beds

Fig.7 demonstrates temperature profile compared with the condition of hanging curtain (case 1) and without curtain (case 2). The diagram indicates that the similar vertical temperature distribution in both cases. It is apparent that in case 1 (with curtain) temperature is higher than that in case 2 (without curtain). The result may be caused by the difference of outdoor air temperature and the operation of air-conditioning.

4.4 Influence of with or without two standing person simulators

In case 4, the mannequins with 60W-heat generation rate of each mannequin as sensible heat load are placed on each side of bed, which is near to the window and on the right side. Keeping other conditions constant, case 2 and case 4 were conducted. Vertical profile of temperature is arranged in Fig.8. There is no large difference between case 4 and case 2. The trend of temperature distribution is consistent, except for the slight temperature difference at P8 (near the two standing persons). It is caused by the sensible heat load of the two standing person simulators.

5. Conclusion

Through comparison analysis, the impact of the indoor temperature distribution caused by the relevant parameters is examined. It is conspicuous that the parameters of dosing positions of tracer gas and the existence of two standing person simulators have slight affect on indoor air temperature. What’s more, the bigger the airflow rate of outdoor air is, the larger the vertical temperature difference will be. Apparently, the airflow rate of outdoor air plays an important role in decreasing indoor temperature. The most important advantage of air-conditioning method by ceiling induction diffusers with low velocity is the high comfort air-conditioned environment, which includes the uniform and stable temperature distribution in the horizontal direction and vertical direction.

Acknowledgements

The authors hope to express sincere gratitude to KIMURA KOHKI Corporation who gave a lot of help to us with experiment.

References

1 Hua Qian, Yuguo Li, Peter V. Nielsen, Carl E. Hydgaard: Dispersion of exhalation pollutants in a two-bed hospital ward with a downward ventilation system, Building and Environment 43 (2008) 344–354


Fig. 8 Vertical temperature distribution (contaminant source position: PR, without curtain, with and without standing persons, air change rate of outdoor air is 2 times·h\(^{-1}\))