THE CONTROL OF THE THERMAL ENVIRONMENT OF PERIMETER SPACES IN BUILDINGS TO PREVENT COLD DRAFTS

- Numerical Simulation and Measurements -

Yuji HUKUSHIMA*[1], Yasuo UTSUMI*[1], Hiroshi KOBAYASHI*[1], Yoshimi ISHIKAWA*[2], Mitsuo SUZUKI*[3] and Tatsuya YAMASHITA*[3]

*1 Miyagi National College of Technology
Natori +981-1239 –Japan
*2 Tohoku Institute of Technology
Sendai +982-8577 –Japan
*3 SANKI Engineering
Yamato +242-0001 –Japan

ABSTRACT

This paper is focused on the evaluation of simulation system using the experiment result and the configuration of peri-counter which is the part of counter unit setting at bottom of window side with heat panel to avoid the influence of cold draft, utilizing simulation system. The simulation shows similar flow pattern to full scale experiment and consequent simulations indicate that cold draft does not flow into interior zone when the heat generation rate exceeds heat loss from the window in most cases. When the heat generation portion is 75% of heat loss from the window, some cases which have certain configuration of peri-counter successfully avoids the influence of draft without fan.

INTRODUCTION

Perimeter space in building is affected by outdoor environment considerably. Accordingly interior zone which adjoins the perimeter is influenced by the outdoor condition. For example, the cold draft which happens at perimeter, where the window and/or wall are not well insulated e.g. single pane window, derives non-uniform distribution of indoor air temperature and air flow in the room and causes discomfort to occupants. Therefore, it is necessary to provide adequate thermal environment of perimeter by certain equipment and its control.

This study is aimed at achieving comfortable thermal environment in office, to show the possibility of the instrumentation of peri-counter on prevention of influence of outdoor environment and also to indicate the effect on energy conservation.

This paper describes the comparison of full-scale experiment results with that of simulation in order to evaluate the simulation system at first. Also the configuration of peri-counter with heat panel and no fan to avoid the influence of the cold draft are examined with the simulation system.

COMPARISON OF EXPERIMENT WITH SIMULATION

(1) SIMULATION SYSTEM AND A ROOM MODEL

The experiment is done with a full-scale room model which is similar to an office space and was set up in SANKI Engineering technical research laboratory [1]. The sectional plan of the model is shown in figure 1. The room has width 2.2m, height 2.35m and depth 5.0m, where indoor temperature and outdoor temperature i.e. the temperature of surrounding rooms are regulated respectively at certain temperature within a tolerance of 0.5 C. Wind speed, wind direction, temperature distribution around peri-counter are measured. One side of a room is a glass window of 12mm thickness.

The simulation was conducted for the same model. The two-dimensional heat and fluid flow simulation is executed using the EWS as hardware, with ANSYS-FLOTRAN ver.5.2A (ANSYS, INC.) [2] [3] as software. This software is solved in alliance with two-equation (k-ε) model and energy equation by the finite element method. The numbers of finite elements, quadrilateral first order element, varies from 6806 to 7157.

(2) RESULT

The simulation results are compared to the measured data in terms of temperature distribution and flow pattern. And also provides the data of the room as the boundary conditions. The heat distribution and the flow pattern by visualization experiment are similar to ones of the measurement. In addition, there is no obvious existence of secondary flow in the experiment room which influences the two-dimensional simulation [1].

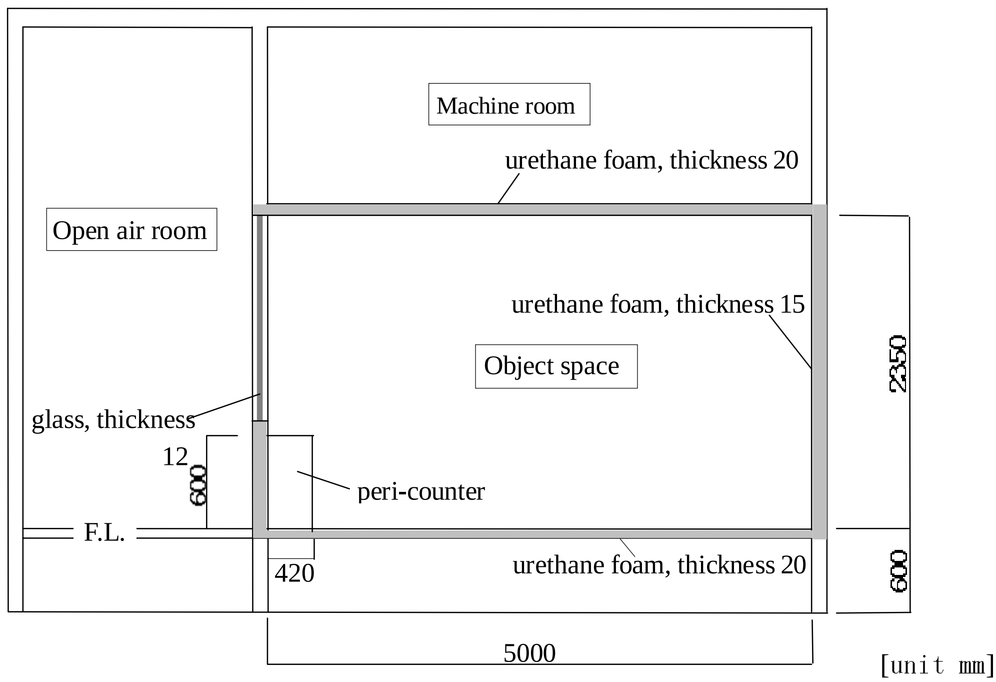
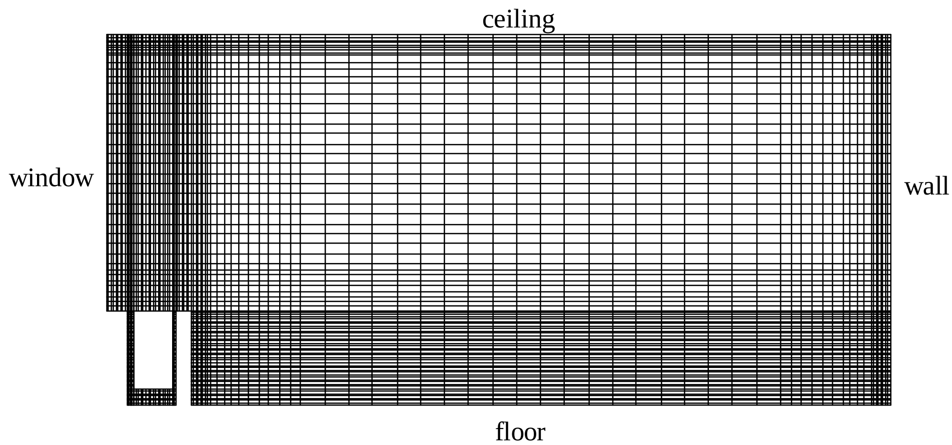
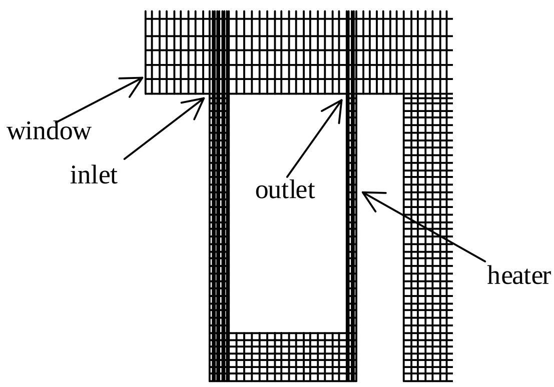


Figure 1 Sectional Plan of the Experimental Model



(1)whole territory of simulation



(2)around peri-counter

Figure 2 Mesh Divisions for the Simulation Domain

PARAMETRIC ANALYSIS OF PERI-COUNTER CONFIGULATION

(1) DESIGN CONDITION

According to the experiment, the configuration con-straints of simulation are set up as follows. The outdoor temperature is 0 C at all time, the glass surface temperature is 13.3 C (180W/m^2 of heat loss from the window) for boundary condition, and the temperature of whole room is 22 C for initial condition. The peri-counter with the built-in heat panel, height 60cm, is located at the lower part of the wall between inside and outside. The number of finite elements is 6782 to 7829. The number of nodes is 6949 to 8112. Mesh division of domain is shown in figure 2 as an example.

(2) PARAMETERS OF THE SIMULATION

Considered parameters are heat generation rate of the heat panel, the size of inlet, the size of outlet, and the angle of inclined panel attached to the top of peri-counter. They are changed in each case for parameter analysis to decide suitable configuration for prevention of the cold draft and energy conservation. The parameters are shown in table 1.

The typical configuration of peri-counter is described in figure 3. The heat generation rate of the heat panel against heat loss from window is 131%(236 W/m^2 (standard)), 100%(180 W/m^2), 75%(135 W/m^2) and 50%(90 W/m^2). As well, expecting the effect by changing the configuration resistance to flowing cold draft into peri-counter, the angle of inclined peri-counter varies 0° (standard), 30°, 45° and 60°. Width of inlet is 4cm (standard) and 8cm. Width of outlet is 2cm (standard), 4cm and 8cm. All calculation conditions are 40 cases as the total.

(3) RESULTS OF THE SIMULATIONS

The result of the vector distribution and temperature distribution as the representative, case2 which can prevent cold draft and case17 which cannot prevent cold draft are shown in figures 4 to 11.

In the case2, vector distribution (see figure 4) shows a clockwise whirlpool in interior zone. On the other hand, two counterclockwise eddies exist around the upper and lower part close to the window. The temperature of the flow from outlet is up to 30 angle and cold draft does not occur, because air rises toward the window. The air flow speed close to inlet is around 0.3m/sec which is upward.

The air temperature close to the window can be less than 15 C as the minimum, while the maximum is around outlet. (see figure 7) The interior zone is nearly uniform at 22 C and the air at 24 C piles up at the upper part of room.

In the case17, which does not have the prevention effect, vector distribution (see figure 8) indicates a counterclockwise whirlpool in the right side of the room, and a smaller clockwise eddy in the left side of the room. The outlet flow moves horizontally into interior zone, because it’s pushed by the cold draft. The flow speed is about 0.3m/sec around inlet.

Heated air from peri-counter is crammed into the interior zone (see figure 10) and the interior zone is almost uniform of 22 C.

THE MOST SUITABLE PERI-COUNTER CONFIGULATION

An outline of the simulation results is shown in table 2. The upward airflow from outlet needs to overcome cold draft for the prevention of cold drafts. Factors needing to be designed are the heat generation rate of the heat panel, the size of inlet, and outlet, and the angle of inclined panel attached to the top of peri-counter.

(1) THE HEAT GENERATION RATE

When the heat generation rate is 236W/m^2, any configuration avoids the cold draft penetration into interior. When the heat generation rate is 180W/m^2 and 135W/m^2, some cases prevent the cold draft with certain configuration of peri-counter. When the heat generation rate is 90W/m^2, the cold draft flows into interior in all of the conditions.

If the heat generation rate is more that 131% and the indoor heating is provided be the peri-counter, there may not exist a cold draft.

(2) THE SIZE OF INLET AND OUTLET

Comparing case4 with case5, the flow pattern doesn’t change by width of inlet, however, temperature around outlet of case5 with larger inlet is higher than the one of case4. Comparing case15 with case18 and also case25 with case28, the airflow from outlet in latter cases rises more than case15 and case25, where the momentum of the cold draft can be utilized to stimulate the upward air flow from the outlet.

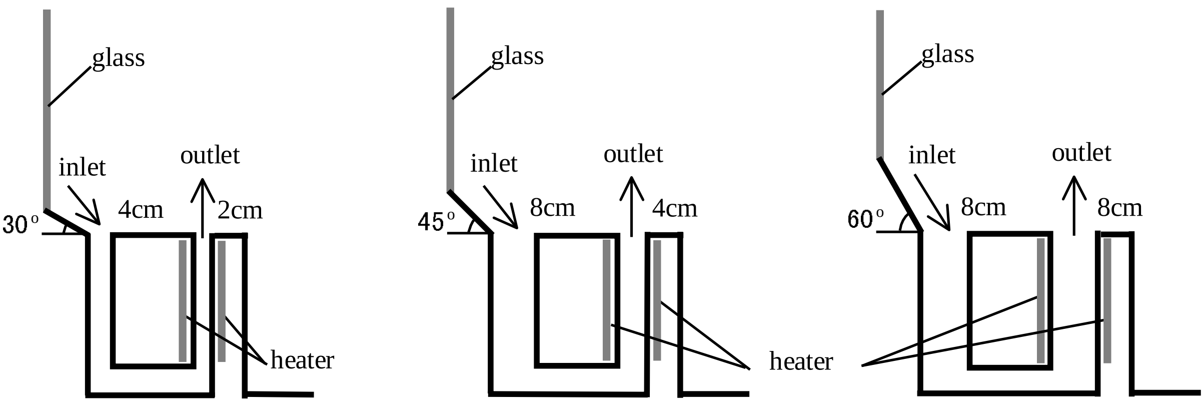
Case35 and case38 reveal this same tendency. In these circumstances, the larger width inlet and outlet enables the down draft to enter the peri-counter and to accelerate the upward flow. This is because the size of inlet and outlet are equal or greater than the depth of boundary layer developed along the window pane.

Table 1 Parameters of the Simulation Model

configuration of peri-counter*	Generation rate of heat panel				element number	node number
	236W/m² 131%**	180W/ m² 100%**	135W/ m² 75%**	90W/ m² 50%**		
d0° in4 out2	case1	case11	case21	case31	6782	6949
d30° in4 out2	case2	case12	case22	case32	7065	7245
d45° in4 out2	case3	case13	case23	case33	7065	7245
d60° in4 out2	case4	case14	case24	case34	7168	7361
d60° in8 out2	case5	case15	case25	case35	7168	7361
d30° in8 out4	case6	case16	case26	case36	7385	7576
d45° in8 out4	case7	case17	case27	case37	7385	7576
d60° in8 out4	case8	case18	case28	case38	7488	7679
d45° in8 out8	case9	case19	case29	case39	7829	8112
d60° in8 out8	case10	case20	case30	case40	7940	8224

* d : angle of inclined peri-counter panel, in : width of inlet (cm) , out : width of outlet (cm)

** % is the heat generation rate of the heat panel against heat loss from window



(1)case2,12,22,32 (d30°,in4,out2) (2) case7,17,27,37(d45°,in8,out4) (3) case10,20,30,40(d60°,in8,out8)

Figure 3 Examples of the Typical Peri-Counter Unit Configurations

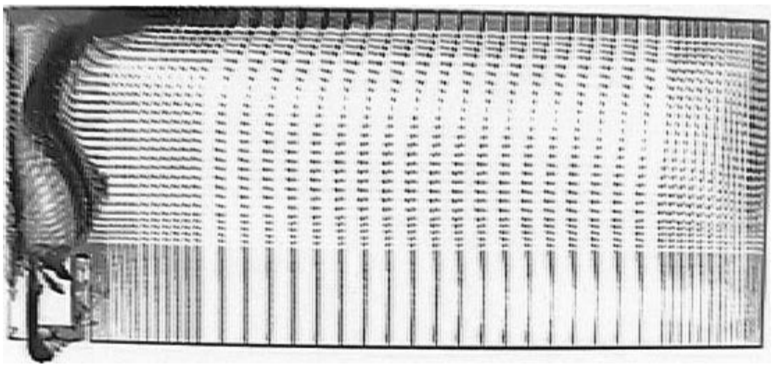


Figure 4 Whole Vector Distribution of case2

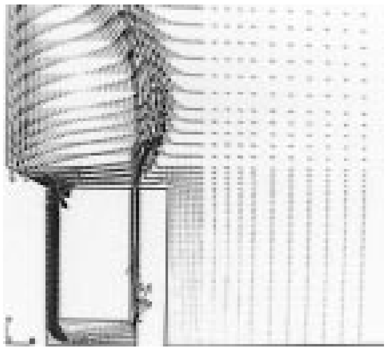


Figure 5 Vector Distribution Around Peri-Counter of case2

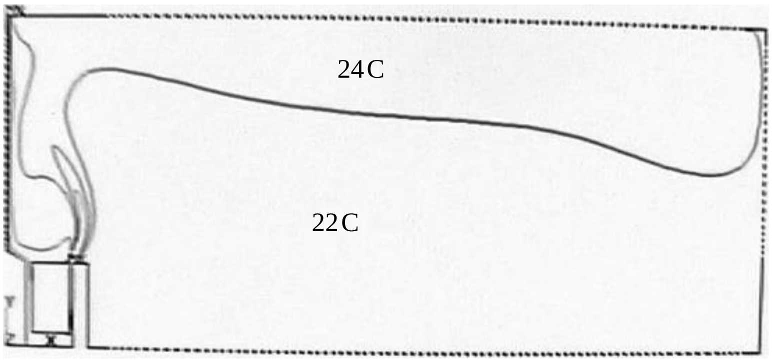


Figure 6 Whole Temperature Distribution of case2

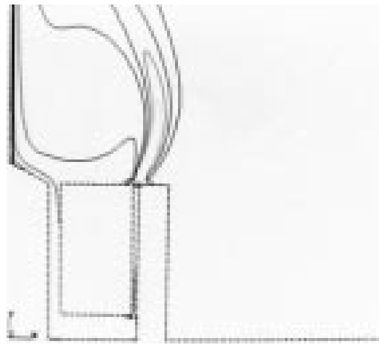


Figure 7 Temperature Distribution Around Peri-Counter of case2

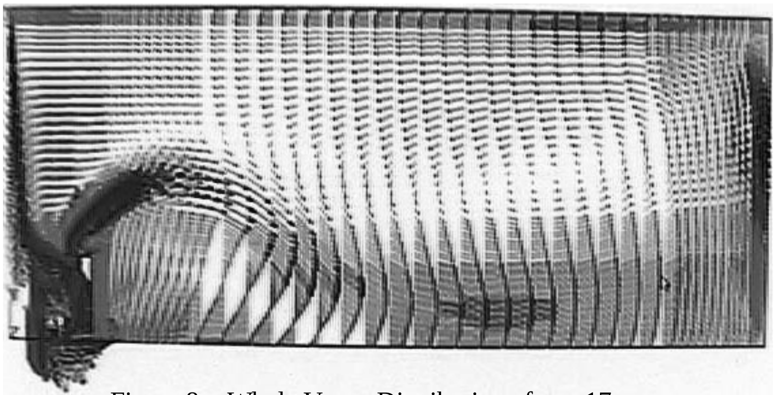


Figure 8 Whole Vector Distribution of case17

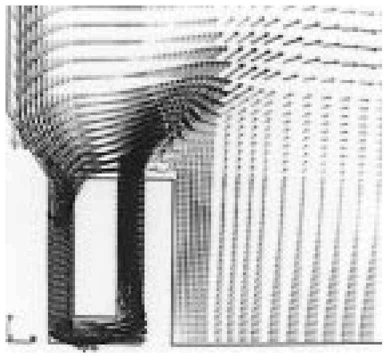


Figure 9 Vector Distribution Around Peri-Counter of case17

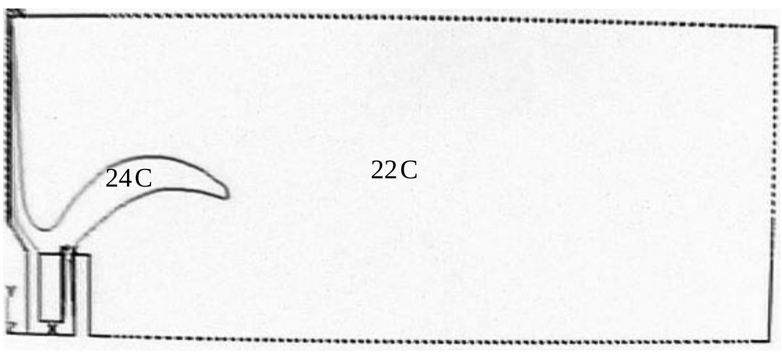


Figure 10 Whole Temperature Distribution of case17

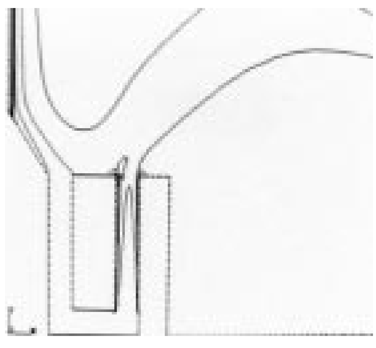


Figure 11 Temperature Distribution Around Peri-Counter of case17

Table 2 Outline of the Simulation Results

configuration of peri-counter *	generation rate of heat panel			
	236W/m^2 131%**	180W/m^2 100%**	135W/m^2 75%**	90W/m^2 50%**
d0° in4 out2	0.3m/s 30C case1	0.3m/s 21C case11	0.3m/s 20C case21	0.3m/s 19C case31
d30° in4 out2	0.4m/s 30C case2	0.3m/s 22C case12	0.3m/s 20C case22	0.3m/s 19C case32
d45° in4 out2	0.4m/s 30C case3	0.3m/s 22C case13	0.3m/s 20C case23	0.3m/s 19C case33
d60° in4 out2	0.2m/s 30C case4	0.3m/s 22C case14	0.3m/s 20C case24	0.3m/s 19C case34
d60° in8 out2	0.5m/s 36C case5	0.3m/s 21C case15	0.3m/s 20C case25	0.3m/s 19C case35
d30° in8 out4	0.5m/s 29C case6	0.3m/s 22C case16	0.3m/s 22C case26	0.3m/s 20C case36
d45° in8 out4	0.4m/s 30C case7	0.3m/s 22C case17	0.3m/s 21C case27	0.3m/s 19C case37
d60° in8 out4	0.4m/s 30C case8	0.3m/s 22C case18	0.3m/s 21C case28	0.2m/s 19C case38
d45° in8 out8	0.4m/s 32C case9	0.3m/s 22C case19	0.3m/s 20C case29	0.3m/s 20C case39
d60° in8 out8	0.3m/s 34C case10	0.3m/s 23C case20	0.3m/s 20C case30	0.3m/s 20C case40

＊ d : angle of inclined peri-counter panel , in : width of inlet (cm) , out : width of outlet (cm)

** % is the heat generation rate of the heat panel against heat loss from window

The flow speed and temperature of this table is whole value around outlet.

(3) ANGLE OF INCLINED PANEL

Considering the case1 to 4 and case6 to 8 that are the same condition except the angle of inclined panel attached to the top of peri-counter, it seems that higher angle provides greater portion of airflow entering the inlet. However, the effect is likely to be less than the heat generation rate and the size of inlet and outlet.

(4) DISCUSSION

The parameter combinations that are able to prevent cold drafts are: (1) cases1 to 10 in which the heat generation rate is $236 w/m^2$, (2) cases16 to 20 and case26 to 30 that have wider inlet and outlet openings respectively.

Especially in the case26 to 30, the heat generation rate is 75% of heat loss from the window where 100% means the heat flow to outside across the window, i.e. the source of driving force of cold draft. Less energy can avoid the cold draft without disturbing the indoor air temperature and fan.

CONCLUSIONS

The results reveal;
(1) The simulation shows good agreement with experiment.
(2) As was expected, the primary factor in preventing cold drafts was the heat generation rate.
(3) The cold draft can be avoided under the condition that the size of inlet and outlet are equal or greater than incoming boundary layer flow.
(4) Increasing the angle of the inclined panel helped to reduce cold drafts; however, the effect is less than the heat generation rate and the size of the inlet and outlet openings.
(5) A certain configuration of the peri-counter units can eliminate cold draft penetration into the interiors, even with 75% of the heat generation rate as a driving force under the cold windows.

In summary, the methods presented here for the design of the peri-counter equipment will help to prevent cold drafts along the cold windows while consuming less energy by not using fans. The effort in developing the design for this equipment can be reduced by using a simulation tool, and it is anticipated that similar procedures may be employed to other cold draft issues when trying to provide a comfortable thermal environment in both the perimeter and interior zones.

REFERENCE

1) FUKUSHIMA Yuji et al., “Study on Control of Thermal Environment of Perimeter Space in Building -Part 2 Numerical Simulation and Measurement on Prevention of Cold Draft”, Annual Meeting of The Society of Heating, Air-conditioning and Sanitary Engineers of Japan, Japan, 1998.8

2) Cybernet Systems, Inc , “FLOTRAN2.1-ANSYS 5.0 basic note”, 1994.6

3) Compuflo, Inc , “FLOTRAN THEORETICAL MANUAL”, 1992