STUDY ON THE ESTIMATE OF THE AIR-CONDITIONING CONTROL SYSTEMS IN LARGE-DOME

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ABSTRACT

In the large space, for example in large-dome, the space is often divided into some zones without partition walls for air conditioning. In this case the following are problematic. The first problem is that it is difficult to control the temperature of the target zone considering the influence by the supply air temperature in the adjacent zone for air conditioning. The second problem is that it is difficult to set the temperature sensor for air conditioning control at the location in which the temperature means the average temperature in the target zone.

To clarify these problems, we set 2 parameters: the temperature of the supply air and the running of the circulating airflow fan, and conducted a scale-model experiment and examined the temperature distribution. We studied concerning the location of the temperature sensor for air conditioning control. As a result, the problems were clarified like follows.

1) In case the temperature in the target zone for air conditioning is affected by the supply air temperature of the adjacent zone, the supply air temperature in the target zone should be determined by considering the temperature in the adjacent zone.

2) In case the temperature sensor could not be set at the location in which the temperature means the average temperature in the zone, the result of the experiment made sure the following. By considering the difference between the temperature in the sensing point and the average temperature in the zone, the temperature in the zone can be controlled.

KEYWORDS

Air conditioning, Model experiments, Sensing point for air conditioning control

1. INTRODUCTION

A large-dome is a typical building with large space. Baseball-games, concerts, exhibitions and other events are held there. It is necessary to save energy than usual, from the viewpoint of cutting running costs and environmental burden. We have studied air conditioning systems in large-dome, for example, the arrangement of the outlet for air conditioning (abbreviated to 'outlet' below), with Computational Fluid Dynamics, model experiments and field measurements of thermal condition in completed large-domes (Takai, H., Arakawa, I., Takahashi, N. and Sato, M. 1996).

As a result, we considered the problems concerning air conditioning control for large space when the space is divided into some zones without partition walls for air conditioning.

The first problem is that it is difficult to consider the influence by the adjacent the seats for spectators toward the field, and disposes of heat load near spectators.

Figure 5 and Table 4 show the results in Case 2. The temperature near the R13-zone is colder than the other area. In the R13-zone the average temperature is 21.1 ℃ in the rear seats and that is 22.7 ℃ in the front seats. It shows that temperature is higher from the rear seats toward the field. The average temperature in the R13-zone is 1 to 2 ℃ colder than the other zones.

Table 1 Examination cases

case	supply air temperature	circulating airflow fans
Case1	17℃ in each zone	off
Case2	14℃ in R13-zone, 17℃ in the other zones	off
Case3	14℃ in R13-zone, 17℃ in the other zones	on

Table 2 Sensible heat generation rate in real scale (MJ/h)

seats	solar	human	transfer	lighting	total
upper	1427	1972	5186	4098	12683
lower	4286	5488	0	0	9774

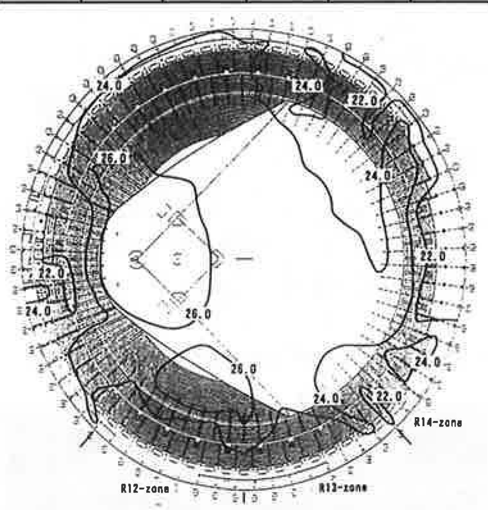

Figure 4 Temperature distribution (℃) in Case 1 (basic condition)

Table 3 Average temperature(℃) in Case 1

zone	R11	R12	R13	R14	L14	L13	L12	L11	whole
front	24.3	24.2	23.8	24.5	24.5	23.7	24.3	24.7	24.3
rear	23.3	23.1	22.6	22.7	22.8	23.1	23.8	23.4	23.1
entire	23.8	23.6	23.2	23.6	23.6	23.4	24.0	24.1	23.7

Figure 6 and Table 5 show the results in Case 3. Average temperature in the rear seats in the R13-zone is 21.7 ℃ and 1 ℃ colder than in the other zones. The average temperature in the front seats is 23.8℃ in the R13-zone, and it is 23.6 ℃ in the R14-zone, 1 ℃ colder than in the other zone.

3.2 INFLUENCED AREA BY THE SUPPLY AIR

Figure 7 shows the temperature difference in Case 2 compared with in Case 1, in the R12 - R14 zones. Table 6 shows the average temperature difference in each zone. An area more than 0.5 ℃ colder than in Case 1 covers the R13-zone and reaches field and boundaries between adjacent zones.

Figure 8 shows the temperature difference in Case 3 compared with in Case 1 in the R12 - R14 zones. Table 7 shows the average temperature difference in each zone. An area more than 0.5 ℃ colder than in Case 1 covers from the R13-zone's rear seats toward the R14-zone's front seats. That is in almost a circular direction along the stream caused by circulating airflow fans. In the R13-zone, the left side of the front seats is not covered by the colder air. It is clearly effect the adjacent R12-zone. As a result, when cooling with circulating airflow fans, the supply air for the upper zone of the circulating airflow fan (R12-zone) influences left side (upper side of the circulating airflow fans) of the front seats in the target zone. The perimeter of the field is out of the colder area and the center of the field the temperature is approximately 1 ℃ higher than in Case 1. Without circulating airflow fans, the supply air flows straight toward the center of the field, but with circulating airflow fans, the supply air makes a detour for the center of the field. So arrival distance is longer than without circulating airflow fans, and heat generation disposed of before arriving field is increased. With circulating airflow fans, the heat generation is disposed of intensively near the seats, so air conditioning for the seats could be more efficient.

3.3 ZONING FOR AIR CONDITIONING

The suitable location of the temperature sensor differs greatly depending on whether circulating airflow fans are running or stopped. According to the influenced area by the supply air, the location of the sensor should be determined. The results in Case 2 and Case 3 mean as follows.

1) When circulating airflow fans are stopped (Case 2)

As mentioned in 3.2, the supply air influences the area covering the target zone. Figure 9 shows the influenced area by the supply air. The influence of the adjacent zone can be ignored except the boundary of the zone. The temperature distribution in the target zone for air conditioning is almost nothing in a circular direction, but the temperature is 2 ℃ higher from the rear seats to the front seats toward the field.

The sensing point should be around the center of the zone because the temperature at the point is the average temperature in the zone. When the sensor is not there, the temperature of the zone can be controlled by considering the difference between the temperature at the sensing point and the average temperature of the zone. For example in Case 2, when the sensing point is put at the rear seats in the R13-zone, the average temperate in the rear seats is 21.7℃, and 1.1℃ colder than the average tem-

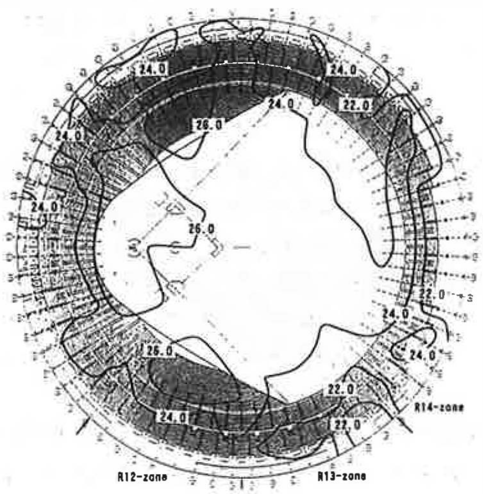

Figure 5 Temperature distribution (℃) in Case 2 (circulating airflow fans : off)

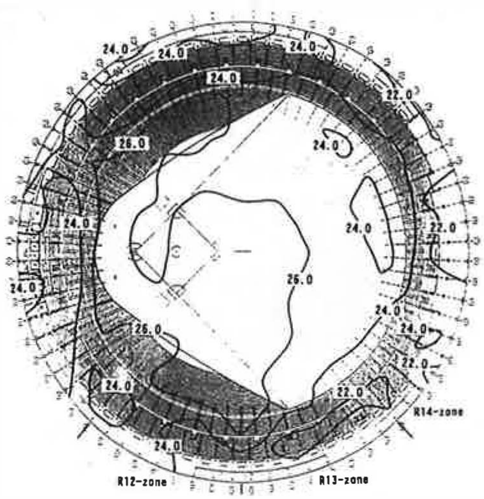

Figure 6 Temperature distribution (℃) in Case 3 (circulating airflow fans : on)

Table 4 Average temperature(℃) in Case 2

zone	R11	R12	R13	R14	L14	L13	L12	L11	whole
front	24.3	24.1	22.7	24.2	24.4	23.5	24.1	24.7	24.0
rear	23.2	22.9	21.1	22.4	22.6	22.9	23.6	23.3	22.8
entire	23.7	23.5	21.9	23.3	23.5	23.2	23.8	24.0	23.4

Table 5 Average temperature(℃) in Case 3

zone	R11	R12	R13	R14	L14	L13	L12	L11	whole
front	24.8	24.7	23.8	23.6	25.5	24.4	23.9	24.8	24.4
rear	23.2	23.4	21.7	22.2	22.6	22.9	22.9	23.5	22.8
entire	24.0	24.1	22.8	22.9	24.0	23.6	23.4	24.1	23.6

When circulating airflow fans are running or in case heat generation is not uniform in the zone, the suitable location of the single sensor in the zone is difficult to determined. In these cases, with plural sensors per zone, suitable air conditioning control may be possible, although it is necessary to examine the contribution rate for each temperature of the sensor.

From now on, we will make experiments and examine the following; air conditioning control in case heat generation is not uniform in the zone, supply air temperature control with the temperature in the occupied zone, air conditioning control considering the problem concerning delay in large space.

REFERENCES

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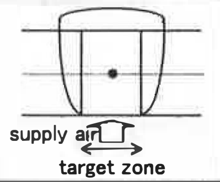
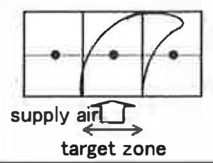
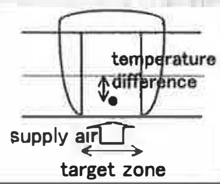
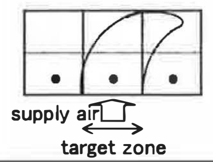
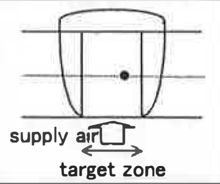
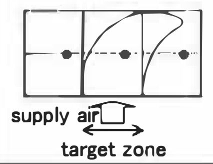
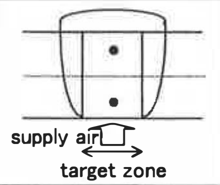
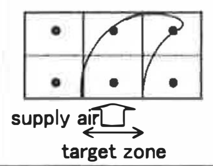
Table 8 Result of examination for sensing point in zone

case	sensing point	circulating airflow fans : off		circulating airflow fans : on	
		influenced area • sensing point	estimate	influenced area • sensing point	estimate
A	1 point in center		suitable		set value of temperature at the sensor needs difference from average temperature
B	1 point in rear		suitable set value of temperature needs difference from average temperature		set value of temperature at the sensor needs difference from average temperature
C	1 point toward lower side		suitable		suitable
D	2 point 1 in front 1 in rear		suitable able to sense both half-zone needs cont-ributiuon rate		suitable able to sense the lower front zone needs cont-ributiuon rate