*Air Distribution in Rooms, (ROOMVENT 2000)*
Editor: H.B. Awbi



# 13319

# AIR CHILLED SUSPENDED CEILING IN COMBINATION WITH SUPPLY OF VENTILATION AIR

H. M. Mathisen

Department of Refrigeration and Air Conditioning at SINTEF Energy Research, 7465 Trondheim, Norway

## ABSTRACT

A suspended ceiling covering a part of the ceiling area, integrated with a ventilation system has be tested in a full-scale laboratory model. The air cools the suspended ceiling before it is supplied to t room. The air flows into the room through a 10 millimetres high slot across the ceiling. The aim of t study was to find how much excess heat this system was able to remove from a typical modern off module of 2.4 times 4.8 meters. Three different shapes of the ceiling were tested. The measureme show that for air velocities of up to 0.15 m/s in the occupied space, heat loads up to 80 to 90 W/ could be removed without draft risk for the best of the tested designs. This is comparable to what \ obtained with a water chilled ceiling with one ceiling mounted diffusers in the same test room. ˜ shape and the size of the ceiling make less of an impact on the result.

## KEYWORDS

Ventilation, Air supply, Suspended ceiling, Thermal comfort, Measurements, Full-scale tests.

## INTRODUCTION

In offices with south facing façades and extensive use of technical equipment, the internal heat loa square meter is high. A water-chilled suspended ceiling in combination with ventilationis often us cool the room in buildings with a high comfort level. This is a relatively costly installation, whic includes a risk of water leakage. Therefore, air-cooled suspended ceilings could have advantage: the other side, water based systems may give lower costs for production and transport of cc energy. According to Makulla (1997) water based systems use less energy for removing heat loa more than 50 W/m$^2$. For Norwegian conditions, this number might be higher due to lower ou temperatures. If low air temperature is used the number could also be increased. As an alternat water based systems and air systems using more air, ABB Environment in Norway has develc new ceiling system. This system utilises low temperature ventilation air to cool a part of the c before it blows the air into the room.

The aim of this paper is to investigate if this new ceiling system is able to remove relativel amounts of excess heat from the room without draft risk for the occupants. It was not the inten study details of the air flow pattern, but the installation, geometry, materials and heat flows should be identical to a real office room.

## DESCRIPTION OF THE CEILING SYSTEM

The ventilation air supply device consists of a curved suspended ceiling covering a part of the ceiling. It is made in different shapes. See Figure 1. The suspended ceiling consist of 0.7 mm thick aluminium sheets with 18% perforation. On the inside, an acoustic sheet is glued to the aluminium. Ideally, the acoustic sheet should be airtight. The suspended ceiling joins close to the inner wall and two sidewalls, while it at the fourth side makes a 10 mm high slot between the ceiling and the sheet. The ventilation air is supplied above the ceiling and flows through the slot into the room. Since cold dry air surrounds the duct condensation will be avoided without insulating the duct.

For summer conditions cold air is supplied. The cold air cools the aluminium sheet which then cools the room through radiation and convection. By doing this the ventilation air temperature will also increase before it flows into the room. This means that colder air could be used than if it was blown directly into the room, because the drop of the cold jet is reduced and condensation is avoided. Three different shapes of the ceiling have been tested, as shown in Figure 1.

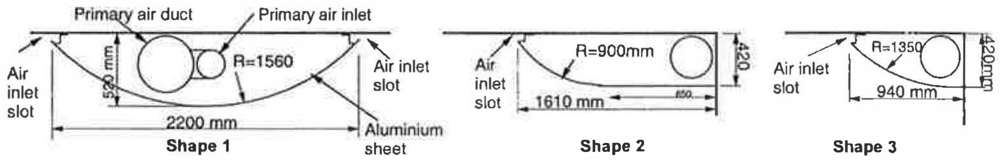


*Figure 1. Three different shapes of the ceiling system. Shapes two and three have primary air inlets equal to shape one.*

## MEASUREMENT EQUIPMENT

The tests were performed at the Refrigeration and Air Conditioning laboratories of SINTEF Energy Research/Norwegian University of Science and Technology. Air temperatures and velocities were measured in the occupied part of the room. The tests were carried out for summer conditions with different heat loads and airflow rates. The construction was the same as for a real office building and the room was furnitured as an office room. Figure 2 shows the test facilities.

The exterior wall has the same construction as for a typical modern Norwegian building. The interior walls were made of plaster wallboards with 3cm insulation. The neighbouring room was kept at the same temperature as the test room to avoid heat transfer through the walls. The primary air temperature was adjusted to maintain equivalence between the supplied heat and the heat removed by the air.

Figure 3 shows the position of the columns with the measuring points. In all points, a thermocouple type T was used to measure the temperature. In 10 of the positions TSI anemometers of type TSI 8475-300 and TSI 8465-300 were used. For the lowest velocities reported in this paper, the accuracy is therefore limited.

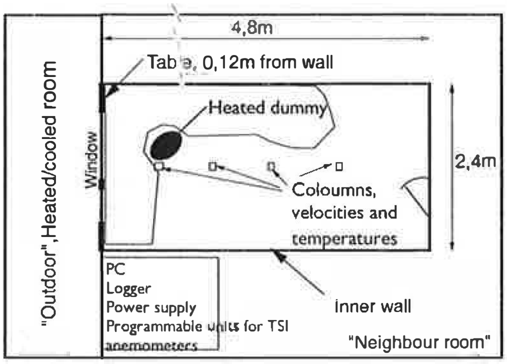


*Figure 2. Test room. The ceiling height is 2.9 metre.*

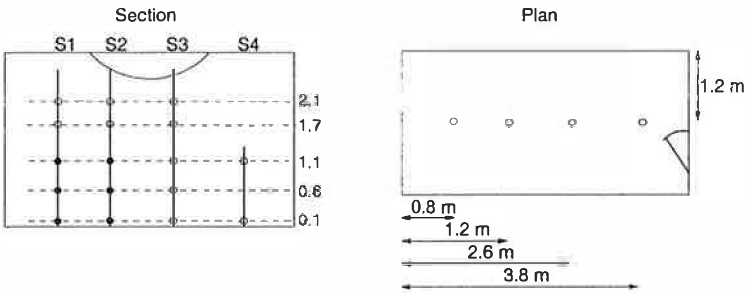


*Figure 3. Location of columns with measuring points*

*TABLE 1* shows the tests that have been carried out with their airflow rates, heat loads, and under-temperature of primary air. The same heat loads applies to all shapes of the ceiling system. The letters in the table corresponds to the heat sources described below the table.

TABLE 1. *COMBINATIONS OF VENTILATION AIRFLOW RATES, HEAT LOAD AND DIFFERENCE BETWEEN SUPPLY AIR TEMPERATURE, AND EXHAUST AIR TEMPERATURE.*

| | | ΔT (supply air temperature minus exhaust air temperature) | | |
|---|---|---|---|---|
| | | 13 °C | 9 °C | 5 °C |
| Airflow rate | 7 m³/hm² | 30.4 W/m² g, d, e, c, b | | 11.7 W/m² b, c |
| | 13 m³/hm² | | 39.2 W/m² g, d, e, c, b, f | |
| | 20 m³/hm² | 87 W/m² g, d, e, c, b, f, a | | 33.5 W/m² g, f(40W), b, c, d, e |

Heat sources:

a) Solar radiation, 560W (Simulated by electric heated sheets underneath the carpet)
b) Fluorescent tubes, suspended lamp, 116 W
c) Low energy bulb, suspended lamp, 18W
d) Table lamp, 18W
e) Extra heat source, 100 W
f) Dummy person, 100W or 40W
g) PC with screen, 92 W

## RESULTS

Figure 4, 5,Figure 5 and 6Figure 7 show some of the measured velocities for shape one, two, and three respectively. The graphs show the velocity in six different measurement positions. These positions were located at columns S1 and S2 at levels 0.1 m, 0.6 m and 1.1m above the floor. See Figure 3 and the points in black. The graphs on the left show the mean of the velocities in the six points, while the graphs on the right show the velocity in the point that has the highest velocity.

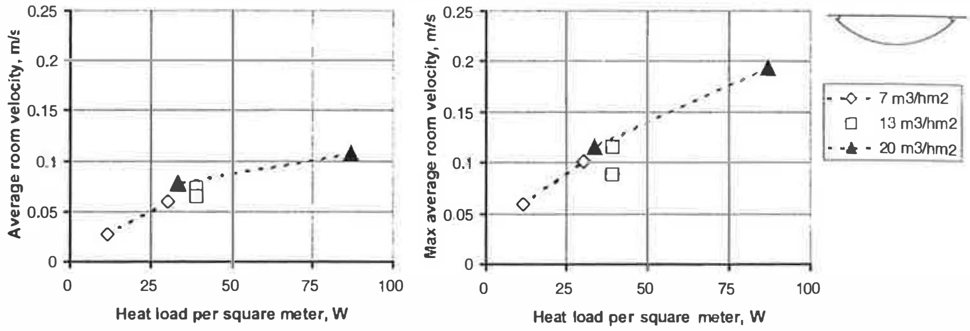


*Figure 4. Air velocities for different airflow rates and heat loads for shape one. Each column contains average or maximum for six different measurement positions in the occupied space.*

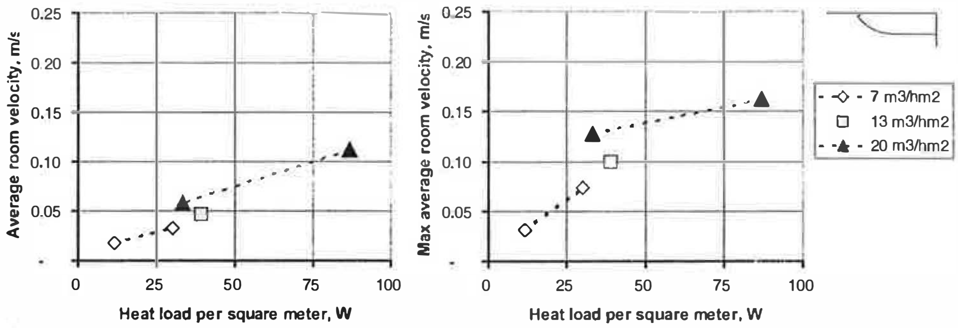


*Figure 5. Air velocities for different airflow rates and heat loads for shape two. Each column contains average or maximum for six different measurement positions in the occupied space.*

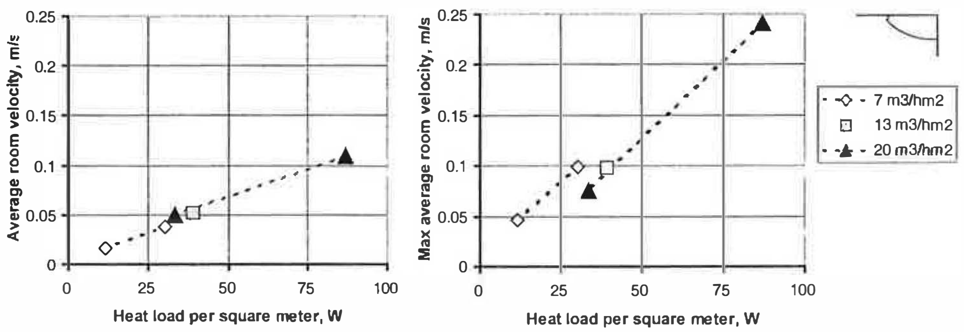


*Figure 6. Air velocities for different airflow rates and heat loads for shape three. Each column contains average or maximum for six different measurement positions in the occupied space.*

A much used draft criterion is that the air velocity should be lower than 0.15 m/s for summer conditions. From the graphs in Figure 8, one can see that the maximum heat load that could be removed from the test room without draft risk was about 80 to 90 W/m$^2$. Any of the three shapes could remove up to 75 W/m$^2$ if one allows a velocity of 0.20 m/s.

How does the suspended ceiling contribute? Figure 9, 8, and 9 show the temperature increase due to the suspended ceiling. As one would expect, the results show that the lower the airflow rate is the greater the temperature increase is. Comparing the gradients in the three figures confirm that the smaller the ceiling area the lower the temperature increase. However, also the smallest module gives a considerable temperature increase.

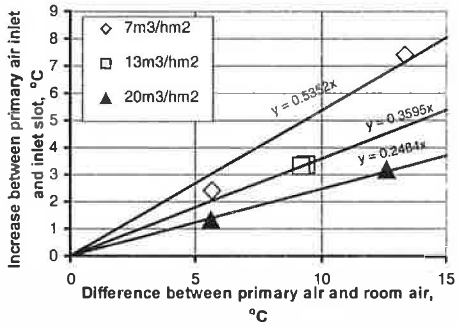


*Figure 7. Temperature increases for shape one.*

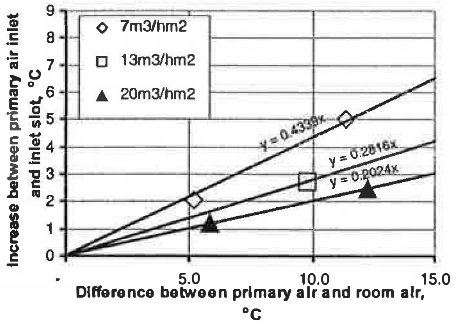


*Figure 8. Temperature increases for shape two.*

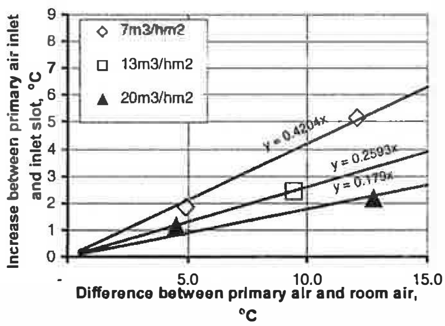


*Figure 9. Temperature increase for shape three.*

A calculation of the heat transfer coefficient based on the ventilation airflow rates and measured temperature differences indicates that especially for the largest airflow rates there must be leakage of air. This occurs through the acoustic sheet and the perforation together with the joints between the sheets.

### *Comparison with other tests*

Figure 12 shows a comparison of the ceiling system with tests of other solution for climatization, done in the same test room with the same inventory and heat sources. In these tests a water chilled suspended ceiling covering the room area was used. The air supply was through a ceiling mounted diffuser; five different brands from four manufacturers were used. 15 m$^3$/hm$^2$ supply airflow was used for all these tests. With an airflow rate of 20 m$^3$/hm$^2$, the air cooled ceiling system gives about equivalent or lower velocities.

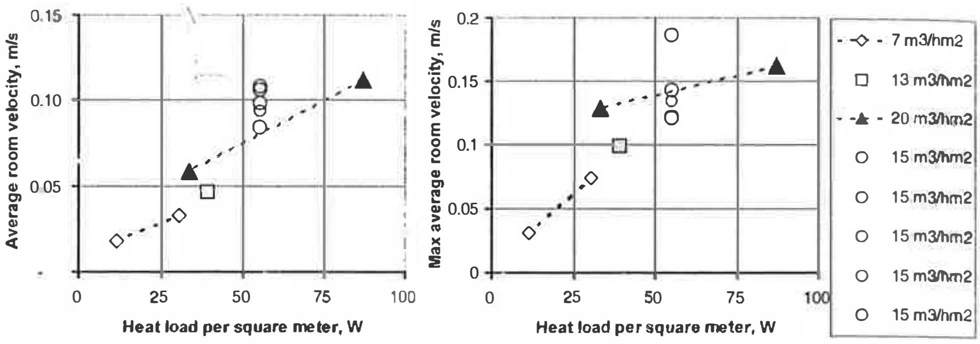


*Figure 10. Comparison with other tests.*

## DISCUSSION AND CONCLUSIONS

The air velocity is very low in most of the tests. That means that the accuracy is limited, but the relative velocity ratio between the tests should give reliable information. For the more critical velocities around 0.15 m/s, the accuracy is reliable.

From the graphs showing the velocity for different airflow rates and heat loads (Figures 4 to 6) it is evident that the heat load has a greater impact on the air velocity than the airflow rate. I.e. the impulse due to thermal forces is greater than the impulse from the inlet jet. The velocity is as low as it could theoretically be. (We can not obtain lower velocity than the thermal movements give).

The air cooled ceiling's thermal comfort and cooling capacity is equal to water chilled ceilings in combination with a ceiling mounted diffuser for single module office rooms. If two ceiling mounted diffusers were used, the cooling capacity would probably improved considerably.

One can conclude that the shape and the size of the ceiling have lessof an impact on the efficiency since the result for the three modules does not differ much. For the smallest ceiling the interior velocity is higher and the temperature lower, this increased the heat transfer.

As a general conclusion, the air cooled ceiling seems to be a well working system in rooms with high heat loads

## ACKNOWLEDGEMENT

This paper is based on projects carried out by SINTEF for ABB Environment from 1997 to 1999. The author would like to thank ABB Environment for their support and their permission to use the results from the projects in this paper.

## REFERENCES

Mathisen, H.M. (1997). Test of supply unit for module office (In Norwegian: Prøving av tilluftsenheter for modulkontor). *SINTEF report no STF84 F97213*, Trondheim, Norway

Makulla,D. (1997). Energetischer Vergleich einer LuftKühldecke mit einer Wasserkühldecke und Quellüftung. *Ki Luft- und Kältetechnik* 7, 299-304.