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# COMPARISON OF VENTILATION SYSTEMS FOR COLD AIR DISTRIBUTION


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## ABSTRACT

Ventilation air is cooled to maintain a low temperature of process or to remove extra heat from working places. Four different kind of supply air devices were measured in a ventilation laboratory in order to find the extreme performance of each device in cold air distribution. The performance of the devices was estimated with cooling capacity, draught parameters and relative efficiency of ventilation. According to the draught parameters the upper limit of operation range defined by the manufacturer turned out to be too optimistic. The air velocity exceeded 0.25 m/s in each test and the effective cooling temperature exceeded 3.5 °C. Therefore, effective cooling by ventilation without draught is difficult. The draught problems should be solved by clothing and local heaters.


## INTRODUCTION

Cold air distribution to workplaces is needed to cool air for the process, to cool the workplace or due to air pollution in cold spaces. The ambient temperature of cool work spaces has also decreased in international regulations. However, there are no studies concerning the guidelines for planning ergonomic cold air distribution systems.

In cold air distribution a displacement or dilution ventilation system can be used. On the market there are also cold air distribution systems based on active displacement. An active displacement air distribution system can tolerate large temperature changes , which make the system insensitive to ambient temperature change.

This study was aimed at determining the draught parameters and the cooling capacity of four cold air distribution systems.

## METHODS

In the ventilation laboratory ( 8 m ∗13 m ∗7 m), four different kinds of supply air devices were measured in order to find the maximum performance of each device in cold air distribution. Measurements were carried out as full scale experiments with an automatical flow, temperature and contaminant concentration measurement system (1). A quarter of the symmetrically installed laboratory was measured. A total of 340 measuring points for flow and temperature were included in one test. The distances between the measuring points were 0.5- 1.0 m in the vertical and horizontal planes and they were placed from 0.1 m height to 4.1 m, at a 0.5 m distance from the front wall and 1.0 m from the side wall.

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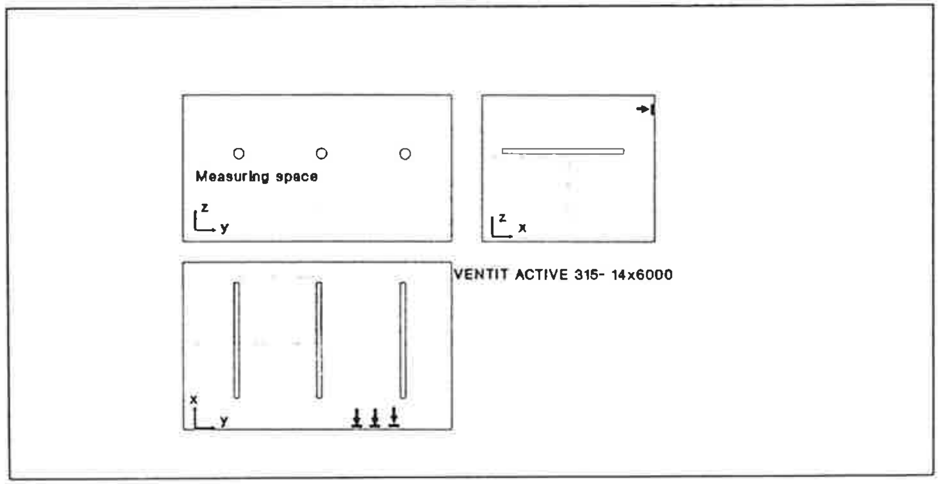


Fig 1. The lay-out of the experiments of the active displacement system. The measuring space was the same for the other ventilation systems

Radiator elements ( 24 units, á 660 W) and two electrical stoves (14 kW) were used to compensate the cooling effect of the ventilation. The heaters were placed on the floor in three lines in the direction of the longer wall, one in the middle of the laboratory and two beside walls. The cooling power in the different experiments varied from 4 kW to 30 kW. The purpose of the heaters was to compensate for the cooling effect and to hold the walls of the laboratory at a constant temperature.

The measured ventilation systems were: 1) a new active displacement system, (Ventit Active, 315-14x6000); 2) a low impulse system , (Sock distributor, 200x5000 (0.26 $m^3/s/m^2$, at 150 Pa)); 3) a displacement system (Floormaster, PND-06-2-315, ) and 4) a turbulent mixing system (Vortex diffuser, VDL-400-B).

The new active displacement system consisted of three elements, placed at a height of 4 m. These ventilation tubes carried out active displacement of air (fig 1). These elements consisted of punched, 10 mm long, 5 mm diameter holes, at distances of 2- 10 cm. The holes were situated in an 180 ° wide sector, which pointed upwards. The low impulse system consisted of three, 5 m long socks installed at 5 m ceiling level. Four displacement supply devices, Floormasters were installed symmetrically by the walls of the laboratory to stand on the floor. The turbulent mixing system consisted of four vortex diffusers at a height of 5.5 m.

Measurements were done with one size of device and with two airflow rates and different temperature differences between the supply and exhaust air. One of the test conditions was selected to be at the upper operating limit defined by the manufacturer of the devices. The other conditions were selected to find the extreme conditions of operation by raising the temperature difference and changing the ventilation volume. The test conditions and parameters are given in table 1.

The performance of the devices was estimated using cooling capacity and draught parameters The effective cooling temperature of the air jet (2), Θ, was defined as:

$$\Theta = T_m - T_i + 8 * v, \qquad (1)$$

where $T_i$= temperature of the air jet, $T_m$= mean temperature of the working zone and v= velocity of the air jet. The temperature efficiency, $\varepsilon_T$ was defined as:

$$\varepsilon_T = (T_e - T_s)/(T_{1.1m} - T_s), \qquad (2)$$

where $T_e$ = temperature of the exhaust air, $T_s$ = temperature of the supply air and $T_{1.1m}$= room temperature at a height of 1.1m.

## RESULTS

A measured air velocity map of the active displacement system is shown in figure 2 as an example of the air movement pattern of different systems. It is measured in a horizontal plane at a height of 1.6m, when the cooling power was 13.6 kW. From figure 2 we can see how the cold air falls down between the Activent tubes, which were situated at a distance of 2.5, 6,5 and 10,5 m from the front wall. Similar air jets existed with the sock distributor, but now the jets were situated just below the distribution socks. The displacement unit had an air jet near the unit at height of 0.1 m. In figure 3 and 4 the measured draught parameters are presented as a function of cooling power. The measured mean air velocities and thermal efficiencies in tests are presented in table 1 together with the test parameters.

Table 1. The measured ventilation systems, their input parameters and measured velocities and thermal efficiency of ventilation. The used notations are: ΔT = temperature difference between exhaust and supply air, Q= airflow rate , P = cooling power of ventilation, $v_{0.1}$ = mean air velocity at a height of 0.1 m, $v_{1.6}$ = mean air velocity at a height of 1.6 m, $\varepsilon_T$ = thermal efficiency of the ventilation ( at a height of 1.1 m ). The upper operating limit of systems as defined by the manufacturer is marked with *.

| Vent. system | ΔT °C | Q $dm^3/s$ | P kW | $v_{0.1}$ m/s | $v_{1.6}$ m/s | $\varepsilon_T$ |
|---|---|---|---|---|---|---|
| 1 | -10 | 720 | 9.0 | 0.21 | 0.17 | 1.02 |
| 1 * | -15 | 720 | 13.6 | 0.26 | 0.19 | 1.09 |
| 1 | -18 | 720 | 15.3 | 0.28 | 0.18 | 1.13 |
| 1 | -15 | 900 | 15.7 | 0.24 | 0.20 | 1.12 |
| 2 | -3 | 1200 | 4.3 | 0.16 | 0.15 | 0.97 |
| 2 | -6 | 1200 | 8.8 | 0.21 | 0.20 | 1.15 |
| 2 * | -3 | 2400 | 8.9 | 0.27 | 0.20 | 1.11 |
| 2 | -9 | 1200 | 13.0 | 0.22 | 0.26 | 1.10 |
| 2 | -6 | 2400 | 16.1 | 0.32 | 0.25 | 1.27 |
| 3 * | -3 | 2400 | 9.2 | 0.18 | 0.08 | 1.88 |
| 3 | -4 | 2000 | 9.4 | 0.18 | 0.08 | 1.22 |
| 3 | -4 | 2400 | 12.7 | 0.22 | 0.09 | 1.52 |
| 3 | -10 | 2000 | 23.8 | 0.21 | 0.06 | 2.06 |
| 3 | -10 | 2400 | 29.7 | 0.23 | 0.07 | 2.40 |
| 4 | -5 | 1400 | 8.2 | 0.17 | 0.18 | 0.94 |
| 4 * | -5 | 2200 | 12.9 | 0.21 | 0.21 | 0.94 |
| 4 | -10 | 1400 | 16.8 | 0.22 | 0.23 | 1.07 |
| 4 | -15 | 1400 | 21.3 | 0.23 | 0.24 | 1.10 |
| 4 | -10 | 2200 | 23.8 | 0.25 | 0.24 | 1.10 |

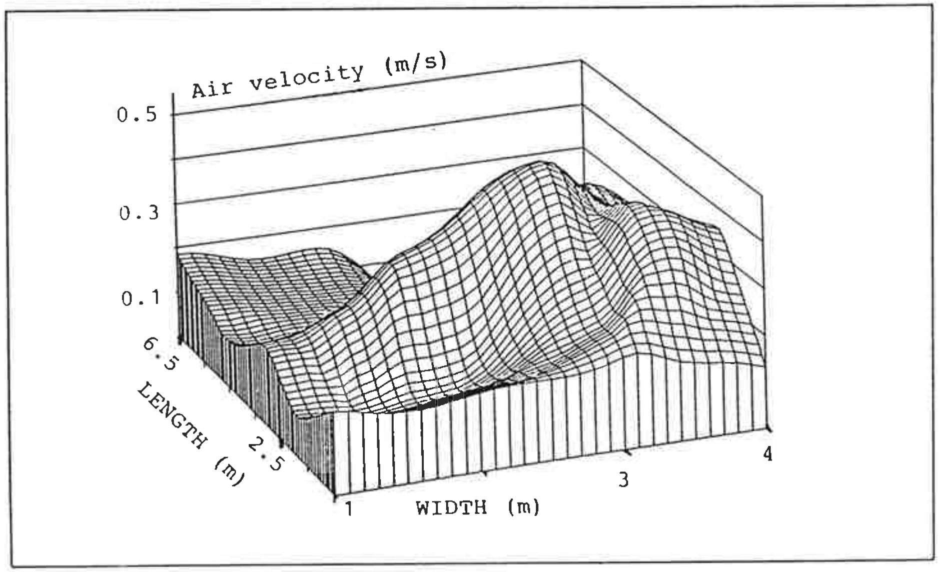


Figure 2. The measured air velocity contour map of the active displacement system in the horizontal plane at a height of 1.6 m, when cooling power was 13.6 kW.

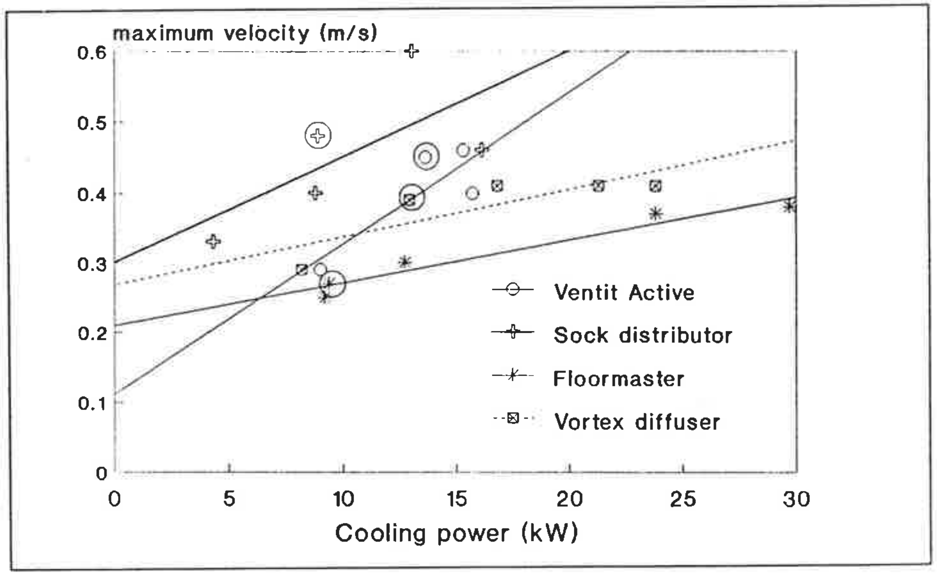


Figure 3. The measured maximum air velocities in the working zone with different distribution systems as a function of the cooling power. The upper operation limit as defined by the manufacturer is marked with O.

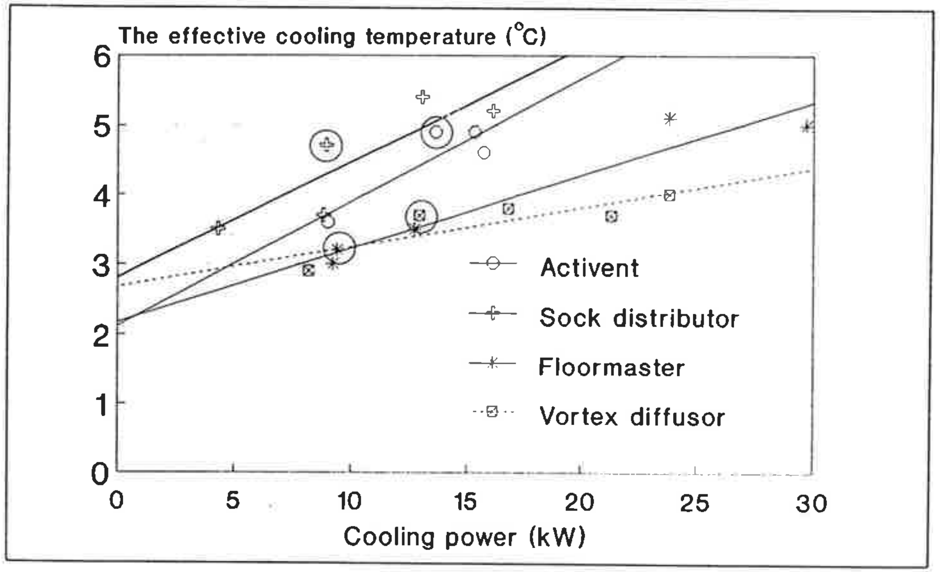


Figure 4. The measured effective cooling temperatures of air jets in the working zone with different distribution systems as a function of the cooling power. The upper operation limit as defined by the manufacturer is marked with O.

## DISCUSSION

We studied in ventilation laboratory four different kinds of supply air devices in order to find the maximum performance of each device in cold air distribution . We measured the cooling capacity, draught parameters and the efficiency of ventilation of an active displacement ventilation system, a sock distribution system, a displacement system and a vortex diffuser system.

The mean air velocity at a height of 1.1 m was about 0.2 m/s with different systems, except the displacement system, which had a mean velocity of 0.1 m/s. At a height of 0.1 m every system had a mean velocity about 0.2 m/s and the maximum air velocity of the displacement system especially was not smaller than others. The maximum values of air velocity in the working area were measured. The velocity limit of 0.4 m/s was exceeded when the cooling power was from 8 to 15 kW, except the Floormaster excepted. In this system, the cold air was distributed near the floor level, so the cold air could not fall with higher air velocity. The highest air velocities were measured with the sock distributor, where the velocity of supplied air was initially 0.26 m/s and, after falling from the ceiling, increased up to 0.6 m/s. Anyone of the systems did not meet the typical draught criteria of 0.25 m/s.

The measurement of the effective cooling temperature as a function of cooling power showed that the maximum temperature value of 4 °C was exceeded when the cooling power was from 8 to 15 kW, except the vortex diffuser excepted. The Floormaster had also low values when used with a cooling power of less than 9 kW.

The thermal efficiency of ventilation systems describes how effectively the cold air can reach the working zone and stratify extra heat to the upper zone of the hall. Only with the displacement system did the thermal efficiency clearly exceed the value 1.0. The vortex diffuser system had the lowest values.

On the upper limit of the operation range defined by the manufacturer of the devices, draught problems occurred. The maximum air velocities were from 0.28 m/s to 0.47 m/s at this limit. The displacement system had the lowest air velocity. The active displacement system and the sock distributor had a high effective cooling temperature ( ca. 5 °C) at the upper operation limit, while the others systems had a more reasonable value ( ca. 3.5 °).

In cold air distribution, the problem is the increasing velocity of the cold air due to density and gravity. A sensation of draught occurs even at low air velocities because of low temperature. Therefore, the downward air flow should be reduced. The used methods are the distribution of air from below (Floormaster), using small differences in temperature (causing large air flow, sock distribution) and effective mixing of cold air before allowing it to enter the working zone. This means that active displacement and vortex diffuser systems can be used over a wide range of air temperature differences. The control range in the lower part is restricted by non-uniform mixing and in the upper part by the power of the fan.

As a summary, we can conclude that the air velocity in the working zone was over 0.25 m/s in each experiment and the vertical temperature differences did not occur in any case causing draught complaints. The floormaster and the vortex diffuser system had the lowest draught parameters. The Floormaster had also the highest thermal efficiency.

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