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OPEN SOURCE COOLING

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ABSTRACT

This new HVAC concept combines low investment and energy costs with excellent comfort conditions.

Instead of dispersing the warm air of the internal heat loads in the whole room and then cooling the room air, the open source cooling system captures the warm air directly at the heat source, cools it down and supplies it into the area of the heat load. The air movement is thus concentrated to the area of the heat load. By putting the natural convection and radiation into use the heat sources can be placed open in the room, no cabinet or covering is necessary.

The cooling element is located above the major heat sources, such as screens and personal computers and is connected to a coolant circuit. There it is able to absorb 80 to 90 percent of the heat load of the nearby apparatus. By cooling the air below room temperature an additional cooling capacity of 100 to 300 W per element is realized. The temperature of the coolant lies between 18 and 20°C, so that during a long period of the year free cooling is possible. Amazing comfort conditions with air velocities below 10 cm/s for cooling loads up to 140 W/m^2 are the result.

The cooling element was investigated in a room climate laboratory under real size conditions. The expected performance regarding cooling capacity and thermal comfort could be verified. For the fresh air supply to the room both displacement and mixing air supply systems were tested and showed no interaction to the cooling element. The promising laboratory results were confirmed in a office installation with a heat load of 120 W/m^2.

With open source cooling the following advantages are expected:

- Demand correlated HVAC installations by spacing of the cooling components within the furniture instead of the building.
- Reduced building control installations due to self regulating systems.
- Considerable improvement of the comfort conditions by reduction of the air movement from a whole room vortex to a vortex around the heat sources.

KEYWORDS

Office buildings, high thermal load, local exhaust, thermal comfort, chamber study

INTRODUCTION

Computer installations in offices for electronic trading multiplied during the last years and will further increase due to the enormous demand for information. The cooling load in those offices reached already in the early 90's the level of 100 W/m^2. Recent HVAC installation are to cool up to 160 W/m^2.

The following cooling systems established for these applications are:

1. Closed desks
2. High rooms with air cooling only
3. Fan coils at floor or ceiling level
4. Cooled ceilings with additional fan coils.

In Europe and Japan, where a high standard of comfort is requested, the systems number 1, 2 and 4 are mainly in use. These installations combine the enormous cooling capacity with a draft free occupied space and - more and more important - with high energy efficiency. High installation costs and inflexibility on the other side prevent these systems from common acceptance.

By using another approach Loomans et al. (1996) investigated a local desk ventilation concept based on displacement ventilation. They could realize a well functioning system for medium size heat loads.

But is there also a simpler and more efficient solution for cooling a office room with high internal heat loads? This question was the starting point for the development of the presented cooling system. Three goals were defined for this project:

1. Simplification of the technical installation
2. Higher flexibility for the user and support personnel
3. Outstanding comfort conditions

The main idea in the development process was to prevent the heat from dispersing in the whole room air, while computer and screens are uncovered and freely accessible. This goal was to be realized with a cooling system that is integrated in the furniture instead of being part of the building structure.

The feasibility was first checked by theoretical calculations and than followed by practical development as it will be described in this paper. For this new office cooling system we use the name cool top. Modifications of the cool top are planed for further users in the future.

METHODS

Technical development

The basic work preceding the technical development was:

1. Analysis of the heat loads in dealing rooms
2. Estimation of the characteristic air and energy flows in dealing rooms

In addition to these basic calculations the comfort conditions in different dealing rooms were investigated by questionnaires and measurements. These data benchmarked the performance of the following developments.

As a result of the intensive preliminary work, the cooling system was realized using simultaneously technical calculations and practical tests. This procedure allowed to develop in record term a system functioning immediately.

The following technical specifications were requested and could be achieved as such:

1. Coolant supply temperature 18 - 20 °C
2. ΔT coolant 4 to 6 °C
3. Highest requirement regarding leakage of the coolant installation
4. Energy consumption for auxiliary equipment max. 4% of the cooling capacity
5. Ability of self regulation, no connection to a building control system

Micro climate concept

The performance of the new system is based on the following functions:

1. Heat transport making use of momentum and buoyancy forces
2. Cooling the occupied zone instead of the whole room volume

In consequence, a micro climate is created in the zone of the heat sources as well as in the area of the employees. So the conditioning of both micro climates can be designed in a optimal way. In the area of the heat sources a forced convection flow is created to transport the heat into the cooling coil. In the occupied zone any air movement is avoided in order to prevent draft sensation and to make the employee feel like sitting in a room without any heat sources.

Beside the two zones no direct influence is taken upon the thermal conditions of the room.

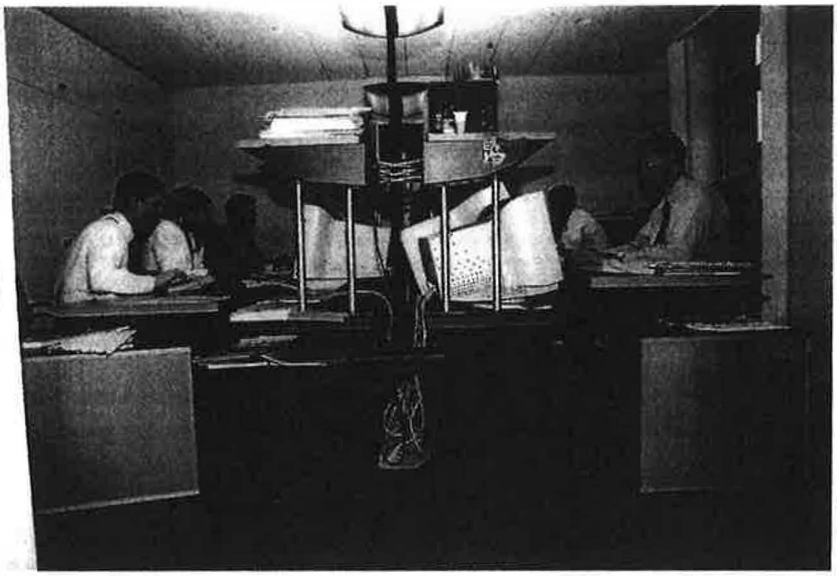

Figure 1 Office desks with computers and cool tops mounted above them

Design of the cooling element

Due to its function, the heat exchanger is located in the area of the heat sources. The integration of the cooling element into the desk design was therefore part of the first development steps. In a close collaboration with a desk manufacturer a cooling element was designed which is integrated almost invisibly into the shelf above the screens. This element is so small and quiet, that the employee will never imagine the enormous cooling capacity just in front of his head.

Preliminary field tests in bank offices

The acceptance of the new system, see figure 1, by the employees was tested in preliminary field tests. This intermediate step during the design process was carried out in order to check its practical value in a early stage.

The results of preliminary measurements were:

1. The cooling capacity is reached and the subjective cooling effect is even better than proposed.
2. No problems with the acceptance by the users.
3. Preoccupation of the system supporters regarding coolant fluid on the screens.

Lab investigation

The cooling capacity as well as the thermal comfort of a prototype cool top were investigated (Oberlin and Kegel 1997) in a room climate laboratory (Lommel and Rueegg 1994). In the testroom of the lab a model office containing computer equipment and the cool top was set up in real size, see figure 2.

Length, width, height and volume of the testroom were 4.5m x 4.5m x 2.7m, 55m^3. The test room envelope was isolated and situated in a conditioned lab hall. Therefore the temperature of the inner surfaces adapted to values around 20°C. Different ventilation systems of low air

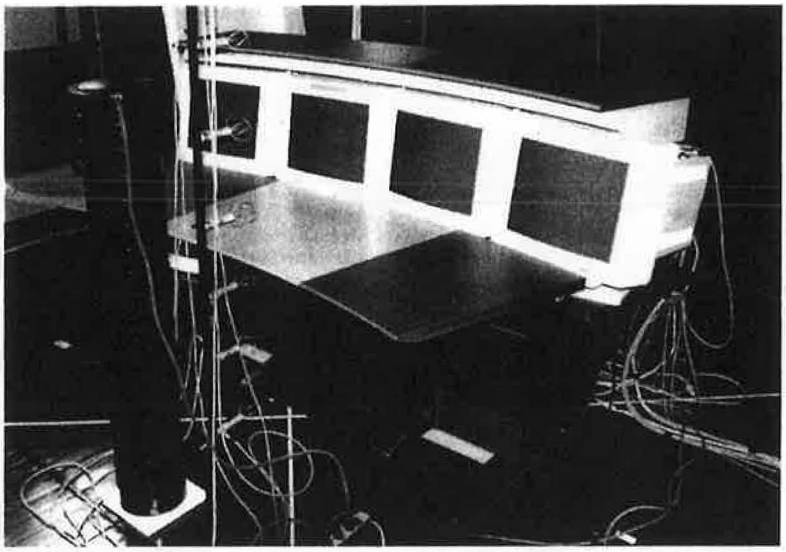

Figure 2 Test room with cool top mounted on computer monitors

change rate were applied to the office: (1) by mixing ventilation with a ceiling rotation diffuser, (2) by displacement ventilation with a wall diffuser and (3) by no ventilation, i.e. natural ventilation. The thermal load in the test room consisted of 4 personal computers with 2'' monitors, of a person dummy, of additional office equipment and of a room illumination. The cool top was connected to a coolant circuit. Constant coolant supply temperatures were selected between 14 and 20°C. The cooling capacity of the cool top was determined by measuring the flow rate of the coolant and its temperatures at the inlet and outlet of the cool top. The conditioning parameters are shown in table 1 and 2:

Table 1 Cool top parameters

Range of values	Air flow rate [m^3/h]	Coolant flow rate [l/min]	Coolant supply temp. [°C]
min	50	2.5	15
max	125	2.9	20

Table 2 Room ventilation parameters

Vent. method	Air change rate [1/h]	Air supply temp. [°C]
mix.	1.5	19
displac.	2.4	19
natural	0	

Furthermore also air speed and temperatures at the fans of the cool top were measured to calculate the cooling capacity. To assess the thermal comfort, air temperatures and velocities in the occupation zone and in a zone apart from it were registered. The air movements were visualized with fog to characterize the air flow pattern close to the cool top and the computer monitors.

A total of 20 experiments were performed with the three ventilation systems and with different settings of the air conditioning parameters.

RESULTS OF THE LAB INVESTIGATION

Figure 3 shows the cooling capacity of the cool top compared to the heat load for different parameters, i.e. ventilation method, coolant supply temperature. Depending on the coolant supply temperature the cool top cooling capacity is slightly lower or even higher than the heat load of the monitors.

That means that the cooling capacity of the cool top is sufficient for the monitors on which it is mounted but that the cool top has also the capacity to take up additional heat loads of the office.

To characterize the dynamic behavior the monitors and the rest of the heat loads were turned on at the beginning of the measurements displayed in figure 4. The coolant supply and return temperatures started immediately to separate, while the room temperature stayed almost constant. The cooling capacity started also to rise and reached the working level after about 2 hours.

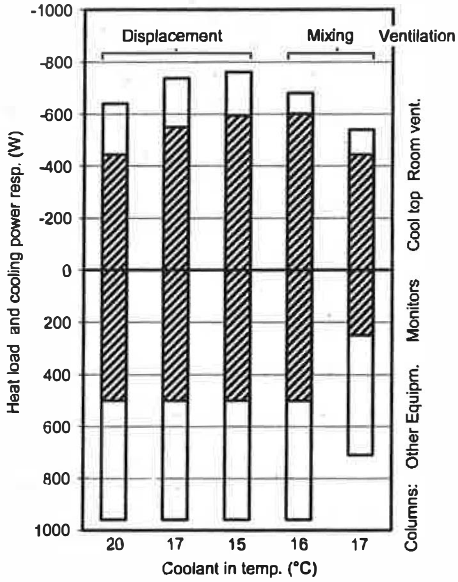

Figure 3 Cooling capacity (upper part) for different parameters compared to heat loads (lower part), meaning of columns at right border

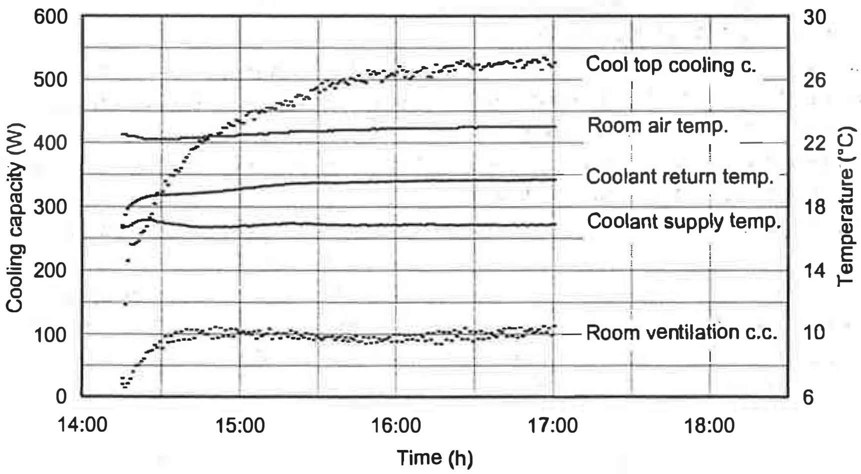

Figure 4 Temperatures and cooling capacity (c.c.) of the cool top and of the office ventilation

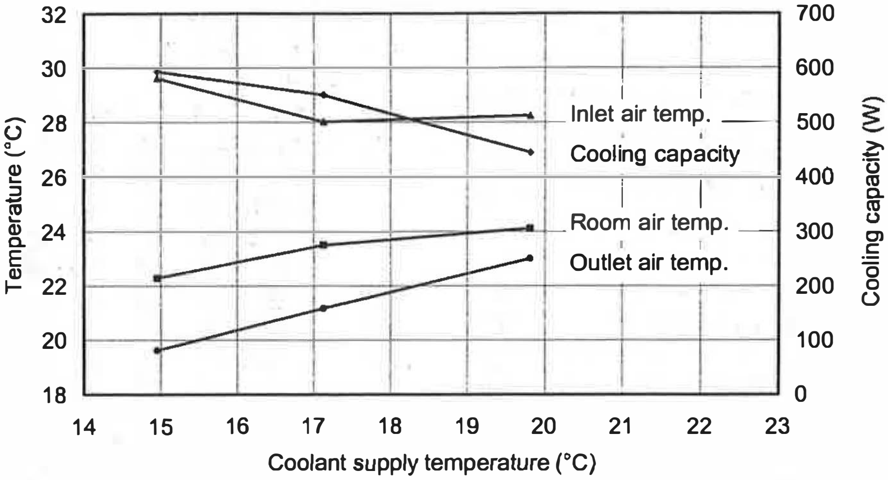

Figure 5 Inlet and outlet air temperatures and cooling capacity in function of the coolant temperature in experiments with displacement ventilation

The dependence of the inlet and outlet air temperature and the cooling capacity on the coolant supply temperature is shown for experiments with displacement ventilation in figure 5. While the outlet air temperature and the cooling capacity were varying linearly, the room air temperature increased only by 2 K. The outlet temperatures were in a range high enough, where they are not expected to degrade the thermal comfort.

None of the measured temperature and velocity profiles indicated a degradation of the thermal comfort. Figure 6 contains the profiles for displacement ventilation and a medium coolant supply temperature. The air velocity did not exceed 12 cm/s and the air temperature remained between 23 and 25°C in all experiments.

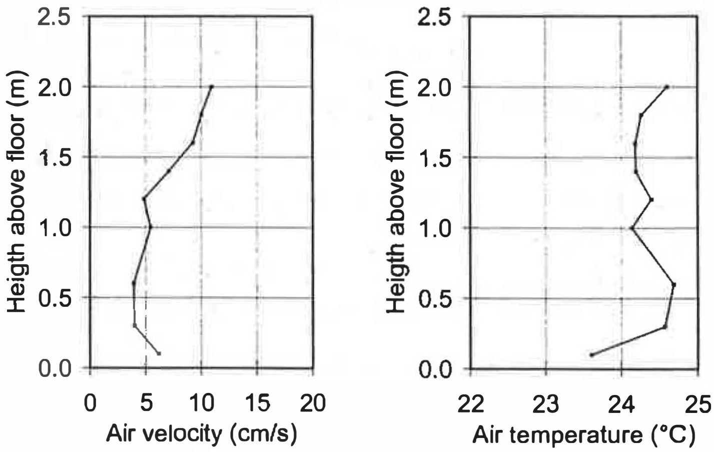

Figure 6 Vertical profiles of air velocity and temperature in front of the monitor desk for displacement ventilation

DISCUSSION

Much interest was given to the first field installations in order to understand the complexity of the system performance under life conditions.

Cooling performance

After the successful laboratory tests the cooling load was increased from 600 to 800 and even to 1000 W per element. These values were reached in every installation since the very beginning. While often doubted by the users, the cooling capacity was never a problem in the application.

The reason for this performance is based upon the micro climate concept. All heat sources of the desk area are directly cooled by the cooling element. The cooling capacity is therefore given by the installed heat load. In addition to this direct cooling, the cool desk zone absorbs further heat from the occupied area due to its gentle undertemperature compared to the room.

Comfort conditions

In terms of comfort the potential draft problems are the most feared. For this reason many clients ask for 12 cm/s as maximum air velocity of the occupied zone. Compared to 15 or 20 cm/s as standard value this is an extremely low level. Nevertheless only a few velocity measurements were taken, because the average velocities were between 4 and 6 cm/s. More than 12 cm/s as peak level was never measured.

These results prove that the cooling effect of the elements is strictly concentrated on the desk zone.

Self regulation

Neither the cooling elements nor the coolant circuit are connected to the building control system. The coolant supply temperature lays generally near 20°C and is kept at a constant level. Figure 7 shows the temperature and the humidity in the occupied zone of a office used during several days. The constant temperature of 24±0.5 °C does not show any variation caused by the heat load varying between 20 and 120 W/m² during the office hours.

The complete self regulation of the cooling elements is the result of the high coolant supply temperature and the heat transfer performance of the heat exchanger.

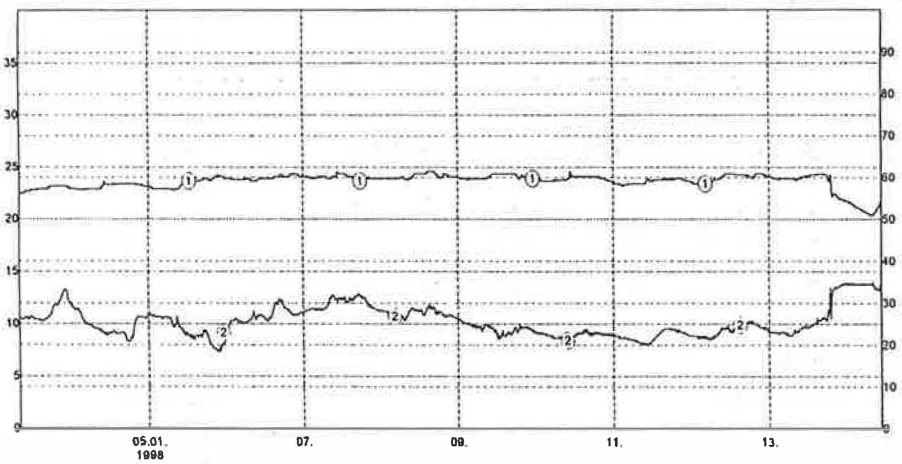

Figure 7 Room temperature and humidity of an office.
Curve 1: temperature (°C), left axis
Curve 2: rel. humidity (%), right axis

CONCLUSION

A new cooling system for high heat loads of screens and personal computers was developed and investigated. The results had shown that heat loads of 120 W/m^2 can be cooled directly at the desk without degrading the thermal comfort. Because of its self regulation the cooling element works without connection to the building control system. The first systems were already installed in offices and are performing very well. Based on these experiences the design will be further improved.

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REFERENCES

Lommel, A., Rueegg, Th. (1994) Die neue Luftstroemkammer der EMPA-Abteilung Haustechnik. Proceedings of the 8. Schweizerisches Status-Seminar 'Energieforschung im Hochbau', Zuerich, Switzerland.

Loomans, M. G. L. C., van Mook, F. J. R. and Rutten, P. G. S. (1996) The introduction of the desk displacement ventilation concept. *Proceedings ROOMVENT '96.* Tokyo, Japan.

Oberlin M., Kegel B. (1997) Messtechnische Ermittlung des Betriebsverhaltens eines Kuehltablars. Diplomarbeit, Technikerschule Heizung/Klima Zuerich.