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METOP - Energy Efficient Office Building

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SYNOPSIS

A prototype of a low cost, low energy office building was built using a new Finnish component system building technology.

Thanks to the energy efficient windows, the thermal insulation of the building envelope and the demand-controlled variable outdoor air flow HVAC system with heat recovery and energy-storing structures, the need for heating and cooling energy has been reduced to such a level that a low energy office can be cooled with outdoor air and with the aid of a heat recovery device. The building is kept warm with the support of its own operations almost throughout the year. It is possible to arrange a good individual indoor climate in this way almost without any purchased heating or cooling energy. There is need for heating only during the coldest but short periods in the night and during the weekends. Even during the summer heat periods, cooling energy produced by refrigerators operating on CFC is not needed.

1. INTRODUCTION

The prototype "METOP" for a low energy office was completed in the test house area of VTT in Otaniemi, Espoo /1/, /2/. The prototype was built for testing the function of the new structural, electrotechnical and HVAC solutions which were developed in different studies (EBES, TAT, ETRR, LVIS-2000, RATA-2000) and in the development projects of different companies. The low energy office, whose total costs were quite low, was built using a new Finnish component system building technology and a factory preadjusted variable air volume HVAC system.

A good, individually adjustable indoor climate has been realised by means of a self adjusting demand-controlled HVAC system with variable air flow. The aim is to create an environment in which heating energy needs to be purchased only during the coldest winter days when temperatures fall below -15 °C. Cooling energy produced by refrigerators operating on CFC is not needed. The follow-up studies on the indoor climate, efficiency and energy consumption will continue for two years.

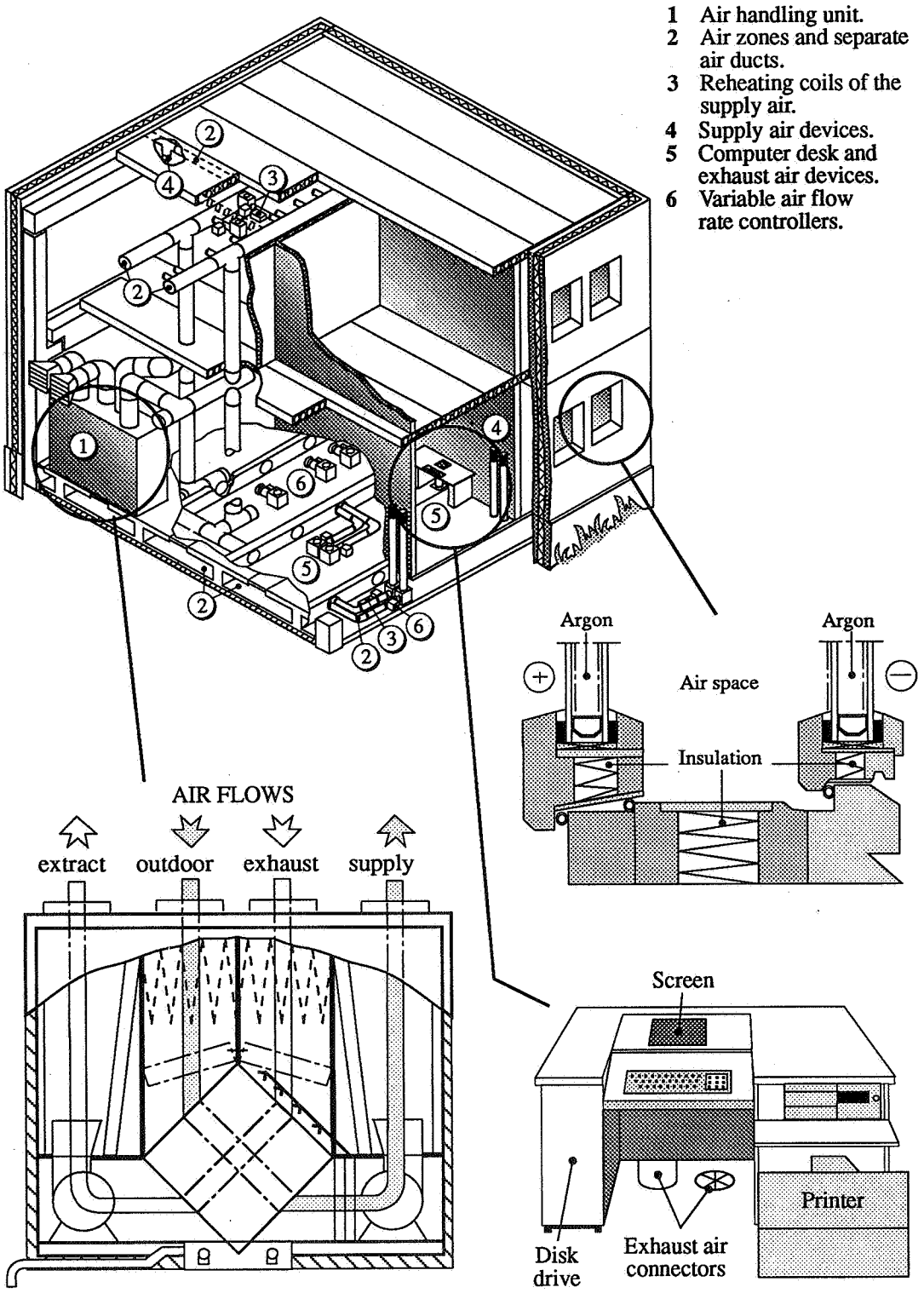


Figure 1. The industrial realization of the METOP low energy office prototype which utilizes the new Finnish component system building technology.

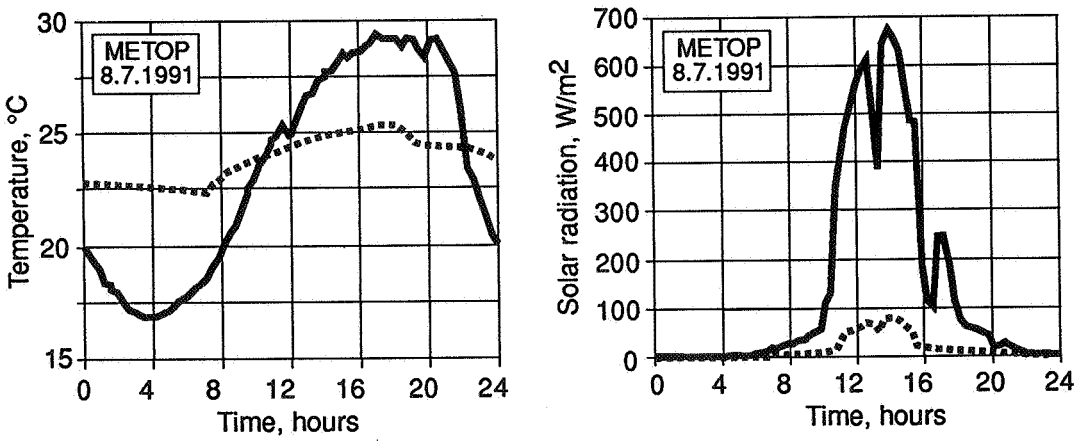
2. NEW WINDOWS PREVENT COLD AND OVERHEATING

In order to obtain a good indoor climate using a simple HVAC system, we must minimize the need for heating and cooling by means of different constructions and control solutions. The windows have an important effect on the heating and cooling need of an office room.

Thanks to a new window solution (U-value 0.5 W/m^2K), it is possible to reduce the heat losses of the window to a quarter of that of a normal triple glazed window used in Finland. Even during hard frosts (outdoor air temperature -26 °C), the lighting alone can compensate the transmission heat losses of the office room (150 - 200 W). Window draughts are eliminated (indoor surface temperature above 17 °C). In addition, windows reduce the need for cooling extremely well. Only 12 % of the radiation energy of the sun comes through the window. The sun shield does not have any essential effect on the amount of the visible light coming through the window, or on the appearance of the window.

At the beginning of July 1991, there was a heat period of about a week (outdoor temperature 14 - 29 °C), and at the turn of July and August, there was another hot period of two weeks (outdoor temperature 15 - 27 °C).

At the end of the first heat period (Figure 2), the indoor temperatures in the late afternoon hours typically rose to 25 °C in the office room facing south, and at the end of the second period, it rose to 26 °C.



Air temperature measurements in summer heat.

Outdoor air temperature
Indoor air temperature

Solar radiation measurements in summer heat.

Radiation to the south window
Radiation through the south window

Figure 2. Measurements at summer peaks.

3. SPECIAL STRUCTURES PREVENT AND STORE COLD AND HEAT

The facing elements and double prestressed solid planks of concrete which are used as installation floors and ground slabs are heat insulated with 120 mm thick polyurethane without CFC. The building is founded on foundation elements of concrete. The frame construction is made of pillars and beams of concrete. Hollow core slabs of concrete function as intermediate floors and roofs. The roof is heat insulated with a 350 mm thick layer of loose-fill insulation. The heat insulations of the office are slightly above the requirements of the National Building Code of Finland.

The hollow spaces of the double prestressed solid planks and the hollow core slabs are partly used as installation spaces for building services and as air ducts. When functioning as air ducts, the structures form a short-term storage area for heating and cooling energy which is used by the HVAC system in heating and cooling situations. In winter, the frame structure can be heated with the air handling unit for night, and in summer, it can be cooled in the nighttime with cool outdoor air for daytime cooling.

4. INDIVIDUAL TEMPERATURE AND VENTILATION

The low energy office needs cooling almost continuously also during the winter because of internal heat loads (people, lighting, different machines and devices). There is a small need for heating only during the coldest but short periods in the nighttime and during the weekends.

The outdoor air flow rate of the office room (10 - 40 dm^3/s) corresponds to the ventilation in winter, and it is also essentially smaller than in spring, summer or autumn when the excess heat can be removed from the building using outdoor air but without refrigerators using CFC.

The demand-controlled variable air flow HVAC system of the low energy office offers the possibility to choose the level of the room temperature and ventilation separately room by room.

The room air terminal devices, which control the indoor climate individually are equipped with reheating coils and a programmable DDC. The room air terminal devices have been preadjusted at the factory so that the air flows automatically adjust themselves to the right level. There is no need for expensive adjusting operations at the construction site.

The computers of the office room are placed in the computer desk. The computer desk is connected to the HVAC system through the exhaust air terminal device. Temperatures measured inside the computer desk on a typical winter day are shown in Figure 3. When the room requires heating, the heat from the computers automatically heats the room (time 8 - 10 in Figure 3). When the room needs to be cooled (time 10 - 16 in Figure 3), the computer desk automatically removes the heat given off by the computers from the building by means of the exhaust air. Heat recovery is applied to preheat the supply air when the outdoor air is cold. Over 60 % of computer's heat load is removed by means of the computer desk. The task of the computer desk is to function both as a heating and a cooling device either by utilizing or preventing the heat loads according to the circumstances.

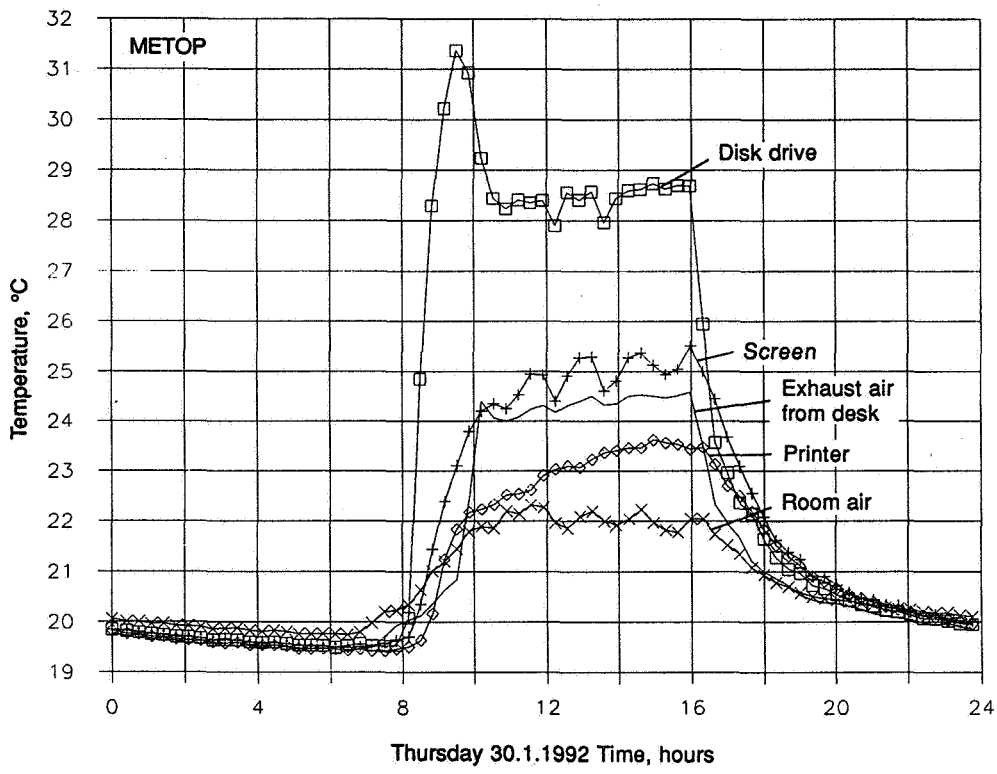


Figure 3. Computer desk temperatures measured in winter.

The HVAC system with a programmable DDC controls the air filtering, the cold and heat recovery, heating, cooling with outdoor air, forced indirect evaporative cooling, pressures and ventilation of the low energy office according to the demands of each room. A communication bus is used between the controller of the room air terminal devices and the air handling unit. The HVAC system has been completed and tested at the factory, and it is ready to operate after pipe and electrical connections. There is no need for expensive adjusting and tuning operations at the construction site. Thanks to its neat appearance, the silent HVAC system does not require any separate machine room.

5. INTELLIGENT CABLING

All rooms of the low energy office have small electric centres of their own, which are equipped with their own power supply. The electric centres control the temperature, ventilation, lighting and energy efficiency individually in each room according to the specific demand so as to minimize the need for cooling. Low energy fluorescent lamps are used for lighting the office. The computer desk as well as direct and indirect lighting are used at the same time to facilitate ergonomical computer work.

6. CONCLUSIONS

6.1 Follow-up study

Two-year follow-up studies on the indoor climate, efficiency and energy consumption will enable us to find out how the new component system building technology has succeeded in realising an ecologically sound low energy office that provides a good indoor climate and low energy use - and which has the advantage of low total costs.

It was noticed during the first heat periods that the control program of the DDC of the air handling unit needed to be developed, and this is why it was impossible to take full advantage of the free cooling effect of the outdoor air. When the effect is fully used next summer, the indoor temperatures of the office rooms can be lowered even further from the present values, which are already quite good.

6.2 A good indoor climate thanks to new technical solutions

Thanks to the energy efficient windows, the thermal insulation of the building envelope, which is slightly above the present level, and the demand-controlled variable air flow HVAC system with heat recovery, the need for heating and cooling energy has been reduced to such a level that the low energy office can be cooled with outdoor air and forced indirect evaporation cooling. The building is kept warm with the support of its own operations almost throughout the year. It is possible to arrange a good individual indoor climate in this way without any purchased heating or cooling energy. In Finland's climatic conditions, a good indoor climate, good energy efficiency and sound ecological principles require the use of demand-controlled, variable outdoor air flows. At the same time, it will be possible to adjust the climatic conditions individually in each room of the office. It is also possible to rearrange the indoor climatic conditions if the structures or the use of the office building are changed.

TECHNICAL SOLUTIONS OF THE METOP-BUILDING

- **Energy economic windows and building envelope.**
- **Air tight structures.**
- **Use of the installation floor and hollow core slabs as installation spaces.**
- **Utilization of the structures as a short time storage of heating and cooling energy by means of an intelligent HVAC system.**
- **Utilization of the external and internal heat loads when heating is needed and their removal when cooling is needed thanks to an intelligent HVAC system and structures.**
- **A new kind of intelligence in the control strategy.**
- **The possibility to choose the quality of indoor climate individually in each room.**
- **Heat recovery in winter and cooling recovery in summer.**
- **Maximum efficiency of heat recovery with a new type of freeze protection.**
- **Heating with return air at night in winter if required.**
- **Cooling with outdoor air at night in summer when needed.**
- **Massive machine rooms for air handling units are unnecessary.**
- **No separate heating and cooling systems are needed.**

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FURTHER INFORMATION

EBES: The integrated HVAC, piping electrical and building system
TAT: Office and apartment buildings' product development
ETRR: Energy Efficient Buildings and Building Components
LVIS-2000: Future Building Services
RATA-2000: Construction Mode 2000.