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High Comfort to Reasonable Cost

B Barath

Ingenieürburo Barath & Wagner GmbH, Meerbusch, Germany

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B. Barath
Ing.-Büro Barath & Wagner GmbH
Meerbusch, Germany

SYNOPSIS

A new ventilation and cooling system called ÖKOMAIR has been developed and investigated. The main idea is to separate carrying off cooling loadsand providing fresh air to the occupants without mixing it with the return air. Return air is cooled by fan coil devices. The undiluted outside air is provided directly to the working zone and cooled by a cold water storage. This storage is charged by cool outside air during night. Use of the new system leads to high comfort for the occupants and reduces cooling energy. This advantages have been proved by measurements, CFD and building loads and energy analysis simulations.

1. INTRODUCTION

We are going to present a new ventilation system for office buildings. It is called ÖKOMAIR, as a derivation from the following three words:

ecological, economical and air.

The basic idea of the new system is to divide the office room in the sense of treatment of the air into two areas, as it is shown in figure 1.

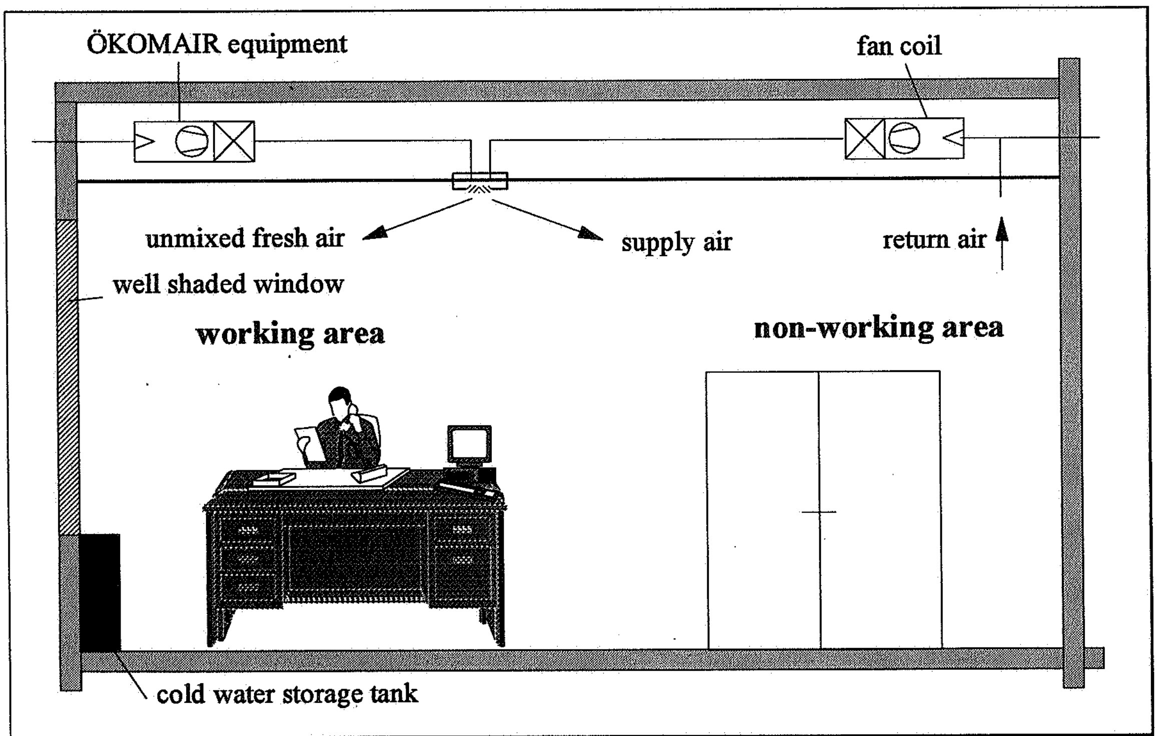


Figure 1: Sketch of the office room

The part, where the occupants most of the working time can be found, we call the working area, the other section we call the non-working area, where the occupants normally only walk through. Hence, we set two different comfort standards for the room air, higher demand in the working area, slightly lower in the non-working area.
Following the basic idea, we separate the outside (fresh) air, necessary for comfort demands of occupants, from the cooling function. Therefore, we've got two rather independent systems serving the office room.
Carrying off the cooling loads is managed by means of fan coil devices. Supply air is delivered in the non-working zone with a maximum temperature difference to the room air of 10K.
The working area is served by unmixed outside air to improve ventilation efficiency. To prevent additional heating by this outside air, it is cooled via a cold water storage if necessary. Due to storage restrictions we must allow an increase of room air temperature up to 28°C during late afternoon hours.
Cold water is charged by cold outside air during night hours. In addition,during night the outside air leaving the cooling coil enters the room cooling the ceiling, floor, walls and furniture as well.
To give proof of the efficiency of this system, we carried out full scale measurements in a modelled office room. Figure 2 shows the results of the measurements compared with an analogous simulation. During this test run storage based cooling was managed just from 3pm, when room temperature has been risen above 24°C.

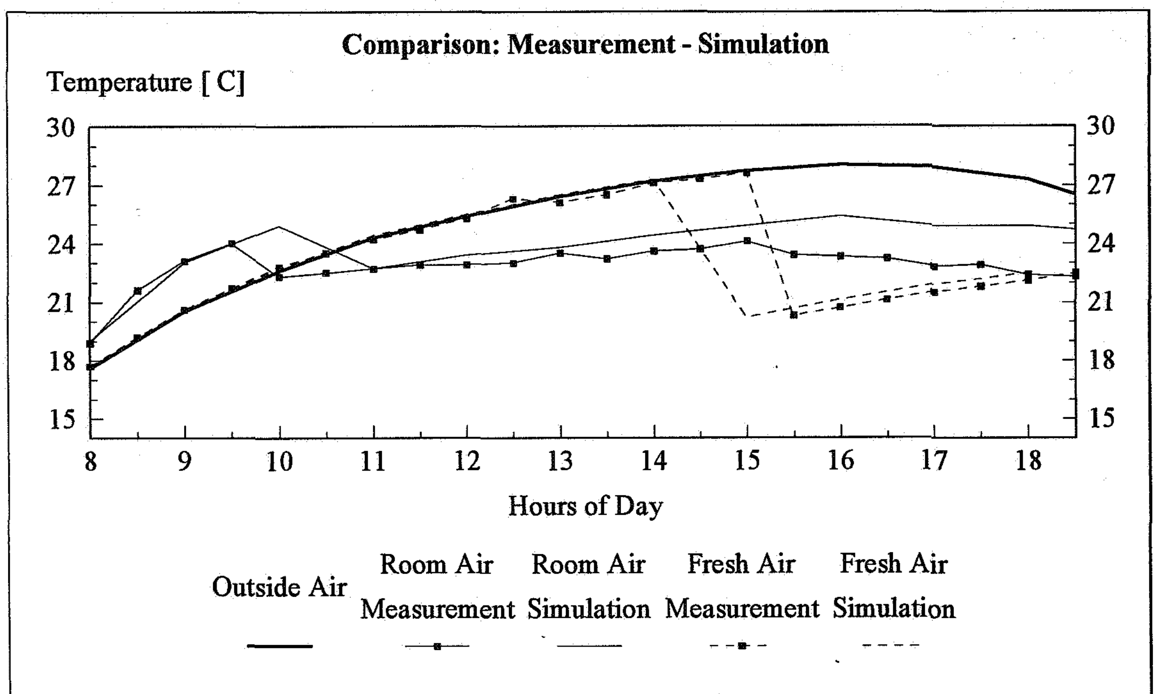


Figure 2: Measurement results compared with adequate simulation

2. BUILDING LOAD AND ENERGY ANALYSIS

According to the measurements we carried out a computer aided Building Load and Energy Analysis. The room and system data has been specified as follows:

- Day: Hot clear summer day (Maximum outside air temperature: 28°C)
- Room Area: $25m^2$, Room Volume: $68m^3$
- Installed Cooling Load: 1000W
- Outside Air Flow Rate: $125m^3/h$, Power Consumption: 65 W
- Return Air Flow Rate: 250 m^3/h, Power Consumption: 49 W
- Water Flow Rate: 150 l/h, Power Consumption: 21W
- Cold Water Storage Capacity: 250 l

We simulated one night charging the cold water storage and one working day with full cooling load. The aim of this simulation was to validate experimental results and investigate the behaviour of the cold water storage and development of room air temperature.

Figure 3 shows the charging process during night hours. Starting at 10pm with outside air temperature of 21°C and stopping 9 hours later with outside air temperature of 15.5°C the water has been cooled from about 24.5°C down to about 18.5°C .

Figure 4 shows the effect of providing unmixed outside air cooling by means of the cold water storage. If the outside air temperature rises above a room air temperature of 24°C (after 10am) the cooling via cold water storage will be activated. Thus, a temperature difference between room and outside air of about 3K can be achieved and room temperature in the working zone slightly increases to 27.5°C at 6pm.

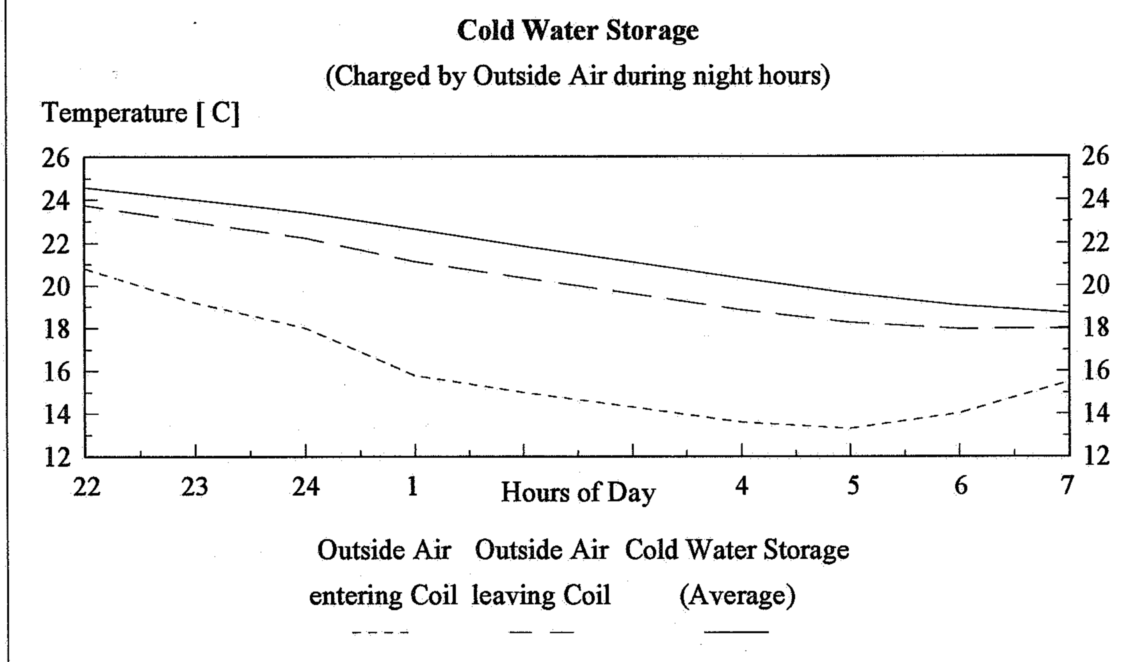


Figure 3: Charging cold water storage during night hours

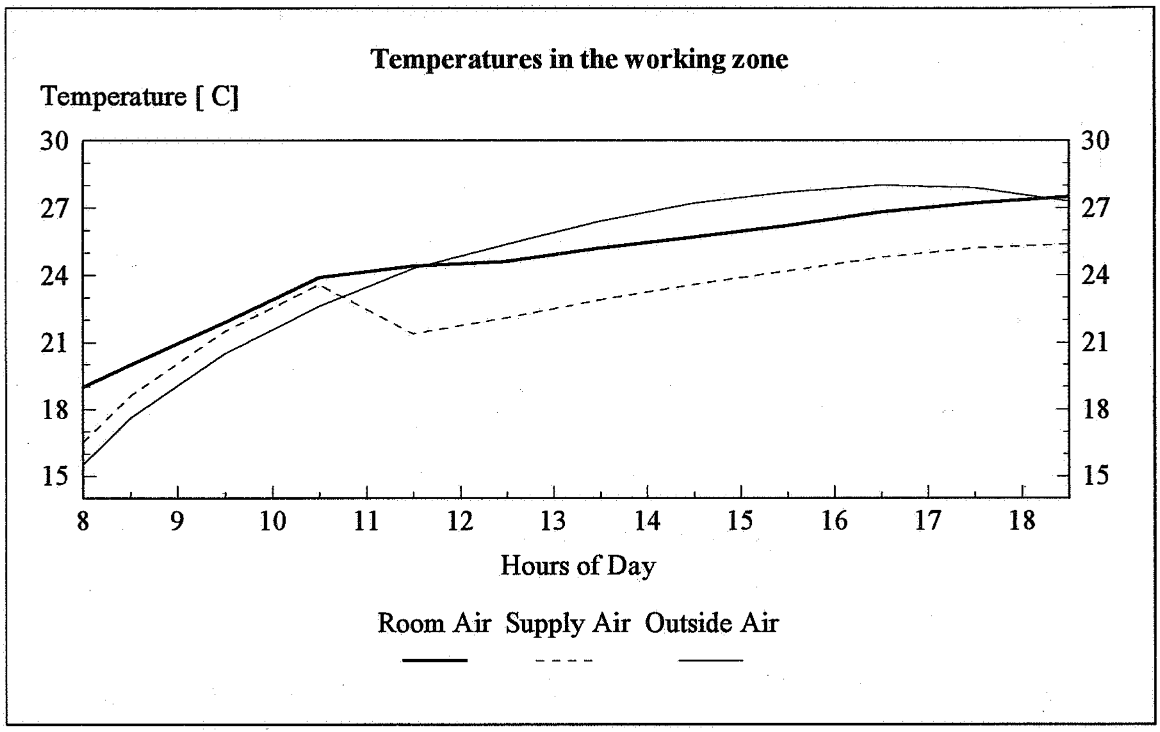


Figure 4: Development of room air temperature in the working zone

3. COMPARISON OF DIFFERENT HVAC-SYSTEMS

The major advantage of the new system is saving cooling energy. To give proof of this statement we carried out comparative investigations of different, widely used HVAC-systems. Besides our systems we simulated a variable air volume system and a two-pipe fan coil system, both serving the same office room, as specified above. These common systems need much more cooling energy for cooling necessary outside air.
A minimum supply air temperature for all systems of 15°C has been defined.
Figure 5 shows hourly room cooling loads and cooling rates of all systems. As it is seen, a small portion of cooling is also achieved by serving the working zone with unmixed outside air in the ÖKOMAIR-system. From high noon to end of working time cooling rates of common systems exceeds room cooling loads due to additional cooling of warm outside air. During first 3 working hours the variable air volume system can serve with outside air only, but it must cooled down to 15°C, what seems to be an disadvantage.
Finally, figure 6 shows the summary of energy consumed by all systems, cooling and electrical energy, respectively. Using ÖKOMAIR-system we must pay saving cooling energy with consuming additional electrical energy due to night storage charging. Taking into account the advantages in improving room air comfort for occupants a major saving of energy costs can be achieved.
Figure 7 shows the investment costs for all system in comparison.

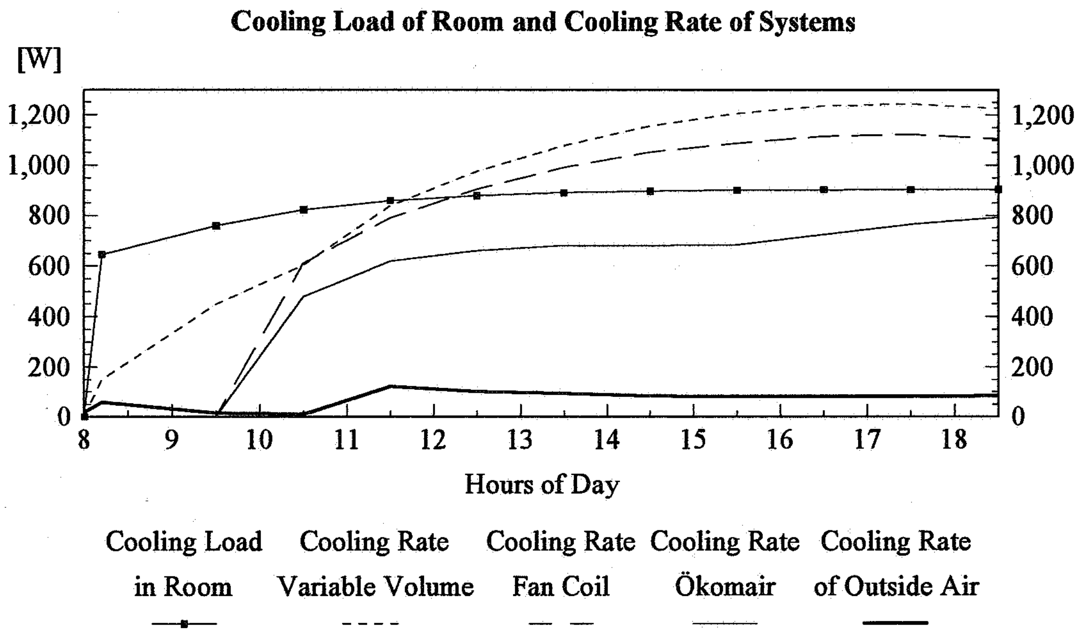
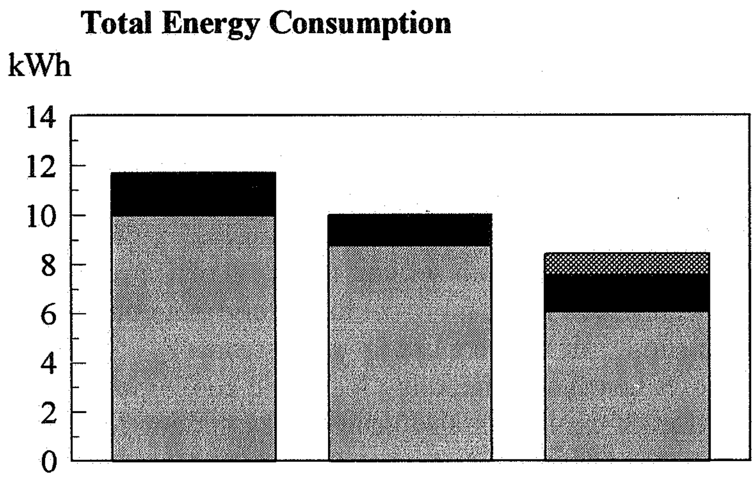


Figure 5: Cooling load of room and cooling rates of investigated systems



	Variable Volume	Fan Coil	Ökomair
Cooling Energy (Day)	10.0	8.8	6.1
Electrical Energy (Day)	1.7	1.2	1.5
Electrical Energy (Night)			0.9
Total Energy	11.7	10.0	8.4

Figure 6: Total energy consumption of investigated systems

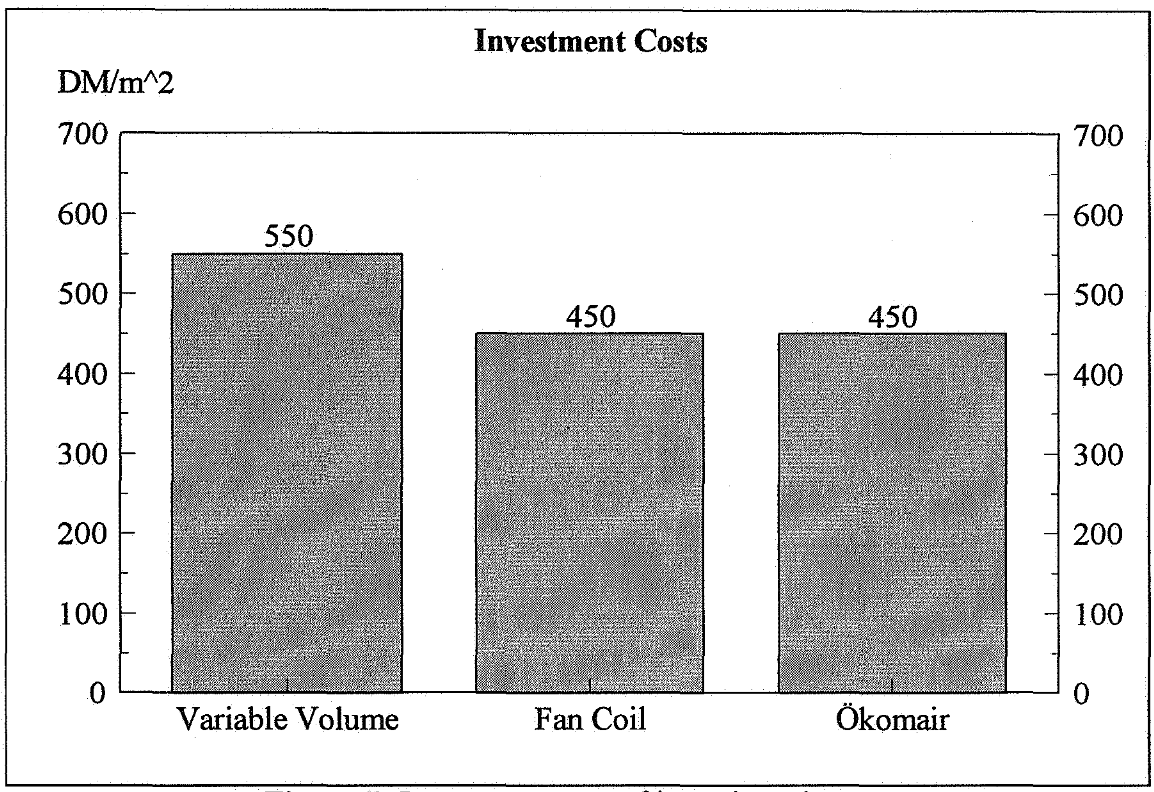


Figure 7: Investment costs of investigated systems

4. INVESTIGATION OF COMFORT AND VENTILATION EFFICIENCY USING COMPUTATIONAL FLUID DYNAMICS

Besides saving cooling energy the new systems takes advantage from improving air quality in the working zone and preventing draft risk due to small temperature differences between room and supplied outside air and small air flow rates. These effects have been studied by measurements and numerical fluid flow calculations.

Figures 8 and 9 show results of the CFD simulations.

Due to authors restrictions only black and white velocity contours are included, coloured plots will be shown at poster presentation.

The velocity plots show room air movements at two selected planes of the three-dimensional computation domain. The junction of these two planes represents the place where the occupant can be found.

Thus, one easily can determine room air speed at occupants level and affects on comfort and draft risk. The figures show low velocity magnitudes near the occupants. In the non-working zone much higher air velocities appear, but without major influence on occupants well-being.

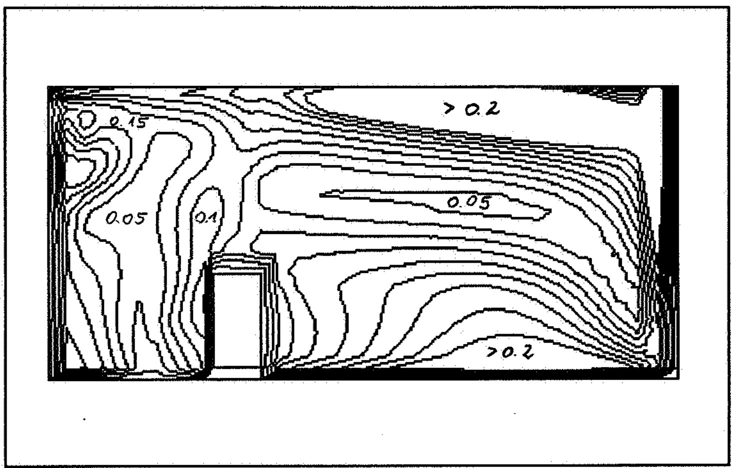


Figure 8: Contours of velocity magnitudes from 0 to 0.2m/s (front view)

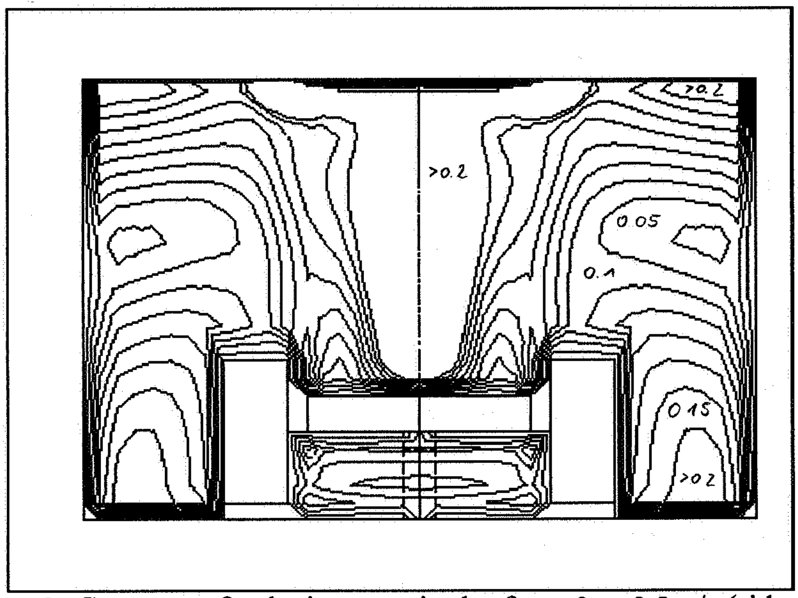


Figure 9: Contours of velocity magnitudes from 0 to 0.2m/s (side view)

ACKNOWLEDGEMENTS

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