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Full Scale Modelling of Indoor Air Flows

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Synopsis

As a result of the "Sick Building Syndrome" (SBS) the confidence of operators of office buildings into HVAC technologies has suffered a considerable drop. One of the most urgent questions before reconstructing or renovating old office buildings is, therefore, whether the air conditioning system to be installed will lead to increasing complaints on behalf of the occupants and how to prevent them. As for indoor air flows, one possibility is given by full scale model experiments leading to results which are very much like the future effective values.

The poster presents the modelling of indoor air flows in an office room. The model chamber, and the monitoring of the measurements are explained. The measured parameters are temperature and air velocity during an extremely hot summer day and an extremely cold winter day, respectively. All measurements were carried out under almost real conditions, i.e. the model chamber was equipped with office furniture and thermal loads were introduced into the room.

An additional advantage of this kind of experiments is that operators, architects, designers, work committee members etc. can have a look at the office rooms in the planning stage so that possible changes can easily be decided and carried out.

1 Introduction

During the last 20 years ventilation systems, mainly air conditioning systems, have gained more and more importance for large buildings. In many branches of production the use of an air conditioning system is vitally necessary, because it has very often a substantial influence on the quality of products. But the air conditioning of office buildings is also important. Correctly air conditioned working areas arrange thermal comfort and can increase the productivity at the place of work and also prevent absence by illness.

In line with increasing numbers of air conditioned buildings the complaints of the building owners and the employees have also increased. The complaints were mainly related to: low or high indoor temperature, low or high humidity, draughts, unpleasant noise level and high ernergy costs. Above all mistakes are made again and again with the air distribution in the rooms. But especialy the air distribution in the room decides about the physiological feeling of the people and the energy consumption of the air conditoning system.

The so-called "Sick Building Syndrome" describes how feel increasing disturbed people by wrong air conditioned rooms.

To avoid mistakes it is useful to make investigations about the air conditioning system in combination with the geometry of the rooms in an early planning stage. The losses by possible bad investment through wrong choice of the air conditioning system and high absenteeism are so big that such investigations are often profitable.

2 Experimental arrangement

The Institute of Applied Thermodynamics and Air Conditioning, University of Essen, possesses a laboratory with a test room to investigate the indoor air flows. In this test room all modes of operation can be simulated on the scale of 1:1. It is possible to investigate different air distribution systems and the figures 1 to 4 show schematicly most of the systems used in practice.

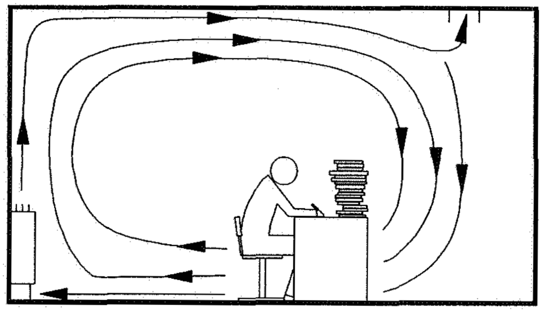

Fig. 1: Air distribution by tangential air circulation (Induction unit)

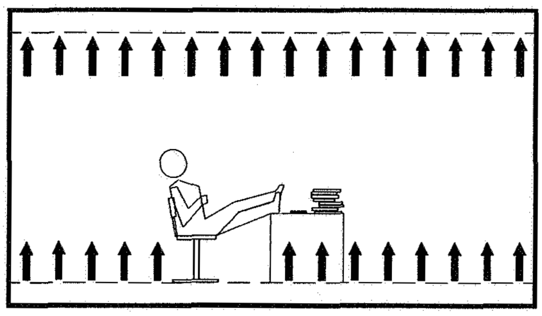

Fig. 3: Displacement flow by air circulation from buttom to top

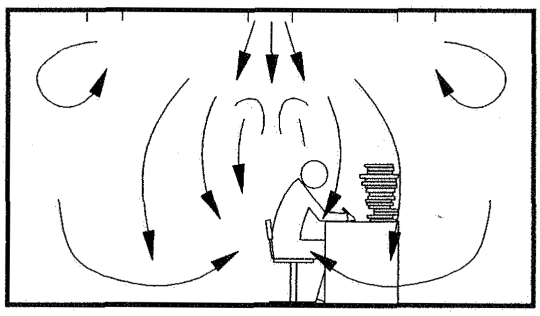

Fig. 2: Air distribution by diffused air circulation

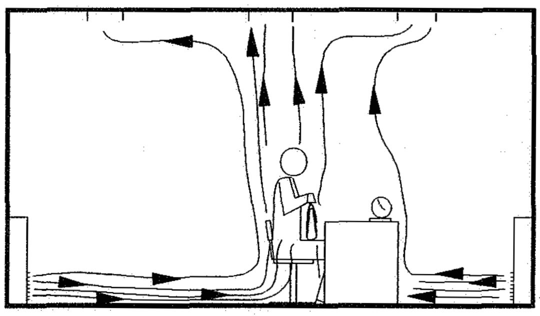

Fig. 4: Displacement flow by displacement ventilation

The test room which is described in the next chapter is equipped with induction units placed under the windows and a specific room ceiling. The room is a replica of a real office in a building which e.g. is to be renovated, and the investigation is made by using the original office furniture.

2.1 Test room

The test room is equipped with four walls, a floor, and a ceiling to avoid disturbing influence from the laboratory. Figure 5 shows the test room with its dimensions in the side view. Two of the walls are painted black and a $0.5 \cdot 0.5$ m grid is stuck on them with a white adhesive tape to get a better contrast when visualizing the flow by smoke.

One of the walls is built true to scale of the original building facade. The window legde is in its geometry and its heat transfer attitude the same as in the original building. The overall coefficient of the heat transfer of the windows in the test room corresponds to the original windows. The front wall (Fig. 6) is made of glass to have a control of the measurements and the experiments with smoke during a special operating condition.

The floor consists of a thick layer of bottom plates and it is built on stilts. The complete test room with exception of the parapet is surrounded by constant air conditions, so that there is no influence of the walls or the floor of the laboratory.

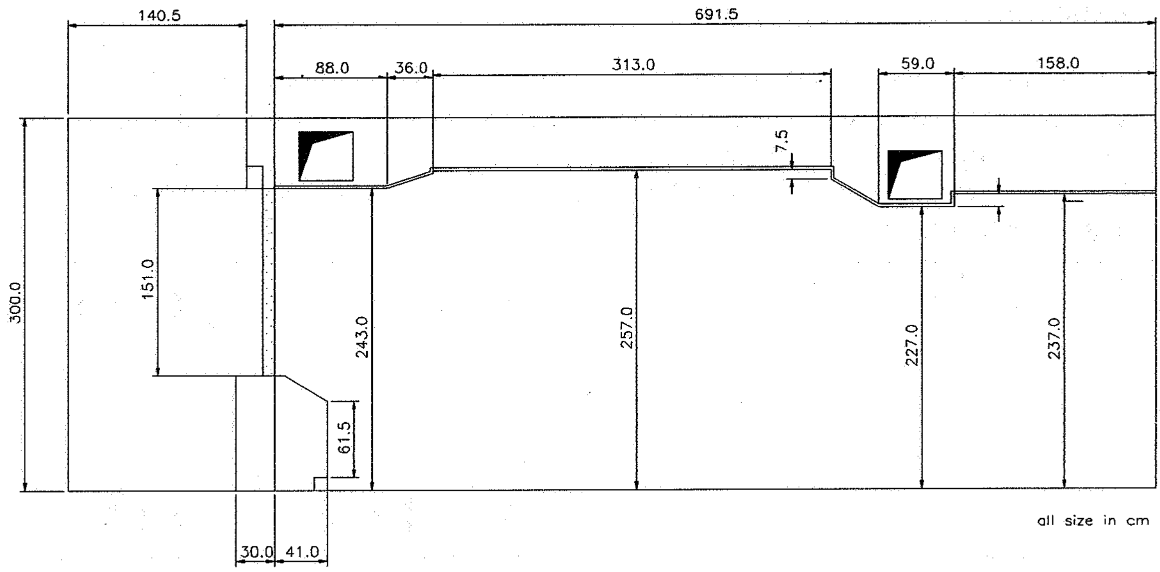

Figure 5: Side view of the test room

2.2 Climatic chamber

The climatic chamber is situated on the window legde of the test room (Fig. 6). The chamber is well insulated to the laboratoy and it is possible to adjust different weather conditions.

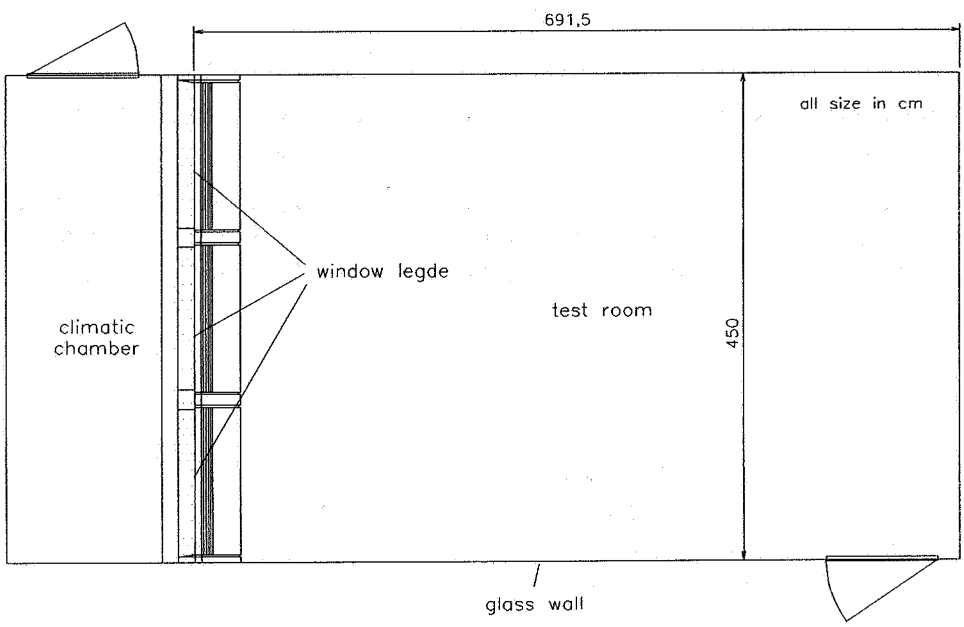

Figure 6: Setup of the test room and the climate chamber

By a refrigerating machine it is possible to get winter conditions with temperatures of -15°C and with a heater fan we get summer conditions (+32°C) in the climate chamber. This range of temperature corresponds to the German standard DIN 4701 (Rules for the calculation of the heat requirement of buildings) and VDI 2078 (Calculation of the cooling load of air conditioned rooms).

3 Measuring device

For the evaluation of the indoor air climate referring to the thermal comfort the following quantities are primarily important and have therefore to be measured in the test room and the climate chamber:

- •Flow of the cold water
- •Flow of the warm water
- •Supply air flow
- •Extract air flow
- •Supply nozzle presurre (Induction unit)
- •Temperature of the cold and warm water supply
- •Temperature of the cold and warm water return
- •Supply air temperature
- •Extract air temperature
- •Surface temperature of the windowpane and windowframe
- •Indoor air temperatures
- •Temperatures in the climate chamber
- •Air velocities in the test room

3.1 Equipment

Figure 7 gives a schematic survey of the fundamental setup of the measuring device. To connect peripheral instruments like a sensor with a computer an additional circuit, a so-called interface, is nessesary. They adapt the computer and peripherial instruments.

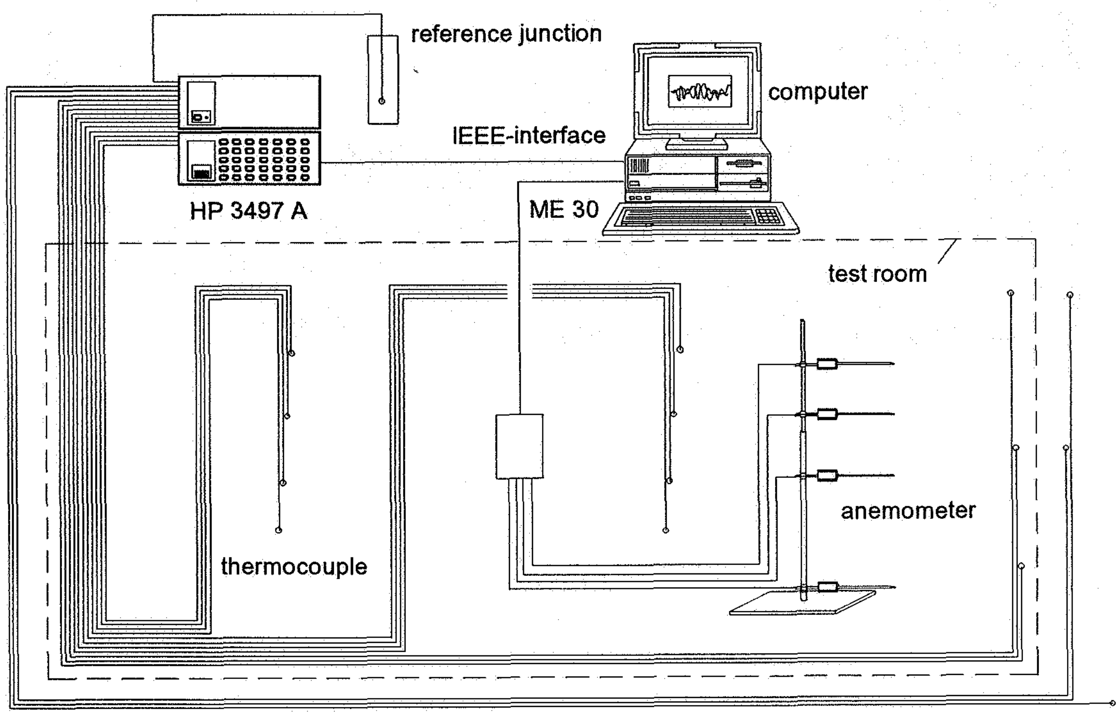

Figure 7: Setup of the measuring device

The measuring device needs a lot of single instruments and interfaces. The following instruments are used by the measurement of the air flow in the test room:

- One AT-80286-12 MHz Computer with 1 MByte RAM, MS-Dos 5.0 operating system and 40 MByte hard disk
- One high resolution monitor with VGA-graphic-card

- One Hewlett Packard HP 3497 A Scanner
- One IEEE-488 interface
- One Meilhaus ME30 multifunction-card

3.2 Control of the measurements

Before the actual measurement can be started the conditions must be constant. Therefore a permanent control of the temperatures is very important. Figure 8 shows the monitor display during the contol measurement.

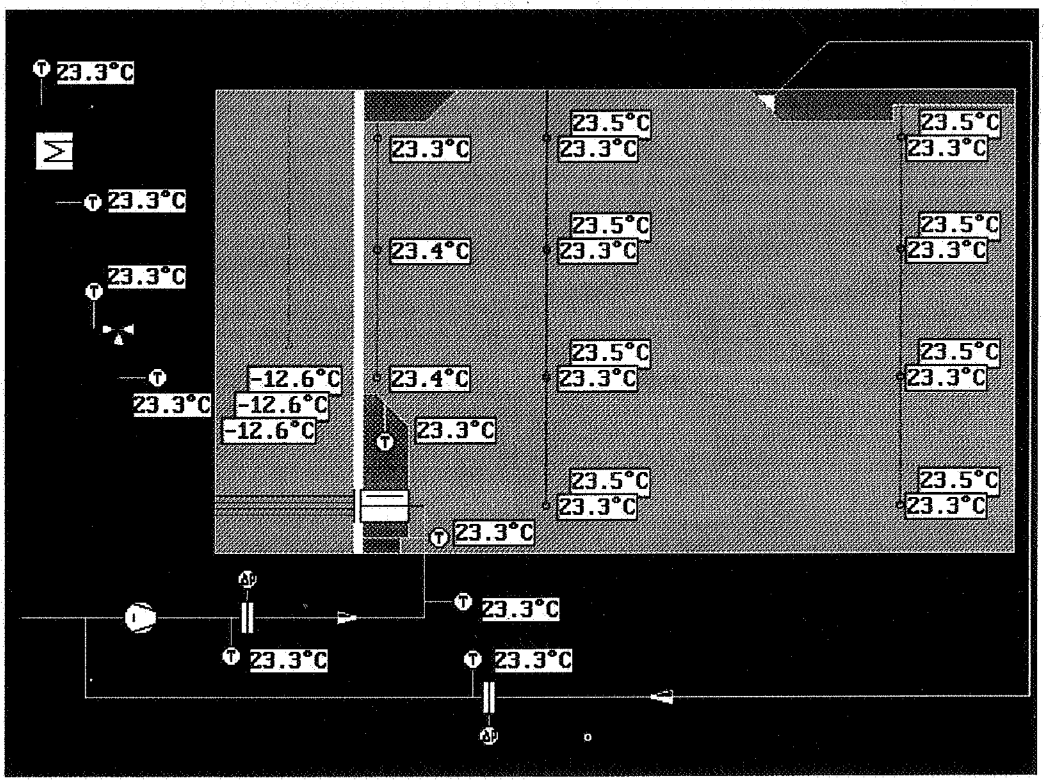

Figure 8: Control-graphic of the testing plant

The graphic shows the test room and the climate chamber and also water and air supply for the induction units. All temperatures are indicated in the graphic at those places where they are measured the temperature in the testing plant. If there is a defect or an error in the test plant, it is shown directly on the screen and can be repaired adequatly. The vertical line in the test room and the climate chamber represents the thermocouples hanging from the ceiling. The temperatures which are very close together on the screen are in the test plant next to each other. If the conditions are constant the investigation of the air flow in the test room can be started.

The air velocity is measured by thermal anemometers and every measured value is shown on the computer screen (Fig. 9). The velocity-graphic is permanently updated. All measuring points of one anemometer are connected by a line and indicated with the same colour, so that it is easy to differentiate the four anemometers. The real air velocity is not represented in this picture. If the maximum of the shown measuring time in the picture is reached (30 seconds in Fig. 9), the graphic and the time axis will be updated.

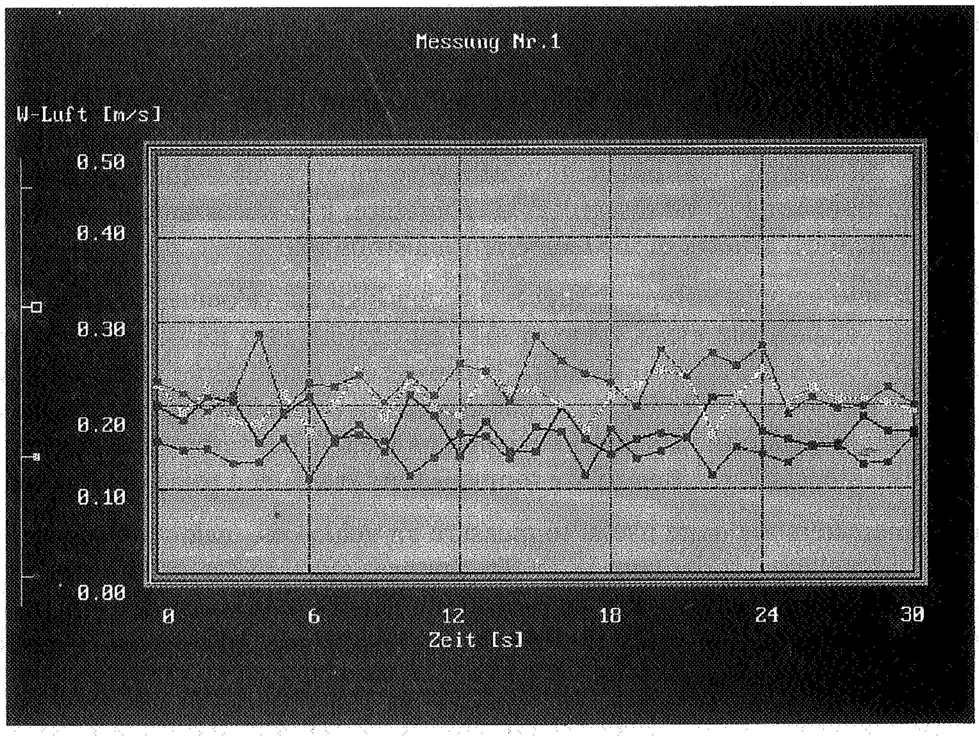

Figure 9: Graphic during the measurement of the air velocity

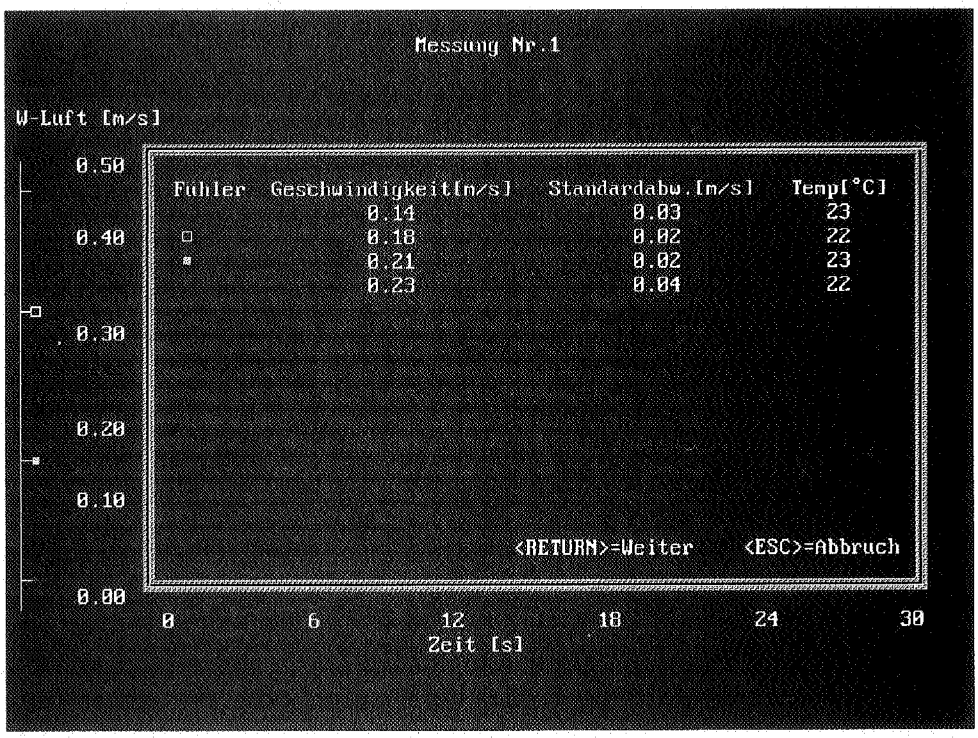

Figure 10: Graphic after finishing the measurement of air velocity

If the measurement of the air velocity is finished, the graphic will be replaced by the table of the results (Fig.10). In this table the following results are shown:

- Air velocity : The arithmetic average of the velocity over the measuring time
- The standard deviation : The standard deviation of the velocity
- Temperature : The arithmetic average of the temperature

4 Test methods

One of the most important criteria with thermal comfort is the room air temperature, its distribution and its occurence. Strongly varying temperatures quickly cause discomfort. In the same way an uneven local distribution of the room air temperature, such as a zone of cold air above floor level is felt disagreeable. Therefore, it is necessary to monitor both the temporal and the local aspects of the temperature distribution.

Very often people complain about draughts, i.e. too high air velocities at often too low air temperatures. Not only the mean value of the velocity but also its variation is of decisive importance in view of the thermal comfort, because even at the same mean value of the air velocity highly turbulent air flows are felt disagreeable. To monitor the mean value of the air velocities and to evaluate the standard deviation as well as the turbulance degree, both the temporal and the local distribution of the room air flow rates need to be determined.

Thermal anemometers are quite useful to measure air velocities, mainly at low air flow rate, and to monitor velocity variations. With the thermal anemometer used here both the air velocity and the air temperature can be measured. Thanks to a computer integrated multi-function-card (analog/digital-card) the measured results are transferred directly to the computer for quick processing.

Velocity and temperature measurements are always executed at the same locations, i.e. at the air outlet of the grille, above floor level as well as below the ceiling and mainly in the breathing area. A brief description of the testing method is given to show the connection between the monitoring programme and the examination of the room air flows.

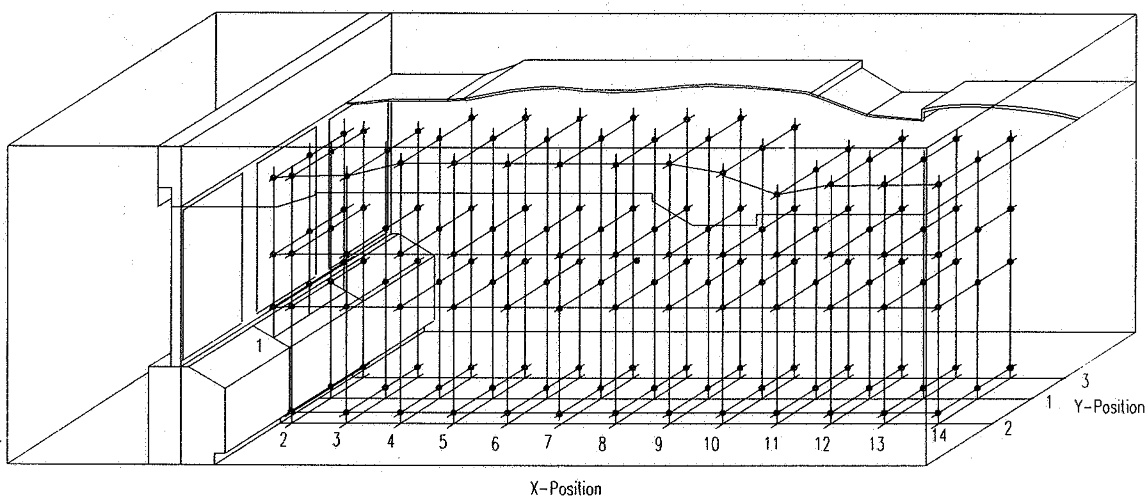

Figure 11: Arrangement of the air velocity meterring points in the test room.

To evaluate the room air flows the room was divided into a three-dimensional grid (Fig. 11). The measurements were executed along three room axes: the center line and two parallel axis at 0.5 m each on the left and on the right from the centre line. Each of these axes is divided into 14 metering points, with the first metering point above the blower aperture of the induction units and the second located at the end of the induction unit cover and with the others following at a distance of 0.5 m each.

At each metering point (with the exception of point 1 of each axis) the air velocity and the air temperature was measured at four different heights.

- 0.1 m (above the floor level)
- 1.1 m (upper part of the body when sitting)
- 1.65 m (upper part of the body when standing) and
- 0.1 m (below the ceiling)

It was the aim of each measurement to determine a velocity profile at each metering point at a certain operating state. For this reason the anemometers had to be transported to the next metering point after each measurement. To do this, however, it was necessary to open the test room. Disturbances going hand in hand with the required opening could hardly be avoided.

The following conditions need to be fulfilled for the series of measurements to be valid:

- The running state must remain stable over a long period of time
- All other parameters (such as the arrangement and kind of the furniture) of the series of measurements must not be changed.
- After changing the metering point a short break has to be kept to allow the flow conditions to be soothed and the disturbances (human body as a heat source, air turbulence due to movements, etc.) to be levelled.

Several measurement series at different operating states and with different furniture arrangements were executed. Moreover, the temperature was measured at four different heights at each velocity metering point and at five other metering points in order to detect possible cold air zones or temperature layers.

5 Summary

With the the test room it ispossible to make different full scale investigations. Following a few advantages of this test plant are presented:

- Quick and relatively simple changes of the room geometry and the equipment (e.g. ceiling, walls, furniture, etc.)
- Investigation of the indoor air flow under different outdoor air conditions (climatic chamber)
- Investigation of the influence of the furniture of the indorr air flow
- Investigation of original facade including windows (e.g. condensation, heat losses, etc.)
- Examination of the thermal comfort with respect to temperature and air velocity

An additional advantage of this kind of experiments is that operators, architects, designers, work committee members etc. can have a look at the office rooms in the planning stage so that possible changes can easily be decided and carried out. It is also possible to use the measurement results from the test room for the examination of the data from computer fluid dynamic programs (CFD).