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INSTITUTTET FOR BYGNINGSTEKNIK

INSTITUTE OF BUILDING TECHNOLOGY AND STRUCTURAL ENGINEERING

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International Energy Agency, Energy Conservation in Buildings and Community Systems, Annex 20: Air Flow Pattern within Buildings

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SELECTION OF AIR TERMINAL DEVICE

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RESEARCH ITEM NO. 1.2 "SELECTION OF AIR TERMINAL DEVICE"

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INTRODUCTION

This paper discusses the selection of the air terminal device for the experiments and numerical prediction in the International Energy Agency Annex 20 work: Air Flow Pattern within Buildings, subtask 1 (see appendix A for objectives and methods of this initial work).

SELECTION OF AIR TERMINAL DEVICE

It is important that the diffuser is able to generate a flow which is typical of modern design and it is also important that the individual diffusers in different countries are identical.

A diffuser of the HESCO-type is selected. The diffuser can be adjusted to a flow which has a complicated three-dimensional structure close to the opening with a high entrainment of room air. This flow pattern is very typical of modern air terminal device design. It is further possible to adjust the diffuser to other and less complicated flows close to the opening. This may be important if the universality of a given computer model is to be tested.

The design of the HESCO diffuser implies that the individual diffusers will be fairly identical.

The diffuser consists of 4 rows with 21 nozzles which can be adjusted to different directions, see figure 1. (The diffuser is identified by HESCO by the following type number KS4W205K370).

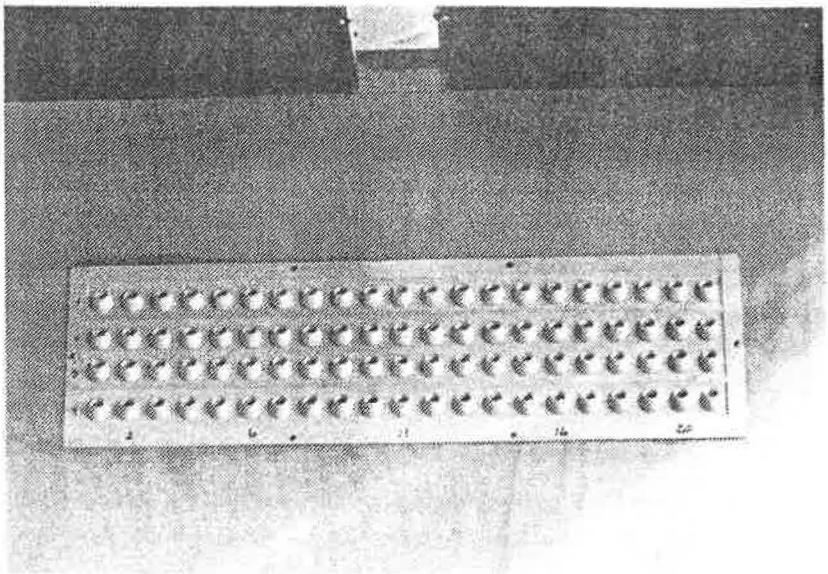

Figure 1. Air terminal device mounted in the end wall of the test room.

The diffuser is mounted in the centre line of one of the smaller walls in the test room and the inner upper surface of the diffuser is located 0.2 m from the ceiling, see refs. [1] and [2]. The velocity distribution in the connection (150 mm) to the supply box had to be fairly even.

All the nozzles are adjusted to an angle of $\varphi = 40^{\circ}$ in upward direction (φ is the angle between the nozzle symmetry line and the horizontal line) and they are all parallel without any adjustment in horizontal direction. It is important to make an exact adjustment of the nozzles and it will therefore be appropriate to make a tool as the one shown in figure 2 for this adjustment.

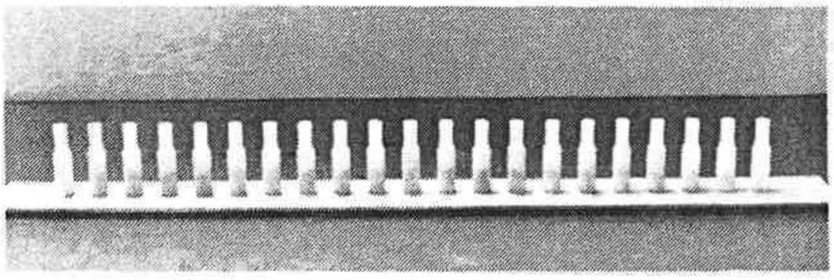

Figure 2. Tool for adjusting 21 nozzles to the same angle.

DIFFUSER FLOW MEASUREMENTS

The participants can incorporate the boundary conditions around the air terminal device in their own way in the computer code, see appendix A. Participants with facilities for both measurements and predictions can therefore make any necessary measurements for the evaluation of a "supply opening description".

It is necessary to make measurements which give a general description of the flow in front of the diffuser. Those measurements can be used as boundary conditions for the numerical prediction according to methods shown e.g. in [3], [4] and [5]. It is also necessary to make some wall jet measurements which are important for the "simplified models", see [6], and these measurements can also be used to compare the diffusers and the measuring equipments in the different countries, see appendix A.

WALL JET MEASUREMENTS

The flow under the ceiling will be a combination of a three-dimensional wall jet and a radial wall jet dependent on the nozzle angle φ. Beltaos shows that an oblique impinging jet generates a wall jet with different velocity decay in different directions θ as shown i figure 3 and reference [7].

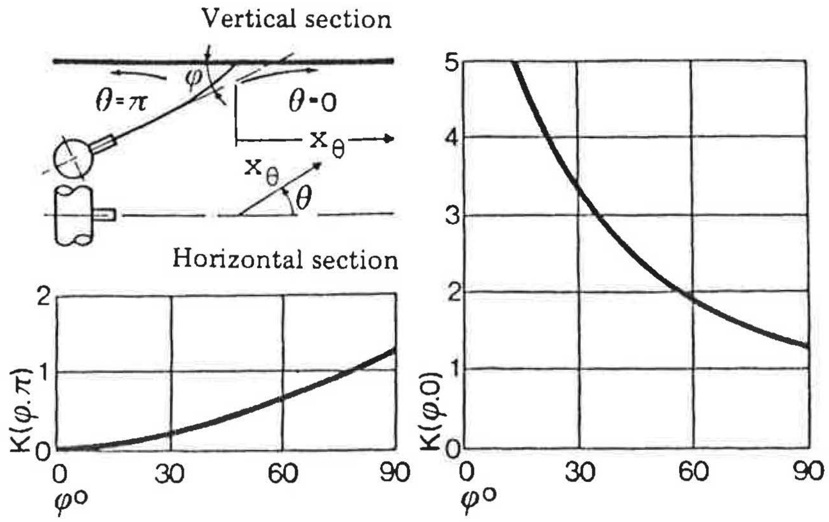

Figure 3. Oblique impinging jet. K(φ,θ) is the coefficient in equation (1).

The velocity decay in the wall jet under the ceiling is given by the following equation

$$\frac{u_\theta}{u_o} = K(\varphi,\theta)\,\frac{\sqrt{a_o}}{x_\theta} \qquad (1)$$

where x_θ is the radial distance and u_o, u_θ and a_o are the supply velocity, the maximum velocity at the distance x_θ and the supply area, respectively.

The flow from the HESCO diffuser with $\varphi = 40^o$ will show a flow of similar type, but we may also expect differences because the supply geometry is different and because the end wall and the side walls will restrict the flow compared to the situation described in figure 3.

The participants could, as a minimum, measure the wall jet along the ceiling in the direction $\theta = 0^o$ which is the longitudinal direction of the room and the location of the x-axis. (The y-direction is vertical and the z-direction is the horizontal direction parallel to the end wall). Further directions could be selected as $\theta = 20^o$ and $\theta = 30^o$, but we could also assume the jet to be a three-dimensional wall jet and then measure the growth rate and the velocity distribution at different distances x. Three-dimensional wall jets (slender and bluff wall jets) are described and discussed in [8] and [9].

A first step in wall jet measurements is the calculation of the supply area a_o. Supply velocities are measured at different locations in front of the diffuser. It is necessary to define the locations for a given diffuser and figure 4 shows the locations suggested for the HESCO diffuser.

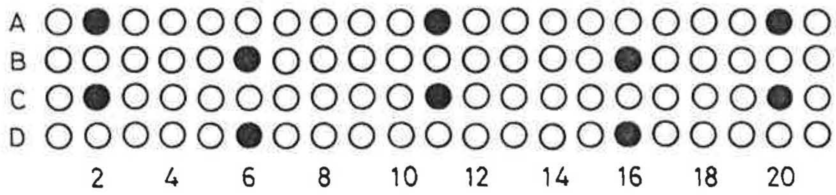

Figure 4. Location of 10 measuring points for measurement of the mean supply velocity.

The supply area is calculated from the following equation

$$a_o = \frac{q_o}{u_o} \tag{2}$$

where q_o is the supply flow. The difference between the geometrical area and the area a_o is small in this case. It is generally important to choose measuring points with high supply velocity to obtain a characteristic expression for the momentum flow at the inlet.

The velocity profile close to the ceiling is measured at different distances x from the end wall. (It must be realized that the maximum velocity u_x may be found outside the vertical symmetry plane of the room). The width δ of the wall jet is defined as the distance from the ceiling to a location in the wall jet where the velocity is $u_x/2$, see figure 5.

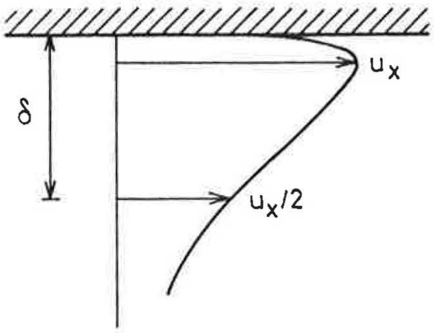

Figure 5. Universal wall jet profile.

The width δ is proportional to the distance $x + x_o$ from a virtual origin, see [8].

$$\delta = D_a(x + x_o) \quad (3)$$

D_a is the growth rate. D_a and x_o are given from the measurements of δ as a function of the distance x as shown in figure 6.

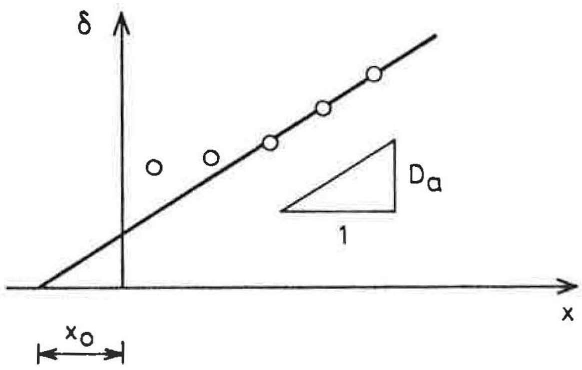

Figure 6. Wall jet width δ versus the distance x.

The velocity decay for a three-dimensional wall jet (and a radial wall jet) is given by the following equation

$$\frac{u_x}{u_o} = K_a \frac{\sqrt{a_o}}{x + x_o} \quad (4)$$

It is convenient to show the measured values of u_x/u_o as functions of $(x + x_o)/\sqrt{a_o}$ in a double logarithmic coordinate system because equation (4) will be a straight line with the slope -1, see figure 7.

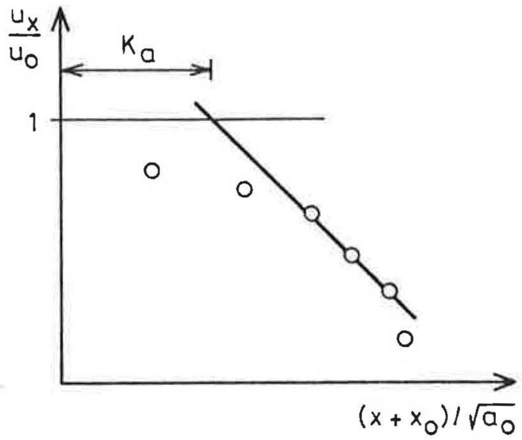

Figure 7. The velocity decay u_x/u_o versus the distance $(x + x_o)/\sqrt{a_o}$ in a double logaritmic coordinate system.

The temperature distribution in a thermal wall jet is given by

$$\frac{T_x - T_R}{T_o - T_R} = K_{aT} \frac{\sqrt{a_o}}{x + x_o} \qquad (5)$$

where T_x, T_o and T_R are the wall jet extreme temperature at the distance x, the supply temperature and the ambient temperature, respectively. K_{aT} is a new constant for the wall jet and the diffuser.

It is possible to express the velocity distribution perpendicular to the main direction in the same way as in a bluff wall jet when φ is small.

$$\delta_z = D_{a,z}(x + x_{o,z}) \quad (6)$$

δ_z is the width of the jet in the z-direction.

Large values of φ give a radial wall jet below the ceiling, and it will perhaps be more convenient to measure the velocity decay u_x/u_o in more directions θ.

All the equations (1) to (6) are based on a fully turbulent flow which is independent of the Reynolds number [8]. The flow may in practice be dependent on the Reynolds number Re, given by

$$Re = \frac{u_o\sqrt{a_o}}{\nu} \quad (7)$$

where ν is the kinematic viscosity. All the parameters a_o, D_a, x_o, K_a, K_{aT}, $D_{a,z}$ and $x_{o,z}$ for the wall jet will therefore have to be measured at different supply velocities and taken as functions of the Reynolds number, see references [10] and [11].

PRELIMINARY EXPERIMENTS WITH THE HESCO-DIFFUSER

Some measurements on the HESCO-diffuser show that the supply area a_o is a weak function of the Reynolds number and a mean value of a_o = 0.009 m² is found. The number of measured profiles is not sufficient to settle the distance x_o and x_o = 0.0 m is used in the following measurements.

Figure 8 shows the level of the K_a-factor. The results in figure 8 are based only on a few measured wall jet profiles and therefore preliminary.

Figure 9 shows the velocity distribution 0.5 cm below the ceiling along the semi-circle with a radius R of 1 m. The profile is slightly asymmetric and dependent on the Reynolds number.

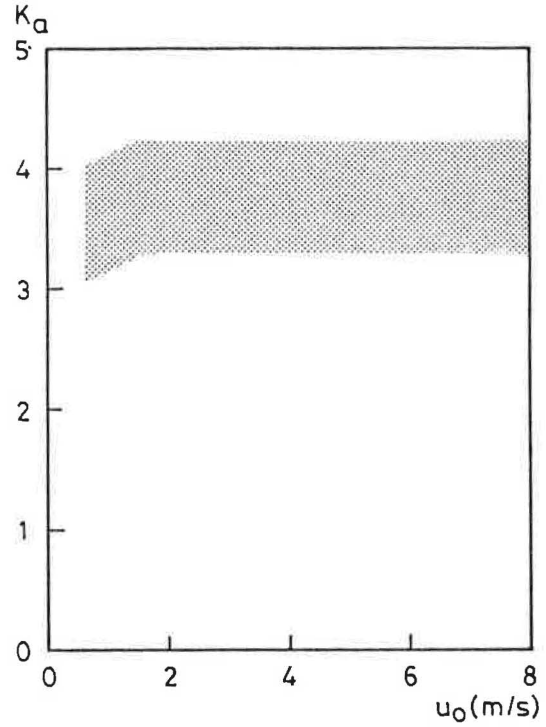

Figure 8. K_a-factor versus supply velocity u_o for isothermal flow. x_o = 0.0, [12].

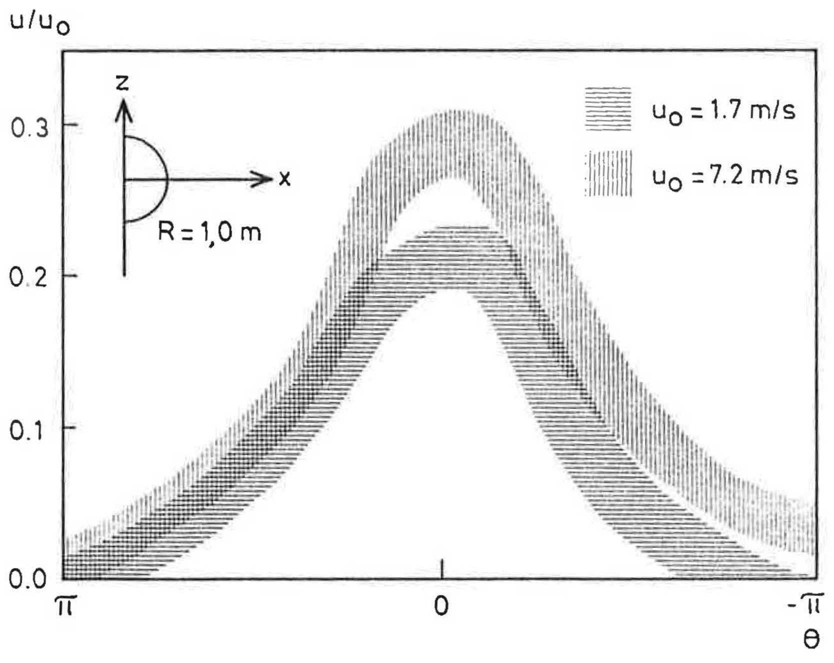

Figure 9. Velocity distribution below the ceiling in a semi-circle around the impingment area, [12].

MEASUREMENT OF THE FLOW FIELD IN THE TEST ROOM

It is too early to determine the measuring points in the test room, but the participants should as a minimum make the necessary measurements for the "simplified models" as described in [6], as well as the measurements for comparisons with the numerical predictions.

Figure 10 shows an example of measurements of the velocity u_r in the return flow in the occupied zone as a function of the supply velocity u_o. The measuring points are located at (x,y,z) = (4.2, 2.3, 0.0) m in a test room of the dimensions L, H. W equal to 5.4, 2.4, 3.6 m. The flow is isothermal and it shows some low turbulence effect. Measurements of this type should especially be made for the maximum velocity in the occupied zone u_{rm}.

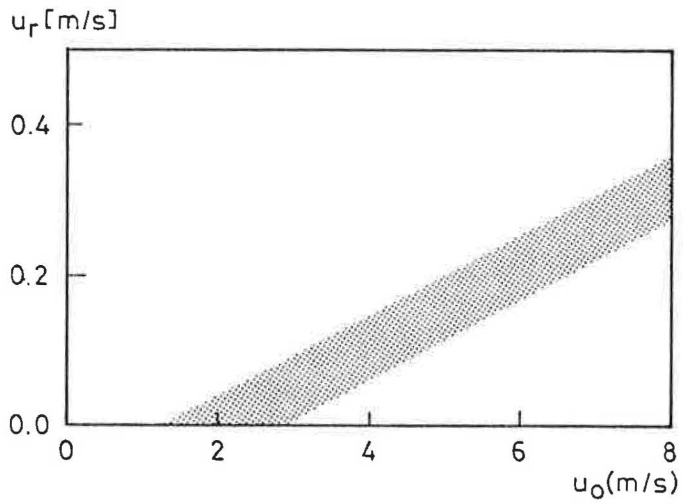

Figure 10. The velocity u_r measured 0.1 m above the floor versus the supply velocity u_o, [12].

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APPENDIX A

Air Flow Patterns within Buildings 1

1.2 May 18. 88

Selection of air terminal device

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Preparation proposed

6/88 10/88

All the participants shall use the same air terminal device in their test room. The participants can incorporate the boundary conditions around the air terminal device in their own way in the computer codes.

- We will get comparisons of measurements in the jet (and in the rest of the room in some cases)
- we will see the influence of different ways of incorporating the supply opening
- We will see the influence of different computer codes

Ask a company to supply a typical but rather new supply opening. Get the individual supply openings tested (by the company) so we know that they are identical in performance.

Install the openings in the test rooms according to instructions. Make the necessary measurements for boundary conditions in the different computer codes (P. V. Nielsen will write an instruction on necessary measurements)

Here we will learn something about the individual differences in a product also.

Input from
Output to

* Selection of supply opening
* Test of the individual openings of same type
* Instructions on necessary measurements Oct. 15, 88