#6006

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Experimental and Numerical Investigations within a Post-Annex-20-Model

B. Hanel, E. Richter, P. Vogel

Technische Universität Dresden, Institut für Strömungsmechanik, Lehrgebiet Thermofluiddynamik, Mommsenstr.13, O-8027 Dresden, Germany

1. Introduction and aims

A small test room has been build which is five times smaller than the so called Annex-20- room (Figure 1 and 4). Different kinds of tracers have been used for visualizing of flow patterns (/1/). Velocities, concentrations and mass transfer coefficients have been measured. The measuring instrumentation is based on thermal anemometry (hot wire probes) and a special ammonia-mass transfer method, respectively, in order to estimate the heat flux coefficient at the walls. The values measured and the flow patterns have been applied in order to compare and to evaluate a computer code developed in Dresden to simulate three dimensional flows. This code is based on a finite-volume-discritization for the transport equations (Navier-Stokes- with k-ε-model) solved with a new iteration technique including a multi grid solver.

2. Measuring Equipment

A test room was constructed at a scale of 1:5 to the test room (/2/,/3/), specified by the international project IEA ANNEX 20 (/4/,/5/). A lot of measuring and computational results are available for this problem. The dimensions of our test room are (L x W x H)=(0,84m x 0,6m x 0,5m). The inlet device has a width of 0,155m and a height of 0,042m. The dimensions of the outlet device are (w x h)=(0,06m x 0,039m). The walls are transparent to make flow visualization possible. At present a maximum velocity of 2m/s can be applied due to the installed equipment. That leads to a Reynolds number relating to the inlet of Re=5500 and an air change rate of n=186 1/h. The flow within the test room is isothermal and visualized by means of several kinds of tracers (e.g. so-called 'disco fog', incense, glycerine-water mixture). A system consisting of light sheet equipment and a CCD camera is applied to get a snapshot of the flow pattern in a specified plane. Averaged velocities and turbulent quantities are measured by means of hot wire anemometry (DANTEC 55M). A unit made by construction elements (ISEL automation) is used to move the probe to the measuring position controlled by the computer. Placing the probe at 100 locations takes about 15 minutes including 2s integration time at every measuring point. It is taken approximately 2000 values for time averaging for each measuring point. Figure 2 shows the special calibration equipment (/5/) used to calibrate the probe right beside the test room within a range of 0,1 to 2,0 m/s.

As mentioned above, heat transfer coefficients are determined by means of the ammonia transfer method (/7/) using the analogy between heat and mass transfer and a computer aided image processing system (Figure 3, /8/). Small quantities of ammonia are added to the supplied air. That causes a chemical reaction at foils moistened with a reaction substance. The colouring of this foils indicates the intensity of the mass transfer. Using the analogy between heat and mass transfer the heat transfer coefficients can be calculated by

$$\alpha = \frac{\beta_{NH_3} \cdot \lambda}{D_{NH_3-L}} \cdot \left(\frac{Pr}{Sc} \right)^n$$

3. Mathematical Model

As basic equations we consider the time averaged transport equations for an in-compressible fluid. By means of Boussinesq's concept, Boussinesq's approximation of buoyancy and a k-ε turbulence model, the following system of differential equations is formed by :

$$\frac{\partial \overline{U}_i}{\partial t} + \overline{U}_j \frac{\partial \overline{U}_i}{\partial x_j} - \frac{\partial}{\partial x_j}\left[\nu \left(\frac{\partial \overline{U}_i}{\partial x_j} + \frac{\partial \overline{U}_j}{\partial x_i} \right) \right] + \frac{1}{\rho} \frac{\partial \overline{p}}{\partial x_i} = \frac{\overline{f}_i}{\rho} - \frac{\partial \overline{u'_j u'_i}}{\partial x_j}$$

$$\frac{\partial \overline{U}_i}{\partial x_i} = 0$$

$$\frac{\partial \overline{T}}{\partial t} + \overline{U}_j \frac{\partial \overline{T}}{\partial x_j} - \frac{\partial}{\partial x_j}\left[a \frac{\partial \overline{T}}{\partial x_j} \right] = \overline{\dot{q}^V} - \frac{\partial \overline{u_j' T'}}{\partial x_j}$$

$$\frac{\partial k}{\partial t} + \overline{U}_j \frac{\partial k}{\partial x_j} - \frac{\partial}{\partial x_j}\left[\left(\nu + \frac{\nu_t}{Pr_k} \right) \frac{\partial k}{\partial x_j} \right] =$$

$$\nu_t \frac{\partial \overline{U}_i}{\partial x_j} \left(\frac{\partial \overline{U}_i}{\partial x_j} + \frac{\partial \overline{U}_j}{\partial x_i} \right) - \varepsilon + g_j \cdot \gamma \frac{\nu_t}{Pr_t} \frac{\partial \overline{T}}{x_j}$$

$$\frac{\partial \varepsilon}{\partial t} + \overline{U}_j \frac{\partial \varepsilon}{\partial x_j} - \frac{\partial}{\partial x_j}\left[\left(\nu + \frac{\nu_t}{Pr_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] = + C_1 \nu_t \frac{\varepsilon}{k} \frac{\partial \overline{U}_i}{\partial x_j}\left(\frac{\partial \overline{U}_i}{\partial x_j} + \frac{\partial \overline{U}_j}{\partial x_i}\right)$$

$$- C_2 \frac{\varepsilon^2}{k} + C_1 g_j \gamma \frac{\nu}{Pr_t} \frac{\partial \overline{T}}{\partial x_j}$$

with $\nu_t = C_D \cdot k^2/\varepsilon$ and $a_t = \nu_t / Pr_t$

In addition, appropriate initial and boundary conditions have to be specified. Details are given by Rösler (/9/). The set of constants of the turbulence model is shown in the table below.

C_D	C_1	C_2	Pr_t	Pr_ε	Pr_k
0,09	1,44	1,92	0,77	1,3	1,0

Instead of solving the fully discretized and linearized equation system we are using an explicit velocity-pressure iteration which is based on the algorithm of the Marker and Cell Method. Our strategy of solution will be presented in the paper /10/.

4.Results

Figure 5 shows the first of the experimental and numerical results of mean air velocities at a Reynolds number of Re=2238 and an air change rate of n=75 at the symmetry plane.
Experimental data have been averaged in time and space, given by

$$|\overline{u}| = \sqrt{\overline{u}^2 + \overline{v}^2} \; .$$

The numerically predicted velocity profiles are in a good agreement with the measured ones. Notice that the velocities are given as absolute values. Therefore the velocities close to outlet device have the same direction like the inlet device velocities. Furthermore, results like flow patterns, mass concentrations at the walls and therefrom heat flux coefficients and turbulent quantities will be shown at the poster because some pictures have a good quality only in the original state.

5. Conclusions

A 1:5 scaled test room was built to estimate and validate a simulation code of three-dimensional indoor air flows by experimental investigations. First results show that the constructed test room is suitable for this task.
Reynolds number, geometry of in- and outlet device, turbulence intensity and direction of supplied air will be varied in further experiments. An improvement of numerical results is expected by using a Low-Reynolds-Number turbulence model.
In addition, it is planned to compare these results with data available from others ANNEX20 participants (/3/).

6. Acknowledgement

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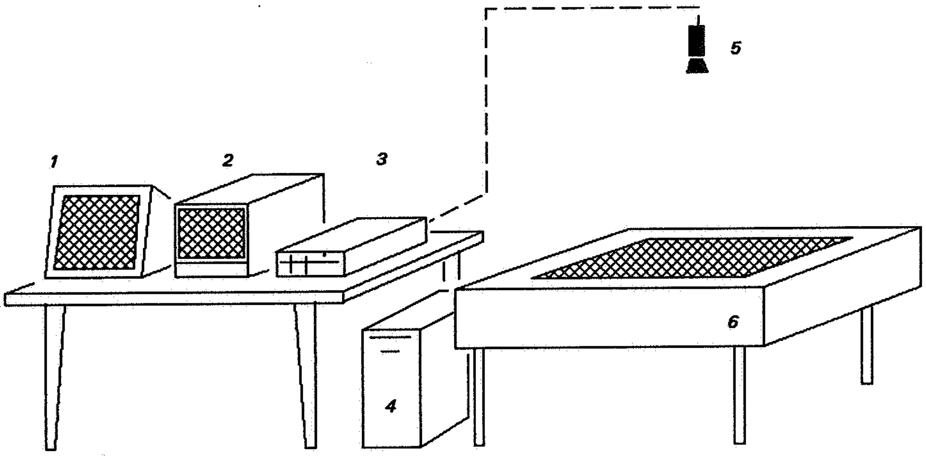
7. Photographs , graphs and diagrams

Photograph not available for Conference Proceedings.

Figure 1: The model "post-annex-20-room" with the moving system for the probes (author : P. Vogel)

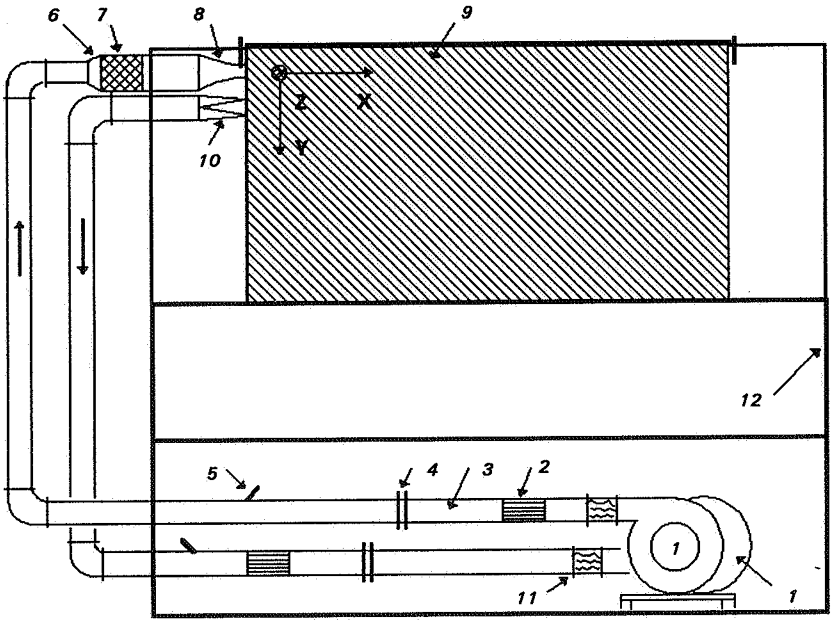
Photograph not available for Conference Proceedings.

Figure 2: The special calibration equipment which is used to calibrate the hot wire probes (author P. Vogel)



1 ... Computer monitor
2 ... Camera monitor
3 ... Control system
4 ... AT 486/33 with a grabber card AT-Chroma
5 ... CCD-camera FK 6512 IQ
6 ... Light table

Figure 3: Picture processing system IMPAC/PiPS



1 ... ventilator
2 ... rectifier
3,4 . air supply pipe with mass measuring equipment
5 ... temperature measuring point
6 ... transition piece
7 ... heat exchanger
8 ... air supply inlet
9 ... model room
10 ... outlet
11 ... vibration compensator
12 ... chassis

Figure 4: The model "post-annex-20-room"

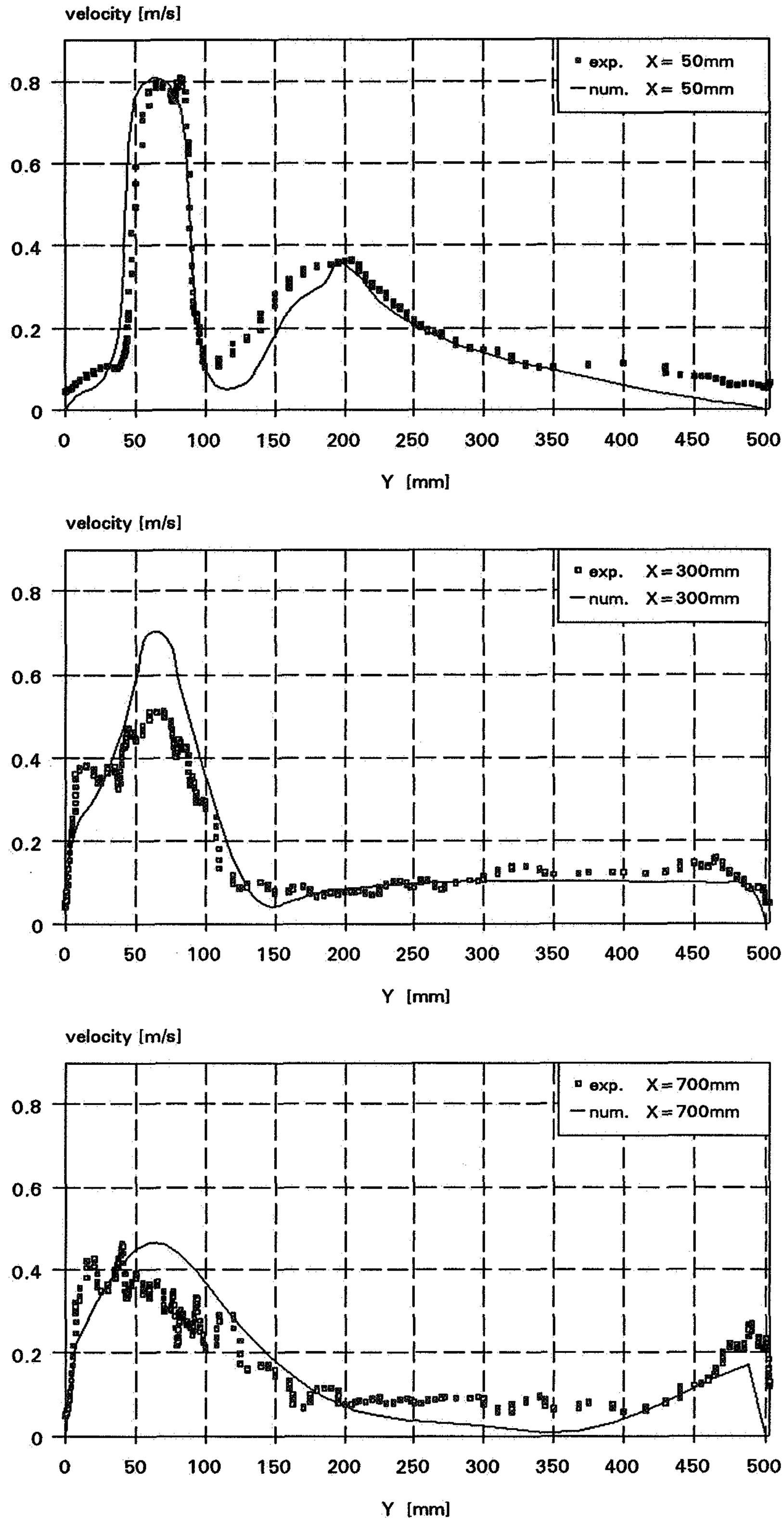


Figure 5: Comparison of experimental and numerical results of the absolute velocities at different Y-Z-planes in the symmetry plane

7. References

/1/ Leitl, B. :
"Erfahrungen bei der Nutzung verschiedener Raucherzeuger bei der Strömungsvisualisierung". Forschungsbericht,
Institut für Strömungsmechanik, Technische Universität Dresden, 1992

/2/ Vogel, P. :
"Entwurf eines Modells zur Messung von Raumluftströmungen". Diplomarbeit;
Institut für Strömungsmechanik, Technische Universität Dresden, 1992

/3/ Hanel, B. :
"Methoden zur Vorausbestimmung von Strömungsvorgängen in klimatisierten Räumen". Habilitation,
Technische Universität Dresden, Fakultät für Maschinenwesen, 1987

/4/ Whittle, G.E. :
"Evalution of Measured and Computed Test Case; Results from ANNEX 20, Subtask 1".
12th AIVC-Converence, Ottawa, 1991

/5/ Moser, A. :
"The Message of ANNEX 20 : Air Flow Pattern within Buildings".
12th AIVC-Converence, Ottawa, 1991

/6/ Heinrichs, P. and Rosenquist, M. O. :
"Vermessen eines Kalibrierungskanals für Hitzdrahtsonden".
Hermann-Föttinger-Institut, Berlin, 1987

/7/ Krückels, W. :
"Eine Methode zur photometrischen Bestimmung örtlicher Stoffübergangszahlen mit Hilfe chemischer Nachweisreaktionen". Dissertation,
Technische Hochschule Stuttgart, 1968

/8/ Richter, E. and Vogel, P. :
"Einsatz eines Bildverarbeitungssystems zur Auswertung von Meßfolien bei der Auswertung von Stoffübergangsmessungen". Institutsbericht, Institut für Strömungsmechanik, Technische Universität Dresden, 1991

/9/ Rösler, M. :
"Mathematisch-numerische Untersuchungen zur Berechnung von dreidimensionalen inkompressiblen Kanal- und Raumluftströmungen". Dissertation, Technische Universität Dresden, Fakultät Maschinenwesen, 1992

/10/ Rösler, M. and Hanel, B. :
"Numerical Computation of Flow and Heat Transfer in Air-Conditioned Rooms by a Special Velocity-Pressure Iteration and a Multigrid Method". Will by published in the Proceedings of the international-Conference "ROOMVENT '92" , Aalburg/Denmark, Sept. 2.-4. 1992