Proceedings of EUROMECH Colloquium 207 in Natural Convection, Delft, 7-9 April, 1986.

NUMERICAL SIMULATION OF AIR MOVEMENT AND TEMPERATURE FIELD IN A ROOM WITH COLD AND HOT WINDOW SURFACE

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INTRODUCTION The air velocity and temperature characteristics of rooms are important to the comfort and well being of occupants. Computations were carried out to predict air flows and heat transfer in a room with natural convection by applying the computer codes CHAMPION SGE and PHOENICS-81 (1),(2) & (3). The computational results of the temperature field and velocity field are compared with corresponding experiments.

COMPUTATIONS AND EXPERIMENTS The present calculations were obtained by solving elliptic, partial-differential equations with velocities and enthalpy as dependent variables. The model makes use of a two-equation ($k-\epsilon$) turbulence model (1). PHOENICS-81 solves three dimensional equations. The program CHAMPION SGE was developed from CHAMPION 2/E/FIX (4) by the authors and now is of the same structure as PHOENICS-81 except that it can handel only two-dimensional problems. Boundary conditions at solid surfaces are applied indirectly via wall-functions. The original wall function for enthalpy did not work very well in the situations here. The heat exchange coefficients are only of the order 0.01 W/m^2K when the distance of the first grid is 15 cm and 1-3 W/m^2K when the distance is 1 cm. After introducing a new wall function for enthalpy, the heat exchange coefficient is about 2-4 W/m^2K when the distance is 1 cm. The new one gave better results. The results presented here are calculated with original wall function in PHOENICS (2D & 3D) and the new one in CHAMPION.
The experiments were done in a full-scale climate room with a cold and a hot window surface. The temperature field was measured by means of thermo-couples with a data logging system and converted into printed results by a micro computer. The velocity field was observed by means of soap-bubbles.
Figs.1 to 4 give the velocity and temperature fields of experiments and computations with PHOENICS-81 and CHAMPION SGE in a room with hot window surface (26 °C). PHOENICS-81 was applied for 3D and 2D situations. In 3D simulation, the side walls were considered as fully insulated and in 2D simulation they were not simulated in the same way as for CHAMPION SGE. The calculations with 2D and 3D PHOENICS therefore should give the same results. The computed velocity fields are similar to the experiments. CHAMPION gives the most reliable results. PHOENICS gives too low velocities. While the too high velocities on the left upper corner are caused by mistakes in plotting program GRAFFIC (5). Fig.5 gives the temperature field. The average temperature of the computations is higher than measurements. The reason is that the heat exchange through the side wall is not calculated. The difference between 2D PHOENICS and CHAMPION

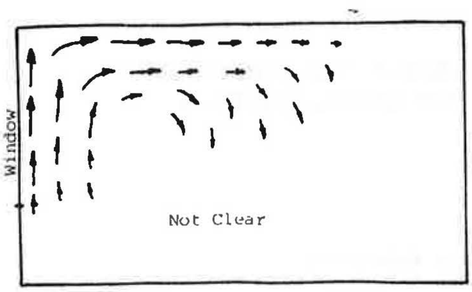

Fig.1 Velocity Field By Experiment

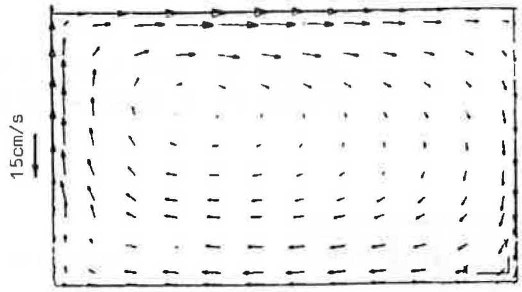

Fig.2 Velocity Field By CHAMPION SGE

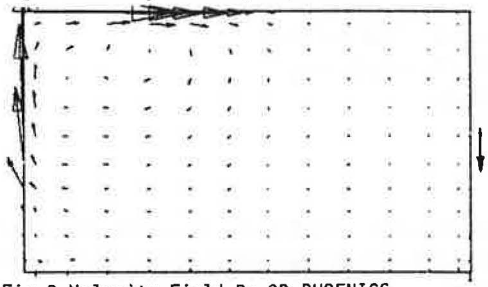

Fig.3 Velocity Field By 3D PHOENICS

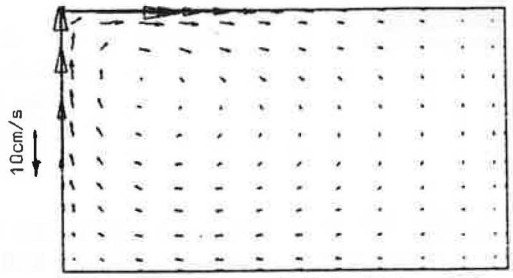

Fig.4 Velocity Field By 2D PHOENICS

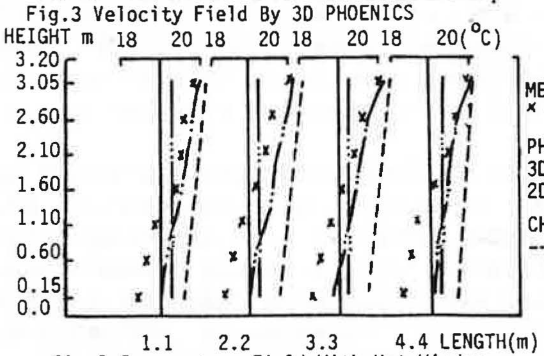

Fig.5 Temperature Field With Hot Window

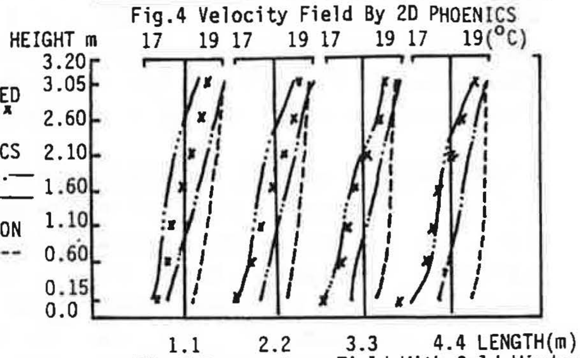

Fig.6 Temperature Field With Cold Window

could be caused by the different wall functions. 3D PHOENICS, which used the same boundary conditions and wall functions as 2D PHOENICS, gives an almost uniform temperature field. The reason can not be found because the program is only available in binary code.
For the situation with cold window surface (10 °C) similar results were got. The temperature fields are presented in Fig.6. Now 3D PHOENICS gives a better distribution but still different from 2D PHOENICS.
CHAMPION SGE which equips false time step converges 3-10 times faster than CHAMPION 2/E/FIX which equips only under relaxation factors.

CONCLUSIONS PHOENICS-81 gives strange temperature profiles in 3D simulation of natural convection with hot window surface. There are differences between 2D and 3D PHOENICS. The exchange through the side walls should be considered. The original wall-function for enthalpy built in PHOENICS can not give right heat exchange coefficients, the new one is better. False time step speeds convergence very much.

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