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# GENERAL FEATURE OF A TWO-DIMENSIONAL ISOTHERMAL MEAN FLOW INSIDE A VENTILATED ROOM WITH A WALL MOUNTED OBSTACLE

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## SYNOPSIS

This paper deals with the elaboration and the validation of a user-friendly numerical program (EOL) for the calculation of the ventilation patterns inside industrial premises. After the running-in. In period, "EOL" will be used by the technical staff in charge of ventilation projects.

Here is set out the EOL unit devoted to the calculation of the mean flow inside the rooms. The structure of the software (presently restricted to two-dimensional mean flow configurations) is explained.

The experimental validation of the software is performed through the use of a test configuration set inside an hydraulic bench. The measurements of the mean flow inside the plexiglass scale model are done by a Laser Doppler system.

For two characteristic profiles inside the measuring section, experimental and numerical results are compared. Very fine agreement is obtained. This result is quite encouraging for the development of the EOL programming operation.

## 1. MAIN PURPOSES

The building of a modern industrial premise requires today an outstanding ventilation system. The optimization of the ventilation patterns is necessary to improve the working conditions inside factories.

The purpose is to develop the preventive concepts for the ventilation technology. The work is to create an engineering tool useful for calculating the main ventilation patterns. This tool will be a programming model (EOL) specially designed to solve air quality problems inside industrial premises. The schedule of conditions includes :
The calculation of the mean flow inside the room (location and size of the recirculating vortices).
The calculation of the pollutant concentration map (when pollutant sources are introduced into the room).
The calculation of the ventilation efficiencies.

The study is divided into two different but complementary parts : the numerical work is to elaborate specialized programming units to calculate the various parameters of the ventilation. Units are based on a turbulent high Reynolds number (k-$\varepsilon$) model. At first, they are elaborated for calculating two-dimensional ("2D") mean flow layouts. The extension for "3D" configurations is under development at INRS. The experimental work consists of the validation of the programming units. It uses an hydraulic water bench inside which scale models of ventilated rooms are tested. The actual air flow through the room is replaced by a water flow. The circulation inside the scale model is carried out by regulated pumps. Of course, it is possible to simulate both "2D" or "3D" flows. The two experimental processings consist of the Laser Doppler Anemometer for the mean velocity measurements, and the video camera system (with specialized image processing) for the pollutant concentration map.

## 2. THE VENTILATION TEST MODEL

The scale model for the validation of the EOL software is a parallelepipedic plexiglass room [(X = 0 to 520 mm) x (Y = 0 to 280 mm) x (Z = 0 to 360 mm)].

The water circulation through this model is a steady flow with "3D" turbulence. The forced water ventilation flow is extracted from the model through a rectangular outlet window (2 mm x 360 mm) at the bottom of the left side of the model. The rectangular inlet window (10 mm x 360 mm) is located at the top of the right side of the model. The floor mounted obstacle is a square section crossbar (50 x 50 x 360 $mm^3$) supposed to simulate a desk inside a room or a machine tool inside an industrial premise. The model is built so that the vertical cross section (X x Y) is not dependent on Z.

The experimental and numerical simulations will concern the central vertical cross section of the model. In that section, the mean flow is supposed to be two-dimensional (geometrical symmetry). The measuring section is drawn in figure 1.

Considering the experiment, the mean Reynolds number (built with the inlet mean velocity U and the height H of the model) is 40 000. Considering the actual air flow, the corresponding parameters are :

$$U = 1.5 \text{ m/s and } H = 2.80 \text{ m}$$

## 3. STRUCTURE AND USE OF EOL

The three major features of EOL is that it is user-friendly, that it contains several tools to analyse the results with an hygienist point of view and that it is in the process of being validated for ventilation situation. Given a particular configuration, you easily enter its geometry and the associated boundary conditions. The program helps to find the appropriate grid, and then computes the flow[1]. Moreover, the possibility of computing local ages, local purging flow rates, time evolution of local concentrations after a sudden contaminant release, local or global concentrations or ventilation efficiencies, and so on is given. EOL is at present restricted to two-dimensional flows in cartesian coordinates but the cylindric and the three dimensional versions are under development[2/3].

The core of EOL is largely inspired by the works of the Imperial College Group[1]. It solves the mean transport equations for U-momentum, V-momentum, mass, turbulent energy and turbulent dissipation. The eddy viscosity is computed using a (k-ε) model[4]. The partial differential equations are transformed into finite differences equations in implicit and conservative form using the hybrid scheme. To satisfy continuity, the SIMPLE[5] algorithm is used.

The mean velocity computation unit of EOL has been used to calculate the mean flow for the considered configuration. The major assumptions for the calculation are : two-dimensional mean flow, steady flow and constant temperature.

The computed numerical mean velocity map is drawn in figure 2. The flow is mainly divided in two big recirculating vortices, separated by the wall obstacle. Let's also underline the importance of the horizontal inlet wall jet.

## 4. VELOCITY MEASUREMENTS

The velocity measurements inside the scale model are carried out by the DANTEC one-component Laser Doppler Anemometer (LDA). The LDA uses the Doppler shift of light scattered by the moving particles mixed with the flow to calculate their own velocity, and then find the flow velocity itself. The probe volume is the crossing of the two monochromatic coherent laser beams. The DANTEC system consists of the 55X backscatter modular optics and the 57 N 10 frequency analyser. The 55X can rotate to fix the direction of the measured mean velocity component and a Bragg cell is used to calculate the sign along that direction.

The direction of the laser beams going through the model can be either horizontal or vertical. The first position is used to measure the components $[\overline{U}, \overline{V}]$ of the mean velocity vector inside a vertical section. The vertical position is used to measure the two horizontal components $[\overline{U}, \overline{W}]$. The steady flow hypothesis makes possible to measure the three components $[\overline{U}, \overline{V}, \overline{W}]$ in sequence for every point inside the scale model.

The first experiment is the validation of the "2D" mean flow hypothesis inside the measuring section.

The measurements of the transversal velocity component [$\overline{W}$] give that this hypothesis is quite true in the first half-section (next to the inlet window). The results are not so sucessful in the second half-section (next to the outlet window). "3D" circulations do exist inside the experimental mean flow, particulary near the wall just behind the floor obstacle.

The second step is the measurement of the experimental mean velocity map [$\overline{U}$, $\overline{V}$ components] inside the test section.

The measurements, consisting of more than 200 points, are drawn in figure 2.

Special studies about the relative accuracy of the measurements have been performed. They basically consist of comparing several same experiments (repetition) and calculating the convergence of the statistical estimators [$\overline{U}(t)$, $\overline{V}(t)$]. The conclusion is that the relative accuracy for the $\overline{U}$ and $\overline{V}$ mean velocity components is generally better than 20 %.

## 5. EXPERIMENTAL VERSUS NUMERICAL RESULTS

For a better understanding of the problems, we have decided to select two characteristic velocity profiles for the comparison.

The profiles deal with the horizontal [$\overline{U}$] mean velocity component. Their location is drawn in figure 3.

The horizontal profile 1 describes the inlet wall jet and the base of the recirculating vortex behind the obstacle. It is exactly located 15 mm away from the wall. The comparison for the $\overline{U}$ velocity component is drawn in figure 4. Inside the wall jet, the major difference between experimental and numerical results is a 9 % overestimation for the experiments. Behind the obstacle, the maximum gap is a 25 % relative overestimation : this is quite important, but let's say that the $\overline{U}$ velocity is nearly zero in this area.

The second horizontal profile is located in the upper area of the measuring section (Y = 235 mm). It is used to describe the top of the two big recirculating vortices. The comparison for the $\overline{U}$ mean velocity is drawn in figure 5. We can see again that the experimental results are overestimated (20 à 25 %) compared with the numerical data.

Generally considering the two profiles, we must first admit that there are some differences between the experimental and the numerical results. Those relative differences are not so much important (10 to 20 %) and are often as high as the relative accuracy of the experimental method.

The very important point of the comparison is that the shape of the two profiles is exactly the same for the two methods.

## 6. CONCLUSION

The EOL software unit for calculating the ventilation flow inside premises has been tested through the use of a characteristic configuration,including a two dimensional mean flow.

The experimental point is to obtain a quasi two-dimensional mean flow in the central section of the scale model. This has been only partially achieved. Nevertheless, the comparisons between experimental and numerical results concerning two characteristic profiles are successful. It must be pointed out that the general shape of the profiles is exactly the same.

Similar results have been obtained concerning other profiles (not drawn in this paper). This example is quite encouraging for the future developments of the program : elaboration of advanced methods for the validation of the numerical software (measurement of the kinetic energy of the turbulence and the turbulent dissipation per unit of mass), study of a "3D" mean flow configuration simulating a living ventilation configuration.

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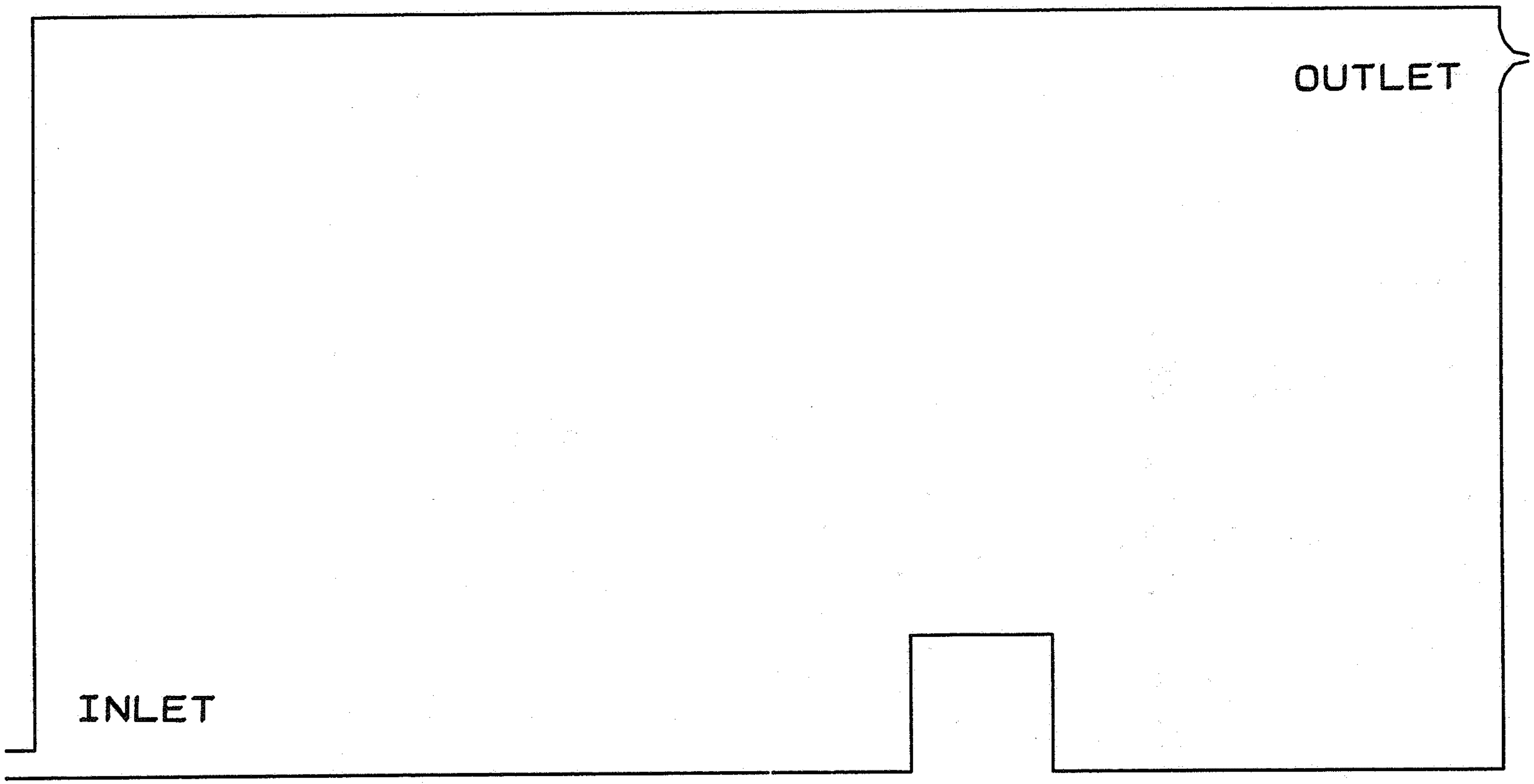
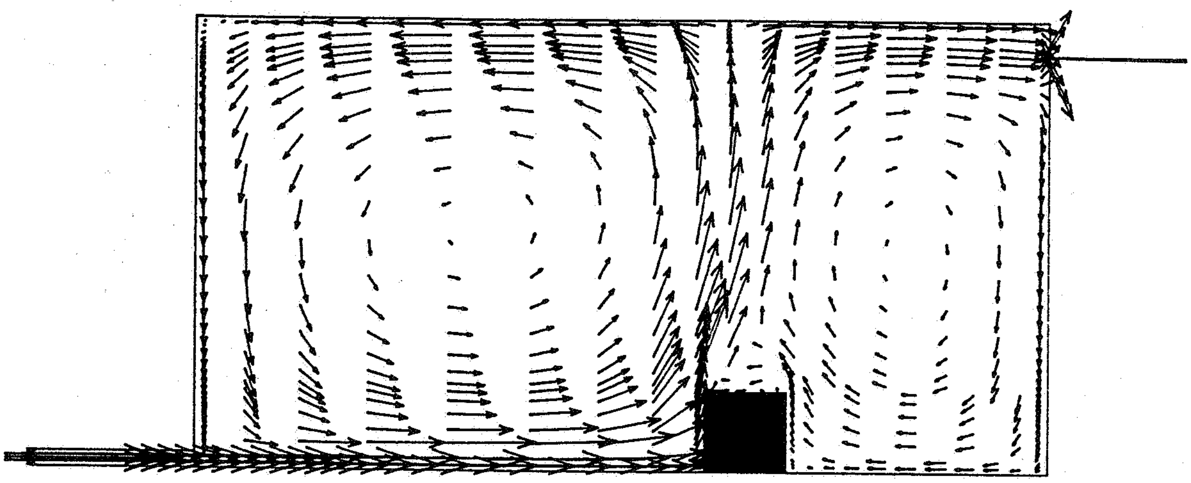


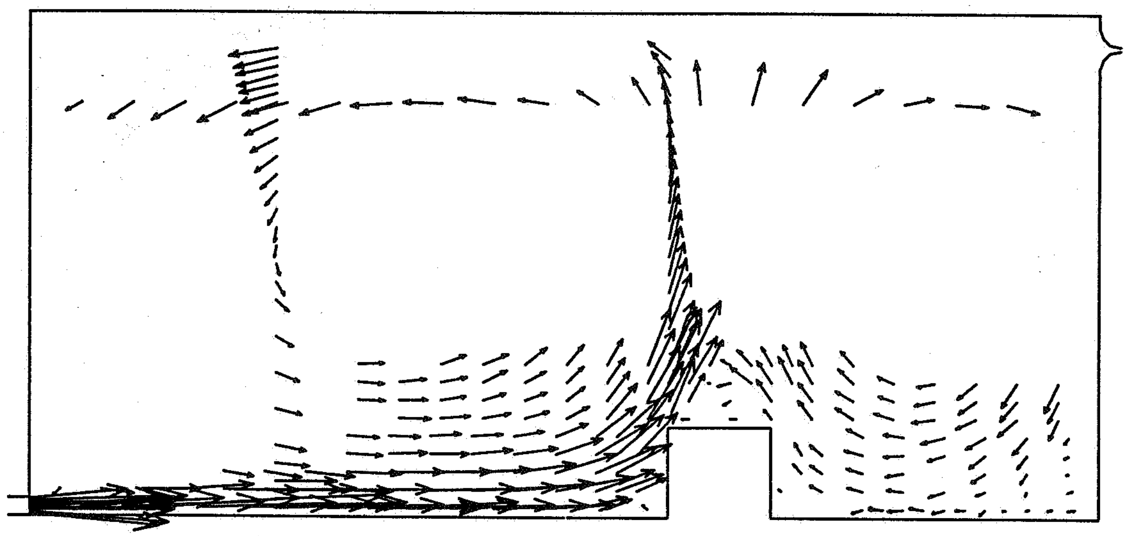

THE MEASURING SECTION INSIDE THE ROOM

('2D' STRUCTURE OF THE MEAN FLOW)

FIGURE 1

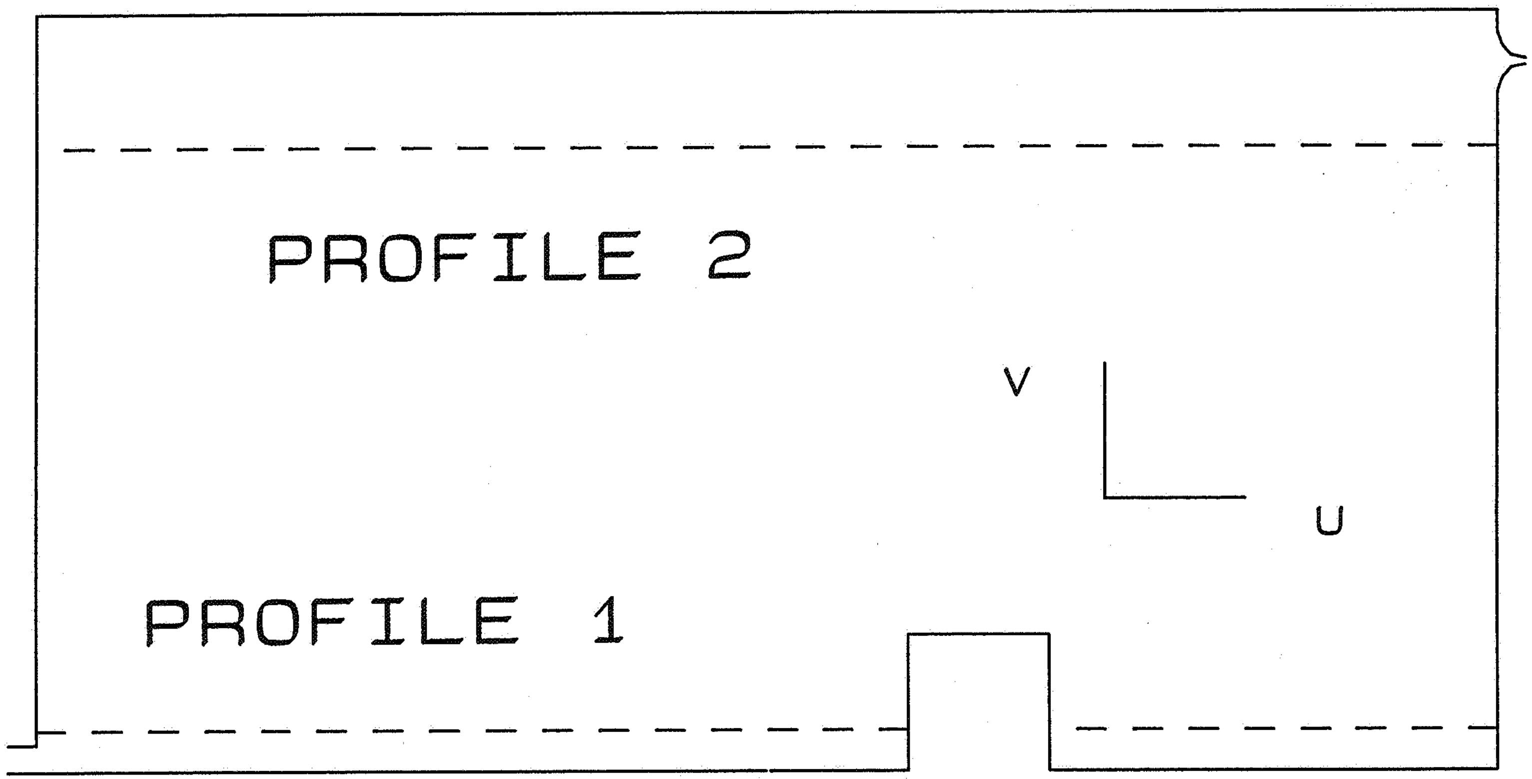


NUMERICAL MEAN VELOCITY MAP



EXPERIMENTAL MEAN VELOCITY MAP

FIGURE 2




LOCATION OF THE PROFILES

FIGURE 3

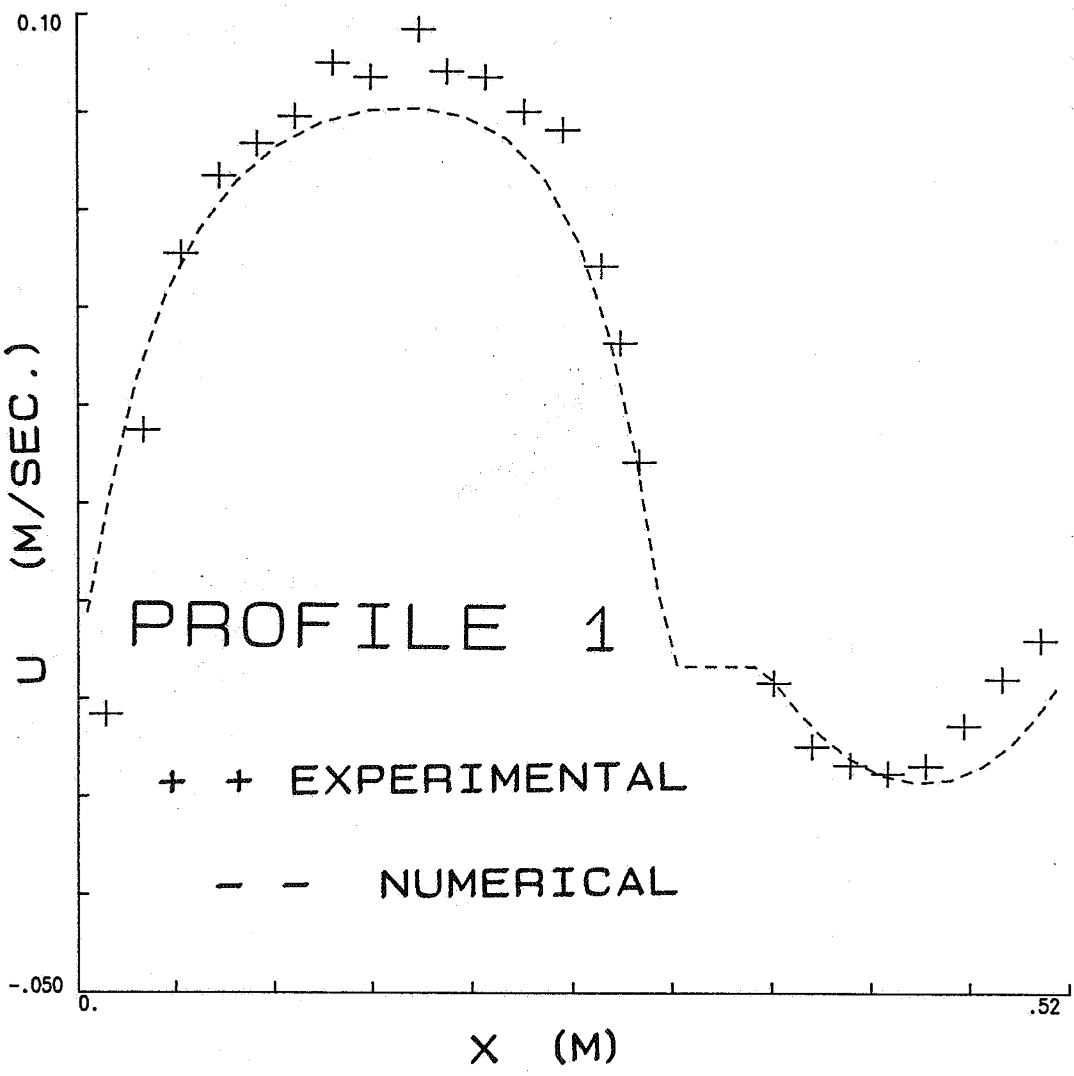



FIGURE 4

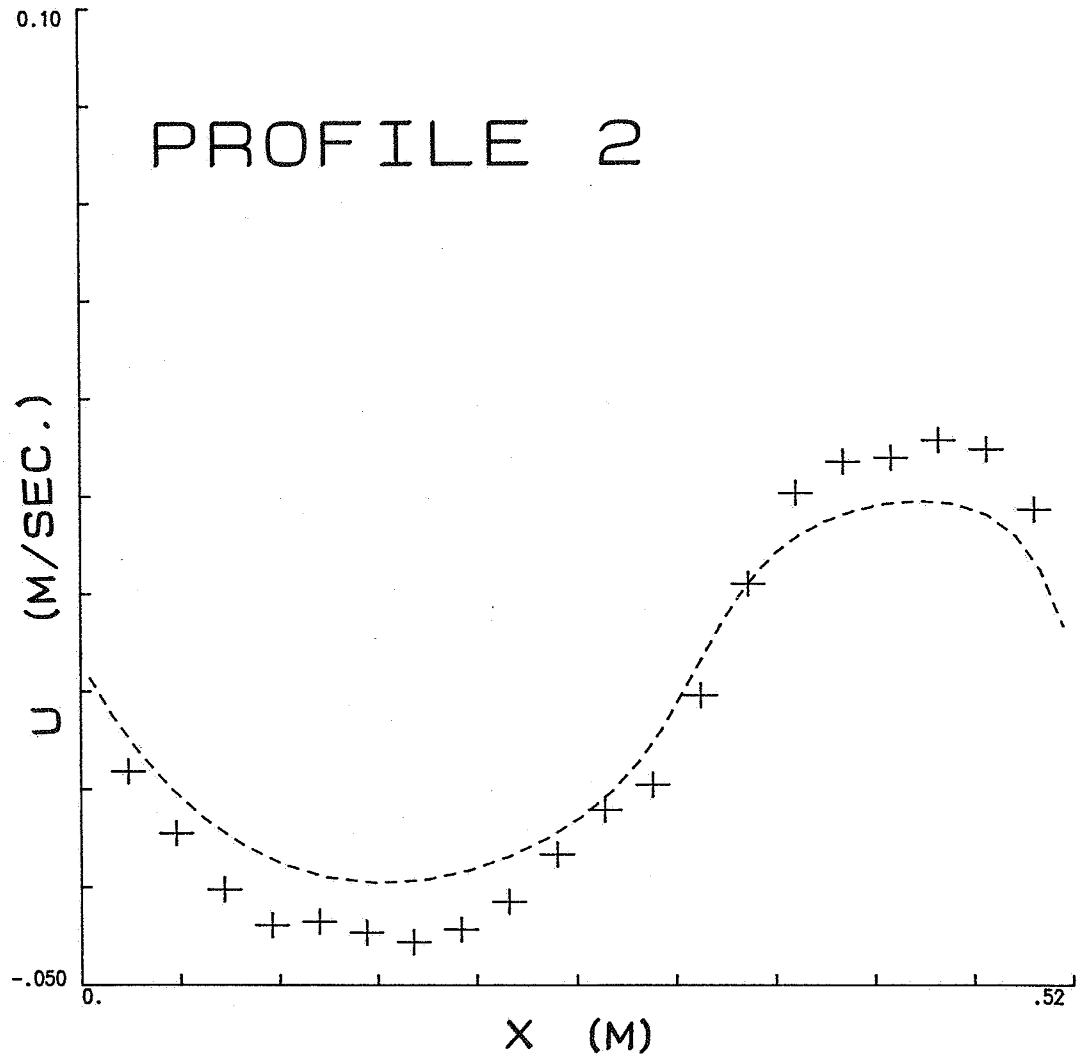



FIGURE 5