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EXPERIMENTAL INVESTIGATION OF A DIFFUSER FOR COOLING AND AIR CONDITIONING SYSTEM

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Abstract

In the present work the flow in a diffuser mounted at the exit cross-section of an air-conditioning system fan has been studied. In the first step, the exit flow condition of the fan has been studied and then, for various diffuser divergence angles, the flow parameters and the seperation regions have been examined using the wool-tuft method. For the quantitative examination of the diffuser flow at various divergence angles, wall static pressure distributions have been measured using a pressure scanning valve with a PCL818 A/D card. The diffuser exit mean flow condition and the turbulence level have been measured using pitot-static tube with an electronic micromanometer and the same A/D card. All these investigations show that the flow is not uniform at the exit of the diffuser and the turbulence level shows important variations from point to point. On the other hand, the flow in the diffuser is seperated at all diffuser divergence angles except less than five degrees for which the flow of the duct is considered approximately uniform.

1.Introduction

Diffusers are geometrically simple fluid mechanical devices, having many applications such as in aircraft jet engines, wind tunnels, air-conditioning, electrostatic precipitator etc., in order to reduce the speed of fluid flow. Basic characteristic of a diffuser in incompressible flows is that its cross-sectional area increases from the entry to the exit plane. Another purpose of a diffuser in an internal flow system is to produce an increase in static pressure without external energy input, by converting the dynamic pressure associated with the inlet velocity profile.

Patterson[1] has investigated flows in ducts, duct losses and duct design for various geometries and types and has given about rules to be followed for the reduction of internal and external drag. Cockrell and Markland[2] have investigated incompressible diffuser flow, and have given an experimental review of the current work. Runstadler et al[3] have prepared a diffuser data book as a technical note for Creare Inc. Sci. and Tech. This study includes a lot of experimental results. Bower[4] has investigated the attached and seperated subsonic diffuser flows, and he has given an analytical technique for calculating the boundary-layer characteristics and the static and total pressure distributions in plane-wall and conical diffusers. Mehta[5] has studied the aerodynamic design of blower tunnels with wide-angle diffusers. In this work, there are a lot of experimental results about wide-angle diffusers and flow control techniques in wide-angle diffusers. Farell and Xia[6] have investigated screen-filled wide angle diffusers. In this study, they have given some analytical techniques and experimental results.

Şahin and Ward-Smith[7] have studied the flow in a diffuser and established the geometry of the seperated flow region, velocity distributions and flow angles across the diffuser. Şahin and Ward-Smith[8] have investigated the application of blanking techniques to vary screen porosity and to study its effect on the performance of plate diffuser combinations. Şahin et al.[9] have studied pressure distributions and pressure losses in plate diffuser combinations as influenced by systematic variations of screen location, type of screen and diffuser geometry.

The principal aim of this paper is to investigate the flow downstream of a diffuser used for an air-conditioning system. The diffuser was taken empty, in other words without flow control devices, and experimental techniques were used. The results shown here are examples of a much larger range of information which can be found in Ref.11.

2. Experimental Arrangement

The diffuser having a rectangular cross-section was made of plexiglass material of 10 mm thickness. The side walls were parallel and vertical walls diverged between zero degree and fifty degrees. The diffuser was placed outlet of the fan. The tongue region of the fan was closed for these experiments since reverse flows were observed under the tongue of the fan, after qualitative investigations using wool-tuft method. Consequently, the entrance of the diffuser was faced with the fan outlet region above the fan tongue. The length of the duct was 42 cm.

Air conditioning system has a fan, driven by an electrical motor of 1HP power and 3000 RPM.

The diffuser walls were equipped with the static pressure taps. The arrangement of the pressure taps is presented in Fig.1. First the static pressure holes were drilled of 5 mm depth and 0,5 mm diameter in internal side of the walls, then the holes in 5 mm depth and 1,5 mm diameter were drilled in the external side of the walls in order to place injector needles of 1,5 mm diameter. The needles were connected with elastic tubes to an Electronic Pressure Scanning Module (EPSM) of Scannivalve ZOC. This EPSM was used with a PC and a PCL818 data acquisition card. Detailed informations about this card and the use and the calibration of the EPSM can be found in Ref 10. Especially designed miniature pitot-static tube was used to measure the velocity distributions at exit cross-section of the diffuser. It was connected to an electronic micromanometer and the data was acquired by the PC. A DISA traversing mechanism equipped with a Stepper Motor and controlled with a Sweep Drive Unit were used to traverse the pitot-static tube.

3. Results and discussions

Qualitative investigations with wool-tuft method have revealed that there were seperation regions and reverse flows in the various regions of the diffuser. The investigations stated also that for small divergence angles, the flow was not symmetric. Wall static pressure measurements prooved the results of the wool-tuft method. Static pressure measurements are presented in Fig.2. The wall static pressure coefficient is defined as Cp,

$$C_p = \frac{P - P_r}{\frac{1}{2}\rho U^2}$$

where P is the local pressure, P_r is the reference pressure taken as average value of the wall pressures while the divergence angle is zero, and ρ is the air density. U is the reference velocity taken as the average value of the exit cross-section velocities of the fan without duct. Its value was 14,80 m/s for these experiments.

The arrangement for the velocity measurements with pitot-static tube at the exit cross-section of the diffuser is shown in Fig.3. For the divergence angles smaller than five degrees, the results of the velocity measurements at the outlet of the diffusers are shown in Fig.s 4. and 5.

The results in Fig.s 4, indicate that the velocity profiles are alike and the flow are not uniform. In order to clarify of the flow field the same velocity distributions are given as three dimensional diagrams in Fig.5. In these figures U1 is the local velocity, and U is the reference velocity as mentioned above.

The complexity of the flow field made difficult the experimental studies for divergence angles higher than ten degrees. Therefore no data is given above ten degrees. Comparison of figures 5a, 5b and 5c shows that, the velocity distribution at ten degrees divergence angles is some different from the zero and five degrees divergence angles.

The variations of the velocities with time at particular stations for zero and ten degrees of divergence angles are given in Fig.6. RMS values of the velocities measured at three places of the diffuser exit cross-section are given in Fig.7. RMS values are defined as

$RMS = \sqrt{1/n\Sigma(Ui-U)^2}$

where Ui is the instantanous velocity and U is the average velocity of these values.

These figures show that the RMS values have roughly the same average value. In the lower, middle and upper levels of the diffuser outlet section. However there is a periodic change in the middle level. RMS values vary generally between 0,5 and 2,5 in the lower and middle levels, and between 2 and 3 in the upper level.

As a conclusion of all the results presented in these figures it can be stated that the flow is far from the uniformity for nearly all divergence angles. The flow uniformity decision can be assessed using the method proposed by the Industrial Gas Cleaning Institute of America (Ref. 7). The rms% is a measure of flow uniformity determined from a

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number of measurements of local velocity distributed over the cross-section. Thus

$$rms\% = 100\sqrt{\left[\left(V_{rms} / V_m\right) - 1\right]^2}$$

$$V_{rms} = \sqrt{\left(\frac{1}{n}\sum V^2\right)}$$

V_m is the mean velocity throuh a cross-section and n is the number of readings. An acceptable degree of flow uniformity correspond to a value of rms% of 15% or less.

In our experiments the following results are found,

Divergence angles	*rms%*
At fan outlet section	17,80
0 degree	13,20
5 degrees	15,41
10 degrees	21,23
20 degrees	36,81
30 degrees	42,77
40 degrees	40,20
50 degrees	56,20

These results show that the flow can be considered nearly uniform only for less than five degrees following the criteria of the Ref.7.

4.Conclusions

In this work the flow downstream of a diffuser used for an air-conditioning system was investigated. The flow was investigated with wool-tuft method, wall static pressures and the exit cross-section velocities were measured for several diffuser divergence angles. The flow in the diffuser was generally seperated for the divergence angles higher than five degrees and non-symmetric for all the diffuser angles. The flow was highly turbulent in the exit cross-section additionally RMS values showed variations from point to point. The flow was highly non-uniform for the diffuser angles higher than five degrees.

As a conclusion of these results, it can be accepted that using only a diffuser at the fan outlet section of an air-conditioning system is not sufficient to decrease the losses. It can be stated also such a system can be expected a very noisy system because of high turbulence level. Our results show that this type of system is convenient only for divergence angles smaller than five degrees, for industrial applications.

Acknowledgement

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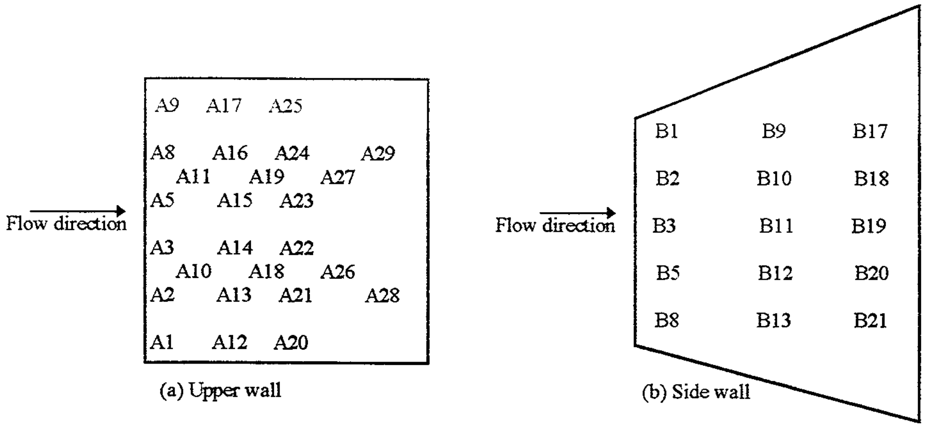

Figure 1 : Arrangement of the pressure taps on the diffuser walls

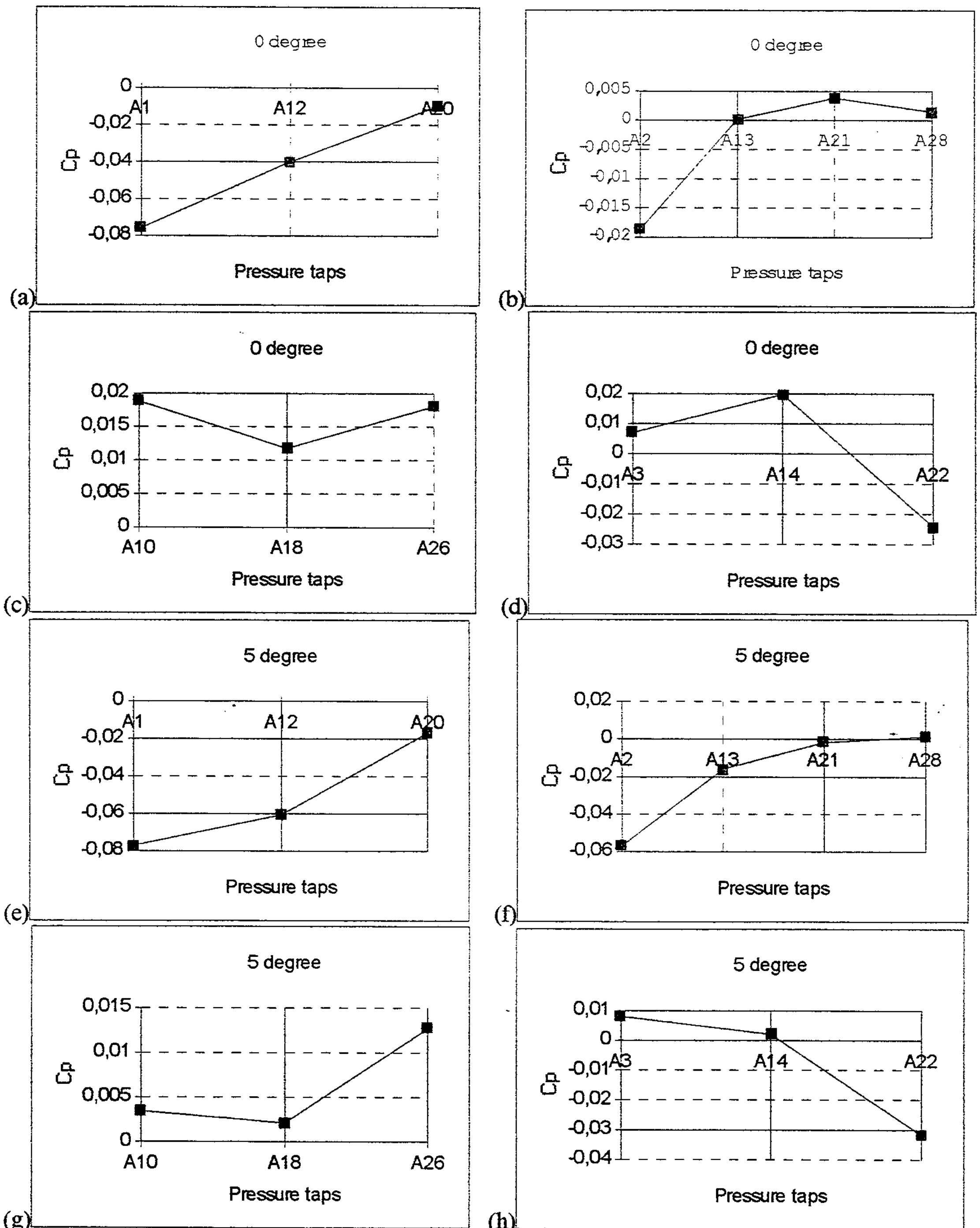

Figure 2 : Wall static pressure distributions along the diffuser

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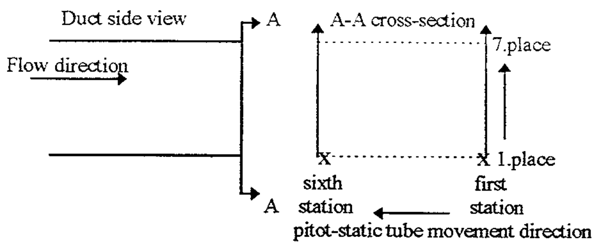
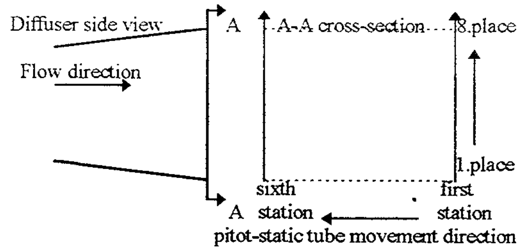


Note: 1.place y=0cm, 2.place y=1cm, 3.place y=2cm, 4.place y=7cm, 5.place y=12cm, 6.place y=17,3cm, 7.place y=18,3cm.

3a : Zero degree



Note: 1.place y=0cm, 2.place y=1cm, 3.place y=2cm, 4.place y=7cm, 5.place y=12cm, 6.place y=17cm, 7.place y=21,2cm, 8.place y=22,2cm.

3b : Five degrees.

Figure 3 : Arrangement of velocity measurements places and directions.

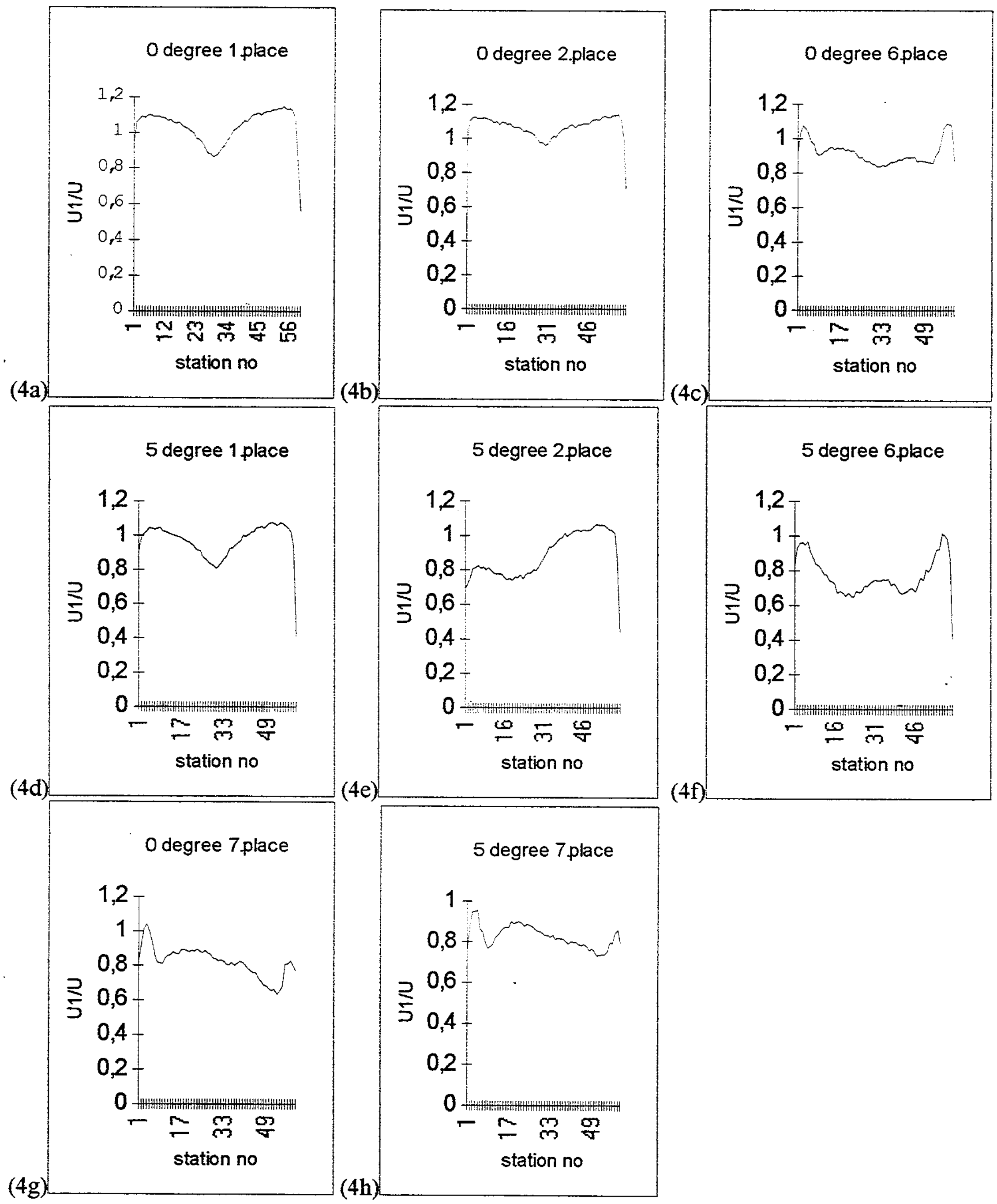


Figure 4 : Velocity profiles.

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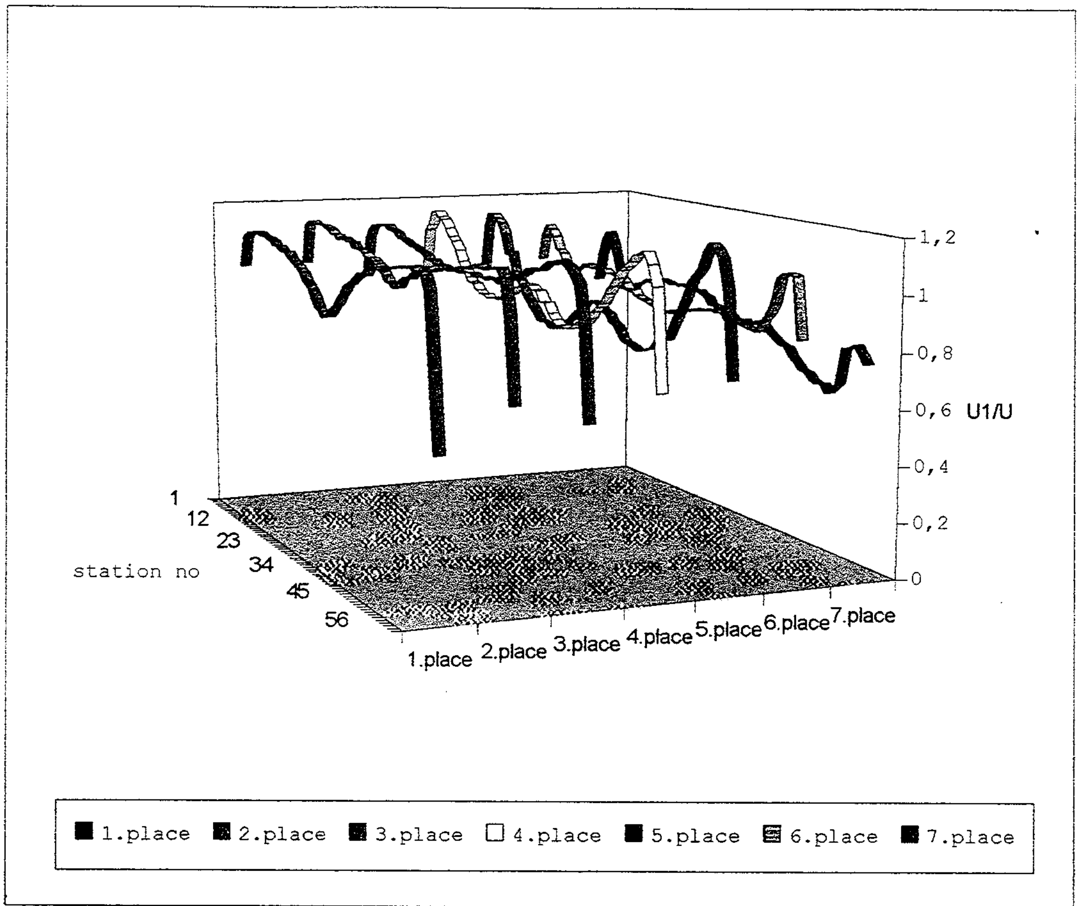

Figure 5a : Zero degree oulet velocity distributions

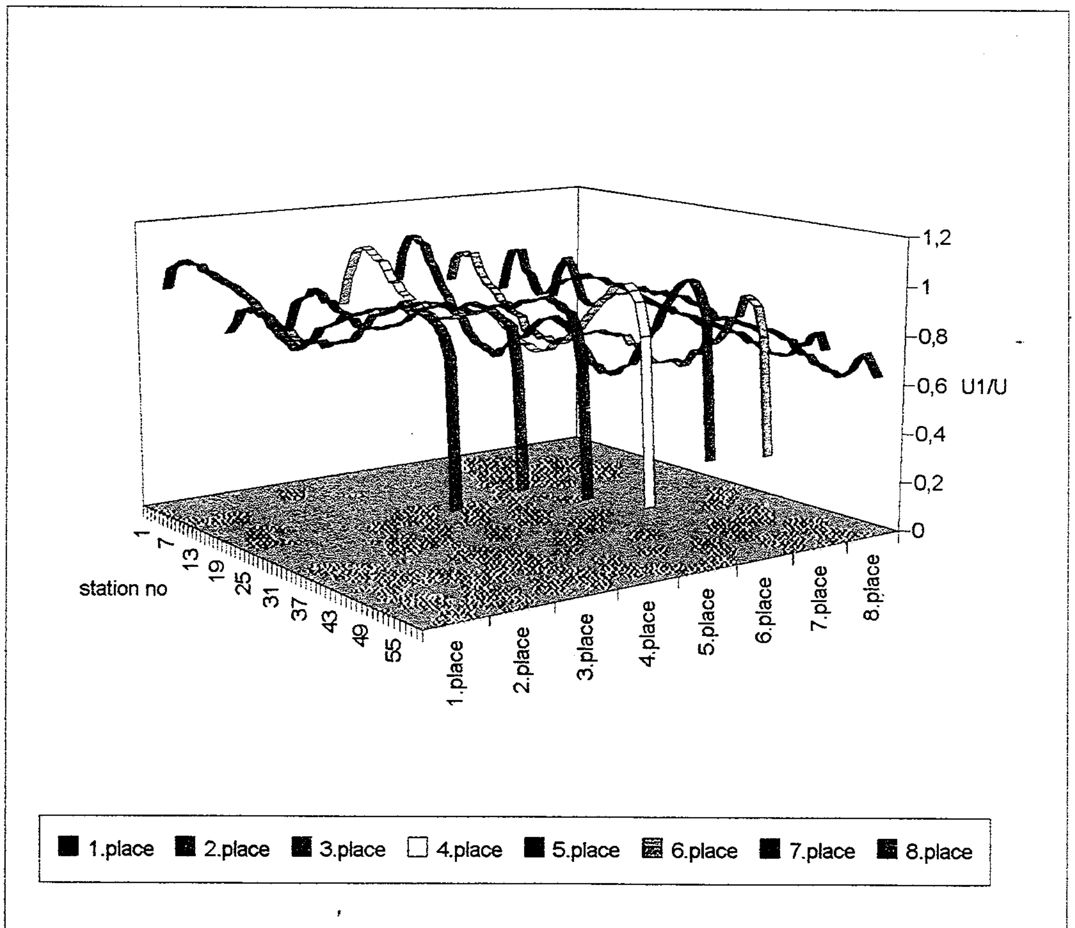

Figure 5b : 5 degree oulet velocity distributions

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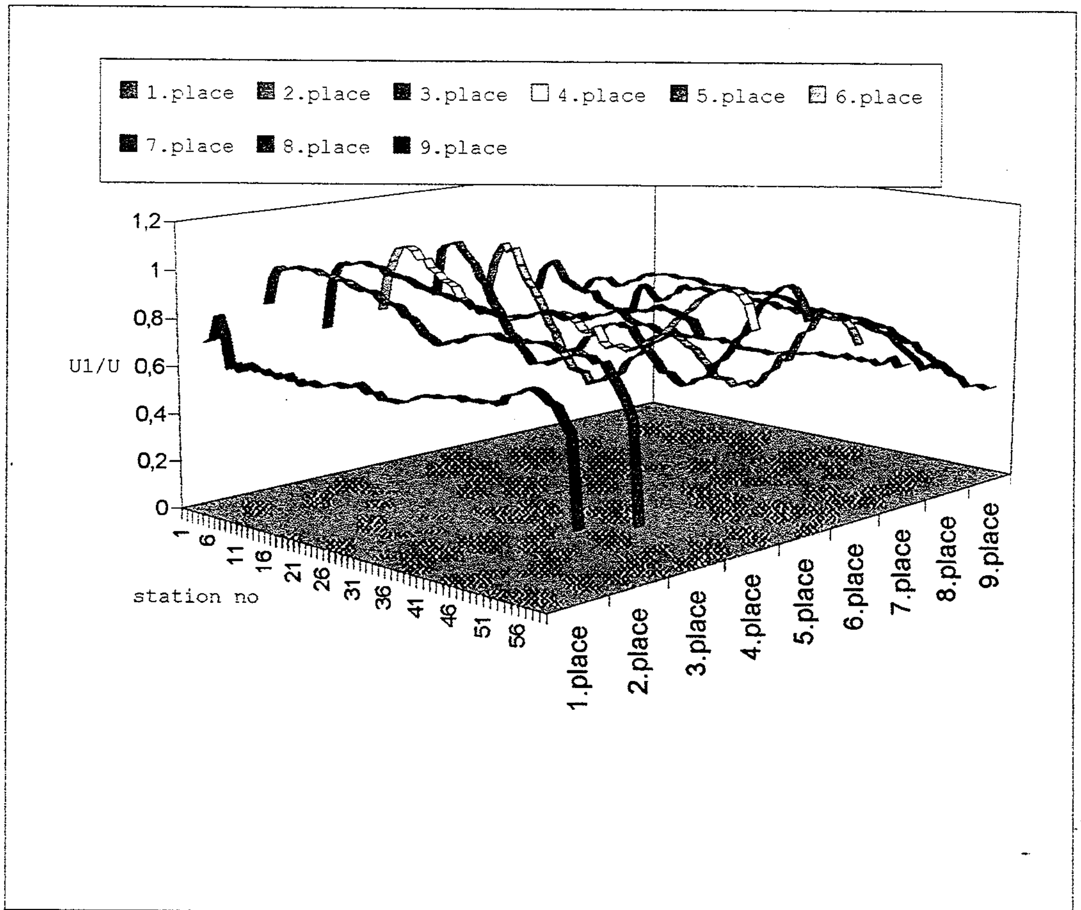

Figure 5c : 10 degree oulet velocity distributions

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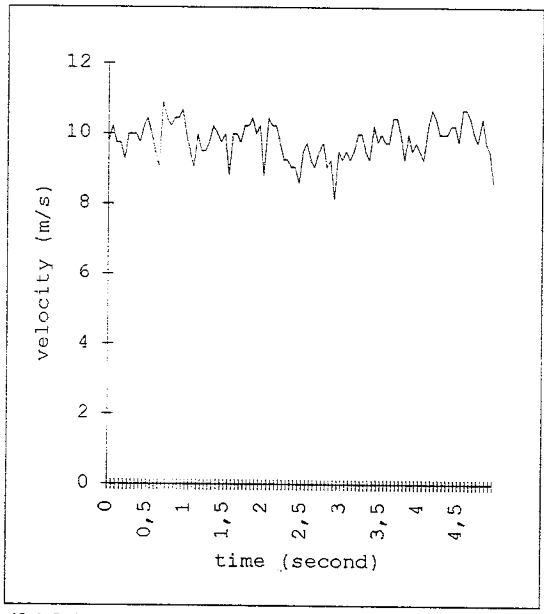
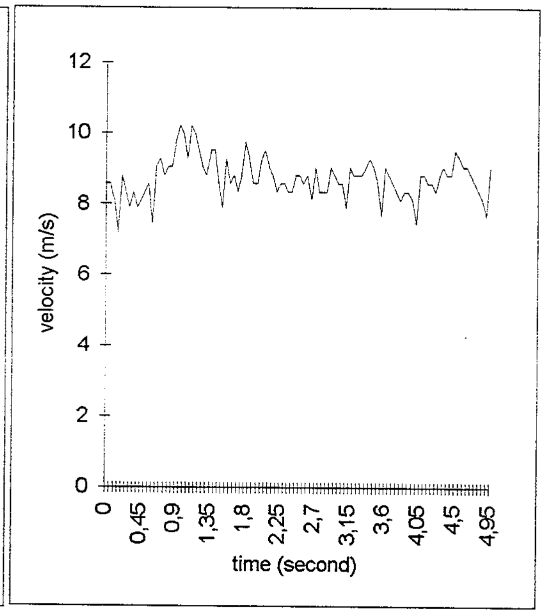
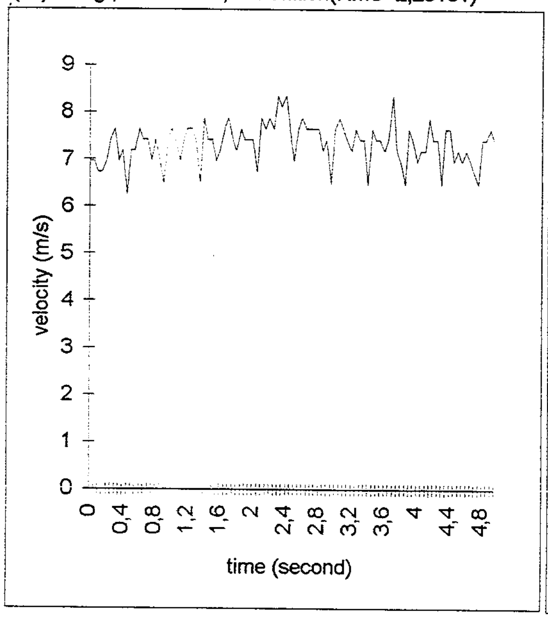


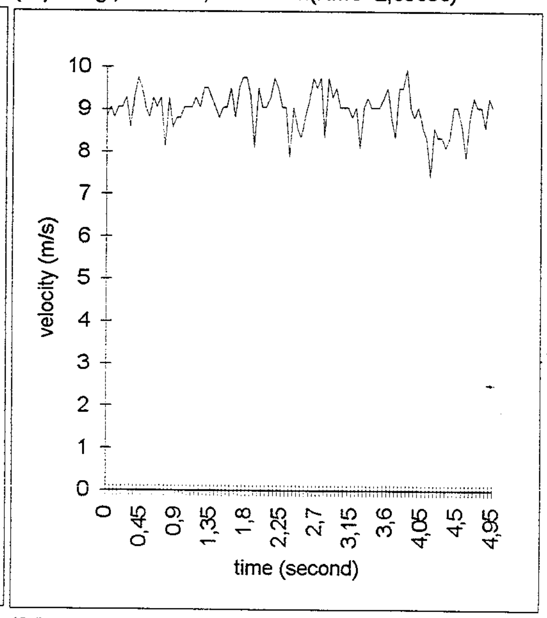
(6a) 0 deg., lower level , 30. station(RMS=2,29191)



(6b) 0 deg., mid.level, 30. station(RMS=2,68686)



(6c) 0 deg., upper level, 30. station(RMS=3,10060)



(6d) 10 deg. , lower level, 30. station(RMS=2,57047)

Figure 6 :Velocity variations with time at related places

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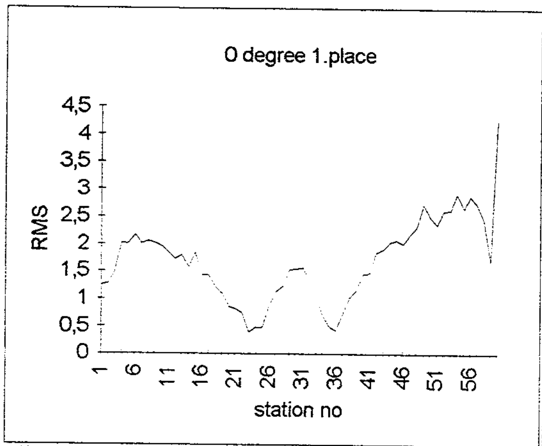
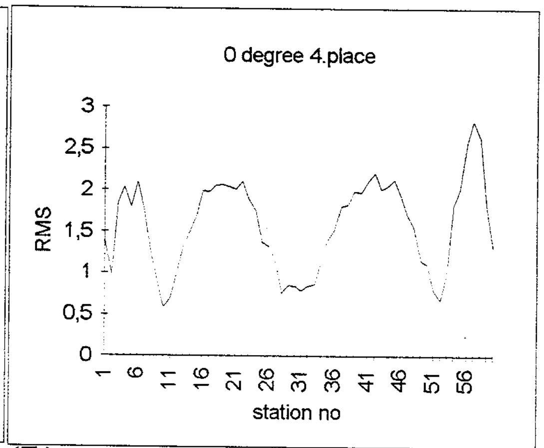
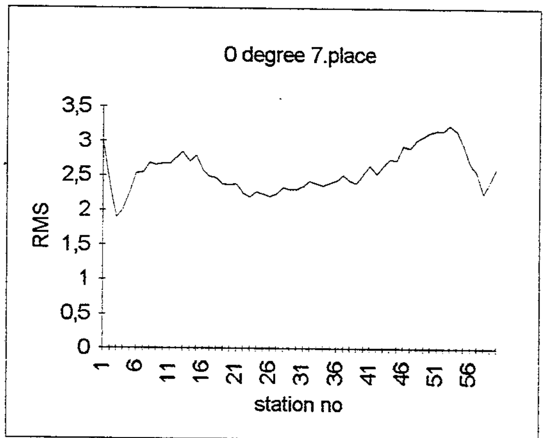


(7a)



(7b)



(7c)

Figure 7: RMS variations at related places.

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