The use of perforated plates to control the flow emerging from a wide-angle diffuser, with application to electrostatic precipitator design

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The flow through a wide-angle, pyramidal diffuser of area ratio 6.8, in which two perforated plates are used to control the emergent velocity distribution, was investigated. (Wide-angle diffusers combined with perforated plates find application in electrostatic precipitator flow systems. The efficacy of these systems depends critically on the uniformity of the gas flow within the collection chamber downstream of the diffuser outlet plane.) The main results of the study are (i) the establishment of the main factor influencing the flow at the diffuser exit plane, (ii) the determination of plate characteristics which produce a uniform velocity profile in the collection chamber, and (iii) the establishment of the corresponding pressure drop characteristics of the plate–diffuser combinations. The results also extend the range of diffuser geometries for which two perforated plates provide uniform velocity profiles at exit.

Keywords: *wide-angle diffuser, gas flow, perforated plates, electrostatic precipitators*

Introduction

Electrostatic precipitator designers have long recognized the need for a uniform velocity distribution in the treatment zone for the efficient removal of dust particles from polluted air. It is essential in this type of system to ensure not only that the dust particles are removed from the air in the treatment zone, where the flow must be slow-moving, but also that they are not prematurely deposited elsewhere in the flow system. Hence it is necessary to use pipework of appropriate size and to expand the gas flow upstream of the treatment zone by means of a diffuser, and typically the flow must be slowed down to about one tenth of the velocity upstream of the diffuser. The conventional solution to this problem is to use a pyramidal wide-angle diffuser, with screens or perforated plates for flow control, upstream of the treatment zone.

Much work has been done on the fluid mechanics of flow through isolated diffusers, and perforated plates and screens. The literature on these topics will not be discussed in detail here; instead the reader is referred to Ward-Smith[1] for a review of this work. There is available only a very restricted amount of published information on the aerodynamic properties of diffusers relevant to precipitator system designs.

Although diffusers with small included angles have the most uniform velocity profiles at exit, such designs are not employed in practical electrostatic precipitator systems, because of the excessive space they occupy. This explains the use of wide-angle diffusers. However, without some form of flow control, the velocity distribution associated with the flow emerging from a wide-angle diffuser is highly nonuniform. By incorporating one or more perforated plates within the diffuser the velocity distribution can be improved very considerably.

One of the earliest experimental investigations of low speed flow through wide-angle diffusers with screens was carried out by Schubauer and Spangenberg[2]. This work concentrated on a diffuser of circular cross-section and area ratio 4.

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Received 30 October 1985 and accepted for publication in final form on 29 September 1986

0142-727X/87/020124-08$3.00

Subsequently, Mehta[3] made a comprehensive literature survey and collected a considerable amount of useful information on the design of wide-angle screened or plated diffusers. Most of the work reviewed by Mehta[3] had been concerned with the design of wind tunnels. Mehta's data, together with those of Schubauer and Spangenberg[2], provide useful guidance for the creation of uniform diffuser exit flows. However, in the context of electrostatic precipitators, the information provided by these sources is incomplete. Firstly, data for area ratios above 5 are sparse. Secondly, criteria by which the degree of uniformity of the velocity profile may be judged have not been given extensive consideration. These factors are important. For example, in the case of electrostatic precipitators, beyond certain limits of flow uniformity, the efficacy of the system rapidly diminishes. For this reason criteria are required for judging the diffuser exit velocity profile. The Industrial Gas Cleaning Institute of America has published[4] appropriate standards for the uniformity of gas flow entering electrostatic precipitators.

The uniformity of flow in models of practical precipitators has been studied experimentally by Reynolds and Page[5]. Overall, four perforated plates of 50% open area were used. Two plates were installed within the diffuser, and a third plate was positioned at the diffuser exit. The fourth plate was fixed at the outlet plane of the collection chamber to reduce coning, a flow condition which is induced by the contraction of the flow downstream of the collection chamber. Some selective blanking of the third and fourth plates, located at the inlet and outlet of the collection chamber, was made to achieve a uniform flow across the cross-sections of the collection chamber.

The present paper incorporates the results of an experimental investigation of the flow through a pyramidal wide-angle diffuser of area ratio 6.8 in which flow control was achieved by the use of two perforated plates. During the entire experimental programme[6] a large amount of information was collected. Only the main findings are reproduced here. The objectives of the present work are (i) to extend the range of diffuser area ratios for which uniform velocity profiles are achieved, (ii) to determine the porosity and positioning of perforated plates which yield satisfactory exit velocity profiles within the diffuser under test, and (iii) to present information on the pressure drop characteristic of plate–diffuser combinations.

The experimental programme

A schematic illustration of the equipment used in the present investigation is shown in Fig 1. The rig was operated in a semi-closed loop mode, a small amount of fresh air continuously being drawn through the system. This mode of operation was selected to avoid the progressive increase in temperature of the working fluid which resulted during prolonged periods of testing in a closed loop mode. Air replacement took place at the section QQ of Fig. 1.

An adequate framing was made to eliminate panel vibration, and action was taken to prevent leakages at joints in the working section.

An axial two-stage fan drew air through the system. The air flow rate was regulated by an adjustable hand-operated damper on the fan. The top mean speed of the air flow was approximately 3.7 m/s, measured at the exit of the diffuser, corresponding to a Reynolds number based on the equivalent diameter of $Re = 2.6 \times 10^5$.

Guide vanes at each bend of the system were incorporated to form a cascade to minimize energy losses and also to maintain control over the velocity profile. Downstream from the final corner before the flow approached the working section (see Fig 1), honeycombs were assembled in two parts to straighten and further improve the velocity profile.

The working section for the plate-diffuser combinations under investigation consisted of a pyramidal wide-angle diffuser with a square entrance duct (46 cm × 46 cm) and a rectangular exit duct (102 cm × 142 cm), as shown in Fig 1. The length of the rectangular duct was 130 cm. The total diffuser divergence angle was horizontally $2\gamma = 97°$ and vertically $2\alpha = 67°$, and the length of the diffuser was $L = 42.5$ cm. The design of the working section was based on the unpublished work of Reynolds and Page[5], which was concerned with model tests of a precipitator used in steel production.

The perforated plates used had holes of diameter $d = 6$ mm and plate thickness $t = 1.5$ mm. Porosities β of 0.4 and 0.5 were investigated. A third plate with holes of diameter $d = 6.35$ mm, of thickness $t = 1.5$ mm and porosity β of 0.58 was also tested. The holes in the perforated plates were approximately square edged at the rear side of the plate, whereas on the front face they exhibited some rounding as a result of the manufacturing method. They were located on an equilateral-triangular pitch.

The plates were rigidly clamped in a vertical plane in the diffuser and the face of the plates was normal to the axis of the diffuser. The plates could be fixed in a number of different positions within the diffuser, the locations being shown in Fig 2. The upstream plate is designated by BB, the downstream plate by AA. In the current investigation no collector plates were installed in the treatment zone, allowing attention to be concentrated upon the characteristics of the flow emerging from the plate–diffuser combinations.

Velocity measurements were taken over a grid of 361 (19 × 19) points at measuring sections S2, S3 and S4 (see Fig 2), using a standard Pitot-static tube. Velocity measurements were made for some tests over the full measuring sections, whilst for some tests only a quarter part of these measuring sections was investigated. Detailed test surveys to investigate flow direction and local velocity distribution were made within the diffuser at seven measuring planes by means of a five-hole Pitot tube. This instrumentation has been described by Sahin and Ward-Smith[7].

Flow measurements

Measurements of the velocity distribution were made in the diffuser and in the treatment zone downstream, and the

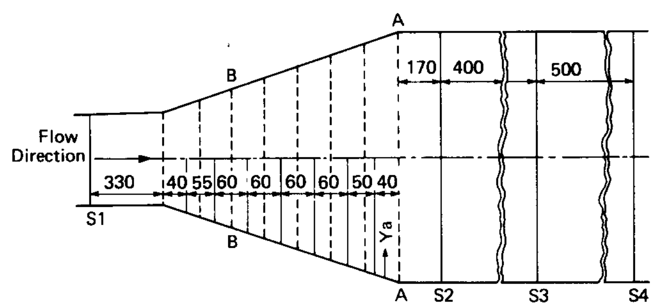

Figure 2 Measuring sections and locations of plate. Dimensions: mm

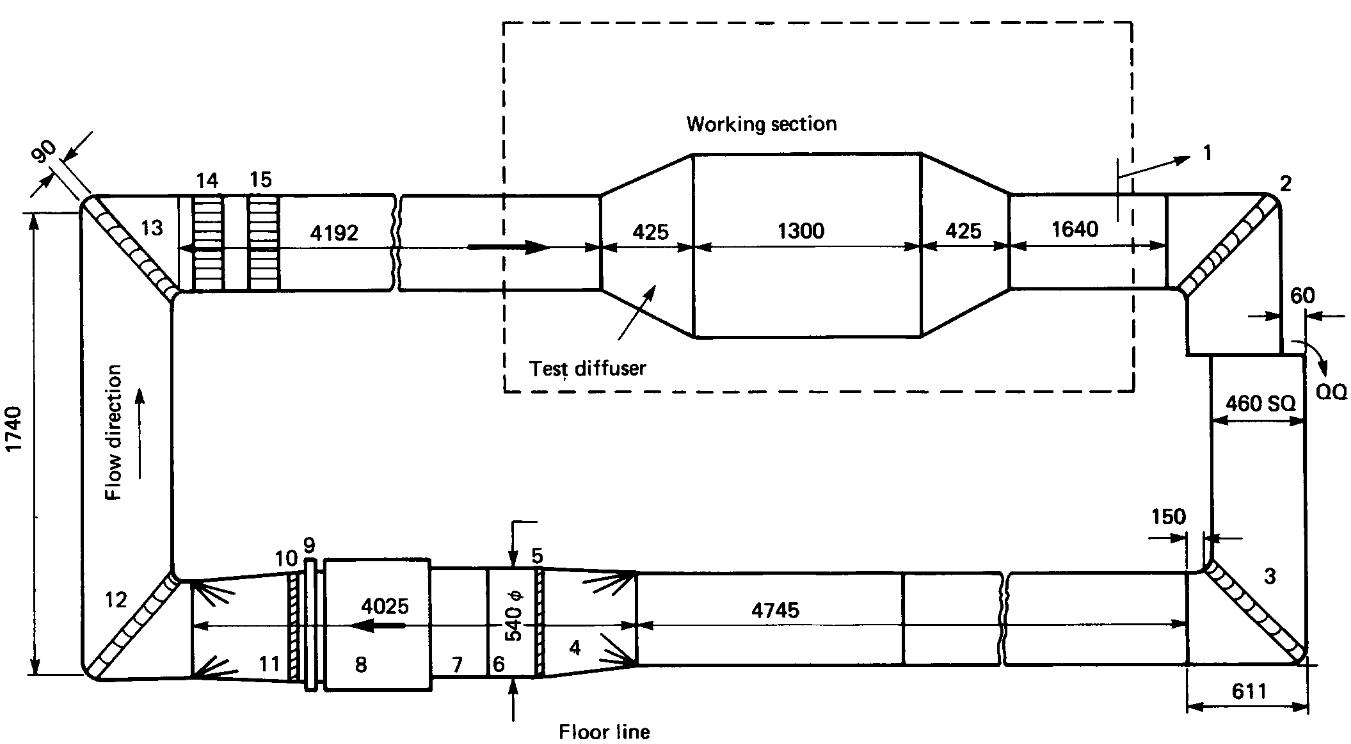

Figure 1 Test-rig layout, elevation. Dimensions (mm) relate to inside of ducting. Not to scale. 1 thermocouple; 2, 3, 12, 13 guide vanes; 4, 11 transition sections; 6, 7 fans; 5, 10 connection spigots, 9 damper; 8 silencer; 14, 15 honeycombs; QQ open gap

influence of plate porosity and the location of the plates within the diffuser was systematically investigated.

The present results tended to confirm the experience of Gibson[8] and Reynolds and Page[5], who recommended the use of perforated plate with a porosity β of 0.5.

In two test series, plates with $\beta = 0.5$ were used. In one set of tests the position of the upstream plate was fixed, and variations of the locations of the downstream plate were investigated. In a complementary set of tests the downstream plate location was fixed and the upstream position was varied. From these tests the optimum plate locations, yielding the most uniform exit velocity profile, were found to be a short distance downstream from the entry plane and just upstream of the exit plane (Fig 3).

The results of tests with plates of porosity $\beta = 0.58$ indicated that, however the plates were located, the value of plate resistance K was too low and the flow could not be evenly distributed over the entire exit plane of the diffuser.

A further series of tests was performed with plates with porosity β of 0.4. The emergent flow from the downstream plate (AA) was diverted with the greatest range of deflection angles, causing the flow to accumulate in close proximity to the duct walls. Correspondingly, the largest region of retarded flow occurred in the vicinity of the axis of the collection chamber, as compared to the other test series. The upstream movement of the plate BB reduced the size of the region of retarded flow.

Prediction of pressure drop

The combined resistance of the perforated plates and diffuser can be predicted by using methods based on a simple one-dimensional flow analysis and summing the losses in the two components. Two separate approaches can be identified and here these will be referred to as theory I and theory II. In both theories I and II, account is taken of the pressure drop through the perforated plates. The differences between theory I and theory II relate to the treatment of the flow through the diffuser. The theories are developed for the situation where two plates are used for flow control.

Theory I

Theory I assumes that the diffuser contributes to the overall loss through the plate–diffuser combinations. One-dimensional flow theory applied between sections 1 and 2 of the diffuser (see Fig 4) gives the pressure recovery coefficient C_{p1} defined as

$$C_{p1} = \frac{p_2 - p_1}{\frac{1}{2}\rho U_1^2} \tag{1}$$

and similarly between sections 3 and 4 for the pressure recovery C_{p2} which is

$$C_{p2} = \frac{p_4 - p_3}{\frac{1}{2}\rho U_3^2} \tag{2}$$

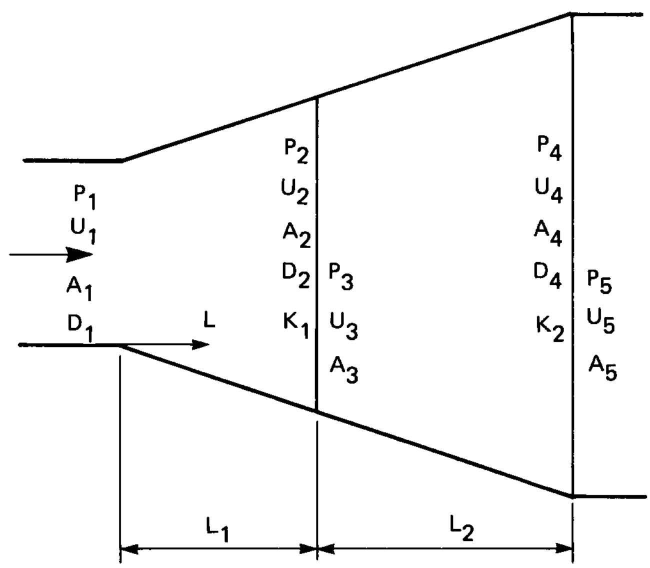

Figure 4 One-dimensional flow in the wide-angle screened diffuser

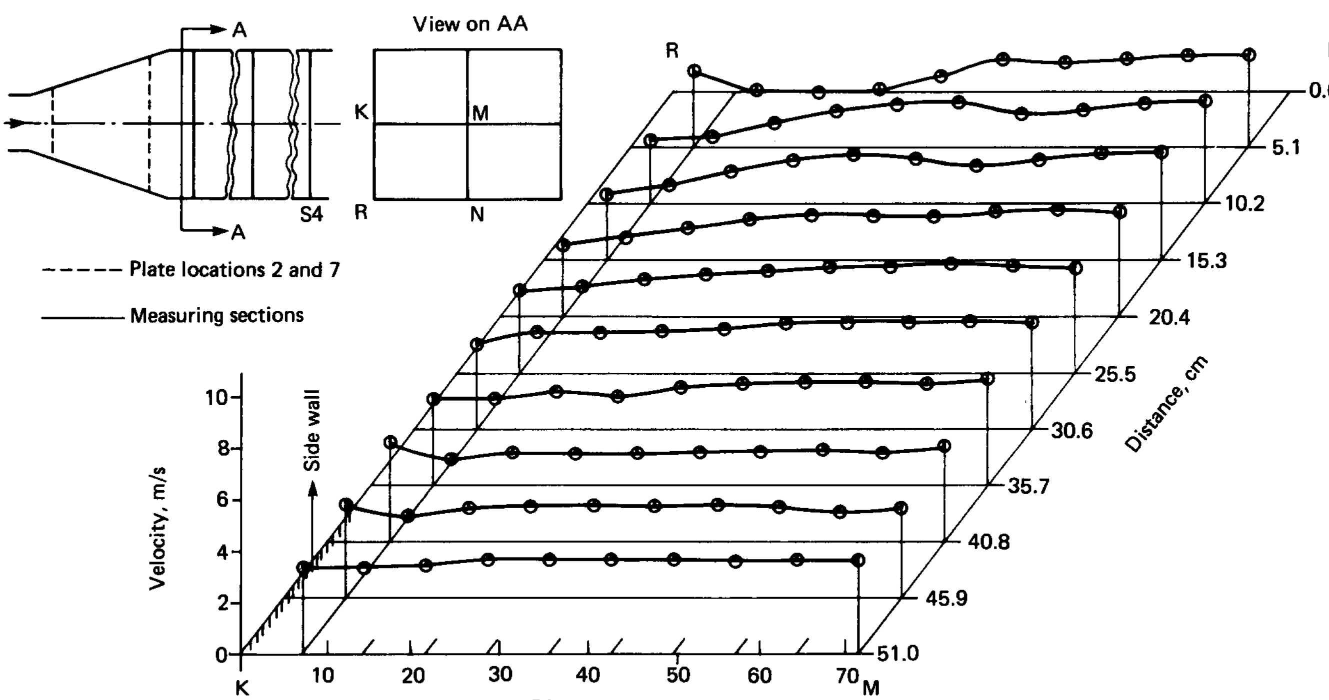

Figure 3 Velocity distributions over a quarter of the measuring section. Section S4. β=0.5

Through the plates, pressure losses occur; the pressure loss coefficient K_1, for plate BB is

$$K_1=\frac{p_2-p_3}{\frac{1}{2}\rho U_2^2} \tag{3}$$

and K_2, for plate AA is

$$K_2=\frac{p_4-p_5}{\frac{1}{2}\rho U_4^2} \tag{4}$$

Combination of Eqs (1), (2), (3), (4) leads to the equation

$$p_5-p_1=-K_1\tfrac{1}{2}\rho U_2^2+C_{p1}\tfrac{1}{2}\rho U_1^2+C_{p2}\tfrac{1}{2}\rho U_3^2-K_2\tfrac{1}{2}\rho U_4^2 \tag{5}$$

Eq (5) is general in the sense that different types of plate are assumed at AA and BB. The equation takes on a simpler form when plates of the same porosity are considered.

Using the relations $K_1=K_2=K$ for the plate resistance, $U_2=U_3$ at the front and rear of the plate BB, and introducing the continuity relation for incompressible flow ($A_1U_1=A_2U_2$), the overall pressure recovery coefficient C_p for the plate–diffuser combination can be calculated. There results

$$\frac{P_5-P_1}{\frac{1}{2}\rho U_1^2}=C_p=[C_{p2}-K]\left[\frac{A_1}{A_2}\right]^2+C_{p1}-K\left[\frac{A_1}{A_4}\right]^2 \tag{6}$$

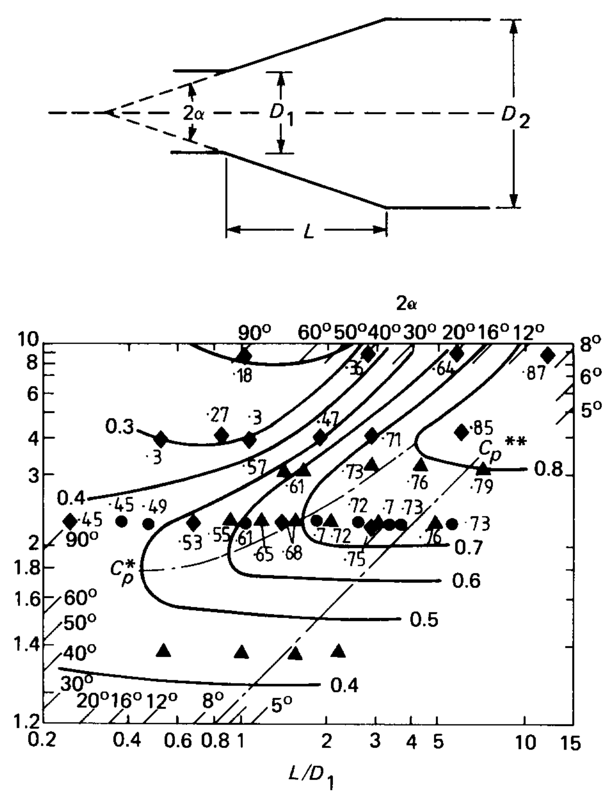

Figure 5 Pressure recovery coefficient for conical diffusers with tailpipe: (⬄) Gibson (1919), (○) Peters (1931), (▲) Miller (1971); (from Ward-Smith[1])

While plate BB is moved from one location to another the values of C_{p1} and C_{p2} change (see Table 1). These pressure recovery coefficients used in evaluating Eq (6) have been extracted from Fig 5. This figure presents the pressure recovery coefficient C_p for conical diffusers in terms of the area ratio (A_{exit}/A_{inlet}) and dimensionless length L/D_1. Since the present diffuser is pyramidal the hydraulic diameter is used instead of the diameter. Consequently, values of C_{p1} and C_{p2} were obtained from Fig 5 in the following way: C_{p1} according to A_2/A_1, L_1/D_1; and C_{p2} according to A_4/A_2, L_2/D_2 (see Table 1). As reported by Sahin[6], experimental values of the plate resistance coefficient K, of 6.4, 2.9 and 1.9 have been determined for the plates with porosities β of 0.4, 0.5 and 0.58, respectively. Finally, the overall pressure recovery coefficient C_p is determined by substitution in Eq (6) for each plate–diffuser combination. The results are presented in Fig 6.

When the plate BB is located at entry, the parameter $L/W=0$, and Eq (6) becomes

$$\frac{p_5-p_1}{\frac{1}{2}\rho U_1^2}=C_p=C_{p2}-K-K\left[\frac{A_1}{A_4}\right]^2 \tag{7}$$

Theory II

Theory II assumes ideal flow in the diffuser, so that there is no irrecoverable loss attributable to the diffuser. Rather, the

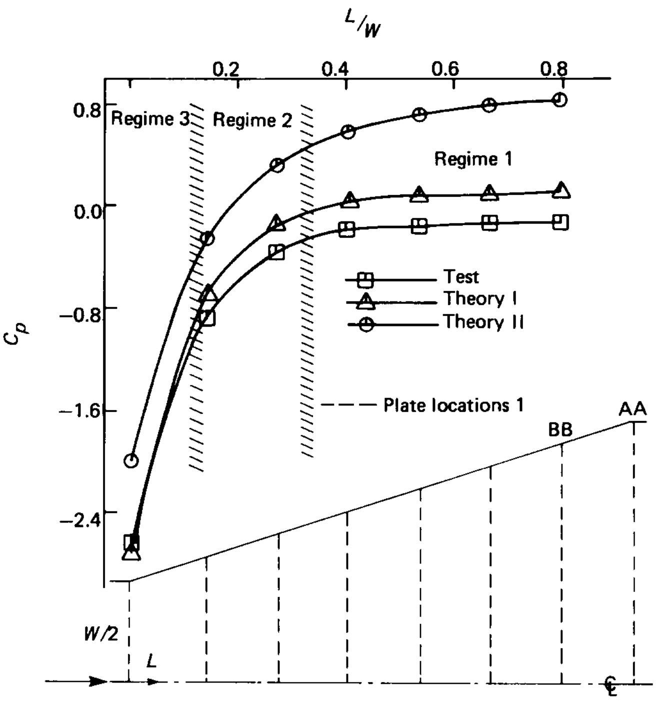

Figure 6 Pressure recovery coefficient through plate–diffuser combinations. Plate AA fixed, position of plate BB variable, β=0.5. Regimes 1, 2 and 3 relate to the type of velocity distributions behind plate AA

Table 1 Data for the geometry of the present diffuser and pressure recovery coefficient[a]

Station No.	A_2/A_1	L_1/D_1	D_1 (cm)	C_{p1}	A_4/A_2	L_2/D_2	C_{p2}	L_2 (cm)	D_2 (cm)	A_2 (m²)	L_1 (cm)
1	5.7	0.79	46	0.24	1.2	0.06	0.35	6	108.5	1.2	36.5
2	4.6	0.66	46	0.26	1.5	0.1	0.43	12	98.2	0.98	30.5
3	3.7	0.53	46	0.32	1.8	0.2	0.40	18	88.3	0.79	24.5
4	2.9	0.40	46	0.38	2.3	0.30	0.37	24	78.1	0.62	18.5
5	2.2	0.27	46	0.42	3.1	0.44	0.36	30	67.1	0.46	12.5
6	1.6	0.14	46	0.43	4.4	0.62	0.27	36	57.5	0.33	6.5
7	1		46		6.8		0.23	42.5	46	0.21	0.0

[a] Extracted from Fig 5

diffuser is assumed to contribute a pressure recovery component. Assuming isentropic flow upstream of the plane of the perforated plate BB, applying one-dimensional flow theory between the inlet of the diffuser and plate BB (Fig 4) gives

$$p_2 - p_1 = \frac{1}{2}\rho U_1^2 - \tfrac{1}{2}\rho U_2^2 \qquad (8)$$

Similarly between plate BB and AA

$$p_4 - p_3 = \tfrac{1}{2}\rho U_3^2 - \tfrac{1}{2}\rho U_4^2 \qquad (9)$$

Consequently, combination of Eqs (3), (4), (8), (9) leads to the equation

$$p_5 - p_1 = \tfrac{1}{2}\rho U_1^2 - \tfrac{1}{2}\rho U_2^2 - K_1 \tfrac{1}{2}\rho U_2^2 + \tfrac{1}{2}\rho U_3^2 - \tfrac{1}{2}\rho U_4^2 - K_2 \tfrac{1}{2}\rho U_4^2 \qquad (10)$$

With $K_1 = K_2 = K$, $U_2 = U_3$ and $A_1 U_1 = A_2 U_2$, and dividing the last equation by $1/2\rho U_1^2$ there results

$$\frac{P_5 - P_1}{\tfrac{1}{2}\rho U_1^2} = C_p = 1 - K\left[\left(\frac{A_1}{A_2}\right)^2 + \left(\frac{A_1}{A_4}\right)^2\right] - \left(\frac{A_1}{A_4}\right)^2 \qquad (11)$$

Finally, C_p can be evaluated for each plate–diffuser combination using the known values of K, and the results are presented in Fig 6 for $\beta = 0.5$. The coefficient of pressure recovery through the diffuser in the absence of plates is $C_p = 1 - (A_1/A_4)^2 = 0.98$. In the presence of perforated plates a negative pressure recovery occurs through the present plate–diffuser combinations.

Fig 6 shows that the values of C_p are in the order Theory II > Theory I > Experiment. It is worth mentioning that Fig 5 only indicates values of pressure recovery coefficient C_p corresponding to the range $0.2 \leqslant L/D_1 \leqslant 15$ and is established for conical diffusers, whereas the present diffuser is a three-dimensional pyramidal diffuser and the dimensionless length L/W is in the range $0.0 < L/W \leqslant 0.924$, so that some values of C_p are extrapolated. Consequently, some differences appear between theory I and experiment due to the two different geometries of the diffuser. Although perforated plates of low porosity cause high pressure losses, which increase as the plate is moved further upstream within the diffuser, they have the beneficial effect of suppressing separation.

Discussion

Velocity distribution

Geometry has an important influence on the flow features for short wide-angle diffusers[1,9]. In the absence of internal flow control, in a wide-angle diffuser the flow separates from the duct walls very close to the point where they start to diverge. Large regions of reversed flow are formed over the surfaces of the diverging walls, whilst a region of high axial velocity is established in the region of the diffuser axis and proceeds through the diffuser[10]. Sideways flapping motion may also be established by the jet[11]. The frequency of the flapping motion remains constant in the lateral direction, whereas it decreases in the longitudinal direction, and its presence is to some extent hidden in the manifestations of the general turbulent activity. Indirect evidence of this flapping type of motion was found in the present rig when, during the preliminary tests, it was run without perforated plates in the diffuser. The walls of the test section were subjected to a severe oscillatory force, which disappeared as soon as perforated plates were introduced into the flow. As uncontrolled diffuser flow was outside the scope of the present work, no attempt was made to take measurements within this unsatisfactory unsteady flow.

The action of a solid plane wall set perpendicular to an axial jet can be considered qualitatively as follows. As the flow approaches the solid wall the flow streamlines tend to diverge, then finally become nearly normal to the original direction. Factors of this kind explain the ability of a perforated plate of the appropriate porosity to spread the action of the axial jet more widely over the cross-section of the diffuser, thereby reducing the scale of any separated flow region. It is a question of correctly choosing the location and geometry of the plates so that separated flow is eliminated whilst excessive diversion of the axial jet to the wall region is avoided.

The design of electrostatic precipitators as a whole needs special attention and care from the aerodynamic point of view. The efficacy of these systems depends vitally on the uniformity of gas flow distribution within the collection chamber downstream of the diffuser exit plane. Any localized region of high velocity would tend to sweep dust particles past the collector plates.

By the appropriate choice of screen geometry and position within the diffuser, separation can be entirely prevented when using two plates, but separation prevention alone is not a sufficient solution for the achievement of uniform diffuser-exit flow. For example, the accumulation of flow in close proximity of the walls may cause a retarded flow region in the vicinity of the axis (see Fig 7). In order to obtain a uniform flow over the cross-section of the diffuser exit, the proper selection of the porosity, the location and number of the plates must be made.

In order that the velocity profile at exit from the diffuser maintains an approximate state of equilibrium in the treatment zone downstream, residual deflection angles, which are created by imperfect plate–diffuser matching, must be avoided. For this reason, it was found that the plate AA should be positioned upstream from the diffuser exit in order to let the flow recover from the immediate effects of the spreading action of the plates in the final stages of the diffuser. By suitable choice of the position of the final plate, the flow direction becomes parallel to the axis at the entry to the collection chamber, and further axial adjustments of the velocity profile are avoided.

Plates of porosity $\beta = 0.58$ provided insufficient spreading action, and high velocities were measured in the central region of the diffuser exit plane (see, for example, Fig 8).

From the velocity and pressure measurements discussed above, together with measurements of flow angle, as illustrated in Fig 9, it was possible to assemble a composite picture of the flow pattern in the diffuser. Some examples are shown in Figs 10(a), 10(b) and 10(c). Where separation occurred, no attempt is made to indicate the form of the streamlines within the separated region, as the number of readings taken was insufficient to define the streamlines with any great precision.

The present tests were conducted in a diffuser of fixed pyramidal geometry, but it may be helpful to provide some guidance on the effects of changes in the diffuser included angles. It has been clearly established that the ability of a plate to change the direction of the incident flow increases with decrease in porosity. Thus, diffusers with very large included angles require plates of porosity less than 50% to improve the flow uniformity at exit. Conversely, as the included angle decreases, so plates of increasing porosity are appropriate.

Experimental investigations showed that the characteristics of the perforated plates are governed principally by the locations of the plates and their porosity β.

The direction and the uniformity of the emergent flow was principally controlled according to the variation of the location of plate BB.

Tests demonstrated that the distance between two plates has an influence on the spreading action of the downstream plate AA. Decreasing this distance, either by moving plate BB downstream from an upstream position or moving plate AA upstream from a downstream position, increases the deflection angle of the emergent flow behind the plate AA.

A nonuniform velocity across the precipitator collection-chamber cross-section reduces the collecting efficiency. Consequently, the Industrial Gas Cleaning Institute established the electrostatic precipitator inlet gas uniformity standard[4]. The local velocity distribution over the cross-section of the collection chamber should have a minimum 85% of the readings within 25% of the mean velocity, with no reading varying more than 40% from the mean velocity; the rms deviation should be 15%

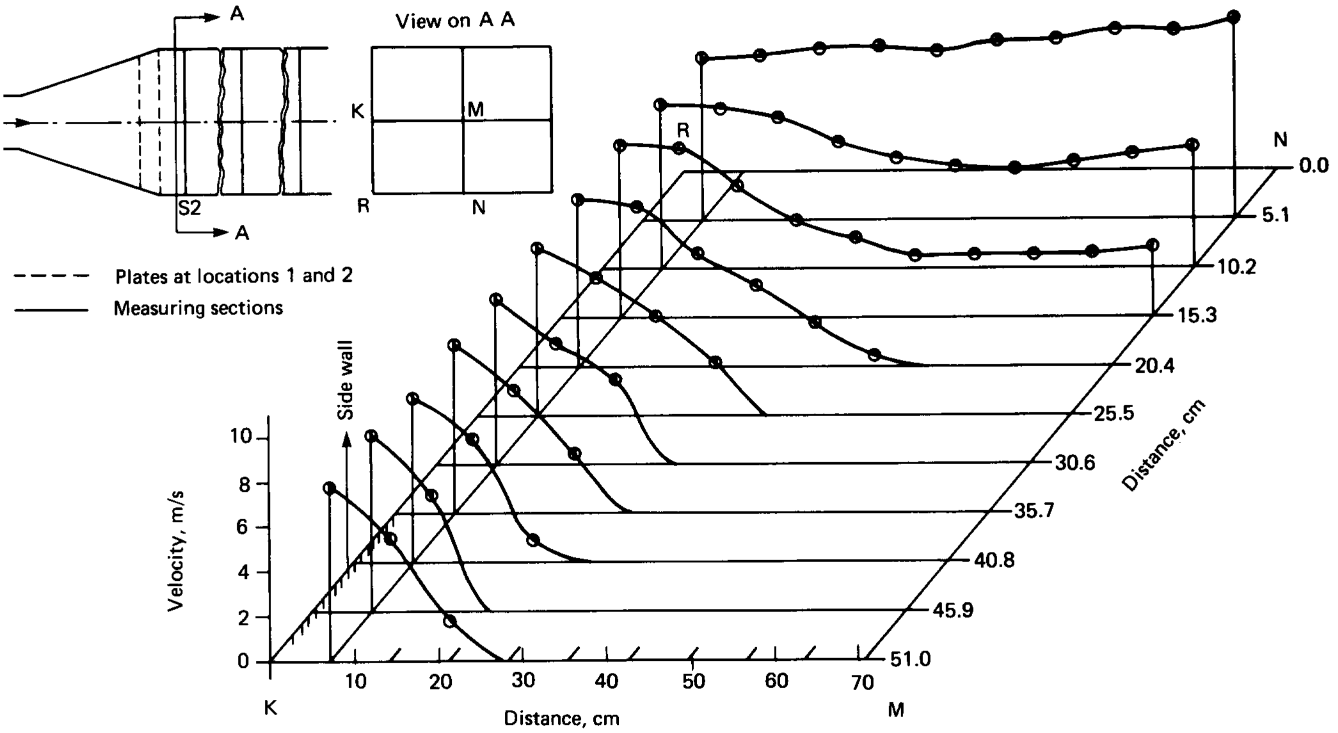

Figure 7 Velocity distributions over a quarter of the measuring section S2; $\beta=0.4$

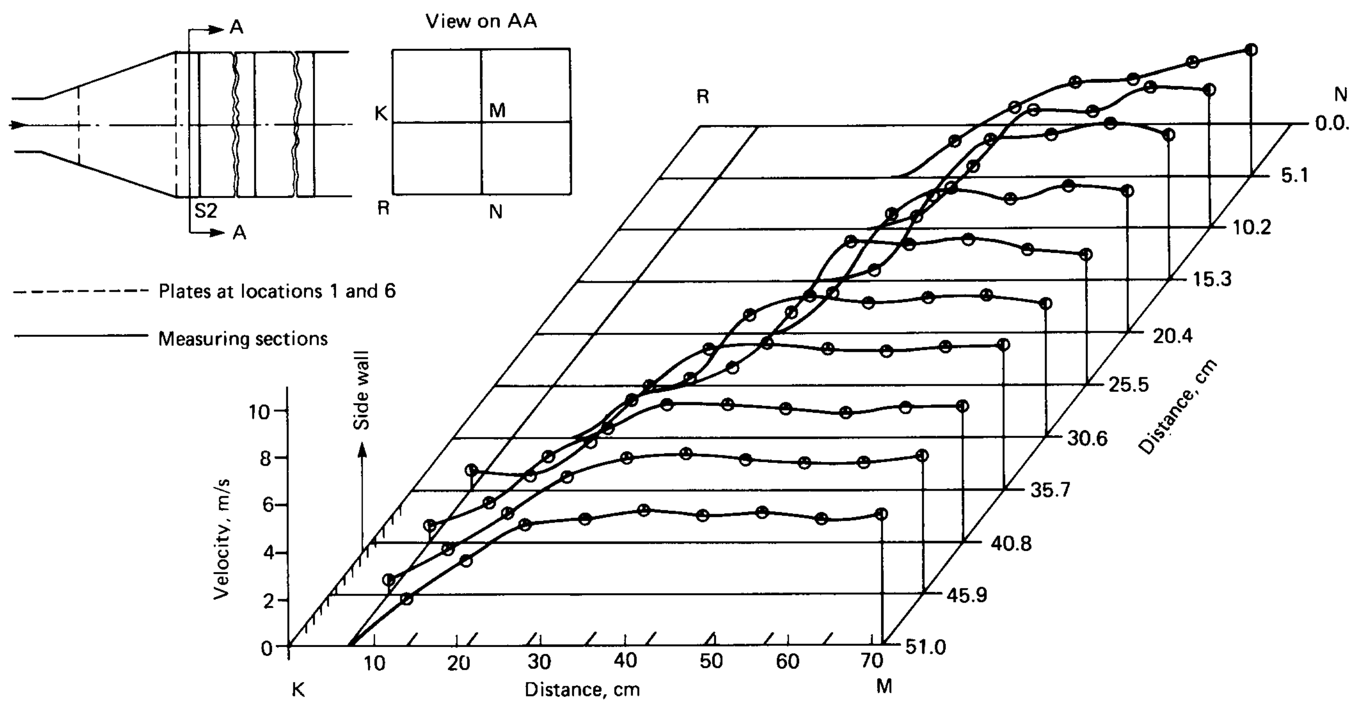

Figure 8 Velocity distribution over a quarter of the measuring section S2; $\beta=0.58$

or less. Based on this standard, the most successful combination of plates had $\beta=0.5$ and the plates were located at $L/W=0.14$ and $L/W=0.78$. For this combination, 94% of the local velocity readings taken at measuring section S2 lie within 25% of the mean velocity, with no reading varying more than 40%, and rms standard deviations of 15%, 16.8% and 13% were obtained at measuring sections S2, S3 and S4, respectively.

Pressure drop characteristics

The relationship between the velocity field emerging from the diffuser and the pressure recovery or pressure loss characteristics of the plate–diffuser combination are of considerable importance, and this is considered in greater detail in Fig 6. Three separate flow regimes are shown in Fig 6, which represents the pressure drop characteristics for the plate which has porosity β of 0.50. Plate AA is fixed at the outlet of the diffuser and the location of plate BB is variable.

Regime 1 corresponds to positions of plate BB in the range $0.40 < L/W < 0.92$. In this range pressure losses are a minimum and a wall-jet was found in the velocity profile behind the plate AA in the collection chamber.

Regime 2 contains the most uniform velocity profiles. A uniform velocity profile can be obtained when the plate BB was located in the range $0.14 \leqslant L/W \leqslant 0.27$ (Fig 6) with plate AA at or near the exit. The optimum uniform flow profile was obtained

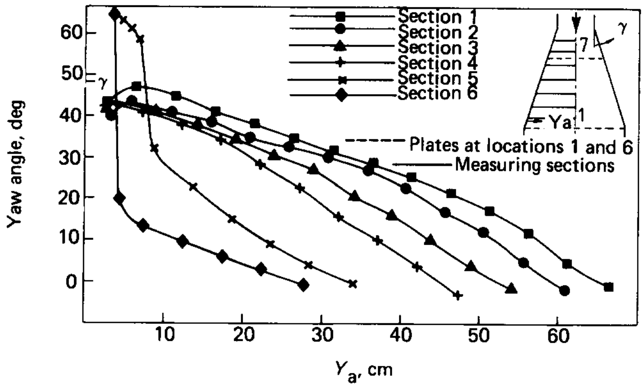

Figure 9 Component of flow direction at the horizontal axis of the measuring sections; $\beta=0.5$, $2\gamma=97°$

by locating the plate BB at station 7, $L/W=0.14$, with plate AA at station 2, $L/W=0.79$. Fig 6 indicates that there is a progressive increase in the pressure drop for decreasing L/W in this regime.

The change of pressure drop in regime 3, compared with other regimes, is increasingly rapid. Locating the plate BB in this regime in the range $0 \leqslant L/W \leqslant 0.14$ (Fig 6) causes a high pressure drop whilst a nonuniform flow remains at the diffuser exit. Flow geometries in this regime are not effective in generating the desired velocity distributions, and the flow remains concentrated in the region of the jet axis. Whilst giving rise to high pressure losses the plates are ineffective in spreading flow more uniformly.

It is worth noting that good flow uniformity at exit has been achieved using two perforated plates, provided they were properly located. Previously Mehta[3] had suggested that 3 or more plates would be required for diffusers of the geometry investigated here.

Concluding remarks

Tests are reported here on the use of perforated plates to control the velocity distribution emerging from a wide-angle, three-dimensional diffuser of area ratio 6.8. The diffuser had wall angles 2γ and 2α of 97° and 67°, respectively. The geometry of the diffuser was identical to that tested by Reynolds and Page[5] in their investigations relating to the design of systems for electrostatic precipitators.

It was found that the most uniform velocity distributions in the collection chamber downstream of the diffuser were achieved using two perforated plates of porosity $\beta=0.5$. The best results were obtained with one of the plates positioned a short distance downstream of the diffuser entry plane (at location 7, $L/W=0.14$) with the second plate just upstream of the exit plane, at location 2, $L/W=0.79$.

Using plates of porosity $\beta=0.4$, it was found that the flow tended to accumulate along the walls of the diffuser, leading to nonuniform conditions at exit. Conversely, plates of porosity $\beta=0.58$ provided insufficient spreading action, and high flow velocities were found in the central region of the diffuser exit plane.

The main effects on the flow in wide-angle diffusers were found to be due to plate location L/W, porosity β, and the number of plates. A proper selection of these three factors can eliminate separation, with the satisfactory achievement of a uniform velocity profile at the diffuser exit.

Acknowledgement

B. Sahin would like to thank the Turkish Ministry of Education, Ankara, Turkey, for its financial support.

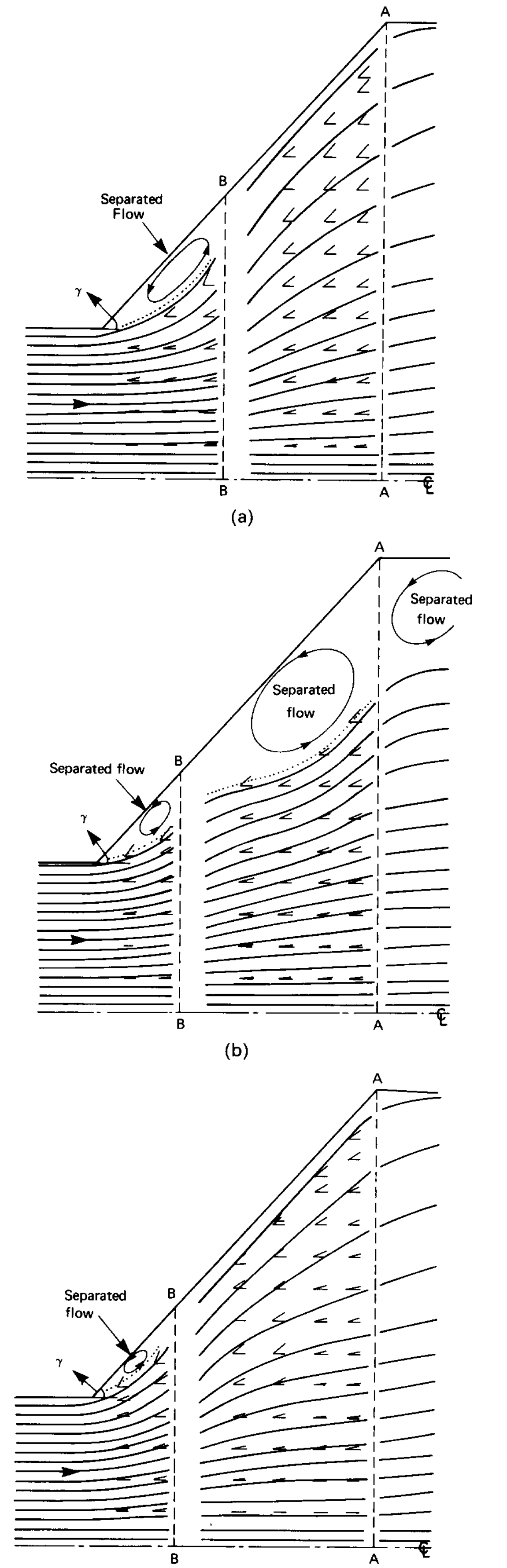

Figure 10 Diagram of the flow pattern in the horizontal and vertical central planes in the diffuser; $2\gamma=97°$; ------ plate location; ······ boundary of the separate flow regions; < local flow angle: (a) $\beta=0.5$; (b) $\beta=0.58$; (c) $\beta=0.4$

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