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A Design of Two Partial Walled Ultra Clean Systems

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INTRODUCTION

Conventionally, ultra-clean ventilation (UCV) system for operating rooms have air supplied from fillers in a downward direction and the air is contained with walls which come to within about 1 foot of the floor; the airflow is generally good (Fig 1).

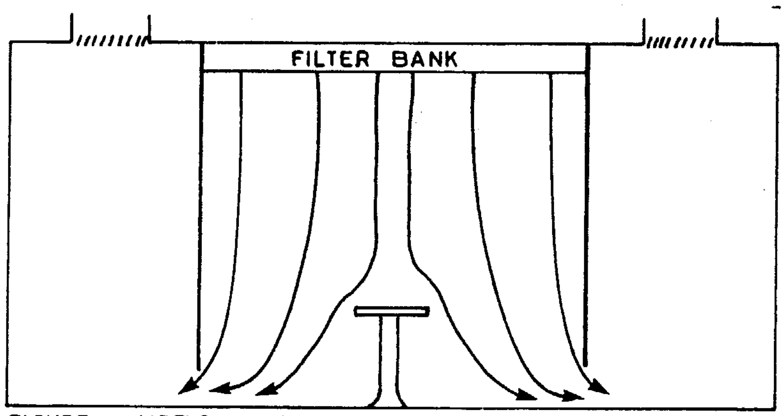

FIGURE 1. AIRFLOW IN FULL WALLED SYSTEM

More recently, partial walled systems have been used in which the wall comes down only a short distance from the fillers and about 2 meters from the floor. Difficulty can be experienced in achieving good airflow due to three problems.

(a) If the air filter supply is warmer than the ambient room temperature the air has difficulty reaching the table because of buoyancy effects and the bigger the Δ T, the greater this effect (Fig 2).

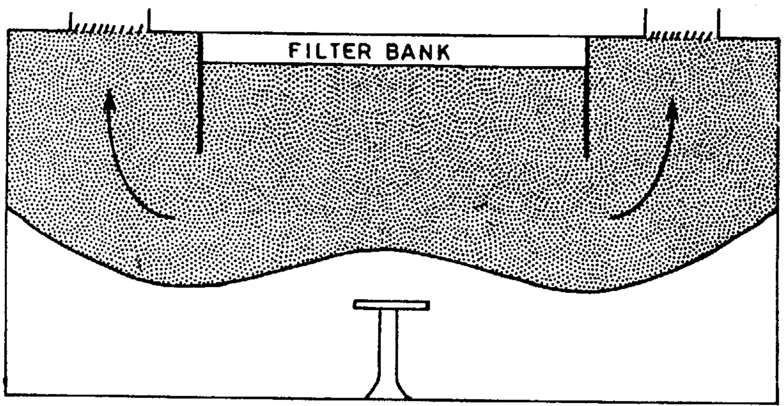

FIGURE 2. BUOYANCY EFFECT IN PARTIAL WALLED SYSTEM

(b) As there are no walls, the more heavily contaminated outside air may enter the clean air and contaminate the sterile area. (Fig 3).

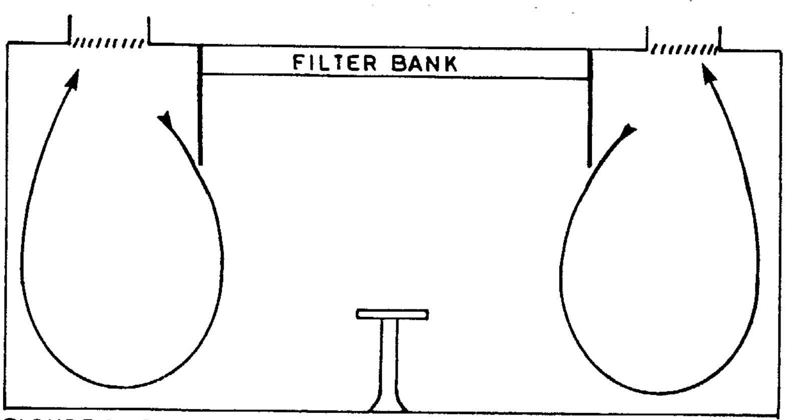

FIGURE 3. ENTRAINMENT IN PARTIAL WALLED SYSTEM

(c) If the return exhausts are in the roof of the operating room (as is normally the case), the air supplied by the filters will turn and move upwards to the exhausts rather than travel downwards, as achieved with the full walled system. (Fig 4). Less clean air therfore reaches the critical area around the wound.

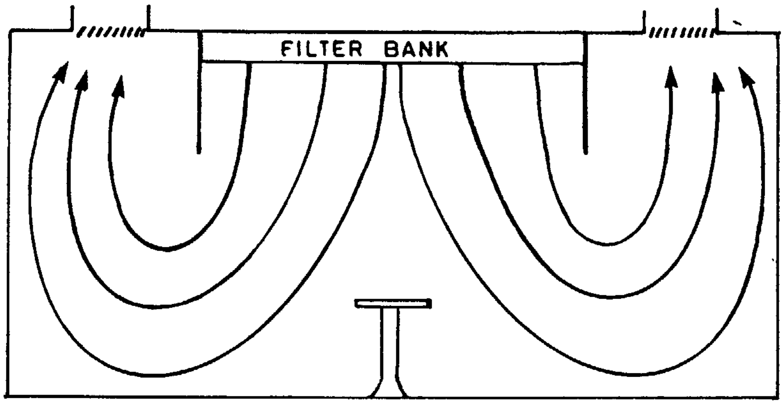

FIGURE 4. AIRFLOW IN PARTIAL WALLED SYSTEM

The problem of a temperature difference must be overcome by assuring that the air supplied is never warmer than the operating room. This may be difficult, as in cold weather, especially with operating rooms with high fabric losses, a warm air supply will be required. The problems of entrainment and containment are difficult ones and influenced by the design of the system. To overcome entrainment, high level extracts have been recommended to ensure that the air direction is contrary to that of the direction of entrainment. However, by pulling air to the extract, less air is available at a lower level for ensuring cleanliness of the whole sterile area. To ensure air flow to a lower level, extracts at floor as well as ceiling level have also been suggested, but these are very difficult to provide and hence very expensive. Walls which do not come to floor level, but 1 metre from the floor, have been suggested as a compromise, in which good air flow, good discipline and reasonable access is provided. It was uncertain which of these options would provide the best answer and so this report was commissioned by the Work Group 10 of the Engineering Division of the DHSS.

Experimental Sites. Two hospital sites were studied. One theatre contained a MAT unit, the other a Charnley Howorth Exflow unit. The same consultant surgeon used the two theatres, but the rest of the operating room personnel were different.

In the Charnley Howorth theatre, the operating team wore Charnley total-body exhaust gowns, but the rest of the personnel wore cotton garments. The average velocity in this system was difficult to measure, largely due to the system

being designed with a varying velocity across the filter face. However, the average velocity 1 metre from the filter in the high speed area of the system was about 0.5 m/s and in the low speed perimeter area about 0.25 m/s, giving an average airflow of about 0.35 m/s.
In the MAT theatre all personnel wore Selguard clothing. This is a polysceter clothing supplied by Fishers Services. The average velocity 1 metre from the filter face was 0.4 m/s. This velocity was reduced to 0.35 m/s for a second set of experiments concerned with the measurement of velocity profiles.

Method of Measuring Velocity Profiles. Because of architectural problems, the MAT system was not located centrally in the room. This was very fortunate, as it was possible to measure velocity profiles around the periphery of the enclosure, when the theatre walls were at different distances from the partial walls. No additional screens were hung on the system, the partial wall being about 2 metres from the floor. A measuring grid was erected at the perimeter of three of the sides of the enclosure. The direction of the air at points on the grid was determined by smoke and the velocity determined by a recently calibrated vane anomometer. Owing to the sucess of the experiments at 0.4 m/s it was decided to repeat this experiment at 0.35 m/s. Only two sides of the system were measured. At the Charnley Howorth theatre, the air speeds were determined at only one side of the system. The area for study was chosen to approximately correspond to one of the theatre wall distances that had been studied in the MAT system. The velocities were slower than with the MAT system; a low speed DISA anaemometer was therefore used.
All equipment in both these rooms was switched off and there was only one person in the room. The air supply temperature in these room was therefore within 0.1^{o} C of the ambient room air.

Method of Measuring Airborne Bacteria. The airborne bacteria were measured by use of a modified high volume Casella slit sampler (700 l/min). By use of a sterile cone, bacteria were sampled within 30 cms of the wound. Bacteria were also sampled at the perimeter of the clean air enclosure and 1 metre from the edge of the partial wall or screen of the clean air enclosure.

All samples were taken at about 1 metre from the floor; this corresponds approximately to the height of the wound and instrument tables. Two bacteria samplers were used. One was used continually to sample air at the wound. About 6, ten minute samples were taken throughout each operation. The other sampler alternated between the edge of the sterile zone (5min sample) and 1 metre outside it (2 min sample). A further three to four samples form each of these two sites were usually obtained.

Operating Studies. Three operations were studied at the MAT theatre. A total hip replacement was studied with panels, which came down to 1 metre from the floor, in place. A total knee replacement was studied in which the panels were removed and replaced during the operation. Finally, a total hip operation was studied in which there were no additional panels in place. The experimental balance between the system with and without the panels was therefore good,

Two total hip replacement operations were studied at the theatre which contained the Charnley Howorth Exflow System.

RESULTS

Velocity profiles from MAT System. Shown in Fig 5, 6 and 7, is the air velocity and direction of the air as it flowed from air filters to exhaust, at three sides of the system. Three results were obtained when the average supply velocity was 0.4 m/s. Shown in Fig 8 and 9 are the profiles obtained when the average velocity was reduced to 0.35 m/s. The air direction is given by an arrow, the size of which is proportional to the velocity. Where a directional arrow is given but no velocity, the velocity is below 0.25 m/s. Where no directional arrow is given, the direction of the air was indeterminate.

Given in figures 5, 6 and 7 is a line of velocity approximately equal to 0.25 m/s, in that area where the supply air comes in contact with room air. These lines should not be considered as particularly significant, but rather as a means of easily seeing the differences between the velocity profiles of the sets of results. A similar line, but at a velocity of 0.20 m/s is shown in Fig 8 and 9.

Velocity profile from Charnley Howorth System. Only one velocity profile was obtained and is shown in Fig 10. The study area was chosen which had a similar distance from the enclosure to the wall to one of the MAT distances. Because of the lower velocities at the periphery of the Howorth Charnley Exflow system, an area slightly above average velocity was chosen. Because of the lower velocities measured, the results are given in cm/sec.

Airborne Bacteriological Results. Given in Table 1 is the average results obtained from the two systems. No statistical difference could be demonstrated in the MAT system whether panels were used or not. No difference could be demonstrated at the wound between the MAT and Howorth system but the counts at the perimeter and outside the clean air enclosure were statistically significant.

When the velocity profiles of the MAT and Howorth were compared, there appear to be little difference. This was not surprising as the difference in velocity between the two systems at the periphery was small and unlikely to seriously affect the air direction.

Excellent bacteriological results were obtained from both systems. The MRC Committee on Ultra Clean Operating Rooms has suggested the airborne concentration should not exceed $10/m^3$ at the wound and $20/m^3$ in the rest of the clean area. However, they also suggest that $1/m^3$ at the wound would be a more desirable figure and our own research has shown that when this level is reached the airborne route of infection becomes insignificant. Both systems easily achieved these levels.

Although the MAT system achieved almost identicle levels when the panels were on or off, it is not suggested that systems with no panels be advocated for major surgery. There are several reasons for this. Panels work very effectivly in preventing casual observers getting close to the wound. Although the bacterial counts at the perimeter of the Charnley Howorth system are excellent, use of a longer wall would have produced even better results. It is also true that both of the systems studied have been designed and built by experts who are aware of problems of thermal differences,entrainment and containment. Other firms may not produce such effective systems. Engineering a partial walled system is not simple and walls, 1 metre (or less) from the floor, are an additional safety measure.

Is was also interesting to note that use of Fisher's Selguard clothing gave results at the wound which were as good as total body gowns. It was also found that the bacterial count in the general theatre area was substantially less (about 6x) in the room using the MAT system compared to the Howorth system. There were, on average, fewer staff in this MAT theatre (7 or 8 people compared to 8 or 9) and this would contribute to the lower bacterial number. However, a more likely reason is the use of Selguard clothing by all the theatre staff in the MAT theatre. These counts outside the enclosure will have little practical importance, although, when no panels are used, more bacteria from the theatre air will be entrained into the sterile area. The higher count at the perimeter of the sterile area of the Charnley Howorth system almost certainly reflects this, but this slightly elevated count is unlikely to contribute significantly to contamination of the surgical instuments.

System	At wound	At perimeter of sterile zone	1 metre outside zone
MAT, with panels	0.59	0.14	10.3
MAT, without panels	0.59	0.16	7.5
Charnley Howorth without panels	0.45	1.45	64.3

Conclusions. The main conclusion of this report is that both of these systems worked well and gave excellent results.

One of the principal reason for carrying out this work was to see if low extracts were necessary. The conclusion of this report must be that low level extracts are not necessary. The supply air in both systems and in the MAT system at the lower velocity was shown at the periphery of both systems to drop below table level before turning noticably and therefore the use of low level extract would have little additional benefit. The air supply temperature and room temperature were, during these studies, isothermal; a higher air supply temperature would invalidate this conclusion and lower extract may then be of benefit.

It was found that the distance the sterile enclosure was from the wall had a very significant effect on the velocity profiles. When the system was close to the wall, the air had to turn more quickly to the exhausts. When the wall was well away from the system, the air turned much more leisurely. However, even in the case where the air had to turn quickly, the velocity and air direction at the area where the surgical instruments would be found was very satisfactory. These were excellant results and it was considered worth seeing if a lower velocity would give much poorer profiles. When the velocity in the MAT system was reduced to 0.35 m/s an almost identicle profile was obtained. This is, on reflection not so surprising, as the velocity drop was small, the condition isothermal and there is no important effect such as drag to seriously change the airflow pattern. These results seem to suggest that lower velocities are as suitable as higher ones. This is not so, as the effect of any temperature differential would be more pronouced at lower velocity and there must be sufficient air to allow the system to recover quickly from movement by the surgeons and to dilute areas of vortex production and stagnacy. Previous research work suggest that 0.3 m/s for a full walled system and about 20% more air for a partial walled system, would be the lower limit.

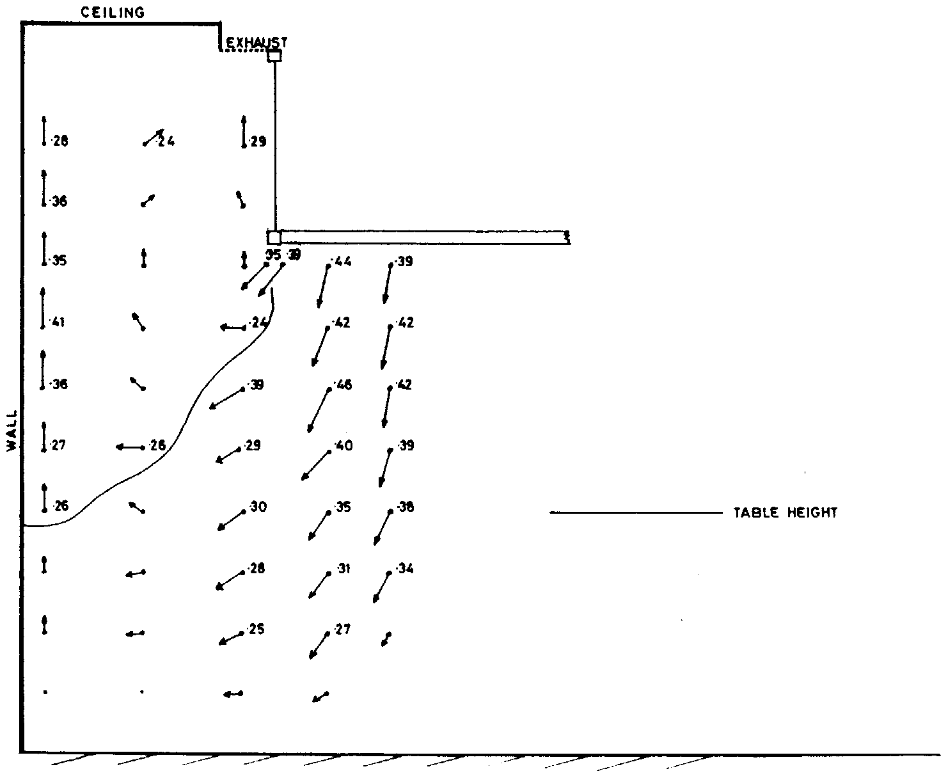

FIGURE 5 Velocity profile MAT system, 1.06m from wall (0.4 m/s)

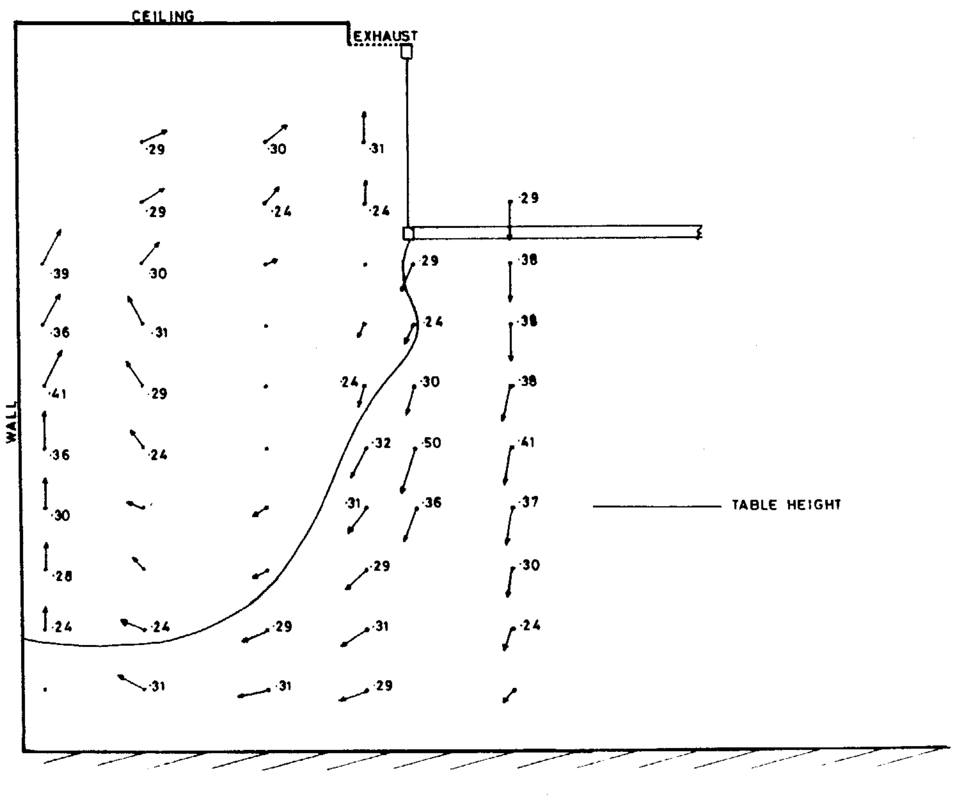

FIGURE 6 Velocity profile MAT system, 1.57m from wall (0.4 m/s)

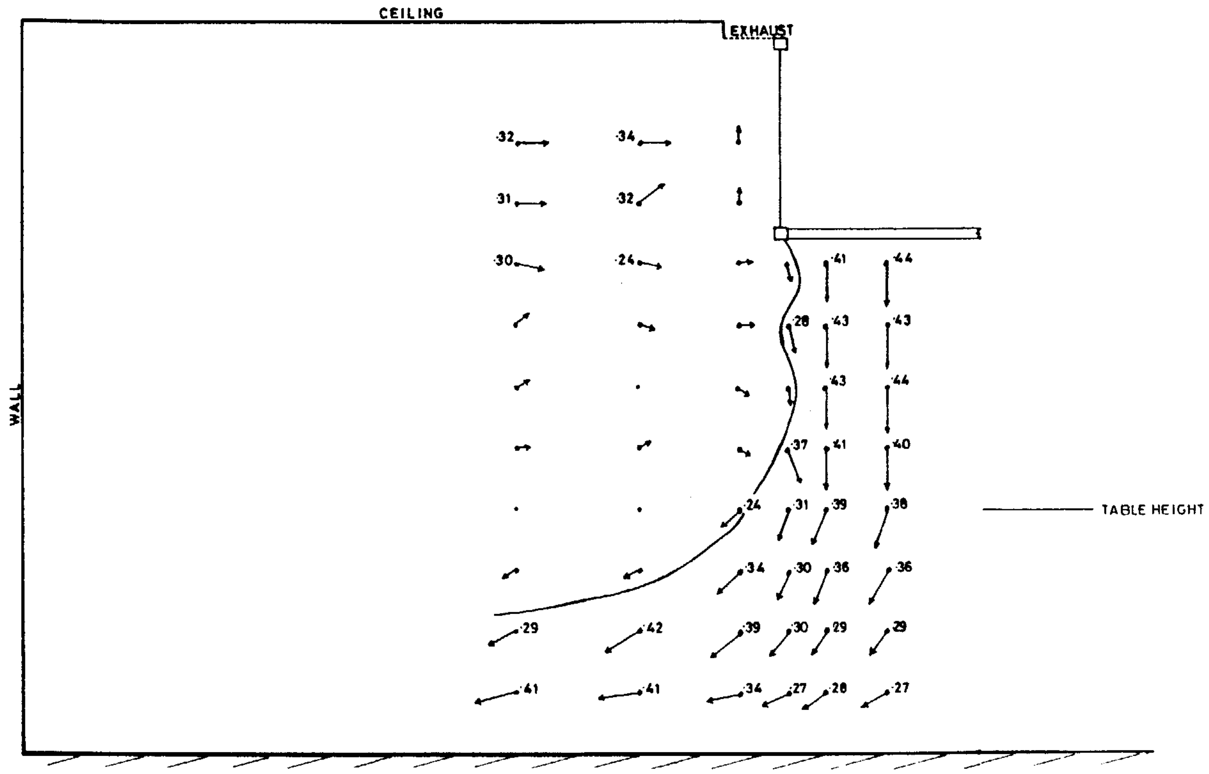

FIGURE 7 Velocity profile MAT system, 3.10m from wall (0.4 m/s)

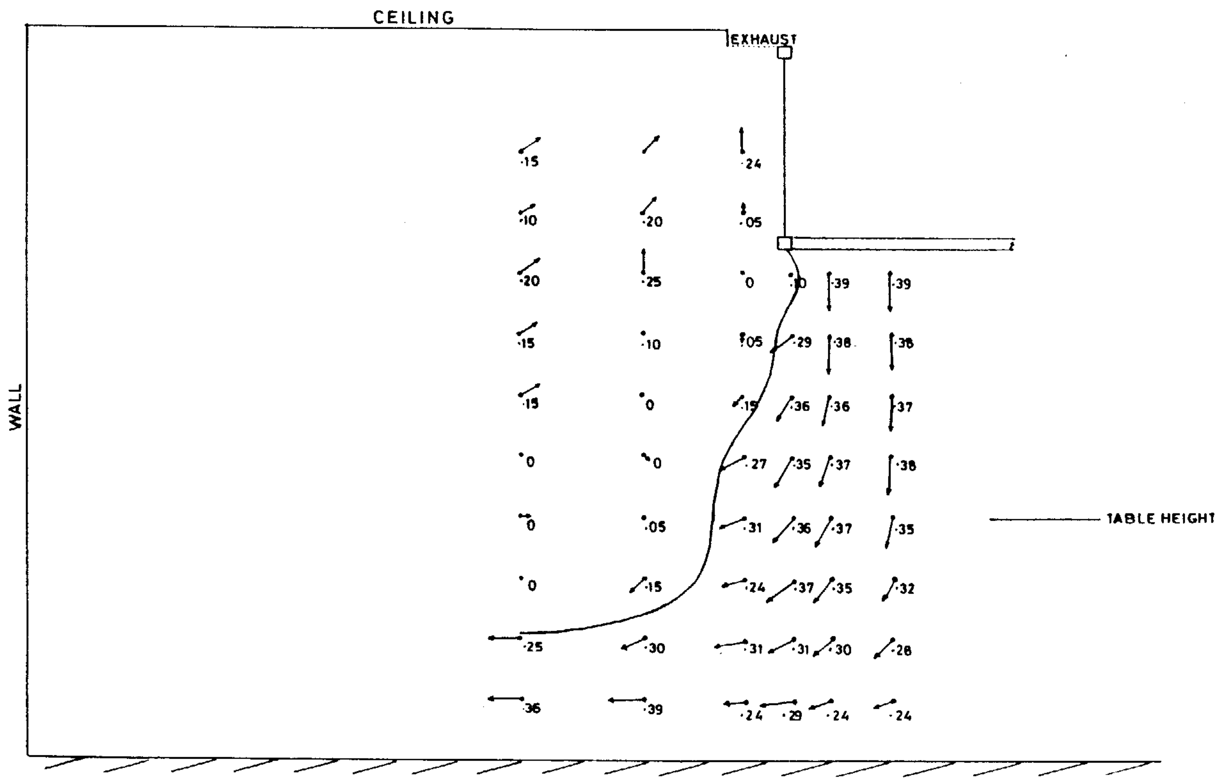

FIGURE 8 Velocity profile MAT system, 3.10m from wall (0.35 m/s)

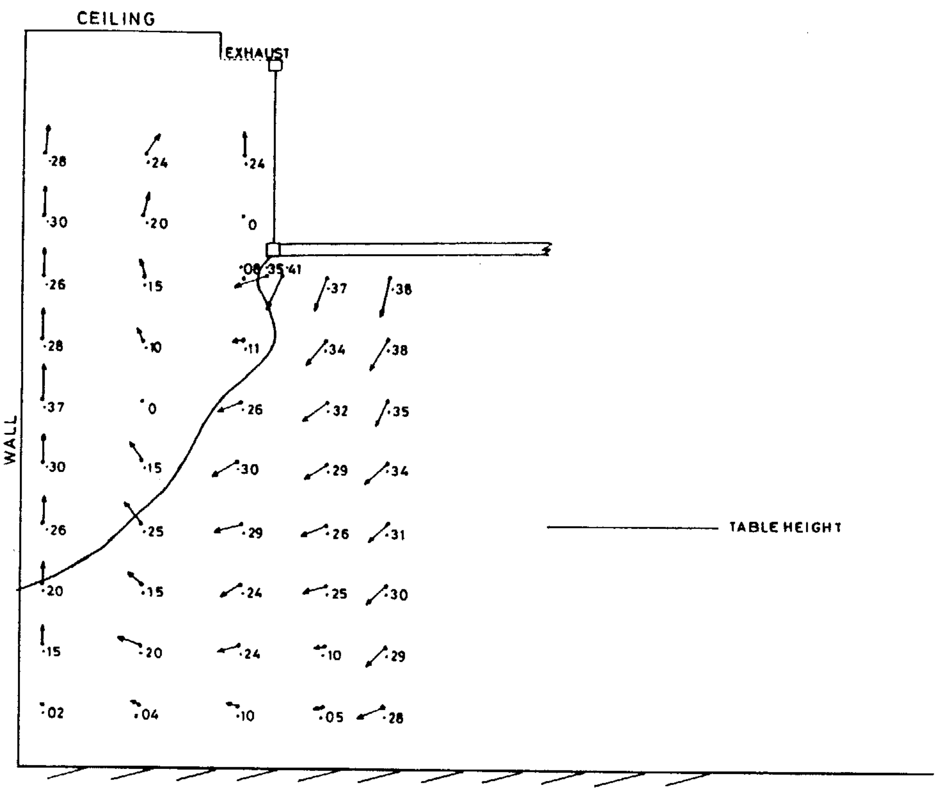

FIGURE 9 Velocity profile MAT system, 1,06m from wall (0.35 m/s)

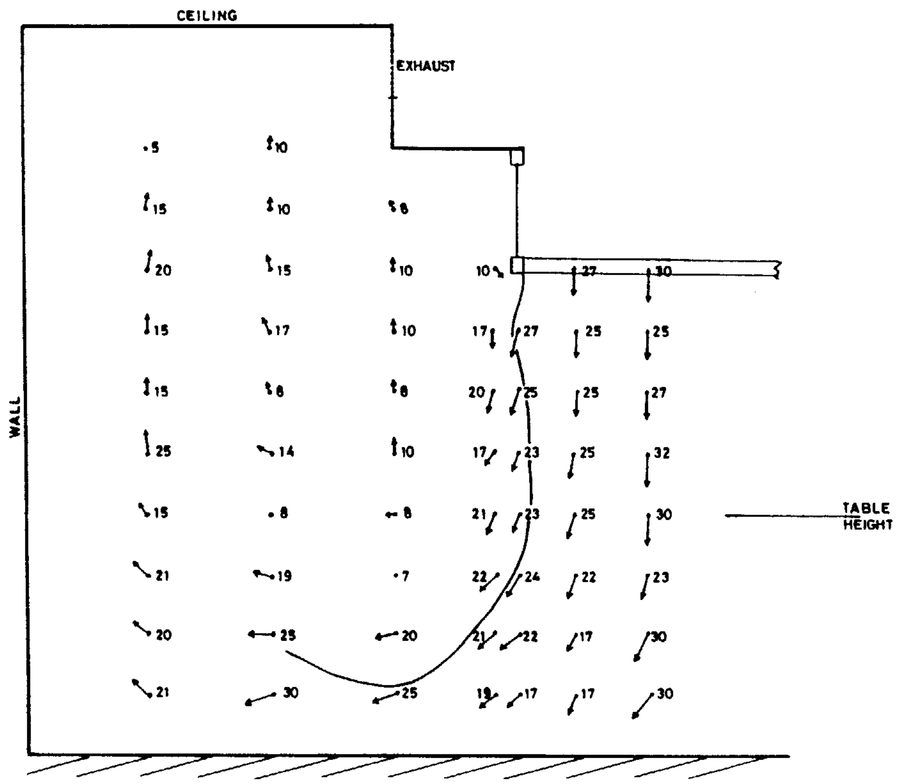

FIGURE 10 Velocity profile of Charnley Howorth system, 1.95m from wall