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Visualization of Air Flow around Obstacles in Laminar Flow Type Clean Room with Laser Light Sheet

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1.INTRODUCTION

Recently, in such advanced technological areas as LSI factories or chemical industries, a clean room system has become indispensable equipment for precise control of airborne contaminants. The air flow in a laminar flow type clean room is very simple when no apparatuses are set up or no operators are present. However there is much equipment and many operators in an actual clean room, and these generate dust into the air flow. Moreover, the air flow around such apparatus or operators is usually highly turbulent and swirly and thus likely to contaminate manufacturing processes.

It is thus important to design an air flow system which can exhaust the dust generated in the room efficiently and which does not diffuse the dust into the larger area of the room. In a laminar flow type clean room, dust is expected to be exhausted without diffusion by means of the plug flow system. But since the air flow is disturbed by the turbulence generated by the apparatus or operators, it is essential that the characteristics of the air flow around flow obstacles such as operators and apparatus be clarified.

In this study a scale model of the laminar flow type clean room is used to visualize the air flow patterns in it. Rectangular prism models with various shapes are used as simplified apparatus. For the flow visualization, a laser light sheet [1),2)] and fine magnesium carbonate powder are adopted as the light source and the tracer respectively. The laser beam is scattered by tracer particles and they are photographed and recorded on video tapes [3)]. Both standing vortexes and turbulent flow around apparatus are analyzed in detail. Basic design data are obtained by observing the flow patterns around apparatus of many shapes and arrangements.

2.DESCRIPTION OF EXPERIMENTAL METHOD

2.1 Clean Room Model and Apparatus Model

Fig.1 shows the 1/6 scale model of the laminar flow type clean room whose dimension is 6m(width)×6m(depth)×3m(height) in actual size. This model is composed of a plenum chamber, an exhaust chamber, and a clean room. Part of the ceiling is made of a wire mesh and a perforated metal sheet so as to model a HEPA filter. The floor is made of honeycomb shapes and a perforated metal sheet which is the model for a floor grating. In all experiments, the supply air velocity at the ceiling is set at about 0.35m/s, which is the same as that of an actual size clean room. Consequently the Reynolds number of the model clean room is 1/6 compared with that of the actual size clean room. It was confirmed in advance that reducing the Reynolds number has little affect on the air flow pattern.

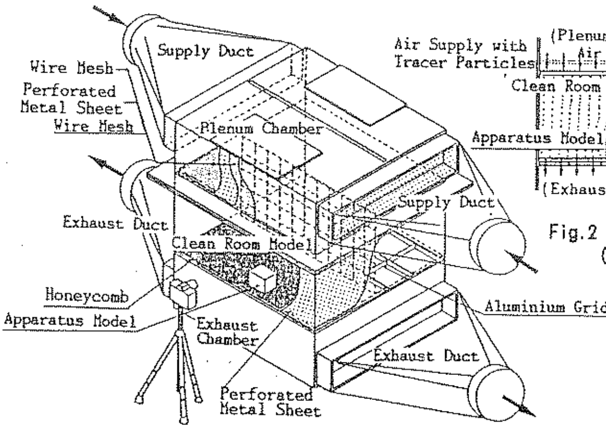


Fig.1 Clean Room Model(1/6 Scale Model)

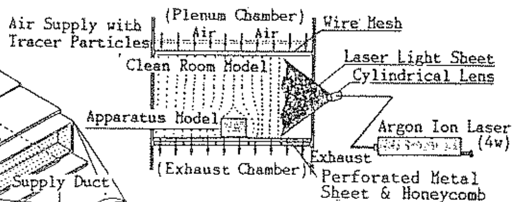


Fig.2 Visualization System (Virtical Section)

Table.1 Photographing Data

Film	ASA1600
Shutter Speed	1-2sec.
Lens	25-50mm Zoom Lens
Iris	4
Distance	0.8 meters

2.2 Visualization System and Photographing Data

Fig.2 shows the visualization system. The light source is an Argon ion laser(4W). The laser beam is led to the cylindrical lens by an optical fiber cable and is then dispersed into a light sheet. Magnesium carbonate powder (Mg_2CO_3, 1 to 10 μm) is used as the tracer. The photographing data are shown in Table 1.

2.3 Experimental Conditions

Various experiments are conducted with changing arrangements of apparatus in the clean room model. Rectangular prism models with various shapes are used as simplified apparatus. In our experiments the rectangular prism { 0.8m(width)×1.0m(depth)×1.0m(height) } is chosen as the basic model of apparatus and a 1/6 scale model is used in the experiment.

The experimental items are as follows.

① Positions of apparatus; ② Shapes of apparatus; ③ Obstacles at ceiling outlets; ④ Positions of the operator around apparatus

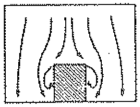
3. RESULTS

3.1 Flow Separations at Side Walls of Apparatus Model

The dimensions given in photos are actual size. (Unit : mm)

(1) Simple Rectangular Prism Model and Side Flow Separations(Photo 1).

Photo 1 shows the air flow in a clean room model in which the rectangular prism model is installed at the center of the floor. The air flow collides with the top surface of the model. Then it separates into two flows and reaches to the side walls. It is clearly observed that the flow is separated from the apparatus at its top corner. The separated flow reattaches to the side walls. Standing vortexes appear inside the separation. Contaminants induced into these vortexes do not seem to be exhausted easily.


Air Flow Pattern

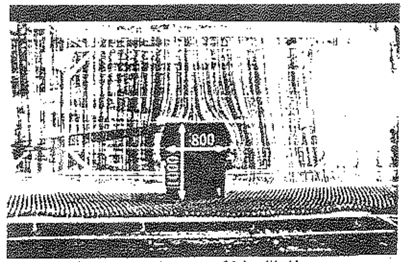
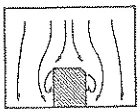


Photo.1 Separation at Side Walls of apparatus Model

(2) Effects of Corner Cutting(Photo 2).

In order to decrease the separated region, the right corner of the top surface was cut off. Photo 2 shows that the separating point on the right side wall moves down to the lower edge of the cut off plane. But the size of separation does not change. Consequently, by cutting off the top corner, it is possible to lower the point of separation apart from the top surface which is to be clean.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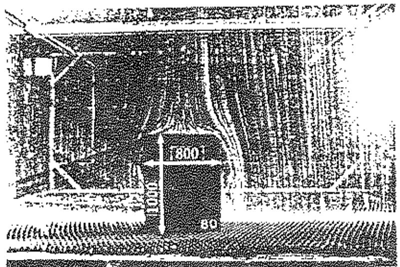
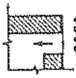


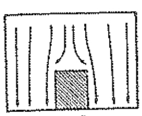
Photo.2 Effect of Corner Cutting

(3) Effect of Suction at Separating Area(Photo 3).

In order to remove the separating area, air inlets are set into the upper side wall of the apparatus model. The size is 950mm(width)×30mm (height) and suction velocity is set at about 0.7m/s(i.e. 2 times of the ambience flow speed). Photo 3 shows the air flow around the apparatus. The separated area disappears. Suction at the separated area is thus very useful in removing the flow separation.



air inlet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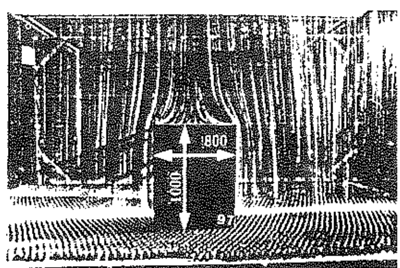
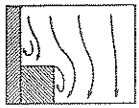


Photo.3 Effect of Suction at Separating Area

3.2 Air Flow around Apparatus Adjacent to Wall

(1) Arranging Apparatus in Contact with Wall(Photo 4).

The basic model is set in contact with a wall. Photo 4 shows that the separation which occurs at the right side wall is just the same as that in photo 1. On the left side of the top surface, a standing vortex appears near the wall. If contaminants are dispersed in this region, they are not exhausted easily.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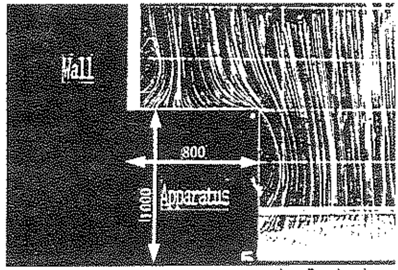
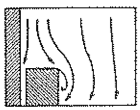


Photo.4 Arranging Apparatus in Contact with Wall

(2) Arranging Apparatus Apart from Wall (Photo 5).

The basic model is set apart from the wall. The distance between the wall and the apparatus is 100mm in actual size. The standing vortex above the upper surface near the wall disappears, so that contaminants can be expected to be exhausted smoothly.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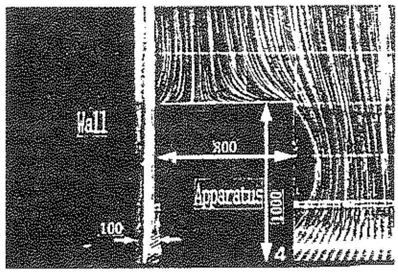
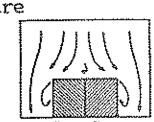


Photo.5 Arranging Apparatus Apart from Wall

3.3 Air Flow around Two Apparatuses

(1) Arranging Two Apparatuses in Contact with Each Other(Photo 6).

Two basic models are arranged in contact with each other. Photo 6 shows that the air flow is stagnant above the center of the top surface and is highly turbulent. There are standing vortexes at the side walls of the apparatus.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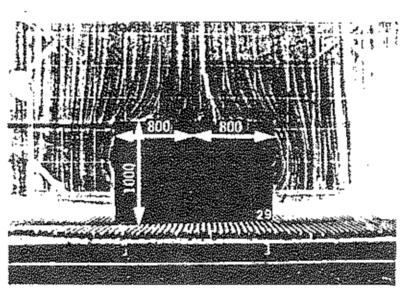
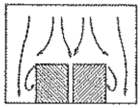


Photo.6 Arranging Two Apparatuses in Contact

(2) Arranging Two Apparatuses with Some Distance(Photo 7).

Two basic models are arranged with a small gap between them which reaches to the floor exhaust. The distance between two apparatuses is 100mm. Photo 7 shows that the air flow above the center of the top surface is not stagnant and is not turbulent compared with the case of Photo 6. Contaminants generated at the top surface will thus be exhausted immediately.



Air Flow Pattern

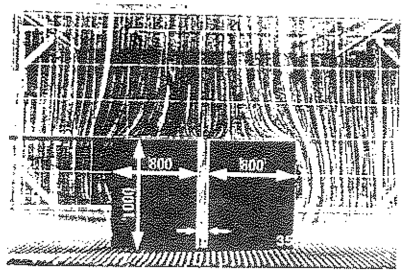
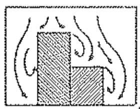


Photo.7 Arranging Two Apparatuses Separately

(3) Arranging Two Apparatuses of Different Heights in Contact with Each Other (Photo 8).

Two apparatuses of different heights are arranged in contact with each other. One is 1,400mm in height (left), the other is 600mm in height (right). Photo 8 shows the air flow around the two models. A standing vortex appears on the right side of the taller one. The air flow is stagnant above the top surface of lower one.



Air Flow Pattern

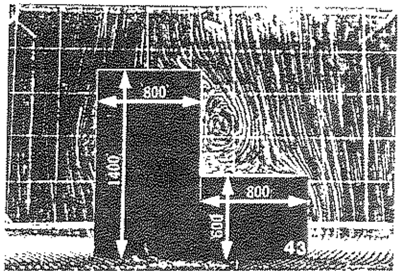
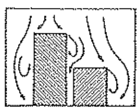


Photo.8 Arranging Two Apparatuses in Contact

(4) Arranging Two Apparatuses of Different Heights Separately(Photo 9).

Photo 9 shows the air flow around two models. As compared with Photo 8, the standing vortex on the right side of the taller one becomes much smaller and no stagnation occurs above the top surface of the lower one.



Air Flow Pattern

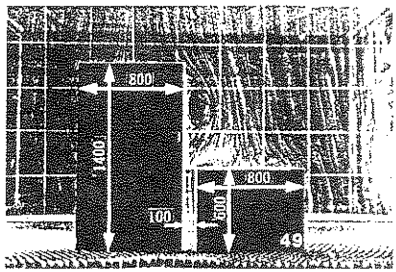
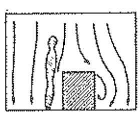


Photo.9 Arranging Two Apparatuses Separately

3.4 Air Flow Influenced by Operator Standing near the Apparatus

(1) Case where Operator Stands Upright Beside Apparatus(Photo 10).

Photo 10 shows the air flow around the operator and the apparatus. The air flow on the left side of the apparatus is different from that on the right side. The air flow around the operator is smooth and is not very turbulent.



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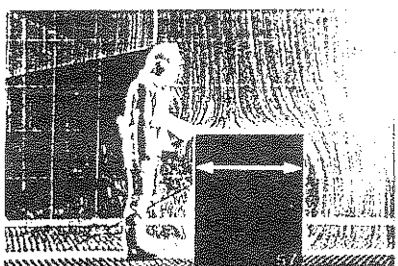
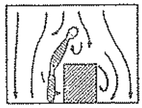


Photo.10 Air Flow around Operator standing Upright Beside Apparatus

(2) Case where Operator Bends Over Apparatus(Photo 11).

Photo 11 shows the air flow around the operator and the apparatus. The air flow around the operator is turbulent and a standing vortex appears between the top surface of the apparatus and the operator. On the right side wall there is no effect from the operator and the air flow pattern is also the same as that of the basic model (Photo 1).



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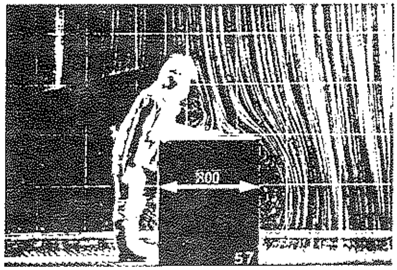
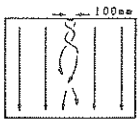


Photo.11 Air Flow around Operator Bending Over Apparatus

3.5 Air Flow Disturbed by Obstacle at Ceiling

(1) Flow Obstacle at Ceiling(Photo 12).

The flow obstacle, which represents some kinds of lighting fixtures or ceiling beams, is installed at the ceiling. Photo 12 shows that turbulence is generated by the obstacle at the ceiling and its scale and intensity is maintained at the floor level.



Air Flow Pattern

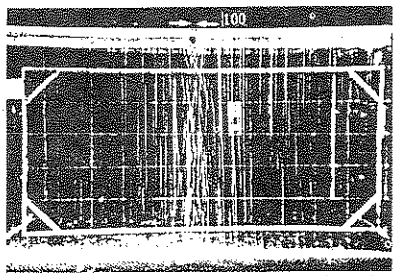
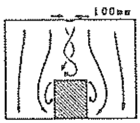


Photo.12 Turbulence Generated by Obstacle at Ceiling

(2) Installing Apparatus inside Turbulent Wake of Obstacle at Ceiling(Photo 13).

The basic model is set inside the wake of the obstacle at the ceiling. The standing vortex above the top surface of the apparatus becomes much larger in this case and it is extremely turbulent.



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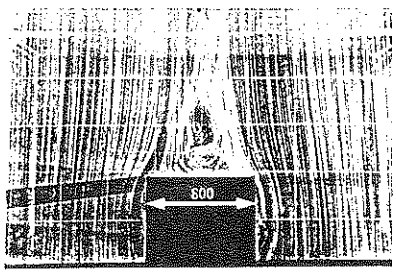
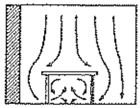


Photo.13 Turbulence Generated at Ceiling, Colliding with Apparatus Surface

3.6 Turbulence Generated by Table

To analyze the air flow around more complicated apparatus, the flow around a table is visualized as an example. The air flow pattern above the top surface of the table is nearly equal to that of the basic model, but under the table the flow is highly turbulent.


Air Flow Pattern

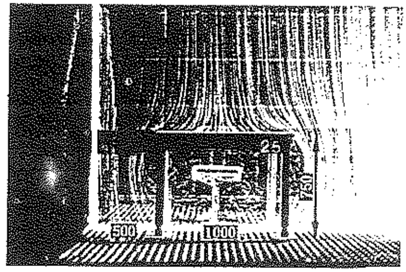


Photo.14 Turbulence around Table

4. CONCLUSIONS

The air flow in a laminar flow type clean room is analyzed by means of the laser light sheet visualization system. The results are as follows.

(1) The air flow is separated at the corners of the top surface of the rectangular prism model. Contaminants which are induced into the inside of the separation do not seem to be exhausted smoothly.

(2) Suction at the separating area is very effective in removing the separation.

(3) When the apparatus is set in contact with the wall, a standing vortex appears above the top surface. To exhaust contaminants smoothly it is desirable to set the apparatus apart from the wall.

(4) When two apparatuses are arranged in contact, a stagnant region appears above the top surface. Just as in (3), it is desirable to arrange the two apparatuses separately.

(5) When an operator is standing upright beside an apparatus, the air flow around the apparatus is not influenced by the operator. When an operator is bending over an apparatus, a standing vortex appears between the top surface of the apparatus and the operator.

(6) Turbulence generated by obstacles at the ceiling is maintained at the floor.

(7) The air flow in the space beneath an apparatus such as a table is highly turbulent and the contaminants here do not seem to be exhausted smoothly.

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