Performance of a Push Air Flow in the Push-Pull Ventilation System

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Introduction

Information concerning the airflow pattern around a worker is essential when capturing contaminants from a nearby source. The level of exposure of a worker close to a contaminant source is dependent on:

- the properties of the source: strength and geometry;
- the distance from the worker and initial velocity and direction of emission;
- the properties of the air flow pattern: directions, velocities, and turbulence;
- the activity and the position of the worker in relation to the air flow pattern.

In many practical exhaust units, such as those installed in booths for splaying grinding or painting with exhaust, airflow into the inlet from behind the worker's back. In such cases high exposure levels have been reported, although the exhausts appear to work efficiently (1). When the supply air originates from behind the worker's back, recirculating flow and convection flow result, which transport the contaminant zone (2).

Current knowledge of the effect of the worker on air flow can be adequately reduced or eliminated by the air flow supplied from push air supplier in the push-pull ventilation system (3,4).

The purpose of this study is to make clear a performance that can be used as a basis for the control of factors affecting the concentrations of contaminants in the breathing zone of a worker, when the worker handles the source of gaseous emission. The experiments were focused on the distribution of contaminants by the effect of variable turbulent intensity of air flow caused by changing an air distributor at the outlet of the push air flow (5,6).

Experimental Apparatus and Method

Experiments were carried out in ducts, an axial fan, perforated plates which have different perforation size and density for air distribution to generate an ideal even velocity airflow pattern, honey-comb screen for smooth air-stream line, two metal ducts with a section of 40 cm x 40 cm and a length of 60 cm as shown in Figure 1.

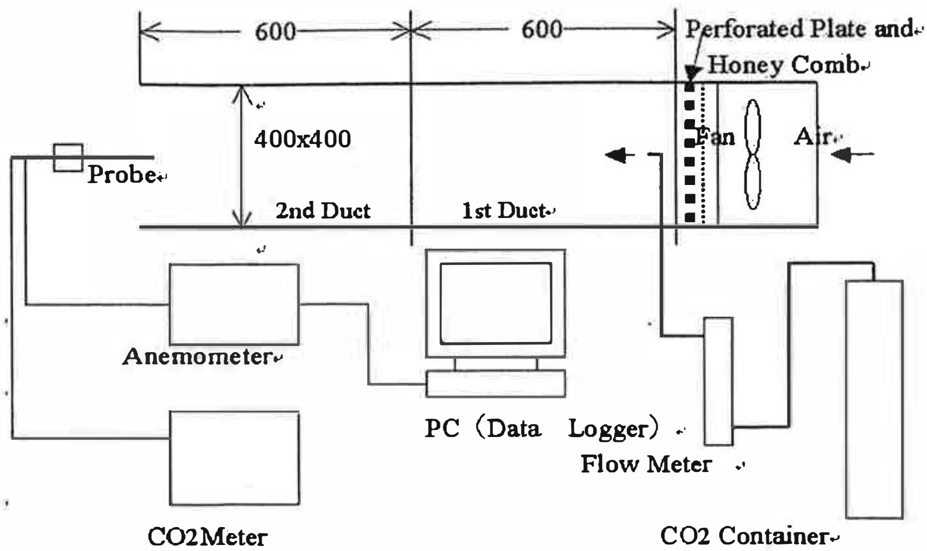

Figure1. Experimental Apparatus

Liquefied Carbon Dioxides gas was used as a tracer gas that was heated to room temperature by electric heater equipped just before the pressure control needle valve. The gas was blown through a copper tube of 3 mm in diameter installed at the center of the duct push air flow, and CO_2 gas was controlled by a needle valve to adjust a blown velocity keeping the isometric velocity with the push air flow.

Hot wire anemometer was used to measure air velocity and turbulent intensity of airflow direction and its rectangular direction by 1000 times within one second. The measuring instrument was connected to the data logger, and data were statistically calculated and stored every second during the whole experiments. Velocities were measured along the grid points of 7x7 (5 cm vertically x 5 cm horizontally) of the duct cross sectional surface by traversing the hot wire probe from point to point.

Concentrations of CO_2 were measured by the instrument equipped CO_2 sensor along the grid points of 7x7 (5 cm vertically x 5 cm horizontally). And for more detail measurement 1 centi-meter grid for an important high concentration area of the duct cross sectional surface was used and measured by traversing the sampling system from point to point.

Measuring it at the end of each duct can see the effect of the low turbulent intensity airflow on the concentration distribution of CO_2 in the duct. 100% of CO_2 gas blown out from the tube just after the honey-comb outlet flowed little down wards due to its heavier density than air, and expanded to the every sides, i.e. downwards and both horizontal sides very slowly due to well-controlled smoothness (low turbulent intensity) of the air flow.

The Reynolds number was around Re=16000 applied for all experiments. The airflow was kept in good conditions showing well-controlled laminar flow in every point that were measured at the outlet of the push air generator, at the 1st duct outlet and the 2nd duct outlet. This means that after once the laminar flow pattern was established, it is hard to be disturbed its flow pattern by any turbulence in the ducts.

After contaminant blown out at the front 1-st duct it was gradually diluted to the point of the contaminated air density reached nearly equal to the surrounding air one. Then it did not be widely expanded or distributed to the surrounding airflow due to the low turbulent intensity of push flow. The air velocity and the turbulent intensity distribution were measured at the push air supplier outlet, at the 1st and the 2nd duct outlet. And these are recorded and summarized in Table 1 and the Figures 2, 3, 4, and 5.

Table 1. Experiments Data Summary

Experiment	Airflow M/S	Turbulent Intensity %	Contaminants area cm^2	Result
Case-1 (a) at Duct-1 Outlet	0.64	Low 2.95	39	Good
Case-1 (b) at Duct-2 Outlet	0.64	Low 3.4	63	Good
Case-2 (a) at Duct-1 Outlet	0.64	High 8.69	360	Poor
Case-2 (b) at Duct-2 Outlet	0.64	High 5.52	Over 363	Poor

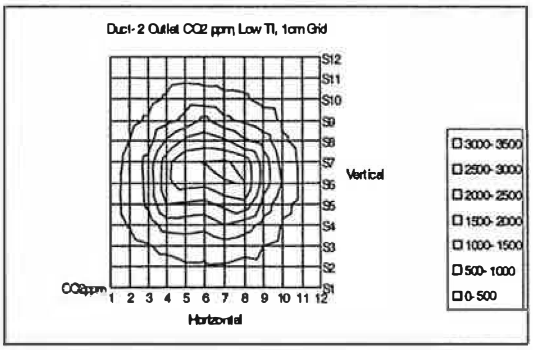

Figure 2. Concentration Distribution of Carbon Dioxides at the 1 st Duct Outlet in the condition under the low turbulent intensity (2.95±1.34%)

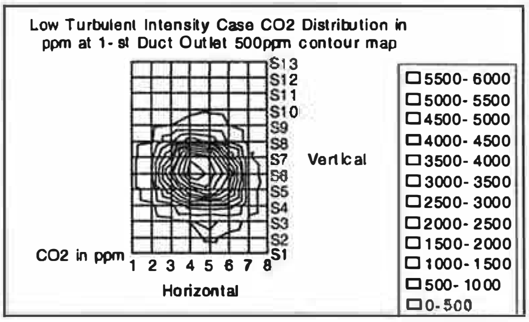

Figure 3. Concentration Distribution of Carbon Dioxides at the 2-nd Duct Outlet in the condition under the low turbulent intensity (3.4±1.69%)

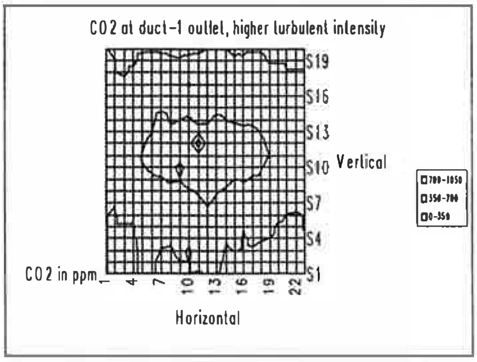

Figure 4. Concentration Distribution of Carbon Dioxides at the 1-st Duct Outlet in the condition under the higher turbulent intensity

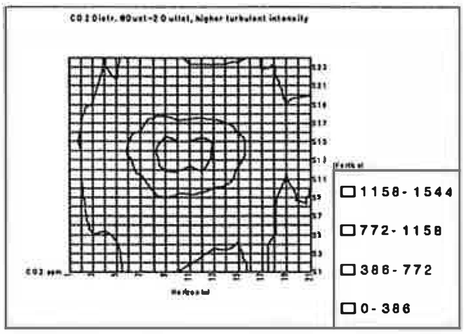

Figure 5. Concentration Distribution of Carbon Dioxides at the 2 nd Duct Outlet in the condition under the higher turbulent intensity

When the turbulent intensity was changed from very low, i.e. 2.95±1.34% and 3.4±1.69%, to a higher one, i.e. 8.69±2.09 and 5.52±1.34%, the contaminants distribution were shown in Figures 2, 3, 4 and 5. The contaminants distribution area was larger at the 2nd duct outlet than 1st one, and under the higher turbulent intensity condition than lower one.

Consideration of Results

It is considered the first duct outlet condition means that after capturing contaminants by the push air it is carrying contaminants in its flow with a cross sectional area of 39 cm^2 (circular equivalent diameter = 7 cm). Because of the low turbulent intensity, i.e. 2.95±1.34% in the first duct and 3.4±1.34% in the second duct, the lower turbulent intensity case showed that the contaminants never spread out widely during its transfer in the 60 cm length of second duct (8.6 times longer than contaminants size of 7 cm). It is spread to a cross sectional area of 63 cm^2 (circular equivalent diameter = 9 cm), i.e. the contaminants distributed area was spread only 1.6 times larger than that of at the first duct outlet.

Therefore, this can be used in the design of the exhaust suction. When the transfer distance from the capture point to the exhaust suction is below 8 times of contaminants flow area, the size of the exhaust suction can be determined as of two times of the cross sectional area of contaminants at the capture point in the transfer airflow.

In the case of higher turbulent intensity, the captured contaminated area at the first duct outlet is 360 cm^2(circular equivalent diameter = 21.4 cm), and the area at the second duct outlet is over 363 cm^2 (circular equivalent diameter = over 21.5 cm). These areas are almost the same.

The ratio of the captured contaminated area at the first duct outlet in the low versus the high turbulent intensity cases is 39:360 = 1: 9.23. This result shows that the original 100% CO_2 is supplied from the copper tube with 3 mm in diameter, and the captured contaminates area is spread out during one duct length to 1: 9.23 depending on the difference of a turbulent intensity. It is more effective and economic when the push airflow with low turbulent intensity is applied as possible as you can.

Conclusion

The airflow having the low turbulent intensity can be used as a well controlled contaminants transfer method after capturing contaminants in its own flow. The distance from the contaminants source to the exhaust suction can be determined as a parameter of the turbulent intensity. Also, the size of exhaust suction can be determined with the same manner.

Acknowledgement
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Reference

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