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A Study on the Ventilation Method for a Factory with a Sealed Structure

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Abstract: On this work, the importance of industrial ventilation was investigated and examined the theoretical point and problems about general ventilation of factory exposed on high temperature during summer. As a case study, the ventilation planning of the printed circuit board (PCB) etching process for an electronic company was carried out and each of those characteristics were compared by installing actual ventilation systems and measuring the changing state of the working environment in accordance with ventilation method during summer. The purpose of the study is to present an efficient ventilation method for a factory with a closed structure under high temperature environment. In summary, for a factory with a sealed structure such as the target PCB manufacturing factory in this study, the forced supply and exhaust method was the most appropriate ventilation method for maintaining a low.

Key Words : Ventilation method, Factory, Air flow, PCB, Structure

1. Introduction

With the rapid economic growth and industrialization of Korea, industrial complexes have been built all over the country, and such industrialization has rapidly progressed since the 1970s. In factories, all sorts of hazardous factors are produced during the manufacture of products using various materials and methods, unlike in houses or office spaces. Accordingly, the occurrence of industrial accidents in Korea has increased, as has the occurrence of work-related diseases (e.g., occupational diseases).

Of the different types of occupational disease that occurred in 2004,[1)] pneumoconiosis accounted for 77%, which suggests that a poor working environment is important. The working environment of a factory is directly related to the health of its workers, and thus, methods of minimizing the production of hazardous factors and the exposure of the workers to them should be established.

In the target factory in this experiment, an etching process for copper clad laminate is performed among the printed circuit board (PCB) manufacturing processes.[2)] In such process, circuit

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boards are manufactured by etching copper clad laminate, on which electronic circuits are printed, in a chemical solution. A scrubber is installed in the interior and locally collects dust and performs exhaust treatment of the corrosive harmful gases (e.g., sulfur dioxide) produced during the process. However, ventilation[3] is absolutely required because the building is a sealed area without any air flow and because the leak in the scrubber is problematic.

In this study, the importance of ventilation was examined through a theoretical review of general ventilation;[4] and the characteristics of a high-temperature environment in summer, which has recently been problematic in many factories, were investigated through the changes in the ventilation method of a factory with a sealed structure.

2. Experiment Outline

2.1 Experiment Subject

The target factory in this study is a PCB manufacturing factory of an electronics company located in Chungcheongbuk-do. It is an outermost building of a five-span structure with a medium-height roof as shown Fig. 1, and its interior has partition walls on all sides. It is box-shaped with a 4m-high ceiling, an automatic door on the southeast side, and another door on the northwest side that is open at all times.

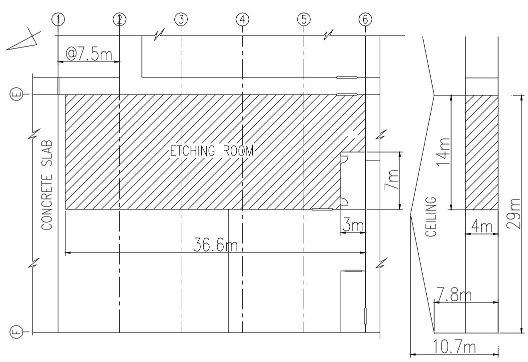

Fig. 1 Ventilation target area

Table 1 Experiment cases

Experiment Case	Exhaust	Supply	Etc.	Time
Case 1	Operation	Operation		13:00 -15:00
Case 2	Stop	Operation		15:35 -17:20
Case 3	Operation	Stop		17:55 -19:20
Case 4	Stop	Stop	Nature ventilation	20:00 -20:40

2.2 Experiment method

The experiment was performed based on four cases, as summarized in Table 1. The experiment site was a factory for manufacturing products, and thus, the experiment was conducted within a range that had no effect on the quality of the products.

Fig. 2 shows the format of the check sheet used to measure the experiment results.

환기상태 check sheet (환기방식: , 측정일시 : 2014. . ~ :)

No	풍속(m/s)			온도(℃)			습도(%)			비고
	1	2	3	1	2	3	1	2	3	
A1										
A2										
A3										
A4										
A5										
A6										
A7										
A8										

Fig. 2 Check sheet

For the measurement points, tags were attached to the floor at four outdoor points and at a total of 57 indoor points (five points along the width and 12 points along the length, excluding the three points where the doors were positioned), as shown in Fig. 3 and 4. For the point where the measurement was difficult due to the apparatus or equipment, the measurement spot was selected within 30 cm of the corresponding point at the breathing line (1.5 m above the floor).

As for the measuring instrument, the Model 6531

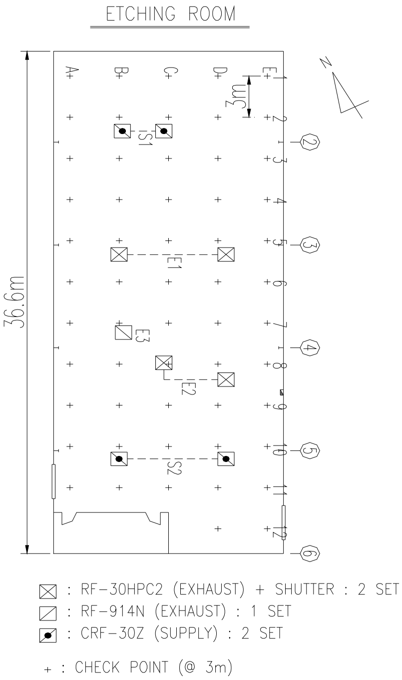

Fig. 3 Indoor measurement point

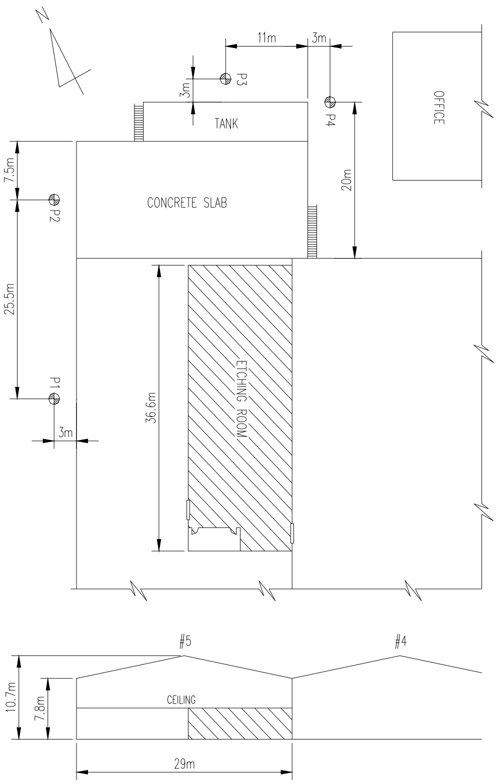

Fig. 4 Outdoor measurement point

Climomaster (hot wire anemometer) of Kanomax, Inc. (Japan) was used to measure the dry-bulb temperature, the relative humidity, and the wind speed. Table 2 summarizes the measurement ranges, and Fig. 5 shows the measurement of the temperature, relative humidity, and wind velocity.

It was difficult to read the continuously changing digital data with the naked eyes during the measurement of the temperature, relative humidity, and wind velocity. Thus, the calculation mode of the instrument was used. In other words, three consecutive measurements were taken for 10 seconds each at a point and averaged.

To measure the wind direction, the Model AS-1 of Komyo Rikagaku Kogyo Co., Ltd. was used. Fig. 6 shows the measurement. To determine the air flow direction, the average wind direction was measured three times at a point using an air flow indicator.[5]

Table 2 Climomaster

Function	Measurement Extent
Wind velocity	0.00-9.99 m/s
	10-30 m/s
Temperature	0.0-60.0˚C
Humidity	2-98% RH

Function	Tolerance
Wind velocity	±(3%+0.1) m/s
Temperature	±0.5˚C
Humidity	2-80% RH: ±2% RH
	80-98% RH: ±3% RH

Function	Indication Unit	Response Time
Wind velocity	0.01 m/s	About 1 second
	0.1 m/s	
Temperature	0.1˚C	About 30 seconds
Humidity	0.1% RH	About 15 seconds

Fig. 5 Measurement image

Fig. 6 Measurement image (air flow)

3. Experimental results

3.1 Indoor Temperature Distribution

Fig. 7~10 show the distributions of the indoor temperatures measured by operating the ventilation system using diverse ventilation methods based on the four experiment cases.

The results of the experiment showed that in all the experiment cases, the average indoor air temperature was higher than the average outdoor air temperature. The ventilation method in Case 4 was natural supply and natural exhaust, and all the indoor air temperatures were higher than the outdoor air temperature. The average outdoor air temperature was 29.1˚C and the average indoor air temperature, 36.8˚C, which showed a 7.7˚C difference. The ventilation method in Case 3 was natural supply and forced exhaust. The average outdoor air temperature was 30.9˚C and the average indoor air temperature, 33.8˚C, which showed a 2.9˚C difference. The ventilation method in Case 2 was forced supply and natural exhaust. The average outdoor air temperature was 31.6˚C and the average indoor air temperature, 34.3˚C, which showed a 2.7˚C difference. The ventilation method in Case 1 was forced supply and forced exhaust. The average outdoor air temperature was 31.5˚C and the average indoor air temperature, 32.5˚C, which showed a 1˚C difference. Thus, Case 1 showed the smallest air temperature difference among the four cases.

The cases with the smallest to the greatest difference between their average outdoor air temperature and their average indoor air temperature were as follows: Case 1 < Case 2 < Case 3 < Case 4. The fact that the indoor air temperature

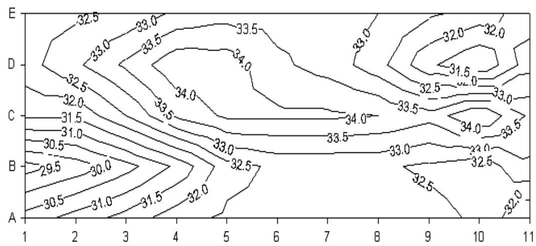

Fig. 7 Dry bulb temperature (Case 1)

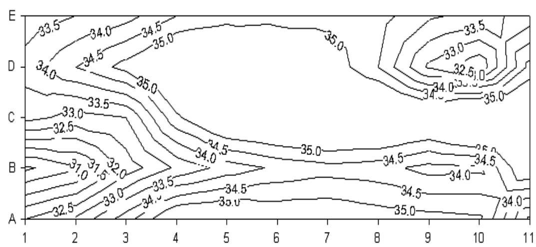

Fig. 8 Dry bulb temperature (Case 2)

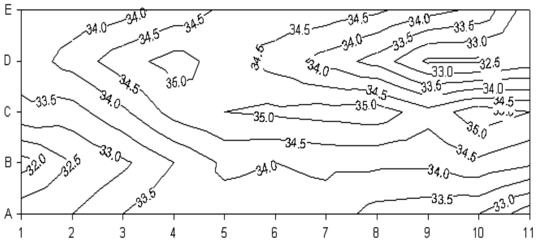

Fig. 9 Dry bulb temperature (Case 3)

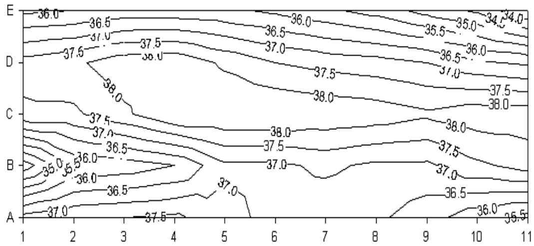

Fig. 10 Dry bulb temperature (Case 4)

distribution in Case 1 was the closest to the average outdoor air temperature indicates that the ventilation method in Case 1 was superior to the other ventilation methods.

Also, the fact that the deviation of the indoor air temperature in Case 2 was larger than that of the other ventilation methods indicates that only the area adjacent to the air inlet was affected by the ventilation system due to the forced supply.

3.2 Indoor Absolute Humidity Distribution

The amount of saturated water vapor changes depending on the temperature, and thus, the relative humidity, has different values depending on the temperature, although the amount of water vapor in the air is constant. Fig. 11~14 show the indoor absolute humidity distribution in each experiment case, to examine the indoor humidity distributions depending on the various ventilation methods (↔ : average outdoor air absolute humidity).

As shown in Fig. 11~14, the indoor air absolute humidity in Case 2 was slightly higher than the outdoor air absolute humidity, and the indoor air absolute humidities in Case 1, Case 3, and Case 4 were lower than the outdoor air absolute humidity.

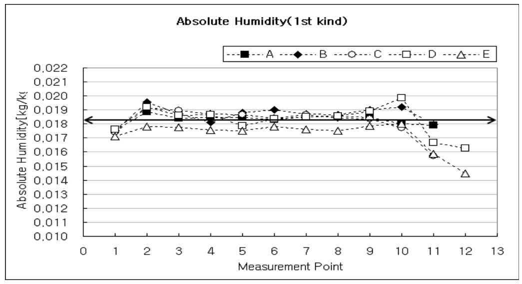

Fig. 11 Absolute humidity (Case 1)

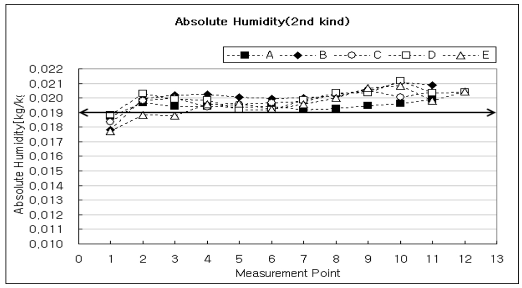

Fig. 12 Absolute humidity (Case 2)

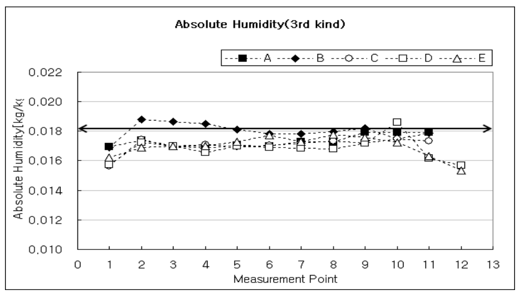

Fig. 13 Absolute humidity (Case 3)

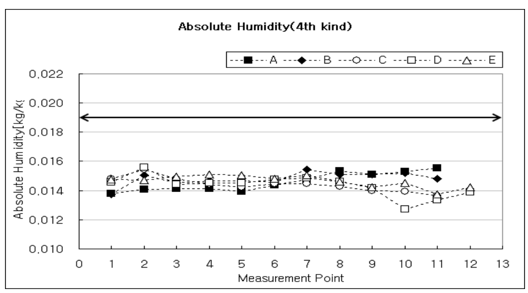

Fig. 14 Absolute humidity (Case 4)

As shown in Fig. 11~14, the indoor air absolute humidity in Case 2 was slightly higher than the outdoor air absolute humidity, and the indoor air absolute humidities in Case 1, Case 3, and Case 4 were lower than the outdoor air absolute humidity.

In Case 1, the average outdoor air absolute humidity was 0.01821 kg/kg, and the average indoor air absolute humidity was 0.01813 kg/kg; in Case 2, 0.01901 kg/kg and 0.01978 kg/kg; in Case 3, 0.01816 kg/kg and 0.01722 kg/kg; and in Case 4, 0.01897 kg/kg and 0.01455 kg/kg.

The differences between the average outdoor air absolute humidity and the average indoor absolute humidity were 0.00008 kg/kg in Case 1, 0.00077 kg/kg in Case 2, 0.00094 kg/kg in Case 3, and 0.00442 kg/kg in Case 4.

The difference between the average outdoor air absolute humidity and the average indoor absolute humidity in Case 1 was the smallest, followed by those in Case 2, Case 3, and Case 4. Therefore, the measurement of the absolute humidity also showed that the ventilation was most efficient in Case 1.

3.3 Velocity distribution of the indoor air flow

Fig. 15~18 show the velocity distribution of indoor air flow. In Case 1 and Case 2, it shows a clear air flow velocity distribution near the supply area, and in Case 1, it is much more affected by the ventilation due to the air supply and exhaust over the whole indoor space than that of Case 2. In Case 3, it shows a weak air flow than Case 1 or Case 2 due to the air exhaust. In Case 4, it shows only a partial air flow so it does not show the distribution for the whole indoor space. This proves the fact that a proper ventilation is not being performed.

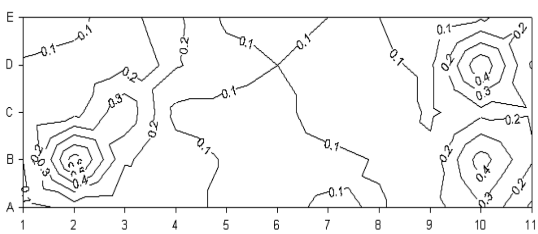

Fig. 15 Air-velocity (Case 1)

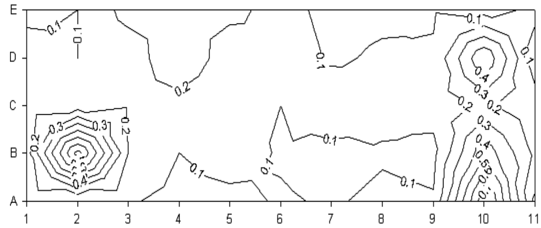

Fig. 16 Air-velocity (Case 2)

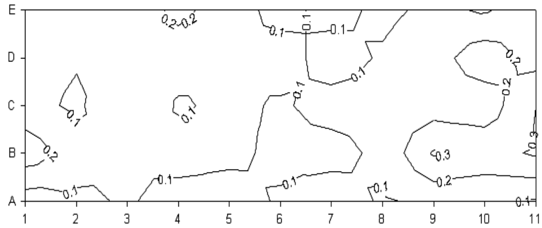

Fig. 17 Air-velocity (Case 3)

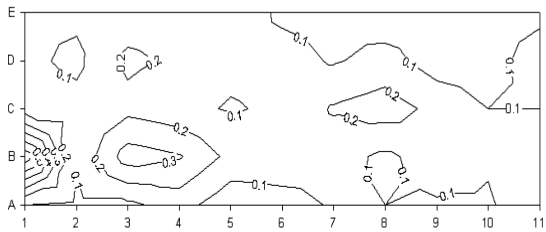

Fig. 18 Air-velocity (Case 4)

4. Conclusions

To establish the most appropriate ventilation plan for the target factory, the distributions of the temperature and the relative humidity were measured based on four experiment cases. The following conclusions were drawn.

(1) In all the experiment cases, the average indoor air temperature was higher than the average outdoor air temperature. The cases with the smallest

to the greatest difference between the average outdoor air temperature and the average indoor air temperature were as follows: Case 1 < Case 2 < Case 3 < Case 4.

(2) The comparison of the average outdoor air absolute humidity and the average indoor air absolute humidity by converting the relative humidity into the absolute humidity showed that the cases with the smallest to the greatest difference between the average outdoor air absolute humidity and the average indoor air absolute humidity were as follows: Case 1 < Case 2 < Case 3 < Case 4.

In summary, for a factory with a sealed structure such as the target PCB manufacturing factory in this study, the forced supply and exhaust method (i.e., in Case 1) was the most appropriate ventilation method for maintaining a low indoor air temperature and for keeping the contaminated air of the factory below the hazardous level. Also, the ventilation method in Case 2 (forced supply and natural exhaust) was more advantageous than that in Case 3 (natural supply and forced exhaust).

References

1. laborstat.moel.go.kr (Employment and Labor Statistics website), 2004, "Industrial accident statistics".
2. H. R. Kim, 2005, “A Study on the Additive Method for the Formation of the Ultrafine Pattern of Printed Circuit Boards (PCB)”, Graduate School of Information Industry, Chungwoon University, M.S. thesis, p. 1.
3. The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, 1996, "Air conditioning. Health Glossary", Ohmsha, p. 115.
4. D. W. Park and N. W. Baek, 2002, “Industrial Hygiene", Korea National Open University Press, p. 213.
5. Minakawa minatoyo, 1969, “Measures for ventilation in summer", Air Conditioning and Refrigeration, Vol. 9, No. 6.