The breakthrough in DCV is likely to happen within the next few years. The growth is expected to increase as a result of both decreasing transmitter prices as well as a result of increasing energy prices. In addition to price, long-term stability and easy calibration have to be considered when investing in DCV.

The market growth will at first be a result of a more complete use in the most obvious areas of DCV, such as schools, conference rooms, theatres, music and exhibition halls. Since the implementation of DCV in old buildings often requires modifications in the ventilation system, the majority of targets will be new buildings at the beginning.

Although the mixed gas measurement concept is theoretically sensible, there are some serious difficulties with using and maintaining these types of transmitters. The winning DCV concept will be based on CO_2 measurement, although other concepts will not disappear completely. Even if CO_2 transmitters can not be used in all types of facilities, they will still be the one most commonly used, not only because CO_2 is an objective indirect parameter for human presence, but since CO_2 measurement is the only simple and reliable solution. As an evidence of this, ASHRAE has chosen CO_2 as the main alternative for DCV [6]. A technically still better all-round solution would be a combined CO/CO_2 transmitter, but it would most probably be too expensive for general use.

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WATER VAPOR PRESSURE CORRECTION OF SEMICONDUCTOR GAS SENSORS FOR MONITORING INDOOR AIR QUALITY AND ITS EVALUATION

Masahiro Hori [1] and Takashi Tanaka [2]

[1] Faculty of Engineering, Yokohama National University, Japan
[2] Yamatake-Honeywell Co.Ltd., Tokyo, Japan

ABSTRACT

Semiconductor gas sensors for IAQ monitoring were used together with monitors of temperature, humidity, carbon dioxide and suspended particles in offices. Temperature and humidity(water vapor pressure) correction for the sensors was shown to be effective. In a series of investigations of offices in which handling conditions of air dampers and dust collectors were set manually. the relationships between the sensor outputs and the concentration of VOC and IAQ voting values as well as the other contaminants were studied.

INTRODUCTION

This study was performed in order to establish a suitable IAQ monitoring method in controlling healthy and comfortable office environments. IAQ in offices has been evaluated by concentration of perspective matter, besides carbon dioxide, carbon monoxide, nitrogen dioxide and suspended particles for health. Perspective air quality, governed by volatile organic compounds(VOC) and some kinds of suspended particles is a direct indication factor for comfort. However, methods and practical sensors for the air quality monitoring are not established.

Semiconductor gas sensor is one of IAQ monitors. The practocal use of semiconductor gas sensors, responding to gaseous reductans such as VOC and carbon monoxide, was doubtful, because of the effect of moisture on the sensor output. In this study, the effect of temperature and moisture correction was examined on sensor output characteristics.

The sensors were applied to a series of environmental comprehensive investigations in offices. The measurement with sensors was carried out parallel to that of VOC, carbon dioxides and suspended particles through four seasons. The levels and characteristics of VOC and relationships between VOC and sensor outputs as well as concentration of other contaminants and voting values were observed. The relationship of cause and effect in indoor pollution is shown in Fig.1 which lists the contribution of four kinds of source to odor generation (1), environmental factors and sensing/humane sensation. The environmental factors contain only main factors such as VOC.

MATERIALS AND METHODS

Semiconductor gas sensor: Slection criteria of semiconductor gas sensors applied in the investigation are shown in Table 1. They were on the market and assembled in test units with output terminals. Any one of the five kinds of sensors is slightly different from the others in gas selectivity and sensitivity, because of the dopant for n-type semiconductor. The gas selectivity of sensors is relative and each one of them responds to all reductive gases. The relative outputs from the sensors were recorded in the datarecorder. The data were corrected later with the room temperature and water vapor pressure(WVP) which were calculated with the temperature and humidity measured simultaneously.

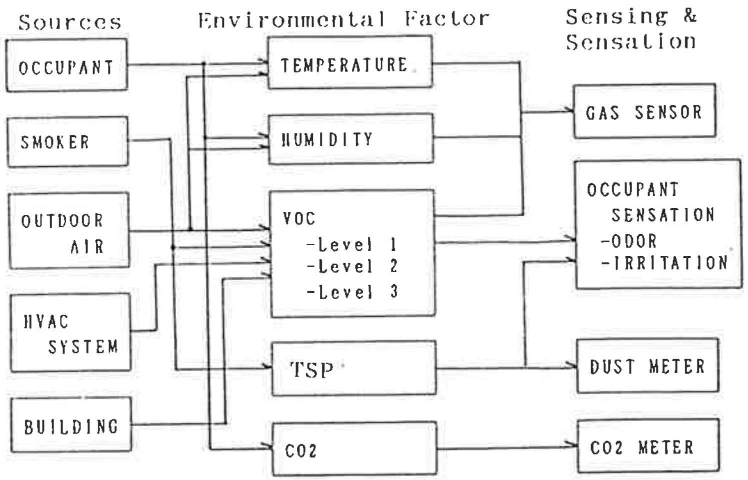

Fig.1 Relationship of cause and effect in indoor pollution

Table 1 Gas sensors applied in measurement

Sensor	Relatively sensitive gas	Air supply	Correction factors* Temp	WVP
A	Carbon monoxide	Diffusion	0.004	-
B	Volatile sulfide	Diffusion	0.014	0.105
C	Hydrocarbon	Diffusion	0.003	0.263
D	Hydrogen, Carbon monoxide	Diffusion	0.004	0.090
E	Volatile sulfide, Aldehyde	Aspiration	-	-

* Correction factors of temperature and WVP(water vapor pressure) on the basis of 25°C and 1.58 KPa(50%).

The characteristics of semiconductor gas sensor for temperature and humidity were examined in a chamber controlled at several constant temperatures and humidities after replacement of its ir by room air. Fig.2 shows the relationship between WVP and sensor outputs. The WVP correction factors of sensor output were estimated at 25°C and 50%.

Measurement of IAQ factors and evaluation of IAQ

VOC values were determined by trapping gas-chromatography after sampling air in plastic bags(Flek-Sampler). The concentration of CO2, carbon monoxide, nitrogen dioxide and total suspended particles(TSP) were measured with usual method. Evaluation of IAQ and odor intensity of room air was performed with questionnaire for voting its levels by the occupants two or three times a day. They had not been especially out of the room just before the vote. Levels with their marks and an example of a result of IAQ were shown in the preceding conference(2).

Office investigations

The investigations were done 6 times in a year and two days at a time. The building, located in an urban area, was built 20 years ago. The room dimensions were [floor area x height]:278m^2 x 2.5m. The number of occupants during working time was approximately 30. The air conditioning systems were Heat-Pump-Package. The damper for supply of outdoor air and dust collector set at the ceiling of the room were independently controlled. The ventilation rates of room A were 0.84/h in closing the damper and 1.45/h in opening. Besides the investigations, in summer(August) and winter (February) their handling condition were changed to control manually the IAQ levels every day for three days.

RESULTS AND DISCUSSION

Correction of semiconductor gas sensor

Correction factors were estimated in this experiment on the assumption that the output is obtained as a sum of a first-order function of total VOC, temperature and WVP independent of each other. The correction factors for temperature(°C) and WVP(Torr) are shown in Table 1. The values of a type of sensor differ from those of the others. The correction factors for WVP were more than that for temperature. Subsequent factors are comprehensive corrections for both of them. Examples of time-courses of original and corrected output, temperature and water vapor pressure measured simultaneously in heating and cooling seasons are shown in Fig.3. The relationships between the chart of original data and WVP e.g., considerable decrease of output in mornings during cooling season, in contrast to that of heating, showed that WVP governs the sensor outputs.

Based on the result of comparison test of sensitivity for the office air, two of five sensors were discussed in detail. The sensitivity of the two sensors, Sensor C and D, for WVP and total VOC concentration were Sensor C:0.263 (V/KPa), Sensor D: 0.0902 (V/KPa) and Sensor C: 0.123 (V/ppm), Sensor D: 0.152 (V/ppm), respectively. The ratio in Sensor C and D was 0.213 and 0.593 (ppm/KPa), respectively. The maximum range of change of WVP is 0.67 to 1.33 KPa at start time of air conditioning. The VOC concentrations corresponding to WVP of 0.67 KPa are 1.4 ppm in Sensor C and 0.39 ppm in Sensor D, respectively. On the other hand the range of change of VOC is a few hundred ppb to a few ppm except methane of 1 to 2 ppm. This shows that the effect of WVP on sensor output is not negligible and the correction of output with WVP is essential.

On the other hand, sensor life had been observed with fluctuations in sensitivity in time based over periods of 3 to 10 years (3). For example the variation of the relative sensitivity of Sensor C was less than 20 % in tests of 47 times for 3 years, and the difference of the level of relative sensitivity at start and that of three years after the start was slight. These results do not, however, mean that the check of output of base line for clean air of 11.9 Torr in water vapor pressure, is unnecessary.

Though semiconductor gas sensors are simple and safe, the sensor output is the sum of it for each component, different from each other. Therefore, the output governed by the composition of VOC is relative, total and rough. The sensitivity of sensor for general organic gas (Sensor C) was superior to that of the others in Table 1. The effectiveness of the corrected sensor outputs as VOC or IAQ sensor was examined. Fig. 4 shows examples of time-course of concentration of carbon dioxide, carbon monoxide and suspended particles measured parallel to the sensors.

The relationship between sensor outputs and IAQ factors

The climate and IAQ of the office for the investigations were as follows: The daily average temperature and humidity were 22.0 - 27.4°C and 20.0 - 49.4 %, respectively. When IAQ

would be evaluated by criteria(4) presented a few years ago, the number of votes whose values cleared the criteria were 6 of the 25 votes.
When corrected by WVP estimated with temperature and humidity, outputs of the sensors were found to have good responses to VOC. The coefficients of relationship between the corrected outputs of sensors C and D and total VOC were 0.47 and 0.58, respectively, through the year. The coefficients between the sensor outputs and the concentration of CO2/CO/TSP were approximately 0.6 through the year. The relationships through the year were hard to find (r<0.1) between corrected sensor outputs and values of IAQ evaluated by voting in the office in which an average of occupants of 66% voted the sensation of odor.

Table 2 Coefficient of relationship between corrected outputs of sensor D and the IAQ factors

Factor	Condition	Feb.1	Feb.2	Feb.3	Total
CO2		0.93	0.77	0.83	0.76
CO		0.91	0.82	0.93	0.78
TSP		0.79	0.75	0.78	0.68
	Air Damper	Close	Open	Close	
	Dust Collector	Off	On	On	

On the other hand, for daily forced handling of the air damper and the dust collectors in approximately constant occupation, examples of daily relationship coefficients are shown in Table 2.
The high relationship between the usual IAQ factors ere and the sensor outputs shows that the sensors are possible to apply to IAQ monitoring. The total coefficient values for 3 days were less than daily ones. The result means that the behavior of TSP in the room was different from those of gases such as CO2, CO and VOC. The effect of the air damper and dust collector on the relationship between the sensor outputs and the concentration of these contaminants was also investigated. Handling of damper effected on only CO2 concentration and sensor outputs. On the other hand, the dust collector effected on only TSP. These results mean that the sensor outputs can not indicate levels of IAQ on TSP.
The studies of real time WVP correction of the sensor outputs and the application of the technic to IAQ control are in progress.

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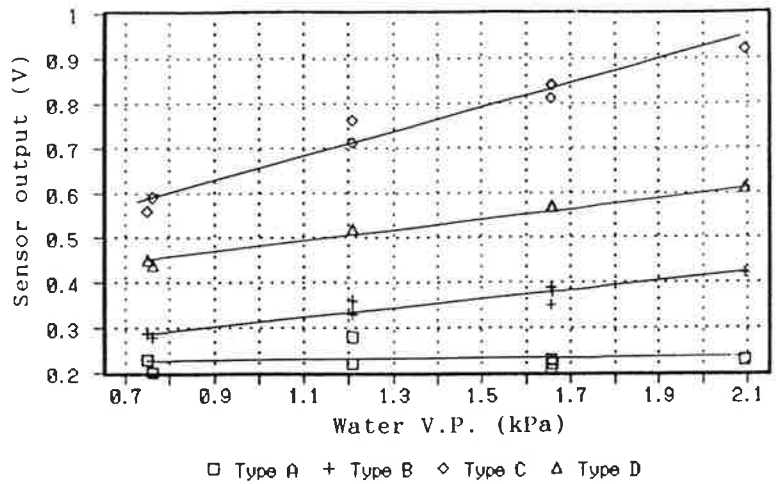

Fig.2 The relationship between water vapor pressure (WVP) and sensor outputs

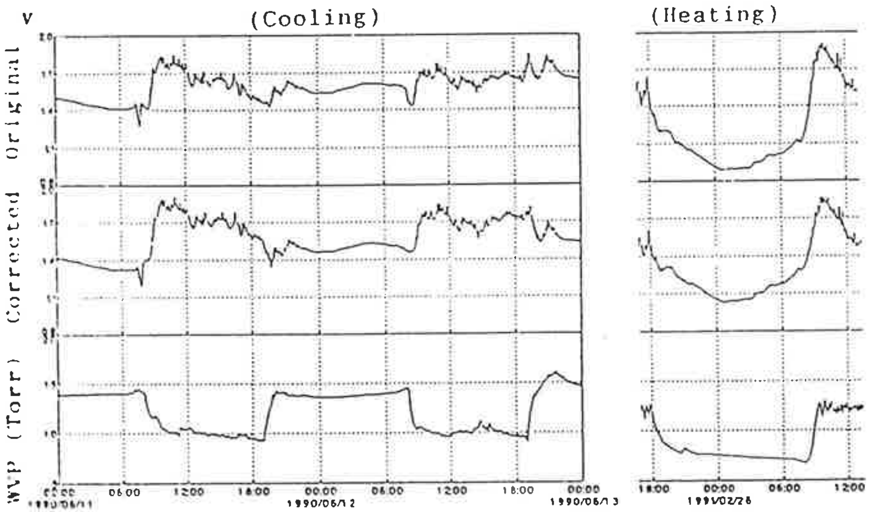

Fig.3 Examples of time-courses of original and corrected sensor outputs

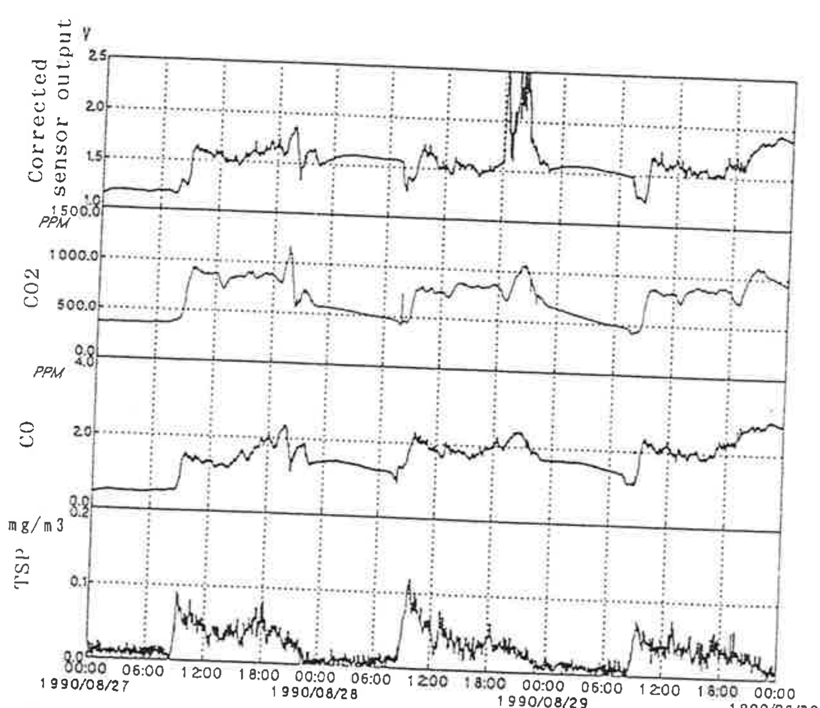

Fig.4 Examples of time-course of concentration of CO2 and CO and TSP measured parallel to the sensors

OCCUPANT USE OF VENTILATION CONTROLS AND HUMIDIFIERS DURING COLD SEASONS

Kevin M. Kelly, Monica Brien and Robert W. Stemp

Jay-K Independent Lumber Co. Inc., New Hartford, New York, USA

ABSTRACT

During the past two decades the desire to save energy has created tight houses with chronic moisture problems. This situation prompted us to mail a questionnaire to 3000 Jay-K Home Center customers in December 1991 to determine heating season fresh air sources, occupants' use of air change devices, (i.e., actual ventilation), humidifier use, and humidifier cleaning. Occupants' disregard for fresh (outdoor) air and replacement air sources when exhausting air with furnaces, exhaust fans, and clothes dryers indicates that occupants are not taking steps to ensure good indoor air quality. The presence of uncleaned home humidifiers adds to the problem. Based on the data obtained, a review of building ventilation standards and humidifier use may be advisable.

INTRODUCTION

We find that the need to conserve energy by reducing convection air change in dwellings and the introduction of gas/vapor barriers which eliminate diffusive air change have precipitated moisture problems and possibly indoor air quality problems during cold seasons (1). Energy conserving measures tend to increase the inhabitants' indoor exposures to pollutants and hence augment the risk of adverse health effects (2). Counseling customers about moisture problems in homes leads us to believe that many occupants do not want to let cold outdoor air into their homes. A commonly advised solution for a moisture problem is the use of kitchen and bath exhaust fans and/or opening windows to supply outdoor air. However, removing heated air with fans or by opening windows appears to be a waste of money to home owners. The noise caused by fans that change air is bothersome and drafts from fans are uncomfortable in any season (3,4). In the present state of the art, residential ventilation must depend upon cooperation from the occupants (5). The objective of our study was to determine if occupants opened windows in cold seasons vs. warm seasons and to determine if occupants supplied replacement air for furnaces, exhaust fans and dryers during cold seasons. In addition, we wanted to see if humidifiers were cleaned as often as recommended in the literature (6).

Therefore we designed a questionnaire to determine whether occupants open windows in warm and cold seasons, whether they use fans and other air exhausting devices, their possible sources for replacement air for exhausted air, and their use and cleaning of humidifiers.