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REQUIREMENT-CONTROLLED VENTILATION OF AN AUDITORIUM

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COMPARISON BETWEEN CO_2 INDICATION AND ODOUR INDICATION

1. INTRODUCTION

Control of the air flow on the basis of the CO_2 content of the air has been tested in numerous applications and has proved to perform satisfactorily. [1] [2] [6] [7]

One of the reasons for the principle not being applied to any significant extent is that the CO_2 indicator is relatively expensive. The rate of air flow must therefore be high if the reduction in the heating costs is to offset the necessary investment, at a reasonable write-off time.

Stäfa Control System markets an odour indicator, the cost of which is no more than a few per cent of that of the CO_2 indicator. [8]

The purpose of this investigation was to test again the use of CO_2 indication for controlling the air flow, and to compare the readings obtained from the CO_2 indicator with those from the Stäfa odour indicator.

2. DESCRIPTION OF THE PREMISES

The tests were performed in the Skanstull High School auditorium, which has seating capacity for 850 persons. The auditorium was built in the mid-1940s and has a volume of approx. 4000 m^3. It is ventilated by one supply air fan and one exhaust air fan, each rated at approx. 2 m^3/s (see the diagrammatic arrangement shown in Figure 1).

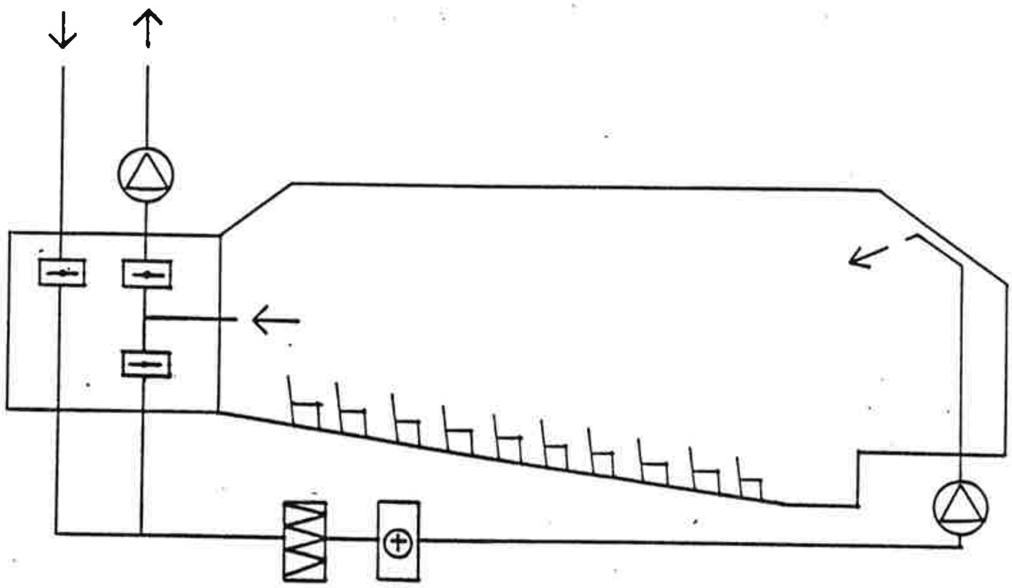

Figure 1. Diagrammatic arrangement of the ventilation system.

Space heating is provided by radiators fitted below the windows. However, the ventilation system can also be used for heating, by running only the supply air fan, recirculating 100% of the air, and using the coil for supplying heat.

3. OPERATION OF THE HEATING AND VENTILATION SYSTEM

3.1 Earlier operation

It is difficult to establish clearly how the system performed before the control equipment was replaced. The heat supplied by the radiators located below the windows was controlled by varying the water temperature which, in turn, was controlled by the outdoor temperature. The fans were started manually whenever the need arose, and the operating time was preset on a timer.

When the fans were running, the room temperature was sensed by a thermostat in the exhaust air duct. If the exhaust air temperature was too low, the thermostat actuated the dampers across a control unit, closing the outdoor air damper to a predetermined minimum position. If the temperature was still too low in spite of the outdoor air damper being at its minimum setting, a motorized valve opened to admit water to the heating coil. The exhaust air fan was thus occasionally in operation when the damper was virtually closed.

3.2 Present operation

An entirely new control system was installed before the tests were started. An unsuccessful attempt was made beforehand to measure the conditions with the earlier control system in operation.

Even with the new control equipment installed, the thermal conditions in the auditorium are the primary reason for the ventilation system being in operation. If the output of the radiators is insufficient for heating, the supply air fan will start, for circulating the air and supplying make-up heat from the heating coil. If the temperature is too high, both fans will start, for cooling the premises with outdoor air. Whenever the temperature conditions in the premises allow, the air flow through the auditorium is controlled by odour indication.

During these tests, odour indication was used as the only control parameter, and CO_2 indication was only used as a check. The sensors were located adjacent to one another in the auditorium, in the vicinity of the exhaust air extraction point.

When the odour attains a certain level, the supply air fan will start and the outdoor air damper will gradually open. At the same time, the exhaust air damper will open and the recirculated air damper will close, since both of these dampers are connected to the same actuator motor. When the outdoor air damper is approximately half open and if the odour is still on the increase, the exhaust air fan will also be started. The odour controls the damper settings, whereas the temperature is controlled by the motorized valve which controls the water to the heating coil.

If the level of odour should drop, the exhaust air fan will be shut down at a predetermined point, the outdoor air damper will close fully in due course, and the supply air fan will be stopped.

4. OPERATION OF THE SYSTEM ON A DAY WHEN MANY PEOPLE VISITED THE AUDITORIUM

Only the hygienic conditions are described below. Although the temperatures were recorded at about ten points, the information of relevance here is only that the outdoor temperature was around +2°C and the temperature in the auditorium was about 22°C throughout the test period. Measurements were started at 11.00 hours and were concluded at 20.00 hours. The CO_2 content and the odour were then recorded by a pen recorder up to 06.00 hours on the following morning.

All readings are shown in Table 1 and the tabulated values are also plotted in a graph (Figure 2).

The two recording principles coincide fairly closely during the introductory stage. It is particularly interesting to note how well the CO_2 indication reacts to the number of persons in the premises. When measurements were taken earlier, with only a few musicians (between 5 and 10) in the premises for a few hours, the instrument provided clear indication that the CO_2 content had increased.

AIR QUALITY TESTS - SKANSTULL HIGH SCHOOL

Potentiometer set to 1.0 (set point)
Outdoor temperature: +2.5°C

21 April 1985

Date	Time	Damper op. = 2 V cl. = 10 V	Vent cl. = 10 V op. = 15 V	ppm	Numb. of pers.	Temp.	Remarks
21.4	11.00	20.0	0.0	500	0	18.8	
	.15	20.0	0.0	500	2	18.8	Lights switched on
	.30	20.0	0.0	500	4	19.3	Spotlights switched on
	.45	19.9	0.0	510	4	19.9	
	12.00	19.0	0.0	510	5	20.4	Different lighting arrangements tested.
	.15	19.0	0.0	510	5	20.2	Varying intensity.
	.30	18.2	0.0	520	5	20.2	
	.45	17.9	0.0	540	10	20.2	
	13.00	17.2	5.0	550	10	20.1	Many people entering and leaving
	.15	17.0	6.5	590	30	20.3	Lights still switched off.
	.30	15.5	8.5	790	160	20.8	Rehearsal starts. Lighting 50% alight.
	.45	13.8	9.0	900	70	21.8	Movement among participants.
	14.00	12.0	9.0	1000	50	21.8	
	.15	10.9	7.0	1170	50	22.1	
	.30	10.9	9.0	1170	10	21.7	Lighting and most of the spotlights
	.45	11.1	9.0	1100	6	20.8	switched off.
	15.00	11.0	9.4	1090	10	20.7	Lighting switched on. No spotlights. People start coming in. Supply air fan starts
	.15	7.0	9.4	1180	100	21.2	
		5.5					Exhaust air fan starts
	.30	3.5	9.5	1400	450	22.3	
	.45	1.5	9.5	1500	450	22.7	
	16.00	1.0	9.0	1600	450	23.3	
							16.10 Intermission
	.15	1.0	9.0	1400	40	23.1	
	.30	2.0	9.3	1100	50	21.9	16.40 People start coming in
	.45	3.0		1050	100	21.9	
	17.00	1.0	9.0	1600	450	23.3	The performance starts. People sitting
	.15	1.0	9.5	1450	450	23.3	inactively.
	.30	1.0	9.6	1500	450	23.4	
	.45	1.0	9.2	1450	450	23.3	
				1580			17.55 People walk out. Doors to the hall opened
	18.00	1.0	9.2	1480	40	23.1	
	.15	1.0		1150	15	21.1	
	.30	3.0	9.2	990	10	20.9	People in the foyer. Doors open.
	.45	1.8	9.2	820	5	20.8	
	19.00	2.5		750	-	20.7	A few people left.
	.15	4.5		580	-	20.8	Lights switched off. Doors closed.
	.30	5.5	9.2	500		20.5	Lights switched on. A few people in the room.
		6.5					19.40 Exhaust fan switched off
	.45				2	20.6	Cleaning by two people

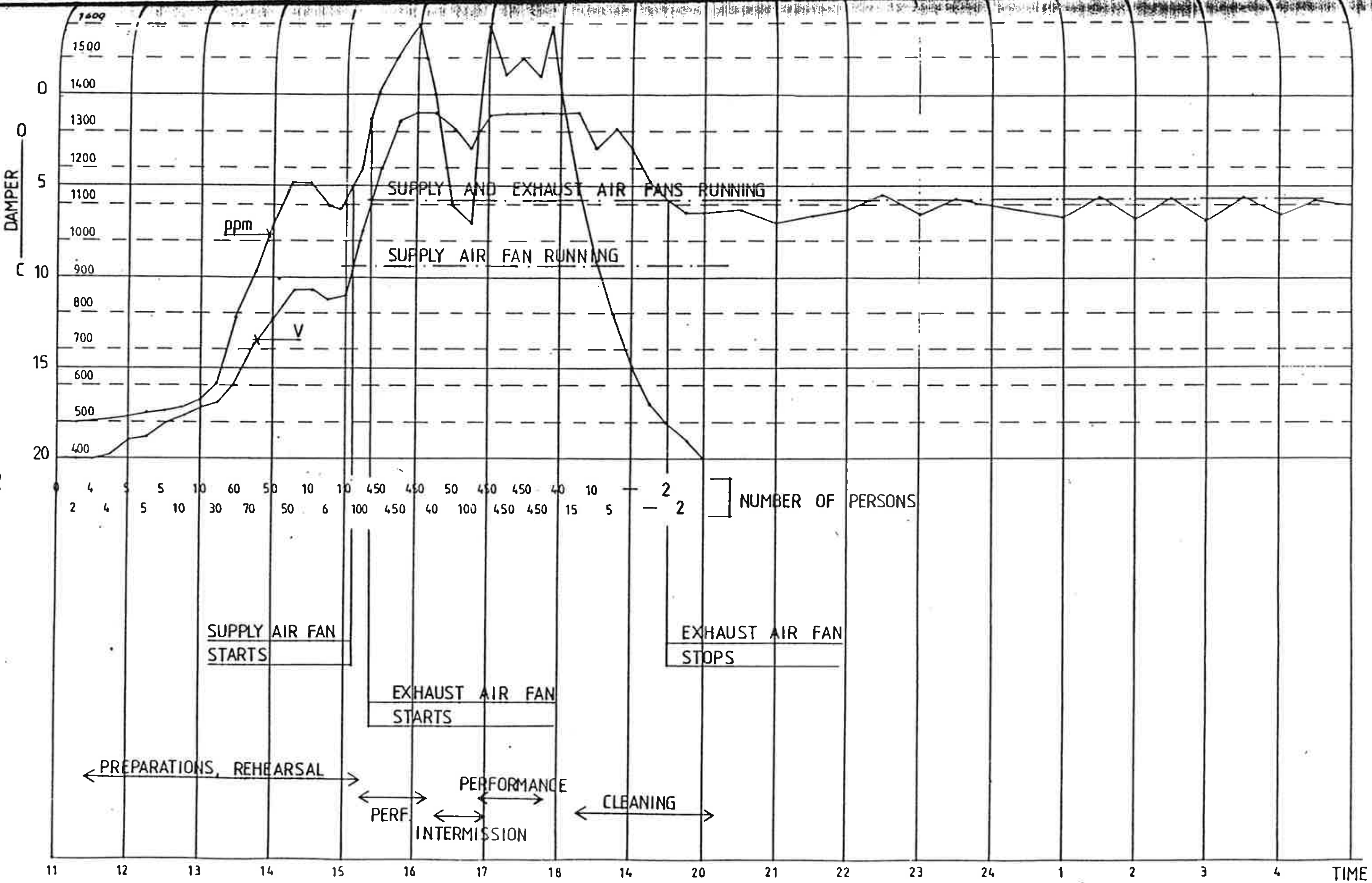

Figure 2

Measurements on the 21 April 1985

The outdoor air generally contains around 400 ppm of CO_2 in this part of Stockholm. When measurements were started on this particular Sunday, the CO_2 content in the auditorium was about 500 ppm, which may have been due to some residue from the preceding evening or to some minor activities already having started in the morning. The set point was adjusted to a relatively high value, and the supply air fan started when the CO_2 content was approx. 1100 ppm.

Between 10 and 70 persons were present in the premises for a couple of hours, rehearsing and preparing for the performance, which was to start at 15.30 hours.

The public started coming in a quarter of an hour earlier, and the supply air fan started when between 50 and 100 persons had been admitted. The CO_2 content and the odour increased gradually as people started coming in. The outdoor air damper opened gradually. Five minutes before the performance was to start, about 250 persons were present in the auditorium. The CO_2 content was 1300 ppm and the exhaust air fan started.

A total of about 450 persons eventually gathered in the premises. Although both fans were running and the outdoor air damper was fully open, the CO_2 content increased to 1600 ppm. A half-hour performance by the children's choir was followed by a 30-minute intermission, during which many members of the audience went out into the foyer. The CO_2 indication as well as the odour indication dropped substantially.

A new performance started at 17.00 hours, and people came back into the auditorium during the few minutes before the appointed time. The instruments immediately recorded an increase. The performance lasted for an hour, and the changes at the beginning and at the end were recorded by the CO_2 meter.

People quickly left the premises after the performance, and the CO_2 content dropped from 1600 ppm to 500 ppm in 1.5 hours. The exhaust air fan stopped at 19.45 hours.

The two methods of indication display a distinct difference at this stage. The odour indication remained at the value which, during the increasing stage, corresponded to approx. 1300 ppm on the CO_2 meter, whereas the CO_2 indication dropped to the outdoor level. Even though the premises were empty, the odour then increased, and the exhaust air fan started again at about 22.00 hours. After half an hour, the odour had dropped and the fan stopped. The odour level oscillated in this manner during the night, and the exhaust air fan started and stopped accordingly.

However, the mean level was roughly constant throughout the recording period.

5. CO_2 CONTENT RECORDED IN RELATION TO THE CO_2 GENERATED

When 450 persons are seated inactively, the CO_2 generated by them can be assumed to be 450 . 20 l/h. This 9 m^3/h of CO_2, added to an air flow estimated to be 7000 m^3/h, corresponds to an increment of 1286 ppm. If the outdoor air contains 400 ppm of CO_2, the content in the auditorium would be somewhat more than 1600 ppm, which is almost exactly what the CO_2 meter had recorded.

6. VENTILATION FOR COOLING OR FOR HYGIENE?

The graph in Figure 3 shows the air flows necessary to remove the heat emitted by an inactively seated person, using air at varying temperatures below the room temperature. The temperature scale has been selected to take into account that the air could be outdoor air.

A curve for 200 W, which corresponds to the heat emitted by one person and one electric light bulb, has been plotted alongside the curve for 100 W. Horizontal lines have then been plotted in the same graph, to show the air flows necessary for maintaining the CO_2 content between the selected levels.

The graph also illustrates that if heat and CO_2 are generated only by persons and 1200 ppm of CO_2 is set as the hygienic limit, the temperature will be decisive to the ventilation air flow rate, provided that the temperature of the supply air is higher than +10°C. At lower temperatures, hygienic considerations, i.e. the CO_2 content, are the decisive factor.

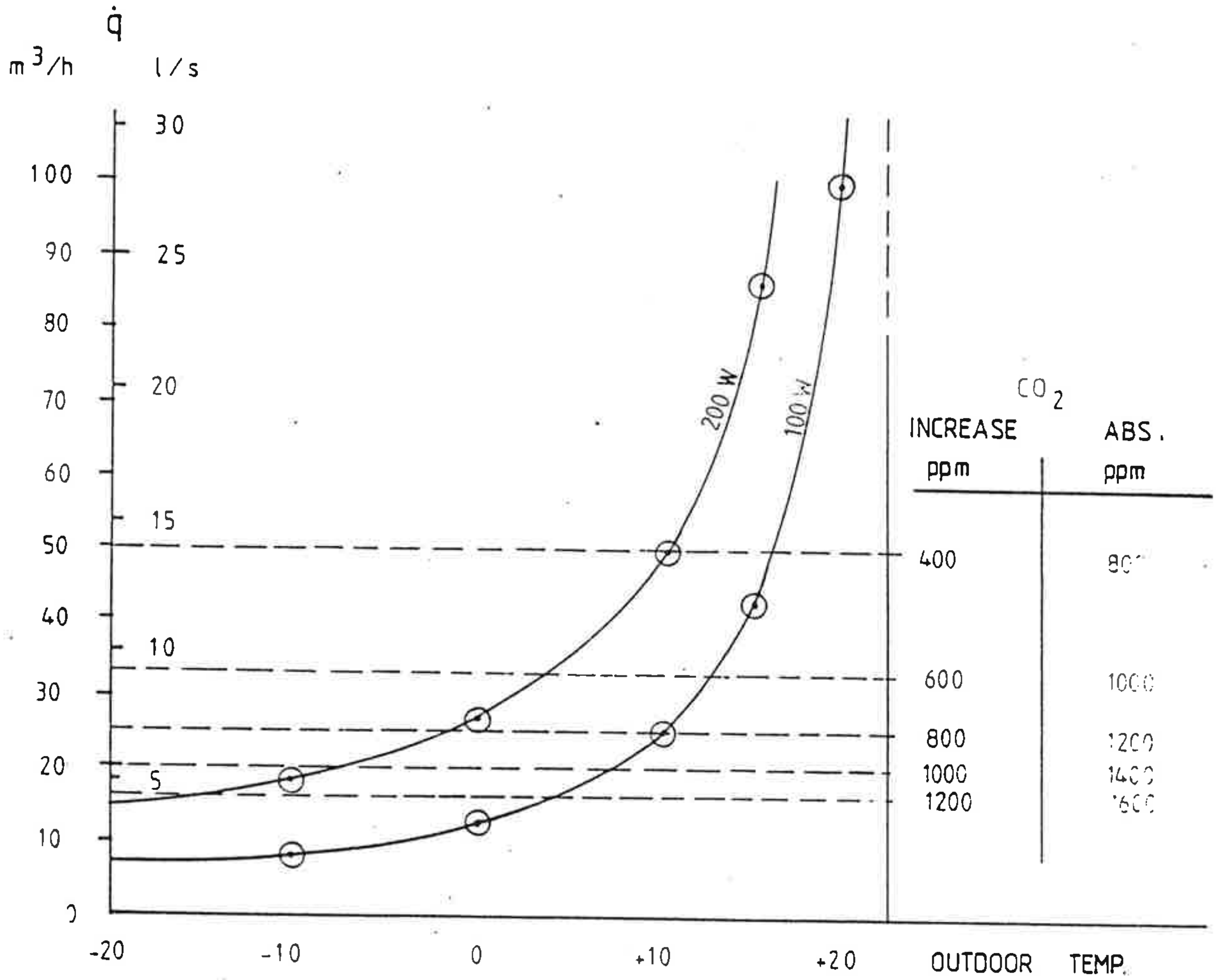

Figure 3. Ventilation flow rate necessary to dissipate the heat and CO_2 emitted by people (and the lighting)

7. DISCUSSION

The indication of CO_2 follows very closely its probable emission and can be regarded as a reliable factor for controlling the ventilation air requirements. During the period when the concentration is on the increase, odour indication corresponds closely to the CO_2 indication. When the concentration is on the decrease, odour indication appears to stop at a certain level, which may be determined by the emission from surfaces to which the recorded substances have adhered during exposure, and then remain at a certain level in the premises for a long period of time. This explanation is not improbable and is confirmed by the residual "atmosphere" in different types of premises. Gymnasiums, military barracks and schools are good typical examples.

This difference between CO_2 and odour measurement need not be regarded as a disadvantage if odour measurement is used as the parameter for controlling the ventilation system. It may be advantageous to remove the odours remaining on various surfaces in the room, even though this demands energy and thus involves additional costs.

It would be of interest to receive information concerning the sensitivity of the odour indicator to different substances. No definite information is available on the repeatability of the odour indicator and its susceptibility to ageing. It is also unknown whether drift of the set point occurs.

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