EFFECTIVE VENTILATION

9th AIVC Conference, Gent, Belgium
12-15 September, 1988

Paper 21

MARKET ANALYSIS OF SENSORS FOR THE USE IN DEMAND CONTROLLED VENTILATING SYSTEMS

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ABSTRACT

In the framework of a project of the International Energy Agency (IEA), IEA-Annex XVIII - Demand Controlled Ventilating (DCV) Systems, which started in fall 1987, a review of the state of the art of already existing DCV systems and devices has been undertaken by all participating countries. This paper is concerned with air quality sensors which may be suitable to control air quality on demand.

The dominant contaminants are not only variing in different kinds of buildings (dwellings, schools, stores etc.) but also from room to room due to different ways of utilizing the spaces. Climatic and environmental differences will have a further impact on the DCV system.

In this context contaminants are discussed which have a dominant regime and impact on indoor air quality and which cannot be avoided by controlling the source. These are humidity, odours (indicator e.g. carbon dioxide CO_2), fumes, and tobacco smoke.

The working principles of various sensors are outlined and possibilities of application discussed.

1. INTRODUCTION

In the past and especially at this time efforts are to be seen to control the air exchange rate on demand particularly in buildings and rooms which have high fluctuations in occupancy, i.e. schools, theatres, assembly halls, kindergartens and office rooms. Although mechanical ventilation systems are common in those buildings, practical application of Demand Controlled Ventilating (DCV) Systems are rarely to be seen. Most DCV systems are in a research state. Often questions arise about what contaminants should be monitored and controlled for what kind of building and usage, where to measure the concentration, and what the benefits are.

Especially calculations on return-of-investment often turn out to be fatal for a DCV system, because the analysing equipment for the gases to detect are very expensive. But before one talks about energy savings, the main objective of a DCV system is to supply occupants with an adequate quality of air and the building fabric with an atmosphere which is not harmful to it (moisture damages). The above stated topics are under discussion in the IEA-Annex 18 working group.

In this paper we are only concerned with the contaminants, which can practically be monitored in DCV systems and about reliable and low cost analysing devices, we'll call sensors to measure concentrations of contaminants as accurate as necessary and as cheap as possible.

2. WHAT CONTAMINANTS SHOULD BE MEASURED AND CONTROLLED

The final report of the IEA-Annex IX "Minimum Ventilation Rates" /1/ gives an overview about the various pollutants of indoor air. From this whole bulk of gases and particles we can avoid most of them by controlling the source, i.e. avoiding special building materials, paints and cleaning fluids. By that we mean formaldehyde, organics, microorganisms, particulates (except tobacco smoke) and also Radon where one may have to take additional actions.

The participating countries in the IEA-Annex 18 work group agreed also on to exclude combustion products of open fire-places. The remaining contaminants are also the main pollutants of concern listed in /1/ p. 179, table 11.1. These are water vapor, body odor and tobacco smoke.

2.1 Water Vapor

Occupants are sensitive to humidities below 30 % r.h. because of the dry out of the respiratory tract. They are not very sensitive to humidities between 30 and 100 % r.h. But high humidities are harmful to the building fabric. The level of humidity we should keep in a DCV system as a function of room temperature, k-value of exterior walls, and material properties of the interior wall surfaces will be the output of the IEA-Annex 14 working group, where the final report will be available in 1990. Although final results are of great interest the absolute value of r.h. is not of essential importance for this topic. Here we generally talk about possibilities to measure humidity with sensors and to control the humidity of the interior air. The finally defined threshold value can then be adjusted.

2.2 Body Odor

It has been proofed by several authors, collected in /1/ that there is quite a good relationship between the respiration product CO_2 of humans and their production of body odor. Therefore, controlling CO_2 with a DCV system means, keeping body odor at a tolerable level. It has to be emphasized, that here only the occupant related CO_2 production is of importance and value. Many tolerable CO_2 levels have been reported in the past, which range between 600 and 2000 ppm. Unfortunately it is not always clear if this concentration means absolute CO_2 concentration (including atmospheric CO_2 content) or only CO_2 production caused by humans. For a first guideline table 1a gives some recommendations.

The next question, if CO_2 concentration in the air is measured, is how much does the ambient CO_2 concentration vary with time, location and environmental impacts. Because CO_2 is not harmful to humans in the ambient concentration range, it was of minor importance in the past. Therefore it has been continously measured over years only at some special places (usually weather stations). But there are continously measured data available from South-Germany from 14 locations including heavy industrialized areas. Table 2 gives ambient annual mean CO_2 levels for various towns.

We can summarize from that, that the ambient CO_2 level in Germany varies between 350 and 450 ppm. As proposed threshold limits for human generated CO_2 varies a lot according to table 1 outdoor fluctuations of 100 ppm are of minor importance. I.e., for human generated CO_2 it is sufficient to measure only the indoor concentration with an offset of the average ambient CO_2 concentration. Therefore, one way to track body odor is to use a CO_2 sensor. Another way is:
odors mostly consist of non-oxidized gases.
There are various sensors on the market which react on non-oxidized gases. Companies often offer them as air quality sensors. There is a responds of those sensors due to odors. But how well this relationship is established has not been proofed yet.

2.3 Tobacco Smoke

Wanner /2/ proposed 1983 to use the increase in CO due to tobacco smoke as a measure. This increase should be kept below 1-2 ppm. In his recently published paper in /1/ be didn't stick to the CO level as an indicator for tobacco smoke.
Looking at the ambient CO level table 3 indicates, that only in rural areas we get a fairly low and constant level, whereas we see great impacts due to traffic and industrialization in towns. Therefore, a detection of a tobacco smoke induzed CO increase of 1-2 ppm is only possible with simultaneously monitoring the ambient level, which increases investment costs. To perform such a measurement in the required accuracy, high cost IR-analyses have to be used. There are no sensors on the market yet, which measure CO with an accuracy of 0.5 ppm in a range between 0-20 ppm selectively. For CO-sensors on the market the lowest detectable CO concentration is ~ 30 ppm.

In conclusion, to use a CO sensor as an indicator for tobacco smoke is not appropriate.

As tobacco smoke consists of more than thausand constituents, also non-oxidyzed gases, there is a significant response also to see from those semiconductor sensors we already discussed in chapter 2.2 to detect odors. To use them also for detection of tobacco smoke seems to be more appropriate and worth to check out.

3. WORKING PRINCIPLES OF SENSORS

The following characteristics of a specific sensor technology are based on product information and various references about sensors and not on own experience.

3.1 Rel. Humidity:

For the measurement of rel. humidity hair and polyethylen-stripe hygrometers, capacitive and semiconductor sensors, and lithium cloride sensors are mainly in use.

3.1.1 Hair_and_polyethylen-stripe_hygrometers

Hair hygrometers change their length for about 2 % for a humidity change from 0 to 100 % r.h.. Also other hygroscopic materials like silk, cotton and synthetic materials are in use. A disadvantage is the necessity of recalibration and for elasticity reasons the placement of the hygrometer in humid air. Hysteresis is between 2-5 %. The length change of the sensor stripe often works on a PT 100-Potentiometer to give the required analogous electric output signal.

3.1.2 Capacitive_Hygrometers

They use a humidity sensitive folio which is placed between 2 electrodes. A change in relative humidity will cause a capicity change. Additional electronics (beside the sensor) is needed to get an analogous output signal in Ohm, Ampere or Volt. Linearization and temperature compensation is often necessary. Capacitive humidity sensors are depending on accuracy and response time fairly cheap. Unfortunately they are sensitive to contaminated air (dust, organics).

3.1.3 Conductance-film_Hygrometer

An electrode is placed on a plastic ground plate and covered with a hygroscopic layer, where the conductivity changes with humidity. The result is a change of the electric current. This sensor type should have high accuracy and short response times, no recalibration or maintenance.

3.1.4 Lithiumchloride_sensor

Uses thermodynamic equilibrium between humid air and a salt solution. The lithium cloride solution absorbs so much water from the air til the total pressure of the solution is the same as the partial pressure of water vapor in the air. Accuracy is between 1-3 %

3.2 Carbondioxide, CO_2

To measure CO_2 in air selectively with a sensor, all designed sensors use infrared (IR) absorption.
There are actually only two types of CO_2 sensors available at this time.

3.2.1 Photoacustic CO_2 Sensor

The sensor consists of a light source, an infrared filter, a cell, and a microphone. A filter in front of the light source takes care that only the wave lengths according to the absorption spectrum of CO_2 can enter the cell with the room air. In the cell the CO_2 molecules absorp the infrared light as a function of their concentration. The absorbed energy increases the vibration energy of the molecules, which leads to more pulses between molecules. The generated acoustic field is measured by a microphone and transformed with a scoring electronic unit. Long term experience does not exist at that time, but a calibration checking is recommended every 1.5 years.

3.2.2 Photometric CO_2 Sensor

Light is emitted through a cell, reflected at a mirror and received by a special detector, which sends the signal to a microprocessor. The microprocessor does a height and temperature correction and produces an analogous output signal.

Cross sensitivities of both sensors are fairly small. Accuracy is between 10 and 100 ppm. Response times are about 3 min.

3.3 Mixed Gas Sensors

For controlling air quality in buildings, homogenous metal-oxide semiconductor sensors and catalytic gas sensors are in use.

3.3.1 Homogenous metal-oxide Sensor

They consist of pure metaloxide compounds (n-type: SnO_2, ZnO, ZiO_2, Fe_2O_3; p-type: CuO, NiO, CoO) where the total conductivity changes due to the reaction of reactive gases with chemisorbed oxygen at the surface. The n-type sensors react on combustible (non-oxidized) gases like CO, H_mC_n and alcohols. Also most human generated odors belong to that group and are detected. The sensors are heated up to 100-500°C.
The structure of the semi-conductor layer can be threefold polycristalline, thin-layer technic, mono crystalline. Polycrystalline sensors are mainly made on SnO_2-basis. Advantages are simple

production and universal application. Disadvantages are response times of some minutes, high cross sensitivities to air humidity and long term drift.
Also using thin-layer technic response times are in the range of some minutes with a fairly high influence of humidity. The advantage of the thin layer is the high sensitivity to simple gases like H_2S, CO, NO_2, CH_4 and C_2H_5OH. Cross sensitivities can be avoided by variation of the working temperature. But reproducibility and long term stability is yet not satisfying enough.

3.3.2 Mono-crystalline Sensors

Most sensors are in a developing state. Obtained results indicate good and reproducible quantitative properties. Only disadvantage are the high costs

Tables 4a-e show the results of a sensor-market analysis. Listed are only the main features of the sensors or of the whole measuring device (sensor + additional electronics). Further information can be requested at the companies, from which addresses are listed in table 4f.

Discussion:

How well sensors work in practise and how well they are suited to control the specific contaminant has to be investigated next. There has been performed a lot of sensor testing in various companies which look for nacked sensors to add the necessary electronics to sell but unfortunately these results have not been published and valuable information is not accessible. It is necessary to test sensors under defined conditions in the future. To guarantee a good indoor air quality on one hand and to keep investment costs at a minimum on the other hand it is essential to investigate contaminant dispersal and the dominant pollutant in the room and in the whole building to answer questions about what, where and how many sensors have to be installed /4/.

Summary

Contaminants to control iaq are - depending on the type of building - humidity, carbon dioxide as indicator for body odor, and tobacco smoke. The various working principles are briefly outlined. The sensors are tabulized and characterized according to company specification.

References:

/1/ N.N. Minimum Ventilation Rates, IEA-Annex IX, final report of working phase I+II, Nov. 87, ISBN 3-921213-87-8

/2/ N.N. Minimum Ventilation Rates, IEA-Annex IX, final report Aug. 1983, p28

/3/ N.N. Statistische Berichte, Statistisches Landesamt Baden-Württemberg Artikel-Nr. 3611 87008 vom 02.12.1987

/4/ Raaatschen, W.; Trepte, L.: Humidity Controlled Ventilating Systems, Proceedings of the ASTM Symposium April 17-18, 1989 Atlanta (GA), submitted for publication

/5/ N.N. Umwelt 1/82

Table 1a: THRESHOLD LEVELS FOR CARBON DIOXIDE (CO_2) IN BUILDINGS IN DIFFERENT COUNTRIES

Concentration Level Country	MAC ppm	Peak limit ppm	Ref.	MIC ppm	Ref.	AIC ppm (absolute)	Ref.	Remarks 1 ppm = 1.806 $\frac{mg}{m^3}$ (at 1 bar, 293 K)
Canada	5000 -	-	21	-		3500 800	22 23	CO_2 level not used as indicator for body odors
Denmark *								
Germany	5000	2 x MAC	8	-		1000 1500 max.	24 24	Pettenkofer-value used to establish necessary AIC-air flow rates
Finland	5000	5000 (15 min)	1	-		-		
Italy	1500	-	2	-		-		
Norway	5000	MAX + 25 % (15 min)	3	-		-		
Sweden	5000	10000	4	-		-		supply air 1/10 of MAC /5/
Switzerland	5000	-	6	-		1000-1500	7	
U.K.	5000	15000 (10 min)	17	-		-		
U.S.A.	5000	-	21	-		1000	20	
Columbus Space station	4000	-	19	-		-		

* no values obtained

References are separately listed in table 1f

Table 1b: MAXIMUM CONCENTRATION LEVEL FOR CARBON MONOXIDE (CO) IN BUILDINGS IN DIFFERENT COUNTRIES

Concentration Level Country	MAC ppm	Peak limit ppm	Ref.	MIC ppm	Ref.	AIC ppm	Ref.	Remarks 1 ppm = 1.149 $\frac{mg}{m^3}$ (at 1 bar, 293 K)
Canada	50	400 (15 min)	21	-		11	20,22	
Denmark *								
Germany	30	2 x MAC (30 min) average	8	43 for 1/2h 10 for 24 h 10 for 1 year	9	1-2	7.2	
Finland	30	75 (15 min)	1	-		-		
Italy	30	-	2	-		-		
Norway	35	+50 % (15 min)	3	-		-		
Sweden	35	100	4	-		12	10	supply air 1/10 of MAC /5/
Switzerland	30	-	6	7-24 h average		2	7.2	MIC: this value ought to be exceeded only once a year
U.K.	50	400 (10 min)	17	-		-		
U.S.A	50	400 (15 min)	20			11	20	
WHO		87 (15 min) 53 (30 min) 26 (1 hour) 9 (8 hours)	10	-		-		Guideline value; based on effects other than cancer or odor/annoyance
Airplanes	50	-	18	-		-		

* no values obtained

References are separately listed in table 1f

Table 1c: MAXIMUM CONCENTRATION LEVEL FOR NITROUS DIOXIDE (NO_2) IN BUILDINGS IN DIFFERENT COUNTRIES

Concentration Level Country	MAC ppm	Peak limit ppm	Ref.	MIC ppm	Ref.	AIC ppm	Ref.	Remarks 1 ppm = 1.888 $\frac{mg}{m^3}$ (at 1 bar, 293 K)
Canada	3	5 (15 min)	21	-		0,19 0,052	20 22	offices homes
Denmark *								
Germany	5	2xMAC, 5 min average	8	0.1-1/2 h 0.05-24 h	9	-		
Finland	-	-		-		-		
Italy	-	-		-		-		
Norway	-	-		-		-		
Sweden	2	5, 15 min	4	-		0.2 0.15	12 10	supply air 1/10 of MAC, max. value for 24 h /5/
Switzerland	3	-	6	0.04-24h a) 0.05 b) 0.016 c)	16	(d		a) value ought to be exceeded only once a year b) 95 % of 1/2 h mean values of a year ≤ 0.05 ppm c) annual arithmetic mean d) there are no building regulations for kitchens with gas-powered furnaces
U.K.	3	5 (10 min)	17	-		-		
U.S.A	3	5 (15 min)	21	-		0.19	20	offices
WHO				0.15	10	0.21 1 hour 0.08 24 hour		AIC: Guideline value, based on effects other than cancer or odor/annoyance

* no values obtained
References are separately listed in table 1f

Table 1d: MAXIMUM CONCENTRATION LEVEL FOR HYDRO-CARBONS ($\Sigma\ C_mH_n$) IN BUILDINGS IN DIFFERENT COUNTRIES

Concentration Level Country	MAC ppm	Peak limit ppm	Ref.	MIC ppm	Ref.	AIC ppm	Ref.	Remarks
Canada	-	-		-		-		
Denmark *								
Germany	-	-		0.05	15	-		
Finland	-	-		-		-		
Italy	-	-		-		-		
Norway	-	-		-		-		
Sweden	-	-		-		0.16	12	supply air 1/10 of MAC, max. value for 3 h /5/
Switzerland	-	-		-		-		
U.K.	-	-		-		-		
U.S.A	-	-		-		-		

* no values obtained

References are separately listed in table 1f

Table 1e: MAXIMUM CONCENTRATION LEVEL FOR FORMALDEHYDE (HCHO) IN BUILDINGS IN DIFFERENT COUNTRIES

Concentration Level Country	MAC ppm	Peak limit ppm	Ref.	MIC ppm	Ref.	AIC ppm	Ref.	Remarks 1 ppm = 1.231 $\frac{mg}{m^3}$ (at 1 bar, 293 K)
Canada	1	2 (15 min)	21	-		0.06 0.1	20 22	
Denmark *								
Germany	1	2xMAC, 5 min average	8	-		0.1	14	
Finland	-	1 (15 min)	1	-		0.12 0.24	11	for new buildings
Italy	-	-		-		-		
Norway	1	+100% (15 min)	3	-		-		
Sweden	0.5	1 (15 min)	4	-		0.1 0.01-0.05	5,10 12	supply air 1/10 of MAC, safety factor 10 AIC-safety factor for avoiding annoyance: 10 /5/
Switzerland	1.0	-	6	-		0.2 0.1	13 7.3	caused by tobacco smoke
U.K.	2	2 (10 min)	17	-		-		
U.S.A	1	2 (15 min)	21	-		0.06	20	
WHO		-		-		0.1 0.08	10 10	 AIC: Guideline value based on effects other than cancer or odor/annoyance

* no data obtained

References are separatly listed in table 1f

Table 1f: Literature to tables 1a-e:

/1/ Air impurities in work place air, Safety bulletin, 3. National Board of Labor Protection, 1981

/2/ Emilia-Romagna Regional Technical Code, Ed. Franco Angeli, Milano

/3/ Administration normer for forurensning i arbeids ahmosfaeren, 1984

/4/ National Board of Occupational Safety and Health, Sweden AFS 1987:12, ISBN 91-7930-046-4

/5/ Building Code ISBN 91-38-05209-1, Sweden

/6/ Arbeitsplatzsicherheit; Dok. SUVA, 1987

/7.1/ IEA Annex IX, literature review, 1983, p. 12-20

/7.2/ page 28

/7.3/ page 35-43

/8/ Maximale Arbeitsplatzkonzentrationen und biologische Arbeitsstofftoleranzwerte 1986, VCH-Verlag, Weinheim

/9/ VDI 2310, Sept. 1974, Maximale Immissionswerte

/10/ WHO Guidelines

/11/ Instruction letter 2/1986 (DNO 5740/02/85), National Board of Medicine, 1986

/12/ Report 77: 1987 "Sunda ock sjuka hus" (in Eng. Healthy and Sick Buildings), National Swedish Board of Pysical Planning and Building

/13/ Formaldehyde in Innenräumen; Bundesamt für Gesundheitswesen, Switzerland

/14/ Proposed by the Federal health department, Germany 1977

/15/ USA National Air Ambient Quality Standards of EPA

/16/ Immissionsgrenzwerte für Luftschadstoffe, Schriftenreihe Umweltschutz Nr. 52; Bundesamt für Umweltschutz, 1986.

/17/ Guidance Note EH 40 "Occupational Exposure Limits", Health and Safety Executive, updated annually

/18/ Joint Airworthiness Requirements, JAR-25.831

/19/ ESA Columbus System Requirements
COL-RQ-ESA-001, page 2, section 4.10

/20/ ASHRAE Standard 62-1981 R, Ventilation for Acceptable Indoor Air Quality Table 3, draft, Dec. 15, 1987

/21/ TLVs "Threshold Limit Values and Biological Exposure Indicies for 1986-87. American Conference of Governmental Industrial Hyienists, 1986 6500 Glenway, Cincinnati, Ohio

/22/ Exposure Guidelines for Residential Indoor Air Quality, Federal-Provincial Advisory Committee on Environmental and Occupational Health, April 1987, Canada

/23/ Outario Ministry of Labour Guideline

/24/ DIN 1946, part 2, Ventilation Techniques Health Requirements, Jan. 1983

Table 2: CO_2 **Concentration at Different Locations in Germany in August 1987 /3/**

Location	monthly mean of half hour mean values in ppm	annual mean from Sept. '86 to Aug. '87 in ppm
Freiburg-West	350 (424)*	388
Weil am Rhein	354 (452)	363
Mannheim-Mitte	353 (447)	380
Eggenstein	355 (463)	370
Heilbronn	358 (455)	378
Ludwigsburg-Mitte	313 (452)	362
Stuttgart-Zuffenhausen	355 (446)	378
Stuttgart-Mitte	400 (462)	381
Stuttgart-Hafen	359 (442)	384
Stuttgart-Bad Cannstatt	358 (453)	378
Esslingen	371 (498)	385
Plochingen	331 (456)	354
Göppingen	364 (509)	373
Reutlingen	358 (480)	373
Aalen-Wasseralfingen	348 (513)	359
Ulm	365 (487)	377

* values in brackets are 1/2 hour mean max. levels

Table 3: Atmospheric CO-Concentrations /5/

	CO-Conc., ppm
natural base level	0.044 - 0.087
rural areas	0.175 - 0.435
industrial areas	0.87 - 1.75
downtown level with heavy traffic	- 40

highest level reported for Augsburg, Aug.'87 was 17.9 ppm

Table 4a: "SENSORS ONLY" FOR MEASURING RELATIVE HUMIDITY

No.	Company/Sensor Type/remark	kind of sensor	range % r.H.	accuracy % r.H.	long term stability/ calibration/gen. remarks	stability/drift cross sensitivity	output	size	prize $
1.	Valvo/ 2322 691 9001/ sensor only	capacitive	10-90	± 2	-/not necessary	-0.1% r.H./K	additional electronics necessary	16x23x17mm	15 1 item 7 1000 items 3.5 5000 items
2.	Murata/HOS 103 sensor only	resistance change	60-100	-	the sensor seems to be used only for dew point detection (Video recorders)	-	ohm, no linear output signal, constant below 60 % r.H.	7x6x1mm	1.2 1 item 0.6 1000 items
3.	Murata/HOS 201 sensor only	resistance change	50-100	-	-	-	ohm	Ø16x10 mm	7.5 1 item 3.7 1000 items
4.	Coreci/CCH/	capacitive	0-98	<±1 at 5< <90%	-/-/water droplets cause wrong output signals for short times	-/-/-	oscillatory circuit necessary	6x6x1.5mm	100
5.	Rotronic/ DMS-100/ hygrolyt	electrolytic solution	0-95	± 1,5	good/6-12 months resistent against agressiv contaminants	good/0.1 % r.H.	Impedance change add. electronics necessary	10x5,5x 3.3 mm 0,5 g	
6.	Rotronic/ C83/hygromer	capacitive	0-100	± 1.0	good/6-12 months	<0.5%/<0.5 %	add. electronics necessary	20x6x0,2mm 0,02 g	

Addresses are listed in table 4f

Table 4b: "COMPLETE SENSING DEVICES" (SENSOR + ELECTRONIC CONVERTER + ANALOG OUTPUT) FOR RELATIVE HUMIDITY

No.	Company/Sensor Type/remark	kind of sensor	range % r.H.	accuracy % r.H.	stability/calibration/general remarks	output	size/weight	prize $
1.	Coreci/CHRTAC humidity+temp.	CCH/capa-citive	5-98	2 at 10<θ<50°C	stable/no/	4-20 mA for hum. + temp.	357x125x80mm 500 gr.	705
2.	Galltec/ FG120 Pt100/ humidity + temperature	polyester stripes, resistance	0-100	2.5 at 40< <100% 3.5 at 10< <40%	-0.25% r.H./K/no calibration in clean air/-	in Ohm	128x74x49mm 200 gr	290 1- 9 items 260 10-19 items 165 20-50 items
3.	Rotronic/ YA100/hum. + temp.	capacitive hygromer C83	0-100	<±1	±0.5% r.H. at Δθ=70K/6-12 months	0÷1V hum. -0.5÷1.5V temp.	195xØ25 mm 150 gr	630
4.	Ahlborn/F 80	plastic stripe	0-100	±2.5	-/-/sensor can be cleaned with soap water, usually no main-tenance	100-138.5 ohm	- 600 gr	255
5.	Driesen/ HMW 20 U	Humicap capacitive from Vaisala (SF)	0-100	<3	-/-/membran filter for sensor protection	0-1 V 0-5 V 0-10 V 0-20 mA	-	340
6.	HY-Cal/ CT 828-A	-	0-100	±3	-/-/time const. 50 s; sensor washable	4-20 mA	110x70x40 mm	-
7.	Vaisala/ HMP 123b/ hum. + temp.	thinfilm	0-100	<2	-/-/-	0-20 mA	Ø12x65 mm	550
8.	Landis & Gyr/ QFA 62.2	capacitive Valvo sensor	20-90	-	-/-/-	0-10 V	-	180
9.	Landis & Gyr/ QFA 62.1/ hum. + temp.	capacitive Valvo sensor	2-90	-	-/-/-	0-10 V	-	195

"COMPLETE SENSING DEVICES" (SENSOR + ELECTRONIC CONVERTER + ANALOG OUTPUT) FOR RELATIVE HUMIDITY
(CONTINUED ....)

No.	Company/Sensor Type/remark	kind of sensor	range % r.H.	accuracy % r.H.	stability/calibration/general remarks	output	size/weight	prize $
10.	Landis & Gyr/ QFM 61.1 abs. humidity	hygro- scopic stripe	0- 20g/kg	-	-/-/-	0-10V	-	570
11.	Landis & Gyr/ QFM 61	Rotronic capacitive sensor	0-100	± 2	-/-/for higher requirements	0-10V		1075
12.	Centra Bürkle/ HKT 1/humidity + temperature	capacitive NTC (temp.)	10-90	≤ 3	max. 0.1 % r.H/K/-/-	0-10V	283x965	305

Addresses are listed in table 4f

Table 4c: COMPLETE SENSING DEVICES FOR "CARBON DIOXID (CO_2)"

No.	Company/Sensor Type/remark	kind of sensor	range ppm.	accuracy	stability/calibration/general remarks	output	size/weight	prize $
1.	Sauter/ EGQ 10 F001/ CO_2 selective	non-dispersive infrared absorpt.	0-2000 0-6000	± 100 ppm.	weak influence of hum. + temp./ 5 years/appr. available July'88	0-10 V 0-20 mA	120x120x60mm 200 gr.	520
2.	Aritron/ AROX 425AB2E3	infrared with micro-phone	35-2000	-	+0.3 % FS/°C +0.06 % FS/% r.H. every 18 months	0-10 V	188x110x70mm	720-1400 depending on country and relativ
3.	AF-Energi/ prototype/exp. with Lund University	infrared absorp.	0-2000		± 20 ppm short time < 200 ppm after 2 months	4-20 mA	-	330

Addresses are listed in table 4f

Table 4d: SENSORS AND COMPLETE SENSING DEVICES FOR "CARBON MONOXIDE (CO)" DETECTION

No.	Company/Sensor Type/remark	kind of sensor	range ppm.	accuracy	stability/calibration/general remarks	output	size/weight	prize $
1.	Unitronic/ TGS 712D	thin film produced by Figaro/ Japan	20-200	-	-/-/working temp. at 200°C	ohm	Ø20x23mm	44 sensor only
2.	Unitronic/ TGS 711	thin film (Figaro/ Japan	50-500	-	-/-	ohm	Ø20x21mm	43 sensor only
3.	Unitronic/ TGS 203	thin film	50-200	depends on sensitivity of circuit	temp. compensation included	ohm	-	130 a)
4.	Unitronic TGS 100 + TBS 800	Figaro sensor	several ppm orabove	-	-/-/suited for CO, H_2, cigarette smoke, gasoline vapor, etc.	ohm	-	12
5.	Unitronic TGS 812	thin film	-		-/-/used for smoke and alcohol detection	-	-	-
6.	Preussag /-/	Figaro sensor	0-45	-	-/-/	digital	-	100 sensor only 710 complete device
7.	Endrich/ NAP-11A/	Semi-conductor	50-	-	-/-/-/	ohm	Ø17x25 mm	25

a) price includes the sensor, the temp. compensation and IC-unit (FIC 5401)

Addresses are listed in table 4f

Table 4e: SENSORS AND CONTROLLING DEVICES FOR "ODOR DETECTION" (MOSTLY BASED ON THE AMOUNT OF NON-OXIDIZED GASES

No.	Company/Sensor Type/remark	kind of sensor	stability/calibration/general remarks	output	size/weight	prize $
1.	Staefa/FRA-Q1/	semiconductor	sensitive to changes in air velocity/ no need/-	0-10 V	10x10x1 cm 50 gr	200
2a	Landis & Gyr/ QPA 61.1/ sensor only	semiconductor heated	-/-/-	0-2.5 mA	100x81x32mm 140 gr	140-240 (D)-(I)
3b	Landis & Gyr/ SER 61.1 com-plate contro-ler unit	QPA 61.1	-/-/0-100 % air quality adjustable	0-10 V	-	220
3.	Staefa/FR-G4/ sensor RNG 92/con-troler	TGS 812 from Figaro semiconductor	sensitive to temp. /-/ signal increases with odors or tobacco smoke	0-20 V	80x80x22mm 185x133x51mm	120 sensor only 375 complete controler
4.	Centra/ CR-LQR1	semiconductor		0-10 V	166x75x34mm	212-380 (D)-(I)
5.	Sauter/EGQ1-F001/sensor ERQ1-F001/ sensor + controler	Figaro	<1%/°C; <0.3%/% r.H. /-/ manual set-point switch at ERQ1 (external one possible), 30 < < 70% r.H.	0-10 V	70x70x50 mm 100 gr	175
6.	Unitronic/ F3801+F3103 from Figaro	semiconductor	-/no/microcomputer enables simulation close to human olfaction	0-20 mA 5 levels	70x50x20 mm 100x70x35 mm	not yet avail-able device sold in Japan

Addresses are listed in table 4f

Table 4f: Addresses of sensor companies

AF	AF-Energi Malmö
Ahlborn	Ahlborn M+R, Eichenfeldstr. 1-3, P.O. Box 1260, D-8150 Holzkirchen 08024-5019
Andros	Andros, USA
Aritron	Aritron AG, Lohwiss-Str.30,CH- 8123 Ebmatingen 01-9803381 Vogtle Malanca, Via Battaglia, I-40 Milano
Centra	Centra-Bürkle GmbH, P.O. Box 1164, D-7036 Schönaich, 07031-557-01
Coreci	Coreci GmbH, P.O. Box 1570, D-7830 Emmendingen, 07641-8365
Driesen	Driesen+Kern, P.O. Box 1126, D-2000 Tangstedt, 04109-6633
Galltec	Galltec GmbH, Boschstr. 4, D-7031 Bondorf, 07457-8158
HY-Cal	HY-Cal Engineering, 9650 Telstar Ave, El Monte, California 91731-3093, USA
Landis&Gyr	Landis&Gyr, Friesstraße 20-24, D-6000 Frankfurt 60, 069-4002-0 Landis&Gyr, Via Rondoni 1, Milano, 02-4248 Landis&Gyr, Baarmatte, CH-6300 Zug, 042-334545
Murata	Murata Erie Electronic GmbH, Kreuzsteinstr. 1A, D-8500 Nürnberg 52, 0911-66870
Preussag	Preussag AG, P.O. Box 1260, D-2060 Bad Oldesloe, 04531-8030
Rotronic	Rotronic AG, Badenerstr. 435, CH-8040 Zürich, 01-4971111
Sauter	Sauter Cumulus GmbH, Hans-Bunte-Str.15, D-7800 Freiburg, 0761-5105-0 Sauter, Im Surinam, CH-4016 Basel, 061-695 55 55
Siemens	Swedish representative is Nissmo AB
Staefa	Staefa Control System GmbH, Humboldstr. 30, D-7022 Leinfelden-Echterdingen, 0711-7987-0 Staefa Control Systems. Laubisrütistr.50 CH-8712 Staefa, 01-9286111
Unitronic	Unitronic GmbH, Talstr. 172, D-7024 Filderstadt, 0711-704011
Valvo	Valvo, P.O. Box 106323, D-2000 Hamburg 1, 040-3296-556
Vaisala	Vaisala, P.O. Box 26, SF-00421 Helsinki