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ENERGY CONSERVATION IN BUILDING AND COMMUNITY SYSTEMS PROGRAMME

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IEA ANNEX 18 / 1

DEMAND CONTROLLED VENTILATING SYSTEMS

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IEA ANNEX 18

DEMAND CONTROLLED VENTILATING SYSTEMS

1. BACKGROUND

People of industrialized countries spend at least 90 % of their time indoors at home or at work. It is therefore essential that the indoor air quality and the indoor climate are acceptable with respect to reducing risks of illness and allergic reactions. The emission can originate from different sources e.g. building fabric, mould groth caused by wetted building fabric (on surface or interstitial). At the same time ventilation systems have to be designed to keep the energy demand as low as possible. This leads to systems where the ventilation rate is chosen as a function of the indoor load of pollutant emission, i e Demand Controlled Ventilating Systems (DCV Systems).

2. OBJECTIVES

The objectives with the annex have been to develop means, methods, and strategies for DCV-systems and to contribute to the implementation. A DCV-system in this annex is defined to be a ventilation system in which the air flow rate is governed by airborn pollutants.

3. WORK DISTRIBUTION

The work within Annex 18 has been subdivided into the following tasks:

Subtask A: State-of-the art
Subtask B: Sensor tests and Case studies
Subtask C: Source book, Theory and recommendations

All countries have participated in Subtasks A and C and have chosen to contribute to the work in Subtask B according to **Figure 1**.

4. INTRODUCTION

The Annex was started in July 1987.
Participating countries are:
Belgium, Canada, Denmark, Finland, Germany, Italy, The Netherlands, Norway, Sweden (Operating Agent), Switzerland.

AIVC has acted as an observer.

The products from the Annex will be five documents.

1 State of the Art Review, published 1990
The content of the report is
- Pollutant levels in various building types.

- Standards for indoor air quality (IAQ)
- Sensors, function principal
- Summary of the review of finished case studies on DCV-systems reported before 1989.
- Review of measured pollutant concentration in occupied spaces.
- Conclusions and recommendations.

2 Sensor market survey, published 1992
This work was finished in July 1991 and is giving names of 52 commercially available sensors with the distribution:

- Humidity	26 sensors
- CO_2	7 sensors
- Mixed gas (also called IAQ, nonoxidized, VOC or hydrocarbon sensors)	7 sensors
- Combined, others	12 sensors

3 Sensor tests to be published 1992
Totally 4 sensors of each 15 types have been tested in laboratory and in field.
The distribution of the three governing pollutants/indicators are

Humidity	8 types of sensors
CO_2	2 types of sensors
Mixed gases	5 types of sensors

4 Case studies to be published 1992
Case studies have been carried out in laboratories in two projects and in the field in several projects. The total number of buildings involved have been 10 single family houses, 7 blocks of flats, 6 office buildings, 2 assembly halls, and 1 school. One purpose with the laboratory project was to study the sensor location when having mixing or displacement ventilation.

Field tests in offices have been carried out in meeting rooms, open area workstations, and whole buildings. For the case of assembly halls both smaller and larger rooms have been studied. Most of the studies in residential buildings have been on ventilation governed by the humidity.

5 Source Book to be published 1992
The headings of the various chapters are
- Introduction
- Pollutants and Relevant Indicators
- Analysis of Prerequisites
- Sensor Types
- Control Principles
- Dwellings, system choice
- Schools and Day Nurseries, system choice
- Assembly Halls, system choice
- Offices, system choice
- Operation and Maintenance
- Conclusions and Recommendations

5. POLLUTANTS AND RELEVANT INDICATORS

A pollutant is a substance that makes another substance impure. Thus, all sorts of substances that are not a natural part of clean outdoor air should be looked upon as pollutants. Often many pollutants are present at the same spot and at the same time. For example, human beings in normal activity produce odours, water vapour and carbon dioxide. In other cases different sources are not related in time and space in a predictable way.

Carbon dioxide in all normal concentrations is not a pollutant but a possible key indicator on generated pollutants. In the following will be described different types of pollutants and their sources.

The human heat production can be indirectly found by measuring the intake of oxygen and the dissipation of carbon dioxide. From experiments we know the heat production from different types of nutrients. A person using "normal" food will dissipate about 20 kJ per litre of oxygen absorbed.

Moisture dissipation from human beings mainly varies with acitivity level and only to a minor part with the water vapour pressure of the air (temperature and relative humidity). Vapour pressure at the skin surface is 5 - 6 kPa, depending on acivity level.

The carbon dioxide and water vapour production of adults related to methabolic load is approximately the following:

Table 1: Methabolic data as a function of activity level

Activity	Lung vent.l/(min.p)	CO_2-prod l/(h.p)	Water evap. g/(h.person) 18	20	22C	Methabolism W/person
Rest	<7	12	30	35	45	75
Office work (writing)	<10	18	35	40	50	110
Standing	10-15	21	45	50	60	130
Walking (4 km/h)	15-25	39	160	180	190	240
Tennis, Shovel work	40-50	65-80	250 and higher	270	330	350-500
Wrestling	>50	110-150	ca 1000			700-900

The discussion above leads to the following short conclusions on different types of pollutants that are normally to be found in buildings.

Table 2: Relative influence of pollutants

Pollutant/ Relevant indicator	Relative Influence on Humans	Buildings	Remark
1. Moisture	Small	Large	Dwellings C + D
2. VOC	Moderate	Small	C
3. Particles	Moderate	-	Respirable D
4. CO_2	None	-	Indicator D
5. Odour	Small	-	Large for visitors C + D
6. Tobacco smoke	Large	Moderate	Furnishing D

C = Constant load, at least over periods of 24 hours
D = Dynamic load, caused by human activities

Water evaporation

Water evaporation from skin as a function of activity level and room temperature can be seen from **Figure 2**. Acceptable long term values of relative humidity (RH) at the higher end are:

50% in order to prevent growth of dust mites
75% building material degradation caused by condensation and high moisture content in the material or both.

Too high RH may cause mould growth which is often found to be the active source for allergic reactions. Short term values of RH often reach 100%, which can be acceptable if the moisture in the room air and in affected building materials is taken away within reasonable time. A guideline can be found in IEA Annex 14, "Condensation". Further studies on interstitial condensation are carried out in IEA Annex 24, "Heat-, Air-, Moisture Transfer in New Retro-fitted Insulated Envelope Parts".

Volatile organic compounds

Volatile organic compounds (VOC) are gaseous substances containing carbon. In most cases the substances also contain hydrogene and as a function of oxidization also oxygene. Many other chemical elements are represented in the VOC:s.

The human response to VOCs is known only for a restricted number of products. The individual concentration of each VOC in a building is normally far below the hygienic limit. On the other hand the number of VOCs is high, and the compound effect of VOCs present at the same spot and at the same time is not known. Threshold values for the individual person are widely different. Thus our knowledge in this area is not deep enough for using the VOC as a relevant indicator for automatic control of indoor air quality.

Average concentration of Volatile Organic Compounds (VOC) in room air in new or refurbished buildings has been found to be about 2.9 mg/m^3 at a ventilation rate of 0.5 air changes per hour. Corresponding value for an old building is in the approximate level of 0.7 mg/m^3.

Moisture accelerates the dissipation of VOC from most building materials. When moistened or wetted such materials might cause a temporary 10-fold higher room air concentration of VOC.

New building materials emit pollutants to a greater extent than older materials. This calls for a larger basic air change rate in a new building than in an older one.

Cleansing compounds often give so high a dissipation of VOC that a forced ventilation is needed during the cleaning operation and for some time thereafter. The forced ventilation may be fulfilled by window airing. The same stands for cleaning by ordinary vacuum cleaners.

Acceptable levels of VOC vary with the type of chemical substance. A maximum outdoor air hydrocarbon concentration of 0.05 ppm is allowed according to German standard. This corresponds to a VOC concentration of about 0.04-0.10 mg/m^3, depending on molecular weight of the pollutant. Thus, most of the indoor air VOC level has its origin in the building itself or in actions by the user.

Particles and tobacco smoke

Particles are defined as solid matter in equivalent sizes less than 1 mm in diameter down to fractions of micrometers. Supply air or room air can be purified from particles by filters (fine or micro filters). Smoke from cigarrettes and pipes are a form of organic and other particles. This smoke is often absorbed by furniture and textiles and thus also represents a source in itself for VOC:s.

In most cases, with the exception of smoking, the particle concentration of indoor air is not crucial because other factors govern the necessary ventilation rate. The use of particle sensors is a possible way of controlling the necessary ventilation rate in rooms where smoking is allowed.

The concentration of particles in room air has been found to be of the following order of magnitude:

Table 3: Particle concentration in room air

Room type and activity	Particle conc. number/m^3	Weight mg/m^3	Rel. level
Appartment or office			
Normal level	$0.3*10^6$	0.05	1.0
Vacuum cleaning	$0.9*10^6$	0.15	1.5
Acceptable level	$1.5*10^6$	0.25	2.5
Fine filtered supply air	$0.1*10^6$	0.01	0.2
Living room, 50 m^3, 0.5 air ch/h			
One cigarrette, side smoke	$40*10^9$	1.0	20
One cig/hour, continuously	$120*10^9$	3.0	60

The ventilation system

The emission of pollutants mainly consists of VOC and is normally indicated by persons present. The emission from the ventilation system is practically constant as long as no wet cleaning of the system is made and no return air or circulation air is used. A constant base ventilation rate to keep the concentration level low is therefore logical.

In order to keep the system as clean as possible the filtration of supply air and of return/circulation air if used should be carried out by using fine filters (preferably F 85, Eurovent class EU 7).

Carbon dioxide

Carbon dioxide is the main exhaust product from methabolism of human beings and animals.

If the maximum CO_2-concentration is allowed to rise to as much as 2 % (20 000 ppm) the necessary ventilating rate for a person at rest is about 0.25 l/s. The oxygen concentration of the surrounding air is thereby reduced from 21 % to 19 %. Lack of oxygen caused by low ventilating rate is not critical, but very high CO_2-concentration is.

Table 4: CO_2 concentration levels as a risk indicator

Situation	CO_2 conc, ppm abs	Remark
Death risk	50 000	-
Medical limit	20 000	Air raid shelter
Hygienic limit	10 000-15 000	Peak 15 minutes
Ditto	5 000	8 hours
Quality level	800-1 500	From methabolism *)
Outdoor air	350-400	

*) CO_2 from open fires not included

Carbon dioxide is often used as a key indicator. It is a good indicator of human presence and has been found to follow the emission of bio-effluents from human beings.

In cases where smoking is allowed the CO_2 concentration cannot be used as an indicator of the odour level. In those cases the ventilation rate should be set by the number of people smoking and the intensity thereof.

Presence indicator

A presence indicator can be designed to indicate movement or radiant heat or both. Thus it can indicate the presence of human beings. In as much as that presence causes a pollution of the room air the presence indicator can be used only to start and stop the ventilation system or alter the air change rate of the treated space. The quality level must be controlled by other types of sensors unless the number of occupants and their activity level is predictable and constant.

Subjective response versus objective data

The human nose can smell most of the VOC:s. The perceived level can serve as a warning signal but it cannot more than seldom inform the indicating person of a possible danger. On the other hand, some VOC:s that are dangerous on short or long term cannot not be indicated by the human nose. Thus the human receptors cannot be looked upon as relevant indicators on VOC:s.

Human beings can not indicate the level of relative humidity if it lies within normally found values, 15 - 75 %.

Under normal circumstances it is not relevant to measure the concentration of respirable particles and use it for governing the air flow rate.

Body odours can be perceived only for a short period of time, after which the receptors in the nose loose their sensivity . Thus, only a "fresh nose" can perceive the odour level caused by human bioeffluents.

An acceptable **room air quality** is said to be at hand if no more than x % of the occupants are unsatisfied. The value of "x" varies from 5 to 20 depending on researchers' points of view and types of person groups interviewed. The value is higher for persons entering a room than for persons already occupying the room, see **Figure 3**. If the number of unsatisfied exceeds 20 %, then some remedial actions is highly recommended. These actions could include increase of air change rate in the occupied zone, improved filtering of outdoor air, local exhaust air terminal devices etc.

6. PREREQUISITES

Factors affecting the possibility of maintaining a desired or acceptable indoor air quality by means of a centralized DCV system are:

1. Pollutant production within the building
2. The building itself
3. HVAC installations
4. The climate

Pollutant production within the building

The main prerequisite for installing a DCV system in a building is that the pollutant emission rate is expected to be one or more of the following:

a) **high** enough as to require the installation of additional (natural or mechanically assisted) ventilation in combination with that provided by natural infiltration

b) **variable in time**

c) **unpredictable** as to time and location of the source

As there are many pollutants produced within the building, it should be stressed that the above properties (variablity and unpredictability) should be simultaneously belonging to the **driving pollutant**. This can be defined as the pollutant, the level of which (or the monitorable symptom of which) is such as to require the highest ventilation rate. A decision diagramme taking into account these factors is shown in **Figure 4**.

Once the decision diagramme has provided a positive answer under the rational point of view, the practical and logistical questions should follow, before a final decision is taken, see **Figure 5**.

Air tightness

If a building is so leaky that natural infiltration gives sufficient ventilation, then a DCV system is clearly not applicable. The tighter the building, the more efficient the control of ventilation by a proper DCV system, and the greater the energy savings will be. As a rule of thumb, if normally more than

50 % of outdoor air comes from uncontrolled natural infiltration, the performance of DCV systems will be low for both IAQ and energy saving.

7. CONTROL PRINCIPLES

Ventilation and the removal of odour

On the definition of 1 olf being equivalent to the dissipation from one person the total load from building and people can be assumed to fall within the ranges given in **Table 5**. The trivial lower limit of personal load is of course zero. The upper limit is calculated from assumptions on the maximum personal load per m^2.

Table 5: Pollutant load ranges from Building and Occupants in a building

Building type	Pollution load (olf/m² floor area) Building Min - Max	Occupants Min - Max	Total Min - Max
SCHOOLS	0.12-0.54	0.00-0.30	0.12-0.84
OFFICES	0.02-0.95	0.00-0.08	0.02-1.03
AUDITORIA	0.09-1.32	0.00-1.10	0.09-2.42
DAY NURSERIES	0.02-0.74	0.00-0.20	0.02-0.94

The main purpose of ventilation should be to take away odours from the treated space. In most cases this transport takes place in the form of a dilution process. The advantage of a large flow rate is much less than is often imagined see **Figure 6.** On the other hand, the operating cost of an increased flow rate and often also the investments follow the flow rate almost linearily. Furthermore, a larger flow rate often causes risk for unacceptable local air velocities in the treated space and call for a higher indoor temperature.

The ventilation concept

It is a fact that building materials emit at all times and emit more when new. Thus increased ventilation rates will be required during the "running-in period" of a new building. It is then also more energy efficient to use heat exchangers or to turn systems off during unoccupied hours. If the system is turned off concentration will build up during unventilated hours.

Preventilation is practically always appropriate. Otherwise there will be a poor first impression in the morning when the nose is fresh and an even worse impression after a weekend stop.

The reasoning above leads to a general concept of operating a ventilation plant. There will be a need for a **base ventilation** to cope with the emissions from the building and its furnishing. This ventilation has to be combined with a **demand related ventilation** which has to be designed under consideration of the age and type of material in the building, the number of occupants and the type of activities taking place in the building.

Control strategy

The first rule of practice is of course to choose materials and surface coatings correctly in order to reduce the emission from the building itself. **The second rule** of practice should be to keep down as low as economically and practically possible pollutants from human beings, pet animals, and processes.

In general, there are two methods for reducing the impact of pollutants emitted in a room:

* The use of local extraction, such as exhaust hoods
* The use of increased general ventilation

The control principles can be summarized to be

Base ventilation rate:
* Around the clock constant
* Part time constant
* Preventilation with higher rate
* Intermittent forced

Presence related ventilation rate:
* Constant around the clock or part time
* Clock control
* Manual control
* Presence sensor control
* Continuous monitoring and control
    - multi speed fans
    - continous modulation

In **figure 7 and 8** is given the choice of control strategies for base and presence related ventilation rates.

8. SAVINGS

In order to investigate the feasiblity of a DCV system a simulation model could be used to make a cost-benefit analysis. The system performance will have to be analysed under typical and not design climatic conditions. The output of the simulation should consist of the following quantities, known as a function of time:

- Air flow rate
- IAQ levels (i.e concentrations)
- Ventilation loads

Table 6 might serve as a guidance for discussing the profitability in using different types of DCV systems in buildings for different purposes. Figures presented relate to DCV ventilation system only. Energy price is supposed to be 0.1 ECU/kWh.

Table 6 Rough estimation (range in percentage of energy used for for ventilation) of energy saving and pay back time by using DCV systems

Building type	DCV system type	Savings range,%	Savings ECU/(m^2.y)	Investm. ECU/m^2	Pay back time,year
Dwellings	Manual or humidity sens.	5-15	1-3	3-5	1-5
Office					
Sales, 40% present 50% heat recovery	CO_2	20-30	1-2	10-20	5-10
Admin, 90% present 50% heat recovery	CO_2	3-5	0.3	10-20	>30
School					
Heat exch	CO_2 Presence	5-10	3-6	5-10	0.5-3.0
No exch	CO_2 Presence	20-40	15-25	20-60	1.5-2.5
Assembly halls	CO_2	20-50	20-40	10-70	0.5-3.0
Day nurs.	CO_2	20-30	3-5	5-10	0.5-3.0
Dep.store	VOC	50-70	15-20	<0.1	<0.1
Athl.hall	VOC	40-60	20-30	5-10	0.2-0.5

The relative energy saving (%) achieved by DCV is calculated from the ratio of the energy demand for the DCV system studied and the energy demand for a conventional system, both at a yearly basis. Once the total energy losses are calculated these will be compared to ventilation energy losses induced by competing systems (e.g constant flow rate ventilation systems).

The energy savings and the extra costs for DCV will have to be compared in order to evaluate the return on investment, the profitability or the Life Cycle Cost of the installation.

One essential part of the energy conservation strategy is to use the ventilation system only when there is a need for it. The main purpose of using a DCV system is to achieve an acceptable indoor air quality under most of the operational time of a building.

In practice, the savings actually achieved have been found in the region of 0-80 % of those theoretically calculated. The zero level normally is a result of lack of proper operation and maintenance.

9. RECOMMENDATION

In Table 7 is presented experience on systems and components suitable for DCV systems as reported from the participating countries and organisations.

Table 7: DCV systems suitable for different types of buildings

DCV system type	Suitable for building type	Remarks and notes
Manual		Foreseen situation or instrument reading
Humidity		High-Low, Continuous fan speed
Carbon dioxide	Domestic, Schools	Open windows when
Particle	All	local vacuum cleaning
Clock relay	Offices, Schools	Pre-airing
Light switch	Bathrooms, WC	
Sensor governed		
Presence	Offices, Schools	System on-off
Humidity	Domestic	High-Low, Continuous
Carbon dioxide	High occupancy	Continuous
Odour	All	Sensor development needed
Tobacco smoke	Room where smoking is allowed	Mixed gas sensor

Base rate ventilation must be chosen at a level high enough to dilute normally existing emission of pollutants from the building, it's installations and furnishing.

Controllable rate ventilation often must be introduced as a complement to the base rate to deal with system sources, i.e. pollutants from filters and ducting.

Variable rate ventilation, the DCV part of ventilation, has to be designed to deal with occupancy load.

Seasonal influence of ventilation rates used for other purposes than room air quality, i.e. free cooling with outdoor air, is to be considered when programming the automatic operational control system. So should leakage through the building envelope, which is normally higher at low outdoor temperature.

New furnishing often causes a relatively high emission of pollutants during the initial time of operation (up to two years). This calls for an increased base ventilation rate during this period, the lenght of which has to be deduced from operational data.

10. ANNEX 18 KEY MESSAGES ON DCV-SYSTEMS

Benefits:

DCV is aimed to guarantee good air quality at low energy consumption and hence lower life cycle costs for many buildings and applications. They will vary depending on climate, building type, ventilation system, and occupancy pattern.

Applications:

The examples presented are cases with a real background and must be suitabaly treated when used in an individual situation. Sensor development is foreseen to be rapid. Thus any given recommendation must be checked at the market before decision on it's use.

Limitations:

Local regulations may inflict on implementation proposals in the source book. Sensor imperfectness may lead to lower savings and higher Life Cycle Cost than expected from general conclusions

Cautions:

The decision on usage of a DCV system must be taken for each type of process and building under the individual auspicies that are at hand.

Development:

Further development is neccessary, expecially in the sensor field, with respect to both control accuracy and long term operation stability.

Conclusion:

There are DCV-systems that work, even work well, save energy, and give acceptable IAQ.

	Sensor tests	Lab. tests	Case studies							
		Offices sensor location	Dwellings			Offices		Auditoria		Schools
Country			RH	CO_2	IAQ	CO_2	time control	CO_2	time control	Presence
Belgium			X							
Canada			X			X	X			
Germany			X							
Italy			X							
Netherlands			X		X					
Norway								X		
Sweden	X	X				X				X
Switzerland	X[1]							X	X	

[1] Sensors were checked in the case study

Figure 1: Work distribution

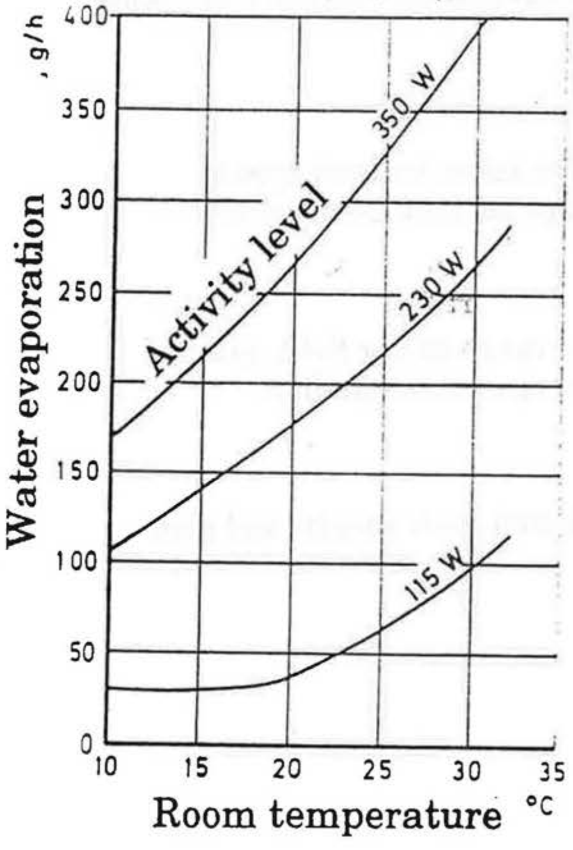


Figure 2: Water evaporation as a function of activity level and room temperature

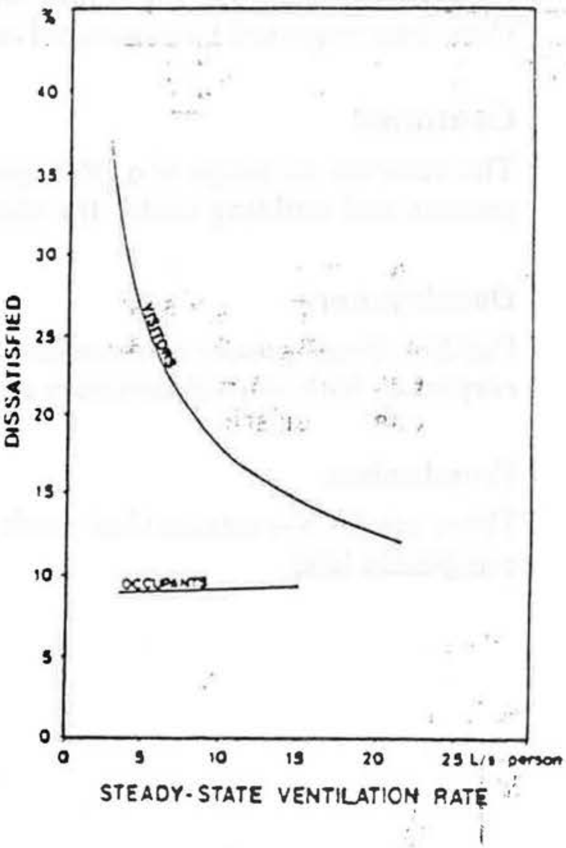
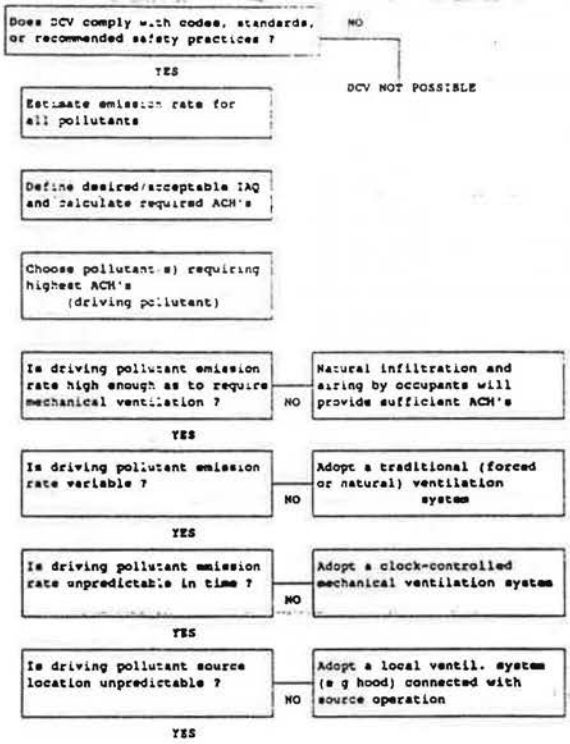


Figure 3: Percentage of dissatisfied visitors and occupants as a function of steady state ventilation rate



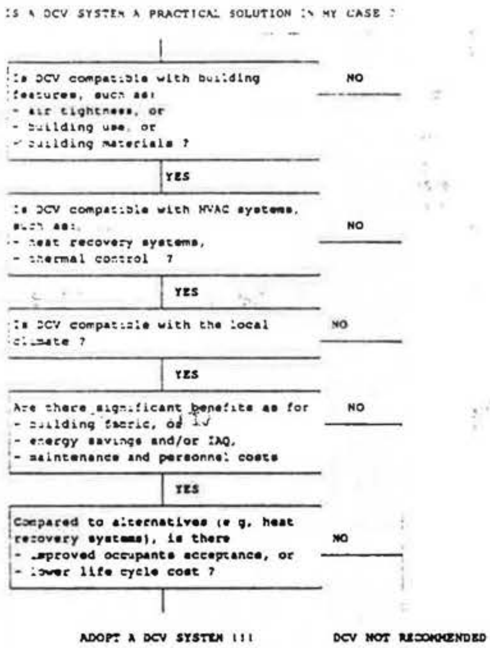


Figure 4: Decision flow chart for choosing a DCV system according to pollutant emission rate characteristics

Figure 5: Practical design flow chart for choosing a DCV system

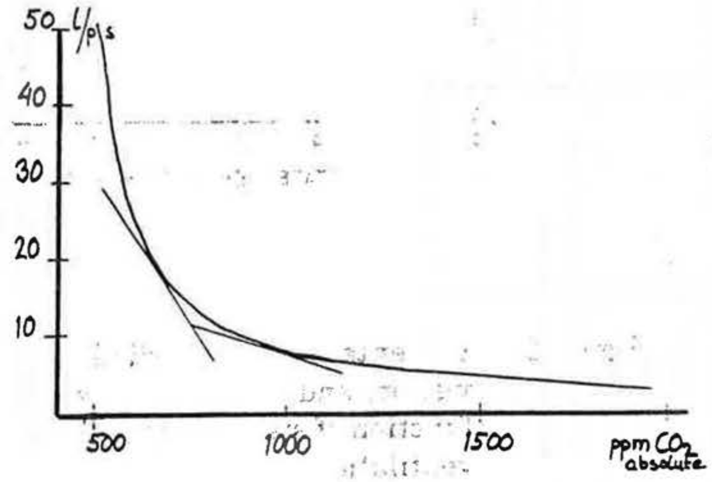


Figure 6: Necessary ourdoor air flow rate per person as a function of indoor air CO_2 concentration.

Characteristics	Control strategy	Possible application	Remarks
- Continuous occupancy around the clock	constant base ventilation around the clock	hospitals, dwellings	
- considerable emissions from building materials - continuous occupancy during known periods	constant base ventilation during part-time	offices, schools, cinemas, theatres, dwellings	- does not solve problem of "sick buildings" - might improve controllability of the system
- low emissions from building materials - continuous occupancy during known periods	pre-ventilation with higher ventilation rate	offices, schools, cinemas, theatres	- gives more emphasis to presence related ventilation
- low emissions from building materials - discontinuous occupancy	intermittent forced ventilation	meeting rooms, department stores, schools, assembly halls	- forced vent. rinsing periods in accordance with source strength, air change rate and occupancy profile

Figure 7 Choice of strategy for base ventilation rate

Characteristics	Control strategy	Possible application	Remarks
- known source strength - no fluctuations of pollutant load	constant ventilation rate	storehouses, archives, offices with constant occupancy load	
- known source strength - predictable fluctuations of pollutant load	clock control	class rooms	- information flow crucial - system cannot handle unforeseen changes in occupancy
- known source strength - unpredictable occupancy - user willing to take responsibility	manual control	class rooms, meeting rooms	- simple installation - user must be instructed - does not guarantee acceptable indoor climate
- constant load during occupancy periods - unpredictable occupancy periods	presence sensor control	one person offices, class rooms	- cannot handle fluctuations of load - pre-ventilation not possible
- one dominant pollutant exists - unpredictable fluctuations of pollutant load	continuous monitoring and control (indicators are CO_2, relative humidity or VOC)	assembly halls, dwellings, offices, meeting rooms	- sophisticated solution - crucial to recognize dominant pollutant - only strategy which really controls indoor air quality

Figure 8 Choice of strategy for presence related ventilation rate

INTERNATIONAL ENERGY AGENCY

**energy conservation
in buildings and community
systems programme**

Annex 18

Demand controlled ventilating systems

Final report

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Annex 18 - DEMAND CONTROLLED VENTILATING SYSTEMS

1. Participating countries and organizations

Participants in the Annex:

Belgium

Canada

Denmark

Federal Republic of Germany

Finland

Italy

The Netherlands

Norway

Switzerland

Sweden — Operating Agent

Observer:

AIVC

1.1 Fulfillment of the subtasks

In the following is described how the participants have contributed to the various subtasks

Country	Subtask A	Subtask B	Subtask C	Working meeting attended	Working meeting arranged
Belgium	Full	Full	Full	5	1
Canada	Full	Full	Full	11	2
Denmark	-	-	Contribution	6	-
Fed. Republic of Germany	Full	Full	Full	11	1
Finland	Full	-	Contribution	8	1
Italy	Full	Full	Full	11	2
Netherlands	Full	Full	Full	8	-
Norway	Full	Full	Full	10	1
Switzerland	Full	Full	Full	11	1
Sweden	Full	Full	Full	11	2

2. Description of Annex

At the Executive Committee meeting in Antwerp in December 1986 the Annex 18 "Demand controlled ventilating systems" was accepted with the scheduled start 1st July 1987.

Many IEA countries have an increasing problem with the indoor air quality and studies are undertaken concerning outgasing from building material, human habits, odour, threshold limits etc. The experiences from all these indoor air quality studies may give as a result an increased demand for outdoor air supply. A demand controlled ventilating system is one of the option to give the occupants a good indoor air quality without unnecessary waste of energy.

The objectives of the Annex are to develop means, methods, and strategies for demand controlled ventilating systems and to contribute to an implementation of the knowledge accumulated during the work on the Annex. The work is directed towards ventilation systems in different types of buildings exemplified by single family houses, apartment buildings, schools, commercial buildings, and administration buildings. The intention is that the final report of the Annex will be a Source book giving guidance how to design and operate demand controlled ventilating systems.

To fulfil the objectives the work is divided into the following subtasks:

A. Review of existing technology

B. Trials

B 1. Long term test of sensors in laboratory and field

B 2. Trials in unoccupied test buildings or test rooms

B 3. Full scale trials in buildings in use

C. A source book on design and operation of demand controlled ventilating systems

2.1 Expected results

The expected results from the subtasks are:

Subtask A

The subtask is completed and the report is printed. Title: Demand Controlled Ventilating Systems, State of the Art Review

Subtask B

Each project in the participating countries will be reported in a standardized way.

In the separate case study reports will be given the results with respect to energy savings, indoor air quality, and the function of the system.

Subtask C

A source book will be written based on the knowledge gained in Subtask A and B and by the experts' knowledge in the participating countries. The main purpose with the source book is to give recommendations how to design DCV systems in different types of buildings.

2.2 Strategy to meet goals/results

The work has been divided into three subtasks

Subtask A

In this subtask the work has been to collect and analyze information about standards and codes, and projects already finished and reported. The state of the art report was put together by Germany after having got a consensus of the content. Later a second sensor market survey has been made by Germany.

Subtask B

To facilitate the work, the task is divided into three parts:

B.1 Long-duration test of sensors both in the laboratory and in the field.
This task contained the testing of electrically regulating sensors. Manufacturers have sent sensors to the laboratory in Sweden, The tests have been carried out on 9 humidity sensors, 2 CO_2 sensors, and 4 IAQ sensors.

The report has been reviewed by the participants and manufacturers.

B.2 Trials in unoccupied test buildings or test rooms have been made to simulate the situation in an office with a mixing system and in a room with displacement ventilation. The main purpose was to find out sensor locations. From the beginning it was planned to have projects besides in Sweden also in Finland and Germany.

B.3 Full-scale trials in buildings in use.

The main purpose was to support the conclusions with good examples. The trials covered most of the building types and was carried out in dwellings, offices, schools, and assembly halls. The result and analysis from each test case is presented in a standardized form. At the working meetings results from all case studies have been presented and analyzed.

Subtask C

The subtask aimed to produce a source book from which national hand books could be written. All participants should contribute to the subtask and come to a consensus of the content. This was finally achieved.

2.3 Annex Beneficiaries

The result of the Annex is the source book with the supporting examples giving the following messages:
* approach exists
* there are many applications and they work
* benefits in energy savings and IAQ
* how to decide if DCV is appropriate
* proposal for further development
* examples

With results from the source book a national handbook can be produced in each participating country.

2.4 Plan for disseminating results

All reports are planned to be accepted for unrestricted distribution.

AIVC will be used as a vehicle to disseminate the results.

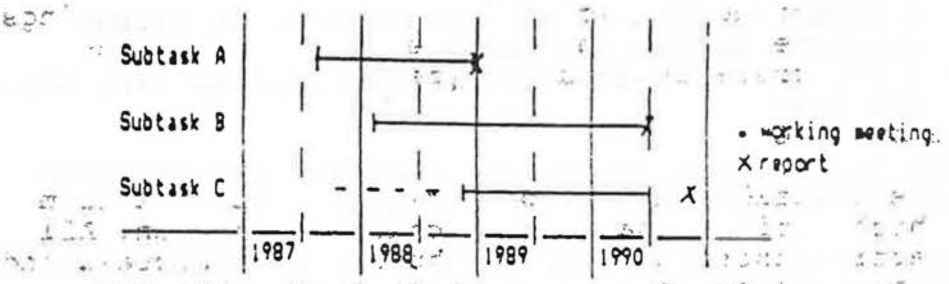
AIVC has presented Annex 18 in AIR as well as presentations of the Subtask reports.

Results from the Annex has been presented at AIVC-conferences.

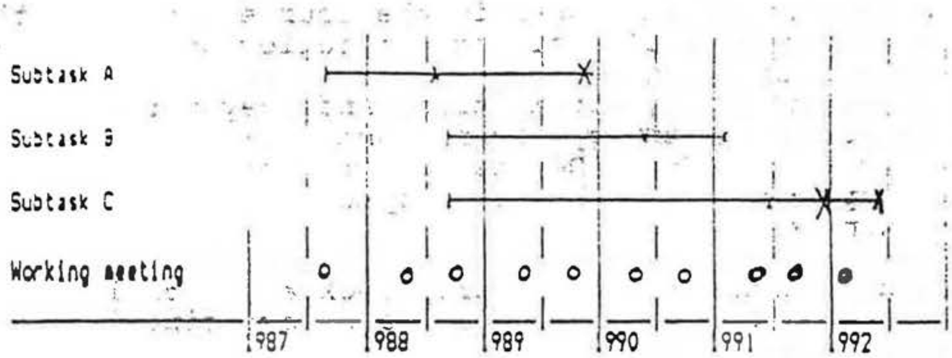
3 Programme Plan

3.1 Time schedule

Original Plan dated May 1987 from the kick-off meeting



The actual time schedule with 10 Working Meeting



3.2 Accomplishments

The following reports from the Annex is planned:

1 State of the Art Review, printed 1990
2 Sensor Market Review, printed Feb 1992
3 Sensor Tests to be printed 1992
4 Case Studies to be printed 1992
5 Source Book to be printed 1992

* A presentation of the sensor market was given at the AIVC conference in Belgium September 1989.
* An overview of annex 18 was given at the AIVC-conference in Finland September 1989.
* Presentation of the Subtask A report has been made in AIR.
* Sensor Market Review is finished

At the AIVC conference 1991 in Ottawa 12 presentations were made on
- conclusions of the annex
- source book
- lab tests
- case studies

4. Management of the Annex

To meet the need to finish the Annex and having a consensus on the content and wording of the source book the work was organized in the following way.

- a final discussion at the 10 working meeting in February 1992, in Italy
- a final version to be commented on or silent approved before 1st April
- a few comments included in the version sent out to the Exco

The sensor test report was sent out and comments should be received before 21 April 1992.

Some case studies still remain to be reported in the format requested (end of April 1992).

* ExCo decision on unrestricted distribution of the following reports
  - Sensor tests
  - Case studies
  - Source Book
* Canada is doing the English brush up
* A better layout of the Source Book
* Printing - autumn 1992

This is the final report of Annex 18 and the work is completed.

Tullinge April 1992

Lars-Göran Månsson