HYBRID VENTILATION CONCEPTS IN COMMERCIAL BUILDINGS- Indoor Air Quality and Energy Economy Perspective

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ABSTRACT

Hybrid ventilation concepts for commercial buildings are presented in this paper. Concepts are specially designed for northern climate conditions. Probably the most potential concept will be a combination of all these concepts, because hybrid systems are always more or less dependent on structure of buildings. The bases of the concepts are efficient and demand based use of low pressure fans. The concepts are equipped with IR- and CO_2-sensors to guarantee the efficient usage of energy. The concepts have been carried out with individual control of indoor air temperature, so they fit well both to open-plan and cellular office types, and make the flexibility possible. The key of the concepts is intelligent automation system.

KEYWORDS

Hybrid Ventilation, Design, Air Quality, Energy Conservation, Demand Control

INTRODUCTION

Hybrid Ventilation is a two-mode system which should provide a comfortable indoor environment with energy efficient way using both natural and mechanical forces at different times of the day or season of the year. The difference between conventional ventilation system and hybrid ventilation systems is that hybrid systems can be controlled automatically between natural and mechanical mode in order to minimize the energy consumption and to maintain a satisfactory indoor environment.[1]

This paper presents three different type of hybrid ventilation concepts for office buildings by taking into account northern climate conditions, which is one of the most demanding climate type for system development. There is very cold winter period and relatively warm summer period, which means that normally both heat recovery and mechanical cooling are requested.

BASIS FOR CONCEPT DEVELOPMENT

In Europe, the request of more natural ventilation solutions has become broadly accepted. Trend is that ductwork should be left off and air should flow indoors naturally. Nowadays, energy issues are concentrated more on reduction of electricity consumption. Typically, energy consumption of fans is about 30 to 50 % of the total energy consumption of air handling units, when efficient heat recovery exists. The biggest electricity saving potential is reached by using demand controlled and low pressure ventilation systems which should be also the basic elements of hybrid concepts. At the same time when energy saving is concerned the indoor quality can not be neglected. The key of hybrid concept is intelligent automation system. With the automation system, the heating and cooling mode is selected and the space conditions are controlled.

Target and Design Values of Indoor Climate

In the beginning of the design process, target values of indoor climate are decided by building owner or builder. In Finland, this practically means that target values are based on classification of indoor climate, (FiSIAQ) at 1995 [2]. These target values are divided into three categories: Category S1, S2

and S3, which are also basis for design values used in dimensioning of heating and air-conditioning equipment. The most important design values of different categories are presented in table 1.

Table 1. Design values for indoor climate [2,3].

Factor	Unit	Category					
		S1		S2		S3	
Room temperature, winter	^oC	21		21		20	
Room temperature, summer	^oC	24		26		27*	
Air velocity, winter	m/s	<0,1		<0,15		<0,15	
Air velocity, summer	m/s	<0,15		<0,25		<0,3	
Air filtering	class	F8/EU8		F7/EU7		F6/EU6	
Air flow for air quality		L/s,p	l/s,m^2	l/s,p	L/s,m^2	l/s,p	l/s,m^2
- Offices		16	2	12	1,5	8	1
- Conference rooms		12	8	9	6	6	4
- Lecture halls		12	12	9	9	6	6
- Class rooms		12	6	9	4,5	6	3

*no mechanical cooling; room temperature can be controlled with window ventilation

Requirements for Indoor Climate and Ventilation

The requirements and restrictions for indoor climate and ventilation are stated in Finnish Building Codes. In the Building Code D2 “Indoor Climate and Ventilation in Buildings” it is required that satisfactory indoor climate must be ensured in all occupied zones, under all normal climatic conditions and circumstances of activity. A satisfactory indoor climate means that the purity, temperature and humidity of indoor air must be under control. Disturbing draft or other thermal factors which markedly reduce comfort or working performance must not occur. Rooms shall be equipped with sufficient ventilation to maintain the indoor air quality at a satisfactory level during activity, economically with respect to consumption of energy.[5]

Requirements for Energy Economy

In the Building Code D3 “Energy Economy of Buildings”, it is required that building and building services should be designed and constructed in a way that the unnecessary use of energy and energy losses are restricted so that good energy economy is achieved. In the Building Code D2 it is required that the energy consumption of the ventilation system must be minimized, and the energy conservation must be carried out without sacrificing satisfactory indoor air quality. Mechanical ventilation system is generally equipped with heat recovery unit when the ratio of supply and return air is 1:1. The heat recovery unit can be excluded if exhaust air flow rate is less than 1 m^3/s, the operating hour of the system are exceptionally short or a sufficient quantity of waste energy is used for heating of supply air.[4,5]

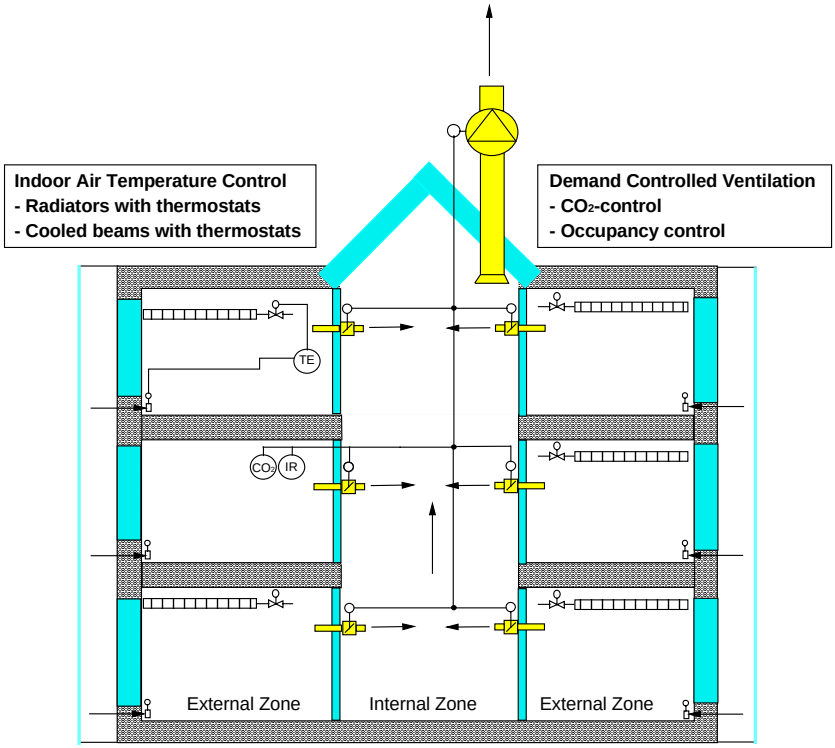
Requirements for energy consumption of fans are not presented in Finnish Building Codes.

CONCEPT PROPOSALS

Indoor climate and requirements of building codes have to be taken into account when hybrid ventilation for commercial building is considered. Hybrid ventilation should always be fixed into building because the best solution might depend for example on number of floors, building shape, floor type etc. In the figure 1, 2 and 3 it is presented different type of hybrid ventilation principles which could be considered when good indoor air quality and energy economy are required.

Concept I: Hybrid Ventilation System with a Mechanical Exhaust

Concept I presents a hybrid ventilation system with a mechanical exhaust. System has been designed to operate partly by natural force (buoyancy) during heating season. Heating of supply air is carried out with wall mounted radiators. During cooling and mild climate period the ventilation is based on mechanical forces and window ventilation. Control of air flow rate of each space has been carried out



with CO_2- and occupancy sensors. Supply and exhaust air dampers are closed when the space is not occupied.

Figure 1. Principle of a hybrid ventilation system with a mechanical exhaust.

Concept II: Hybrid Ventilation System with Supply Air Ducts

Concept II presents a hybrid ventilation where supply air is led into building through Air Handling Unit (AHU) only during heating and cooling season. During mild climate season (-5…+10 ^{o}C) supply air by-passes AHU and flows into building naturally. A combined heating and cooling coil has been integrated with a supply air device. Supply air is blown through nozzles into a device, and through slots into room. Air blown through the nozzles induces air around it, and causes air circulation in a room via combined heating and cooling coil. During heating season air is extracted through a heat exchanger coil and heat is recovered. Control basis for air flow rate are same as in concept I.

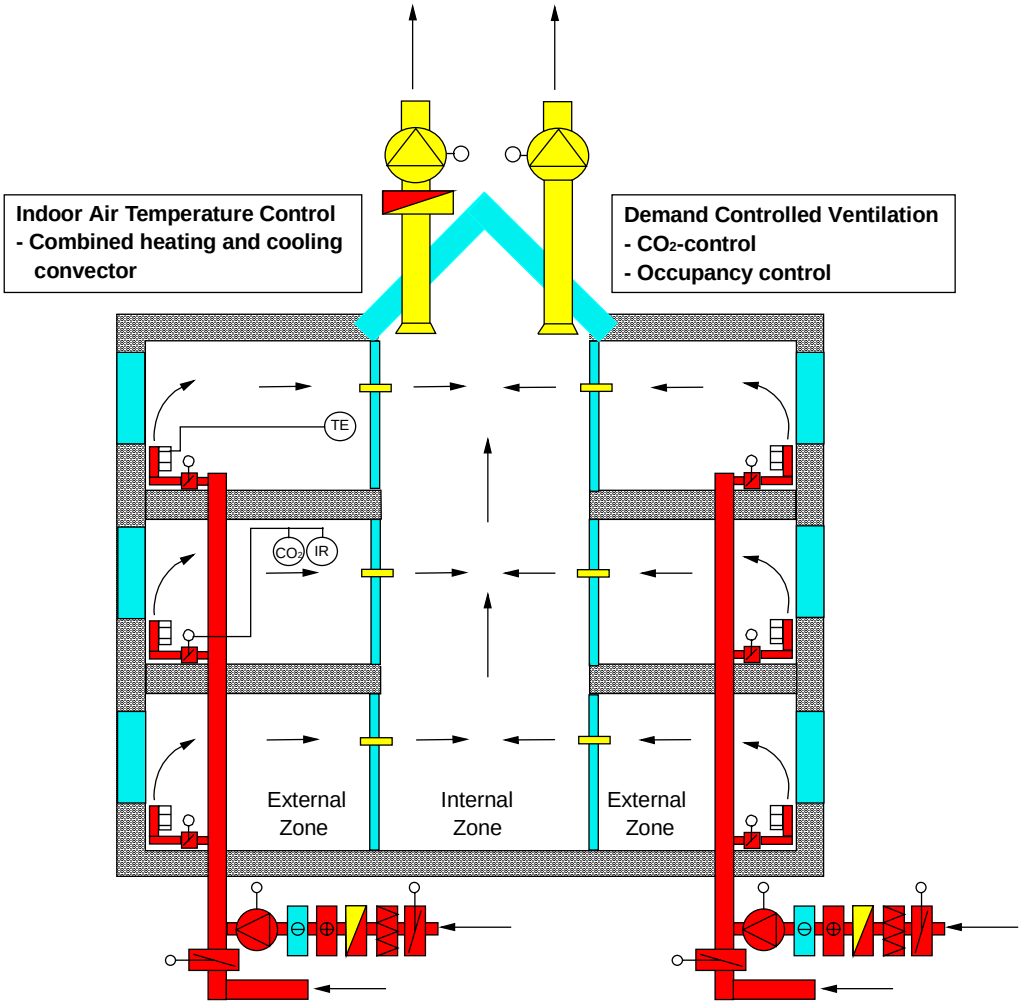


Figure 2. Principle of a hybrid ventilation system with supply air ducts.

Concept III: Low Pressure Hybrid Ventilation system

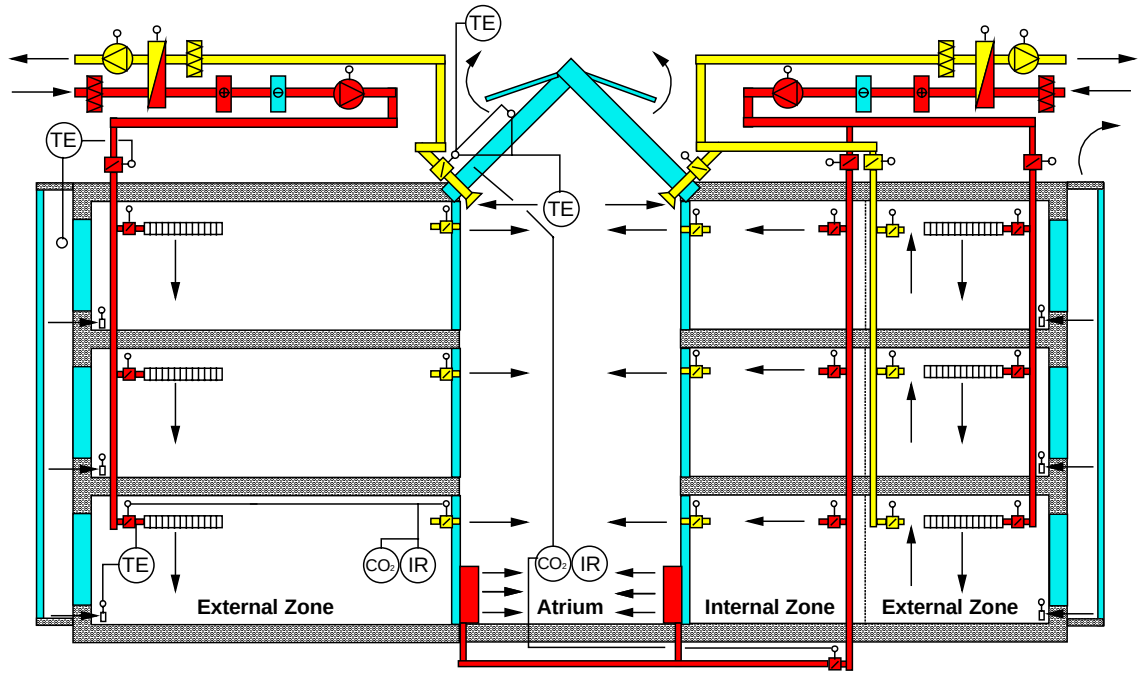


Figure 3. Principle of a low pressure hybrid ventilation system.
Concept III presents the hybrid system, where the low pressure balanced ventilation system is a basic system, and operation of ventilation is based on mechanical forces during heating and cooling season. During mild season supply air to external zones can be taken direct from outside through external walls or windows. Driving forces are based then on window ventilation and mechanical exhaust. Control principles of air flow rates and indoor temperature are mainly same as in concepts I and II.

Different design aspects, advantages and disadvantages, related to building and proposed hybrid ventilation concepts are presented at the table 2.

Table 2. Design aspects for concept proposals.

Building	**Concept I**	**Concept II**	**Concept III**
Building shape	Limitations to facade to facade distance	No limitation	No limitation
Number of floors	No strict limitation, Mechanical exhaust	No strict limitation, mechanical exhaust	No limitation
Double facade	Needed for preheating supply air	Optional	Optional, Preheating of supply air
Floor layout	No strict limitation, open-plan better	No strict limitation, open-plan better	No limitation
Ventilation	**Concept I**	**Concept II**	**Concept III**
Pressure losses	<100 Pa, mech. Exhaust	<100 Pa, mech. Exhaust <500 Pa, else	< 500 Pa
Size of components	Big end and control units	Big ducts, others a little bit bigger than normally	A little bit bigger than normally
Availability of components	End and control units limited	End unit limited, central units normal	Normal availability
Technical feasibility	Almost normal	Almost normal	Almost normal
Design	Accurate dimensioning of control units	Intelligent control system, dimensioning of AHU	Intelligent control system, dimensioning of AHU
Space demand	Less than normally, amount of ducts minimized	Less than normally	A little bit bigger than normally
Air filtering	Fibre filters can be used, Limited filtering when natural ventilation mode	Fibre filters can be used, No filtering when natural ventilation mode	Fibre filters can be used, Limited filtering when natural ventilation mode
Energy efficiency	Fans better than normally, Heating less than normally, no heat recovery	Fans better than normally, Heating almost normal; water circulated heat recovery	Fans better than normally, Heating better than normally
Opening windows	Optional, During mild season	Optional, During mild season	Optional, During mild season
Controllability of indoor climate	Good, Individual control possibility Moisture during summers	Excellent, AHU and individual control possibility	Excellent, AHU and individual control possibility
Initial cost	Less than normally	Normal	Bigger than normally
Flexibility	Good	Good	Good

DISCUSSION

The most feasible hybrid ventilation concepts for northern climate conditions has been presented in this paper. Probably the most potential concept will be a combination of all these concepts, because hybrid systems are always more or less dependent on structure of buildings.

The bases of these concepts are efficient and demand based use of low pressure fans. The concepts are equipped with IR- and CO_2-sensors to guarantee the efficient usage of energy. Building zones can also be operated separately, i.e. ventilation of unoccupied building zones is closed. In northern climate conditions the most efficient heating and cooling of supplied air should be carried out by centralized way (concept II and III). Heat recovery can be excluded in some cases if waste or passive heating energy is available; or in some part of building, when hybrid system is a combination of proposed concepts.

Nowadays flexibility and controllability of indoor climate have become more and more important design requirements for the building services. Thus attention has been paid on these requirements, when concept proposals have been developed. The concepts have been carried out with individual control of indoor air temperature, so they fit well both to open-plan and cellular office types, and make the flexibility possible. However, dehumidification of supply air is not possible with concept I, which might cause a little bit of discomfort during summer time. Nowadays important design requirement is also ceilings without any ductwork or any other component of building services. Concept II is an excellent solution for this requirement.

When hybrid ventilation with passive stack is considered (concept is presented by Vuolle and Heinonen [6]) , the key element is driving pressure difference which in this kind of system is very low compared to the concepts presented in this paper. Thus attention should be paid on many items, which differ remarkably from the design of these concepts. Main uncertainties in design and construction of hybrid systems with supply air stacks are related to technical attributes like pressure loss of ventilation components.

ACKNOWLEDGEMENTS

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