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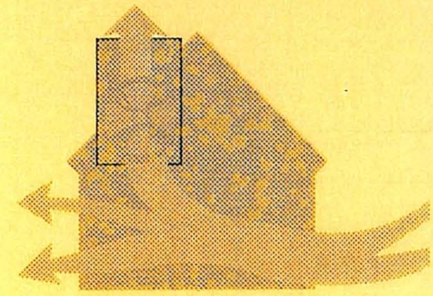

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DESIGN PROCEDURE FOR HYBRID VENTILATION

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ABSTRACT

Mechanical and natural ventilation systems have developed separately during many years. The natural next step in this development is development of ventilation concepts that utilises and combines the best features from each system into a new type of ventilation system – Hybrid Ventilation.

Buildings with hybrid ventilation often include other sustainable technologies and an energy optimisation requires an integrated approach in the design of the building and its mechanical systems. Therefore, the hybrid ventilation design procedure differs from the design procedure for conventional HVAC. The first ideas on a design procedure for hybrid ventilation is presented and the different types of design methods, that is needed in different phases of the design process, is discussed.

1 INTRODUCTION

Mechanical and natural ventilation systems have developed separately during many years. Mechanical ventilation has developed from constant air flow systems through systems with extensive heat recovery and demand controlled air flows to energy-optimised low pressure ventilation systems. Natural ventilation has in the same period developed from being considered only as air infiltration through cracks and airing through windows to be a demand controlled ventilation system with cooling capabilities and heat recovery and air cleaning possibilities. The focus in the development has for both systems been to minimise energy consumption while maintaining a comfortable and healthy indoor environment. The natural next step in this development is to develop ventilation concepts that utilises and combines the best features from each system into a new type of ventilation system – Hybrid Ventilation.

Hybrid ventilation systems can be described as systems providing a comfortable internal environment using different features of both natural ventilation and mechanical systems at different times of the day or season of the year.

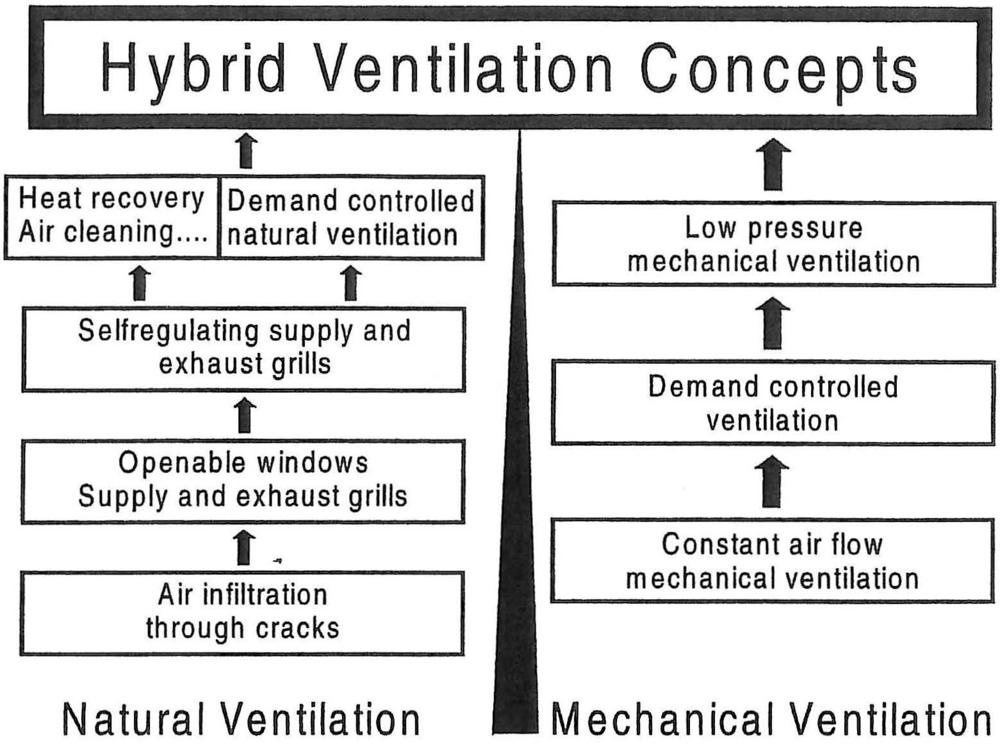

Figure 1 Development of natural and mechanical ventilation systems (Wouters 1999).

It is a ventilation system where mechanical and natural forces are combined in a two-mode system. The basic philosophy is to maintain a satisfactory indoor environment by alternating between and combining these two modes to avoid the cost, the energy penalty and the consequential environmental effects of year-round air conditioning. The operating mode varies according to the season and within individual days, thus the current mode reflects the external environment and takes maximum advantage of ambient conditions at any point in time. The main difference between conventional ventilation systems and hybrid systems is the fact that the latter are intelligent with control systems that automatically can switch between natural and mechanical mode in order to minimise the energy consumption.

Hybrid ventilation should dependent on building design, internal loads, natural driving forces, outdoor conditions and season fulfil the immediate demands to the indoor environment in the most energy-efficient manner. The control strategies for hybrid ventilation systems should maximise the use of ambient energy with an effective balance between the use of advanced automatic control and the opportunity for users of the building to exercise direct control of their environment. The control strategies should also establish the desired air flow rates and air flow patterns at the lowest energy consumption possible.

2 INTEGRATED AND CLIMATIC DESIGN

Buildings with hybrid ventilation often include other sustainable technologies like daylightning, passive cooling, passive solar heating etc, and an energy optimisation requires an integrated approach in the design of the building and its mechanical systems.

Today, the construction industry is in the early stages of reinventing the design process that was used before the advent of mechanical systems. Design teams including both architects and engineers are formed and the building design is developed in an iterative process from the conceptual design ideas to the final detailed design. Building energy use and HVAC equipment sizes are reduced without the use of sophisticated technologies, but only through an effective integration of the architectural and HVAC designs. The integrated design approach achieves this improved energy utilisation due to the relationship that exists between the building, its surroundings and architecture and the mechanical systems. In the integrated design process the expertise of the engineer is available from the very beginning at the conceptual design stage and the optimisation of the architectural and HVAC designs can start at the same time as the first design ideas are developed.

The art and science of using the beneficial elements of nature – sun, wind, earth and air temperature, plants and moisture – to create comfortable, energy-efficient and environmentally wise buildings is called climatic design. The desirable procedure is to work with, not against, the forces of nature and to make use of their potentialities to create better living conditions. The principles of climatic design derive from the requirement for creating human comfort in buildings using the elements of the natural climate. Perfect balance between natural resources and comfort requirements can scarcely be achieved except under exceptional environmental circumstances and the climatic design will vary throughout the year depending upon whether the prevailing climatic condition is "underheated" compared to what is required for comfort (i.e., like winter) or "overheated" (i.e., like summer).

The integrated design of the heating, cooling, lighting and ventilation of buildings can be accomplished in three separate steps. The first step is the design of the building itself to minimise heat loss and maximise heat gain in winter, to minimise heat gain in summer, and to use daylight and fresh air efficiently. Decisions at this step determine the size of the heating, cooling and lighting loads. Poor decisions at this point can easily double or triple the size of the mechanical equipment eventually needed. The second step involves the climatic design where the passive heating, passive cooling, daylighting techniques and natural ventilation heat the building in the winter, cool it in the summer and light and ventilate it all year. The proper decisions at this point can greatly reduce the loads as they were created during the first step. Step 3 consists of designing the mechanical equipment to handle the loads that remain from the combined effect of steps 1 and 2, see figure 2.

	Heating	**Cooling**	**Lighting**	**Ventilation**
Step 1	*Conservation*	*Heat avoidance*	*Daylight*	*Natural ventilation*
Basic Design	1. Surface to volume ratio 2. Insulation 3. Infiltration	1. Shading 2. Exterior colours 3. Insulation	1. Windows 2. Glazing 3. Interior finishes	1. Building form 2. Location of windows and openings 3. Stacks
Step 2	*Passive solar*	*Passive cooling*	*Daylighting*	*Natural ventilation*
Climatic design	1. Direct gain 2. Thermal storage wall 3. Sunspace	1. Evaporative cooling 2. Convective cooling 3. Radiant cooling	1. Skylights 2. Light shelves 3. Light wells	1. Wind induced ventilation 2. Bouyancy induced ventilation 3. Air distribution 4. Control system
Step 3	*Heating system*	*Cooling system*	*Electric light*	*Mechanical ventilation*
Design of Mechanical Systems	1. Radiators 2. Radiant panels 3. Warm air system	1. Refrigeration machine 2. Cooled ceiling 3. Cold air system	1. Lamps 2. Fixtures 3. Location of fixtures	1. Mechanical exhaust 2. Mechanical ventilation 3. Air conditioning

Figure 2 Typical design considerations at each design step. Revised from (Lechner 1991).

The heating, cooling, lighting and ventilation design of buildings always involves all three steps whether consciously considered or not. Minimal demands have in the recent past been placed on the building itself to affect the indoor environment. It was assumed that it was primarily the engineers at the third step which were responsible for the environmental control of the building. Thus architects, who were often indifferent to the heating and cooling needs of buildings, sometimes designed buildings with large glazed areas for very hot or very cold climates, and the engineers would then be forced to design giant heating and cooling plants to maintain thermal comfort. On the other hand, when it is consciously recognised that each of these steps is an integral part of the heating, cooling, lighting and ventilation design, better buildings result. The buildings are better for several reasons. They are often less expensive because of reduced mechanical equipment and energy needs. Frequently they are also more comfortable because the mechanical equipment does not have to fight giant loads.

3 HYBRID VENTILATION DESIGN PROCEDURE

The hybrid ventilation process is very dependent on the outdoor climate, the microclimate around the building as well as the thermal behaviour of the building and it is, therefore, essential that these factors are taken into consideration in the basic design step. The output from the first step is a building orientation, -design and -plan that minimises the thermal loads on the building in overheated periods, that together with the selected ventilation strategy makes it possible to exploit the dominating driving forces (wind and/or buoyancy) at the specific location and that ensures a proper air distribution through the building. It is also important that issues like night cooling potential, noise and air pollution in the surroundings as well as fire safety and security are taken into consideration.

In the climatic design step the natural ventilation mode of the hybrid system is designed. The location and size of openings in the building as well as features to enhance the driving forces as solar chimneys and thermal stacks are designed according to the selected strategy for both day and night time ventilation. Passive methods to heat and/or cool the outdoor air is considered as well as heat recovery and filtering. Appropriate control strategies for the natural ventilation mode are determined and decisions are made regarding the level of automatic and/or manual control and user interaction.

In step three the necessary mechanical systems to fulfil the comfort and energy requirements are designed. These can range from simple mechanical exhaust fans to enhance the driving forces to balanced mechanical ventilation or air conditioning systems. The hybrid ventilation and corresponding whole system control strategy are determined to optimise the energy consumption while maintaining acceptable comfort conditions.

Effective and efficient climatization and ventilation of indoor spaces has the best chance for success when the design process is carried out in a logical, subsequent manner with increasing detail richness towards final design, and in the framework of a design procedure. In the case of hybrid ventilation the need for a design procedure is even more evident due to the comprehensive design team, where users, building owner, architect, civil engineer and indoor climate and energy counsellor must all be involved – simultaneously.

A HVAC design procedure consists of different phases: conceptual design phase, basic design phase, detailed design phase and design evaluation, see figure 3.

	A	B	C	D	E	F	G	H	I	J	K	L
	Design phases ==>	**Conceptual Design**		**Basic Design**		**Detailed Design**		**Design Evaluation**		**Commissioning**		
1		**Initial conside-rations**	**Building initial design**	**First design of room environment**	**Building, system first design**	**Final design of room environment**	**Building, system final design**	**Validation of room environment design**	C O	**Building, system commiss.**	**Commissioning of room environment**	M A
2	***Involved parties***	owner,arch., users, consultants	architects, IAQ-experts	indoor climate eng., architects	HVAC syst. eng, indoor climate eng	indoor climate eng., architects, HVAC syst. eng.	HVAC -syst.eng.	indoor climate/ CFD-expert	N	HVAC-syst.eng.	indoor climate/ measurement expert	
3	***Building, site, use, room***		from B7	from C7 update on occupant use, heat- and con-taminant emission	from C7 update with new informat-ion	from D3, E3 update information, especially on use and sources	from F3 update with info from E7, F7	from F3, F7	S	from G3		I N
4	***Design speci-fications***		no healthpr. few com-plaints good pro-ductivity	normative: airflow rates summer, winter indoor temp. normative filter use	from D4 add normative energy consumption	thermal comfort indices, air quality indices, energy effici-ency indices as agreed on in B7, and coarsened to detail-level of tools, methods used	as for F4	thermal comfort indices air quality indices energy efficiency indices as agreed on in B7	T R	from B7, G3, G7	thermal comfort indices air quality indices energy efficiency indices	T E
5	***Design scenario***	typical use scenario	updated typical use scenario	design summer and winter conditions	"design year"	design summer and winter conditions other load scenario	hour by hour through a «design-year»	scenario selected from building dynamics simulation evaluation	U	design summer, winter cond.	as for H5 if possible	N
6	***Tools, methods***	questions to involved experience case stud. discuss: occup.use intern.heat cont.sourc. solar heat	arch. guidelines regulations case studies experience	load evaluation: occ. use, int.heat- and contaminant loads, solar load climatization: guidelines, experi-ence, case studies assumption of ven-tilation efficiency assumption of infiltration rate	system guide-lines calculation methods for coarse yearly energy con-sumption and peak power	reevaluate contaminant- and thermal loads and consider source control/ use of local extracts, cons. local air supply guidelines for space climatization (possibilities for large spaces) improved assumption of infiltration rate, location engineering methods: flow element models, zonal models	building dyna-mics sim.codes (FRES, TSBI3, DEROB, DOE2 etc.)	CFD-codes to compute: velocity,temp.,conc.fields (FLOVENT, TASKFLOW, FLUENT, KAMELEON, TEACH, FLOW-3D etc.) guidelines for CFD-use calc. PPD, DR, VTG, RA calc. of occupant contam. expos. CFD-simulations to f ind ventilation effectiveness indices (physical models may be used)	C T I O N	methods and equipment to measure: airtightness airflow rates supply air temperatures	methods and equipment to measure IAQ, thermal comfort and efficiency indices, contaminant exposure, thermal stress	A N C E
7	***Results***	location space demand, functions building size, form, cost limit room target indices for IAQ, thermal comfort, energy efficiency, noise	interior: material use exterior: U-values, airtightness windows cost estimate	suggested solutions: load reduction local ventilation space ventilation, heating, cooling	arch. drawings energy consumption system layout ductwork layout	optimum design for climatization, energy use: type and location of air terminals, heating, cooling, selected equipment for air supply, extract, heating, cooling control strategy, sensor placements	optimum design for building and system yearly energy consumption peak loads first cost, running cost, life cycle cost	prediction (detailed) of air quality, thermal comfort, contaminant exposure, thermal stress indices etc. as agreed on in B7 eventually: investigate problems by analyzing CFD-simulation results in detail calculate appropriate ventilation and efficiency indices	P E R I O D	comparison with plans, assumptions	at measurement points: PPD value directly air temperature mean radiation temp. radiation asymmetry air speed, turbulence intensity, humidity cons. of actual contaminants	P E R I O D
8	***Specs. O.K. ?***		reconsider or decide to build	redesign or proceed	redesign or proceed	redesign or end room environment design work	redesign or end building, system design work	redesign or make decision to construct as designed		rectify or proceed	redesign and rectify or end work task	

Figure 3 Hybrid ventilation design procedure.

The conceptual design phase includes decisions on building form, size, function and location. Targets are set for indoor air quality, thermal comfort and energy use as well as cost limits. The conceptual design of the hybrid ventilation system is based on these considerations, guidelines and experiences from previous buildings. The natural ventilation principle (stack and/or wind driven, single sided and/or cross ventilation) to be used is decided together with the principle of the necessary additional mechanical systems.

In the basic design phase the building heat, sun and contaminant loads are estimated and the hybrid ventilation system layout designed. The necessary air flow rates as well as expected indoor air quality and temperature levels are calculated. A coarse yearly energy consumption is calculated together with the necessary peak power demands. If the results do not meet the targets, the building and its systems will have to be redesigned before entering the next phase.

In the detailed design phase contaminants and thermal loads are re-evaluated and source control options are considered and/or optimised. The type and location of hybrid ventilation system components are selected as well as the control strategy and sensor location. Based on hour by hour calculations through a design year, the whole system (building and technical systems) is optimised with regard to indoor climate, energy consumption and costs (first and running costs).

Finally, in the design evaluation phase, detailed predictions of indoor air quality and thermal comfort are performed to control if the design fulfils the targets of the project.

The hybrid ventilation design procedure differs from the design procedure for conventional HVAC systems, in the way that the design in all phases need to focus on all three steps in the integrated design approach and not only on step three. The hybrid ventilation design must also be an integrated part of the design of the building and other sustainable technologies. A design procedure for hybrid ventilation, that comply with the above mentioned requirements, will be developed within Annex 35.

4 HYBRID VENTILATION DESIGN METHODS

Different phases in the design process calls for different types of design methods. Guidelines, decision tools, experiences of colleagues and catalogues on products are useful in the conceptual design phase. In this phase input data are not well known and/or can vary within large ranges and output only need to be accurate enough to make principle decisions on which systems and/or combination of systems that are appropriate to use in the given situation.

In the basic design phase analytical calculations and simulation programmes are used to develop the design. Input data are known with a much better accuracy and output data should be detailed enough to convince the designer that the system can fulfil the energy targets and the comfort requirements for the building.

In the detailed design phase the individual components are designed and the system and control strategies are optimised with regard to energy consumption and comfort conditions. The design methods are the same as for the basic design phase, but input data on building and individual components are well known in this phase and output becomes therefore accurate enough to perform a system optimisation.

Finally detailed simulation methods or physical models are used to evaluate the final design. These analysis methods are expensive and time-consuming to use. They require very detailed input data and are able to give precise predictions on the performance (energy, IAQ and thermal comfort) of the building and the ventilation system.

Suitable methods as we know them for mechanical systems are not available for hybrid ventilation systems. Valid methods would give architects and engineers the necessary confidence in system performance, which in many cases, is the decisive factor for choice of system design. Annex 35 develops methods on different levels that are applicable to the different phases in the design process. Recommendations to the level of detail in input data as well as the level of detail and accuracy of the output data and thereby the expectation to the results will be made.

As the hybrid ventilation process and the thermal behaviour of the building are linked the development of design methods for hybrid ventilation must take both aspects into consideration at the same time and include efficient iteration schemes. This is the case for all types of methods from simple decision tools, analytical methods, zonal and multizone methods to detailed CFD analysis methods. A major focus will be on combining thermal simulation models with existing multizone air flow models. In this way the thermal dynamics of the building can be taken into account and this will improve the prediction of the performance of hybrid ventilation considerably. The combined model will be capable of predicting the yearly energy consumption for hybrid ventilation and will therefore be the most important design tool for hybrid ventilation.

Due to the development of computer and information technology, decision tools and analytical calculation methods are today combined in new and more powerful computer tools that are very useful in the early phases of the design process. Annex 35 will expand developed tools for natural ventilation to include hybrid ventilation concepts.

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