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Design Tool for Optimizing the Selection of Ventilation Plants

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DESIGN TOOL FOR OPTIMIZING THE SELECTION OF VENTILATION PLANTS

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Introduction

The selection of ventilation plant and it's level of energy efficiency is often done without economic calculations. The reason could be lack of time or knowledge.
The result will be the selection of the plant of lowest investment cost, which means' a small plant of inefficient type. This normally includes a fan-wheel of the "sirocco type" followed by a large electric motor. The motor should be large enough to stand for the rise in power due to increased fan power if the calculations of the ductwork systems pressure-drop show up to be wrong or the flow rate must be increased because of too large ductwork system leakage. In other cases the selection in the end will be the same in spite of a god selection from the beginning. This could be the case when the total cost of the whole building show up to be larger then calculated. The first cost to cut will often be the installation cost. The cut will, in many cases, be made by reducing the size of the ventilation plants and selecting more energy demanding equipment.
The economic consequences of such a selection are seldom analysed. This paper describes a tool to improve the knowledge of the economic consequences and help the designer to make the wright choice.

Synopsis

The main goals for this design tool are:

- A powerful, but simple to use, technical and economic tool for selecting a ventilation plant.
- Guide and control the consultants in accordance with the owner's economic preferences.
- The long run extra cost, if one is forced not to follow the guidelines of the method is calculated in order to get the economic backgrounds for a decision.
- Creating a key-value for the cost of ventilation that can be understood by engineers and people with economic education.

The three most important parts of the selection of this design tool are:

1. The representative or equivalent parameters called "the equivalent working condition". This operating condition has the same electric energy consumption as the sum of all running condition of the selected ventilation plant will run at. VAV system is transformed to a CAV system running at a fixed air flow rate.
2. Selecting key-values are presented, for the pressure drop in the plant, fan efficiency and the efficiency of the heatrecovery equipment and optimal specific fan power, to guide the designer.
3. When the selection is made the "specific total cost" of the selected plant is calculated and compared with the optimal cost. This "specific total cost" describes the cost for operation,

maintenance and capital cost for the ventilation-function.

* The kernel of this design tool (selection method) is " the database of performance and investment cost for manufactured ventilation plants" , " The general economic evaluation key-values stipulated by the owner " and "the equivalent conditions ". This kernel make it possible to find the best set of performance key-values similar to the ventilation plants that have the lowest Life Cycle Cost in the database.The performance sets with lowest Life Cycle Cost in the database, modified to suite "the equivalent working condition", are chosen to derive performance key-values diagrams.

Description of the design tool from the user point of view.

The flowchart fig. 1 shows the basic steps of this method. Here are some more details of the different parts of this method.

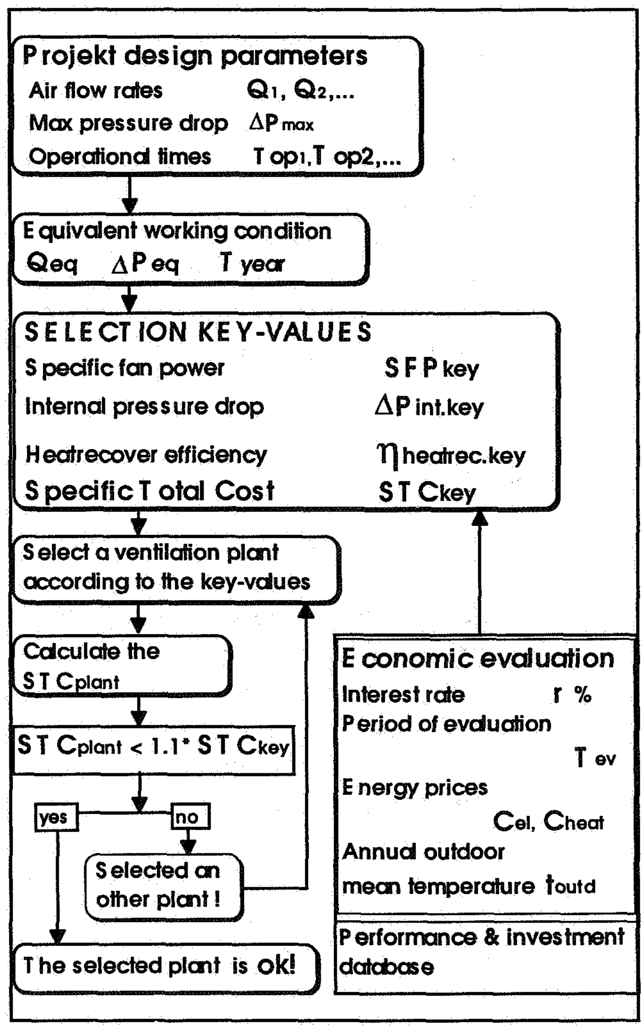

fig 1

The first things to do when selecting a ventilation plant is to document the design parameters of the project.

1. *Project design parameters*

The specific project design parameters as working conditions and operational time are specified under this header.

Working conditions used by this design tool is:

The different air flow rates to be used.

$Q_1, Q_2, ...$ [m^3/s]

In case of Variable Air Volume system (VAV) an approximation with a number of fixed flow rates are used.

The pressure drop for the largest air flow rate

ΔP_{max} [Pa]

Exhaust air temperature

t_{exh} [°C]

Supply air temperature

t_{sup} [°C]

The operational time for the specified flow rates

$T_{op1}, T_{op2}, T_{op3}, ...$ [hours]

2. *Calculation of one equivalent working condition*

From the project design parameters one equivalent working condition and the total annual operational time are calculated.

The parameters of the equivalent working condition are:

Equivalent air flow rate	$\mathbf{Q_{eq}}$	$[m^3/s]$
External pressure drop for the system at the equivalent air flow rate	$\mathbf{\Delta P_{eq}}$	[Pa]
Total annual operational time	$\mathbf{T_{year} = \sum (T_{op1}, T_{op2}, T_{op3}, \ldots\ )}$	[hours]

During the selection procedure the ventilation plant is assumed to be a constant air volume system, CAV. system, with the equivalent flow rate, Q_{eq}, and the equivalent pressure drop, ΔP_{eq} and operating time, T_{year}, equivalent to the sum of the operating time of the all working conditions. The equivalent working condition is chosen to have the same electricity consumption with the operating time, T_{year}, as the sum of all the different working conditions under the ventilation plant will operate.

Performance and investment cost database

The kernel of this design tool (selection method) is " the database of performance and investment cost of manufactured ventilation plants" together with " The general economic evaluation key-values" these parts makes it together with "the equivalent conditions " possible to find the best set of performance key-values. This set of key-values is similar to the ventilation plants that have the lowest Life Cycle Cost in the database. The ventilation plants have different kind of heatrecovers and transmission(f or instance belt transmission or direct drive including equipment modulating the current frequency).
The data in the database describes the performance of a number of ventilation plants from three manufactures (minimum, could be increased to a arbitary number) in three different working conditions. The air flow rate is 1, 3 and 5,4 m^3/s in the three different cases. The pressure drop is 500 Pa in all three cases. The energy demands for these three cases are calculated at three different running times. This makes nine " performance sets" for each ventilation plant.

General economic evaluation key-values

The owner, or the one in charge instead of him, declare his economic preferences by setting up a couple of key-values that should be used by the consultant in the evaluation procedure of this method. These key-values will be used in the Life Cycle Cost (LCC) calculation that will be used to evaluate the selection of ventilation plants.
These economic key-values should be reconsidered, for instance once a year.

Interest rate (excluding inflation)	**r**	[%]
Period of evaluation	$\mathbf{T_{ev}}$	[year]
Energy prices (mean value under the evaluation period, excluding the inflation)		
Specific electricity price	$\mathbf{C_{el}}$	[Ecu/kWh]
Specific heat price	$\mathbf{C_{heat}}$	[Ecu/kWh]
Annual outdoor mean temperature of the building site	$\mathbf{t_{outd}}$	[C°]

Life Cycle Cost calculation

With data from the performance database and the "general economic evaluation key-values the Life Cycle Cost (LCC) are calculated for all " performance sets".
The amount of air V [m^3] passing through the ventilation plant each year is calculated by multiplying the running time with the largest of the support air and the exhaust air flow rate.

$$\mathbf{V = T_{year} * Q} \quad [m^3]$$

Specific Total Cost (STC)

In order to get a key-value for the total functional cost for the air transportation (including capital costs) the LCC for each performance set is divided with the air volume (V) multiplied with the number of years the LCC calculation is made for.

$$\mathbf{STC = LCC/(V * T_{ev})} \qquad [ECU/m^3]$$

Key-values diagram

The performance sets in the database, modified to suite "the equivalent working condition", are grouped by working conditions as running time and air flow rate, type of heatrecover and type of transmission.The performance sets from the ventilation plants with lowest **STC** for each group are chosen to derive performance key-values diagrams. These diagrams should be used to find a recommendation of performance sets for ventilation plants with low LCC. Choosing a ventilation plant with performance similar to the recommended performance set should give a ventilation plant with low LCC. In fig. 2 is an exampel of key-value diagram (SFP)

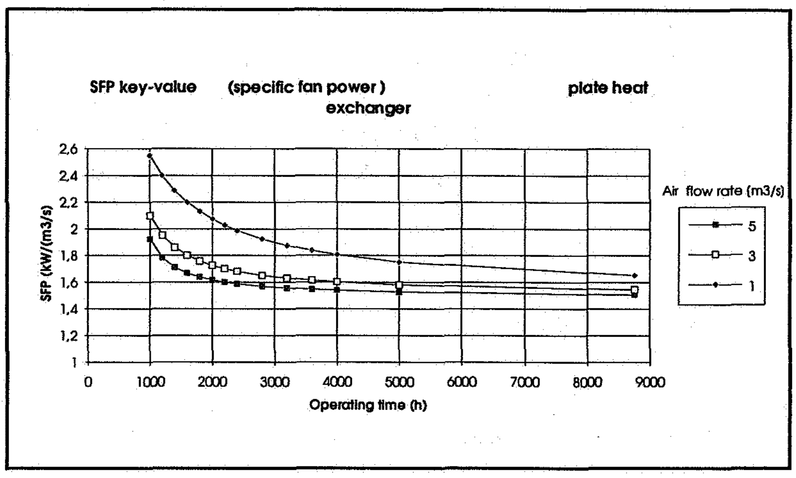

fig. 2

Selecting a ventilation plant

Select the ventilation plant that best suits "the selection key-values". The one you choose must not meet all the key-values, they are just meant to be guidelines. The only thing that counts in the end is that the Life Cycle Cost of selected plant is low.

Calculate the Specific Total Cost of the selected ventilation plant

Now is the time to calculate the STC of the selected plant. To your help there is a tool making it easy to calculate the heat and electricity demand of the selected plant. From the diagram in **fig. 3** you can find the mean supplementary energy demand percentage. per volume [m^3]. The input to the diagram is the temperature of the exhaust and supply air and the heatrecovers temperature efficiency reduced with a factor due to lower efficiency in the future when the heatrecover is old and dirty.

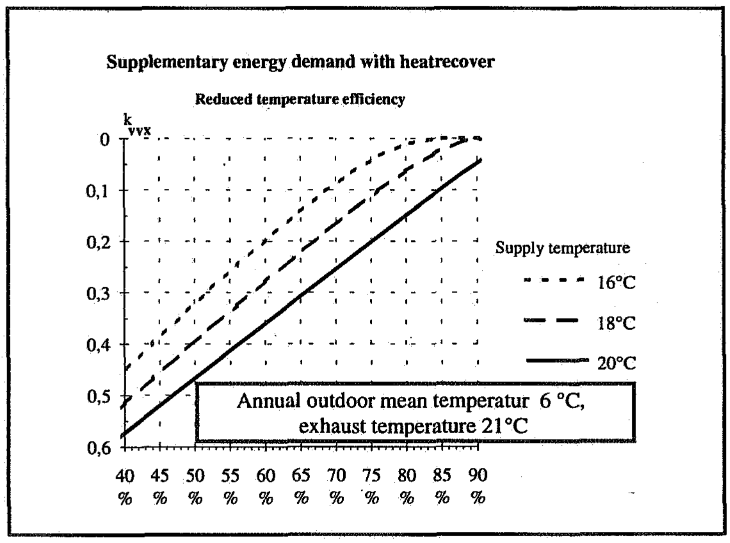

fig. 3

Evaluation of the selected plant

If the selected plants **STC**$_{plant}$ not exceeds the **STC**$_{key}$ with more than **10%** it is accepted and the selection procedure is finished. Otherwise one has to go back again and try with an other ventilation plant.

Restrictions in the size of the plant room space and other selection restrictions

If thera are any kind of restrictions, as restricted hight or floor area, of the selection of the ventilation plant choice, the method compare the extra cost for not selecting the plant with lowest LCC with the extra cost for removing the restriction.

Documentation

All the steps in this method are documented in a special form. This make it possible in the future to go back and see what parameters used, and the reason a certain plant was chosen.

Further development

To make this tool even more powerful a computor data program version will be developed in 1995. The program will shorten the time of selection and make it easier to compare different alternatives. The key-values sensitivity to changes in "the general economic parameters" will easiely be analysed.

List of Symbols

$Q_1, Q_2, \dots$	[m^3/s]	The different air flow rates to be used.
ΔP_{max}	[Pa]	The pressure drop for the largest air flow rate
t_{exh}	[°C]	Exhaust air temperature
t_{sup}	[°C]	Supply air temperature
$T_{op1}, T_{op2}, T_{op3}, \dots$	[hours]	The operational time for the specified flow rates
Q_{eq}	[m^3/s]	Equivalent air flow rate
ΔP_{eq}	[Pa]	External pressure drop for the system at the equivalent air flow rate
$T_{year} = \sum (T_{op1}, T_{op2}, T_{op3}, \dots\ )$	[hours]	Total annual operational time
r	[%]	Interest rate (excluding inflation)
T_{ev}	[year]	Period of evaluation
C_{el}	[Ecu/kWh]	Specific electricity price (excluding the inflation)
C_{heat}	[Ecu/kWh]	Specific heat price (excluding the inflation)
t_{outd}	[C°]	Annual outdoor mean temperature of the building site
$V = T_{year} * Q$	[m^3]	The amount of air V [m^3] passing through the ventilation plant each year is calculated by multiplying the running time with the largest of the support air and the exhaust air flow rate.
LCC	[Ecu]	Life Cycle Cost
$STC = LCC/(V*T_{ev})$	[ECU/m^3]	Specific functional cost for the air transportation

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