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(Title)

Economical comparison of comfort ventilation and air-conditioning plants.

(Authors)

Fritz Steimle, Sönke Biel, Jürgen Röben

(Affiliation)

Universität Essen
Institut für Angewandte Thermodynamik und Klimatechnik
Universitätsstr. 15
45141 Essen, Germany

Synopsis

Continuously rising energy costs, the demand for reduction of CO_2-emission and the prohibition of CFC-containing refrigerants create a base for new concepts of air-conditioning (A/C) systems. A primary action must be the prevention of heat consumption and cooling load by improvement of the building architecture. Additional the efficiency of the A/C process must be improved, in order to reduce the energy input.

In most cases the target is to replace the dehumidification process, which normally is realized by refrigerating cycles, by alternative systems. The air dehumidification by cooling the air below the dew point involves a high energy consumption.

The paper treats three different A/C systems for non industrial buildings. The task has been the economic evaluation of the air-conditioning plants and the demonstration of the different energy demand. Referring to the expected costs of the A/C systems the price of a new dehumidification unit, which is developed at the university of Essen (see figure 3), has been determinated. The results show that a higher price of the new system can be equalized by lower energy costs.

1. Introduction

The calculation bases on a model which describes the A/C of office buildings. In order to simulate the operation of the A/C-systems, four buildings with different air flow rates are designed. The design of the systems is carried out so that comfort room air condition will be reached for every outdoor air condition. The capital costs of the installed components are determinated with price lists of manufacturers. The operating costs for heat, electricity and water are calculated for a continuous plant operation over the year. The calculations are carried out referring to the German VDI-Standard 2067 by using a statistical procedure.

2. List of symbols

OA	Outdoor Air
SA	Supply Air
RA	Return Air
EA	Exhaust Air
P	Preheater
R	Reheater
C	Cooler

(System 1)

3. Presentation of the A/C-systems

The energy transport of the designed systems is guaranteed only by air. System 1 which presents the conventional A/C system is shown in figure 1. Cooling and dehumidification of the air is realized by a compression refrigerating cycle.

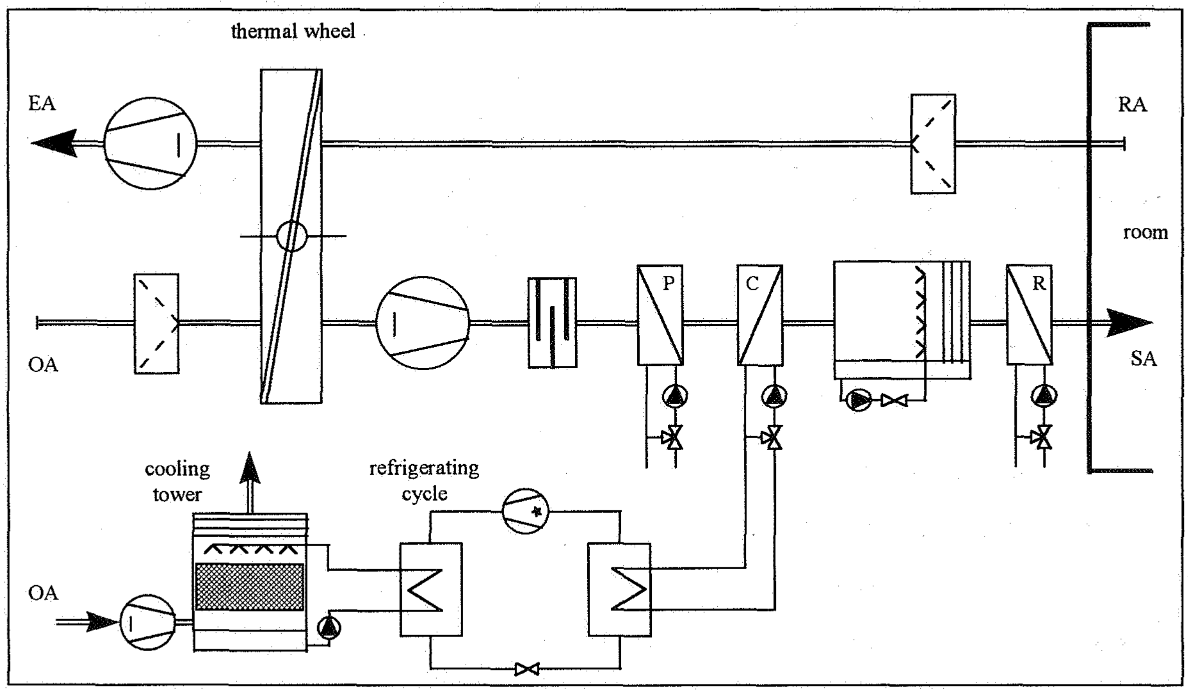

Fig. 1: System 1, with refrigerating cycle and dehumidification by cooling the air below the dew point.

The systems 2 and 3 are A/C plants, by which a comfortable room air is reached by sorptive dehumidification and cooling by evaporation of water (DEC = **D**esiccative and **E**vaporative **C**ooling), so that the thermodynamic functions cooling and dehumidification are seperated. The difference in the considered sorptiv systems is mainly the dehumidification process.

System 2 works with solid sorbent which becomes active on the surface layer of a dehumidification wheel. The regeneration of the sorbent is reached by heating a part of the return air which passes through the dehumidification wheel. The cooling of the supply air is realized by evaporation of water in humidifiers installed in the ducts of the return air (indirect cooling) and the supply air (direct cooling). The calculation of the air condition in system 2 shows that there could be some problems to reach low temperatures of the supply air when, the outdoor air is warm and humid. The lowest temperature is given by the boundary temperature of the evaporation process. Figure 2 shows the general assembly of system 2.

(System 2) → dehumidifacation vervangen door deh. wheel; stelt nomo-problemen door (systeem 3)

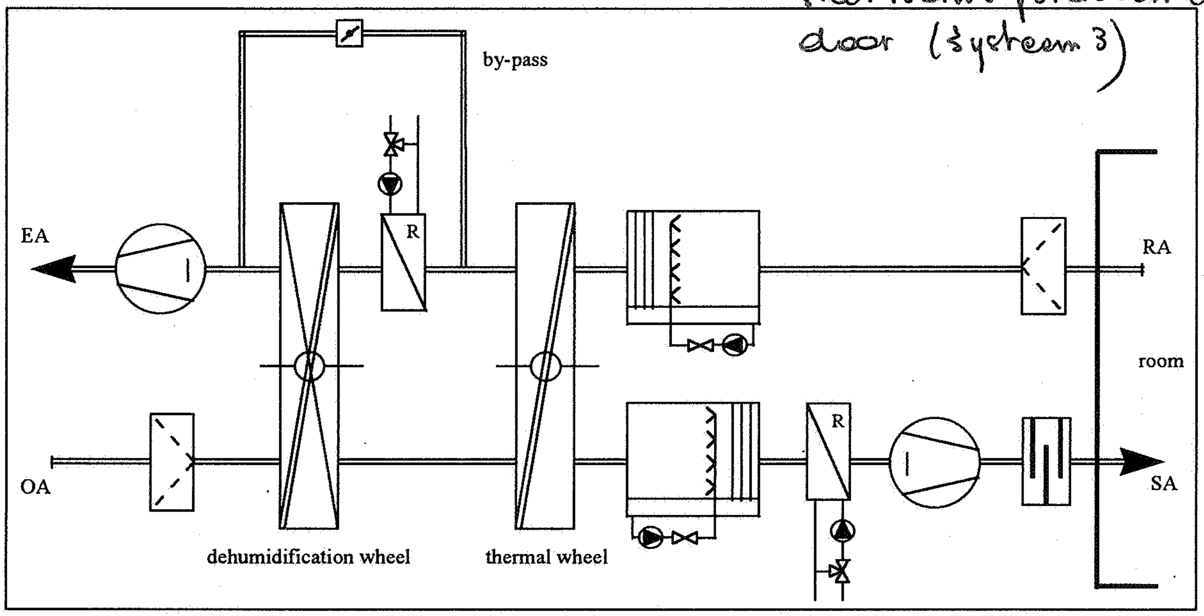

Fig. 2: System 2, Desiccative and evaporative cooling (DEC-system).

System 3 works with a new type of absorber which is integrated in a dehumidification unit. The outdoor air is dehumidified by a liquid desiccant and cooled indirectly by a cooling tower. The advantage of a cooled absorber is a lower process temperature, so that every supply air condition can be reached. Figure 3 shows the assembly of system 3.

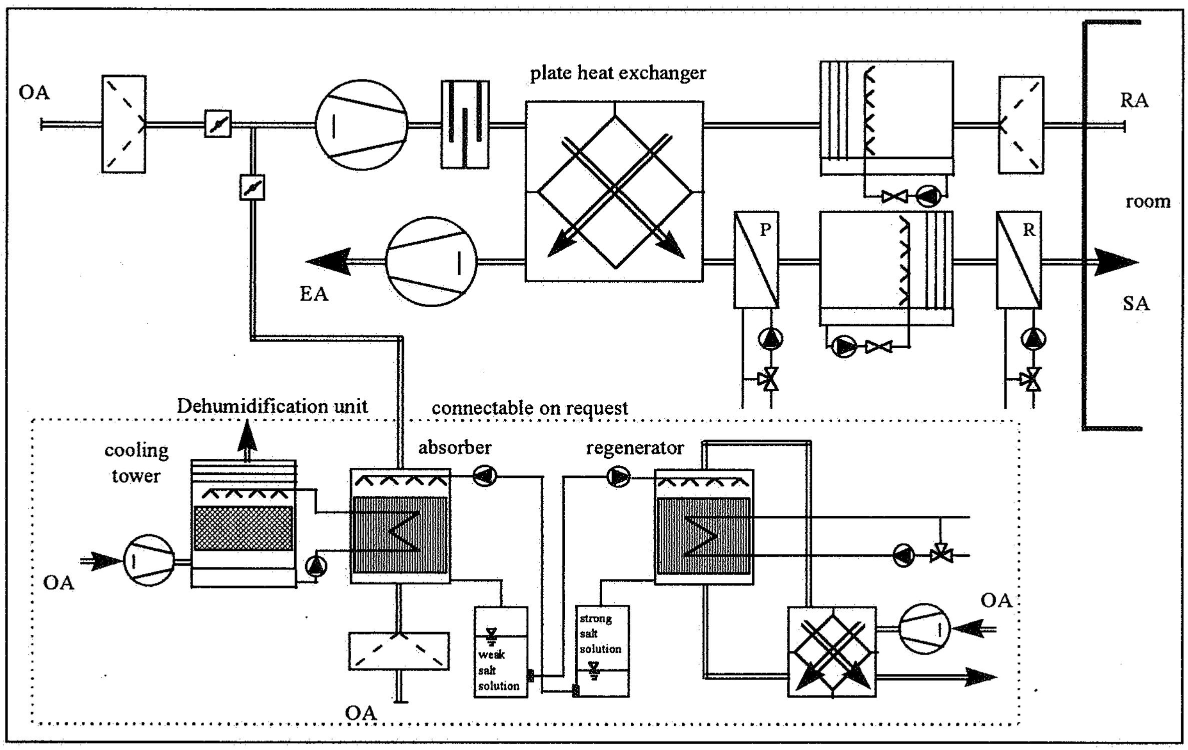

Fig. 3: System 3, evaporative cooling and dehumidification by absorption.

The regeneration of the weak salt solution is carried out in a separate regenerator where the solution is heated and the water evaporates. In opposition to system 2 the heating of the regeneration process has no influence on the supply air. The use of a plate heat exchanger is advantageous. The supply air fan is installed in front of the heat exchanger, so that the heat gain of the fan can be released in the heat exchanger. As there is a complete separation between the return air duct and the supply air duct, it is possible to oversaturate the return air in order to increase the heat transfer.

4. Results of the economical comparison

The specific investment prices of the A/C-system in [DM/(m³/h)] correlate to the air flow rate. Figure 4 shows the expected prices of the regarded systems.

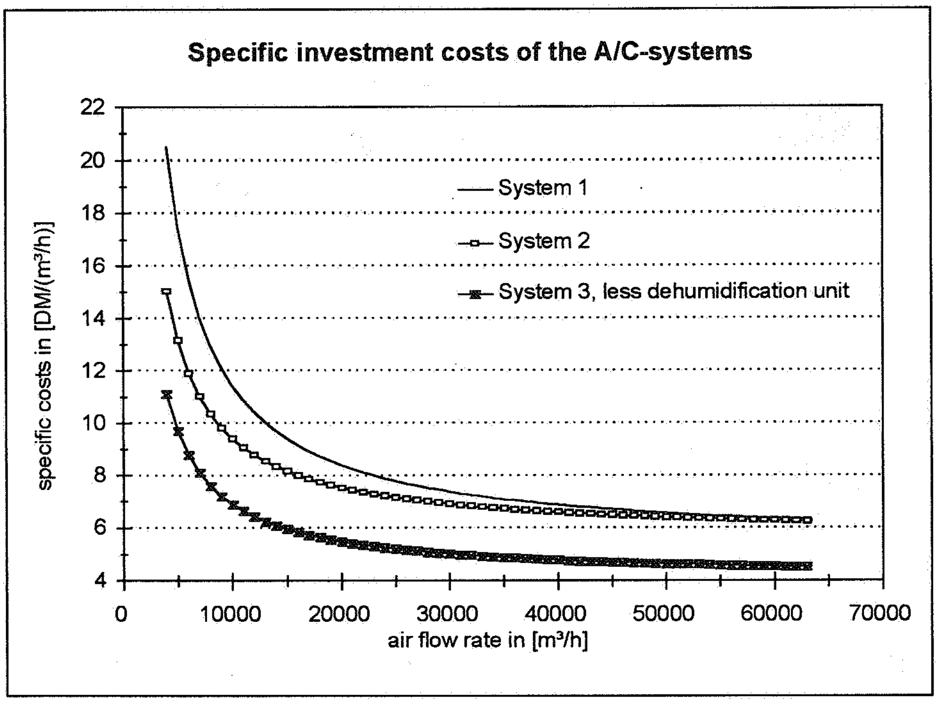

Fig. 4: Specific investment costs of the A/C-systems as a function of the air flow rate.

The specific costs of system 3 are charged without the costs for the dehumidification unit. That's why it is between 3,- and 2,- DM/(m³/h) cheaper than the other systems. The price of the dehumidification unit will be evaluated referring to the operating costs (see figure 8).

The following figures only pay attention to the energy costs, however it is possible to recalculate the energy consumption by using the energy prices. The prices for energy have been stated by data of energy supply companies.

Energy prices: heat: $k_H =$ 0,05 DM/kWh (natural gas)

electricity: $k_E =$ 0,19 DM/kWh

$k_{EP} =$ 160,00 DM/kW$_{el}$ (price for required power)

water: $k_W =$ 3,00 DM/m³

The analysis of the calculation shows that the distribution of the operating costs of one system doesn't change very much with the airflow rate. Figure 5 shows exemplary the energy costs for a building with a maximum air flow rate of 30 000 m³/h. The results are valid for a continuous plant operation over the year. For the comparison the costs are related to the costs of system 1.

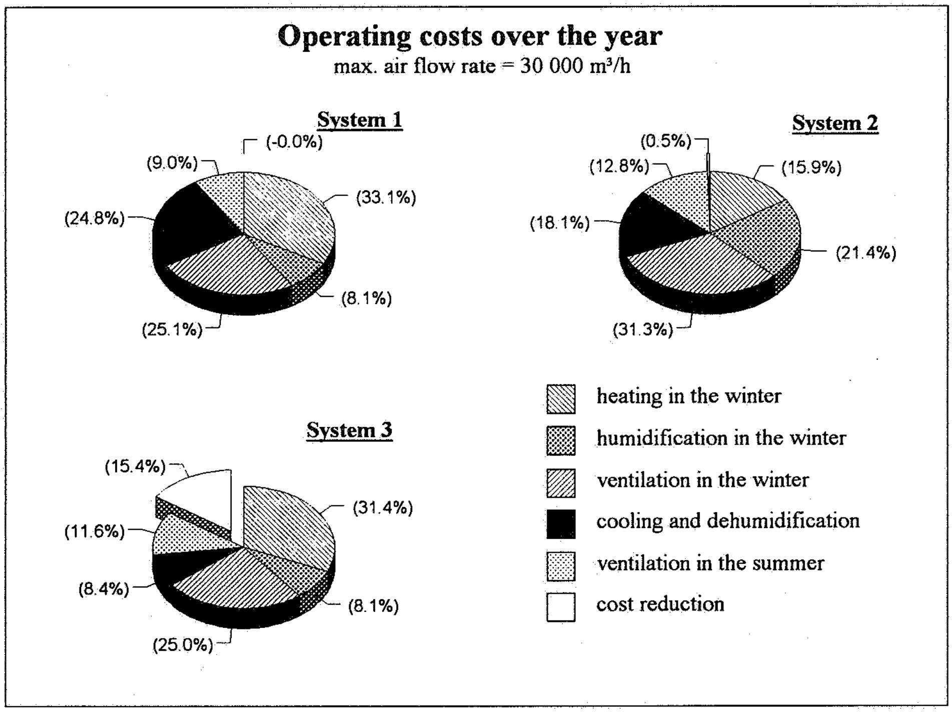

Fig. 5: Operating costs for a continuous plant operation over the year referring to system 1.

The absolute energy costs during the winter time are nearly equal for all systems. Approximately 65% of the energy costs of system 1 and 2 have to be payed for heating, humidification and ventilation in the winter. With system 3 the part of the energy costs in the winter is about 80% of the total energy costs. The distribution of the energy costs of system 2 in the winter is different to those of system 1 and 3. The reason for this difference is the use of the dehumidification wheel for recovery of moisture and the installation of a thermal wheel with a high efficiency for the indirect evaporative cooling in the summer. The calculation demonstrates that the annual energy demand of system 1 and 2 is nearly equal.

It becomes obvious that the 15% cost reduction of system 3 is a result of the replacement of the cooling and dehumidification process. For a better explanation the operating costs expected in the summer time are exactly described in figure 6.

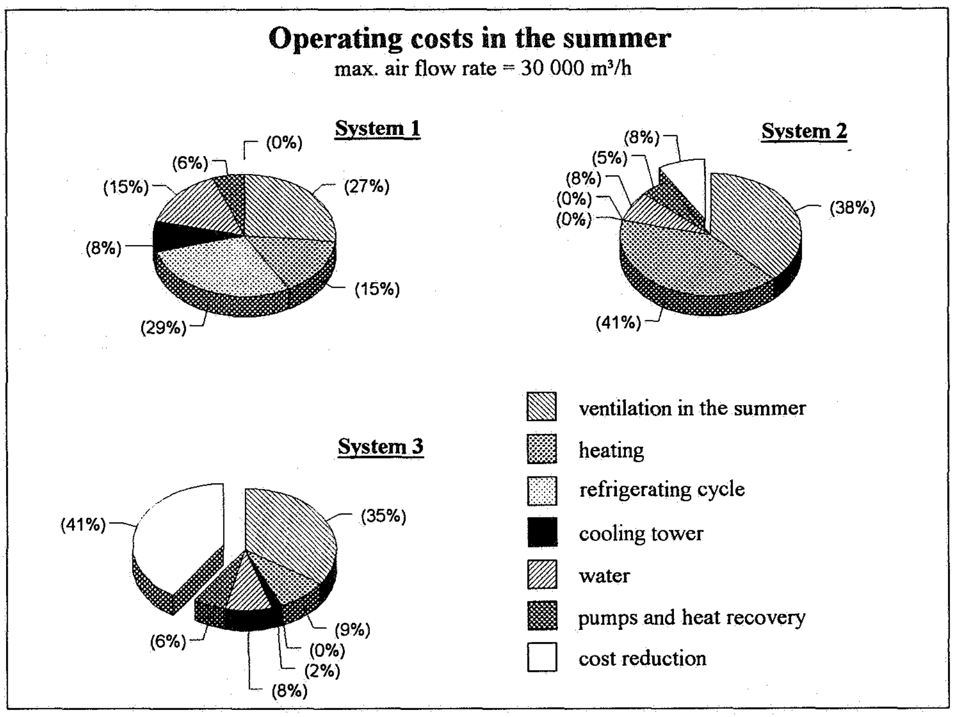

Fig. 6: Operating costs for a plant operation in the summer time referring to system 1.

The results of figure 6 show clearly that there are great differences between the regarded systems concerning the energy demand. The A/C-system with the refrigerating cycle causes the highest operating costs in the summer. By using system 2 it is possible to reach a cost reduction of about 8% and with system 3 it is possible to reduce the energy costs in the summer around 40%.

As there are more components in the A/C-plant which causes higher pressure differences, the ventilation costs of the sorptive systems are 30% higher than those of system 1. The input of heat in system 1 is necessary to reheat the air coming from the cooler up to a comfortable supply air condition. It is obvious that the highest heat demand is given in system 2. In the sorptive systems the heat is necessary for the regeneration of the sorbent. System 2 needs a three times higher energy input for the regeneration then system 3. The difference is given by the way of heating the sorbent. In system 2 the regeneration air flow must be heated which causes great heating loss over the exhaust air. Whereas in system 3 the heating of the sorbent is done directly by water and the process-heat is recovered in a heat exchanger. The need of fresh water for cooling in system 1 is higher than that of the systems with evaporative cooling. The reason is that the amount of heat originated from the refrigerating cycle and released by the cooling tower is higher then the cooling load, which is released directly in system 2 and 3.

Up to now the considered costs exclusively refer to the energy costs. Supplementary costs must be expected for the disposition of electricity. This price has normally to be payed for a maximum power requested in a period. Paying attention to the costs for required power the distribution of the annual operating costs (shown in figure 5) changes considerably. Since the refrigeration cycle works with electricity, the operating costs of system 1 rise more then those of the sorptive systems. The influence of the costs for required power on the annual operating costs is shown in figure 7.

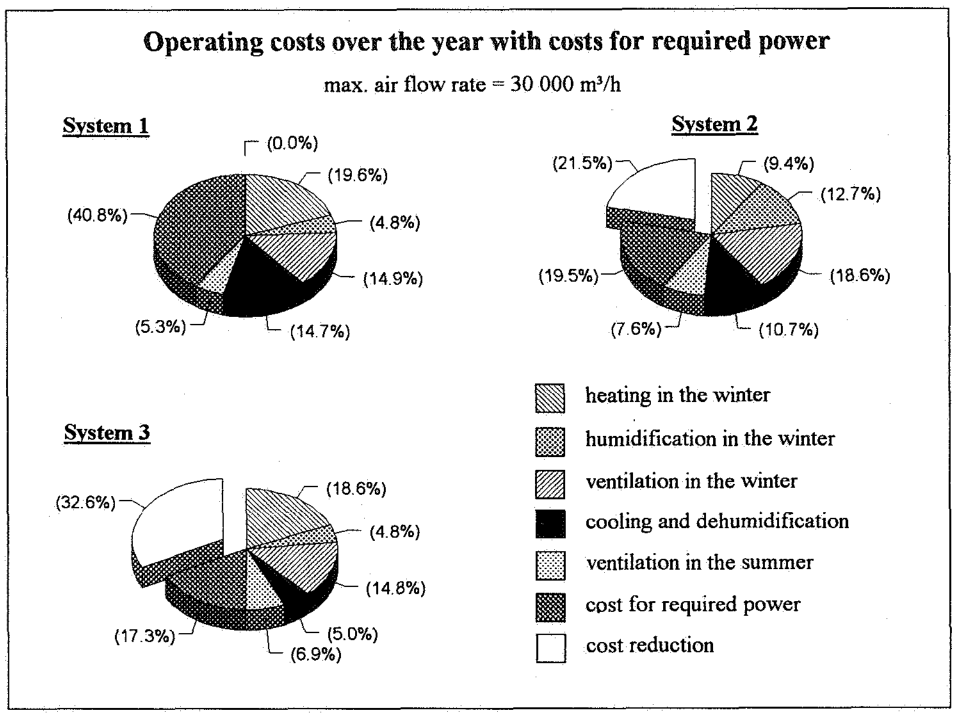

Fig. 7: Operating costs for a continuous plant operation over the year with costs for required power.

Figure 7 shows that the influence of the costs for required power can not be neglected. The use of the electrically driven refrigeration cycle causes annual cost reductions about 20% for system 2 and 30% for system 3.

The calculated cost reduction of system 3 has been taken to determine a price for the new absorptive dehumidification unit. The calculated price for the dehumidification unit so presents the maximum costs in order to compete economically with the other systems. Figure 8 shows two curves in which the specific costs are presented as a function of the air flow rate.

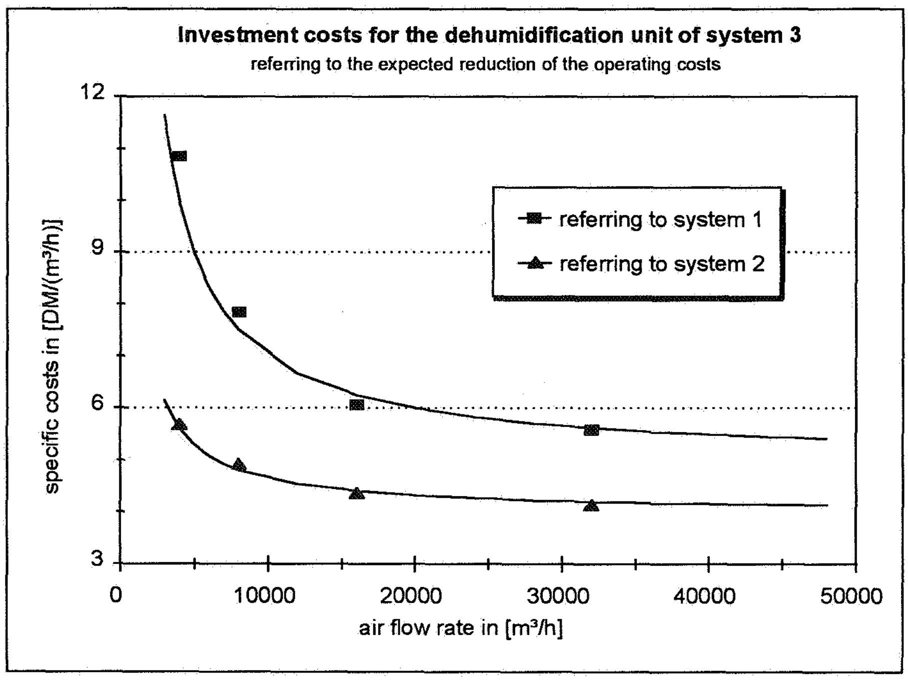

Fig. 8: Investment costs for the dehumidification unit of system 3, referring to the expected reduction of the operating costs of figure 7.

The price for the dehumidification unit resulting from the comparison of the investment costs (see figure 4) may come to an amount between 3,- and 2,- DM/(m^3/h), so that the installation of system 3 will still be attractive. Paying attention to the reduction of the operating costs, the price of the dehumidification unit of system 3 could be between 9,- and 4,- DM/(m^3/h), depending on the size of the A/C-plant and the reference A/C-system. The result shows that a higher price of the new system can be equalized by lower energy costs.

5. Acknowledgement

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