PROGRESS AND TRENDS IN AIR INFILTRATION AND VENTILATION RESEARCH

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NEW DESIGN OF CENTRAL UNITS IN AIR HEATING SYSTEMS FOR HEATING AND VENTILATION IN DOMESTIC BUILDINGS

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NEW DESIGN OF CENTRAL UNITS IN AIR HEATING SYSTEMS FOR HEATING AND VENTILATION IN DOMESTIC BUILDINGS

Synopsis

In central units of air heating systems the supply air flow must meet the actual heating demand. Most of central units for air heating systems have only one fan, which is designed for the maximum air flow at the maximum heating capacity. Fan motors are designed for variable-voltage-drive to enable a reduction of air flow to the necessary value at different heating demands. However, the electrical efficiency is decreasing strongly. The supply air fan is working mostly under part-load conditions. Therefore the control strategy used now is very ineffective. It is suggested to install 2 fans in an air handling unit. One of them is working at full capacity all over the year, but the second one starts only to deliver the additional air flow required in case of higher heat demand. Charts basing on calculations will demonstrate the relation between outdoor air temperature and the demand of energy for both systems.

1. Introduction

By advanced insulation standards of buildings and development of window-constructions the heating demand for building decreased strongly. Nevertheless it is necessary to exchange a certain rate of indoor air: pollutant concentrations and vapour have to be kept below a certain level to avoid sickness of persons or damage of the building construction. Some years ago gaps in walls and window-components provided sufficient air infiltration to minimize pollutant concentration. Modern building constructions however require intensive ventilation by opening windows or better by mechanical ventilation. Several researches have been finished with the conclusion, that an air exchange rate of 1 h^{-1} up to 1.5 h^{-1} should be reached. One very important advantage of mechanical ventilation is the possibility of heat recovery. This method helps to reach a considerable potential for saving energy as shown in figures 1 and 2 by the increasing percentage of ventilation heat demand.

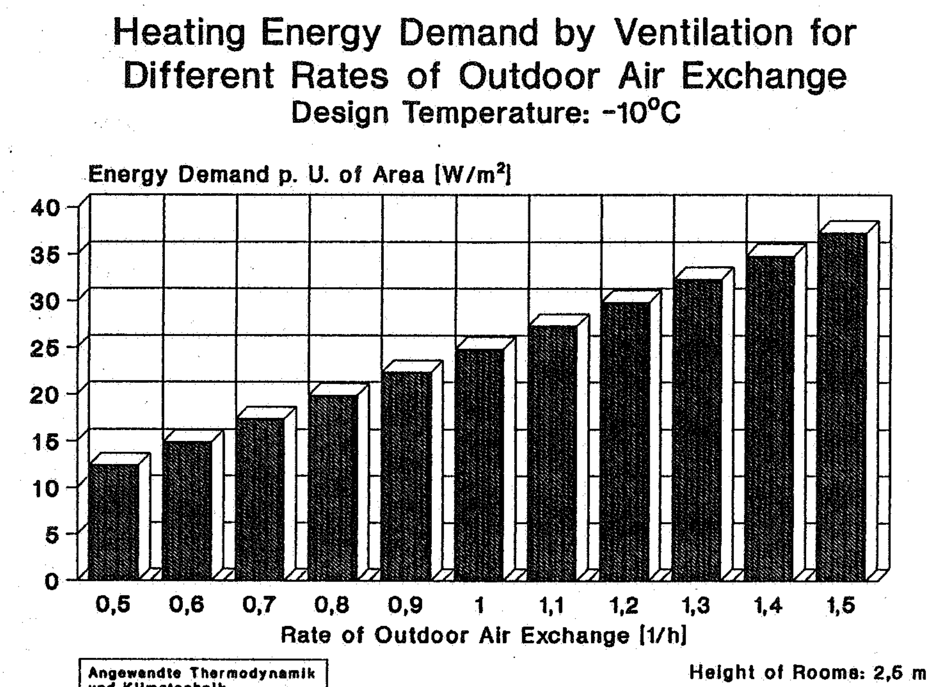

Fig. 1

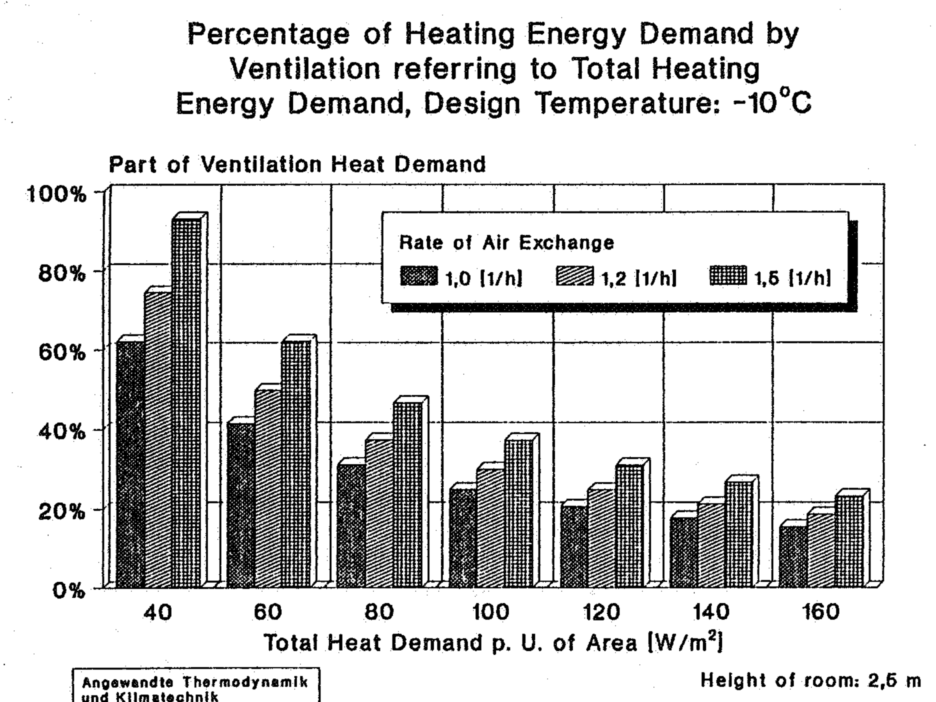

Fig. 2

In order to reduce first costs the combination of heating and ventilation systems is quite obvious. Without any additional water circulation system the supply air will be used to transport heating energy to the rooms. According to the above mentioned range of air exchange the following calculations base on 1.0 h^{-1} as the minimum value. Considering the comfort limits concerning the maximum supply air temperature (55°C just at the central unit) air heating system provide an energy transport of 29 W/m^2. The heat demand for the outdoor air change is delivered directly in the central unit to the air flow. It is not necessary, therefore, to transport this heat to the rooms (See figure 3). Only in buildings with a heat demand by transmission above 29 W/m^2 the transport capacity of ventilation air rate is not sufficient: it is necessary to increase the transport capacity by return air.

System Design

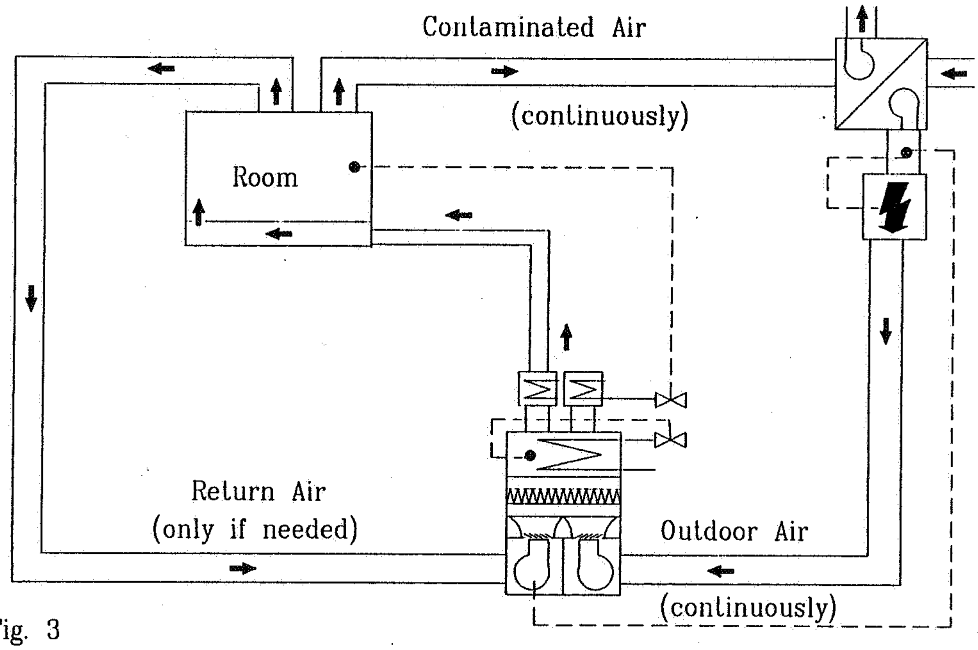

Fig. 3

2. Conventional Conception of Control Strategies

For those systems in buildings with a transmission heat demand below 30 W/m^2 the supply air temperature for each room can be modified by separate heat exchangers. An adaption of the heating capacity by reducing the supply air flow to the rooms has to be declined as waste of energy. Moreover, the ventilation function of the system is restricted by reducing the supply airflow: this is an obvious contradiction to the desired equivalence between heating and ventilation combined in one system.

In buildings with higher heating demands the maximum supply air temperature will be reached at outdoor air temperatures above the heating design-temperature. This will actually happen while reaching an outdoor air temperature range between -4°C and 0°C in buildings with an average insulation standard (Figure 4). An additional return air flow will be necessary to perform sufficient transport capacity. Of course, highly contaminated air must not be used as return air. This air from kitchen and bathrooms will go directly to the heat recovery system.

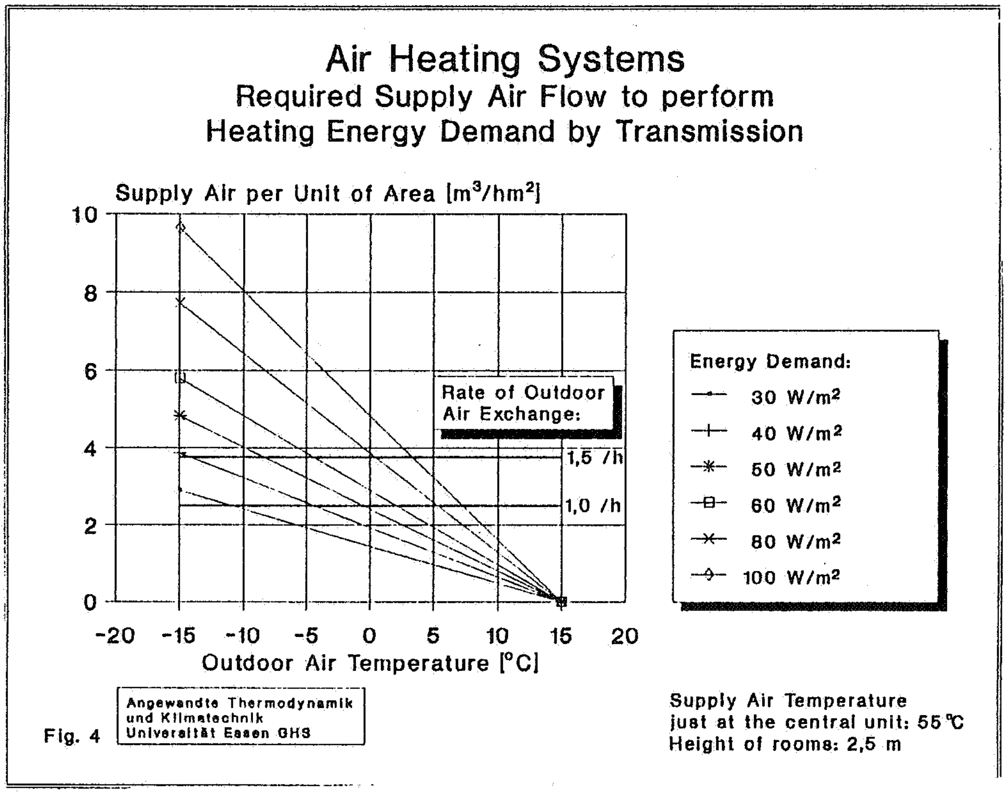

Fig. 4

Conventional central units of air heating systems with only one fan for supply air can increase the fan speed to perform higher heating capacities. Therefore special disc-type motors are available allowing a modification of the driving capacity by reducing the motor operating voltage. Usually the central units are equipped with a sequence switch for up to five operating points. At low outdoor air temperatures the return air flow damper will be opened and the operating voltage of the fan motor will be raised. Other central units are available performing continous adaption of fan capacity. Of course these systems cause higher first costs although there is no significant reduction of operating costs.

As a matter of principle the fan-motor has to be designed for the maximum desired air flow corresponding to the maximum operating voltage.

3. Improved Methods of Designing Central Units

A well designed fan shows an efficiency characteristic which follows exactly the system pressure-volume characteristic. That means that the mechanical efficiency is not influenced by the speed variation. The electrical efficiency of the motor however decreases strongly with reduced operating voltage. Characteristics of such fan-units measured by the producers show that the reduction of air flow to 50% causes the total efficiency dropping down to 20% of the full-load efficiency (Figure 5). The physical reason has to be seen in the low part-load efficiency of motor.

Air Heating Systems
Typical Characteristic for Fans used in Central Units (up to 1000 m^3/h)

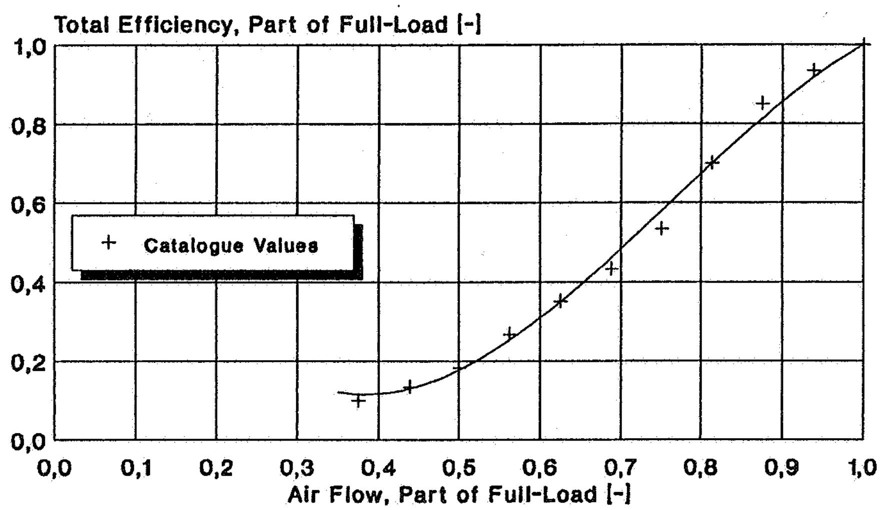

Fig. 5 Angewandte Thermodynamik und Klimatechnik Universität Essen GHS

Pictured according to producer's measurements

It is a fact that fans in the central units of air heating systems will be operate under part load conditions most time of the year. Figure 9 shows the frequency distribution of outdoor air temperatures in the German town of Essen. Only 300 h/a outdoor air temperatures below -4°C have to be expected. Considering the low efficiency of air feed along this time the operation of those plants is more expensive than necessary. One method to improve the electrical efficiency under part-load conditions is to accomodate the speed by means of frequency transformation. The costs for such electrical controls are much higher than costs for a complete fan unit. So another way has to be found to guarantee lower driving energy demand for the air feed.

An effectful possibility would be a new construction of central units equipped with two fans. One of them is designed to transport ventilation air for outdoor air temperatures above -4°C. This fan will always operate at its maximum electrical efficiency.

The second fan is designed to transport both ventilation air and additional return air considering the higher pressure-drop in the supply air system. So the air flow capacity of this second fan has to be more than twice of the first stage fan. During operation of this fan the first one stops.

A modification of this concept can be made by operating the ventilation air fan all over the year even for low outdoor air temperatures, when the second fan is working additionally. In this design the return air fan can be designed smaller than above mentioned. The total air flow will be produced by both fans for low outdoor air temperatures.Indeed, the operating point of the ventilation air fan moves to a lower airflow as a consequence of the increasing pressure drop. This will cause a lower rate of outdoor air exchange and an insignificant decrease of the total efficiency for this fan. Both effects can be accepted without any problem. At low outdoor air temperatures the absolute humidity is very low so that the indoor air humidity will not rise to an inacceptable value with the lower air exchange rate. The reduced ventilation fan efficiency for low outdoor air temperatures can be neglected, because the operating time (300 h/a) is very short.

In comparison with the conventional concept the average efficiency of fans can be raised remarkable.

4. Conclusion

Depending on the above mentioned facts a comparison between air feed energy demand of a conventional plant (1-fan-system) and improved construction (2-fan-system) is made. The following charts basing on fan characteristics from a well-known German producer and meteorological dates from DIN 4710 proove that annual operating costs for the driving energy can be reduced to about 50% to 30%. This new concept could help to improve the economy of operation of air heating systems without raising first costs.

This seems to be an important fact to help air heating systems getting more distributed. Discomfort of persons caused by exceeding maximum pollutant concentration on indoor air as well as damages of building construction surely can be avoided by using ventilation systems. Combining heating and ventilation in domestic buildings should find greater acceptance than the urgency to spend more money for separate systems. Therefore further development of modern air heating systems will be a duty for producers and scientists.

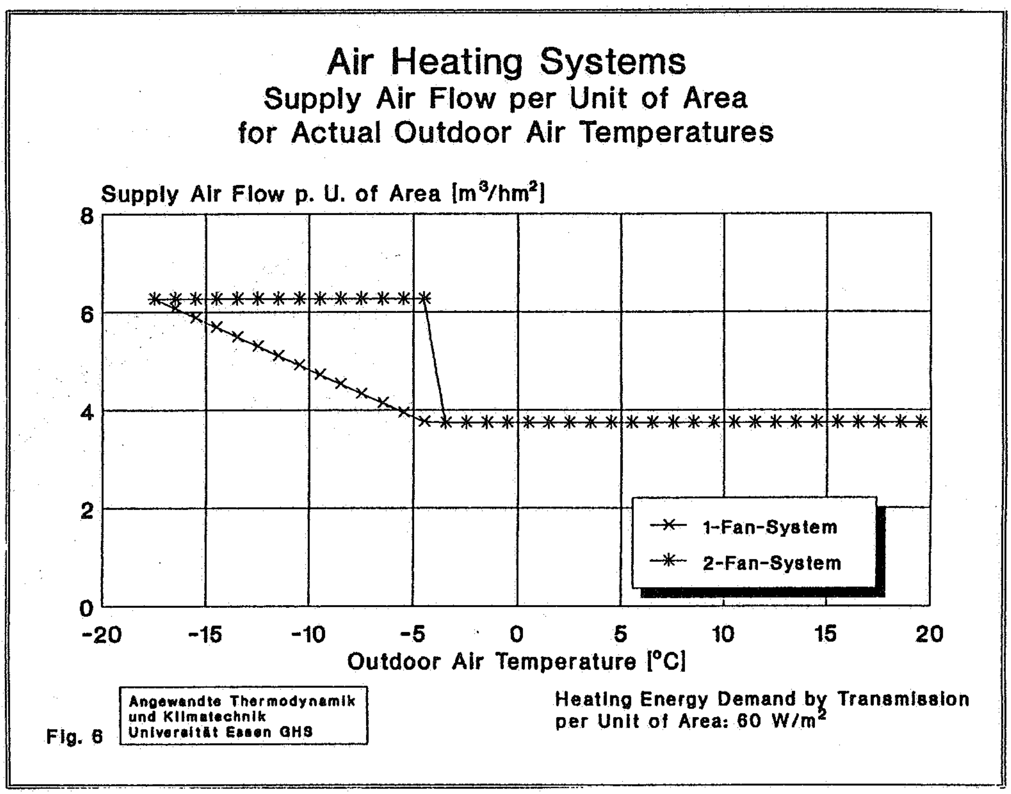

Fig. 6

Air Heating Systems
Fan Efficiency for Actual Outdoor Air Temperatures

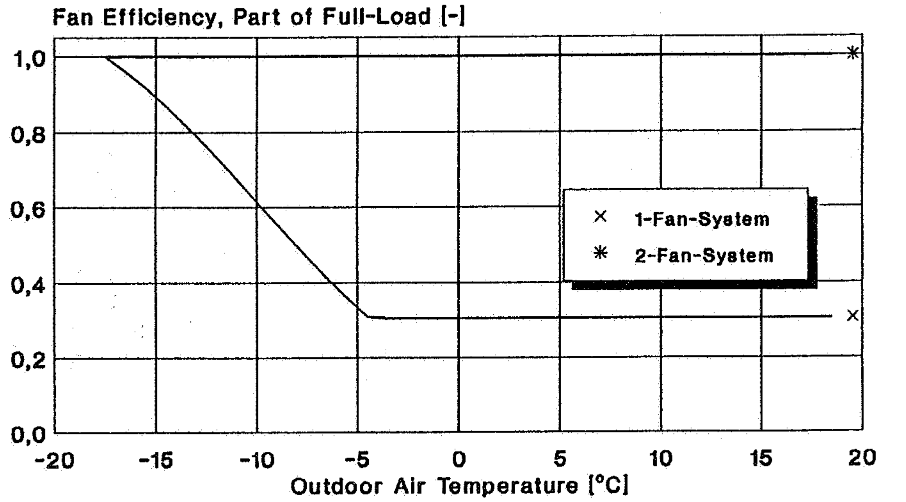

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Fig. 7

Heating Energy Demand by Transmission per Unit of Area: 60 W/m²

Air Heating Systems
Fan Power Input for Actual Outdoor Air Temperatures

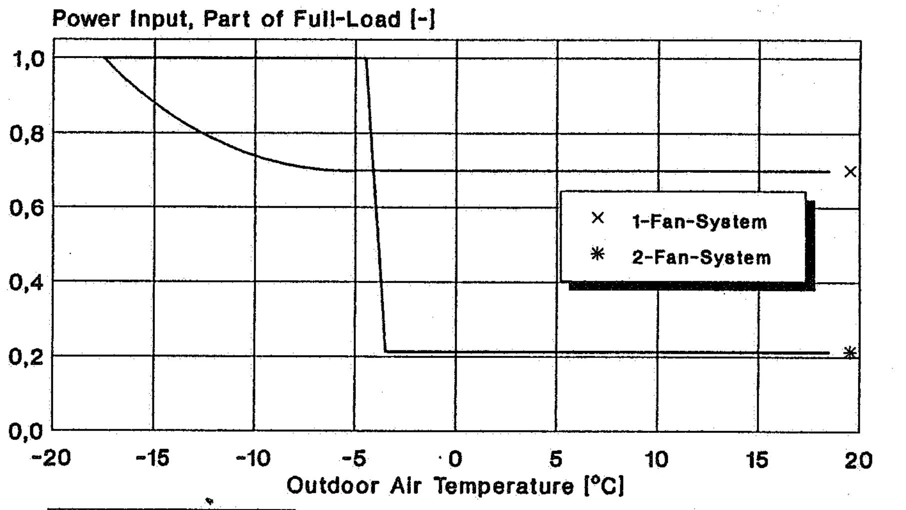

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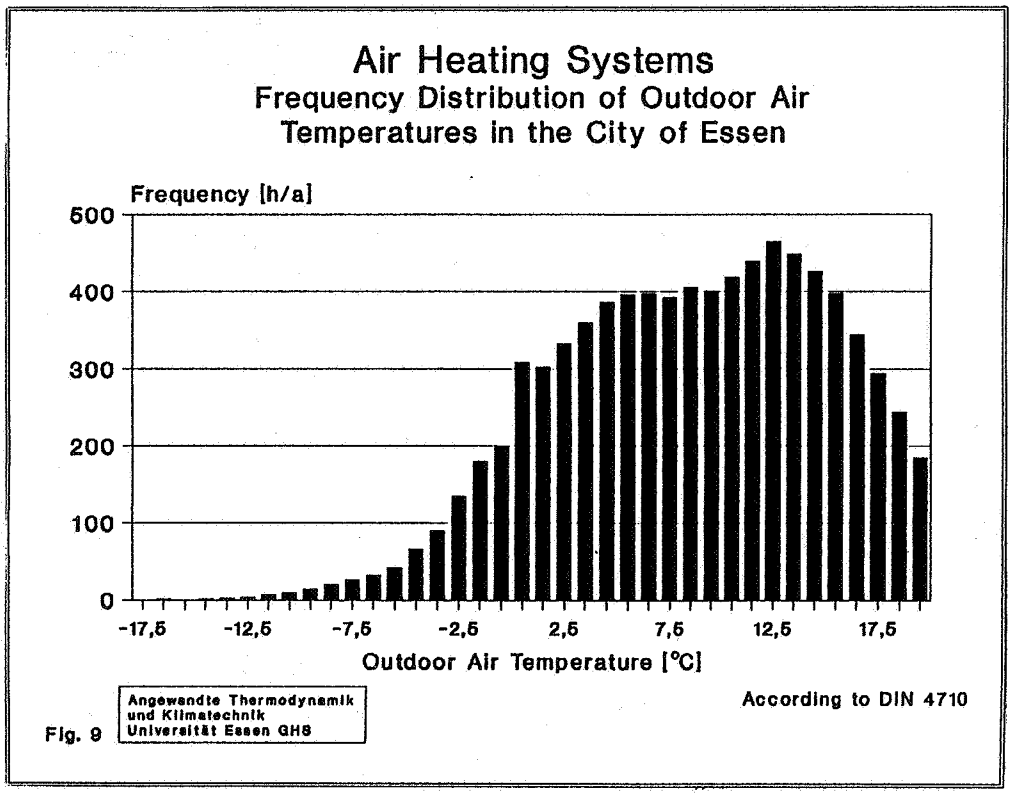
Fig. 8

Heating Energy Demand by Transmission per Unit of Area: 60 W/m²



Air Heating Systems
Frequency Distribution of Outdoor Air Temperatures in the City of Essen
Frequency [h/a]
500
400
300
200
100
0
-17,5
-12,5
-7,5
-2,5
2,5
7,5
12,5
17,5
Outdoor Air Temperature [°C]
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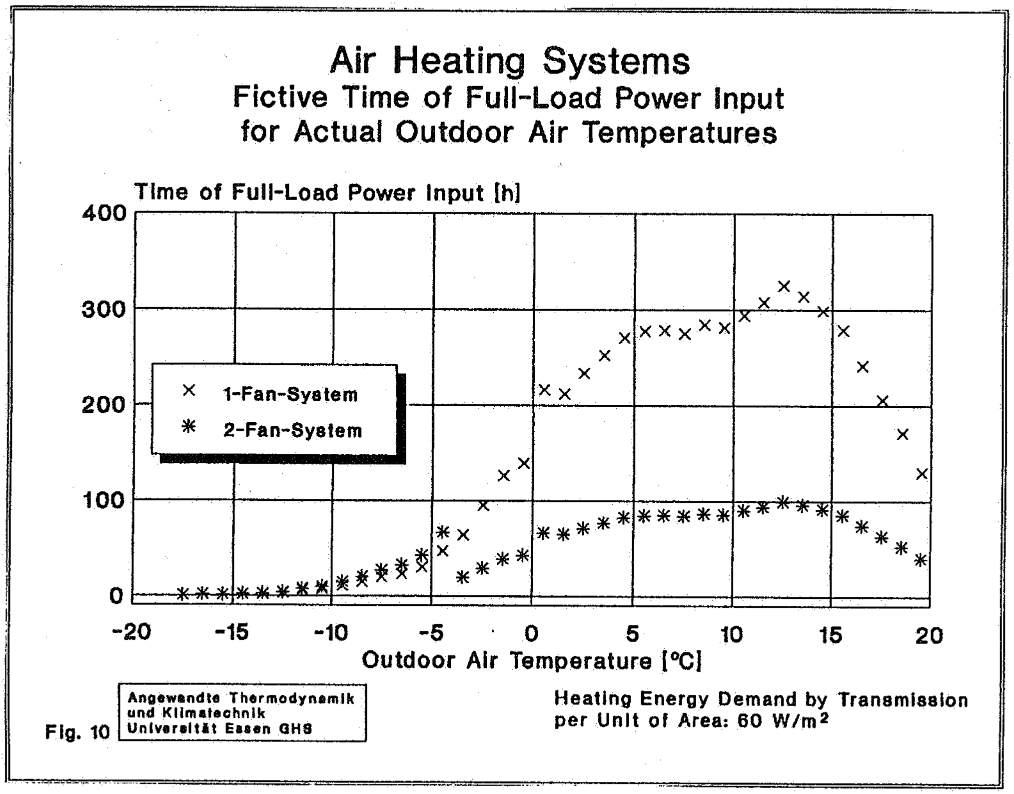
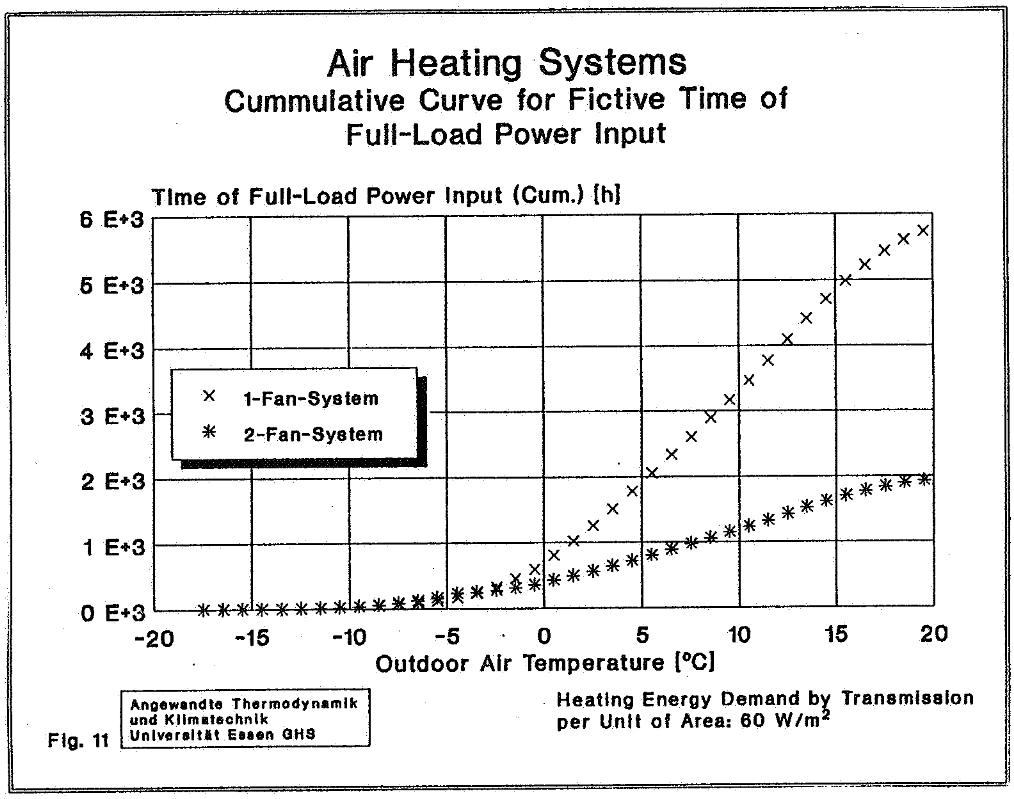
According to DIN 4710

Fig. 9



Air Heating Systems
Fictive Time of Full-Load Power Input for Actual Outdoor Air Temperatures
Time of Full-Load Power Input [h]
400
300
200
100
0
1-Fan-System
2-Fan-System
-20
-15
-10
-5
0
5
10
15
20
Outdoor Air Temperature [°C]
Angewandte Thermodynamik und Klimatechnik Universität Essen GHS
Heating Energy Demand by Transmission per Unit of Area: 60 W/m²

Fig. 10



Air Heating Systems
Cummulative Curve for Fictive Time of
Full-Load Power Input
Time of Full-Load Power Input (Cum.) [h]
6 E+3
5 E+3
4 E+3
3 E+3
2 E+3
1 E+3
0 E+3
1-Fan-System
2-Fan-System
-20
-15
-10
-5
0
5
10
15
20
Outdoor Air Temperature [°C]
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Heating Energy Demand by Transmission
per Unit of Area: 60 W/m²

Fig. 11