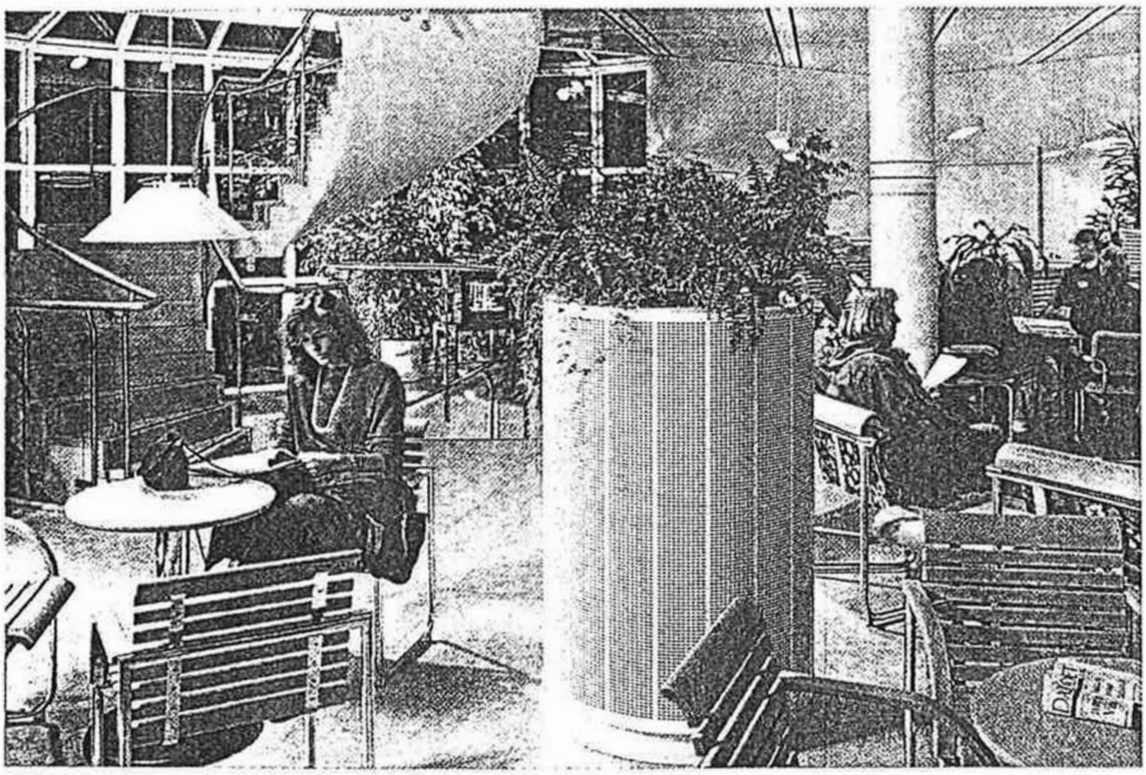
A THERMIE PROGRAMME ACTION

THERMIE

INNOVATIVE and ENERGY EFFICIENT AIR CONDITIONING SYSTEMS



R.U.E.

European Commission
Directorate-General for Energy (DG XVII)

1. INTRODUCTION

In the 1960's and 1970's hardly any large office or administration building was planned or built without installing an extravagant air conditioning system. Architects and building owners succumbed equally to this trend, which had its roots in particular in the United States of America.

This development inevitably brought about the erection of multi-storey office buildings and the introduction of open-plan offices. High pressure air conditioning systems, dual duct systems, induction systems, zone regulation, etc. are terms which were used in connection with large office buildings at this time.

However the majority of office employees had difficulties coming to terms with the change from an individual work-place in a smaller room with windows that could be opened, to an open-plan office, even if their new work-place had a more modern and pleasant design. The general decline in working conditions was, rightly or wrongly, often blamed on the air conditioning.

Complaints about a lack of fresh air and the disturbance and inconvenience caused by draughts were an everyday occurrence. This resulted in the acceptance of air conditioning systems sinking dramatically in the early 1980's. Furthermore other problems were in store for the operators after two energy supply crises and the corresponding high increase in operation costs, particularly energy costs.

This led to the development of new solutions, which firstly were to increase the comfort in air-conditioned rooms, and secondly to cause lower costs. Furthermore the alarming condition of the earth's atmosphere today means that it is imperative that environmentally friendly techniques and technologies be applied, also in the field of air conditioning. In particular this applies to refrigeration plants for the purpose of cooling the incoming air.

A brief overview of the latest developments on the air conditioning sector will be given in this brochure. It will be limited to a simple and easily understandable portrayal and elaboration of the most important development trends.

2. INNOVATIVE AND ENERGY EFFICIENT AIR CONDITIONING SYSTEMS

2.1 Air Conditioning Systems with Variable Air Volume Systems (VAV Systems)

2.1.1 Description of System

With conventional single duct air conditioning systems the supply air flow is kept constant and its temperature is regulated according to the requirements. With VAV systems however the supply air temperature is kept constant at certain levels and the volume flow is variable.

In the case of cooling, which mainly occurs, the supply air is fed in at 16°C - 18°C. If the room temperature increases, for example because of inner loads, then the supply air flow is increased, if the temperature falls it is lowered. A minimum limitation guarantees that a hygienically necessary minimum air flow is maintained. The regulation of the volume flow control is effected by thermostats, which are installed in individual rooms or also in larger areas.

The total volume flow of a system is therefore changeable within wide limits. Throttling the supply air alone via the volume flow control would be uneconomic, a regulation of the ventilator via a pressure sensor in the channel network would however be useful.

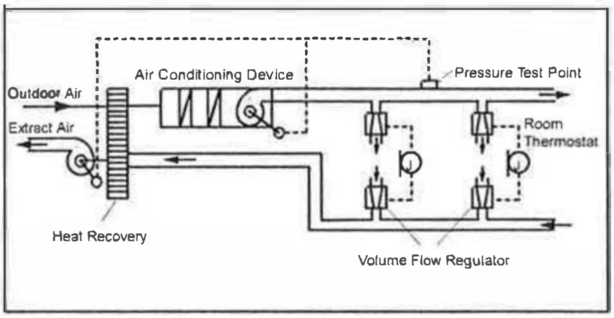


Fig. 2.1.1.1 Scheme of the single duct air conditioning system with variable volume flow (VAV system) (1)

The adaptation of the total volume flow to the requirements can energy-wise best be achieved for radial ventilators by speed regulation, with axial ventilators by adjusting the blades. For both ventilator types a vane control possibly in connection with a pole-changing, multi-speed motor is often economic.

Also, the exhaust air volume flow must be regulated according to the supply air flow.

Figure 2.1.1.1 shows the simplified principle of a VAV system.

The front cover shows the application of a supply air terminal device for source ventilation. (8)

Cologne March 1996

CONTENTS

THERMIE (1990-1994)

This is an important European Community programme designed to promote the greater use of European energy technology. Its aim is to assist the European Union is achieving its fundamental objectives of:

- improving the energy supply prospects of the European Union;
- reducing environmental pollution by decreasing emissions, particularly those of CO_2, SO_2 and No_x;
- strengthening the competitive position of European industry, above all small and medium-sized enterprises (SMEs);
- promoting the transfer of technology to Third Countries;
- strengthening economic and social cohesion within the European Union.

The majority of the funds of the THERMIE Programme are devoted to financial support of projects which aim to apply new and innovative energy technologies for the production, conversion and use of energy in the following cases:

- rational use of energy in buildings, industry, energy industry and transport;
- renewable energy sources such as solar energy, energy from biomass and waste, as well as geothermal, hydroelectric and wind energy;
- solid fuels, in the areas of combustion, conversion (liquefaction and gasification), use of wasters and gasification integrated in a combined cycle;
- hydrocarbons, their exploration, production, transport and storage

The THERMIE Programme (1990-1994) includes a provision for the enhanced dissemination of information to encourage a wider application and use of successful energy technologies. This information is brought together, for example, in publications such as this maxibrochure. Maxibrochures provide an invaluable source of information for those who wish to discover the state of the art of a particular technology or within a particular sector. The information they contain is drawn from all Member States and therefore provides a pan-European assessment.

To guarantee the maximum effectiveness of the funds available, the THERMIE Programme (1990-1994) includes an element for the co-ordination of promotional activities with those of similar programmes carried out in Member States and with other European Community instruments such as ALTENER, SAVE, SYNERGY, JOULE, PHARE and TACIS.

JOULE-THERMIE (1995-1998)

The first THERMIE Programme for the demonstration and promotion of new, clean and efficient technologies in the fields of rational use of energy, renewable energies, solid fuels and hydrocarbons, came to an end in December 1994. In January 1995 prescribed in the Treaty on European Union, this programme brings together for the first time the research and development aspects of JOULE (managed by the Directorate General for Science, Research and Development, DG XII), with the demonstration and promotion activities of THERMIE (managed by the Directorate General for Energy DG XVII). A budget of 532 MECU has been allocated to the THERMIE component for the period 1995-1998.

Colour Coding

To enable readers to quickly identify those maxibrochures relating to specific parts of the THERMIE Programme, each maxibrochure is colour coded with a stripe in the lower right hand corner of the front cover, i.e.:

- ■ **RATIONAL USE OF ENERGY**
- **RENEWABLE ENERGY SOURCES**
- ■ **SOLID FUELS**
- ■ **HYDROCARBONS**

This maxibrochure was produced within the framework of the former THERMIE Programme (1990-1994).

Further information on the material contained in this publication, or on other THERMIE activities may be obtained from one of the organisations listed inside the back cover

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Innovative and Energy Efficient Air Conditioning Systems

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Directorate-General for Energy (DG XVII)

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2.1.2. Fields of Application

VAV systems are only suitable for air conditioned rooms in which changeable cooling loads have to be removed, e.g. in office buildings, assembly rooms, department stores, etc..

In the past they were often installed in connection with induction air conditioning systems, whereby the air-conditioning of the outer zones was effected by the induction zones, while the VAV system supplied the inner areas. In principle VAV systems are however also only suitable for air-conditioning as single systems.

As in the usual single-duct construction of such systems no heating load can be met. The outer zones must be supported by a heating system in the winter months, which also can be used for initial heating before beginning operation.

In order to keep the operation periods of the VAV system low, it makes sense to install radiators or a window blowing system. Otherwise a particular temperature rise control switch would have to be provided, or, if necessary, an additional hot air duct may need to be installed.

2.1.3. Characteristic System Components

Volume Flow Control

The volume flow control of VAV systems has the task of adjusting the quantity of air demanded by the thermostats, and to keep it constant if the channel pressure fluctuates. Decisive for energy savings in air transportation is the quality of the control, which is fed into the systems by these terminating elements.

For the regulation of the volume flow two principles can basically be applied, whereby a servo motor is necessary in both cases.

1 The thermostat resets the setpoint value of the volume flow control via the servo motor (self regulating system). The regulation results automatically from the channel pressure. In order to guarantee that the regulation is efficient, a minimal supply pressure of 200 - 300 Pa is necessary.

2. In order to save driving power for the ventilator, one can often do without relaxing (throttling) the appliance and also without the automatic volume flow control. Instead one uses a control with auxiliary energy or one does without any kind of volume flow control. The thermostat then resets a throttle valve or a similar installation directly. The appliances are easier to construct and need less energy (pressure loss approx. 100 Pa).

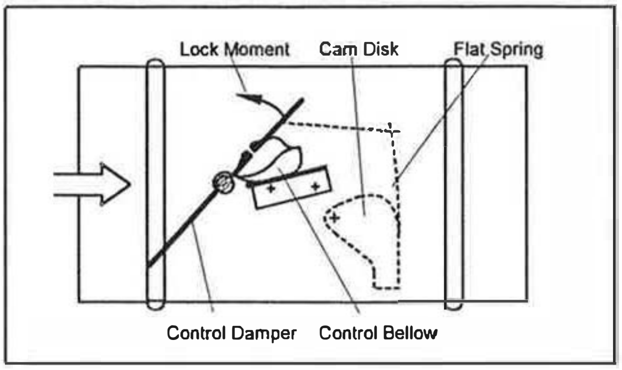


Fig. 2.1.3.1. Volume flow control with switch damper (2)

There are for example throttle valves with asymmetric lever kinematics so that a practically linear control ratio exists between the control pressure and the volume flow.

If a volume flow control is dispensed with, then however, the channel pressure loss must have been accurately determined.

Air Terminal Devices

In the choice of air supply terminal devices one must also consider that they also permit a high reduction in the air quantity, which as a rule is only the case with air outlets with a high induction efficiency.

However special constructions have been developed for variable air quantities, presented as an example in the following figures.

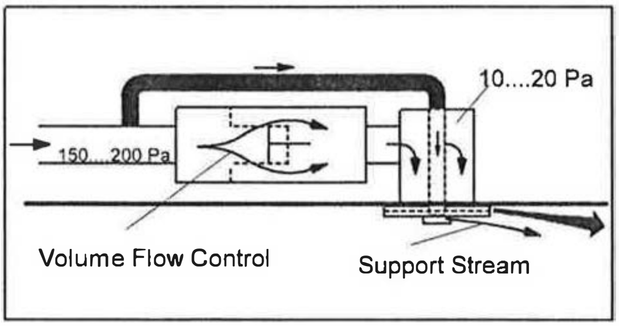


Fig. 2.1.3.2 Air diffuser with supporting stream (1)

At the air diffuser of figure 2.1.3.2 a constant support stream flows out at high speed, while the main volume flow, controlled by the thermostat in the rooms, can be varied.

At the air diffuser Fig. 2.1.3.3. the pneumatic servo motor moves not only the ball-shaped distribution body but also the nozzle plate.

During „heating" and thereby at minimal air flow, the radial clearance is practically closed and the air flows downward. During cooling the radial clearance for larger quantities, twist air diffusers were developed, whose twist blades can be adjusted by means of an

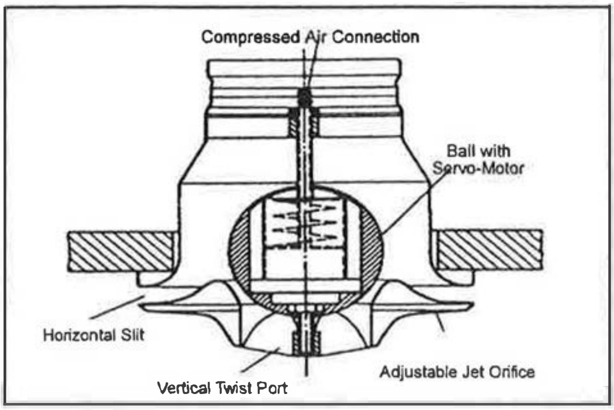


Fig. 2.1. 3.3 Round air diffuser (1)

electric or pneumatic servomotor. These diffusers can also be applied to a certain extent in VAV systems, whereby particular care should be taken to adhere to the minimum volume flow.

2.2 Source Ventilation, Displacement Flow

2.2.1 Description of System

In air conditioning one differs mainly between two types of flow:

Mixed air flow (fig. 2.2.1.1)
Displacement flow (fig. 2.2.1.2)

With mixed air flow the supply air enters the room with a relatively high entry impulse, and circulates the air volume in the whole room, and/or mixes with the air volume (fig. 2.2.1.1).

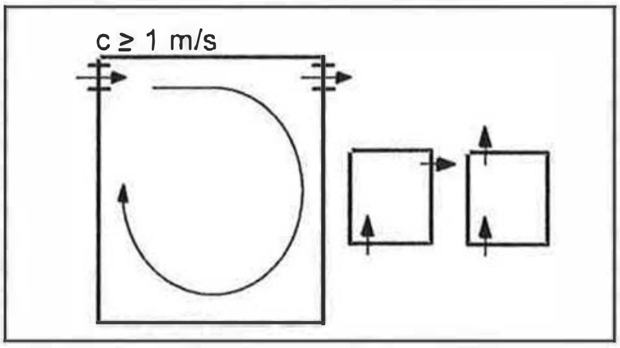


Figure 2.2.1.1 Mix flow (3)

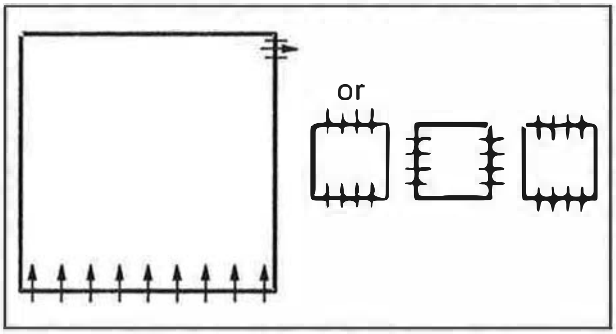


Fig. 2.2.1.2 Displacement flow (3)

With displacement flow, the air enters the room and is distributed equally. The air outlet lies on the opposite side (fig. 2.2.1.2):

If there is a heat source in a displacement flow that runs from below to above, then this changes the flow pattern to thermally regulated air conduction, which is referred to as source controlled flow (fig. 2.2.1.3).

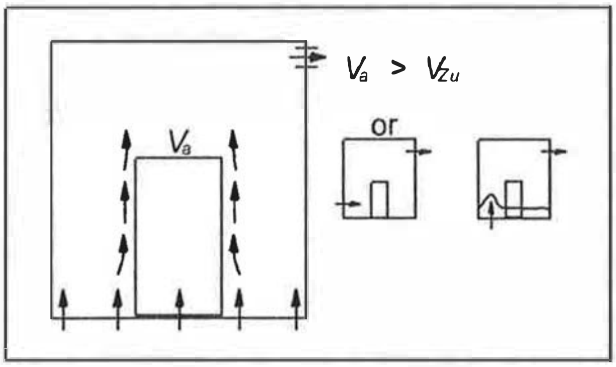


Fig. 2.2.1.3 Source ventilation (3)

This flow is determined not only by the upthrust at the heat source but also by the type of air injection and the air volume flow fed in.

Often this type of flow is referred to as laminar flow or "free convective flow".

The heat source causes various differing air movements in the room, which in the end lead to good ventilation of the room.

Increased demands for freedom from draughts and new knowledge about better removal of pollutants and toxic substances by increasing the ventilation effectiveness, have caused the thermal convection flow to increase in popularity.

2.2.2. Fields of Application

Originally this form of displacement flow was often applied in industrial production sites, in particular

Fig. 2.2.2.1 Air terminal device for source ventilation in a casino (5)

where pollutants arise from the production process, which could be harmful or simply a nuisance to people, or could lead to a disturbance of production. If the air injection temperature is correspondingly lower, then high heat loads can be eliminated in this application field.

Due to the high comfort compared to the mixed ventilation this system is, however, being increasingly used for air conditioning rooms in offices and administration buildings.

2.2.3 Characteristic System Components

Air Terminal Devices

For source ventilation supply air terminal devices no special construction measures are necessary.

It is therefore possible to a large extent to have design flexibility and adjustment to the corresponding structural conditions. The outlet levels consist mostly of fleece or foam, or in some cases merely a finely perforated sheet of metal. Thereby mainly flat outlets in the walls, in the socket area or in window sills come into consideration.

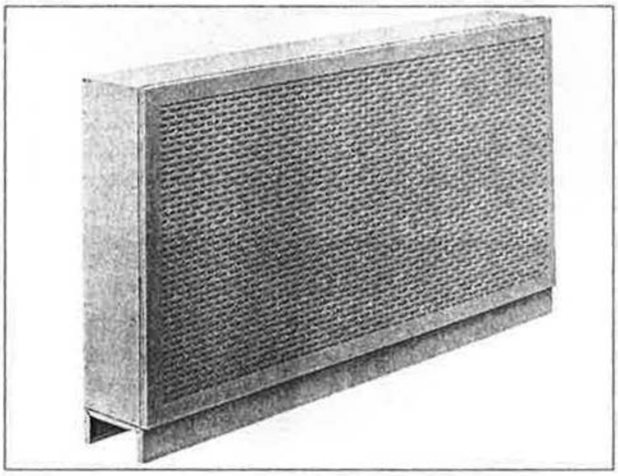


Fig. 2.2.3.1. Supply air terminal device of source ventilation (2)

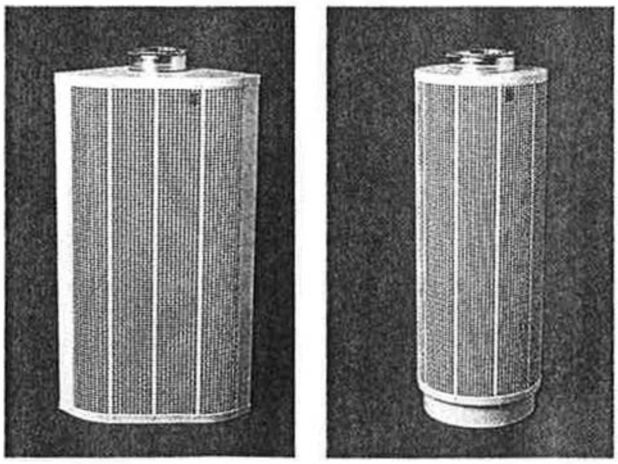


Fig. 2.2.3.2 Supply air terminal device of source ventilation (8)

However cylindrical devices in pillars, or cylindrical segments for walls and in the corners of the room are also common (Fig. 2.2.3.2).

A perforated double bottom floor with air permeable carpeting can be taken into consideration for large surface floor supply air terminal devices.

As in its application in air-conditioned rooms the lower temperature of the supply air in general is limited to approx. 2 - 3 K. Relatively large volume flows could be necessary for the removal of any cooling load arising. In order to keep the central unit and the channel network small. source air terminal devices with induction were developed. Primary air with a lower sub-temperature can be conveyed and in the outlets room air is added to heat it up to the permissible sub-temperature.

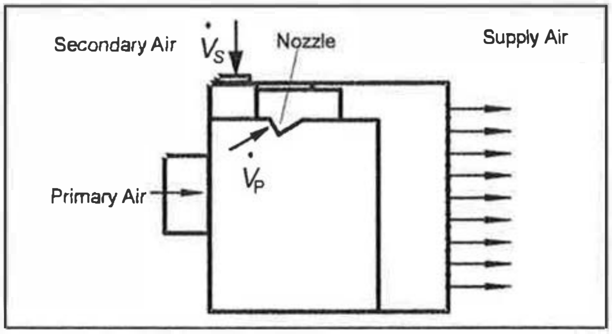


Fig. 2.2.3.3 Induction air terminal device source in linear form. (9) $V_S / V_P \cong 2/3$

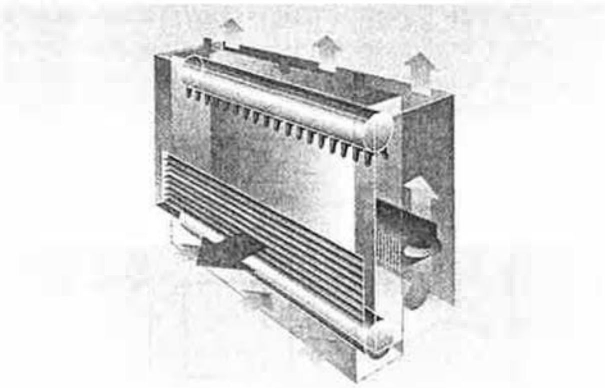


Fig. 2.2.3.4 Source air terminal device with induction for only-air-systems for window sill installation combined with static heating convector. (2)

The combination of the advantages of source ventilation, such as higher thermal comfort and good air quality, with the advantages of the induction plant and low operation costs. led to the development of source-air-induction units and appliances with heat exchangers.

These appliances are often applied in the system renewal and renovation of administration buildings, which are still equipped with conventional induction appliances from the 1960's and 1970's.

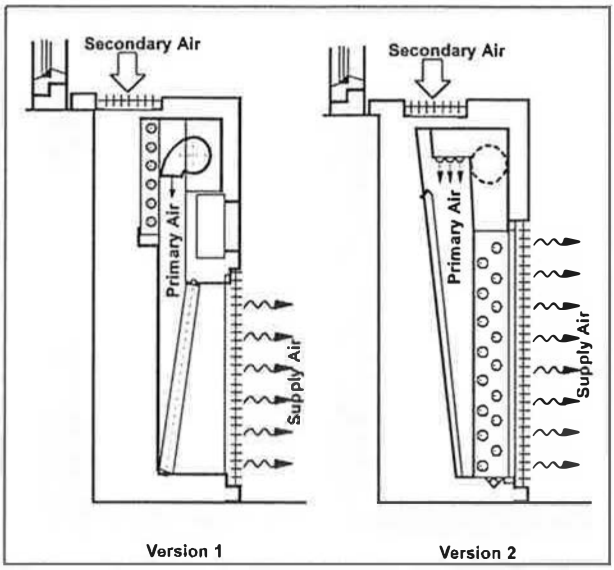


Fig. 2.2.3.5 Source-air-induction unit appliances (10)

In version 1 only secondary air, in version 2 primary air and also secondary air is supplied via the heat exchanger. With these appliances cooling efficiencies of up to approx. 60 W/m² are achieved. (11)

2.3 Cooled Ceiling Systems

2.3.1 Description of System

Cooled ceilings serve to remove cooling loads in rooms, mainly by means of pipes which have been laid in the ceiling and through which water flows. Furthermore there are also systems through which air flows and combined air/water ceiling systems.

These systems remove heat from the room by means of radiation exchange and convection, which vary according to the version of the cooled ceiling. However, only dry (sensitive) cooling loads can be removed.

Cooled ceilings can be used in rooms which only have window ventilation as well as in connection with VAC systems.

2.3.2 Construction Forms

With the cooled ceilings through which water flows, one differs between two main forms according to their main method of functioning (Fig. 2.3.2.1):

- radiation ceilings
- convention ceilings

Cooled ceilings with closed smooth undersurfaces transfer about 50 - 60% of the cooling effect through radiation and are accordingly called radiation ceilings.

According to the cooling load they can either be installed holohedrally or only in segments.

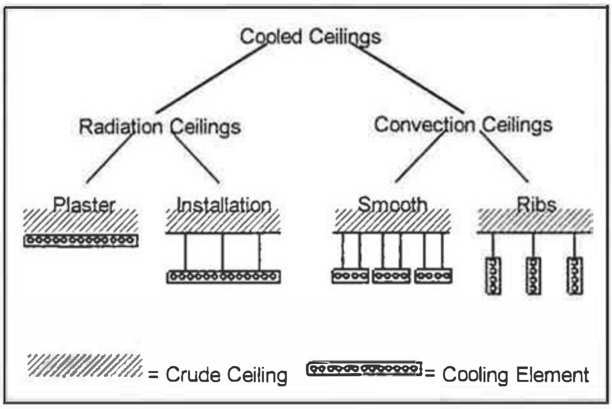


Fig. 2.3.2.1. Cooled ceiling systems (12)

The convective heat transfer and therefore also the total cooling effect is increased through a breakdown of the ceiling and thereby through additional activation of the upper side of the cooling segments, or also through ribbed construction forms. These construction forms are called convection ceilings. (Fig. 2.3.2.1)

Special forms are systems for cooled ceilings with air or a combination of air and water.

According to a general market overview published in the technical press (20), 70 cooled ceiling systems are offered at present, with an upward tendency. However the differences between some of the systems are very slight and in principle the same systems are presented by different manufacturers. The number of really independent system solutions is therefore clearly lower. In this market overview more than 90% of the systems use water for cooling.

2.3.3 Cooling effect

The cooling effect achievable by cooled ceilings depends not only on the construction but mainly on the temperature difference between the room and the cooling medium. The requirements made on the room temperature lie in Central Europe at max. +27°C at an outside temperature of +32°C.

The lower limit of the cooling medium temperature is determined by the danger of dewdrops forming on the ceiling. Experience shows that a cooling medium flow temperature of 16°C has proved successful. At this temperature the humidity of the outside air only leads to a condensation risk on a few days in the year.

At the values named for the room and cooling medium temperatures, cooled radiation ceilings achieve a specific cooling effect of 80-90 W/m² (12). With cooled convection ceilings values of over 200 W/m² can be achieved, depending on the design (12). However cooled convection ceilings with a specific cooling effect of between 120 and 150 W/m² are mainly used.

2.3.4 Fields of Application

The use of cooled ceilings only makes sense when the air volume flow, which is necessary to remove sensitive heat, is considerably higher than the air volume flow required to remove latent heat and to remove pollutants and/or to supply fresh air. Three balance equations are to be observed, in order to maintain a pleasant climate in the rooms:

For the removal of sensitive heat (1)
For the removal of moisture (2)
For the removal of pollutants (3)

Only when the air volume flow calculated according to (1) is larger than the values according to (2) and (3) is the application of cooled ceilings sensible. Only then does removal of the heat loads of the room with water instead of with air economically worthwhile.

Cooled ceilings can be used in practically all air conditioning systems. Good experience has been made, for example. in

- administration buildings
- main bank halls
- conference rooms
- data processing centres
- studios
- shopping centres

The air volume flow is reduced considerably if cooled ceilings are used, compared to conventional VAC systems, as under the above-mentioned conditions only the necessary outdoor air rate has to be inserted, while in the only-air-systems the volume flow must be much larger, in order to achieve the necessary cooling with air alone.
The room air speed of the VAC systems is reduced thereby considerably, which is a further contribution to increasing the room comfort.

2.3.5 Characteristic System Components

The most important element of a water cooled ceiling is the pipe system which is installed in the ceiling. Very differing systems are offered on the market whereby the pipes are not only made of plastic but also of metal.

One system uses capillary tube mats made of high quality plastic for the radiation cooling ceilings. These capillary tube mats have proved successful in underfloor heating. The capillary tubes normally measure 2.4 mm x 0.35 mm, and the distance between the tubes in the mats is 15 mm. With modules that are 250 mm wide, mat lengths of up to max. 3500 mm are possible. (5)

The cooled radiation ceilings can be designed as plaster ceilings or as metal panels. With plaster ceilings the capillary tube mats are installed on cement, gypsum-cardboard panels or other plaster coatings on the underside of the ceiling, and are bedded in a covering layer of plaster, limestone, cement or special acoustic plaster, with a minimum thermal conductivity of 0.3 W/m^2K.

With metal acoustic ceilings the cooled tube mats are laid or stuck directly on aluminium or steel ceiling coffers and/or panels. The ceiling panels surface on the room side should have a minimum degree of emission of 0.9.

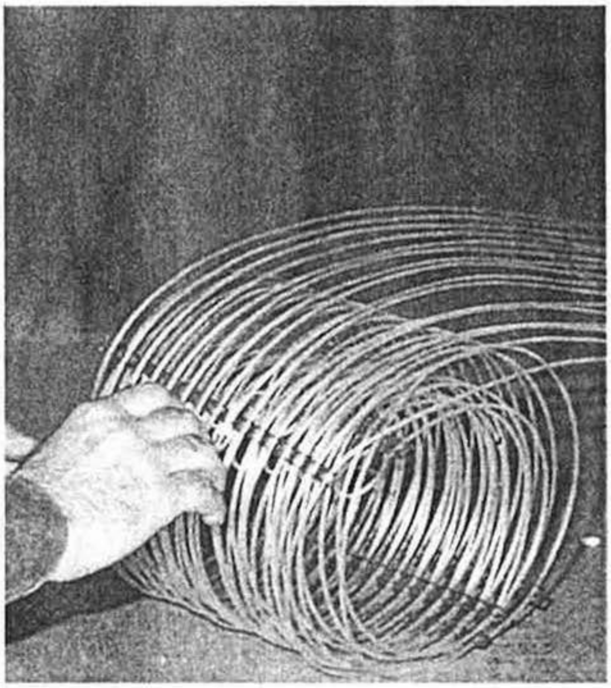


Fig: 2.3.5.1 Capillary tubes (5)

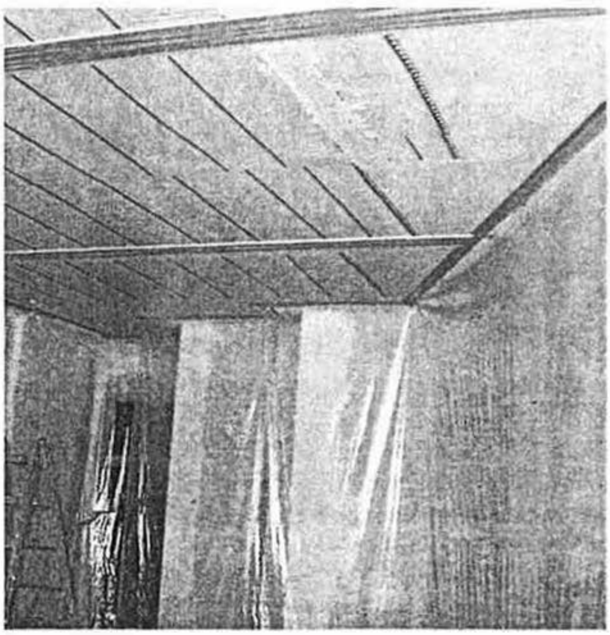


Fig. 2. 3.5.2 Capillary tubes installed in „mat system" before ceiling is plastered (5)

Another cooled ceiling system is to be classified as a convective system. Above the permeable ceiling layer on the side of the room cooling flanges are arranged,

of the water cooling system is installed. Depending on the cooling load that has to be met, more or less grid rows can be equipped in this way.

A new "All Air Principle" is the so-called fresh air cooled ceiling system. It consists of sound absorbing hollow coffers, into which the cooled outdoor air is fed. Figure 2.3.5.6 shows the fresh air ceiling from above.

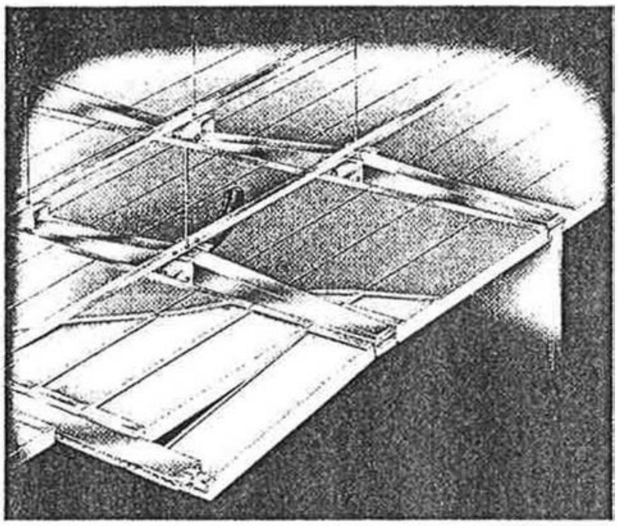
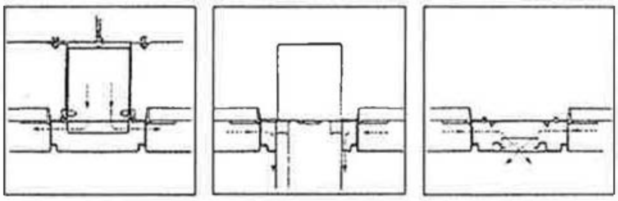


Figure 2.3.5.6 Ceiling as panel module ceiling with partition connection (25)

The coffers are suspended via a hinged mechanism in panel module profile. The following illustration shows the various forms of the panel module profile according to their function: supply air duct, wall connection with ceiling source outlet or ceiling air outlet as an option for large rooms.



Raster profile with supply air duct and cooled coffers | Wall connection with source air terminal device | Raster profile with supply air terminal device

Fig.: 2.3.5.7 Panel module profile (26)

The panel measures 110 cm, the coffer is 40 cm wide. Towards the ceiling cavity the coffers have a mineral fibre insulation that is 30 mm thick. A constant air distribution in the ceiling and an equal surface temperature is achieved via an elaborate system of staggered perforated areas in the panel module profiles and in the sides of the metal coffers. This guarantees that there is a controlled flow of cooled air into the coffers where it is turbulated, and then either reaches the source outlet or enters the next coffer.

All cooling coffers can be removed easily and without the necessity to switch off the air conditioning system.

In principle all lighting systems can be used. Also other ceiling installations such as loudspeakers, sprinkler systems etc. can be integrated without any difficulties.

2.4 Substitute Volume Flow System (SVF System)

2.4.1 System Description

Under the cost pressure which building plans have been subjected to recently, it is becoming more and more difficult to justify the installation of the classic air conditioning systems. However a good eye is needed in the co-ordination of the structural, physical constructional, heating and aerodynamic concepts, in order to be able to recommend acceptable and favourably priced solutions for the user. These types of concepts are a mixture between calculable risks and acceptable compromises regarding the utilisation of a building.

The desire for better air quality in workplaces is not necessarily bound to air conditioning. In the difficult field of solution finding, the limitations of window ventilation with heating must be determined, and simple reliable ventilation systems must be conceived.

Firstly, one tries to cope with window ventilation, however even with low machine loads unbearably high air temperatures can quickly occur. If this room temperature cannot be accepted, then a small, purified flow of outside air must be mechanically fed into the rooms. Instead of window ventilation the substitute volume flow system, as a favourably priced VAC system, is recommended.

Plant specific data of the SVF system.
System characteristics

- One channel plant, constant volume flow, low speed channels
- No waste air system, excess pressure system
- Source ventilation principle, so that without individual room regulation a load dependent air temperature adjustment can result in the waiting rooms
- No heat recovery plant, as it is not economical for a low volume flow
- Window ventilation also possible during operation of the VAC plant.

Air purification

- Two-step filtering
- Air reheating
- Air cooling (peak cooling) always without dehumidification
- Alternative - humidification

Design

Standard 4.5 $m^3/h\text{-}m^2$ corresponding to LW 1.5 h^{-1}
Maximum 7.5 $m^3/h\text{-}m^2$ corresponding to LW 2.5 h^{-1}
In principle only outside air, which is used for the window ventilation, should be purified.

In the following figure 2.4.1.1 the SVF system is schematically portrayed.

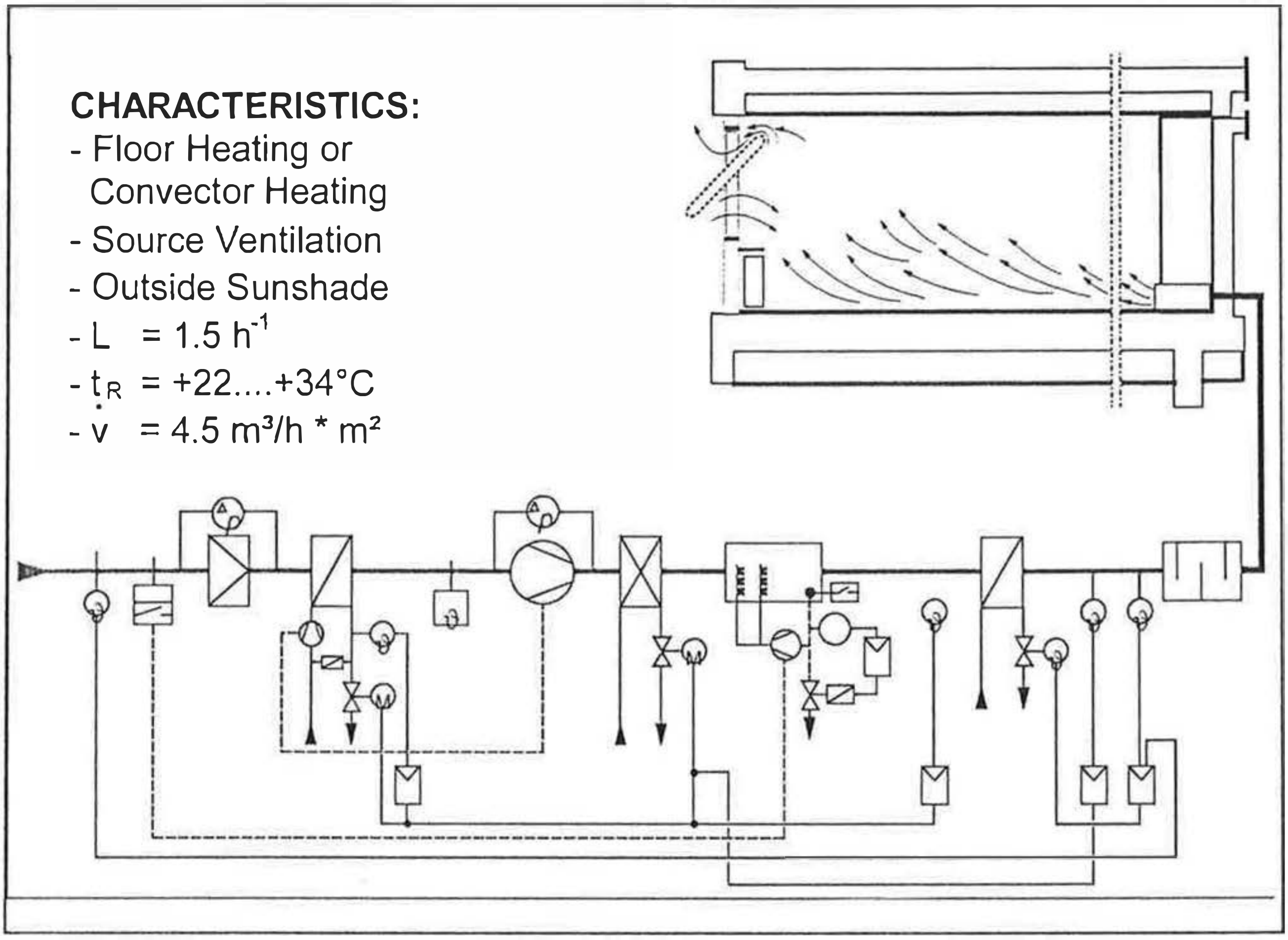


Fig. 2.4.1.1 Scheme sketch of substitute volume flow (17)

2.4.2 Fields of Application

The SVF system is suitable for all office and administration buildings, in which, due to their situative or climatic situation, a window ventilation is either not possible or not sufficient to provide a comfortable room climate.

It is an energy saving and low cost system, which is expressed in its low investment and operation costs.

With the design to outside air, as is otherwise foreseen by the window ventilation, the system offers to a large extent flexibility as a supplement or alternative to window ventilation. If operation is limited to days or annual periods as it is required, this minimalizes the operating costs even further.

2.4.3 Characteristic System Elements

With the SVF system no special system elements are required. Only simple and reliable construction components are used to secure a high operational safety and easy maintenance, which also means that the operational costs can be kept low. Source ventilation is dealt with in detail in another part of this brochure.

2.5 Dessicative and Evaporative Cooling, (DEC)

2.5.1 Description of System

Beside the advanced damage to the earth's atmosphere caused by the coolant CFC, the CO_2 emissions caused by the generation of heat and electricity are responsible for the change in the earth's climate.

As refrigeration also contributes not negligibly to this environmental pollution, with an upward tendency, procedures are of interest in which coldness is gained by a CO_2-low generated motive energy and through CFC-free operation resources. Last but not least this development is also supported by the world-wide aim to abandon the use of CFC's.

In the conventional air conditioning the moisture extraction of the outdoor air, in particular in summer results from keeping below the dew point in the coolers which are supplied by the refrigeration plant. The air temperature achieved is as a rule considerably lower than is required for the room supply air. Through the necessity of reheating, enforced energy destruction is carried out. A way out of this dilemma lies in splitting the moisture extraction and the cooling into two different procedures.

Although sorptive air drying has been well known for a long time, it has only started to be used recently in air conditioning. In connection with air cooling through adiabatic evaporation an alternative in the air cooling compared to the traditional procedures is given.

The method of functioning of this air conditioning system can be elaborated in detail on the basis of the following diagram.

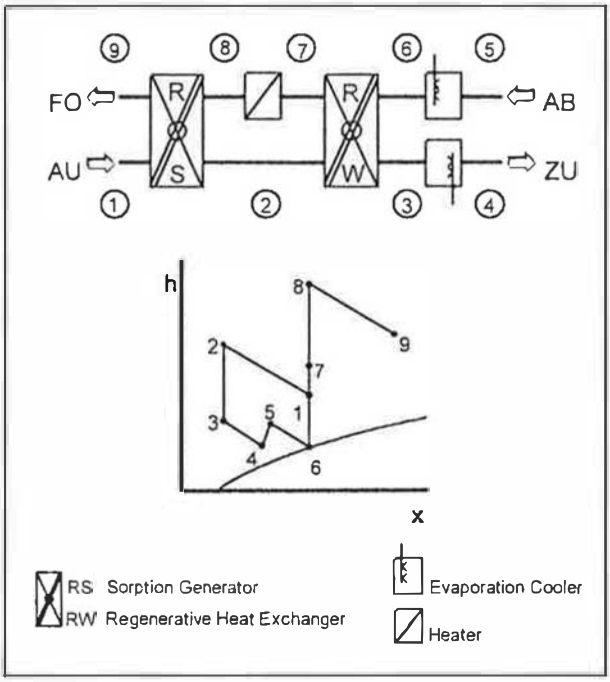


Fig. 2.5.1.1 Thermodynamic basic circuit of the DEC procedure and course in h,x diagram. (18)

The outdoor air at phase ① is dehydrated in a sorption generator and heats up as a result of condensation heat that is released in phase ②. Through the following regenerative heat exchange with exhaust air. cooling to phase ③ results. According to the requirements the supply air is brought further to the desired phase ④ by adiabatic evaporation. In the room requiring air conditioning the air goes through a change in phase from ④ to ⑤. The exhaust air from the room is moistened practically to saturation point ⑥ and thereby cooled for the supply air. before the regenerative heat exchanger for coldness recovery. The heat recovery from ⑥ to ⑦. as well as further heating to phase ⑧ serves the regeneration of the sorption heat exchanger. which the extract air leaves at phase ⑨.

For winter operation the air can be moistened and heated up with the applied system components.

This procedure enables in general a considerably higher energy efficiency and even the prescribed basic circuit leads to an approx. 30% higher degree of utilisation of the primary energy in comparison to conventional air conditioning coolant generation. (18)

A further improvement energy-wise is achieved by the incorporation of an air-air-heat-pump. Instead of the evaporative cooler on the side of the supply air the direct evaporator is installed. and the condenser is installed in the exhaust air after the regenerative heat exchanger.

The technical and procedural advantages compared to the basic circuit lie in the fact that the supply air is sensitively cooled from ② to ④ and therefore the predrying and remoistening can be avoided. The dry recooling of the supply air in the evaporator leads to a decrease in the temperature level of the phases ② and ⑧, which results in a higher energetic efficiency. The condenser of the heat pump provides a large part or all of the heating energy required for regeneration of the sorption generator. This double energy use of the heat pump leads to a considerably higher primary energy saving compared to the basic circuit.

2.5.2 Fields of Application

DEC moisture extraction systems have been used world-wide successfully for about 10 years in process technical plants with high hygiene requirements and moisture extraction efficiency. also in the food and pharmaceutical industry.

In the USA these systems are used in the same period of time, also in air conditioning systems, in particular in department stores. Also in Germany some air conditioning systems have been equipped with DEC technology in the last few years.

In principle all air conditioning plants which work as pure outdoor air systems are suitable for the installation of DEC systems.

In air conditioning systems in which moisture extraction is not desired, the adiabatic evaporation of the extract air with following regenerative coolness exchange at the outdoor air can also be applied alone.

2.5.3 Characteristic System Components

An excellent component of the DEC system is the sorption generator. All other components are well-known and reliable elements in conventional air conditioning systems.

The most common absorption material in air conditioning technology is siliceous gel. also called silica gel. This chemically pure quartz (SiO_2) is prepared by certain methods in such a way that its surface is considerably enlarged. The water steam of the previously filtered damp outside air sticks to the surface via absorption or adsorption and is condensed. If the absorption material of the generator is saturated then it must be regenerated. This is done with the heated air or overheated steam. After it has cooled, the material is once again absorptive. For this reason the absorption material can only be admitted periodically.

In air conditioning technology, rotating generators have proved successful which are similarly constructed like rotation-regenerative-heat exchangers, and can equally be used in the outdoor air flow and the extract air flow. In the rotating wheel thin foils of a ceramic-silica gel combination are arranged in a honeycomb structure. The regeneration is effected by reheated extract air. The thermal energy for the further heating to phase ⑧ can result among other things via solar collectors or other regenerative energy sources.

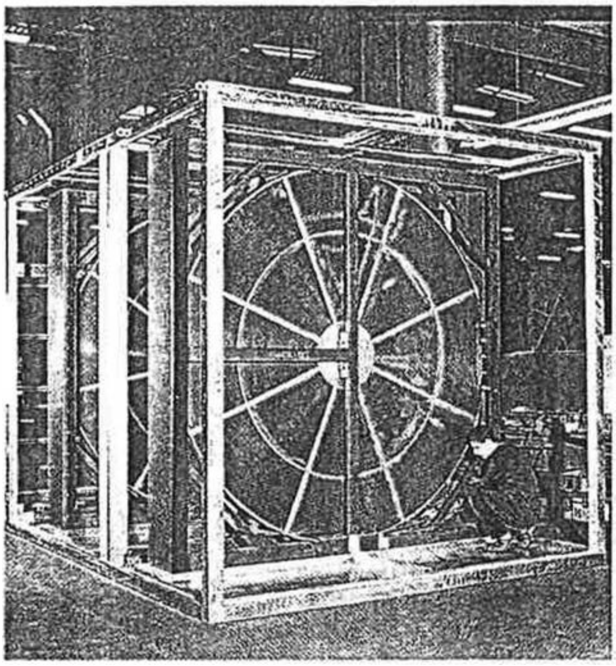


Fig. 2.5.3.1 DCS Assembly (19)

In winter the rotor can simply stand still. An over-saturation does not take place which means that reactivation is not necessary when it is put back into operation. The rotation bodies are easy to maintain, any dirt or contamination can easily be cleaned with compressed air or a stream of water.

3 COMFORT CRITERIA OF INDIVIDUAL SYSTEMS

3.1 Definition of Thermal Comfort

Due to new findings on the technical health requirements made on air conditioning systems, above all in the field of the limitation of air movement. the applicable assessment criteria were reviewed and are now available in the new edition DIN 1946 part 2. from Jan. 1994. They serve a basis for the assessment of the air conditioning systems described here.

Thermal comfort is achieved when a person feels that the air temperature, the air humidity, air movement and radiation exchange with the environment, is optimal.

Temperature

The local temperature resulting from the combination of air temperature and radiation temperature is referred to as operative room temperature or sensed temperature and defined by the following approximation equation:

$$t_o = 0.5\,(t_a + t_r) \qquad (21)$$

whereby

t_o = local operative room temperature °C
t_a = local air temperature °C
t_r = local irradiation temperature °C

$$t_r = \sum_{K=1}^{n} \varphi_K \cdot t_K$$

φ_K = irradiation figure between the space point and the area K

t_K = temperature of the area K in °C

The range of recommended operative room temperatures for office work and for light to medium clothing, depending on the outdoor air temperature, is represented in the following figure 3.1.1 by crosses.

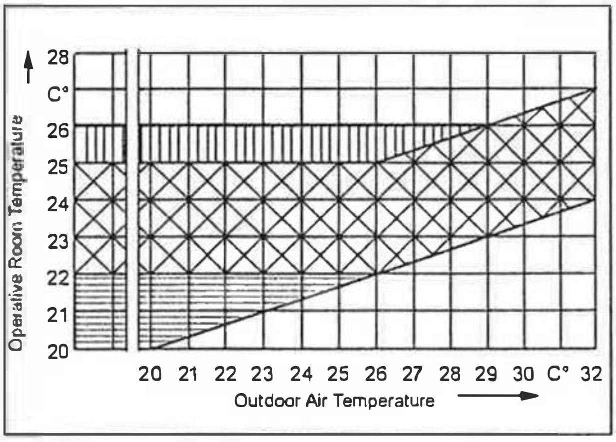


Fig. 3.1.1 Range of operative room temperatures

In the Technical health requirements of DIN 1946 part 2 an increase in the operative room temperature is permissible in the summer period (over 29°C) and when short term high thermals loads occur (vertical shaded area)

In certain air conditioning systems (e.g. source ventilation) temperatures in the horizontal shaded area between 20° C and 22° C are permissible.

Concerning the air temperature not only its level but also the vertical temperature gradient in the waiting and working areas is of importance for the feeling of well-being. This may not exceed 2K per metre of room height.

Therefore the room temperature at 0.1 m height above the floor should not exceed 21° C.

Humidity

The upper limit of comfort lies at a humidity of 11.5g water per kg dry air and 65% relative humidity. The lower limit can be set at 30% relative humidity, to a large extent independent of the air temperature.

Air Movement

The personal thermal comfort is determined in particular by the air movement in the waiting and working areas. Figure 3.1.2 shows the boundary values of the air speed in the comfort range, depending on the air temperature and the degree of turbulence. (21)

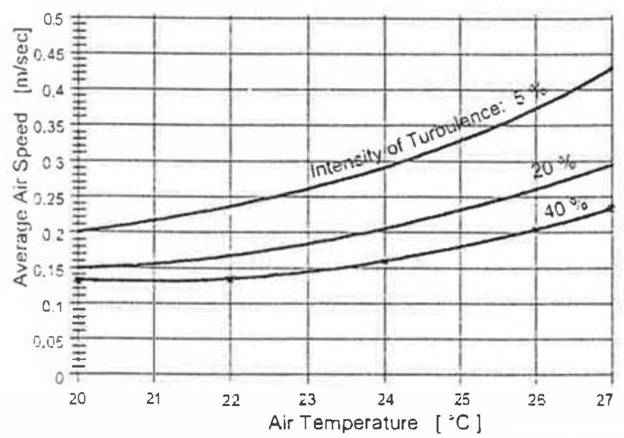


Fig. 3.1.2 Mean air speed dependant on air temperature and degree of turbulence

The degree of turbulence is the standard deviation (maximum value) related to the average speed

$$T = \frac{s_v}{\bar{v}} \cdot 100$$

whereby

T = degree of turbulence in %
s_v = standard deviation of the momentary value of air speed
$\bar{v}$ = mean air speed in m/s

$$s_v = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(v_i - \bar{v})^2}$$

$$\bar{v} = \frac{1}{n}\sum_{i=1}^{n} v_i$$

n = number of measuring points
v_i = momentary value of air speed in m/s

Room Air Quality

The quality of the room air is determined not only by the quality of the supply air but also by impurities and contamination caused by utilisation and by the room itself.

In connection with the air conditioning systems described here, priority should be placed on their ventilation efficiency.

The air flow in the room should be conducted in such a way that the exchange of the room air and supply air, as well as the removal of impurities or contamination and of odours, can be effected as efficiently as possible. The ventilation effectiveness serves as an assessment criteria, and is defined as follows:

$$\varepsilon_V = \frac{1}{\mu_{RA}} = \frac{C_{AB} - C_{ZU}}{C_{AZ} - C_{ZU}}$$

whereby

μ_{RA} = contamination degree = relationship between the load applicable in a certain room area and the room load supplied
C_{AB} = pollutant concentration in the waste air channel
C_{ZU} = pollutant concentration in the supply air
C_{AZ} = pollutant concentration in the waiting and working areas

An air ventilation system removes impurities and contamination more efficiently as the ventilation effectiveness increases. An air conditioning system should therefore aim at $\varepsilon_V > 1$. The ideal mixed air flow is $\varepsilon_V = 1$.

3.2 VAV Systems

A major criteria for the thermal comfort of an air conditioning system is its ability to keep the room temperature within the desired comfort range at varying load.

As the VAV system has a high regulation ability the cooling effect can be regulated individually in each room. During a large part of the year this means that in practise the room temperature can be kept at the desired level without additionally supplying heat.

However careful choice of the air outlets is vital in order to achieve a satisfactory comfort in the room air movement. Highly suitable are air outlets with a high induction efficiency . The automatic regulation of the supply air outlets in dependence on the volume flow leads to a more favourable situation. This is described in detail in section 2.1.3.

3.3 Source Ventilation

When complaints are made about the room air condition in air conditioned rooms, most commonly draught problems are mentioned. The main reason is that the medium air speed is too high, as can occur with mix flow which as a rule has a high degree of turbulence.

With the source ventilation the supply air feed is very low in turbulence and also has very little under-temperature. Due to self-convection at the heat sources a further air movement takes place which, however, is slight.

Subjective measurements with test persons (4) have shown that an optimal assessment of this air conditioning system results when the air temperature in the floor area does not fall below 22°C and the temperature increase to the head area does not amount to more than 2K. If the laminate air outlet speed is under 0.2 m/s forced convection is not to be expected.

When heat and impurity sources are coupled. as is the case with people, then with source ventilation the air quality is not only improved by the vertical concentration distribution in waiting and working areas but also through the uplift flow on the person in comparison to mix flow. New investigations in rooms with moving people (dummies) have shown that the source ventilation compared to the turbulent mix flow, brings a 10-20% higher ventilation effectiveness. (7)

Regarding the thermal comfort and air quality the source ventilation is today regarded as the optimal air conditioning system.

3.4 Cooled Ceiling Systems

If the surface temperature of the ceiling is considerably lower that the air temperature in the room then a person can give increased heat to the ceiling by radiation. He therefore perceives his surroundings as pleasantly cool, even if the air temperature is higher. The ambient temperature is perceived as approx. 1-2 K lower.
The heat delivery through convection to the large surface area of the ceiling merely produces a minimal air movement in the room without causing draughts. However this is sufficient for the even temperature distribution in the room.

Cooled ceiling systems contribute not only on their own to an improvement in the air and room comfort, but also in connection with air ventilation systems.

3.5 Substitute Volume Flow System (SVF System)

The principle of source ventilation, which is used with this system, causes a thermal alleviation of the occupied zone due to its upward movement, and results in only slight load-dependant fluctuations in working areas. At a supply air temperature of approx. 20°C this lies between 22°C and 26°C, as seen over the whole year. These values are regarded as comfortable according to the current norms.

4 ADVANTAGES AND DISADVANTAGES OF THE INDIVIDUAL SYSTEMS

4.1 VAV Systems

Advantages

- Reduction of the energy consumption of air feed and coldness with reducing volume flow.
- Reduction of the investment costs through measurement of the central device with simultaneity factor 0.7 - 0.8.
- Possibility of the utilisation of the cooling potential of the outside air (free cooling) in interseasonal periods, as VAV systems work with pure outside air.

Disadvantages

- If the supply air quantity falls and the air flow changes draughts can occur.
- In certain cases limited air quality at load reduction, without any simultaneous reduction in the number of people present.

4.2 Source Ventilation

Advantages

- Low wind speeds in the room (freedom from draughts).
- Higher ventilation effectivity (10-20 % higher). (7)
- Better air quality in occupied zones.

Disadvantages

- Limitation of the cooling load removal (max. 40 W/m^2). (6)
- Limitation of the possibilities for regulating the room temperature.

4.3 Cooled Ceilings

Advantages

- Universal application range with or without VAC systems.
- Little space required.
- Operation costs savings of 20-40% compared to VAC systems. (13)
- High thermal comfort.
- Even temperature distribution in room.
- Low room air speeds.
- Better acceptance with the user than other air conditioning systems.
- Lower noise level.

Disadvantages

- If the surface temperature chosen is too low, there is the danger that the heat extraction is too high.
- In connection with window ventilation there is the danger of condensation when the surface temperature is too low.
- Danger of water damage to office equipment.
- Architectural design is limited as only the ceiling can be used.

4.4 Substitute Volume Flow System

Advantages

- Continual supply with outside air.
- Comfortable room climate over approx. 90% of the useful working life.
- Little space required for installations (e.g. as there is no waste air system or energy recovery).
- Low investment costs.
- Low annual energy requirement values and energy costs.
- Per person up to 250W machine load can be calculated.

Disadvantages

- Limited comfort at peak load times.

4.5 DEC Plants

Advantages

- Environmentally friendly procedure, which serves the reduction of emissions.
- High degree of utilisation of primary energy.
- Reduction of operation costs.

Disadvantages

- Increase in the ventilator energy through increased air resistance.

5 SPECIFIC COSTS OF THE INDIVIDUAL SYSTEMS

It is difficult to give details of effective specific investment costs for the individual plant systems, as there are too many factors which influence the price. Beside the type of building utilisation and the corresponding efficiency and power of the air conditioning system, the costs are also made up of the standard of the design and equipment and the desired level of comfort.

In specialised literature (1) the following specific manufacturing costs in DM per m³/h supply air volume flow including heating and cooling plant are quoted for example for Germany for 1990 for VAC systems for outer zones:

Induction plant	35 ..... 45 DM per m³/h
Dual duct plant	30 ..... 35 DM per m³/h
Single duct plant with variable volume flow (VAV)	25 ..... 35 DM per m3/h

Moreover the price level of the constructor of the plant also plays an important role, in particular also in comparison of the individual member states of the European Community in the determination of manufacturing costs.

Therefore it is only possible to conduct a relative comparison of the systems described here with the conventional systems.

5.1 VAV Systems

Investment Costs

In comparison with constant-volume-flow systems VAV systems can be smaller in design, as a comparably lower simultaneousness can be fixed. Beside a simultaneity factor for inner loads, an important influence was also the building's alignment to the cardinal points. This has a positive effect on the manufacturing costs. However in order to exhaust all possibilities for the plant optimisation a high level of engineer knowledge is necessary for the planning and execution. The investment costs can be lowered considerably by careful design of the individual plant components, in particular also by the choice of suitable air outlets that are not so extravagant or costly.

In comparison to conventional air conditioning systems with the same comfort of individual room regulation, as e.g. a dual duct outlet, the investment costs for the VAC plants are about 15-20% lower. Furthermore there are the cost savings for the lower amount of space required for the central system. (1)

Operation Costs

As a rule the total air power can be reduced by up to 2/3 of the power of a comparable constant-air-plant system in the plant design. The annual energy requirement in contrast to this is considerably lower in operation, as the correspondingly required volume flow of the plant can be reduced when the load sinks compared to the peak requirement

2 Source Ventilation

estment Costs

th this ventilation principle the heat load is first en up by the supply air at the place of creation. This ans that the temperature of the exhaust air is higher n the mean room temperature in the occupied nes.

is advantage can be taken into consideration in the sign of the plant through reduction factors in the oling load calculation. The consequence is a reducn of the air volume flow required for the removal of heat load. On the other hand this results in lower nt costs.

eration Costs

rough a lower air volume flow the operation costs tomatically fall as well. Furthermore the supply air nperatures of 20-22°C, which are high in comparison conventional systems, require less energy to cool air. 4)

3 Cooled Ceiling Systems

vestment Costs

egarding the investment costs, the water cooledceig system in connection with mechanic ventilation, is t necessarily cheaper than air-only-systems. The mparison is however all the more favourable for the ater cooled ceiling system, the higher the specific oling load is of the room. It can be roughly said that r specific cooling loads with more than 45-55 W/m² e investment costs for water cooled ceiling systems is wer than for air-only-systems. At lower loads the tio is vice-versa. (22) (23)
ir cooled ceiling systems are comparatively cheaper an water cooled systems. At specific cooling loads of - 60 W/m² the investment costs are approx. 3% lower an for water cooled ceilings. (27)

peration Costs

ue to the low energy consumption of pumps and venators, as well as the advantages of the coldness genetion through higher minimal water temperatures the eration costs of water cooled ceiling systems inclung ventilation lie about 20-50% lower compared to nventional air-only-systems. (13)

e operation costs of air cooled ceiling systems lie in e lower cooling load at around 40 W/m², only marnally higher than water cooled system. In loads over W/m² this becomes more unfavourable with air contioning systems with constant volume flow, as, in dition to the hygienically necessary air requirement, ger quantities of air must be heated, cooled and transported. This disadvantage can be extensively compensated through the use of VAV systems, as in particular in winter lower air exchanges become necessary. (27)

5.4 Substitute Volume Flow System

Investment Costs

As there is no exhaust air system and heat recovery the plant costs are considerably lower. In comparison to a VAV system they are about 30% lower. (17)

In comparison to conventional air conditioning systems there are also the advantages of the source ventilation systems which also leads to further cost reductions.

Operation Costs

The annual energy costs are about 30% lower compared to a VAV system. (17)

6 CASE STUDIES

6.1 Case Study 1

Variable Air Volume Systems in Broadgate City Complex in London (15)

Fig. 6.1.1 Total view of the Broadgate City Complex

Broadgate is a new, modern city complex in London, which has a unique character from the point of view of its dimensions alone. The tenants are in particular the top level of the finance and consultancy organisations, who thereby will also be suitable represented in London in the future.

Within this complex the technical construction for the object Broadgate Phase 3, the new financial centre of the Union Bank of Switzerland (UBS) was realised.

The scope of the foreign exchange and securities departments meant that these construction plans portrayed a milestone in the field of technical building installations.

Fig. 6.1.2 UBS - Broadgate

The size of the construction is impressive. UBS - Broadgate has a floor space of approx. 36.000 m^2 distributed over 2 basement floors, a ground floor and up to 8 upper floors used for the following purposes:

Basement floors
Technology centres, underground carpark, main hall, sales rooms

Ground floor
Entrance lobby, building administration, training areas

First floor
Technical floor with offices and equipment

Second and third floor
The heart of UBS - Broadgate is the design of areas over two floors for the foreign exchange and securities trad

Fourth floor
The main reception area lies in the centre of the building, and from here the conference rooms, presentation rooms and a dining hall unfold.

Upper floors
These floors are used as general office rooms.

The planning management for construction and technical installations was primarily interested in the demand for flexibility.

The demands of the major Swiss bank were high, but also energy conscious and required new technical concepts:

- energy and maintenance low systems, fully automatic
- high quality/availability/modularity
- price - cost ratio for a long service life of the system
- a lighting installation without manual switches on the basis of IR sensors as automatic presence detection switches
- a fully integrated energy management system with electrical load / emergency power control
- maximal free cooling with strainer cycle
- the first VAV air conditioning for extremely high, controllable load fluctuations, in connection with a three dimensional large panel ceiling as an air outlet and indirect lighting

The following installations should concentrate on the latter system components.
The areas of the foreign exchange and securities trade are relatively highly populated with 4.65 m^2 per person and 3-5 terminals of approx. 500 W machine heat and therefore have high cooling loads.

Machines, people and lighting give off a specific cooling load of up to 150 W/m^2 simultaneous to relatively high demands on the outer air rate. Outer cooling loads through solar irradiation have in comparison little influence.

The large areas of 2.900 m^2 and 625 workplaces per floor require an efficient removal of the cooling load. With the relatively high temperature difference of 12 K in the occupied zones a volume flow of 38 m^3/h m^2 is necessary. Taking any future extensions into consideration, the system was dimensioned to a volume flow of 50 m^3/h m^2.

The high efficiency in the removal of the cooling load is achieved by the following features of the mirror section ceiling;

- the grids are installed at a distance of 200 mm under the flat acoustic ceiling, designed as hollow sections with air outlets. The escape surface lies at a height of 2.90 m.
- the supply air is distributed extremely finely through the aerodynamic vent width of 2.5 mm. The mixing ratio lies at 1:25 to 1:30
- this good mix allows a cooling load removal with a temperature difference of 14K.
- the exhaust air with an excess temperature of 2-3 K is sucked out through the lighting approx. 550 mm above the air outlets.
- the high induction ration of the mirror section grid allows operation with the energy saving VAV system

Fig. 6.1.3 Work area of the foreign exchange and security dealers with mirror section grid ceiling

The high efficiency of the cooling load removal is furthermore achieved through the particular features of the draught-free room air flow.

Under the air outlets a quick temperature exchange and velocity reduction is maintained. Even 0.8 - 1.0 m after the air outlet no under-temperatures and velocity peaks are to be noted.

- As the air circuit directly fans out vertically into the occupied zone and as the used air is removed above the air outlets, the air distribution is free from diagonal flows.
- The formation of large air rolls or a directed flow in occupied zones is excluded.
- The air velocity level in the occupied zones amounts to only 0.1 to 0.12 m/s. The room air flow is homogenous, diffused and not directed and is mainly determined by the natural thermal convection

Cooling system

The cooling circuit is designed so that it works in free cooling as often as possible. Thereby it is supported by a system that is known as "strainer cycle". The cooling tower water is cleaned up to 120 microns through a self-cleaning multi-element filter, so that it can be fed into the cooling water circuit directly.

6.2 Case Study 2

VAV Air Conditioning and Openable Windows in the Administration Building of the Colonia Versicherungs AG in Cologne, Germany (29)

In many parts of Europe an air conditioning system in office buildings is not necessary due to the outdoor climate. It is also known that people like to open windows in buildings if the conditions of the outside air and the noise level permit it.

Fig. 6.2.1 Total view of the building complex

The building complex of the Colonia Versicherung was established on the outskirts of the city of Cologne practically in the "green meadows", that is to say, in a quiet area.

The building consists of five office buildings of a similar construction, which are grouped around a central building, and which only differ in the number of floors

The office area of the building complex is approx. 30,000 m² and is equipped for 2,000 workplaces.

Before the air conditioning system was decided upon, the building owners discussed the various aspects of the air conditioning with their employees and the planners. Thereby the wish for "supportive aeration and ventilation" resulted, in principle an air conditioning system which functions as required. The most important new conditions were the wish for windows that could be opened and for an air conditioning system that could be turned off by the people using the room (partial air conditioning system). Experiments were carried out which determined the limits of the outdoor air conditions at which the windows can be opened. The air conditioning system should start to function when the outdoor temperature is higher that 24°C, lower than 15°C or when the wind velocity over the building is higher than 2.5 m/s.

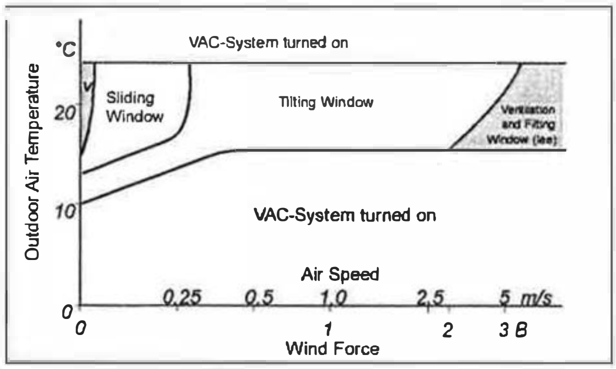


Fig. 6.2.2 Types of operation for window ventilation and supportive aeration and ventilation

For very low outdoor air velocities the temperature limit could possibly be reduced to 10°C (see Fig. 6.2.2)

These limits were modified somewhat later. Today the system runs at an outdoor temperatures under 13°C and over 22°C.

The office area which had originally been planned as a larger, open-plan area, therefore had to be divided and be separated regarding the inflow technique by walls, so that windows could be opened on opposite facades. So-called group rooms were thereby created.

The term "partial air conditioning system" refers here to a fully functioning HVAC system with all necessary process levels, which can be turned off in the individual areas.

The limits for the supportive ventilation reached in a certain occupied zone, are determined by a central air engineering and are transferred to each ventilation centre. From there, the limits are forwarded to the people using the rooms by means of a simple optical display apparatus.

The air conditioning system of the individual office buildings are designed as VAV systems and conceived in such a way that, from a central point in the group rooms, it is possible to switch it off or on individually in the room areas via throttle valves in the supply air and exhaust air ducts.

The supply air temperature assigned to the group rooms is taken in dependence on the exhaust air temperature (= mean value of the temperature of the group rooms). A group room is divided into several control zones, corresponding to the cardinal point of the facade sections. In each control zone static heating is technically control coupled with the volume flow regulator of the ventilation, whereby the target temperature for the control zone is controlled via a thermostat in the room.

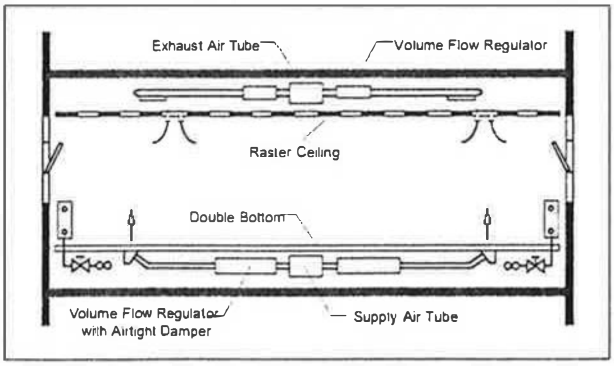


Fig. 6.2.3 Cross section of a room

In the meantime experience has been made over several years of operation. Of particular interest is the answer to the question of for how long the windows can be opened. In this connection the operation times measured for the year 1991 were used and portrayed in figure 6.2.4. In comparison the figures calculated according to DIN 4701 and for the test reference year (TRY) without taking wind velocity into consideration, were used. A very good concurrence can be seen.

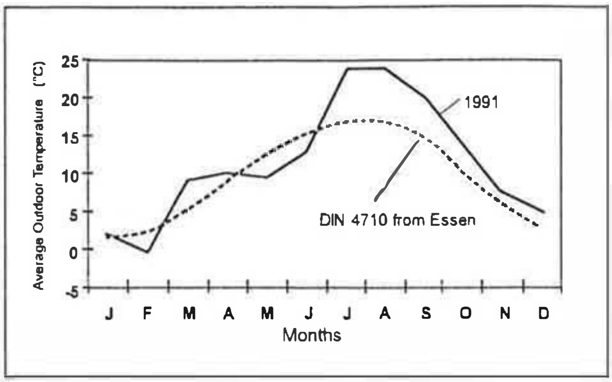


Fig. 6.2.4 Mean value of the outdoor air temperatures 1991 and according to DIN 4701 for Essen

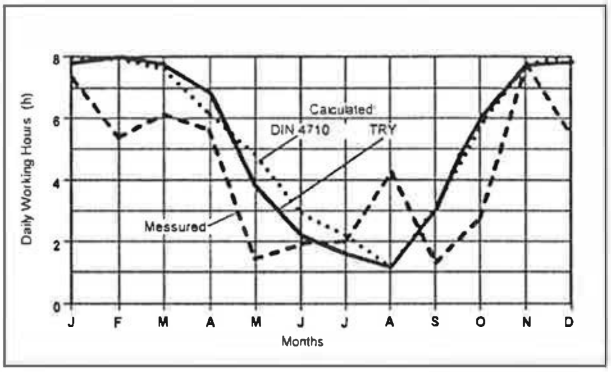


Fig. 6.2.5 Operation periods of the VAC system

The longest operating period occurred in November with 7.6 hours per day. This is still lower than the normal operation time, which normally amounts to 10 hours in offices. The lowest operation times lie in the months May, June, July and September, on average with less than 2 hours per day.
The main proportion of energy saving through the considerably reduced operation times of the VAC systems as a result of windows being opened, lies in the electricity consumption required for the air feed. The saving of thermal energy is lower as the periods of standstill mainly correspond with the periods of reduced demand.

6.3 Case Study 3

System Replacement with Source Air-Induction Units in an Administration Building in Cologne/Germany (30)

Twenty to thirty years ago many administration buildings used induction units as air conditioning systems. Most of these systems now have to be reconstructed. This reconstruction can be successfully executed with newly developed source ventilation induction units. An example for such reconstruction measures is the building of the Financial Divisional Administration in Cologne.

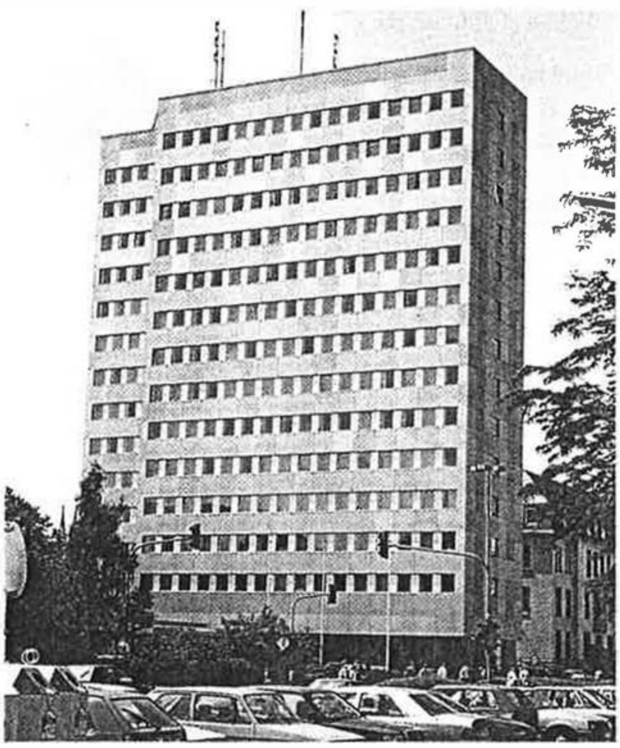


Fig. 6.3.1 View of the building

The building is a free-standing multi-storey building with 13 floors. The facade consists of concrete with metal curtain facades. This kind of building contains few energy storing substances.

The room measurements can be seen in fig. 6.3.2. Each window element has a module width of 1.90 m.

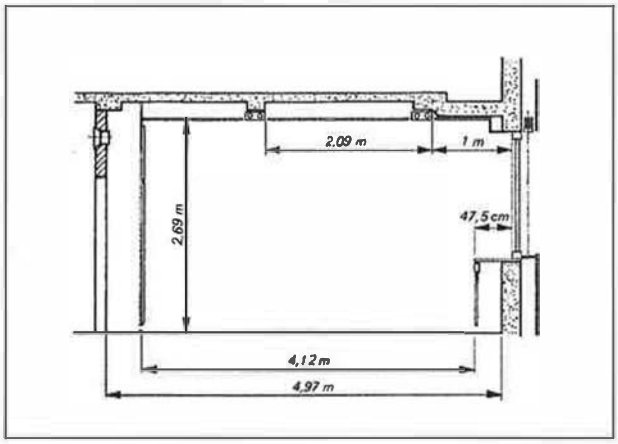


Fig. 6.3.2 Cross section of an office room in the Financial

The cooling load of the rooms is comparably low. In the most unfavourable cases cool loads of 430 W per window module of approx. 50 W/m^2 result.

A considerable disadvantage of the old systems was that they were designed as so-called Change-Over-Systems with only 2 water supply pipes. For the reconstruction of the system there are four possible alternatives, which result from the combination source ventilation or mixed air flow and induction or VAV systems. Therefore both induction systems were compared in the environmental laboratory in a space flow test. Due to the output variation necessary a system with 4 supply pipes was chosen.

The primary volume flow per induction unit can be reduced in periods of low cooling load from 60 to 45 m^3/h. This is possible because the source ventilation is not dependant on a high exit impulse as is the tangential ventilation.

The exhaust air is sucked out at the ceiling as is important for the source ventilation.

An air velocity of 0.1 m/s was measured at 1.2m distance from the air outlet.

The temperature increase in the occupied zone amounts to 2 K/m.

For the air conditioning in winter the suction inlet for the secondary air had to be lengthened over the whole width of the window parapet in order to prevent the cold air that flows downwards along the inner sides of the window from entering into the room.
Regarding the heating one should differ between two cases: heating during the office times, i.e. with primary air operation, as well as heating outside office times, where the appliance operates as a normal convector.

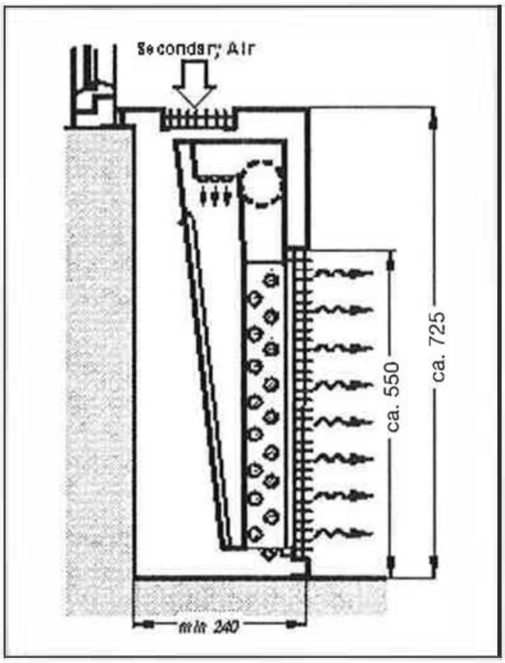


Fig. 6.3.3 Cross section of the source ventilation induction (10)

The air duct system for supply air and exhaust air of the existing system could be kept after corresponding cleaning. An additional distribution system for the hot water had to be installed upstream. The central air conditioning system in the basement was renewed. It is a pure outdoor air system with heat recovery.

The primary air volume flow amounts to 32,500 m^3/h, a total of 542 devices were installed. The new system conception met with great approval among the occupiers of the office. There have been no complaints about draughts and despite a reduction in the quantity of outdoor air, the air quality is felt to be better in the rooms in comparison with the previous situation.

6.4 Case Study 4

Cooled Ceiling System Combined with Source Ventilation

Training and Social Building of the Gothaer Insurance Company in Göttingen/Germany (5)

Fig. 6.4.1 View of the building

The building has 3 main areas of function:

ground floor:	company restaurant/cafeteria
1 and 2 floor:	seminar and group rooms
3 - 5 floor:	office rooms

The aim of the owners was the construction of office rooms which are up to the latest technological developments in the field of workplace design.

A good room climate should make a considerable contribution to a good working climate. An air conditioning system was chosen which does not need high air exchange figures, which were given as a reason for complaint about conventional air conditioning systems.

Plastic capillary tube mats were chosen as a cooled ceiling system, and were fixed on a hanging plaster cardboard ceiling with a metal sub-construction by so-called omega bands, and covered with acoustic plaster.

The ceiling cooling systems is fed by an artificial lake, which lies in front of the terrace of the restaurant and cafeteria.

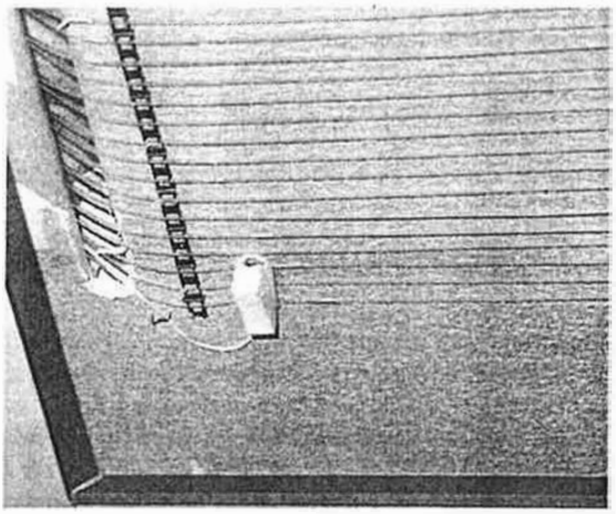


Fig. 6.4.2 Plastic capillary tube mate

Technical data on the cooled ceiling

Total ceiling cooling area:	1020 m²
Specific efficiency of the cooled ceiling	
Cooling water temperature:	64 W/m²
	t_{WV} = 15°C
Room air temperature:	t_{WR} = 18°C
	t_R = 25°C

Air Conditioning System

The supply of room air to the building results through source ventilation systems.
Company restaurant and cafeteria

- V_{zul} = 19,000 m³/h - volume flow regulated source ventilation via wall outlets
- Seminar and group rooms
  V_{zul} = 16,300 m³/h
  Source ventilation via perforated double floor covered with carpet.
- Office rooms
  Source ventilation with air outlets in cupboard bases

6.5 Case Study 5

Cooled Ceiling System in Connection with a Variable Air Volume Flow System in the Annexe of the Building Society Schwäbisch Hall AG, Germany (15)

Fig. 6.5.1 Partial view

The architecture of the building is marked by the task of creating PC workplaces. The usable area of the office is divided into group rooms of different sizes from 19 to 48 m², which are occupied with 3-8 employees. As the location of the building is in a quiet, low-traffic residential street it was possible to install windows that could be opened.

- Despite this it is necessary to cool the rooms for the following reasons:
- relative high personnel in the rooms with approx. 6-8 m² per person

- high cooling load through many intensive EDP supported workplaces with 80 W/m²

The outer cooling load is minimised through the following measures:

- the south facade which is partially naturally shadowed by existing buildings is complemented by a horizontal continuous grate installed above the window
- particularly exposed areas are equipped with outdoor blinds
- the roof areas are fully and intensively planted
- all the windows are equipped with interior reflex blinds for PC workplaces for individual handling they have a transmission coefficient b = 0.25

The storage ability of the building is safeguarded by 30cm thick cement ceilings. In connection with the exhaust air fed freely over the ceiling cavity, a stabilisation of the peak loads can be achieved.

In order to dispose of the cooling load in an energy saving way a cooled ceiling system is installed in the operation rooms.The water cooled ceiling panels situated on both sides of the supply air slotted outlets absorb heat via convection and irradiation. The heat exchange via the high efficiency cooled ceiling panels is so intensive that the whole ceiling area is not needed as a cooled ceiling but only about 10% thereof.

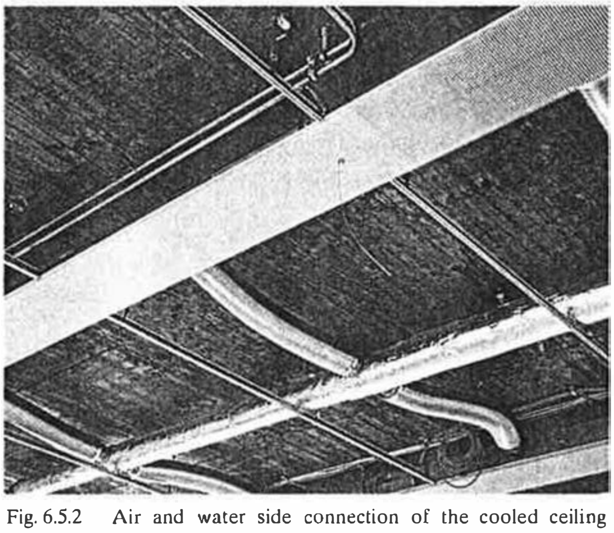


Fig. 6.5.2 Air and water side connection of the cooled ceiling panels

With this system it is possible to reduce the air volume flow drastically and to distribute the hygienically desired outdoor air rate without addition of recirculated air into the rooms, without draughts.

The air exit from the perforated underedge has an aerodynamic slot width of 2.4 mm.Thereby the system, operation and construction costs can be greatly reduced.
The integrated solution of the highly inductive air entry in connection with the cooling elements offers various important advantages:

- extremely high mixing ratio of the supply air of 1:25 to 1:30
- high temperature difference supply air/room air of 10 to 12 K
- quicker equalisation of temperature and velocity decrease already 0.8 to 1.0 m after the air outlet
- velocity level of 0.1 to 0.12 m/s in the occupied zone
- high induction ratio of the slotted outlets permits energy saving operation with variable air volume flow system (VAV system)
- homogenous, diffuse and non-directional room air flow mainly determined through natural thermal convection

In order to increase the acceptance of the air conditioning system further, the users are given various possibilities to create "their own climate" individually:

- the target room temperature can be corrected in each room by +/- 3K
- it is possible to open the windows, whereby the air conditioning is then switched off in the room concerned
- a high air quality is achieved through a general no-smoking policy in the offices. Certain closed rooms are available for short "cigarette breaks"

The exhaust air is taken up via slots through the ceiling cavity and is reused twice to ventilate the technology centre and then to ventilate the underground carpark.

The corridors and hallways are supplied with fresh air via a constant volume flow regulator independent of a temperature regulator.The air flows from the corridors and hallways into the toilets and copy area.The air supply for the operation rooms results via an air conditioning central appliance in the technology centre beside the underground carpark. In order to save energy recuperative heat recovery from the exhaust air was installed. The transmission heat losses are compensated in winter by plate radiators.

The building control system installed only safeguards the controlling and energy optimising task

Technical data:

Distribution of usable area:	
Enclosed area	15,900 m³
Main usable floorspace (gross)	1,700m²
44 group rooms (net)	1,375 m²
from 19 - 48 m²	
8 conference rooms (net)	165 m²
from 13 - 31 m²	
Additional usable area	1,180 m²
Sanitation, cleaning material,	
storage, vehicle parking space	
Traffic area	780 m²
Occupation	6-8 m²/person

Technical room air data

Total supply air quantity	21,500 m³/h
Total cooling load	102 kW
Specific cooling load	
group rooms	55-80 W/m²
Specific air quantity min/max.	5-10 m³/hm²
Corresponding air exchange LW	= 1.8-3.6 1/h
(during rinsing)	12 m³/hm²
Outdoor air rate 100%	60-80 m³/person
VAV system $V_{min} : V_{max}$	= 50%
Conference rooms:	
Specific cooling load	60-90 W/m²
Specific air quantity min/max.	7.5 - 1m³/hm²
Corresponding air exchange LW	= 2.7 - 5.5 1/h
(During rinsing)	18 m³/hm²
Outdoor air rate 100%	20-40 m³/person

The user behaviour regarding the possibility to open the windows at differing outdoor air conditions is recorded via the building control system. The following dependencies resulted:

Regardless of the outdoor temperature the windows are opened between 7:00 and 8:00 a.m., shortly before work starts, and between 12:00 a.m. and 1:00 p.m. This principle procedure, dependant on the time of day with the aforementioned maxims, shifts in dependence on the outdoor temperature. At outdoor temperatures under 0°C and over 28°C the rate at which windows are opened sinks to about 20%. In the range from 0-28°C about 20-70% of the windows are open on average. Thereby windows that face the east and south east are in particular opened more often than windows that face the west or north west.

6.6 Case Study 6

Cooled Ceiling System in the Stadtsparkasse Cologne (Communal Savings Bank) (5)

The head office of the Stadtsparkasse (savings bank) in Cologne is an excellent example of modern architecture. This bank building with seven floors was erected at the Rudolfsplatz, a central spot in the city centre in Cologne. It is architecturally eye-catching in the shape of a glass rotunda.

For design reasons the technical installations required according to the concept of the planner had to be placed into the background. It was decided to install cooled ceilings in those areas which were destined for the public and to equip them as radiation ceilings. A system was chosen which uses capillary tube mats made of polypropylene.

Fig. 6.6.1 Entrance Hall

The cooling radiation ceilings were constructed not only as metal coffer ceilings but also as plaster ceilings. The ceiling coffers consist of 0.7mm thick steel sheets and are tiltable as individual elements. The cooling tube mats were covered with mineral wool panels.

The second cooled ceiling system consists of a hanging metal sub-construction and corresponding plaster panels with mechanically applied plaster coating in which the cooling tube mats are embedded.

Fig. 6.6.2 View of the open

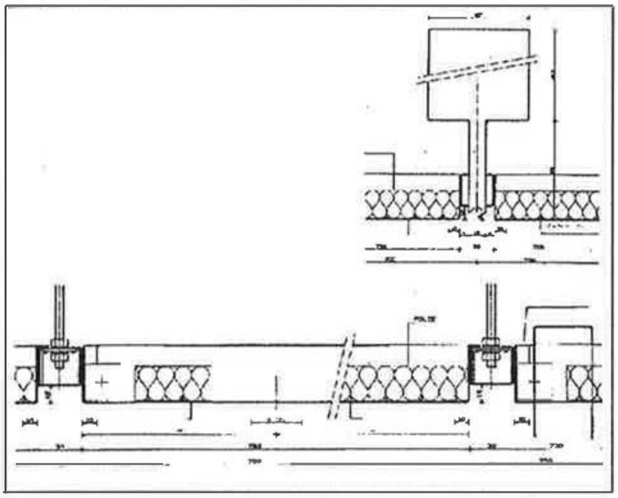


Fig. 6.6.3 Cross section of the ceiling

Technical data on the cooled ceiling

Ceiling cooling area:	approx. 3,000 m²
Max. specific cooling output:	
plaster ceilings	up to 90 W/m²
metal ceilings	up to 80 W/m²
Cooling water temperatures:	t_{WF} = 16° C
	t_{WR} = 18° C
Maximum room temperature:	t_R = 26° C

6.7 Case Study 7

Fresh Air Cooled Ceilings in an Administration Building in Mülheim/Ruhr, Germany (25)

In the design of this new administration building of the DIG Deutsche Innenbau GmbH, a high value was placed on the functionality

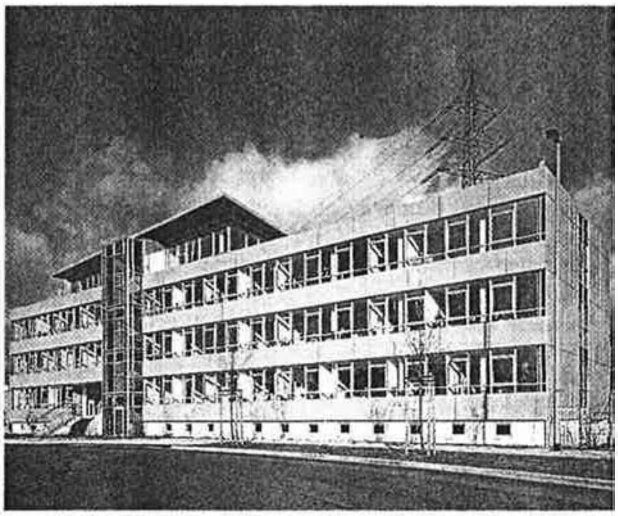


Fig. 6.7.1 View of the Building

The building is a steel and concrete skeleton construction with a central hallway and offices on the north and south sides. The window module width is 1.10 m. The hallway walls of the offices are fitted with casing. Light partitions between the individual offices safeguard a high degree of flexibility for the creation of the office size and any possible future conversion measures.

The building contains approx. 1500 m² net office space, divided over three floors, as well as a cafeteria and a conference room in the roof pavilion.

A fresh air cooled ceiling system was installed for the air conditioning of the rooms. Central elements of the cooled ceiling are the air conductive metal coffers, which are hung between the band grid profiles, which run horizontally to the facades. Cooled outdoor air is fed into these hollow coffers in source air outlets, which are set in the peripheral joints of the ceiling area to the office partition walls.

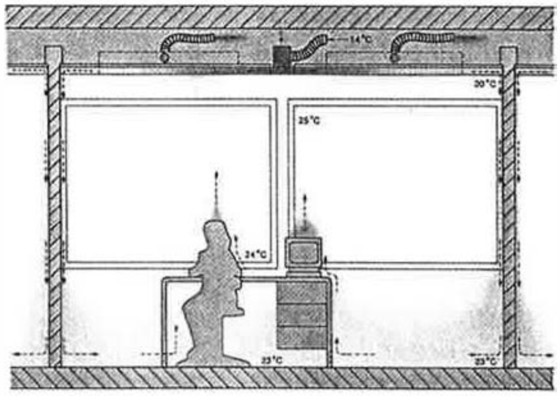


Fig. 6.7.2 Air flow in a 2-module room

The air flows along these walls in a thin layer to the ground, whereby it is heated increasingly through the heat radiation given from the room to the ceiling and walls. Once it has reached the floor a lake of fresh air is formed, the temperature of which is maximal 1K cooler than the mean room temperature.

Fig. 6.7.3 View of the ceiling in an office

Measurements carried out and the satisfaction of the room occupiers confirm that draughts do not occur even at maximal cooling output.

Per extension module width, 20 to max. 60 m³/h supply air can be chosen, so that a permanent cooling output of approx. 50 W/m² is possible. This corresponds to max. 9.6 m³/hm² or respectively 3.7 times air exchange.

Heavily loaded or larger rooms have in addition a source ventilation from the ceiling. Around 20% of the fresh air quantity flows through the underside of a perforated coffer covered with fleece directly into the rooms.

As the building is equipped with windows that can be opened, butterfly dampers are installed in the supply air and exhaust air ducts in each room module, which can be operated individually via a switch in the room. The dampers can also be adjusted to intermediate positions.

The north and south zone of the building have separate supply air ducts and supply air control circuits. At outdoor temperatures under 12°C both zones have a supply air temperature of 19°C. This is steadily lowered to 14°C as soon as the outdoor temperature exceeds 21°C. Even at the lowest supply air temperatures the ceiling temperature to the room does not fall below 19°C.

The supply air is distributed through volume regulators that are separated floor-wise, which can be controlled independently of the pressure in the supply air duct. When the individual room dampers are closed the volume flow is accordingly reduced.

The exhaust air is sucked out of the rooms through horizontal slots in the upper area of the fitted cupboards along the hallway walls.

The outdoor air is drawn off on the west side of the building and conventionally prepared and transported through a speed regulated ventilator into the duct network. For the north and south zone there are separate secondary coolers.

Between the central exhaust air device and the supply air preparation lies a heat recovery device in the form of heat exchangers with a connected water circuit. As soon as the supply air has to be cooled in summer, a spray air washer is out into operation in the exhaust air and the warm exhaust air is adiabatically cooled. Through the connected heat exchanger the heat can be thereby removed from the outdoor air, which enables the installation of a smaller refrigeration machine.

In winter the exhaust air humidifier is not put into operation. The warmer exhaust air gives its energy to the supply air system to preheat the outdoor air.

In order to cover the transmission heat losses in winter, static heating areas are to be installed in the window parapets.

Technical data

Supply air flow:	15000 m³/hour
Exhaust air flow:	15000 m³/hour
Power demand at the shaft	
Supply air ventilator:	9.3 kW
Power demand at the shaft	
Exhaust air ventilator	7 kW
Air heater output	159.9 kW
Pre-air cooler output	105.1 kW
Secondary cooler output	20 kW resp. 30 kW

6.8 Case Study 8

New Isothermal Building Concept in Fribourg/Switzerland (28)

The Swiss company Geilinger AG, Winterthur, developed the interesting concept of an isothermal building, in which thermoactive ceilings combined with source air systems replace conventional heating and air conditioning systems.

This concept was realised in the Sarinaport office complex in Fribourg, Switzerland, where a total of 9400 m² office area is air conditioned. The idea behind this concept is to eliminate the influence of the outdoor climate on the room climate as far as possible. This is achieved by a dense, very well heat-insulated building shell which, in comparison to the regulations regarding insulation against heat loss that are applicable in Germany, is supposed to have data results that are about 100% better. An important part of this low-energy building are the so-called HIT windows (high insulation technology). These are window elements made of two panes of glass and in addition two taut PET foils with an insulation covering against heat loss in the cavity between the glass panes. With a k-value of 0.6 W/m² K its thermal insulation properties are more than twice the properties of the normal thermal insulation glazing that is common today.

Secondly the building substance is used particularly effectively as an energy buffer no only in summer but also in winter.

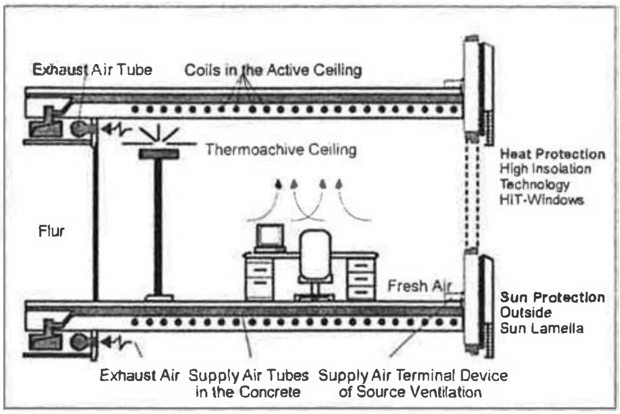


Fig. 6.8.1 Schematic construction of the combined heating and air conditioning concept

The heating/cooling pipes of the new building system are embedded in the massive concrete ceiling.

An important prerequisite for the construction of an isothermal building, which also makes particular demands on the control technology, is the adherence to a constant ceiling temperature of 22°C throughout the whole year.

At a constant 22°C surface temperature the ceiling acts as a cooling element at room temperatures over 22°C, at temperatures below it acts as a very mild radiation heating.

The maximum cooling load lies with this system at 30 - 40 W/m², the heating load at approx. 20 W/m².

The water temperature of the system is max. 26°C in winter and min. 18°C in summer. Therefore on the heating side the option of solar energy use is given, as flow temperatures of 26°C can be generated also during the heating period with comparatively cheap collectors.

If dehumidification of the room air is not necessary in summer, then mechanically generated cold water, by means of a refrigeration machine, can be dispensed with in favour of evaporative cooling. Preferably the "cold storage" of the isothermal building is "loaded" during the night, i.e. the concrete ceilings are cooled during the night.

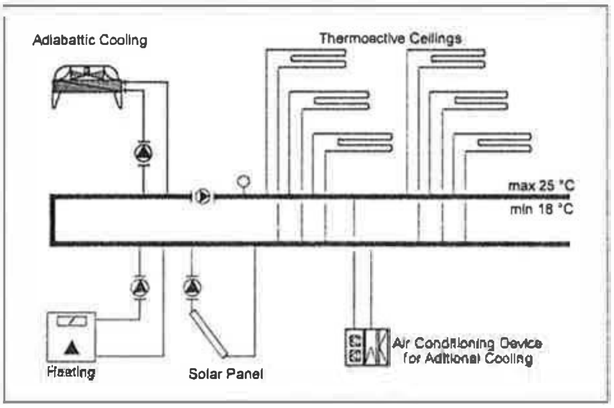


Fig. 6.8.2 Scheme of the water circuits heating and cooling

In a similar way to conventional cooling ceilings, source ventilation offers the ideal combination to the isothermal ceiling.

As the air does not need to fulfil any heating or cooling function, an approximate 1-time air exchange is sufficient. Complex air preparation systems are not necessary. The supply air is only preconditioned (filtered, preheated, precooled, or also dehumidified if necessary), and is afterheated, respectively secondary cooled to about 1 degree under the room temperature on the way through the cast integral channels in the concrete ceiling. This under-temperature causes the supply air to form a "fresh air lake" at the floor level from which "heat sources" (personnel, computers, lighting) transport the fresh air to the ceiling through the uplift flow

Rooms which make high demands on the cooling (EDP and conference rooms) receive additional air conditioning systems with recirculated air as cased or chest appliances, whose condensation heat is used anew.

Compared to buildings that are conventionally built and equipped, an approximately 10% more favourable cost-utilisation ration is achieved

6.9 Case Study 9

Cooling Ceiling System in Club Doré Cinema in Barcelona

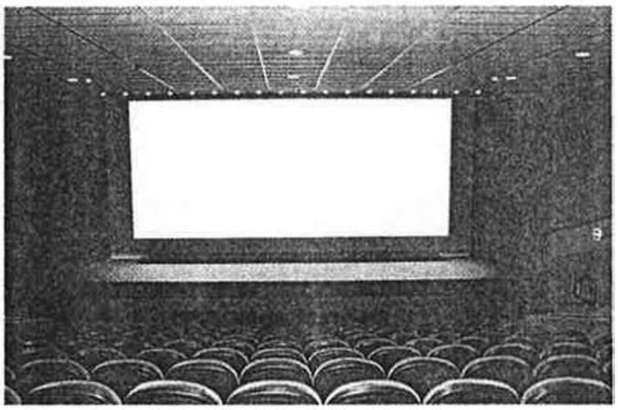


Fig 6.9.1 Auditorium of the Club Doré Cinema

The choice of the cooling system for the auditorium of the Club Doré Cinema took into account such considerations as the variation of thermal load according to occupation and sound levels demanded by the pubic in the cinema, as well as the energy savings obtained from operating in closed circuit.

The system consists of a closed circuit formed by the ceiling of the cinema, through which cold or hot air circulates, cooling or heating the surface through conduction, the ceiling receiving or emitting thermal temperature waves from the different sections of the premises. A regulating centre controls comfort conditions and prevents condensation.

The system functions as follows: cold air is produced by a cooling unit at 12-15°C and circulated around the loops created by the modules. This air cools the ceiling through conduction, making it a cold body. The hot bodies in the cinema emit radiation to heat this cold body. At the same time, the hot air close to the ceiling is cooled by conduction, increasing in density and falling without turbulence, thus decreasing air temperature.

The combination of the system with free cooling results in an excellent combination of comfort and energy saving. The radiation cooling system controls uniformity of temperature around occupants of the cinema, whilst the free-cooling systems controls air temperature throughout most of the year.

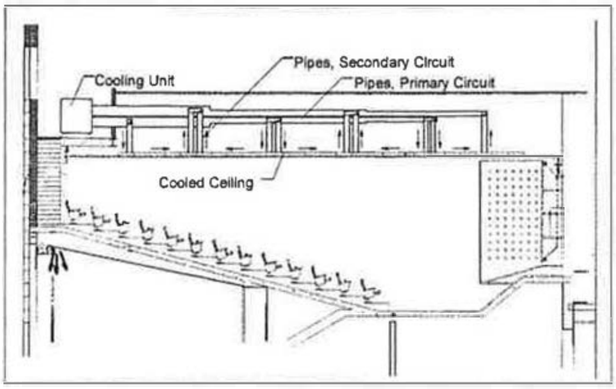


Fig. 6.9.2 Cross section of the auditorium

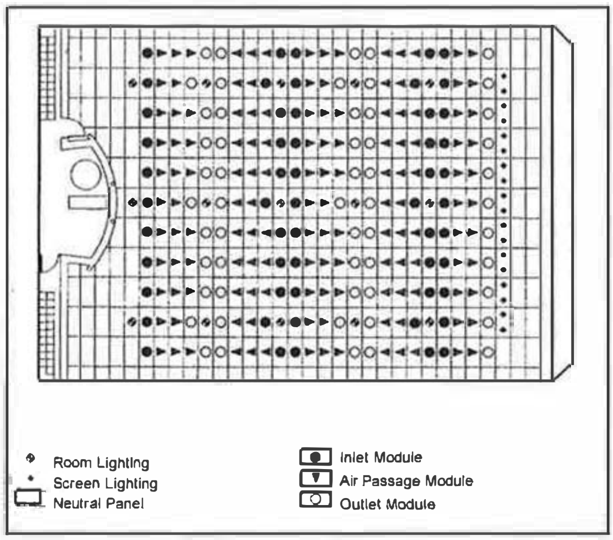


Fig. 6.9.3 Operation principle of the system

For regulation it was decided to install a series of independent systems according to function and which, suitably adjusted, work as a team. These systems are proportional regulation for external air and free cooling, all-or-nothing regulation for the closed circuit, and the system's control centre for interior temperature and dew-point control.

The construction consists of a modular 60 x 60 cm or 60 x 120 cm at the periphery, and each module is formed by a heat conducting panel (decorative element), an aluminium tube with two PVC swan-necks (allowing each module to be connected to the next), equipped with compressible joints and insulation consisting of 50 mm of mineral rock wool fixed to the top with the dual objective of forcing the system to work downwards and improving the insulation of the premises.

HVAC System

External temperature:	Summer: +31°C Winter:+2°C
Internal temperature:	Summer:+23°C Winter: +20°C
Total air flow:	18,000 m³/h
Total cooling power:	35 kW
Total heating power:	19.6 kW
Ceiling surface covered:	67%
Input temperature:	7-10°C
Cooling power of free cooling:	8.6 kW

Data

Maximum capacity:	259 people (large proportion children)
Total area of premises:	253 m²
Total volume of premises:	1013 m³
Lighting:	7.2 W/m²

6.10 Case Study 10

Full Air Conditioning of a Hotel without CFC's with Cooling Ceiling, Source Ventilation and Desiccated Cooling (19)

The hotel „Zur Post", close to the main railway station in Bremen, had already used new possibilities for technical installations in buildings in the past. In this hotel one of the first air conditioning systems with combined heat and power with gas-fired combustion motors was installed in a hotel business.

Through the conversion of rooms for use as high-class conference and seminar rooms an expansion of the air conditioning became necessary. Through the utilisation of newer air conditioning technology the excess heat of the cogeneration plant can now also be used in summer for cooling purposes.

Due to the confined space conditions the utilisation of conventional air conditioning technology was not possible. In the existing ceiling cavity it was not possible to install larger air ducts.

Therefore it was decided that the air conditioning should result via a cooling ceiling in connection with source ventilation.

Ceiling elements made of plaster panels were used, in which the plastic capillary tubes had already been fitted by the manufacturers factory. A smooth closed ceiling was created, which did not need any additional space. The high demands made by the architect on the ceiling creation could be harmonised with the cooling function without any limitations.

The air supply could be dimensioned to the hygienically necessary minimum air exchange. The source air outlets were integrated in the wall panelling.

The desiccant cooling system was used to dehumidify and cool the outdoor air, which can operate without a refrigeration machine.

The functioning of the procedure has already been described in detail in Chapter 2.5.

In this building the waste heat of the cogeneration plant was used to after-heat the exhaust air.

The system was put into operation in 1991.

6.11 Case Study 11

"Desiccated Cooling" Systems In The Saxony State Government Building in Dresden, Germany (19)

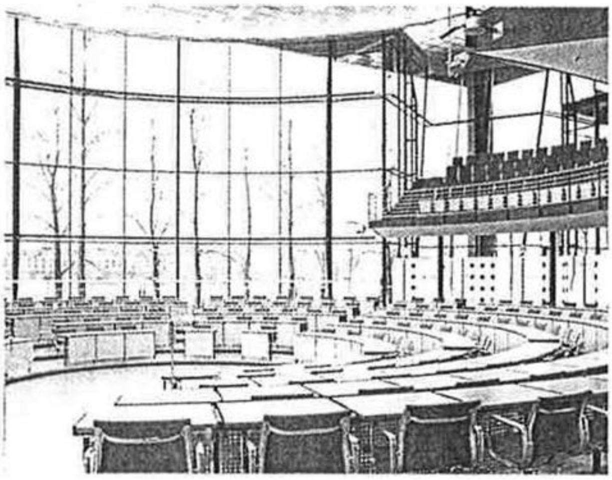


Fig. 6.11.1 Plenary hall

The new construction of the state government building is air conditioned with two DCS systems. In summer district heat is also available from combined heat and power, which is sufficient for operation of the plant.

The plenary hall and the meeting and conference rooms are air conditioned via a source ventilation system. In the plenary hall the supply air is blown in through steps and in the conference rooms though floor and/or wall outlets.

This air conduction system has proved particularly reliable also when the room loads change.

Technical Data

Start of operation:	1993
Air rate:	2 x 25,000 m³/h
Condition of outside air, summer:	32°C, 40% r.h.
Condition of supply air, summer:	18°C, 80% r.h.
Cooling power:	2 x 170 kW

6.12 Case Study 12

Cooling with Solar Energy Air Conditioning of an Administration Building of a Company in Cologne, Germany

Demonstration Project from the THERMIE Programme (31)

The office has an interior space of 8000 m³ and an area of 1628 m² that is to be air conditioned. The building was built in 1970, the air conditioning system was updated in 1995.

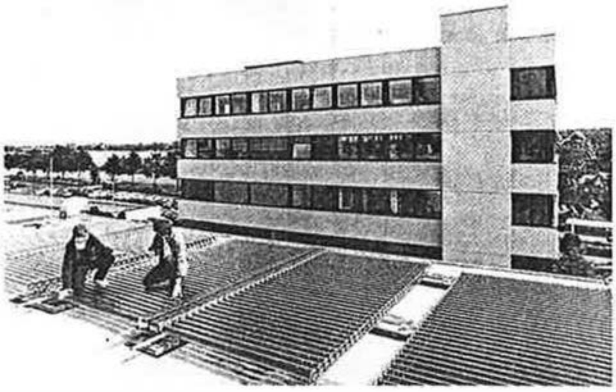


Fig. 6.12.1 Air conditioned office building

- This pilot project, subsidised by the THERMIE support programme, had three simultaneous aims: the substitution of compression refrigerating machines by a CFC-free system
- to dispense with electrical energy in the refrigeration generation through the utilisation of solar energy in summer
- to dispense with the use of fossil fuels as far as possible through the utilisation of solar energy in winter

The solar collectors and the absorption refrigerating machine therefore play a key role in the realisation of the concept.

In order to compensate a peak cooling load in summer of 80kW, 176 m² solar collectors were installed on the flat roof of a neighbouring building, which supply a heating output of max. 107 kW. Highly evacuated tubular collectors provide an optimal energy yield through minimal thermal losses. They heat the expellers of the two absorption refrigeration machines each with 46 kW nominal refrigeration output. These refrigeration machines, developed by the Frauenhofer Institut, work at lower temperatures in comparison to existing absorption refrigeration machines.

The cold water temperatures which supply the air conditioning system are 16/22°C.

As a reserve, a 5 m³ cold water storage was sunk into the earth. The following schematic diagram shows the construction of the refrigeration generation and supply:

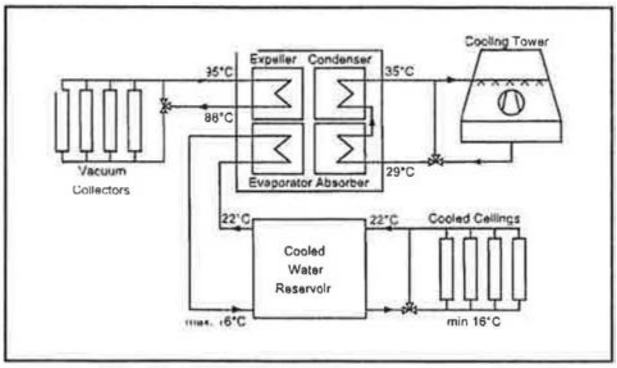


Fig. 6.12.2 Schematic system diagram refrigeration generation

"Cooling girders" with water flowing through them were installed at a later date in the office rooms, which provide a climate free of draughts at max. 26°C through radiation and convection.

Fig. 6.12.3 Installation of the "cooling girders"

In winter the low-temperature heating of the building is supported by vacuum-solar collectors.

In total approximately 16,500 m³ natural gas could be saved each year by the solar system.

The total costs of the system lay at approximately DM 800,000.-

This kind of system can in general cover 70-80% of the air conditioning under middle European conditions. It is more suitable for south European countries, where the pay-back period of the high investment costs is much quicker.

6.13 Case Study 13

High Quality Air Conditioned Office Building with Low Energy Costs (32)

One Bridewell Street, Bristol, United Kingdom

Fig. 6.13.1 One Bridewell Street, Bristol (32)

The six-storey building, completed in 1987, includes a full height corner atrium facing south-east and a small 2-storey wing accessible both from the main offices and separately.

The shared ground floor contains car parking, mini-computer room, storage and maintenance areas, and a small gym/fitness facility.

The building provides a high quality of environment, flexibility of operation and an attractive and bright appearance.

The atrium provides an impressive entrance with reception at ground level and circulation on the floors above. Temperatures in the atrium are not tightly controlled and daylight is good, giving a possible net benefit in energy terms - however this aspect has not been specifically monitored.

Office Ventilation and Air Conditioning

The main office areas are served by variable speed supply and extract air handling units with a mixing chamber in the roof plant room. Humidification in cold dry weather is by steam from packaged electrode boiler units. A control systems air quality sensor regulates the minimum amount of fresh air admitted.

Duct sizes are generous and pressure drops low, giving low fan energy running costs. Dampers to supply and return air branches to each floor allow air conditioning hours to be matched to local needs.

The Variable Air Volume (VAV) system provides conditioned air to mixing boxes and linear diffusers in the office ceilings. For most of the area the systems cools only, with the amount of air delivered by each box under the control of local thermostats. The primary air temperature is scheduled against outside air temperature and reset by return air: it varies from typically 13°C in high summer to 23°C in mid-winter.

At the perimeter the VAV system is augmented by ceiling void-mounted heating only fan-coil units with central Building Energy Management Systems (BEMS) control and local room thermostats. The fan coils neutralise fabric heat losses and provide local control where there are cellular offices.

A similar but smaller VAV system serves the partners' wing, which consists largely of meeting rooms.

Central chilled water for the air conditioning plants comes from two reciprocating chillers with air cooled condensers which operate as required: normally only from May to September, and then often only in the afternoon.

Other Ventilation and Air Conditioning

Upper levels of the atrium are conditioned at low cost by exhaust air from the office system, transferred and warmed where necessary by fan-convectors which draw air from the ceiling voids of the adjacent office floors. In very hot weather, a roof fan exhausts air from the top of the atrium, but this is seldom needed.

The lowest level of the atrium has a small constant-volume air-conditioning system to provide comfortable conditions for visitors and reception. A warm air system for the gymnasium is controlled by the BEMS to avoid unnecessary use.

Toilets and the small kitchens are on a separate supply and extract system.

Heating

The gas-fired boilers provide low temperature hot water to the various air handling units and to fan-coil units in perimeter offices.

The boilers are controlled from the electronic BEMS, and are sequenced with a check to ensure that the lag boiler is not brought in unnecessarily for short periods.

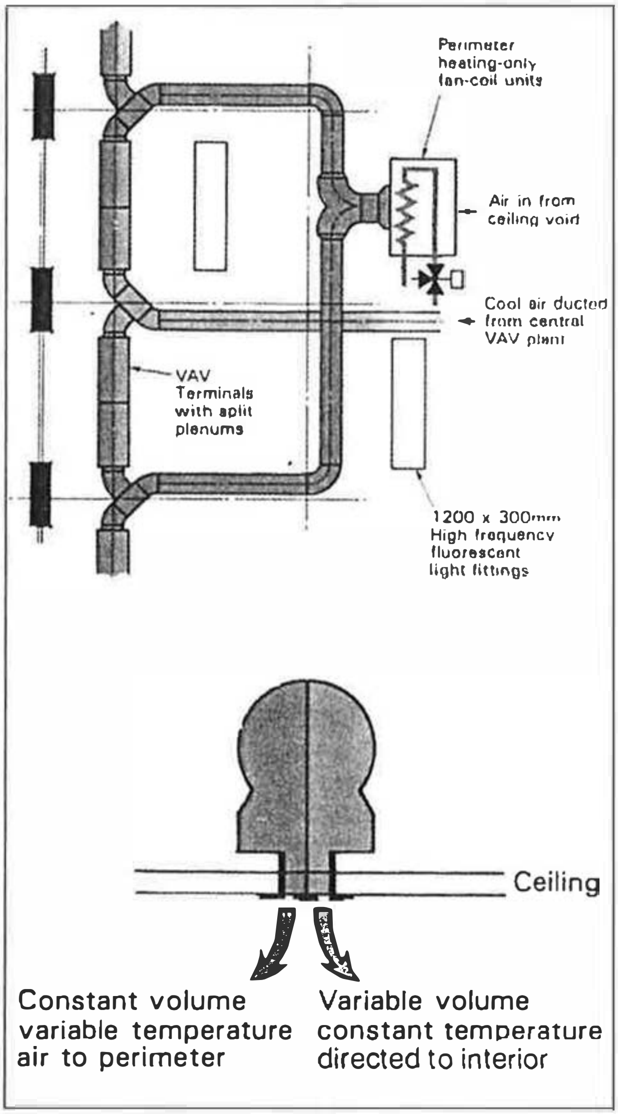


Fig. 6.13.2 Perimeter systems in ceiling void (32)

Optimum start of the plant is phased to stop the air handling units running until the heating is up to temperature: this saves electricity and prolongs the life of the boilers.

The boilers are switched off entirely in summer as there is no reheat load and domestic hot water is independent.

HVAC Controls

The BEMS provides all timing functions, most central temperature controls, and supervises dedicated electronic controls for the air conditioning plant. Room temperature control of VAV and fan coil units is local. The building manager operates the system so that chillers and boilers never run simultaneously.

Air conditioning is often required until 8pm for late working on some floors but has not been found necessary for weekend users as the well insulated, compact building maintains a stable temperature. At 139 kWh/m^2 of treated area, energy use is very low for an air conditioned building.

Data
Building Details

Pre-let office, completed	1987
Floors:	Ground+5+roof plant room
Gross floor area:	6360 m^2
Treated floor area	5020 m^2
Net floor area	3650 m^2
Typical number of occupants:	310
Typical hours of use:	8:30 am - 6:30 pm or 8 pm weekdays plus some week-end work.

Ventilation and Air Conditioning

Variable volume air conditioning with perimeter fan-coils to offices: 200 kW 5-stage compression chiller with air cooled condensers.

Tempered mechanical ventilation to toilets and gym.

Constant volume air conditioning to lower part of atrium.

Heating

Atmospheric gas boilers: 2 x 400 kW

Constant-temperature LTHW to air handling units and ceiling fan convectors.
Electric heating for frost protection and door heaters.

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8. TERMINOLOGY, GLOSSARY

Outdoor air (AU): Air introduced from free atmosphere.

Supply air (ZU): All air flowing into the treated space (as viewed from within the space).

Exhaust air (AB): Air removed from the treated space by way of an air treatment or natural ventilation system (as viewed from within the space).

Recirculated air (UM): Exhaust air returned as supply air to the air treatment system from which it originated.

Extract air (FO): Exhaust air discharged to the atmosphere.

Air change coefficient (LWS): Air volume flow rate for an enclosure relative to the volume of the enclosure.

Air conditioning centre: Central appliance in which the outside air is filtered (purified) and according to the requirements, is heated, and is fed into the service areas by a ventilator via ducts.

Supply air terminal device: Air openings through which the supply air is fed into the rooms, e.g. through the ceiling, wall etc.

Exhaust air terminal device: Corresponding to waste air

High velocity air conditioning systems Air conditioning systems in which the air ducts are of a small dimension, in order to save space, with the consequence of higher air speeds in the ducts, as well as higher ventilator pressure.

Ventilator pressure: Excess pressure, compared to the atmospheric pressure, generated by the ventilator to press the air through the ducts.

Single duct air: The supply air is supplied with condition preregulated temperature systems via a duct into the rooms

Dual duct air: The supply of feed air results via a hot air duct parallel to which conditioning systems runs a cold air channel. Before reaching the room that is to be air conditioned the desired supply air temperature is produced by mixing accordingly.

Induction air conditioning: Within individual appliances set up in a room (mostly in the systems window sill) purified outside air is blown out of nozzles at high speed. Thus, room air is sucked into the appliance (induced), mixed with the fresh air and blown back into the room as supply air.

Displacement flow: With the displacement flow the air enters the room evenly via the supply air ductwork, is displaced evenly and leaves the room on the opposite side.

Source ventilation: Source ventilation occurs when a heat source (person, machine) is placed in the upward displacement flow, which additionally favours the flow through thermal buoyancy. As the heat source is the decisive motor of the flow form, the term „source ventilation“ has become common.