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TECHNICAL COOLING SYSTEMS IN OFFICE PREMISES

CHŁODZENIE TECHNICZNE POMIESZCZEŃ BIUROWYCH

***Summary**: In the paper, the characteristic of the object was presented. The problems concerning comfort which should be met by the office rooms were discussed. The questions relating to the heat profits and the methods of obtaining the mentioned profits were presented. Also, the need of ventilation of the office premises and the problems resulting from cooling of the mentioned rooms were discussed. The characteristics of the air system and their types were outlines. In the paper, two air supply systems: CAV and VAV were compared.*

***Keywords**: ventilation, air-conditioning, dew point, venting system, air, dry cooling, wet cooling, heat gains*

***Streszczenie**: W pracy została przedstawiona charakterystyka obiektu. Poruszone zostały kwestie dotyczące komfortu, jaki powinny spełniać pomieszczenia biurowe oraz zagadnienia dotyczące zysków ciepła i w jaki sposób można było te zyski ciepła pozyskać. Omówiono potrzebę wentylacji pomieszczeń biurowych, a także problemy wynikające z chłodzenia tych pomieszczeń. Zostatała przedstawiona charakterystyka systemów powietrznych, a także ich rodzaje. W pracy zostały porównanie między sobą dwa systemy powietrzne CAV i VAV.*

***Słowa kluczowe**: wentylacja, klimatyzacja, punkt rosy, system wentylacji, powietrze, chłodzenie suche, chłodzenie mokre, zyski ciepłay*

Introduction

Ventilation is an organized or non-organized air exchange from a given room with the aim to its refreshing. We can distinguish natural (non-organized) and mechanical (organized) ventilation [1].

Natural ventilation is the air exchange into a fresh one in a given room, as a result of the difference in pressure, caused by difference in temperature between the internal and external air. The mentioned exchange occurs in the case of leakage and through the openings in the building, with the support of auxiliary, electric current-driven devices [2, 3]. In effect, there is no possibility of regulating the quantity of the air exchange and its parameters (temperature, humidity). Hence, there is the name: non-organized ventilation.

Mechanical ventilation is also the air exchange nut using the mechanical, electrically driven equipment [4]. It enables regulation of the amount of the supplied and exhausted air. The whole air exchange is possible due to designing of individual supply-exhaust ventilation channels; therefore, mechanical ventilation is also called the organized system [5].

On the other hand, air-conditioning is a process which gives the specified parameters to the air in a closed space, being necessary for maintaining the appropriate thermal comfort due to hygienic requirements and those resulting from the technological needs. Full conditioning takes place when the following thermodynamic processes are implemented: heating, cooling, wetting and drying [6, 7].

The dew point is the temperature which – under the given pressure and gas composition – may commence the process of condensation. In the air-conditioning, the dew point is the important factor. In the premises which are air-conditioned, there is always the need of maintaining the appropriate values of the air [even in winter time) [8]. At the external temperature of 26°C and humidity of 50%, the temperature of dew point will be equal to 15°C. We should always remember that the temperature of cooling water has not to drop below 16°C. Exceeding the mentioned temperature will commence the process of condensation – the humidity will appear on the internal partitions in the room. The change in the value of humidity in the given premise is affected also by opening of windows [9, 10]. With the air conditioning on, the windows should be not opened because it causes exceeding of the dew point in the room [9]. If the air-conditioning system will be operating above the dew point, we will have to deal with the so-called dry cooling. A high cooling performance may be obtained by a wet cooling. The temperature of cooling water will drop then below the dew point and the humidity will appear on the heat exchanger (in such situation, it is necessary to install a tray for condensate under the heat exchanger [10].

Air-conditioning in office premises

The main task of the air-conditioning and ventilation of the office rooms is as follows:

- maintenance of thermal comfort in a given room,
- neutralization of the resulting heat gains,
- supply of the appropriate amount of the fresh air,
- maintaining of the set air temperature,
- maintaining of the set air humidity,
- maintaining of the set air velocity [5, 6].

When calculating the heat gains, we may determine demand on a fresh air stream which should be supplied to a given room in order to neutralize the gains of heat [8]. It concerns the amount of heat, expressed in watts [W] which should be removed from the mentioned room in order to maintain the appropriate thermal comfort.

Heat profit resulting from the sun and transparent partition (windows)

The summer gain of heat, coming from the sun is understood as the sum of solar radiation which penetrates the room via windows and the sum of the heat stream which results from a difference between the external air temperature and that one of the inside the room. The mentioned parameters are dependent on the season of the year, hour of the day, situation of a given window in relation to the world parts as well as on latitude and atmosphere transparency [5].

$$Q_{ok} = F \cdot [\varphi_1 \cdot \varphi_2 \cdot \varphi_3 *\cdot (k_c \cdot R_s \cdot l_{cmax}) + k \cdot (t_z - t_p)][W]$$

where:
F – is a surface of window [m²];
φ_1 – is a participation of glass surface in the surface of window;
φ_2 – is a correction due to the height above the sea level;
φ_3 – is a coefficient, considering the type of glass and of the equipment;
k_c – is the coefficient of accumulation;
R_s – is the coefficient of sunny area and total area;
I_{max} – is the maximum value of the radius intensity;
k – is the coefficient of window penetration [W/m²K];
t_z – is the calculation temperature of external air;
t_p – is the calculation temperature at a given room.

Profit obtained from the non-transparent partition (wall)

The summer period considers also the heat gains coming from the walls. As a result of solar radiation, the temperature of the wall surfaces is changed, so the appropriate amount of heat penetrates the room [4].

$$Q_{śc} = F \cdot K \cdot \Delta_{tc}\ [W]$$

where:
F – is the area of the surface of non-transparent partition [m²];
K – is the coefficient of partition heat penetration, adopted as 0.2 [W/m²K];
Δ_{tr} – is the equivalent difference of temperature [K].

Heat gain resulting from electric light

During winter time when the solar radiation is not high, the heat gains coming from the switched electric light are also taken into consideration, [2].

$$Q_o = N \cdot \varphi \cdot \alpha \cdot k\ [W]$$

where
N – is the total capacity of the installed light [W/m²];
φ – is the coefficient of coincidence;
α – is the coefficient, considering the exhaust of heat via ventilated fittings;
k – is the coefficient of accumulation.

Heat gain coming from equipment

Heat is also emitted by the equipment, installed in the room (Table 1). The mentioned values are estimated and their sum is always dependent on the time in which a given device is working [3, 4].

Table 1. Heat gain, coming from electric devices [8]

Type of equipment	Nominal capacity	Time of equipment operation	Sensible heat gains
	[W]	[min/h]	[W]
PC Computer	100 ÷ 150	60	100 ÷ 150
Terminal	60 ÷ 90	60	60 ÷ 90
Dot matrix printer	20 ÷ 30	15	5 ÷ 7
Laser printers	800	15	200
Plotter	20÷ 60	15	5 ÷ 15
Scanner	180	30	90
Copying machine	1600 ÷ 1700	45 ÷ 55	1200 ÷ 1550
Electric typewriter	50	60	50

Maintaining the determined humidity, temperature and air velocity

The temperature of the appropriate value should ensure a thermal balance to a human body in the surrounding environment. The optimum value is dependent on the following factors: insulation of the cloths, physical activity of man and the season of the year [5, 6, 7].

The optimum values for summer winter periods are given in Table 2 and 3.

Table 2. Optimum values for the summer time [4]

SUMMER				
Parameter	**Unit**	**Small physical activity**	**Medium physical activity**	**High physical activity**
Optimum values (air-conditioning)				
Temperature in a given room	[°C]	23 ÷ 26	20 ÷ 23	18 ÷ 21
Range of relative humidity	[%]	40 ÷60		
Maximum air velocity	[m/s]	0.3	0.4	0.6
Admitted values (ventilation)				
Temperature at heat gains up to 50 W/m² of the floor	[°C]	$t_z + 3$		
Temperature at heat gains above 50 W/m² of the floor	[°C]	$t_z + 5$		
Relative maximum humidity	[%]	70		

Table 3. Optimum values for winter [4]

WINTER				
Parameter	**Unit**	**Small physical activity**	**Medium physical activity**	**High physical activity**
Temperature of a given room	[° C]	20 ÷ 22	18 ÷ 20	15 ÷ 18
Optimum range of relative humidity	[%]	40 ÷ 60		
Minimum relative humidity	[%]	30		
Maximum air velocity	[m/s]	0.2	0.2	0.3

The need of ventilating the office premises

The office premises are the place where we should have the ensured appropriate air temperature of work. To this end, air-conditioning is used. The air-conditioning system is aimed at maintaining the appropriate temperature in a given room throughout the whole year, irrespectively of the external conditions. The mentioned temperature should be always automatically regulated owing to the heater or cooler [5, 6]. It prevents from the exceeding the relative humidity φ = 70% which is a limit of thermal comfort in the room. If we want to ensure the more precise regulation of the air humidity in the air, we speak then about the full air-conditioning system which is able to maintain automatically all appropriate conditions of micro-climate [7].

When determining the minimum air stream which should be supplied to the premise depending on the number of the present persons, the standard PN-83/B-03430/Az:3 200 [1, 2] is taken into consideration. In order to keep the set the temperature and humidity parameters, when the windows are not opened, the stream of the air from the air-conditioning system should be equal to 30 m/h/. On the other hand, when the windows had been opened, the mentioned stream would amount to 20 m³/h. In the calculations of the stream of the required air, we have to consider the factors (heat gains), the higher values of which would cause the rise of the demand on the fresh air, as being supplied to the room [3, 4, 5].

The problem of cooling the office premises

When choosing the system of ventilation of the office premises, we should pay attention to the following factors:

- natural ventilation will never ensure the air stream to the room for the whole year, also due to the hygienic aspects;
- in multi-storey buildings, there are big differences in the pressures, occurring at their higher floors; it is caused by the effect of wind on external partitions what may cause the impossibility of ventilating the premises at opened windows (in this case, the system of double facade may be a good solution) [4, 5];
- when the windows are opened, the street noise may be a problem;
- atmospheric contamination of the air which comes from the neighbouring streets; it is caused by sealing of the buildings and non-opening of the windows;
- heat gains coming from solar radiation, heat gains coming from the people, light and electric devices are the cause of the rise of temperature inside the premises;
- cooling of the office rooms ensures the comfort for the customers and renders the attractiveness to the building.

The systems of cooling the office premises

The choice of the system of cooling of the office rooms should be always considered individually. It is determined by the following factors: number of storeys, size of the surface, transparent size of the surface (window), construction of the building (constructional partitions) and the number of the present persons [2, 3].

The air systems

CAV (Constant Air Volume) System

It is a system which supplies the air to the specified zones in a room with the constant yield but with the varying temperature of the air blow. The air is factor which shapes the microclimate in the premises. When the temperature outside is increased, the temperature of the supplied air is lowered. The regulation of the air temperature is ensured by automatic system of heater and cooler in the air handling unit [1, 2, 3].

VAV (Variable Air Volume) System

VAV system is the solution where the air stream is variable and temperature is constant. The demand of each room zones on heat is equalized by the change in the intensity of the delivered air stream. When the temperature in the room is increased, the stream of the air is increased; when it drops, the stream is decreased. The changes in the air in the particular premises are carried out using VAV regulators, based upon the signals obtained from the rooms (temperature). Then, the change of the angle of throttle takes place [1, 2, 3].

Single-pipe systems (CAV and VAV)

Single –pipe (one-conduit) system supplies air with the appropriate temperature and with a given flow to the premises. In the particular branches, the regulators, which will maintain the flow at the set level, may be installed. The sensor informs currently about the recommended value of the air stream. The mentioned sensor is installed in the given room [2, 4].

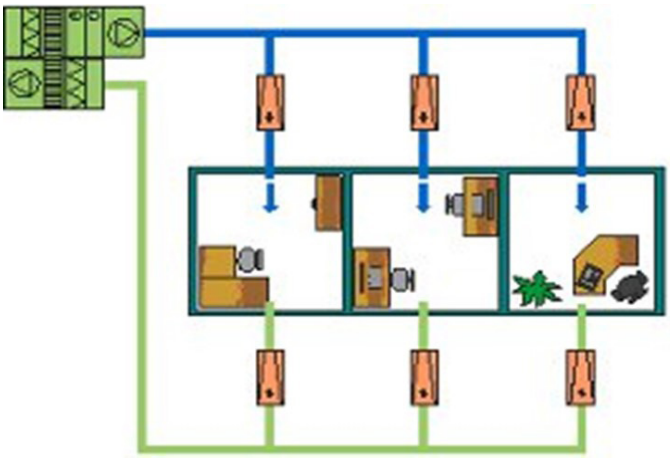

Fig. 1. Single-pipe system with a separate regulator of the blown and exhausted air [2]

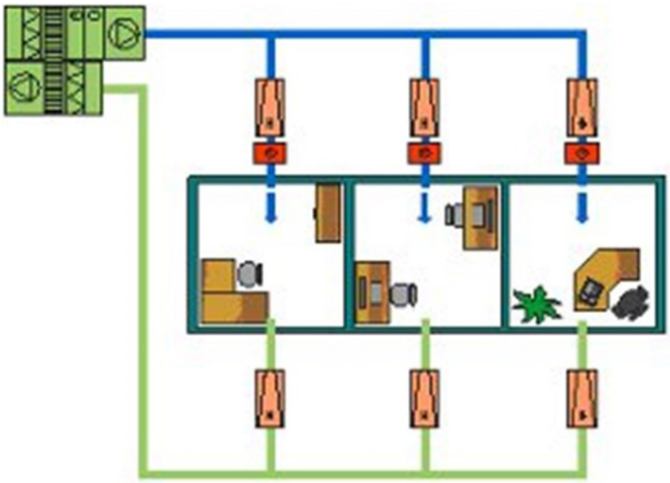

Fig. 2. Single-pipe system with zone heaters [2]

Double-pipe (VAV) system

Two-pipe VAV system is characterized by two air streams, running in two separate channels. Warm air flows via one channel and the cold air flows in the other one. Each of the channels is directed to each of the rooms where they are mixed in the mixing chamber. The mixing chamber is responsible for mixing of the both streams and it supplies the air with a required temperature to the air diffuser. The shortcoming of the system consists in too much developed system of ducts [2, 4].

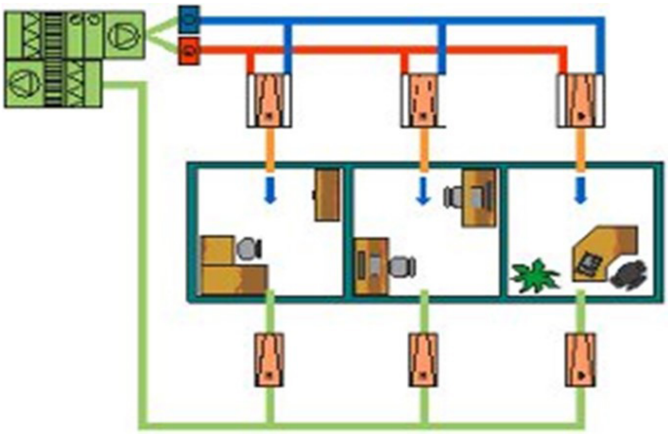

Fig. 3. Double-pipe system [2]

The system with direct evaporation (direct cooling)

VRF (Variable Refrigeration Flow) /VRV (Variable Refrigerant Volume) (this last name is reserved by the producer)

The variable flow of refrigerant consists of external unit and several internal parts. The external unit is found in the room. It is composed of evaporator (exchanger of the direct evaporation of refrigerant), throttling element, ventilator and a control element [2, 4]. The external unit is the refrigeration aggregate which is equipped with condenser, compressor with varying capacity and ventilator. If the thermal load is increased and there is a need of temperature regulating, the automatic regulation causes start of the successive compressors; owing to this fact, the change in the flow of refrigerant goes smoothly [4, 5].

Split system

The Split system consists of the following elements: external module (condenser), internal module (evaporator with ventilator), compressor and throttling element. The both modules are linked by two conduits in which the refrigerant flows in as form of water and gas. On the other hand, the air form the room is cooled down in evaporator, emitting the heat to the refrigerant. The gas refrigerant is compressed in the compressor (its temperature is increased) and it becomes a liquid with a high pressure. In the condenser, the heat from the refrigerant is exhausted to external air. The present gas is condensed under the high pressure and is then throttled in the expansion valve. His temperature and pressure are lowered. The cooled down refrigerant goes to evaporator and there it is again heated up by the internal heat and changes into gas [6, 8].

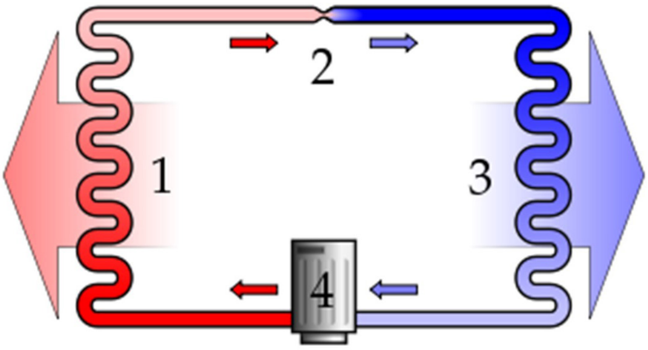

Fig. 4. Scheme of functioning of air-conditioning system of Split type [6]

Fig. 5. External unit of air-conditioning system of Split type [6]

Multisplit

Multisplit system differs from the Split system in respect of the possibility to install up to 5 internal units. The total refrigeration capacity of such system does not exceed 16 kW. The external unit is always connected with the external unit by the individual system of pipelines. The expansion valve is situated near to the external unit (as in the case of Split system). Each of the internal unit is operated irrespectively of the other, using pilot and from the panel, installed in a given room [7, 8].

Fig. 6. Multisplit system [7]

System of refrigerating water

In the system of cooling water (the so-called ice water), cooling down of the air is effected in the evaporator for cooling of the liquid instead of the air cooler. It is the so-called plate or jacket-pipe evaporator, being also named water chiller. Water at a low temperature (supply; 5 – 10oC, return: 10 – 16oC) is distributed via the system of pipes from the source to the receivers. The receivers are fan-coil units (heat exchangers of water-air type) [8, 11].

During the transitory and winter period when the external temperature drops, it is possible to utilize the natural cold source i.e. external air. It may be implemented using the additional, built-in exchanger in the chiller, installed near air condenser. Without starting the chiller, the external low temperature will ensure cooling of the transfer medium. Such possibility is called a free cooling [11, 12].

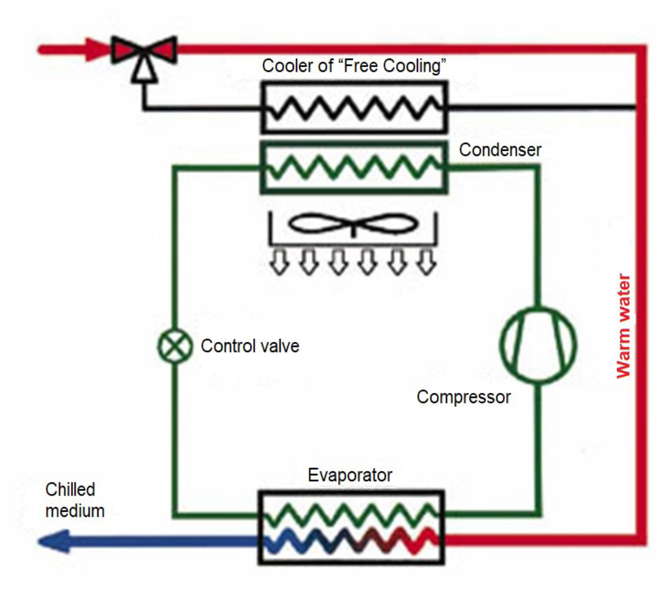

Fig. 7. System of cooling with transfer medium with the closed three-way valve of free cooling [11]

Fan-coil units and induction units

This name refers to the devices aiming at maintenance of a constant temperature in a given room. Water or its mixture with the refrigerant is the refrigerant in the fan-coil units. The discussed devices are installed under the window and in the suspended ceiling. The air delivered to the fan-coil units is centrally treated in ice water aggregate. We can distinguish induction units and fan-coil units [9, 10].

The induction units utilize the power of induction of the external air; they suck the room air in and direct it to the heat exchanger and then, to the blow element [8].

Fan-coil units possess a fan in which the filter may be installed before the exchanger. The fan-coil unit may be connected to the network of ventilation ducts [7, 8].

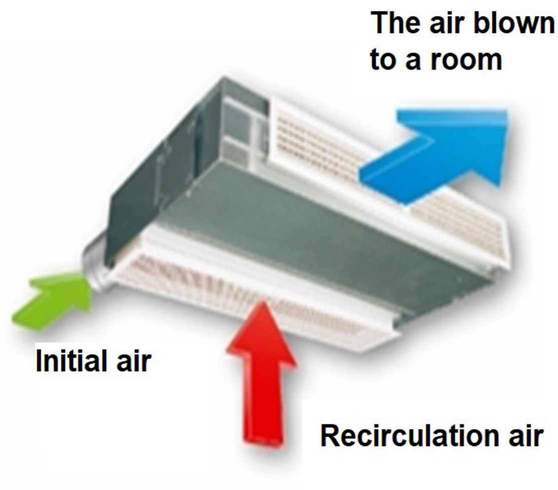

Fig. 8. The circulation of the air in the fan-coil unit [8]

Table 2. Comparison of the air systems [8] (bold type represents the advantages of the system)

Air systems	
CAV	**VAV**
There is a possibility of regulating the air temperature	Lack of temperature regulation. There is a possibility of regulating the temperature by installation of individual air heaters, fed with warm water or electric energy. In such case, it is unfavourable to situate the source of warm air in the inter-ceiling space as it is connected with the feeling of cold in the vicinity of windows; it also increases the costs of installing the individual heaters.
Favourable solutions for the objects where the constant heat gains and the constant number of persons in a room occur	**Maintenance of the set parameters in many zones**
Saving of refrigeration capacity (in the case of one room)	Lack of saving of refrigeration capacity (in the case of one room)
Impossibility to regulate the flow	**The possibility to regulate the flow, depending on the need**
	Smooth regulation of the flow
The regulators' work cannot be connected with the possibility of cooperation with the whole managed building (BMS – Building Management System, BMS)	**Regulators' work is connected with the possibility of cooperation with the whole managed building (BMS – Building Management System, BMS)**
More expensive operation of the system	**Cheaper operation of the system**
Constant power consumption by a fan due to the demand on the air at a given moment	**Variable power intake by a fan**
Supply of the air to all premises, even those non-utilized	Lack of the supply of the air to all premises, even those non-utilized
Failure to keep the set parameters in many zones	Keeping the set parameters in many zones

Summing up

The effective system of refrigerating the office premises is a complex matter. We cannot univocally determine which system is the best. The choice of the system is determined by several factors. The first one includes architectonic conditions of the building, i.e. the place where the offices are situated and whether it is a new building or the older one. If the building has the suspended ceilings, we may choose the air system and air-water system where the air channels may be installed in the mentioned ceilings. The air-water systems have the advantage in relation to the size of the channels of the installation. We mean here the cross-sections smaller than 1:300. The second factor which decides on the choice of the appropriate refrigeration system includes the type of the premises which will be cooled down. We must answer the question: how many persons will be staying in a given room, what temperature is to be maintained in a given room, what will be the heat gains and how many rooms will be cooled down. Maintenance of the appropriate temperature and humidity in a room must always be regulated by the sensors, installed in the rooms. The automatic system must be adapted to the existing internal and external conditions. It is important to calculate the heat gains in the design stage what is connected with the required demand of blown heat stream. We must also remember about the financial and economic questions. We must decide whether the heat gains are recognised as enough high as to install the air-conditioning system or it is sufficient to ensure the mechanical ventilation without all functions of air-conditioning. We should also remember about the natural ventilation, i.e. opening of the windows (airing of the premises), the system of double facades and utilization of glazed atriums. However, in the case of natural "cooling down", there is no possibility of regulating the values of temperature, humidity and the amount of the supplied air.

Reassuming, there is no ideal, model solution which refrigeration system is the best. We should always remember that each office building should be considered individually and in all aspects. When analyzing a given building and considering its all architectonic, technical or economic potentials, we cannot forgot about the needs of its users

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