Local and centralized conditioning systems

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Abstract. This article discusses two main types of air conditioning systems in office buildings: local and centralized systems. Since equipment developers, customers and users have different requirements for the design, installation and operation of air conditioning systems in office buildings, depending on the workload of buildings, location, external conditions, as well as space-planning solutions, air conditioning systems currently come in different types and configurations. Reliable knowledge of classification and the ability to distinguish one system from another is key when choosing the right air conditioning system for the customer. To form a proper understanding of the systems discussed, it is necessary to understand some of the basic terminology and principles of air conditioning systems. These include methods for system design criteria, load calculations (tangible and latent thermal loads, penetration loads, equipment and appliance loads, and air conditioning system requirements).

In the modern world office air conditioning is one of the main components of a comfortable office microclimate in summer. Air conditioning in an office or in a group of offices is solved in various ways depending on the design of the office space, budget, the completion degree of the office building, and many other factors [1].

It is necessary to understand some basic terminology and principles of air conditioning systems to form a proper understanding of the systems under discussion. They include methods of design criteria for systems, load calculations (sensible and latent heat loads, penetration load, load on equipment and devices, air conditioning system requirements and others), the composition of sun orientation and heat transfer through the building envelope.

In figure 1 there is the simplest scheme of the air conditioning system in office buildings. Such an air conditioning system includes an air condition plant and a heat distribution system. Heat energy in the form of sensible heat or latent heat must be transferred from the conditioned space to cool the space, as shown [2]. The heat distribution system serves to transfer energy between the air conditioning system and the air-conditioned space. The heat distribution system also helps to improve air quality in the air-conditioned room by controlling the estimated amount of fresh air supply to the air-conditioned space.
Figure 1. Scheme of the air conditioning system in office buildings.

Centralized air conditioning systems are the systems with all heating and cooling performed in a central room and transferred to the other rooms through the air ducts. In demi-centralized air-water systems, centrally cooled or heated air is additionally heated or cooled at the room entrance. In turn, local air conditioning systems are systems with all operations performed separately in each room. The possibilities to range and to combine the systems types are limited only by the capabilities and the knowledge of the company developing the system for a particular customer and the technical factors of the building [3].

The heating is easier to control than the air cooling, most of the centralized and demi-centralized air conditioning systems cool the air been overheated before. The charges obtained as a process result can be minimized through the careful design and control.

The equipment can be set to service several different types of air distribution systems in the central air conditioning system.

Centralized air conditioning systems in office buildings with a single zone of constant volume are rather value-priced and easy to put in service, but they cannot provide adequate control of zones with different and simultaneous heating or cooling requirements. Several separate systems may be used to serve the different rooms, it increases capital cost and the production area to place the system.

The systems with variable air volume (VAV) solve the problem of different requirements zones ranging the amount of air supplied to each zone. The constant temperature air is supplied through thermostatically controlled blocks of dumpers (called VAV blocks). The air volume and as a result the cooling volume ranges depending on the requirements of each zone. Usually there is a possibility to release "constant" temperature.

Air exchange in a centralized system through VAV blocks does not affect the comfort in office rooms and simplifies the general system design. This approach allows to take two potential advantages of VAV systems. First of all, the maximum cooling is not required at the same time for all cooling zones in the office, and the choice of the centralized system should reduce capital cost taking into account reduced requirements for some zones [4].

Secondly, the maximum cooling is required for a very few days a year in the most office buildings, for example, in the Russian Federation, so using the centralized system of variable volume the air specifications are minimum for much time. This will lead to significant energy savings, fan power reduction and air heating and cooling.
The systems with two air ducts can be designed on the same operation principles as the constant volume systems or VAV. The name of this centralized system type implies two channels to be used in its work, one of which transfers the heated air, and the other one transfers the cold air into the room, where the air is mixed in a thermostatic mixing box usually placed in the suspended ceilings.

These systems provide accurate temperature control in rooms, but the space requirements are higher, as they require two sets of air ducts. In their constant volume system, double air ducts often mix heated air (using energy), with cooled air. The operation principle of such a centralized system is schematically presented in the figure 2.

![Figure 2. The operation principle of air conditioning systems with two air ducts.](image)

However, if to talk about the "comfortable cooling" in the office space with account taken of the employees' individual requirements, local systems are better for such cases. Centralized air conditioning systems are usually drained only for cooling during the summer period, only for summer cooling. Other air conditioning functions, such as fresh air supply, humidity control and heating do not have to be available in centralized systems.

There are several types of local systems like the wall-mounted systems (which are quite popular in Mediterranean countries). As a rule, such systems represent a small cooling system with a built-in air circulating fan. The room air cools and returns back. The removed heat is brought out of the wall [5].

There are some advantages of using these systems in office buildings such as low costs to install them and easy using through the local settings by the user. However, such a system is not sufficiently effective to control the temperature in the room because of the sensors location (in the wall panels) and the imperfect design of the on / off system. Besides, the system type requires wall mounting and can be noisy and not very efficient. The servicing of a large number of such local systems can be difficult in one office building. Besides, such a system is difficult to integrate into the central air conditioning system.

"Split blocks" are another type of local systems, which are probably more popular in many countries than the wall-mounted systems. The system part installed in the room images a fan coil, but the cooling is provided with refrigerant, not refrigerated water. The cooling part of the plant may be placed away from the space occupied by office staff. Some split systems have adjustable-speed compressors and
complex modulating temperature control with remote sensors. Advantages and disadvantages are the same as in wall-mounted systems.

Individual reversible heat pumps are also the type of local air conditioning system in office buildings, they can have the same operation principle as a split system or a local wall-mounted system [6].

VRF systems (variable refrigerant flow) are rather new types of local systems. They represent a heat pump with a separation structure. Several room coolers are connected directly to an outdoor refrigeration unit in such systems. Refrigerant flow can be varied through an adjustable-speed compressor responding to changes in cooling requirements. A complex control system allows to switch between heating and cooling modes. In more complex versions, internal blocks can work in heating or cooling mode independently of each other. Such an approach to air conditioning (due to the independence of the system blocks) provides a potential energy economy, when heating and cooling are required simultaneously in different areas of the office building. VRF systems are rather variable from the technical point of view, but as well as all local systems require serious costs for servicing, although the local systems are competitive with traditional engineering systems in initial capital costs.

The following identities can be used to create a heat and humidity balance:

\[
\begin{align*}
G_{oda} \cdot I_{oda} + G f c \cdot I f + \sum Q_{gen} &= G_{rem c} \cdot I_{rem} + G f c \cdot I_{remf} \\
G_{hc} \cdot d_{oda} + G f c \cdot d f + 1000W &= G_{rem c} \cdot d_{rem} + G f c \cdot d_{remf}
\end{align*}
\]

Where:
- \( G \) — amount of air, kg/h;
- \( I \) — enthalpy of air, kJ/(kg dry matter);
- \( d \) — moisture content, g/(kg dry matter);
- \( \sum Q_{gen} \) — total general heat excess indoors, kJ/h;
- \( W \) — total moisture release indoors, kg/h.

\( oda \) — the parameters of plenum outdoor air (ODA) blown from central air-conditioner;
\( \text{rem} \) — the parameters of air, removed from the room by a forced exchange exhaust system;
\( f \) — the parameters of plenum air, blown into the room by fan coils;
\( \text{remf} \) — the parameters of air, removed from the room by fan coils;
\( \text{ind} \) — the parameters of indoor air in serving or working area.

This formula can be used to calculate the volume of supply or released air mass:

\[ G_{c} = \frac{G}{(1 + d)} \]  

Considering that the air humidity is from 0.008 to 0.012 kg/kg of air power, the above-mentioned identities change a little:

\[
\begin{align*}
G_{oda} \cdot I_{oda} + G f c \cdot I f + \sum Q_{gen} &= G_{rem c} \cdot I_{rem} + G f c \cdot I_{remf} \\
G_{oda} \cdot d_{oda} + G f c \cdot d f + 1000W &= G_{rem c} \cdot d_{rem} + G f c \cdot d_{remf}
\end{align*}
\]

According to the formula, it means the air volume is measured as kilograms to hours; it is associated with air enthalpy and measured as kilojoules to kilograms of air power; \( d \) is the air mass humidity and is measured as grams to kilograms of air power; \( \sum Q_{gen} \) characterizes general absolute heat excesses indoor and it is measured as kilojoules to hours; \( W \) is associated with general moisture liberation indoor and expressed as kilojoules to hours.

It is necessary to know the temperature values of the air mass to determine the air enthalpy, so the identity reshapes:

\[
G_{oda} \cdot t_{oda} + G f \cdot t f + \sum Q_{gen} = G_{rem c} \cdot t_{rem} + G f \cdot t_{remf}
\]
Considering this identity, $\Sigma Q_{\text{gen}}$ is associated with common apparent excesses of thermal energy indoor and it is measured as kilojoules to hours.

The above-mentioned identities are the excellent foundation for the identity derivation, on the basis of which the return air volume from the heat-exchanger blocks is calculated:

$$G_f = \frac{(\Sigma Q_{\text{gen}} - Goda (I_{\text{rem}} - I_{\text{oda}}))}{(I_{\text{remf}} - I_f)}$$ \hspace{1em} (7)

$$G_f = \frac{(1000W - Goda (d_{\text{rem}} - d_{\text{oda}}))}{(d_{\text{remf}} - d_f)}$$ \hspace{1em} (8)

The condition must be followed:

$$G_{\text{oda}} = G_{\text{rem}}$$ \hspace{1em} (9)

The return air volume from the heat-exchanger blocks can be calculated according to any formula, but in our case, the following one is appropriate:

$$G_f = \frac{(\Sigma Q_{\text{gen}} - Goda (I_{\text{rem}} - I_{\text{oda}}))}{(I_{\text{remf}} - I_f)}$$ \hspace{1em} (10)

The reason for such a decision is the variable air humidity indoor and, in the heat-exchanger blocks [8].

It is necessary to apply the following air exchange coefficients to relate the parameters of the air mass in the working space with the parameters of the supply and release air mass:

$$K_t = \frac{(t_{\text{rem}} - t_n)}{(t_{\text{rp3}} - t_n)}$$ \hspace{1em} (11)

$$K_d = \frac{(d_{\text{rem}} - d_n)}{(d_{\text{rp3}} - d_n)}$$ \hspace{1em} (12)

The analyzed air conditioning systems require the introduction of two different values of the specified coefficients, so the system includes not only the central air conditioner, but also heat exchangers. If the situation is considered as a whole, the coefficients of air exchange depend on the type of air flow exchange, the type of air flow distributors, the placement of intake ducts and extract ducts relative to each other, the placement of heat and eco-dangerous sources and other factors.

Anyway, the use of the air mass exchange coefficient or the management of one’s own experience forces the developer to focus on the temperature values of $t_{\text{remf}}$ and $t_{\text{rem}}$ based on the air flow temperature in the workspace and the placement of the exhaust equipment and heat exchangers. Absolute supply of heat energy from people in the room, lighting equipment, office equipment, computer devices and ultraviolet rays are calculated without any justification. The same goes for humidity. [7]

Calculating the volume of street air mass, it is necessary to go by [8]:

- the required and minimum volume of air mass on the basis of sanitary regulations;
- the volume of air mass needed to compensate a local exhaust and to form a blockage in the air-conditioned room;
- the volume of air mass needed to assimilate the heat excesses indoor as cold weather comes.

Due to the fact that the air conditioning system with heat exchangers provides for the use of refrigeration equipment, during the warm season street air mass must be cooled through the central air conditioner to 18-22 degrees Celsius. This situation leads to a partial assimilation by the external air mass of excess heat energy indoor. This also eliminates additional problems with the air flows distribution.

Based on the starting parameters of the street air mass and the resultant cooling temperature of the air flow in the coolhouse system surface of the central air conditioner, computer reporting can be used to determine the temperature, humidity and enthalpy of the supply air, heating-adjusted in the ducts and
fans by 0.5-1 degrees Celsius. The last value is affected by the duct length and the absolute fan pressure [9].

A more complex procedure is to determine the air parameters of the outlet heat exchanger, as its cooling capacity is affected by the entering dry-bulb and wet-bulb temperature.

However, the air cooling in the heat exchangers has a certain lower limit associated with the temperature on the fan coil surface. The last one is affected by the initial and resultant temperature of cold water. In the case of sample calculations, you can be guided by the following formula:

\[ t_f = twk + (1 - 1.5 \, ^\circ C) \] (13)

Based on this formula, twk is a design water temperature from the heat exchanger.

In this case, the relative air humidity (rh) going out the heat exchange can be equated to 90-95 percent.

It is possible to introduce a fractional error within 0.5 degrees Celsius and 5 percent, respectively. The reason is to clarify the values of the design temperature and relative humidity during the final calculations.

Provided the above three indicators it is possible to determine the humidity (df) and the air mass enthalpy going out the heat exchanger.

Summarizing this calculation stage, we have:

- volume, temperature, enthalpy, humidity of the supply air mass;
- the air flow volume released from the room and its temperature;
- temperature, enthalpy, humidity of the supply air mass going out the heat exchangers;
- total absolute emissions of thermal energy and humidity indoor;
- the rated temperature of the internal air mass in the working space.

Most developers have to be guided by a higher water temperature in order to exclude humidity. Moreover, even taking into account a temperature of 10-15 degrees Celsius in the warm season and a high humidity indicator of street air mass, the processes in heat exchangers will perform under conditions of slight drainage. It follows that the need of humidity is a must. [10]

At the same time, increasing water temperature helps to reduce both the total and apparent cooling capacity of the heat exchanger.

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