Effeciency Solutions to Refresh the Air in Rooms with the Heat Releases

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Abstract: - The paper focuses on modeling the phenomenon of air recirculation in rooms with heat releases. Modeling highlights the connections existing between climatic values (pressure-temperature) and allows the determining of an *airing constant* used in describing the efficiency of a passively climatized room. In the second part of this paper the authors propose efficient solutions to remove heat from the room, using conventional air conditioning equipment.

Key-Words: Modeling and simulation, Heating systems, Location modes.

1 Introduction

Application of air conditioning equipment is very large. Several models are distinguished by:
- type of cooling (cooling devices incorporated or separate machine);
- the treatment of air (apparatus operating all year or part of the year with an automatic temperature and humidity);
- type of discharge (directly or through a network of water);
- use (devices that maintain a comfortable climate artificial comfort zone or air conditioning devices in industry whose role is to create the climate conditions in relation to needs manufacturing);
- the type of energy used (electrical operated with electricity, gas, etc.).

Whatever the model, choosing a type of device is based on several criteria. Climatic conditions influence the choice of air conditioning through balance of power in the room. For example, if an area with appropriate climatic parameters of a dry tropical climate, it is possible to refresh the air by humidification (by using a "fan-coil), in an area suitable climatic parameters of humid tropical climate, can not achieved only by cooling and refreshing air dehumidification using an air conditioner.

When there is a difference in pressure between the inside and the outside environment of a room, as a result of an existing source of heat which makes the temperature inside higher than the one outside, meaning that the specific weight of the air inside is diminished as compared to the weight of the air outside, climatization is possible.

2 Variation of Pressure with Temperature in Room

In this situation, it can be achieved either by mechanical means (climatization installations), or naturally (passive climatization), in the case of large air flows when the installation becomes expensive to operate. Air density decreases with the increase of temperature, according to the relation

$$\rho_a = \rho_0 \frac{273 + \theta_0}{273 + \theta} \quad [\text{kg/m}^3], \qquad (1)$$

in which $\rho_0 = 1.2$ kg.m^{-3} represents air density at temperature $\theta_0 = 20^0$C.

Air recirculation in a room with heat releases can be assimilated with a pipe (Fig. 1a) through which the same flow of air circulates (hot inside and cold outside).

The cold air will enter the room by natural or artificial convection, pushing the hot air out if the room is provided with openings (for natural convection), or aspiring and evacuating holes (for artificial convection). The openings situated in the lower part of the room, or the upper part, respectively, both on the same side or on opposite sides, constitute local pneumatic resistances for the recirculating circuit.
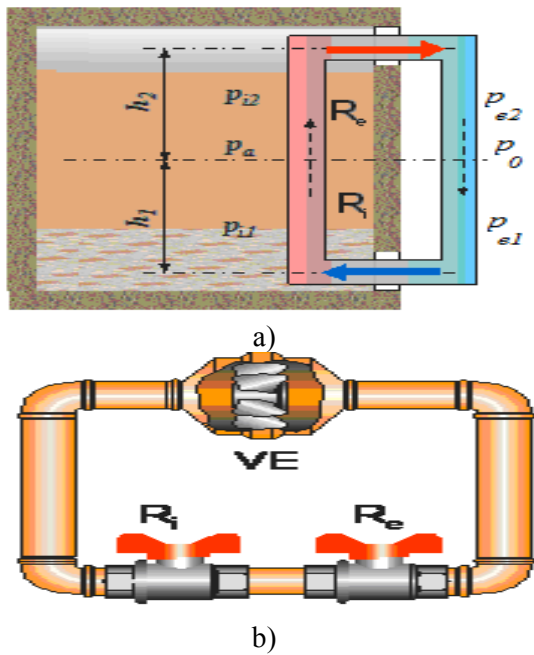
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Fig. 1: Explanatory schemes on air recirculation: VE - fan, R_e, R_i - pneumatic resistances.

Static pressure difference (also called thermal pressure difference), computed by relation [1], [4]

$$\Delta p = gA(\rho_d - \rho_a) \ [Pa], \qquad (2)$$

in which ρ_d, ρ_a are the densities of cold and hot air, and A is the height between the openings in the room, will lead to changing the state of the air, therefore to its recirculation. This phenomenon requires existing ventilation and is illustrated by ventilator VE, in Fig. 1b. Replacing g with its value ($9.8 \ m.s^{-2}$), and the expressions of density in equation (2), we obtain the approximate relation

$$\Delta p \cong 3450 A\left(\frac{1}{\theta_d + 273} - \frac{1}{\theta_a + 273}\right) \ [Pa], \qquad (3)$$

in which θ_d, θ_a are hot and cold air temperatures. For small differences in temperature between the inside and outside air, the result of multiplication $\theta_d\theta_a$ is neglected because $\theta_d\theta_a <<(273)^2$, and static pressure difference can be determined by the approximate relation

$$\Delta p \approx 12.6 A\left(\frac{\theta_d - \theta_a}{273 + \theta_d + \theta_a}\right) = \frac{12.6}{273 + \theta_d + \theta_a} A(\theta_d - \theta_a) \ [Pa]. \qquad (4)$$
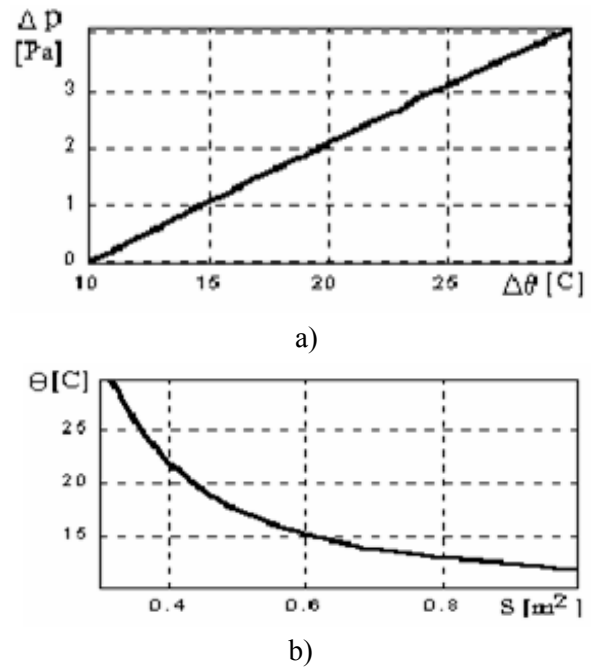

Fig. 2: Connections between pressure, temperature and the opening section of the room:
a) variation of pressure with temperature for $\theta_d = 10 \ ^0C$, $\theta_a = 32 \ ^0C$, A=4.5 m.

For local pressure losses computation, expressed in Pa or N.m^{-2}, *Weisbback* relation is used, in form [2]

$$\frac{1}{2}\rho\frac{D^2}{S^2 K_D^2} = RD^2 \ [Pa], \qquad (5)$$

where: S is the opening section surface; K_D is the opening coefficient (K_D=0.65 for widely open orifices); D is the airflow volume; R is the pneumatic resistance of the opening. *Bernoulii* equation corresponding to the recirculation phenomenon in the room (Fig. 1a), if there are pressure losses as a result of local resistances

$$gA(\rho_d - \rho_a) = \frac{1}{2}\rho_d\frac{D^2}{S_i^2 K_D^2} + \frac{1}{2}\rho_a\frac{D^2}{S_e^2 K_D^2} = R_iD^2 + R_eD^2 \ [Pa], \qquad (6)$$

is equivalent with the one corresponding to the pneumatic circuit in Fig. 1b (consisting in two serially linked pneumatic resistances)

$$gA(\rho_c - \rho_h) \cong 12,63 A\left(\frac{\theta_d - \theta_a}{273,15 + \theta_d + \theta_a}\right) \cong \frac{1}{2}\rho\frac{D^2}{S^2 K_D^2}, \qquad (7)$$

in which S_i, S_e and S are inflow and outflow surfaces, and the equivalent surface of the two pneumatic resistances (Fig. 1b) respectively, computed by the following relation

$$\frac{1}{S^2} = \frac{1}{S_i^2} + \frac{1}{S_e^2} \,, \tag{8}$$

and ρ is the average value of the two densities ρ_a and ρ_d.

Relation (4) illustrates a linear dependence between the pressure difference and the temperature difference in the room (Fig. 2a).

Relation (7) facilitates the computation of the opening section surface (Fig. 2b), in order to establish recirculation [5].

3 The Model of the Room as a Quadruple

Hypothesizing there is heat release in the room, for an elementary volume of fluid, mono-dimensionally moving along x (along the inner pipe), *Newton's* second law of movement and the continuity equation are written as [4]

$$\frac{\partial H}{\partial x} + \frac{1}{gS}\frac{\partial D}{\partial t} + \frac{k_f D|D|}{2gZS^2} = 0 \,,$$
$$\frac{\partial D}{\partial x} + \frac{gS}{v^2}\frac{\partial H}{\partial t} = 0 \tag{9}$$

where: v is the air speed in m.s⁻¹; D is the airflow volume expressed in m³s⁻¹; t is time, in s; Z is the pipe diameter, in m; S is the transversal section surface of the pipe expressed in m²; H is the total pressure (static and dynamic), expressed in m, given by relation [1]

$$H = \frac{p}{\rho g} \,, \tag{10}$$

in which p is the total pressure in N.m⁻².
Rubbing coefficient k_f depends on the flowing regime (in other words, on *Reynolds' number* Re) and is computed as it follows [2]:
- for laminar regime (Re<2000), by *Poiseuille's formula*:

$$k_f = \frac{16}{\text{Re}} \,,$$

- for turbulent regime (Re>3000), by *Colebrook-White's formula*:

$$k_f = \frac{0.25}{4\lg\left(\frac{k_s}{3.7Z} + \frac{5.75}{\text{Re}^{0.9}}\right)} \,,$$

in which k_s is the relative rugosity parameter [1]. Noting H_0 and D_0 the absolute values of the total pressure and the flow on the exterior pipe section, and going to the relative coordinates $h = \frac{H}{H_0}$, $d = \frac{D}{D_0}$, we will obtain

$$\frac{\partial h}{\partial x} + \frac{D_0}{H_0 gS}\frac{\partial d}{\partial t} + \frac{k_f D_0^2}{2gZS^2 H_0}d|d| = 0 \,,$$
$$\frac{\partial d}{\partial x} + \frac{H_0 gS}{D_0 v^2}\frac{\partial h}{\partial t} = 0 \,, \tag{11}$$

and then, working on the equations the equations $\frac{\partial h}{\partial x} \to \frac{\Delta h}{\Delta x}$, $\frac{\partial h}{\partial t} \to \frac{dh}{dt}$, $\frac{\partial d}{\partial x} \to \frac{\Delta d}{\Delta x}$, $\frac{\partial d}{\partial t} \to \frac{d(d)}{dt}$, we obtain

$$\Delta h = -\frac{D_0\Delta x}{gH_0 S}\frac{d(d)}{dt} - \frac{k_f\Delta x D_0^2}{2gZS^2 H_0}d|d| \,,$$
$$\Delta d = -\frac{H_0 gS\Delta x}{D_0 v^2}\frac{dh}{dt} \tag{12}$$

Noting $\frac{D_0\Delta x}{gH_0 S} = L$, $\frac{k_f D_0^2\Delta x}{2gZS^2 H_0} = R$, $\frac{H_0 gS\Delta x}{D_0 v^2} = C$, equations (12) for a discrete volume of moving fluid become

$$\Delta h = -L\frac{d(d)}{dt} - Rd|d| \,, \quad \Delta d = -C\frac{dh}{dt} \,, \tag{13}$$

and represent the basic equations of the T-shaped electrical circuit (quadruple) in Fig. 3a [6].

The block structure scheme of airing the room, in the case of heat releases illustrated in Fig. 3b, corresponds to the electrical circuit in Fig. 3a. Connecting the T-shaped electrical circuit to a source developing variable voltage (Fig. 4a), is similar to airing the room.

Room airing effectiveness can be calculated using the airing constant $T_C = \frac{H_0 S}{D_0}$, where S_c represents the cross section surface the discreet volume of fluid traveled through. In climatization technology, in rooms with or without heat releases,

recirculation processes are considered isobaric (because pressure variations with atmospherical pressure are insignificant), therefore this paper has not focused on featuring results coming from the model of the room as a quadruple.
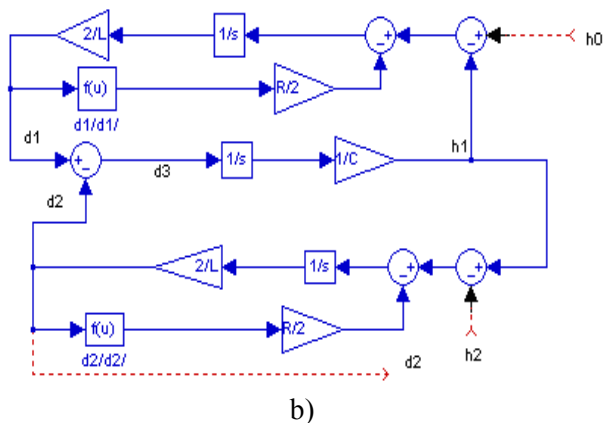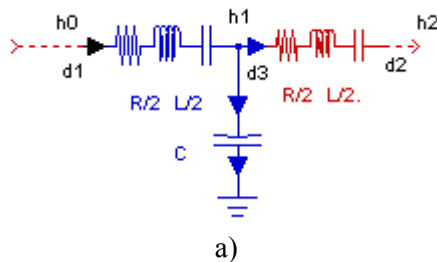

a)

b)

Fig. 3: The model of the room as a quadruple:
a) scheme of the analog electrical circuit similar to recirculating a volume of fluid;
b) the block structure scheme of airing the room, in Simulink.
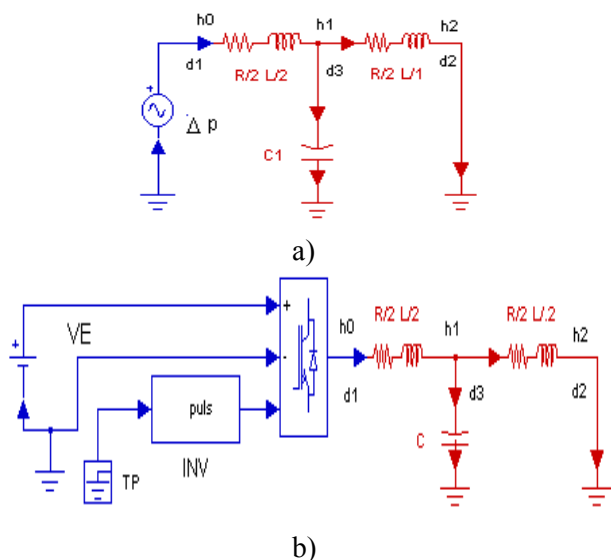

a)

b)

Fig. 4: The electrical circuit similar to airing the room: a) by natural convection; b) with a regulated fan.

However, in the case of starting the fan for ventilation results in [3] were obtained, highlighting pressure variations (with negative impact on the

installation or on the placement area) in the room. This phenomenon diminishes if the fans are started slowly via an invertor regulating the speed. Air recirculation by a fan VE (modeled as a source of constant pressure), managed by an invertor INV which receives its information from a pressure translator TP, placed in the room, is similar to the behavior of the electrical circuit illustrated in Fig. 5b.

4 Effecienty Solutions to Evacuate the Heat

A quality air conditioning installation must meet several requirements, such as a convenient operating cost, a limited degree of dehumidification of air, a low noise level and an absence of air currents. To meet these requirements must be considered: device configuration, cooling effectiveness, reversibility of its sound quality, location of evaporator in the room, place the outdoor unit, air conditioner adjustment, etc.
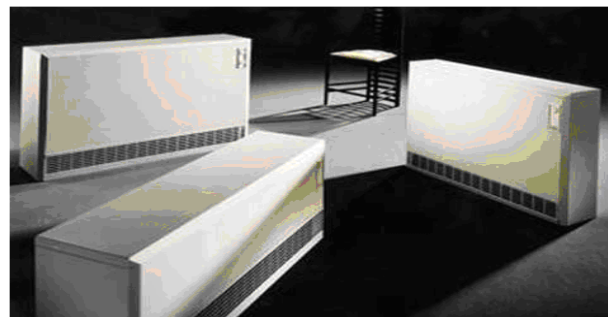

Fig. 5: Examples of indoor unit of air conditioning equipment.

Location of indoor unit is subject to strong occupant comfort (Fig. 5). Movements of air currents in the room depend on the location of the discharge openings / blower and exhaust in relation to the location of occupants. Reference values: maximum flow. A movement of cold air masses causes a slight impression of air currents (especially the neck and legs).

In practice, the average air velocity VR repressed in the occupation will be limited to the values given in Tab. 1.

Tab. 1

Host rooms, hospitals, rooms for education, entertainment and meeting rooms, offices and premises	$v_r = 0,12$m/s
Business premises, workshops	$v_r = 0,17$m/s
Sports facilities, shops and large industrial facilities	$v_r = 0,25$m/s

Choosing mouth discharge position of the air conditioning: it is not necessary to obtain comfort in all the room because there may be some areas occupied by residents. Occupation zones of a room are the recommendations Eurovent (Fig. 6).
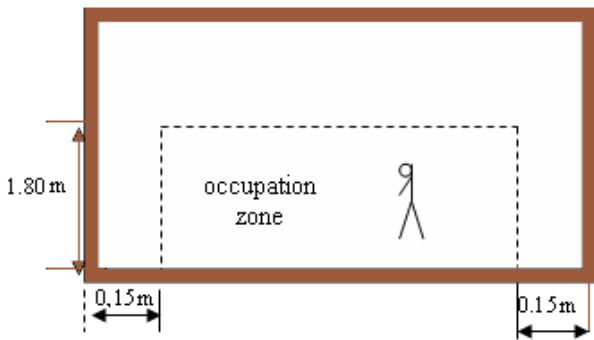

Fig. 6: Defining the occupied zone.

Developed jet must always lie outside the occupied zone. In any case airflow can not achieve its occupants before it is mixed with ambient air. In cooling operation, the most favorable position is that it can send a location opposite horizontal blast, blast that avoids air stratifications and formation of air currents inevitably occupation zones (Fig. 7).
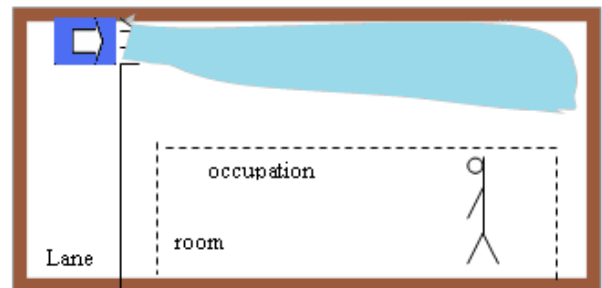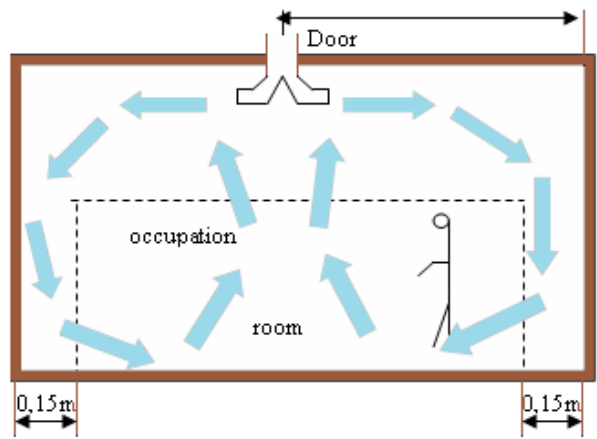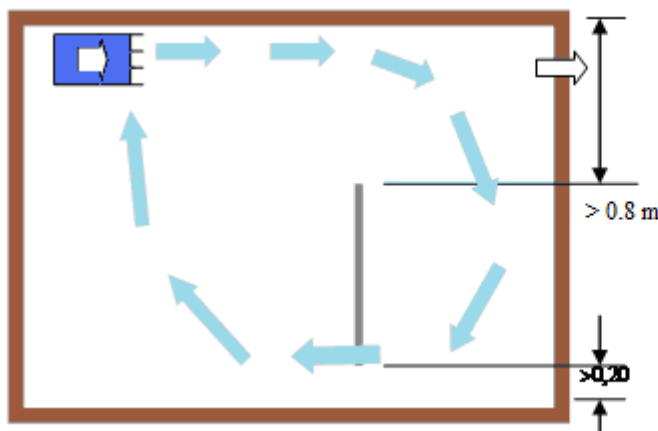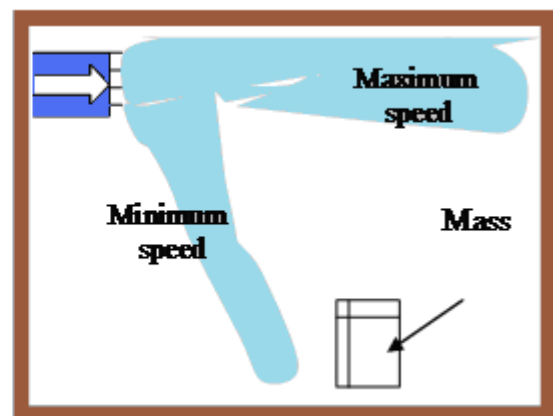

Fig. 7: Explanatory discharge openings on the location of air conditioning equipment.
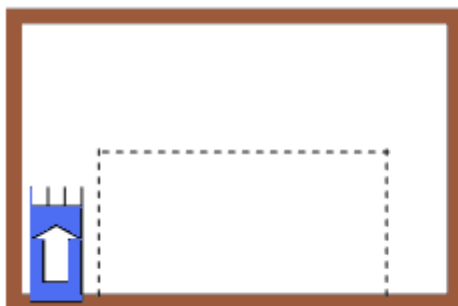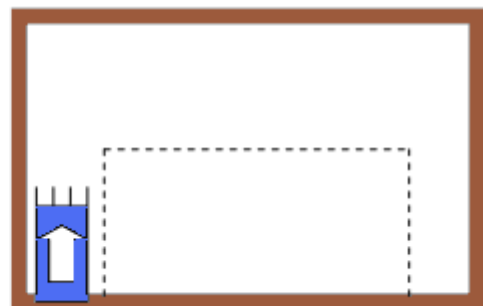

a)　　　　　　　b)
Fig. 8: Situations that may arise in the operation of air conditioning.

a)　　　　　　　b)
Fig. 9: Location of the discharge openings of air conditioning in heating mode.

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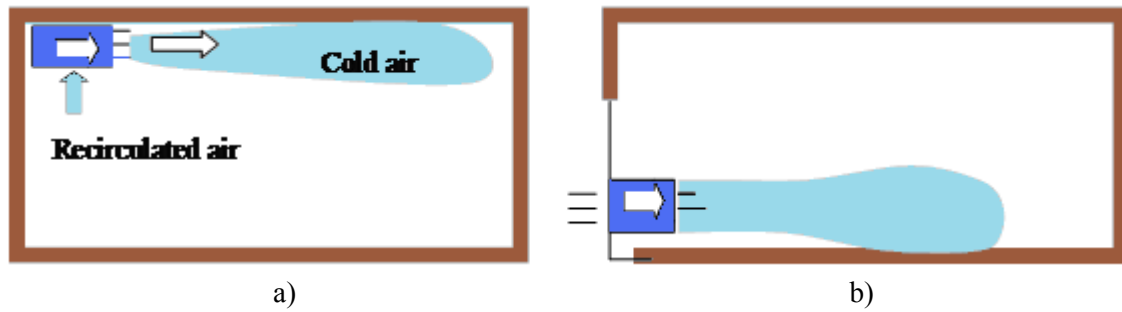Mastorakis, Jean-Octavian Popescu

a)   b)

Fig. 10: Explanatory location of air conditioning.

In this case, the location of the separation wall should not impede air circulation inside the room (Fig. 8a). The recommendation for discharge under the ceiling height can be uncomfortable if the room is very small, in which case it will be difficult to avoid a blast zone of occupation. Moreover, air conditioners have generally a range of three speeds. If equipment sizing is done based on a maximum speed, current low-speed operation may cause a rapid drop of the airflow on occupants and lead to human discomfort (Fig. 8b). Air diffusion in the room with air conditioning will be preferably based on an average speed. So the choice of air conditioning will be considered in catalog production, the speed is calculated based power device chosen. For products, local presence of distribution piping and adjustable openings significantly reduces this factor. When the device provides the functions of heating, the most favorable solution consists of a vertical wind starts blowing from the mouth of a lying on the ground or disposed on a console, such as air temperature will be limited stratification and cold penetrated through the joints windows in the cold is diminished (Fig.

9). This recommendation is not required in the cooling mode, in which case no one is in immediate proximity of the blast hole. Also, avoid tables, curtains, which can prevent proper air diffusion [9].

If a device placed in the ceiling, to ensure both cooling and heating (Fig. 10a) requires that it be equipped with a Standing jet orientation tuning. This will create a horizontal blast, during warm (cold air to avoid falling to occupants), and a breath downwards in the cold (to limit hot air stagnation at ceiling level).

If such a case does not exist (for example, a grid system or discharge pipe is not orientable), will be essential to adjust the discharge rate.

In heating mode, the device must operate at high speed to increase the volume of air. To have an operation range on how setting both cold and hot mode, the power device will be chosen based on a maximum speed but average speeds or even on the lowest speed. Finally, whatever the manner of use of air blast systems or obliquely arranged horizontally on the ground or half-height (the air conditioning, phone, piece) are uncomfortable posing serious problems (Fig. 10b).
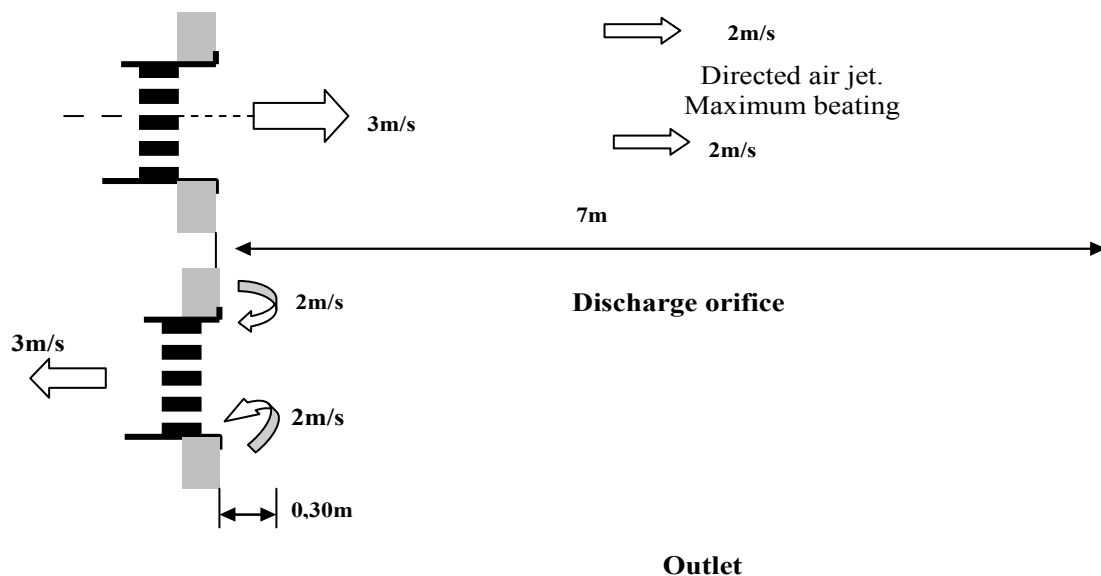

Fig. 11: Guidance on the location of the discharge openings for air conditioning systems.

Evacuation of condensate: condensate extracted from the ambient air vaporizer to be evacuated. Depending on the location of the evaporator, it will be by natural flow or by a pump. Wherever possible, have tried not to sacrifice comfort for easy disposal. To discharge condensate must take account of some technical recommendations [8]:
- choosing a discharge device disposed in the wall rather than the ceiling;
- perhaps the presence of beams perpendicular to the exhaust path, make things difficult;
- a tailings disposal common connection must be made with a soda to prevent spreading odors.

Condensate evacuation is not always natural and as such it is important to check the installer as it seeks to achieve (it is included in price). Also, keep in mind that steam must be integrated into the overall aesthetics of the site access and facilities
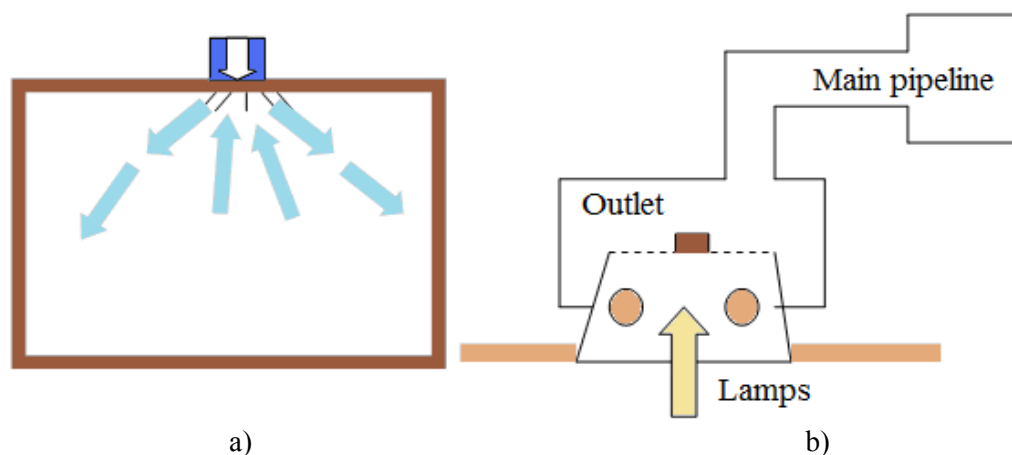
Tab. 2: Values of speed indoor air exhaust.

Discharge mouth position	Recommended discharge speed
outside the occupied zone	4.5 m/s
area occupied seats on the	between 3.5 and 4.5 m/s
occupied zone close seats	between 2.5 and 3.5 m/s
mouths the doors	between 1.5 and 2 m/s
under the door	between 1 and 1.5 m/s

Recirculated through the roof is not recommended when the air conditioning must work in heating mode. Warm air tends to remain near the ceiling, with the likelihood of direct recirculation of hot air before the exhaust to achieve a polluted air. In

Fig. 12: Explanatory position openings air conditioning systems.

maintenance cost and cost determined after sale service [7], [9].

Choosing mouth discharge position (for piping systems): comparing the effect of a grid used in the discharge / blast and another grid used in exhaust / intake, for the same air speed (eg 3 m/s) will be seen that (Fig. 11):
- produces a jet discharge mouth "the door" of 7m;
- outlet jet produces a door 0.3 m (in both cases, opening the door corresponds to a relative at a speed of 0.2 m/s).
Suction, air velocity decreases rapidly with distance once the opening, since the air intake comes from the area around the mouth (Tab. 2). This speed is not critical to the thermal comfort level, but may be the acoustic comfort. Conversely, if recourse to a recirculating circuit phenomenon must be considered: air blown into the room is sucked before replacing the polluted, ie before being influenced by ambient temperature (Fig. 12).

contrast, cooling only mode, will not be short-circuits and mouth or recirculating exhaust stroke is far from the maximum discharge openings. Is paradoxical when repression and recycling are located very close to each other and refresh the room air is quite good. With circular speakers mounted in ceilings, air is blown through the outer cones and drawn through the center. If a room is used to restore both the false ceiling to conceal piping and air conditioning equipment for the lighting, then recirculation or exhaust air must pass through the illumination lamps. Thus, the room heat load will be reduced by taking these and heat caused by the life of lamps is much larger. Location at the top of the wall provided that repression can be grouped and evacuation. Evacuation on the ground / floor is not recommended because of mouths that quickly turns into dirt collectors.

Examples of combining refulării eviction. Fig. 13 illustrates some examples of the location of air conditioners and exhaust vents (they are ranked from most comfortable to least comfortable).

Location of outdoor unit: capacitor placement plays an important role in terms of external appearance of the building, but also in terms of energy efficiency of the air conditioning [11], [12].
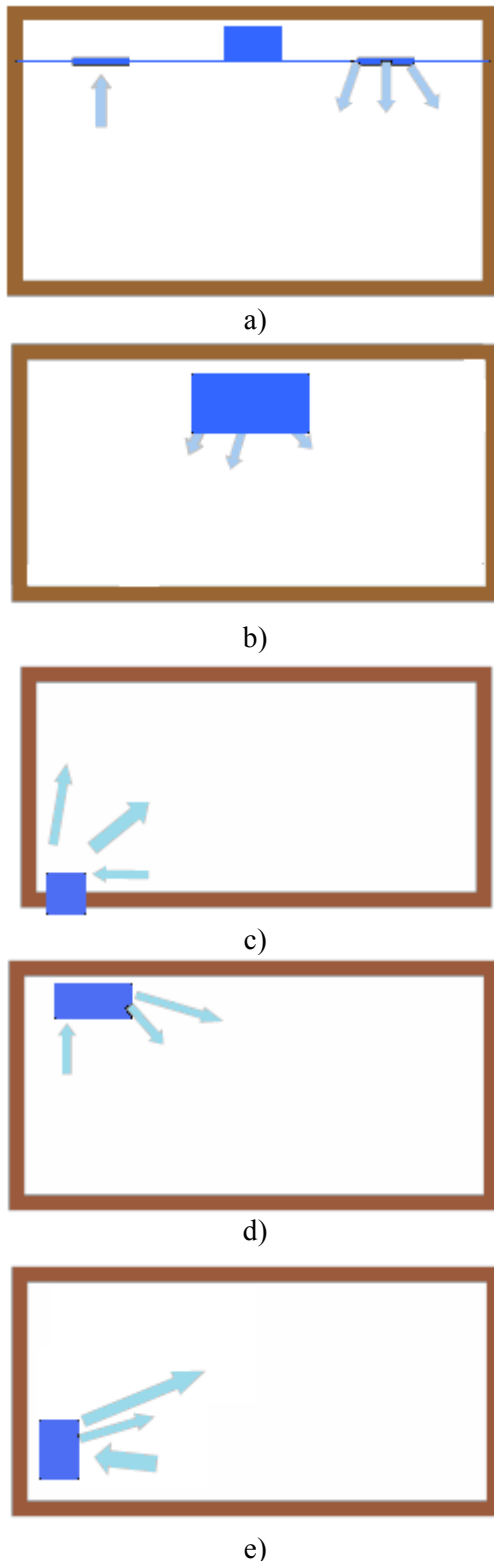

a)

b)

c)

d)

e)

Fig 13: Location configurations air conditioning equipment.

Condenser position makes both the energy consumption of air conditioner and its reliability and longevity [11].

Tab. 3

Advantages	Disadvantages
• optimum air distribution. • low noise. • false ceiling mount option. • multiple combinations. (Fig. 13a)	• short circuit risk because mouths are very close
• optimum air distribution. • low noise. • false ceiling mount option. (Fig. 13b)	• condensate evacuation difficulty (the need for dropping a slope)
• proper functioning heating and cooling mode (Fig. 13c)	• risk of short circuit and a very low speed blower •volume occupied the ground / floor •condensate evacuation difficulty (the need for a slope failure)
• optimal distribution of cold air humidified. • without volume occupied ground. • without volume occupied ground. (Fig. 13d)	• temperature stratification in heating mode • risk of horizontal temperature gradient • short-circuit heating mode • temperature stratification in heating mode • often very high air velocity space
• unit for a large column (Fig. 13e)	• discomfort in human height • short-circuit risk • risk of horizontal temperature gradient

Not recommended:

- *Installation of capacitor in an area exposed to the sun*. If the outside air temperature is high, then the capacitor will have difficulty in evacuation thermal load (heat quantity). Extreme example is the location of the condenser in a tightly closed and lined roof. In such places during the summer (much to the sun), roof surface temperature can reach 70 ° C. Conversely, mounting the condenser in a yard or well-ventilated and shaded area will improve its performance [10], [13].

- Mounting condenser winds in exposed places: in this case, venting, fan will have to overcome wind speed, in which case will not work correctly.
- Capacitor installation on a roof not accessible to man. Besides it will be necessary for maintaining a level of access, the maintenance will be little by little attention. Therefore, the performance of air conditioning and longevity will feel, and the cost of a breakdown will be higher.
- Installation of condenser on the ground close to the ground. The presence of fallen leaves on the ground, and dirt are easily sucked in by the fan, condenser being maintained dirt.
- Aesthetic destruction of a building facade. Condensers are less aesthetic elements. To determine the location will be considered for possible inclusion on the front blocks. Will prefer a less visible position in the human eye.
- Neglect of maintenance. Condensorul be simultaneously located in a place less exposed to poverty but also accessible to those who deal with its maintenance.

Ambient temperature in a room air is regulated by a thermostat acting on the compressor environment (stopping or starting its operation). The fan discharge shall be controlled, while the compressor, be allowed to operate continuously. The second mode is more favorable for the comfort of air conditioning when you need a continuous flow of air to air înlăturestagnarea hot or so cold and uncomfortable condition.

Location of a thermostat plays an important role both in terms of energy consumption and in terms of comfort in the room. Thermostat must be placed in a value representing the average temperature of the room, which means removal of hot or cold sources (lamps, lighting, windows in summer, areas exposed to sun, wind area of the device). Preferably, the thermostat should be placed in the mouth of the discharge. Otherwise, you will need to be calibrated.

By a simple room temperature control to ensure economic operation and programming functions occupation room (off air and repression treaty) should be expected in an intelligent manner.

Using a thermostat control with an important role in effective management of occupants ambiance. If the order is placed on your roof, the occupants will take care to adjust the desired temperature.

5 Conclusions
Modeling the phenomenon of air recirculation in the case of heat releases is important, on the one hand, because it highlights the connections between climatic variables (pressure-temperature), and, on the other hand, because it facilitates the computation of an *airing constant* used in establishing the *efficiency* of a passively climatized room.

In the second part of the paper were illustrated and commented on some modern solutions rebreathing in rooms where there is the heat. These solutions are a result of modeling done in the first part of this paper,

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