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# The Hygienic Ventilation in Combination with Radiant Heating for Industry Buildings

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## Abstract

*Our national husbandry belongs among economies with the biggest energy consumption per an inhabitant. Slovak republic consumes for making of product's unit approximately twice more energy than the average in forward European countries. Such a big reserves, that we have to achieve in the area of effective increasing of energy utilization are not possible only by administrative way, but by establishing of new technical solutions into a general practice too. In a part of large-area industry operations, the new technical solution lies in the combination heating system by radiant panels with ventilation by air handling unit with integrated device for heat recovery, which considerably reduces the operation costs.*

*Paper shows the advantages of this combination described in a computational example, as well as experimental measurements.*

*Every step in the calculations and measurements leads to create an optimal working environment for humans with minimum energy requirement.*

**Keywords – mechanical ventilation, radiant panel, industry large-area buildings**

## 1. Introduction

A comprehensive attitude has to be taken when creating a work environment in an industrial hall, in a large-area building. It is not only the issue of the heating itself but the way of air supply and air heating as well. The dimensions of halls and the underlying physical laws enable to create zones that are the major factor to choice of heating and ventilation systems. The new technical solution lies in the combination heating system by radiant panels with ventilation by air handling unit with integrated device for heat recovery, which considerably reduces the operation costs. [1]

Every step leads to create an optimal working environment for humans with minimum energy requirement.

## 2. Basic Zones of Energy Intensity

Every large-area industry building can be divided into zones, which are characterized by a different temperature of indoor air in the vertical direction of an object.



The direct contact with the building encasement – the roof and the skylights, as well as the walls and windows, causes increased heat loss. The higher the temperature of indoor air in these zones is, the greater the heat loss and energy requirements are. It is therefore necessary to include the above mentioned features of each zone when designing ventilations systems. [2]

### 3. Combination of Heating with Ventilation

With regard to the amount of the ventilation air supply, there are two categories of ventilation systems. Ventilation in clean areas, where minimum pollutants occur during the manufacturing process, is so called *hygienic ventilation* with 0,5 ÷ 1,0 times/h air exchange. If there is multiple air exchange during the manufacturing process due to the increased amount of pollutants, we talk about *technological ventilation*.

#### 3.1 The combination of suspendable radiant panels with hygienic ventilation

The principle of vertical air flow is suitable for hygienic ventilation. It uses the air heat capacity from the neutral zone and the zone of the building's energy consumption. Recuperative unit draws warm air from the roof space through suction elements. Then it brings it through a collecting duct towards recuperation exchanger unit. Ventilation air heated from  $\theta_e = -15\text{ °C}$  to  $+3\text{ °C}$  is blown by the diffuser into the space. The diffuser vanes settings allow to bring the colder air horizontally into the space bellow the radiant panels. Afterwards it is mixed with the warm air ( $\theta_{ai} = +18\text{ °C}$ ) and slowly sinks into the occupied zone, where it reaches the desired temperature  $\theta_i = +16\text{ °C}$ . Increased performance of the radiant panels is required in order to enable thermal energy to reach ventilation air temperature  $+16\text{ °C}$  in the area of the neutral zone (from the temperature  $+3\text{ °C}$ ). The principle of air supply and its heating fully supports its delivery using the thermal capacity of “the warm pad” under the roof covering. [1], [3]

The values are chosen according to a sample design of ventilation in a large-area building (Fig. 4) with a height of 7,2 m below the roof covering and diffusers mounted in a height of 6,0 m with unit output 920 m<sup>3</sup>/h. Total air flow rate  $V$  is:

$$\begin{aligned} V &= n \cdot V_1 \\ V &= 5 \cdot 920 = 4600 \text{ m}^3/\text{h} \end{aligned} \quad (1)$$

where  $n$  is number of diffusers,  $V_1$  is an air flow rate of one diffuser. Air exchange in a building  $i$  is:

$$\begin{aligned} i &= \frac{V}{V_b} = \frac{V}{(l \cdot w \cdot h)} \\ i &= \frac{4600}{(60 \cdot 18 \cdot 7,2)} = 0,59 \text{ times/h} \end{aligned} \quad (2)$$

where  $V$  is total air flow rate of diffusers,  $V_b$  is object's volume,  $l$  is length,  $w$  is width,  $h$  is high of object.

The basic settings of vanes (Fig. 3) for the outlet temperature  $\theta = +3\text{ }^{\circ}\text{C}$  to  $0^{\circ} \div 45^{\circ}$ . For temperature  $+3\text{ }^{\circ}\text{C}$  to  $+16\text{ }^{\circ}\text{C}$  continuously towards the outlet angle of  $60^{\circ}$ . The angle of the vane changes with the increasing height of the object, or diffusers' suspension (to  $90^{\circ}$ ). Continuous change of the vanes' settings are controlled by a signal  $0 \div 10\text{ V}$ , depending on the temperature of incoming ventilation air.

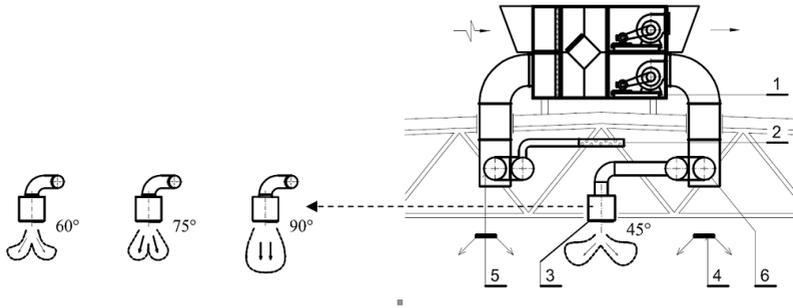


Fig. 3. The basic settings of vanes of diffuser  $0^{\circ} \div 90^{\circ}$

- 1 - ventilation heat recovery unit, 2 - exhausting diffuser, 3 - supply diffuser, 4 - suspendable radiant panel, 5 - exhausting air conduit, 6 - supply air conduit

Another option for hygienic ventilation is a unit with the heat recovery (located on the roof of building) without central air distribution. These units, among others, are always equipped with effective filtration, heat recovery bypass, adjustable air output and a measurement and control module.

There is a shutter under the ceiling that exhausts the polluted air and at the end of the duct there is a remote controlled nozzle outlet, which supplies the ventilated space with fresh air. After recovery, they can also be equipped with supplementary air heating, but that is not usually necessary when combined with the suspendable radiant panels.

Exhaust air inlet has to be placed in the area above radiant panels, in the as highest place as possible. It is clear that the rising warm air flow almost along the entire surface heated by the floor is the basic principle of radiant heating. This is proven by visualization of temperature distribution and air velocity across the entire hall. Obviously, the cooler air falls down in the areas which are mostly cooled by the roof covering. This always happens below the skylights and on the peripheral walls, particularly if they are provided with windows. The fresh air outlet should be placed in the area below the skylight. A vertical flow of supply air is introduced into the natural downward convection below the skylight and then it rises up once again together with the air heated from the floor.

The principle of air flow in radiant heating is fully respected and the hall space is perfectly rinsed (Fig. 5).

Fig. 4. Large-area building

1 - ventilation heat recovery unit, 2 - exhausting diffuser, 3 - supply diffuser, 4 - suspendable radiant panel, 5 - exhausting air conduit, 6 - supply air conduit

Under certain circumstances, low (outdoor temperature) it may be advantageous to use the outlet and the possible horizontal flow which at a sufficient velocity at the peripheral walls changes into a vertical one, descending downwards to the floor. After its heating by the floor it goes upwards and the hall is being rinsed. (Fig. 6). In both cases, however, it is possible (to a certain outdoor temperature) to operate just with the heat recovery unit, without subsequent reheating of fresh air, because the supply air is reheated not only by induction but also by the so-called secondary heating surfaces.

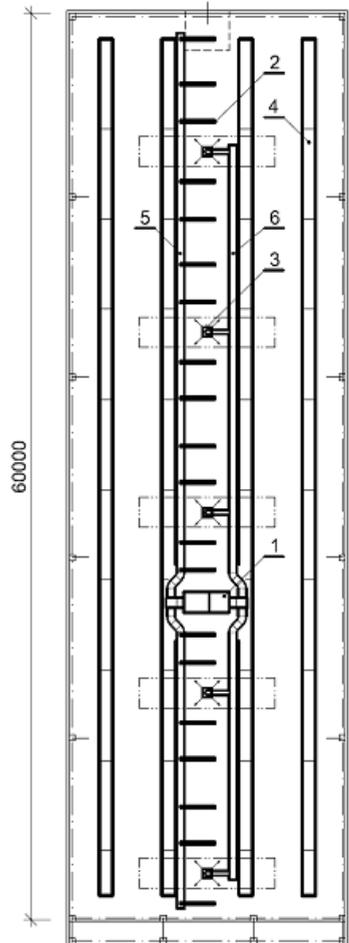
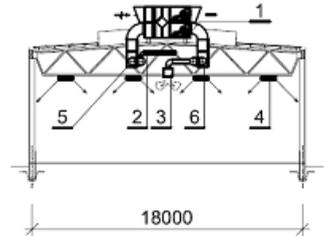


Fig. 5. Vertical airflow input



Fig. 6. Horizontal under ceiling airflow input

### 3.2 The combination of suspendable radiant panels with technological ventilation

In the manufacturing halls with more pollution, both supply and heating of the ventilation air as well as the removal of contaminated air including its thermal capacity has to be taken into consideration. The combination of radiant heating with ventilation and the related method of creating microclimatic conditions makes it a very efficient technical solution.

Radiant heating provides thermal energy by radiating the floor. The air is subsequently heated by the floor and then rises towards roof covering. This principle can be used to deliver fresh air into the working zone. The large-format diffuser are located along the circuit of the heated and vented workshop bringing the heated ventilated air to a temperature of about  $1 \div 3$  K, which is lower than the temperature of the indoor air in the space. The discharge rate is  $0,3 \div 0,5$  m/s. Its reheating takes place from the warmer part of the floor and machines, and subsequently rises towards the roof covering. The working zone is being filled with fresh air while the pollutants are being removed. [2]

A significant advantage of this solution is that the exchange of air for ventilation calculate with the space's height of up to 3,5 m. As a variation, you can use the recovery unit located either on the roof or on one of the front walls. [10], [11]

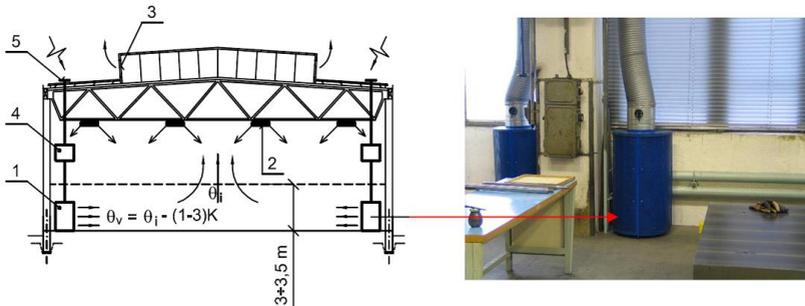


Fig. 7. The principle of ventilation by large-format diffusers

1 – large-format unit, 2 – suspendable radiant panel, 3 – axial fan, 4 – air heater, 5 - outside (fresh) air input

The air of the above mentioned temperature of  $1 \div 3$  K, lower than the temperature of the indoor air in the ventilated space, is delivered by the air conduit towards outlets. Its removal takes place in the upper part of the object from the area of so called "warm pad" under the roof covering. This is done by air suction elements via the recovery unit.

In the example presented, a workshop measuring  $36 \times 18 \times 7,2$  m was chosen, with required air exchange ventilation 6 times/h and total air flow rate  $V_1$  is:

$$V_1 = i.V_b = i.(l.w.h) = 6.(36.18.7,2) = 27994 \text{ m}^3/\text{h} \quad (3)$$

where  $i$  is air exchange ventilation,  $V_b$  is object's volume,  $l$  is length,  $w$  is width,  $h$  is high of object.

If you take into account only the height up to 3,5 m above the floor, the total air flow rate  $V_2$  will have the value:

$$V_2 = i.V_b = i.(l.w.h) = 6.(36.18.3,5) = 13608 \text{ m}^3/\text{h} \quad (4)$$

The ratio of these both total air flows is:

$$\frac{V_2}{V_1} = \frac{13608}{27994} = 0,48 \quad (5)$$

This number accounts for 50 % heat saving needed for heating the ventilation air. This ratio is always determined by the real height of the object.

The control of this combined heating and ventilation system is performed as follows – the performance of radiant panels is controlled by the temperature taken by the spherical sensor. The inlet temperature of the ventilation air falls down in the duct to a constant temperature of about 2 K below the estimated air temperature in radiant heating. [4], [8], [9]

#### 4. Experimental measurements

In according with STN EN ISO 7726 (2001) we had been two experimental measurements in large-area industry object (Fig. 4), which had the task to objectively evaluate the combination of heating system by suspendable radiant panels with ventilation.

In 12 measuring points, randomly distributed in different parts of the whole area of building, was measured following physical parameter:

- indoor air temperature in the level of the head man, measured at a height of 1,70 m above the floor,
- indoor air temperature in the level of the ankles man, measured at a height of 0,15 m above the floor.

Measurement results are shown in Table 1.

Table 1. Measurement results of indoor air temperature in two levels

Physical parameter	No.	Measuring point number											
		1	2	3	4	5	6	7	8	9	10	11	12
1. $\theta_{ai, head}$ (°C)	1.	19,8	19,9	19,9	21,2	19,8	19,8	21,6	21,3	20,7	24,4	22,8	21,5
	2.	19,7	19,9	19,8	21,4	19,7	19,8	22,0	21,2	20,5	23,9	22,5	21,3
	3.	20,0	19,8	20,0	21,2	19,8	19,6	22,7	21,3	20,7	24,2	22,9	21,3
2. $\theta_{ai, ankles}$ (°C)	1.	20,4	20,3	20,4	19,3	20,3	18,9	19,2	19,3	21,6	22,1	21,3	19,6
	2.	20,1	19,8	20,2	19,4	20,3	18,7	19,0	19,2	21,4	21,9	21,3	19,4
	3.	19,8	19,9	20,2	19,3	20,5	18,7	19,1	19,2	21,7	22,0	21,5	19,5

The following diagram (Fig. 8) illustrates the indoor air temperature running in the work area of human.

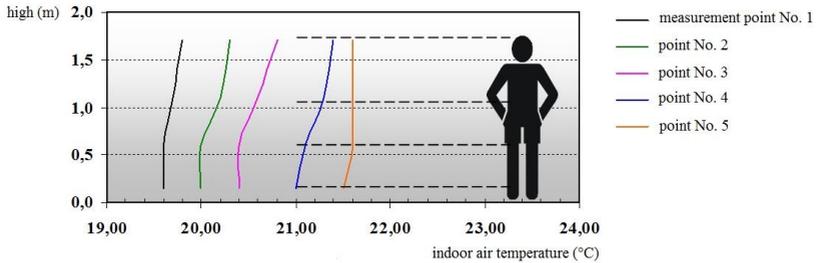


Fig. 8. Vertical temperature gradient of indoor air temperature

Difference between the maximum and the minimum value at a particular point is a maximum  $\Delta\theta_{ai} = 0,4$  K. The rule according technical norm is maximum 3,0 K.

Thanks assessment we can confess that the combination of heating system by suspendable radiant panels with ventilation stood as positive in terms of uniformity of thermal conditions in the indoor environment. [6], [7]

## 5. Conclusions

The described method with vertical ventilation of fresh air supply in combination with radiation heating is particularly advantageous for the ventilation of indoor space to ensure hygienic minimum when  $i \leq 1$  times/h. In many cases this may be suitable for air exchange of bigger volume. Those are the areas where the obstacles in the movement of persons could be of issue in reaching stabilized supply. In both cases, it is always necessary to carefully consider the flow velocity in the occupied zone in order not to exceed health standards. Ventilation system with vertical inlet can be applied to less clean premises. However, we have to respect the above mentioned principles when designing and the principle of its parallel run with heating system. The result is a paying system which can be easily operated and does not require a lot of investments. Moreover, it enables to adapt easily to changing operational and technological requirements. [5]

The cooperation between ventilation and heating systems in industry large-area buildings is very important. Design of one system without the other causes an increase in operating costs mainly in energy consumption (electricity, heat, cooling, etc.). And there is not ensured required parameters of indoor living area. Therefore, we as designers should keep in mind the rule about creating an optimal working environment for humans, but at the same time at the lowest possible energy consumption.

## Acknowledgment

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