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INDOOR AIR QUALITY AND MECHANICAL VENTILATION FOR TECHNOLOGY BUILDINGS

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Abstract: Creating of indoor environment in the work area in industrial buildings should be based on cooperation between heating and ventilation. However, practice shows that this is not truth in many cases. Both professions are many times designed separately. Result is their non-cooperation leading to a mutual obstruction in terms of disposal location or functional operation of the systems. Creating a heating and ventilation system, which would both be designed in accordance with applicable legislation and it would create an optimal indoor environment for people in working area, to find solution in combination of radiant heating with ventilation air recovery unit.

Keywords: Indoor air quality, Ventilation, Radiant heating; Heat recovery unit

1. Introduction

Every design of Heating, Ventilating and Air Conditioning (HVAC) in project activity is based on a large number of assumptions whose veracity is supported either in theory (literature) or by experience-based knowledge. However, there are cases with a unique input, or with a brand new, yet uncommon HVAC system. Unfortunately, all other modifications and repairs result in increased investment costs compared to the forecasted ones [1], [2].

In other cases, it is not unusual that the expected parameters of the internal environment calculated by the designer are not being reached after implementation.

A computer analysis on a defined model of an industrial building may be very beneficial for solving this issue. It can be verified whether the proposed system will or will not bring the expected results in creation of thermal comfort in the work area of a human and whether this creation of the 'comfort for a human' will not be at the expense of too high energy consumption [3], [4].

The aim of this article is to introduce the technical solution that brings the benefits both on the energy savings, as well as in achieving optimal microclimate for the man in his work area.

2. Principles of cooperation of the two systems

Radiant heating system is designed to cover the heat loss in winter. Suspended radiant panels provide thermal energy to the heated space mainly by radiation (70%). The radiant component heats the building structures constituting the internal space - walls and floors, from which, in turn, the internal air inside the work area is heated. The convection component by the performance of radiant panels (30%) rises by convection (flow) upwards into the roof space of the hall where it diminishes in form of heat loss by the roof structure. Yet, this lost heat can be used in a heat recovery air unit for heating (or preheating) of fresh, but cool outdoor air, designed for sanitary ventilation of an industrial building. The principles of the vertical airflow through large surface diffusers are suitable for sanitary ventilation. Thanks to their length, they are a suitable distribution element - shown in *Fig. 1*. The accumulated heat capacity of air from the neutral zone and the energy performance zone of the building is of use to the recovery unit by in-taking of the warm air from the space under the roof through the suction elements (e.g. a single row rectangular diffuser) [5].

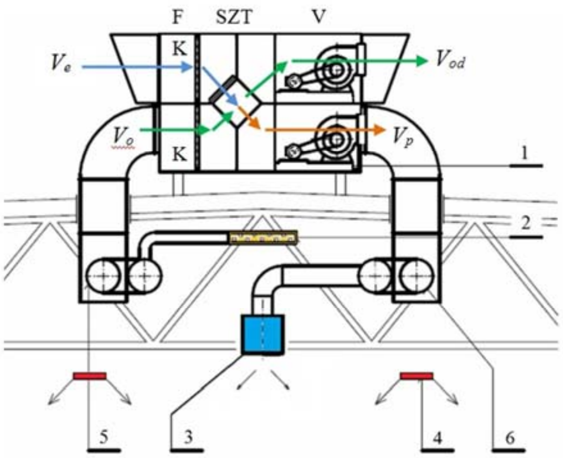

Fig. 1. Ventilation recovery unit with central air distribution via volume diffusers [6]
1 is the recovery unit; 2 is the rectangular single row diffuser (air discharge); 3 is the volume diffuser (air supply); 4 is the suspended radiant panel; 5 is the air channel for exhaust air; 6 is the air channel for supply air; V_e is the external air flow; V_p is the supply air flow; V_o is the discharge air flow; V_{od} is the waste air flow; K is the flap; F is the filter; SZT is the reverse heat gain in heat recovery exchanger; V is the fan

Consequently, it is piped by the air channel into the plate heat exchanger in a heat recovery unit where the air transmits its heat energy to the colder outside intake air, which is heated to an acceptable temperature in regard to recovery heat exchanger efficiency. As mentioned above, this air is blown by the large-volume diffusers into the space below the suspended radiant panels. In this area, it is mixed with the warmer internal air inside, and such compressed air slowly descends into the work area where it reaches the desired calculated internal temperature. The thermal energy necessary for additional heating of the external from the air temperature behind recovery heat exchanger to the internal calculated temperature of air has to be delivered to the heated area by increased thermal performance of radiant panels [7], [8].

3. The model of a hall storage building

The example of calculation and design of systems in combination of sanitary ventilation with radiant heating is used in the construction of one-floor, single-aisle free-standing hall building with socio-administrative annex situated at the head of the building (*Fig. 2*).

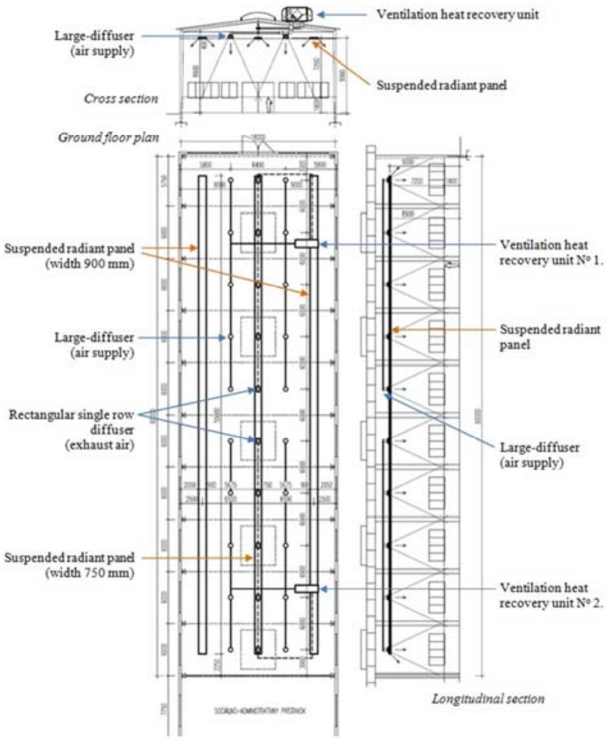

Fig. 2. The ground floor plan, the cross and longitudinal section of an industrial building and a diagram of the combined system [6]

It is a storage building with a frequent intake and outtake of goods. The building situated in the city of Bratislava (Slovakia) belongs - in terms of the area type - to the first temperature range zone in winter ($\theta_e = -11^{o}\mathrm{C}$), to the second wind zone with wind speed between 2-5 m/s and to A-temperature zone in the summer ($\theta_{e,m} = 20.5^{o}\mathrm{C}$) [9], [10].

3.1. Defining the external environment parameters

When calculating the heat gain within the meaning of STN 73 0548:1985, the ambient temperature θ_e = 30 °C is considered (*Fig. 3*). However, in the calculation of the heat gain from the outside air intake, it is preferable to consider a higher temperature of θ_e = 35 °C, so that the HVAC unit regulation could guarantee the required indoor air temperature of θ_i = 26 °C during extremely warm summer days, although the legislation allows to reduce the intake of outside air to its half value for a short period in case of maximum outside air temperatures [11], [12], [13].

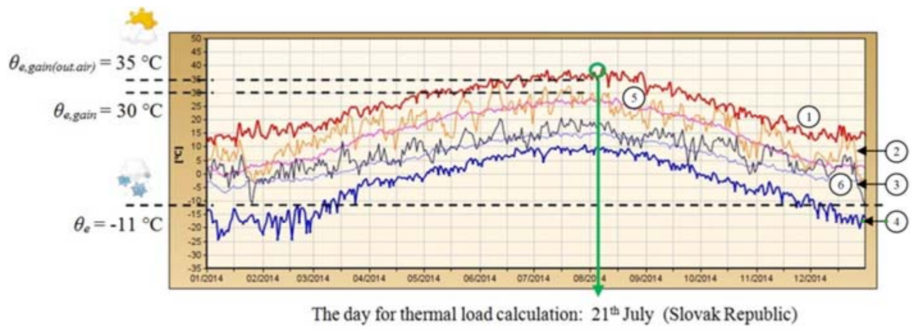

Fig. 3. The maximum and minimum outdoor air temperature - Bratislava - airport 2014
1 is the absolute maximum daily air temperature for the period 1951-2013; 2 is the daily maximum air temperature for the year 2014; 3 is the daily minimum air temperature for the year 2014; 4 is the absolute minimum daily air temperature for the period 1951-2013; 5 is the long-term average daily maximum air temperature for the period 1961-1990; 6 is the long-term average daily minimum air temperature for the period 1961-1990 [11]

When the intensity of solar radiation changes so does the intensity of diffuse solar radiation as well as the outside air temperature θ_e (*Table I*).

Table I

The average outdoor temperature θ_e (° C) per month

Month	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Temperature θ_e	-11	-5	+10	+15	+20	+25	+30	+27	+20	+10	0	-8

3.2. Defining the parameters of the internal environment

Indoor air temperature θ_i and the relative humidity of indoor air φ_i are important in terms of analysis of the combined system (*Table II*). The binding regulation refers to the maximum value for the summer season (θ_i = 26 °C) and minimum values for the winter season (θ_i = 18 °C).

Table II

Indoor air temperature θ_i [° C] and relative humidity of indoor air φ_i (%)

Month	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Temperature θ_i	18	18	18 → 26			26	26	26	26 → 18			18
RH φ_i	30 - 70											

4. Overview of energy balance in each month

Energy balance in general is the ratio between energy intake and expenditure. In terms of the operation of a building, the balance between the heat load Φ_{load} and heat loss Φ_{loss} is monitored. It reaches its maximum during the summer and winter, but in inverse proportion - in summer the maximum load and loss is minimal or zero; and vice versa during winter [14], [15]. In the transitional seasons (spring, autumn), these two values converge. When the outside air temperature changes, the required indoor air temperature can be achieved only by the delivery of energy, produced in the form of heat and cold. If the amount of energy consumed equals the amount of energy delivered, then the energy balance is just right. Gradually, the input values for the total energy balance calculation were calculated by using the defined parameters of external and internal environment [16], [17], [18]. The results are shown in the *Table III*.

The table shows the impact of changing climate of the outside environment on the heat loss and heat loads values inside the industrial building. They are quite different during the year.

For better orientation in these issues the results are shown in *Fig. 4 - Fig. 9.*

5. The analysis of combined system operation

The aim is to find out how their mutual cooperation reflects the need for heat and cooling energy in comparison to a situation where there would be two separate operating systems (ventilation by direct-hot air heating units + heating by radiant panels) [19], [20].

Table III

The summary of the energy balance results

Month	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
External Environment Parameters												
Temperature θ_e [°C]	-11	-5	+10	+15	+20	+25	+30	+27	+20	+10	0	-8
Intensity of solar radiation I_o [W/m^2]	710	700	674	596	558	492	511	598	575	558	550	540
Intensity of diffuse solar radiation $I_{o,dif}$ [W/m^2]	10	45	75	100	112	122	117	99	78	50	25	7
Internal Environment Parameters												
Temperature θ_i [°C]	18	18	18	18	20	25	26	26	20	18	18	18
RH φ_i [%]	30 - 70											
Calculated values of energy balance												
Thermal gains Φ_{gains} [W]	0	0	34050	38417	40842	38460	38630	36403	34467	29336	0	0
Thermal gain (outdoor air) $\Phi_{e,gain}$ [W]	0	0	0	0	0	0	43414	40953	0	0	0	0
Thermal load Φ_{load} [W]	0	0	34050	38417	40842	38460	82044	77356	34467	29336	0	0
Supply of heat energy _ Heating system (Radiant ceiling panels)												
Heat output Φ_{panels} [W]	86326	62404	28321	14424	0	0	0	0	0	28321	51043	73523
Supply of heat and cooling energy _ HVAC system (Ventilation recuperative unit)												
Air temperature (under the roof) $\theta_{i,tv}$ [°C]	19.50	20.24	21.16	21.53	20	25	26	26	20	21.16	21.92	19.45
Air temperature (behind heat exch.) $\theta_{i,rec}$ [°C]	17	18	19	20	20	28	28	28	20	19	19	18
Efficiency of heat exchanger η_{he} [%]	93	90	76	75	75	75	75	76	76	78	88	91
Heat output heater Φ_h [W]	600	200	-	-	-	-	-	-	-	-	-	600
Cooling output cooler Φ_c [W]	-	-	-	-	41012	42760	83580	78360	35704	-	-	-

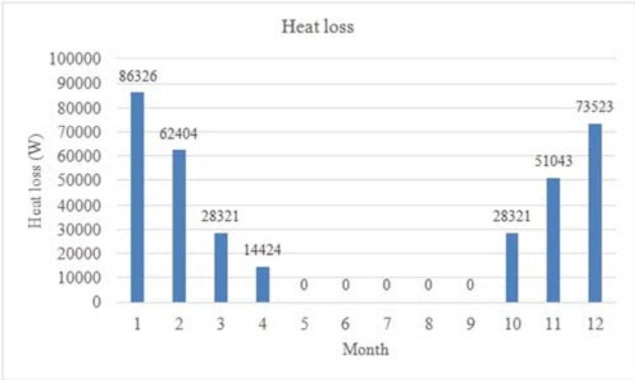

Fig. 4. Heat loss of large area storage building

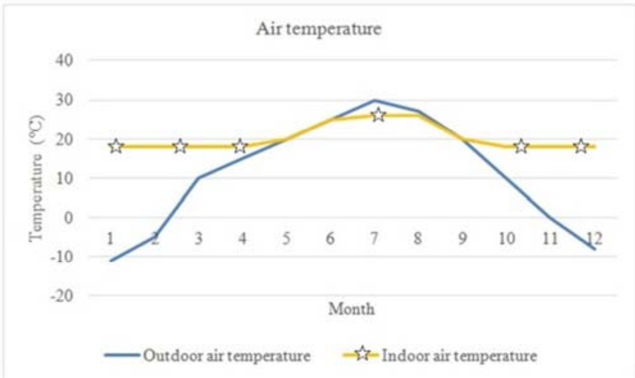

Fig. 5. Progress of outdoor and indoor temperature during whole year

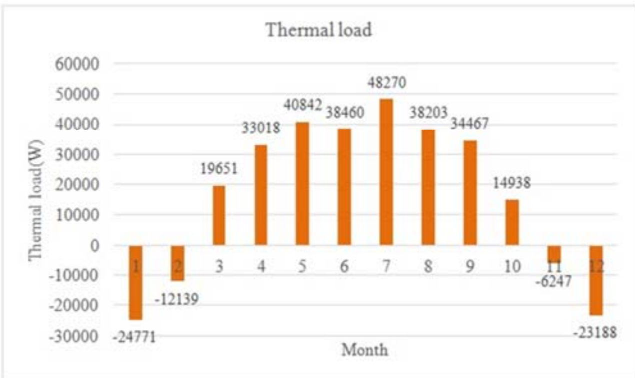

Fig. 6. Thermal load of large area storage building

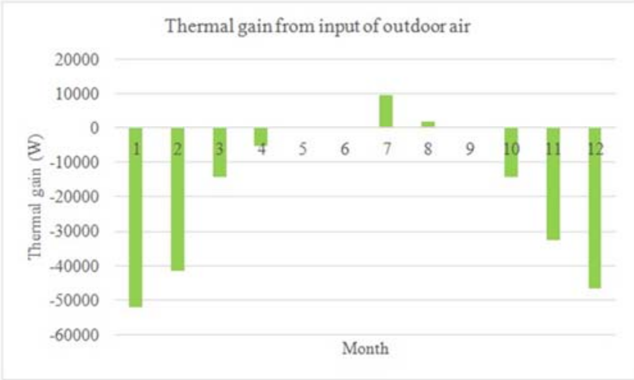

Fig. 7. Thermal gain from outdoor air

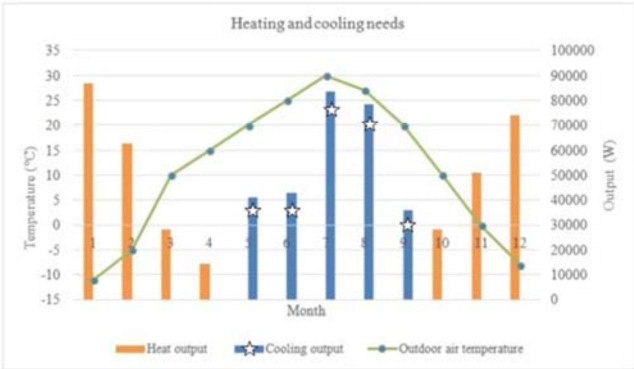

Fig. 8. Heating and cooling needs in relation to outside air temperature (the combined system)

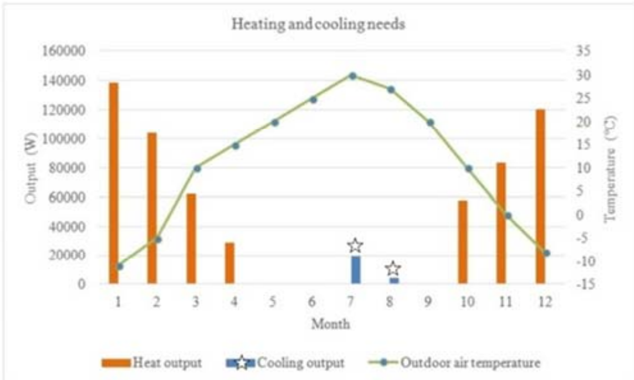

Fig. 9. Heating and cooling needs in relation to outside air temperature (two separate systems)

6. Conclusion

Based on the analysis of the graphical outputs, it can be stated that the numbers speak clearly in favor of the combined system.

As it can be seen from the results, the combined system partly needs a heat and cooling energy during whole year in relation to outside air temperature. But compared to separate systems maximum heating needs is higher by 37% against the separate systems (combined system approximately 87 kW, separate system approximately 139 kW) in winter period.

As for the summer period, a separate system does not solve inside microclimate in no way. Inside air temperature mostly reaches the value 29 °C or higher, which is unacceptable from a health perspective. Therefore, the cooling needs is necessary.

Thanks to its function and mutual cooperation we can achieve significant energy savings in comparison to the ventilation system with direct ventilation while meeting the requirements of the internal working environment.

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