INFORMATION - CALCULATION METHOD FOR ENERGY EFFICIENCY RADIANT HEATING SYSTEMS IN INDUSTRIAL PREMISES

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Abstract: *The paper considers a model and an algorithm for predicting the thermal regime in work (home) accommodation with radiant heating. The algorithm allows the analysis and design of cost-efficient option for realization of this type of heating.*

Keywords: INFORMATION-CALCULATION METHOD, ENERGY EFFICIENCY, RADIANT HEATING SYSTEM

1. Introduction

Temperature, relative humidity, air mobility in the occupied areas, the surface temperature of the surrounding building elements, and the temperature of the equipment in the facility prove essential to the flow of vital processes in the human body.

The multifactor system determining the thermal conditions is the basis for choosing a heating system of the manufacturing facilities. Serious attention should be paid to all these factors, since not only the quality and functioning of the equipment situated in the production room depends on this, but also has an impact on the effectiveness of workers who spend most of their time indoors.

Constant temperature of the air in the manufacturing facilities is usually needed, without radical changes which could have a negative impact on the installed equipment and the employees. It is also necessary to take into account regulatory requirements in terms of explosion and fire safety. The production facilities themselves usually occupy a considerable area, on which the different production or technical equipment is installed. Ceiling height is not small, which creates additional difficulties when choosing a suitable heating system.

2. Solutions for radiant heating

The use of radiant heating allows the obtaining of better results in the heating of production premises with respect to the uniformity of the temperature distribution of air in the vertical and horizontal [1]. The increased surface temperature of the surrounding elements allows the maintenance of a lower air temperature while preserving the thermal comfort of the workers. With these, the heating is via infrared heat energy radiated from emitters situated directly above the work area. By reflectors, this energy is directed to the heated area, while both the air and the surrounding surfaces are heated. Part of the indicated advantages of radiant heating also includes the short period necessary to achieve thermal comfort. In radiant heating with radiating bands is advisable to bear in mind that they are not recommended for premises, which are expected to accommodate high equipment and bulk materials. They are considered very inappropriate for low premises.

Infrared emitters can work with gas or electricity. Depending on the surface temperature there are light and dark emitters.

High temperature tubular heaters are also considered very appropriate for production halls. The heating fixture consists of a bundle of tubes coated with heat-insulated tin jacket. The number of tubes in a bundle can vary, and it is typically from 2 to 6, and their diameter usually ranges from 180 to 600 mm. Their length is determined depending on the shape and dimensions of the room.

The heating is by direct combustion of gas or diesel. The emitted flue gases are disposed outside the premise. In practice, systems with recirculation or direct current systems are used in heating of premises with high temperature piping.

Sizing of heating systems

Heating systems are sized for indoor air according to design regulations. These parameters are determined on the basis of a set of hygienic and economic considerations. Thermal comfort is defined by temperature conditions satisfying the occupants of the room. It cannot be unequivocally that is why, permissible temperature conditions are admitted, which underline in the basic methodologies for calculating HVAC (heating, ventilation and air conditioning) systems [2].

An important point in the sizing of the heating system is the determination of heat losses. It is customary to calculate them in stationary conditions of constant temperatures, the characteristic of structural elements, etc. In their determination it is necessary to take into account the fact whether the heating will be with or without interruption.

It should be kept in mind that the operation of heating systems is associated with high costs, formed mainly from energy consumption.

It is recommended even at the design phase to take measures to reduce them. Among the possible measures are to allow for good thermal insulation of buildings; regeneration and recuperation of the heat of the exhaust air; choice of secure system for automatic regulation and others.

3. Research method and results

The idea is to develop an approximate mathematical model of the complex heat and mass transfer processes occurring in a room with radiant heating and ventilation. The mathematical model constitutes a system of equations for the air and heat balance in the specific volume and the surrounding surfaces of the room. The site is a production room, in which a radiant heating system is installed, without other heat sources. The heat flows from the radiating sources are: convective currents which are located in the top part of the room and give warmth to the interior walls and radiant component. The interior surfaces transfer heat by convection and radiation in the closed premises. Part of the heat is lost by transmission through the outer wall of the building.

The air is fed in the direction of the work service area in quantity M_{nr} and is given to the upper area with an expenditure $M_b = M_{nr}$. At the level of the upper work service area the expenditure of air in the stream is M_{str}. The increase of air flow is due to air circulation, which constitutes a drop in the flow. The cross-border flows are shown by dashed lines in figure 1. The calculated volumes are chosen: region (an area with a constant presence of people); the volume of the supplied air flow and the wall convective flows. The direction of the wall convective flows depends on the ratio of the temperature of the inner and outer surfaces and the ambient air.

The air temperature in the service area t_{wz} is formed by mixing the air from the air flow for heating, the wall convective flows and the convective heat from the inner surfaces of the floors and the walls. In reporting the developed scheme for heat exchange and circulation of air flow (figure 2, 3) the algorithm is drawn for calculating the heat and air balance for the given volume.

The air flow in the range [4], defined by the convective flow is:

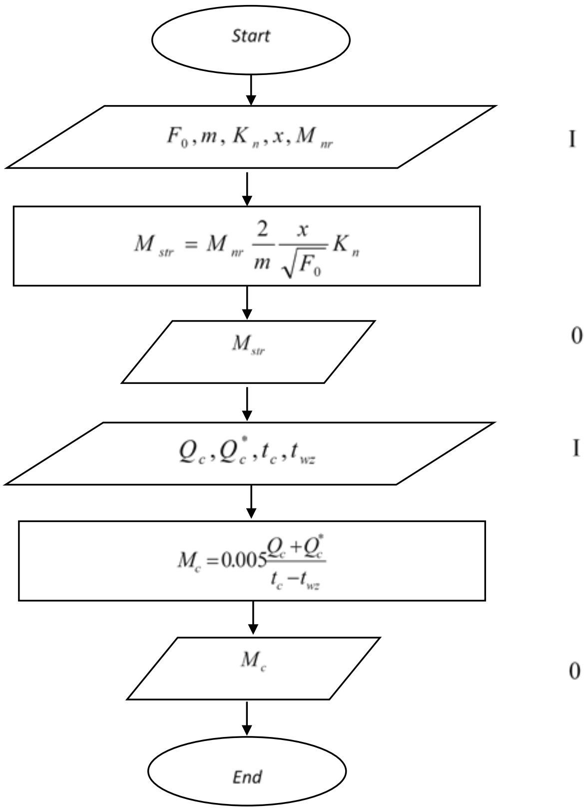

Figure 2

m - damping ratio

F_0 - section of the inlet air-distributing diffusers, [m^2]

x - the distance from the diffuser to the point of basic service area, [m]

t_c - temperature of the inner surface of the external wall, [^{0}C]

c - specific heat capacity, [J/(kg.°C)]

Q – power of the gas radiant system, [W]

Q_c и Q_c^* - convective heat transfer from the inner surfaces of the walls in the service area, and of the wall above the service area, [W]

t_{str}, t_c, t_{wz} - air temperature in the inflow into the work area in the wall convective flows and work area, [^{0}C]

Q_{mn} - heat loss in the room, [W] (equal to the amount of heat loss through the building envelope).

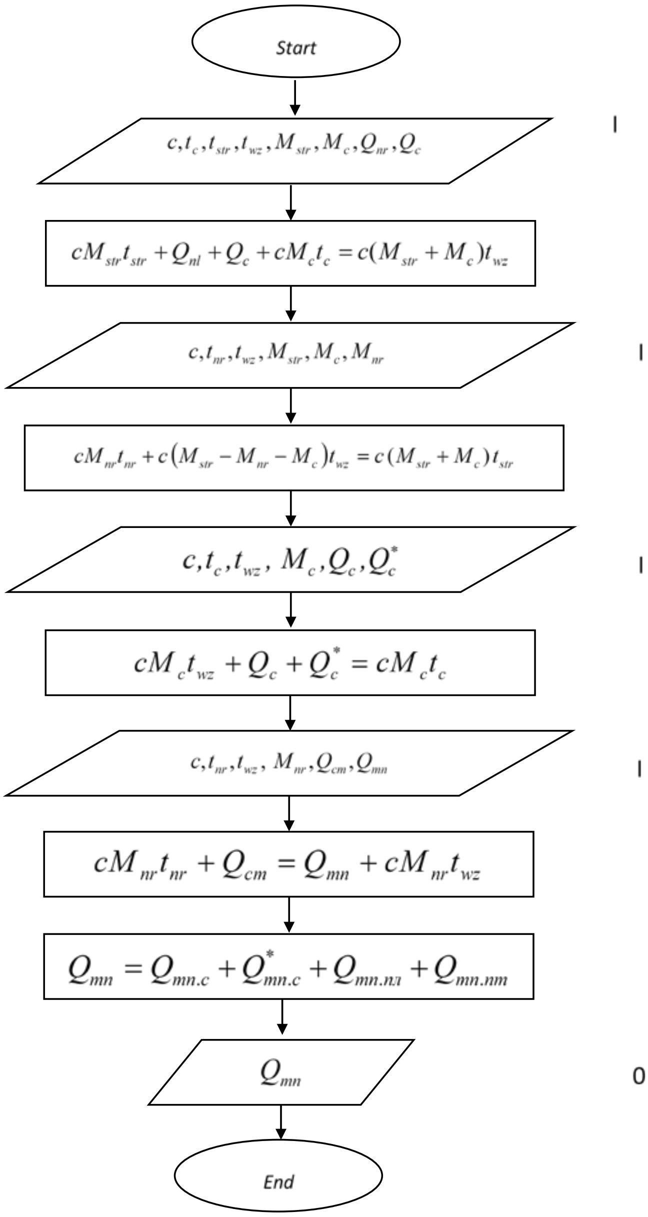

Figure 3

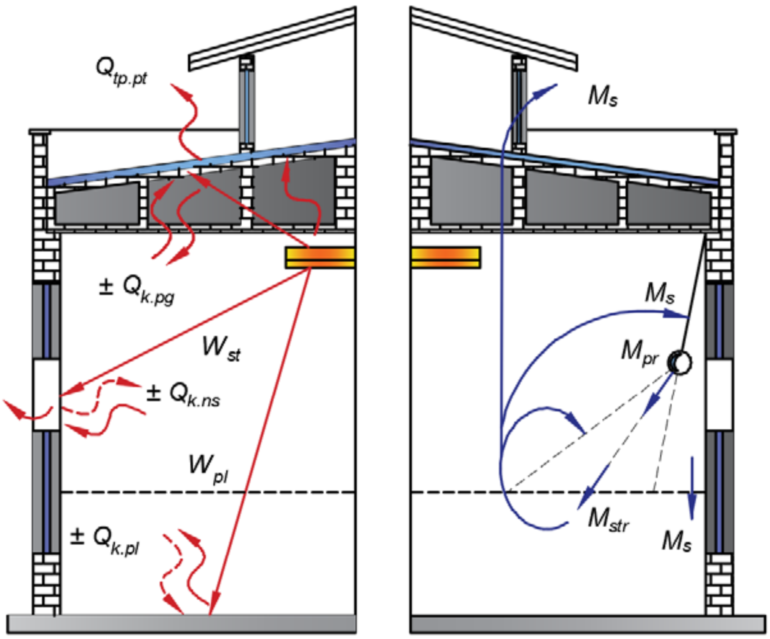

Figure 1

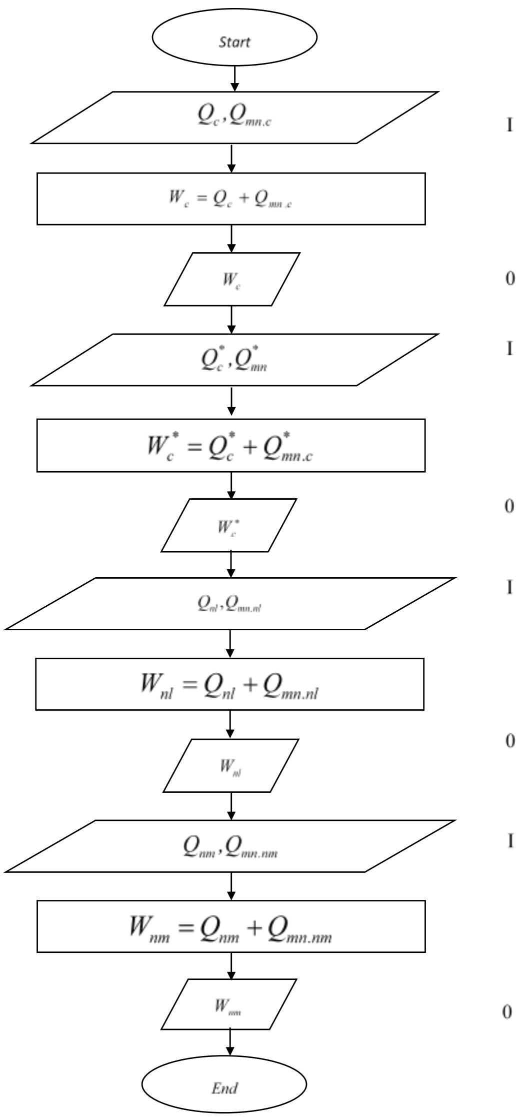

Figure 4

Q_c, Q_c^*, Q_{nl} и Q_{nm} - convective heat transfer from the inner surfaces inтo the service area - walls over the service area, the floor and the surrounding walls, respectively, $Q_{mn.c}$, $Q_{mn.c}^*$, $Q_{mn.nl}$, $Q_{mn.nm}$, - heat losses from the relevant structures, W_c, W_c^*, W_{nl} и W_{nm} - radiant heat flows from the source flowing into these surfaces.

Convective heat loss is determined by:

$$Q_j = m_j F_j \Delta t_j^{4/3}, \qquad (1)$$

m_j - factor determining the direction of heat flow with reference to surfaces, F_j - surface area, [m^2], Δt_j - temperature differential between the environment and the surfaces, [^{0}C], j - index indicates the type of surfaces.

Heat loss can be expressed through:

$$Q_{mj} = F_j \frac{\tau_j - t_н}{R + R_н}, \qquad (2)$$

$t_н$ - outside air temperature, [^{0}C], t_j - the temperature of the inner surfaces of the outer walls, [^{0}C], R и $R_н$ - resistances of heat transfer, [m^{2}K/W].

The radiant heat flow from the source of radiation W_j at an arbitrary orientation of the radiating system and the surrounding surfaces is calculated by:

$$W_j = c_0 \varepsilon_{ij} H_{ij} \left[\left(\frac{T_i}{100} \right)^4 - \left(\frac{T_j}{100} \right)^4 \right], \qquad (3)$$

c_0 - emission ratio of blackbody, [W/(m^2 K^4)], ε_{ij} - degree of blackness, H_{ij} - area of the radiating surfaces, [m^2].

The solutions of the resulting mathematical models of the processes of heat and mass transfer [3] under the joint action of radiant heating and ventilation allow the obtaining of basic characteristics of the thermal regime in the design of systems for radiant heating of various buildings equipped with ventilation systems.

4. Conclusion

Heating systems with infrared emitters are the preferred solution for heating of premises in which organic dust or fire hazardous aerosols are not emitted.

They are recommended for buildings with low thermal insulation and for heating of separate areas in unheated premises. Among their advantages are small heat inertia, the ability to operate in the mode of a general or zone heating, economical operation, the ability to heat open areas, high reliability and easy maintenance.

Their disadvantages are mostly related to the high temperature of the radiating plate, the need of ventilation for removal of waste products from the combustion in using gas emitters. It should be kept in mind that it is not recommended to install infrared emitters in premises with increased fire hazard and in areas where there are materials which under the influence of infrared radiation modify their properties.

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