EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research,
Development and Education

MINISTRY OF EDUCATION,
YOUTH AND SPORTS

ESF II project of the University of West Bohemia in Pilsen

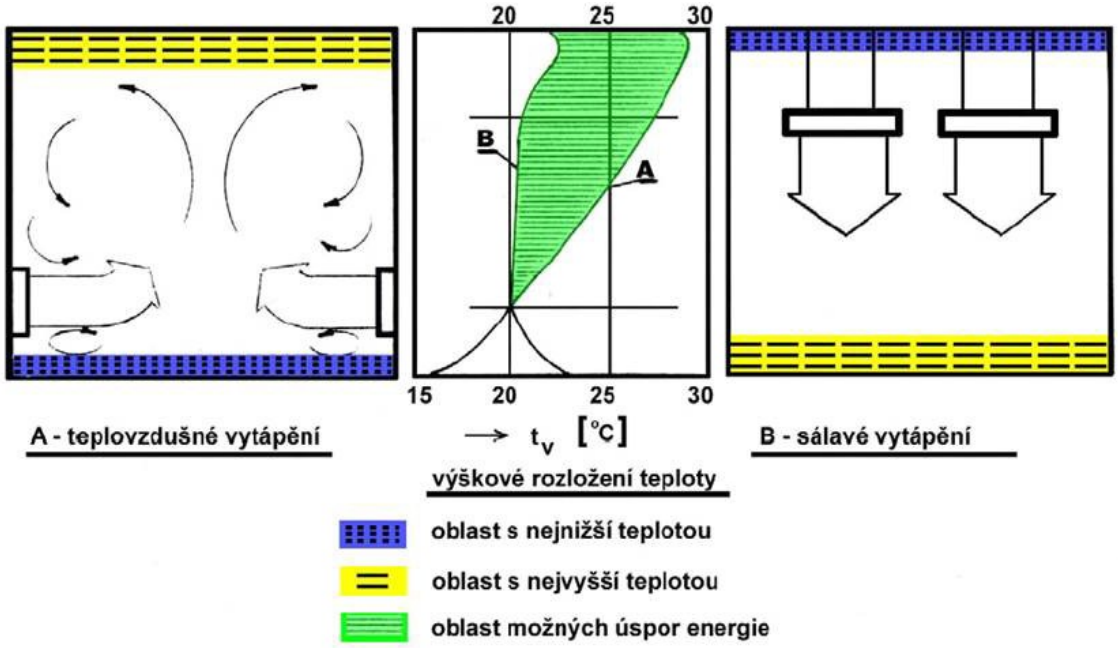
reg. n. CZ.02.2.69/0.0/0.0/18_056/0013239

Determining the radiation efficiency of radiant panels

Introduction:

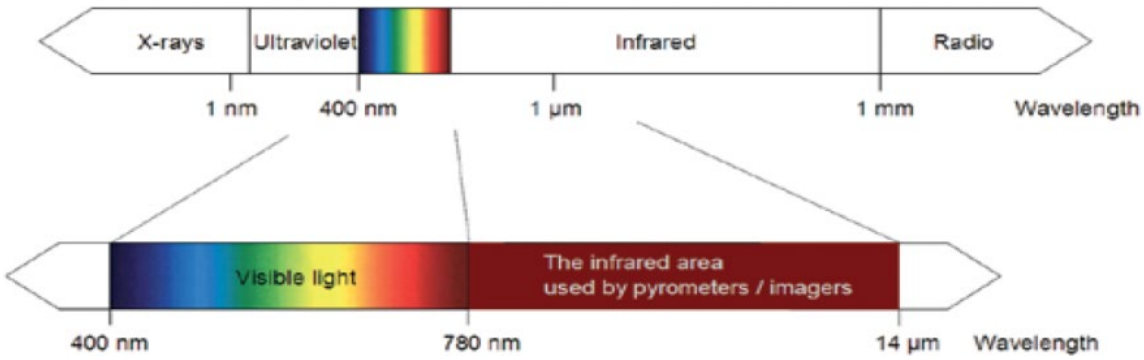
Electric radiant panels, suspended from the ceiling or walls of the heated space, are a source of heat radiation. The radiation spreads through the space without heating the air. When it hits the surface of a solid body (floor, wall, furniture or other indoor equipment), depending on the degree of absorption, reflectivity and permeability of the surface, it is transformed into heat. The air is a medium for this radiation
"transparent", it is heated only secondarily from the surfaces of heated bodies.

The advantages of radiant heating with suspended panels (electric, hot water, gas) compared to hot air heating (conventional central heating radiators, oil radiators, fan-assisted electric heaters, storage heaters, etc.) can be seen in the following figure:



Theoretical analysis:

Infrared radiation is electromagnetic waves that are invisible and carry heat energy. The wavelength range of infrared radiation is approximately from = 780 - 14 000 nm.



In a transparent environment, this radiation propagates in all directions and is refracted at the interface between two environments with different densities. Other properties of electromagnetic waves from this wavelength range include reflection from shiny surfaces and the possibility of concentration. This radiation also affects, for example, photographic material.

Any body that is in a transparent environment and has a temperature above 0 K becomes a source of infrared radiation. The radiant energy that is absorbed by the opaque body is converted into thermal energy.

Use of infrared radiation: infrared radiation is mainly used for heating substances. When radiant energy is incident on the surface of a body, its temperature will initially rise quite rapidly and with it the body's own radiation to a cooler environment. After some time, a steady state will develop where the temperature of the irradiated body will be constant and independent of time.

Several types of infrared heaters have been designed for the use of infrared radiation, which can be divided into two groups:

infrared heaters

luminous infrared

heaters dark

radiant panels

a) Fluorescent emitters emit energy in the wavelength range of 700 - 2000 nm, meaning that some of the emitted energy falls in the visible region. The radiation source is a tungsten filament with an operating temperature of 2100 - 2400 K. The glass bulb of this illuminator is in the shape of a parabolic reflector, which is coated on the inside with a reflective metal layer (aluminium, silver). The efficiency of this illuminator is 65 %.

The group of luminous radiators also includes quartz infrared radiators. A heating coil made of resistive material is axially placed in the quartz tube, which has an operating temperature of up to 1500 K. The source of infrared radiation is both the spiral itself and the heated quartz glass tube.

b) Dark infrared emitters emit energy predominantly in the wavelength range 1600-4000 nm. This means that their operating temperatures, which are in the range of 450 - 1000 K, will be lower compared to illuminated emitters. The source of the radiant energy is usually a ceramic mass that is heated by a heating coil pressed inside. These types of ceramic radiators are used with different shapes (trough, mushroom). These sources are much more resistant to mechanical damage due to their luminous nature.

c) Radiant panels - the resistive heating element in the heater is heated by the passage (resistance) of an electric current and also heats the front surface. The magnitude of the radiant heat transfer flux is determined not only by the material properties of the emitting (heating) surface, but also by the correlation between the spectrum of the transmitted radiant flux and the spectral absorption of the absorbing surface. Through this surface the required wavelength of infrared energy is formed, the so-called infrared radiation. This energy is converted into heat when it hits any solid objects - it heats all objects that are exposed to this energy. In the case of heating, the materials in the heated space that have the ability to store heat (walls, floors, ceilings, etc.) are crucial. For example, a building structure can accumulate heat and secondarily return it to the heated space (emissivity of materials) and determine the thermal comfort of the heated space by its temperature. It is in the ability of building materials to accumulate "infrared heat" that the principle of low-temperature infrared radiant panel heating (sometimes referred to as "infrared heating") lies. If the proposed heaters are to be used for heating and drying materials that have significant selective properties, it is possible to significantly improve the radiative properties of the heaters by selecting the optimum selective surface and thereby improving the radiative heat transfer between the heater and the material. Optimal design and appropriate construction of heating surfaces increasing the radiative component of heat transfer has the greatest impact on energy savings in heating.

Infrared radiation is used for a variety of purposes. Due to their low penetration, electromagnetic waves of these wavelengths are used in industrial applications mainly for drying paints, paper, fabrics, enamel and ceramics - materials with a small thickness, while radiant panels are mainly used for heating rooms or industrial halls.

Measurements:

The objective of the measurement is to determine the radiant efficiency of the specified panel:

In horizontal

position In vertical

position

Determine the wavelengths of radiation as a function of panel surface temperature

Procedure:

1. Connect the radiant panel to the mains via a W-meter. After switching on the radiant panel, record its temperature at the selected point using a coordinate recorder and a thermal imaging camera. At intervals of one minute, take pictures of the radiant panel wall using the thermal imaging camera and record the power input at the same time until the temperature on the surface of the panel has stabilised. Once the temperature on the surface of the radiant panel has stabilized, proceed with the actual measurement. Using a thermal imaging camera, take a picture of each wall of the radiant panel. Carefully measure and record the dimensions of the radiant panel to be measured. From the thermometer on the wall of the laboratory, record the air/environmental temperature. For the highest temperature value on the radiant side of the panel, determine the magnitude of the wavelength λ of the radiation from Wien's law.

$$\lambda T = 2898[\mu m]$$

Where:
λ wavelength [μm]
T thermodynamic temperature [K]

In steady state, determine the heat loss of the panel by flow through the side walls, radiant surface and cover. The losses are determined using Newton's law:

$$P_Z = \alpha(\vartheta_1 - \vartheta_2)S$$

Where:
P_Z heat loss [W]
α heat transfer coefficient [$W.m^{-2}.K-1$]
ϑ_1, ϑ_2 temperature [°C]
S area [m^2]

α_1 ... for vertical walls $\alpha_1 = 1,55\Delta\vartheta^{0,33}$, $\alpha_1 = 4,1\Delta\vartheta^{0,13}$

α_2 ... for horizontal walls down $\alpha_2 = 1,28\Delta\vartheta^{0,25}$, $\alpha_2 = 1,08\Delta\vartheta^{0,33}$

α_3 ... for horizontal walls up $\alpha_3 = 2,0\Delta\vartheta^{0,33}$, $\alpha_3 = 2,5\Delta\vartheta^{0,25}$

For each measured position, determine the radiant efficiency of the panel: $\eta = \frac{P - \sum P_z}{P}$ [%]

Where:

P power input [W]

P heat loss by flow [W]

Geometrie sálavého panelu.

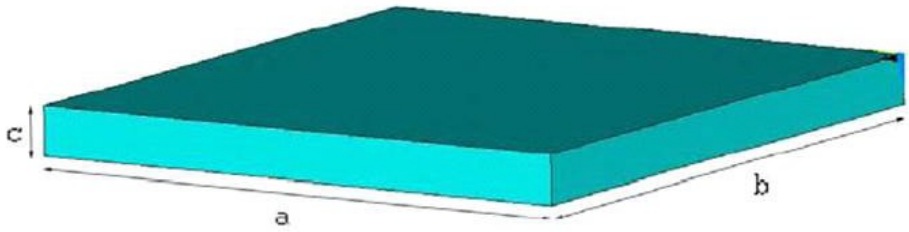


Fig. 1: Panel diagram.

Calculate the surface area of each radiant panel, according to the actual measured panel. Don't forget to measure the dimensions of the measured panel!

Tables of measured and calculated values:

Based on the measurements using the coordinate recorder, determine the settling temperature char.:

t [min]	0	1	2	3	4	5	6	7
ϑ [K]								
T [°C]								

Table 1: Recorded temperatures during the settling of the radiant panel surface temperature Omit the temperature progression from switching on the radiant panel to the settling of the surface temperature in the graph. **For steady state, provide a thermal imaging camera image for each panel wall**

The bottom wall of the radiant panel (radiant wall):

Using a thermal imaging camera and specialized software, determine the average wall temperature.

Average temperature:

ϑ [°C] =

T [K] =

Upper wall:

Using a thermal imaging camera and specialized software, determine the average wall temperature.

Average temperature:

ϑ [°C] =

T [K] =

Side walls:

Using a thermal imaging camera and specialized software, determine the average temperature of the side walls of the radiant panel.

Wall	1.	2.	3.	4.
ϑ Average[°C]				
T Average[K]				

Table 2: Side temperatures.

Calculations:

Determine the flow losses for each wall and tabulate

Wall	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
P_Z [W]						

Using the Stefan-Boltzmann law, determine the radiation losses for each wall and tabulate

Wall	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
P_S [W]						

Based on the sum of the flow losses and knowledge of the power input of the radiant panel, determine its radiant efficiency

$\eta = \frac{P - \sum P_z}{P}$ (%)

Indicate the measuring instruments used:

State the conclusions of the measurements (evaluate the measurement process and the results obtained):

Instructions on how to use the thermal imaging camera can be found on courseware.

At the same time, you will also find a video-training of a specialized worker on how to use the thermal imaging camera on:

http://kryton.zcu.cz/public/GALERIE%20-%20TRANSFER/KA2_advanced/IRCAM_Analyzer_siti_20110913.mp4