The infrared thermography of buildings proceeding its surrounding and their thermal performance

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The brightness equation of the buildings in their surroundings - conditions and suppositions

In carrying out the qualitative thermographic research of buildings, including quantitative and qualitative methods, as well as the conditions to conduct thermographic research of buildings, one must take into account a rather small rank of temperature differences between buildings and their surroundings. This is particularly vital if one compares other types and methods for carrying our thermography survey. In this connection, for the thermographic researches of buildings and defining the conditions for such research, it appears that the key issue is the equilibrium amounts of the heat radiation at the surveyed surface and resulting of the brightness of imaging surface. This equilibrium provides for the brightness equation of imagining surface. This brightness equation of imagining surface in diathermic media constitutes a very important equation for distribution of heat radiation in thermal scene consisting of the buildings and their surroundings.

The brightness B of an object in the scene, as radiance of the heat radiation netto in this scene, equals the difference between the radiant emittance – M from the object and irradiance E at the object from its surroundings. This is described below:

$$B = M - E \tag{1}$$

where the entire emittance M from the object equals the sum of the special emittance of the object M_e (this special emittance is described as the Stefan-Bolztmann black body law of radiation $M_e = \varepsilon\sigma T^4$) and quantity of the heat radiation reflected by the object as irradiance $E_O(x)$ coming onto the object from its surrounding

$$M(x) = M_e(x) + \rho_d(x)E_0(x) \tag{2}$$

From eq. 1 with connection eq. 2, one can arrive at basic equation of imaging thermal scene:

$$B(x) = \varepsilon(x)\left[\sigma T^4(x) - E_0(x)\right] \tag{3}$$

In order to assure proper function of the radiation detector to make fairly exact thermal images, there one additional condition must be met: the irradiance of the thermal detector from its surrounding must be equal to the irradiance of the object from its surrounding.

$$E_0(x) - E_D(x) \tag{4}$$

Usually in the standard thermography we accept the basic assumption of thermography that irradiance $E_O(\mathbf{x})$ at the object from its surrounding which irradiates the imaged object, is equal to constant radiance of a black body in the temperature of its surrounding T_O. Based on this assumption, in thermography research of brightness of the buildings in the temperature T, it the surroundings of the temperature $T_{O,}$ such brightness is equal to:

$$B(x) = \sigma\varepsilon(x)\left[T^4(x) - T^4{}_0(x)\right] \cong 4\sigma\varepsilon T^3{}_0(T - T_0) \tag{5}$$

Thermal building performance

The buildings are artefacts erected to safeguard against the outdoor climate factors and to secure proper thermal comfort for human beings who use those buildings. Therefore the buildings need constant supply of energy from outside. The reasonable usage of the accessible energy, including the energy used to heat building is an important factor effecting development prospects of the society. The energy supplied to the building is changed into the heat creating comfortable conditions inside. The characteristic feature of the heat is its constant movement, delivery or receipt by different media that have different temperatures. The flow of heat is stopped if there are no different temperatures. In cold session the heat is emitted from houses to the surroundings. Frequently, in hot session the heat is moved out houses by using work powered by energy. The value of dissipated heat depends on thermal performance of the building, that could be described similarly the performance of a heat engine. The thermal performance of the building is described by the ratio of the heat value dissipated from the building to its surrounding to the value of the energy supplied to the building at the beginning in order to create a thermal comfort inside such building.

The coefficient the permeability of the heat U is calculated assuming that heat movement is stationary along one axis. From that density flux of heat $q = U \cdot \Delta T$ is independent of time and is constant along perpendicular axis to the buildings wall. Density of the heat flux q_I from inside of the building is equal density of heat flux out q_O from the building to its surrounding:

$$\Phi_O / A = q_O = q_I = \Phi_I / A \qquad (6)$$

$$q_I = (T_I - T_S) / [1/h_I + 1/\Lambda] \qquad (7)$$

where: q_I – is density of the heat flux from inside buildings to the wall,

$$q_O = h_O (T_S - T_O) \qquad (8)$$

q_O – is density of the heat flux from wall buildings to the surrounding.
T_I - temperature inside the building [K],
T_O - temperature surrounding of the building [K],
T_S - temperature of the external wall surface in the building [K],
h_O – coefficient of heat transfer at external wall surface [W/m^2K],
h_I - coefficient of heat transfer at internal wall surface [W/m^2K],
$1/\Lambda = b/\lambda$ – heat resistance of wall [m^2K/W],
λ - coefficient of heat conductance of wall materials [$W/m \cdot K$],
b – wall thickness [m].

From the preposition about equality of the heat fluxes (eq.6), it results the following consequence:

$$1/h_I + 1/\Lambda = (T_I - T_S) / h_O (T_S - T_O) . \qquad (9)$$

For describing coefficient of heat permeability U we use the following:

$$1/U = 1/h_O + 1/\Lambda + 1/h_I \qquad (10)$$

and for that value of heat permeability U, that characterizes isolation parameters of the building walls, is:

$$U = h_O (T_S - T_O) / (T_I - T_O). \qquad (11)$$

Quantitative building thermography is radiometric imaging method to determinate values like coefficient of heat permeability U and thermal building performance η or the permeability heat from the buildings θ. In the heat conductance through the building envelope all above values were inter-connected by the coefficient heat transfer h_O at a wall surface of the surveyed building envelope.

The energy supplied to the building is changed into the heat Q^0; part of that Q is dissipated to the building's surrounding, and at the same time, the other part of that Q^0-Q is used to change values of parameters of the indoor climate to achieve the optimal value of the thermal comfort inside. Thermal performance in this case is equal:

$$\eta = \frac{Q^0 - Q}{Q^0} \qquad (12)$$

Permeability of the heat thought the building envelope is then:

$$\Theta = Q/Q_0 = 1 - \eta \qquad (13)$$

By use as the expressions of leading and dissipated heat, functions of temperature and expand them in the Taylor series are:

$$Q = Q(T_s) - Q(T_0) = Q(T_0 + \Delta T) - Q(T_0) \cong \left. \frac{\partial Q(T_0)}{\partial T} \right|_{T = T_0} (T_s - T_0) \qquad (14)$$

$$Q^0 = Q^0(T_I) - Q^0(T_0) = Q^0(T_0 + \Delta T) - Q^0(T_0) \cong \left. \frac{\partial Q^0(T_0)}{\partial T} \right|_{T = T_0} (T_I - T_0) \qquad (15)$$

and from that one obtain following expression of thermal performance of the building envelope:

$$\eta = \frac{T_I - T_S}{T_I - T_O} \qquad (16)$$

where: T_I – temperature of inside building envelope behind imaging wall, T_S – temperature of external surface imaging wall, T_O- temperature surrounding.

From eq.11 i eq.16 one can see rather simple dependence that:

$$U = h_O \eta \qquad (17)$$

The computer procedure has been designed to evaluate the thermal performance of buildings.