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THEORETICAL RESEARCH REGARDING HEAT TRANSFER BETWEEN GREENHOUSES AND ENVIRONMENT

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Abstract: *Because the greenhouse heating costs represents approximately 40% of the total cost production, heat loss must be kept under control and even lower, which leads us first to understand the way in which heat transfer occurs between the greenhouses and the environment. Heat loss from a greenhouse usually occurs by all three modes of heat transfer: conduction, convection and radiation. Usually many types of heat exchange occur simultaneously. The heat demand for a greenhouse is normally calculated by combining all three losses as a coefficient in a heat loss equation. In the paper the author's presents from the theoretical point of view the impact and the calculation of heat loss in greenhouses.*
Keywords: *greenhouse, energy, heat, losses*

1. INTRODUCTON

In greenhouses complex thermal phenomenon occur due to the exchange of hot or cold air, it also signaled the ventilation airflow through frequent ventilation of farmed environment. Solar energy which penetrates the greenhouse suffers significant changes that occur largely by the passage of radiation through the material that covers construction. Inside the greenhouse, solar radiation contributes to the overall heat exchange, to establish the balance of heat and radiation, complex phenomena involving temperature and humidity, evaporation and condensation, plants, soil, the design, heating ducts. Losses and heat accumulations occur, frequent exchanges of air that strongly influences the greenhouse microclimate.
The transfer and the heat exchange are made through three distinct mechanisms:
Thermal conductivity, mainly characterized by the coefficient of thermal conductivity λ, expressed in $Kcal/m^2$ • grd. sau W/m^2 °C;
Convection, the heat is transported once with the conductive environment in motion and can be:

a) spontaneous convection (natural and free) due to natural causes such as temperature difference that causes difference of air density, giving rise to it;
b) forced convection due to imposed external causes;

Radiation, when the heat transport takes place by means of electromagnetic waves between the areas having different temperatures; the two surfaces can be separated, such as greenhouses, by an environment more or less "leaky" to thermal radiation.

2. HEAT TRANSFER BETWEEN GREENHOUSE AND ENVIRONMENT

Heat transfer and heat exchange of the greenhouse is illustrated by the overall heat transfer coefficient or heat transfer (K), which characterizes very well convection between greenhouse air and the inner surface of the roof (α_i), conduction between the two surfaces of the roof (δ / λ) and convection between the outer surface of the roof of the greenhouse and adjacent air layer (α_e).
The coefficient K is determined with the following expression:

$$K = \frac{1}{\frac{1}{\alpha_i}+\frac{1}{\alpha_e}+\frac{\delta}{\lambda}} \quad (1)$$

where: α_i - inner convection coefficient in kcal / m2 * h * deg;

α_e - external convection coefficient in kcal / m2 * h * deg;

δ - thickness of the transparent cover, in mm;

λ - coefficient of conductivity, in kcal / m2 * h * deg;

Gac (1967) shows that the ratio δ / λ ranges from 0.02 to 0.001 kcal / m2 * h * degrees, and the ratio $1 / \alpha_i$ is equal to 0.25 kcal / m2 * h * degrees, wich demonstrate that in greenhouse the heat transfer by convection is frequently and totaly limited by conduction. It depends on the movement of the inside air flow, by the outside wind speed, on the nature of constructive elements, by the radiation coefficient of the cover surface and the difference between adjacent air temperature and surface temperature of the glass or plastic cover of the greenhouse.

In greenhouse, the convection coefficient α is a function of the wind speed and frequency, the ratio between these two factors are directly proportional.

Coefficient K grows by increasing wind velocity through the coefficient α, determination worthy of taking into consideration for greenhouses (Figure 1)

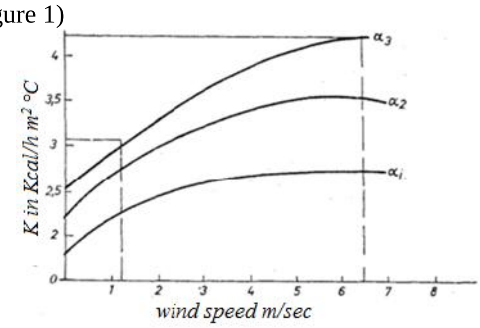

Figure 1 : Variation of the overall heat transfer coefficient in a glass greenhouse, depending on the wind speed, for three convection coefficient

The coefficient K has different values depending on the materials used in the construction of the greenhouse and some of them are given in table 1.

Table 1: The heat transfer coefficient (K)

Name of building and coverage elements	K (Kcal/m2.h.grd)
A. Infrastructure	
Concrete base with thickness of:	
20 cm	2,7
25 cm	2,45
30 cm	2.2
B. Over-glass structure	
Simple glass with wooden structure	5,0
Simple glass with steel structure	5,5
Double glass with wooden structure	2,8
Double glass with steel structure	3,0
C. Over-plastic structure	
A polyethylene foil layer	6,2
Two layers of polyethylene foil	3,0
Rigid PVC plate	4,9
Polyethylene plate	4,7
Polyester plate doubled with polyethylene layer	2,8

The direction of heat exchange in greenhouses is variable in that a certain phenomenon or energy transfer mechanism, which contributes to the accumulation of heat during the day can become a loss of heat at night and vice versa. The amount of heat introduced in a greenhouse should be at least equivalent to the amount of heat that is lost to the outside (the greenhouse effect). By raising the temperature will increase the necessary of heated to be added by conventional way , which will inevitably leads to the increase of losses, that otherwise is explained by the increased temperature gradient. In the same way once the outside air temperature will be lower the heat losses will be higher. These losses increase by 5-15% during the year period in which the cold and strong winds are blowing.

Cultivated plants actively participate in the sensible and latent energy exchange with the environment, through the mechanisms of heat transfer. Temperature of plant is one of the essential elements of the heat transfer mechanisms in greenhouses. This can be determined by knowing the ambient temperature. However, there is a difference between the plant temperature, which may be higher during the day and lower at night, than the ambient temperature. Usually, the calculations are taking into account the temperature of inner air, since it can be measured more easily than the temperature of the plant.

Heat losses occur through the transparent cover of the greenhouse due to irradiation, through over structure and greenhouse soil by conduction and through construction joints leak, by convection (Figure 2).

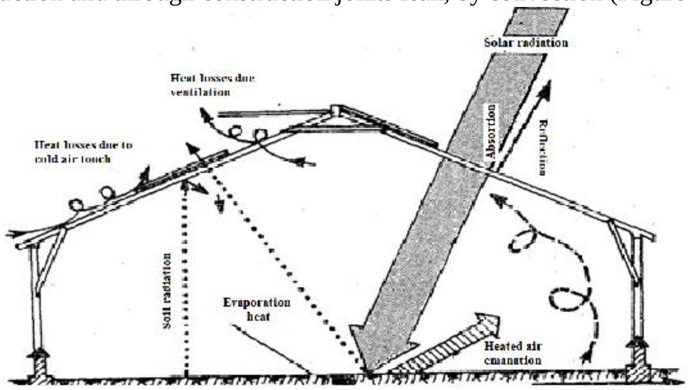

Figure 2 : The main scheme of heat loss in the greenhouse (Mad Seeman)

Heat losses by radiation

Among the mechanism of heat transfer an important role plays infrared radiation, which influences temperature distribution in the greenhouse. Heat exchange caused by this phenomenon can be written as a radiative balance. There is always an exchange of radiation (longer wavelengths) between plants, soil in greenhouses, superstructure and exterior space.

During the night the conditions are of particular interest, since during this period the heat deficit is maximum. Over the night the outside atmosphere is cooling thanks to that the greenhouse constantly emits radiant heat flux. Radiation losses can be calculated according to Walker's relationship as follows:

$$Q_{rad} = 4{,}4 * 10^{-8} * S * P(T_i^4 - T_e^4) \quad (2)$$

where: Q_{rad} - the quantity of heat lost by irradiation Kcal / h;

S - area under the cover of the greenhouse m^2;

P - Transparency empirical factor (values: Polyethylene = 0.8; glass = 0.04);

T_i - Indoor temperature in ° C;

T_e - the outdoor temperature in ° C;

Irradiation losses are less than the losses by convection, but considerably higher than the losses due to conduction through infrastructure and the soil of greenhouse.

Heat losses by convection

A substantial contribution to heat loss in greenhouses brings the convective exchange between the internal and external atmosphere. These losses have the largest share in the global balance equation, for which almost all sizing calculations using formulas losses that takes into account only the losses by convection.

For example according to Romanian standard the heat loss is given by:

$$Q = K * S(T_i - T_e) \quad (3)$$

where: Q - amount of heat lost (convection) in Kcal / h;

K - overall heat transfer coefficient in Kcal / m^2;

S - surface construction elements in m^2.

Besides the heat lost through structural elements and warm air infiltration through atmosphere due to imperfect tight of joints, cracks, defective joints of constructive elements, broken windows, broken plastic, a certain amount of the heat (Q_{inf}.) is lost to heat the cold air that enters in greenhouse from the surrounding atmosphere. In this case,

$$Q_{inf} = 0{,}31 * V * (t_i - t_0) \quad (4)$$

The heat consumed for heating the infiltrated air is conditioned by the wind speed, the length of leaks, the quality factor of glass or plastic and the pressure difference between inner and outer air. For greenhouses, Nafrady (1953) proposes the following mathematical expression:

$$V = L * a * (p_k - p_e)^{\frac{3}{2}} \quad (5)$$

where: Q_{inf} - the heat consumed for heating the infiltrated air in greenhouse, in kcal / h;

0.31 - specific heat of air Kcal / m^3 degrees;

V - the volume of infiltrated air m^3 / h;

L - length of cracks in m;

a - quality factor of the windows (3 ... 10);

(P_k - P_e) - pressure difference between inner and outer air in mm mercury column.

Heat losses through greenhouse soil

Represent a weigh higher or lower depending on the convective heat transfer, by the regime of water evaporation from the ground and physico-thermal characteristics of cultivated land. Heat loss through the soil is conditioned by the fact that the land is heated artificially or by solar energy. The loss of the heat in the soil may be in its depth, on vertical, or perimeter, horizontally. From observations can be noted that the nature of the soil, ground water level, irrigation system and land moisture directly influence the heat losses, uniform temperature distribution in the soil. The convective heat transfer increases with the speed of air movement at soil surface which leads to an heat loss increased by 5-20%, depending on the coating system of the greenhouse.

Also, the reduced values of the air temperature above the ground and elevated temperature on the ground surface, increases the amount of heat loss due to convection $Q_{conv.s}$. In this case,

$$Q_{conv.s.} = \alpha' (t_{ss} - t_{gp}) \quad (6)$$

Where (t_{ss} -t_{gp}) represents the difference between temperatures at the soil surface and ground proximity and the coefficient α 'characterizes the conditions of the exchange of heat between the soil surface and the layer of air adjacent to a wind speed up to 5 m / s.

Heat loss through evaporation of the soil is determined using the equation proposed by Korolkov (1955);

$$Q_{ev} = 0,6 * G \quad (7)$$

where 0.6 is a characteristic number and G results from Dalton's equation:

$$G = \eta(21,9 + 17,8v) * (p_{ss} - p_{gp}) \quad (8)$$

where: Q_{EV} - the amount of heat lost through the evaporation of ground water in Kcal / h;

G - the amount of water evaporated in g / m^2h;

v - wind speed in m / s;

η - coefficient equal to 0.3 showing reduced evaporation from the soil surface compared to slick surface;

p_{ss} - water vapor pressure at soil surface in mm Hg;

p_{gp} - pressure of water vapor in the vicinity of the ground in mm Hg; 22.9, 17.8 - Characteristic numbers.

However, the heat lost from the soil through evaporation does not greatly affect the heat balance of the greenhouse because it is found in moist air closed by roof. Some of this heat is released to transparent cover through condensation, and when the inside air reaches saturation and settle on glass or plastic roof in the form of a continuous layer or droplets of water.

3. CONCLUSION

1. Heat loss from a greenhouse usually occurs by all three modes of heat transfer: conduction, convection and radiation.
2. Heat transfer and heat exchange of the greenhouse is illustrated by the overall heat transfer coefficient or heat transfer (K).
3. The direction of heat exchange in greenhouses is variable in that a certain phenomenon or energy transfer mechanism, which contributes to the accumulation of heat during the day can become a loss of heat at night and vice versa.
4. Heat losses occur through the transparent cover of the greenhouse due to irradiation, through over structure and greenhouse soil by conduction and through construction joints leak, by convection.

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