MODELS OF ENERGYECONOMICAL LIVESTOCK BUILDINGS

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***Abstract**: Conceptual schemes for reconstruction of energyeconomical livestock buildings with controlled natural ventilation are considered in the paper. A business-scheme for effective building reconstruction and mathematical models of the investment are presented too.*

***Key words:** Livestock Buildings, Controlled Natural Ventilation in Buildings.*

INTRODUCTION

The livestock building is energytransforming object, where the production efficiency depends on the energy utilization degree of the fodders, animals, environment and microclimate systems. Therefore, all these processes have to be considered in their unity and by means of the building construction and building thermal properties this unity be ensured. Every building design should lead to exergy increase of every energy flow forming building balance [1]. The pursuit of these aims has to be accompanied with creation of effective, module and accessible building constructions and types of livestock buildings. On this base, systematic investigations have been carried out at the University of Rousse and the main results are presented in this paper.

1. Model formulation

A synthesized scheme of the exergical contours and streams in a livestock building has been initial base during models' developing [2]. The simplified diagrams of buildings' models are presented in Fig.1. The basic variant is shown in Fig.1a. The all area of the enclosed construction is formed as recuperative heat-exchangers. The air circulation is carried out on the route: inlets (4) → inlet channels (1) → inlet (13) → premises → outlets (5) → outlet channels (2) → ridge vent (3) → atmosphere. The heat utilization is carried out on through air route. In order to air circulation be carried out, the heater contours have to be situated low in the animal zone. The use of a heated floor – contour (7) is more suitable to the occasion. The schemes allow a thermal-pump to be embedded. The valve (10) ensures fluent adjustment of the circulatory air through the building.

The building heat losses decrease, as the losses to the environment do not depend by temperature difference $(\theta_T - \theta_0)$. They depend by the difference $\left(\theta_0^* - \theta_0\right)$. The air warm temperature in inlet channels reach to several degree. For example, for θ_T =30 ^{0}C and θ_0 = -10 ^{0}C the air heating is about 6 ^{0}C [1]. The relation $(\theta_T - \theta_0)/\left(\theta_0^* - \theta_0\right)$ is 2.5 units.

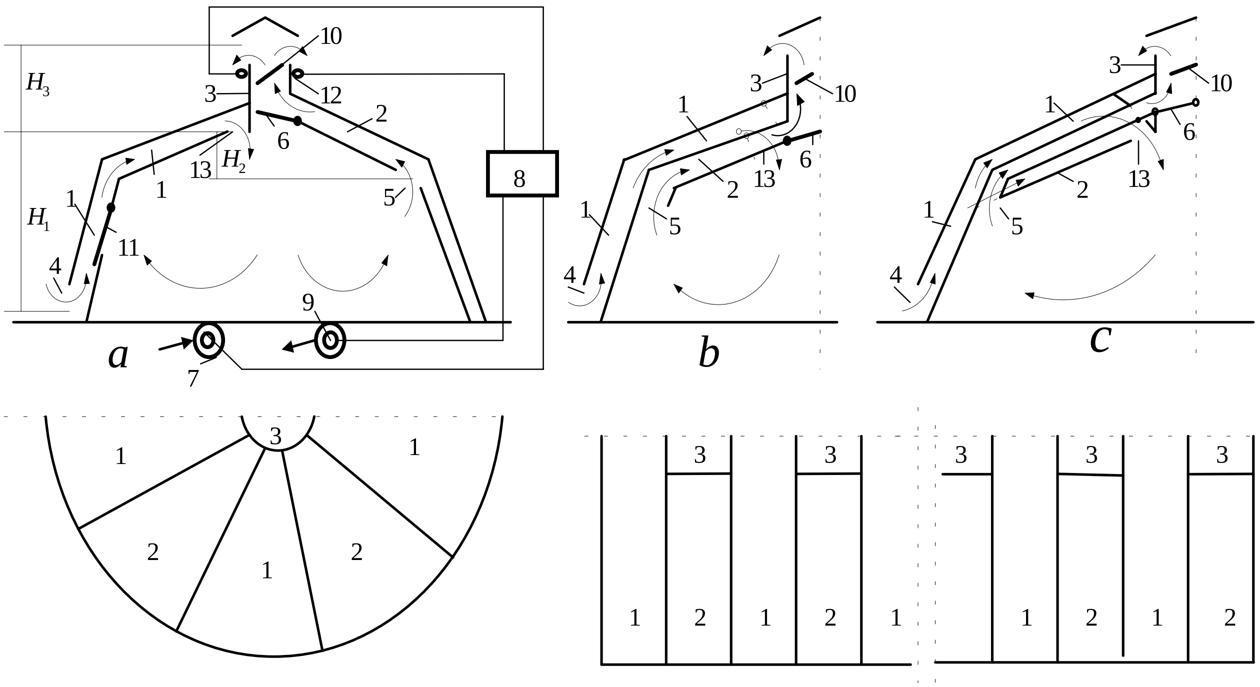

Fig.1. Construction schemes of energyeconomical livestock buildings (a – alternation of inlet and outlet channels; b - parallel situation, with one contacting area of inlet and outlet channels; c - parallel situation, with two contacting areas of inlet and outlet channels).

1 - inlet channels; 2 - outlet channels; 3 – ridge vents; 4 – inlet; 5 – exhausting inlet; 6 – bottom valve; 7 – floor heating streamer of outer source; 8 – thermal pump; 9 - thermal pump capacitor; 10 – control valve; 11 – side wall valve; 12 - thermal pump evaporator; 13 – inlet.

During summer days the heating of the all area of the enclosed construction is restricted by reason of the presence of the air channels and the absence of accumulative mass.

The pressure head *(*Δ*P)*, being the driving force of the air circulation, due to thermal buoyancy, depends by temperature difference $(\theta_T - \theta_0)$ and geometric heights H_1, H_2 and H_3. The pressure head *(*Δ*P)* is given by the relationship [5]:

$$\Delta P = \left(H_1 + \frac{H_2}{2} + H_3 \right)(\rho_0 - \rho_T) - \frac{H_2}{2}(\rho_0 - \rho_0^*) \qquad (1)$$

where ΔP is pressure head inside the building, Pa;

ρ_T - air density inside the building, kg/m^3;

ρ_0 - density of the outdoor air, kg/m^3;

ρ_0^* - density of the outdoor air, after its heating in the inlet channel, kg/m^3.

The air circulation in the building by the route inlet-outlet channels 1 and 2 through whole year is ensured without use of the side wall valves 11 when the channels width is chosen by the conditions $(\rho_0 - \rho_T) \leq 0.07$ and $(\rho_0 - \rho_0^*) \leq 0.03$.

After substitution into Eqn (1), the relationship for maximum permissible air speed in the channels is obtained by

$$\nu_{\max} \leq \sqrt{\frac{4.7}{\sum_{1}^{\xi_n} \xi_i + \sum_{1}^{i_n} l_i}} \qquad (2)$$

where ξ_i are coefficients of the local hydraulic losses;

l_i – channels' lengths, m.

The maximum width of the channels *(b)* will be

$$b = \frac{G_{\max}}{L\nu_{\max}} \qquad (3)$$

where G_{max} is maximum volumetric ventilation rate, m^3/s.

Thus suggested microclimate aeration schemes provide for more fully use of building energy potential (the air heat inside the building and heat emanated by animals), as and the potential of outdoor air. The processes exergy of the building ventilation increases [5]. As an example, the exergy coefficient of efficiency is determined and calculated for a restructured pig building. The exergy coefficient of efficiency of this building was compared with those of the buildings with force ventilation (Fig.2).

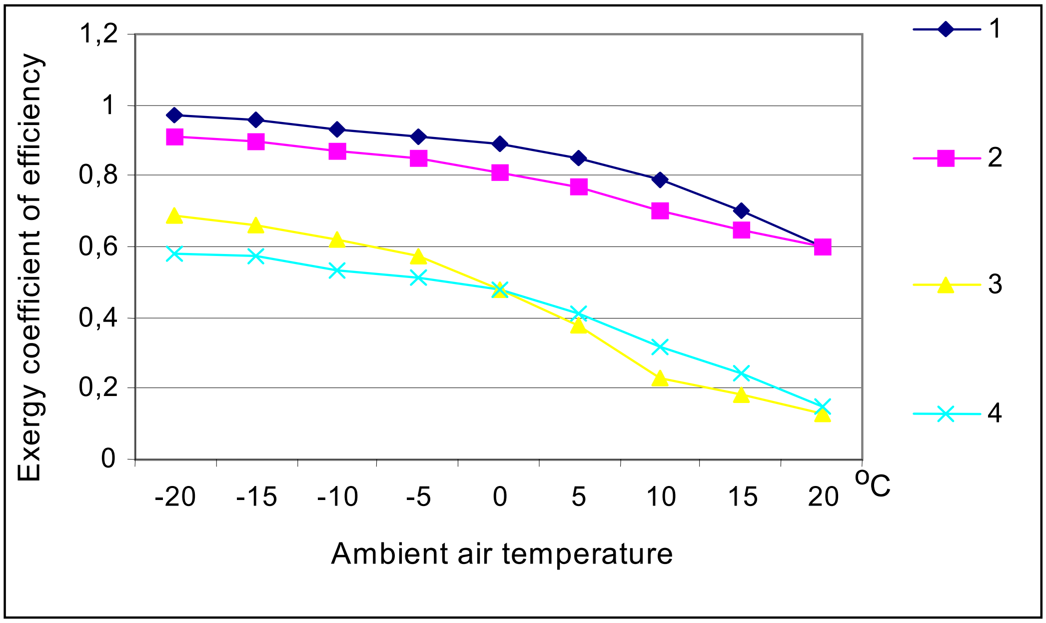

Fig.2. Exergy coefficient of efficiency of the buildings for finishing pigs
1 - model building at the beginning of the technological cycle; 2 - model building at the end of the technological cycle; 3 - extant building at the beginning of the technological cycle; 4 - extant building at the end of the technological cycle.

2. Model for reconstruction of livestock building type "Gi&Gi"

The livestock buildings type "Gi&Gi" are wide spread in the built farm and livestock complex in a lot of country and at home. It is suitable to carry out the reconstruction when the heat insulation of the roof is being changed. The reconstruction scheme is shown in Fig.3 [2,4]. The scheme from Fig.1a is suitable. The building construction is kept.

The inlet 1 and outlet 2 channels are built between bearer frames 11. The channels are manufactured from reinforced polyethylene foil, which covers the whole ceiling area. The polyethylene foil is mounted to frames 11. The bottoms of the inlet channels 1 are protected with insulation 10. On the outlet channels are put an insulating layer 14 by styrofoam, mineral batting or polypropylene on the area toward the roof.

The insulating side-walls 15 are mounted over building sides. They cover the building walls fully and fix to the vertical columns of the bearer frames 15. The air exchange is controlled by the valve 4. The inlet channels connect to frameworks of the building windows.

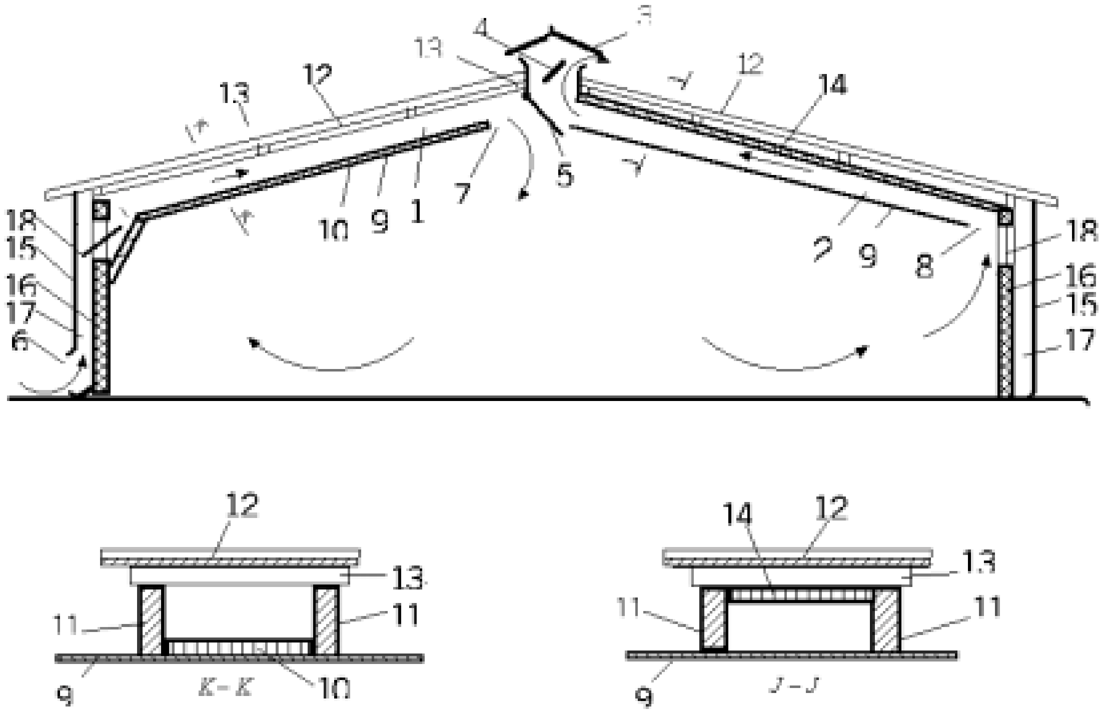

Fig.3. Reconstruction scheme of livestock building type "Gi&Gi"

1 - inlet channel; 2 - outlet channel; 3 – ridge vent; 4 – control valve; 7 – bottom valve-vent; 6 – inlet; 7 – inlet opening; 8 - exhausting outlet; 9 - outlet channel bottom; 10 - inlet channel bottom insulation; 11 - bearer frame; 12 - roof asbestos sheets; 13 – transverse beams; 14 - outlet channel insulation; 15 – insulation side-walls (mounted under reconstruction); 16 – extant wall panels; 17 - inlet channel to side-walls; 18 – windows.

3. Model for reconstruction of panel sectional livestock buildings

The reconstruction is carried out in like manner as the precedent building (Fig.4). The channels' bottoms take shape by means of affixing of the reinforced polyethylene foil 9 to bearer frames 11. The inlet channels 1 are insulated with the insulation layer 10. The outlet channels do not need by insulation. Along the building ridge some openings are taken form in which the ridge vents 3 and control valve 4 are mounted. The windows 17 are kept.

On the base of presented schemes, some pig buildings – type "Gi&Gi" for 2000 finishing pigs and 2 buildings for weaned piglets were reconstructed. The results of their investigation are shown in [3]. A decreased death-rate up to 3.3% is found, increase of the daily liveweight gain up to 12.8%, decrease of the fodder consumption up to 10.2%. The energy consumption for building ventilation dies out. The quantity of building electrical installations decreases two times.

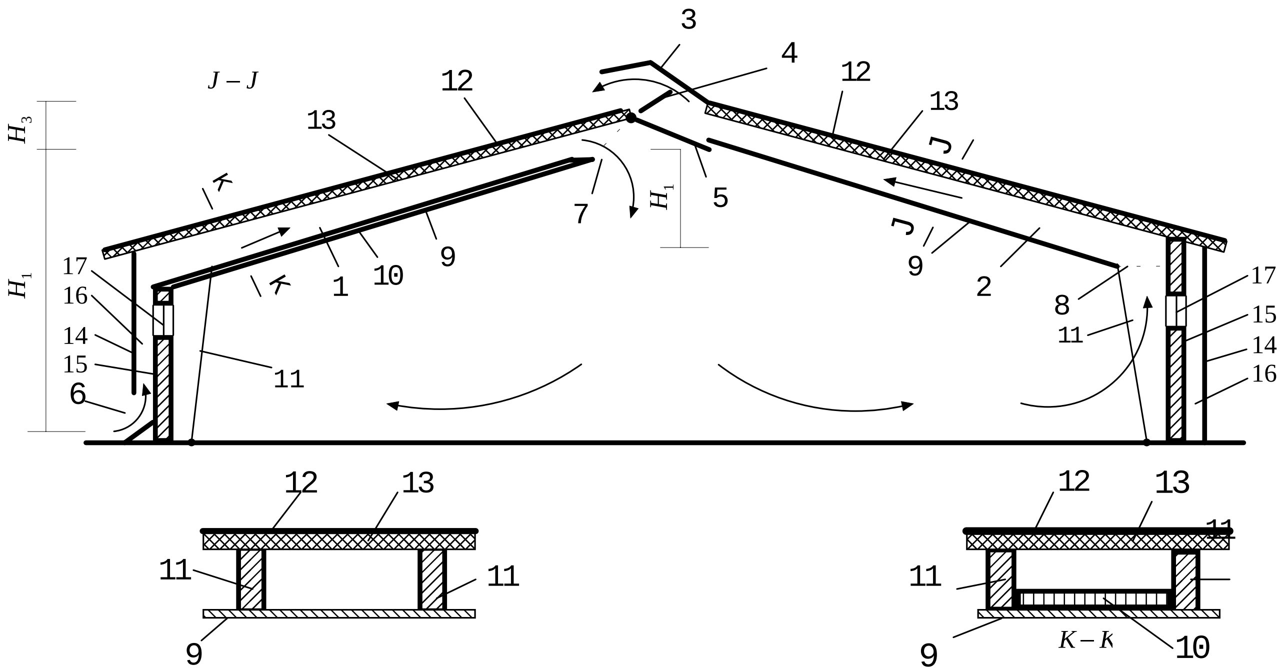

Fig.4. Reconstruction scheme of panel sectional livestock building
1 - inlet channel; 2 - outlet channel; 3 – ridge vent; 4 – control valve; 7 – bottom valve-vent; 6 – inlet; 7 – inlet opening; 8 - exhausting outlet; 9 - outlet channel bottom; 10 - inlet channel bottom insulation; 11 - bearer frame; 12 - roof panels; 13 – insulation of the roof panels; 14 – insulation side-walls (mounted under reconstruction); 15 – extant wall panels; 16 - inlet channel to side-walls; 17 – windows.

4. Module livestock building

The providing of the livestock breeding with new effective livestock buildings is linked with development of a new technology for their manufacture. Therefore the building construction is suggested to be built by means of module approach (Fig.5). The module consists two blocks: block A – body of the module element, in which the inlet channels are embedded; block B - body of the module element, in which the outlet channels are embedded. Every block could be made centrally in industrial estate. The gabarit and mass of the elements permit their transport and assembly to be carried out with the standard transport and assembly technics. Every block is assembled by bearer beams 5 and frames 1. Every block is assembled by bearer beams 5 and frames 1. The roof elements 4 are made thus, that the module assembly form the roof at the same time (Fig.5 - C). During assembly, the frames 1 connect by the bolts 10. Thereby the common bearer frame is made and forms the building without some other operation.

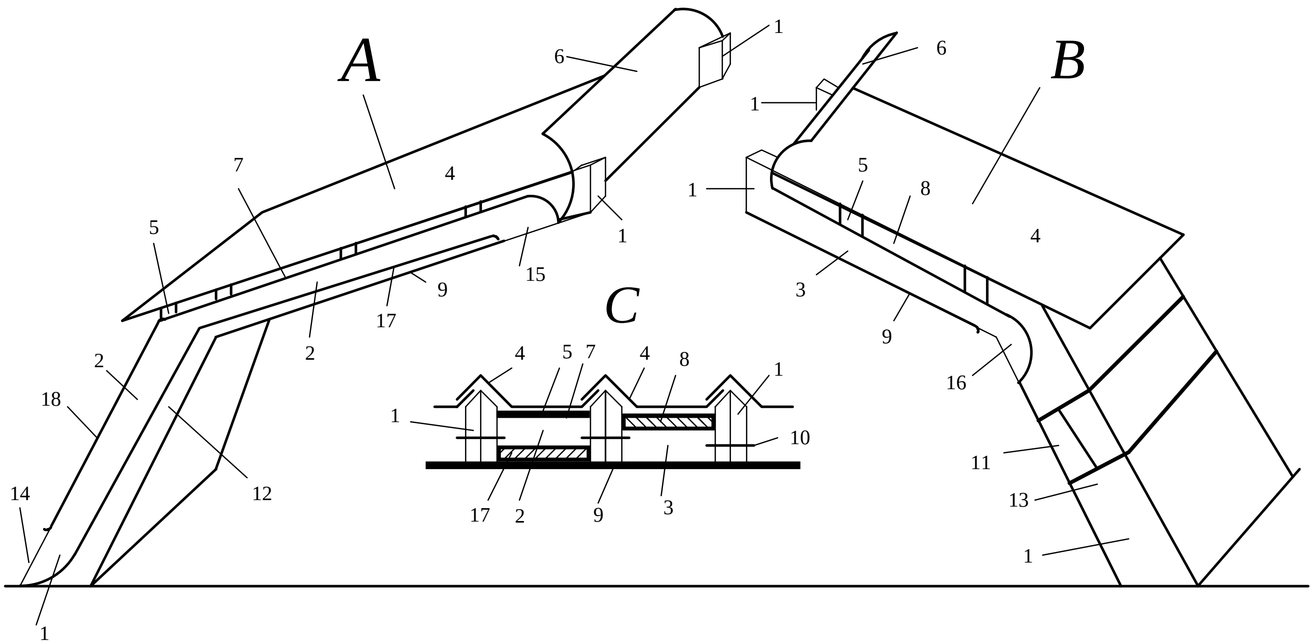

Fig.5. Construction scheme of the module for erection of module livestock buildings Block A – body of the module element with embedded inlet channels; Block B - body of the module element with embedded outlet channels.
1 - bearer frame; 2 - inlet channels; 3 - outlet channels; 4 – roof element; 5 – binding beams; 6 – ridge-vent elements; 7 - roof insulation toward inlet channels; 8 – roof insulation toward outlet channels; 9 – channels' bottoms; 10 – bolt for frame binding; 11 – window; 12 – wall toward inlet channels; 13 - wall toward outlet channels; 14 - inlet; 15 – outlet; 16 – inlet opening; 17 - inlet channel bottom insulation; 18 – external sheets of the inlet channels.

5. Effective business-schemes for buildings reconstruction

The presented scheme allows the reconstruction to be synchronized with pig – breeding technological cycles, so that the production is not interrupted and the cycles earnings to accelerate the credits' recovery. The reconstruction investment divides in three main transhes (Table1)[6]: K1 – investment for elaboration and assembly of the ridge vent; K2 - investment for elaboration and assembly of the inlet and outlet channels; K3 - investment for elaboration of the insulation of the side-walls. Every transh could be shared in range stages – K11,…, K1p; K21,…, K2l; K31, …, K3d (Table1).

Transh matrix for digestion of the investment **Table 1**

Transhes	Stages of digestion
K1 – elaboration and assembly of the ridge vents	K11, K12, … , K1p
K2 – elaboration and assembly of the channels	K21, K22, … , K2l
K3 – elaboration of the insulation of the side-walls	K31, K32, … , K3d

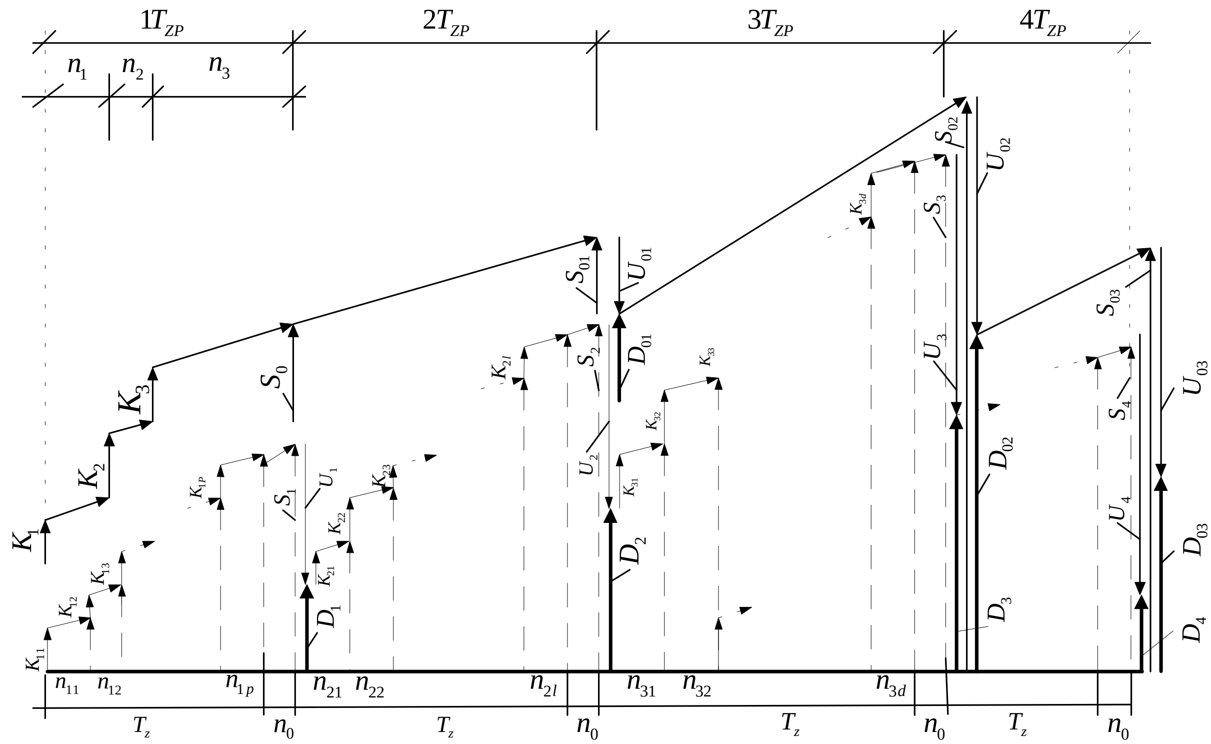

Fig.6. Business-scheme for effective building reconstruction

The business-scheme is diagrammed in Fig. 6. The amassed sums and the odd money in the end of every technological cycles will be:

$$S_1 = K_{11}[1+y(T_z+n_0)] + K_{12}\left[1+y\left(\sum_2^p n_{1i}+n_0\right)\right] + \ldots + K_{1p}[1+y(n_{1p}+n_0)] \quad (4)$$

$$D_1 = S_1 - U_1 \quad (5)$$

$$S_2 = (D_1+K_{21})(1+y(T_z+n_0)) + K_{22}\left[1+y\left(\sum_2^i n_{2i}+n_0\right)\right] + \ldots + K_{2i}[1+y(n_{2i}+n_0)] \quad (6)$$

$$D_2 = S_2 - U_2 \quad (7)$$

$$S_3 = (D_2+K_{31})[1+y(T_z+n_0)] + K_{32}\left[1+y\left(\sum_2^d n_{3i}+n_0\right)\right] + \ldots + K_{3d}[1+y(n_{3d}+n_0)] \quad (8)$$

$$D_3 = S_3 - U_3 \quad (9)$$

$$S_4 = D_3(1+y(T_z+n_0)) \quad (10)$$

$$D_4 = S_4 - U_4 \quad (11)$$

$$S_0 = K_1(1+yT_{zp}) + K_2[1+y(n_2+n_3)] + K_3(1+yn_3) \quad (12)$$

$$S_{01} = S_0(1+yT_{ZP}) \quad (13)$$

$$D_{01} = S_{01} - U_{01} \quad (14)$$

$$S_{02} = D_{01}(1+yT_{ZP}) \quad (15)$$

$$D_{02} = S_{02} - U_{02} \quad (16)$$

$$S_{03} = D_{02}(1+yT_{ZP}) \quad (17)$$

$$D_{03} = S_{03} - U_{03} \quad (18)$$

$$\Delta S = D_{03} - D_4 . \quad (19)$$

where:
T_Z is the continuance of the technological cycles for breeding of the animals or birds, days;
T_{ZP} - the continuance of the technological cycles for breeding of the animals or birds, including pause n_0, days;
n_0 - the continuance of the pause for preparation and recharge of the parcels, days;
$n_{11},\dots,n_{1p}$; $n_{21},\dots,n_{2l}$; $n_{31},\dots,n_{3d}$ - the continuance of the stages of digestion through technological cycles under reconstruction without production interrupting, days;
n_1, n_2, n_3 – the number of days for the transh digestion under reconstruction with production interrupting, days;
K_1, K_2, K_3 – the number and the transh size under reconstruction without production interrupting, days;
$K_{11},\dots,K_{1P}$; $K_{21},\dots,K_{2L}$; $K_{31},\dots,K_{3D}$ – the number and size of the stages for digestion of the transh K_1, K_2 and K_3 under reconstruction without production interrupting, days;
S_0, S_{01}, S_{02}, S_{03} – the amassed sums before the beginning of every technological cycle, under reconstruction with production interrupting, lv;
U_{01}, U_{02}, U_{03} – the earnings, realized after technological cycles under reconstruction with production interrupting, lv;
D_{01}, D_{02}, D_{03} – remainders before the beginning of every technological cycle, under reconstruction with production interrupting, lv;
S_1, S_2, S_3, S_4 – the amassed sums before the beginning of every technological cycle, under reconstruction without production interrupting, lv;
U_1, U_2, U_3, U_4 – the earnings, realized after technological cycles under reconstruction without production interrupting, lv;
D_1, D_2, D_3, D_4 – remainders before the beginning of every technological cycle, under reconstruction without production interrupting, lv;
ΔD_1, ΔD_2, ΔD_3, ΔD_4 – differences between the remainders before the beginning of every technological cycle, lv.

6. Conclusions

The presented conceptual schemes of energyeconomical livestock buildings show that the manufacture of the livestock production can be put of the principled new base, if some preconditions for benefits in respect of the energy consumption, buildings' construction and improvement of environmental norms are created.

The energy benefit is provided by building aeration during whole year, the heat-exchange realization through construction of the building, using of the heat emanated by the animals and utilization of the exhausted dirty air heat by heat-pump effect. The microclimate process exergy is increased.

The environmental improvement and providing of ecological cleaner production is achieved by means of uniform air distribution in the building, natural contact of the animals and poultry with surrounding environment, lack of noise, draughts and decreased dust.

The microclimate control system structure is changed with decreased quantity of electrical equipment (electrical motors, fans, control devises etc.), new control algorithms and increased operational reliability, independence by electrical interrupting.

The buildings construction change is principled and requires the buildings to be designed, built and used in quality different mode.

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