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ON THE ENERGY MODEL OF THE FUTURE WORLD ON THE BASIS OF SOLAR SILICON ENERGETICS

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The energy model of the future world has been offered that is based on round-the-clock electric power generation by solar power plants and on energy systems and networks on the basis of N. Tesla technologies. In Russia new energy technologies have been developed allowing to create the global solar energy system within the framework of an international project involving concerned energy companies, the International Energy Foundation, IRENA, UNESCO, the UN and other national and international organizations and financial institutions. The development of silicon energetics will make it possible to reduce negative impact of hydrocarbon energy on climate, environment and human health, as well as to reduce greenhouse gases emission down to safe level.

Keywords: energy model, power of the future world, global power system, photovoltaics, silicon energetics.

Each technological mode and corresponding energetics is characterized by the phases of development, flourishing and decay. The XX century was the period of maximum development and use of hydrocarbon energy which by the end of the XXI century may be replaced by fuel-free power generation on the basis of renewable energy sources. Decline in the development of hydrocarbon energy will stem not from depletion of hydrocarbons reserves but from the development of new energy technologies and emergence of new energy carriers allowing to reduce the cost of energy resources, raise their use efficiency and diminish energy negative impact on environment.

In 2004-2005 Russian researchers offered the energy model of the future world based on the creation of global solar energy system with electric power generation in the amount of 20 000 TW·hour per year which is equal to current global energy consumption [1-5]. The global solar energy system comprises three solar power plants (SPP) installed in deserts of Australia, Africa and Latin America and connected to one another and to national energy systems of all the countries all over the world with waveguide resonant lines for electric power transmission on the basis of N. Tesla technologies [6].

Each SPP parameters:

size	200 × 200 km;
electric capacity	2.5 TW;
efficiency	25%;
service life	50 years

Computer simulation of the global power system parameters with due account to meteorological data on solar radiation for the whole observation period at SPP location areas confirmed uniform year-round electricity production irrespective of season, in the amount equal to global consumption [7-10].

For the global solar energy system high-voltage silicon solar modules (HVSM) with 1 000 V voltage, efficiency of up to 25% at 50-100 solar concentration and service life of up to 50 years have been developed [11-13]. HVSM high efficiency was confirmed by test records at the independent foreign laboratory. The price of silicon HVSM is 1000 times lower than that of heterostructure cascade solar cells with the same area. Over 100 RF patents on the design and technologies of SPP with concentrators have been obtained.

Modern solar energy is mainly based on planar low-voltage silicon solar modules without concentrators with 15% efficiency and overall production of modules 30 GW/year and of solar silicon - $2 \cdot 10^5$ t/year. SPP with 2.5 TW capacity at 100 concentration would require $3 \cdot 10^5$ of silicon which is comparable to current volume of silicon production for electronics and photovoltaics. Silicon content in the Earth core exceeds the content of all other elements with the exception of oxygen, that is why it is silicon that will remain basic material for solar energy in future.

Let us consider other possible applications of silicon as fuel for energy generation. By analogy with hydrocarbon energy this trend can be termed silicon energetics. Let us consider four known methods of using silicon for energy generation:

1. Silicon combustion in air oxygen:

$$Si + O_2 = SiO_2 \quad (1)$$

2. Silicon catalytic combustion in water:

$$Si + 2H_2O = SiO_2 + 2H_2 \quad (2)$$

$$2H_2 + O_2 = 2H_2O \quad (3)$$

3. Silicon catalytic combustion in nitrogen:

$$Si + 2N_2 = SiN_4 \quad (4)$$

4. Physicochemical reactions in molten sodium silicate [14]:

$$sNa_2r\, SiO_{(2r+s)} \Rightarrow Na^+ + Si_mO_n \quad (5)$$

In **Table 1** the comparison of calorific efficiency of silicon and hydrocarbons is given.

Table 1

Comparison of calorific efficiency of silicon and hydrocarbons

Reaction number	Fuel	Calorific efficiency
1	Silicon	205 kcal/mol
2	Silicon	205 kcal/mol
2 + 3	Silicon	273,3 kcal/mol
4	Silicon	180 kcal/mol
-	Methane	210 kcal/mol
-	Coal	94 kcal/mol
3	Hydrogen	68,3 kcal/mol
5	Sodium silicate	8500 Mcal/mol
-	Heavy oil	8500 kcal/mol

On the basis of Table 1 the following conclusions can be made:

1. Initial and final products of silicon energetics are not radioactive, do not pollute environment and do not generate greenhouse gases.

2. In combustion in air, silicon as fuel is twice more effective than coal and is almost equal to natural gas.

3. If associated with nitrogen in oxygen-free energetics, silicon as fuel is twice more effective than coal. Nitrogen content in atmosphere exceeds all other gases content.

4. Thermal energy of high-temperature physical-chemical reactions in heterogeneous media of high-modulus silicate solutions, for example, of sodium silicate, thousand times exceeds calorific value of hydrogen fuel with the same mass. Electrochemical current source with molten electrolyte with nonstechiometric composition on the basis of sodium silicate with megawatt capacity has calculated price of electricity of 80 euro/MW·hour [15].

Conclusions

1. The energy model of the future world has been offered that is based on round-the-clock electric power generation by solar power plants and on energy systems and networks on the basis of N. Tesla technologies.

2. In Russia new energy technologies have been developed allowing to create the global solar energy system within the framework of an international project involving concerned energy companies, the International Energy Foundation, IRENA, UNESCO, the UN and other national and international organizations and financial institutions.

3. The development of silicon energetics will make it possible to reduce negative impact of hydrocarbon energy on climate, environment and human health, as well as to reduce greenhouse gases emission down to safe level.

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HIGH-VOLTAGE SILICON MODULES FOR CONVERSION OF CONCENTRATED SOLAR RADIATION*

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The results of research of high voltage 840 V 20% efficiency silicon solar modules for conversion of concentrated solar radiation are presented. Their electric and optical characteristics are considered. High voltage solar modules can be used for the construction of solar power plants with 110-500 kV output operating voltage, that can be connected to direct current transmission lines without step-up transformers and ac-dc converters.

Keywords: *high voltage solar module, 20% efficiency, operating voltage 840 V, direct current transmission line.*

Introduction

Research organizations and companies in many countries of the world are developing silicon solar modules (SM) of the third generation with efficiency of 25% and more, suitable for large-scale industrial production. Planar solar cells and silicon modules with up to 25% efficiency has been developed by Professor Martin Green from the University of New South Wales (Australia) [1], though they are not produced because of the complicated and expensive manufacturing technology. On industrial scale planar SM with 20% efficiency are produced by Sun Power (USA), but they find limited use because of high cost. All known silicon planar SMB are not used at concentrated solar radiation because of sharp decrease of efficiency at higher illumination. Currently all plants both in Russia and abroad are producing silicon SM with 15-18% efficiency. To raise efficiency over 25% in mass production new physical principles, new structures and advanced SM technologies are required.

So far it was considered that p-n junction in whose electric field minority carriers generated by solar radiation, are separated, plays a critical role and its area should be similar to SM area. However, p-n junction has some negative properties. There are recombination losses in its area. Through p-n junction dark saturation current is flowing, related to heat generation of charge carriers and causing photo-emf decrease. Doped layer over the plane of p-n junction has high series resistance increasing ohmic losses, especially in the process of conversion of concentrated solar radiation. Doped layer absorbs short wave part of solar radiation because of losses at free carriers, and its contribution to photo current is inconsiderable because of charge carriers recombination at crystal structure defects and impurity centers in highly doped semi conductors.

We offered to divide illuminated SM into areas of charge carriers generation and p-n junction areas where charge carriers are separated and accumulated. In this process the area of doped layer, p-n junction and $p-p^+$ junction at illuminated surfaces is reduced more than 50 times, and 99% of the surface area is designed for electron-hole pairs generation in condition of direct interaction of solar radiation with the SM base area.

In 1967 we developed and tested high-voltage solar modules (HVSM) of the first generation [2], made in the form of a silicon solid matrix of microcells commuted in series or in parallel, with vertical p-n junction. Microcells density at HVSM operating surface was 25 cm^2 and they had 1-2% efficiency at 7 700 kW/ m^2 illumination intensity.

In 1970 the ion implantation technology was used for the development of the second generation HVSM with 10% efficiency at 2.5 kW/ m^2 illumination. The microcells density was increased 10 times - up to 250 cm^{-2}, and HVSM with 4 cm^2 area had 400 V voltage [3]. The solar array with 1 m^2 area and 32 kV voltage was developed and tested in 1972. The 40x100 mm solar module with 28 V operating voltage was installed at the international station “Venera-70” and successfully tested. 36%

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efficiency and electric capacity of 3.6 kW/cm^2 were obtained in conditions of HVSM illuminating with a pulse neodymium laser at 10 kW/cm^2 illumination intensity.

As to foreign authors, the best known are the works by D.L. Sater [4, 5] who developed HVSM experimental prototypes with 20% efficiency at radiation 2500 kW/m^2.

This work is designed to develop and study high-voltage solar modules of the third generation on the basis of single-crystal silicon with working voltage of up to 800 V and 20% efficiency at concentrated solar radiation.

The High-Voltage Solar Modules of the Third Generation

The high-voltage bifacial solar module is made in the form of a matrix of commutated miniature solar cells (micro SC) with one or two linear dimensions commensurable with diffusion length of minor carriers in base area, and p-n junction planes are perpendicular to the HVSC operating surface (fig. 1).

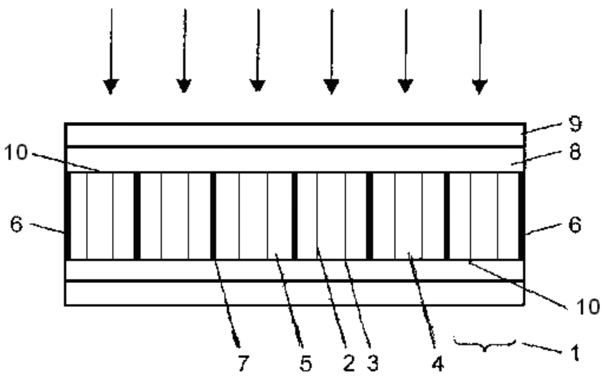


Fig.1. High-voltage solar module on the basis of single-crystal silicon (1-10 in the text)

Figure 1 demonstrates that HVSC consists of miniature solar cells 1, containing p-n junction 2, isotopic junction 3, base area 4 of n-type and doped isotopic p$^+$ layer 5, external metal contacts 6, internal metal contacts 7, passivating film 8 and antireflection coating 9 at working surface 10. In this case p-n junction 2 are located perpendicularly to the operating surface 10. One or two linear dimensions of micro SC 1 are commesurable with diffusion length of minor carriers in base area 4. 10-30 nm thick passivating film 8 is located at surface 10 free of n-p junction.

In this paper a simplified HVSM model is considered, wherein antireflection coating 9 on the working surface is absent.

The RF Federal Intellectual Property, Patents and Trademark Service have selected 100 best of 42 000 RF patents, and in this list the patent for the third generation MSC and the technology of its manufacturing has been included.

At the International Forum "High Technologies of the XXI Century" held in April, 2010, GNU VIESH of RAAS became the Laureate of the competition "High Technologies – the Basis of Modernization of Economy and Industrial Development" and was awarded a medal for competitive project "Photovoltaic Silicon Modules with Increased Efficiency (24%) for Solar Power Plants with Concentrators".

The third generation HVSM with 20-24% efficiency at concentrated solar radiation were developed and tested in 2009 [7-8]. HVSM are fabricated at the experimental technological site at GNU VIESH.

The third generation MSC technology is adapted to industrial production conditions and does not involve such labor-intensive processes as multistage diffusion, photolithography, screen-printing, vacuum metallization, etc. We have succeeded in excluding silver for making contacts, as silver consumption at global level of SC production of 30 GW exceeds 400 tons per year, which creates serious problems to the future development of solar industry.

Study of High-Voltage Solar Modules in the Conditions of Solar Illumination and Concentrated Radiation

Solar radiation was measured with the use of an actinometer and a pyranometer. In laboratory conditions at concentrated radiation HVSM characteristics were measured using a pulse simulator. A xenon flash lamp whose spectrum is similar to solar spectrum, was used in the simulator as a light source. Flash duration was about 5 ms. Variable electronic load provides volt-ampere characteristic measurement for period from 2 to 5 ms. In this process from 6 000 to 16 000 value of current-voltage pairs were read while radiation intensity was also recorded. Measurements were taken with the use of a memory oscilloscope OTsZS-02-6, after that the data was processed by dedicated VAX software.

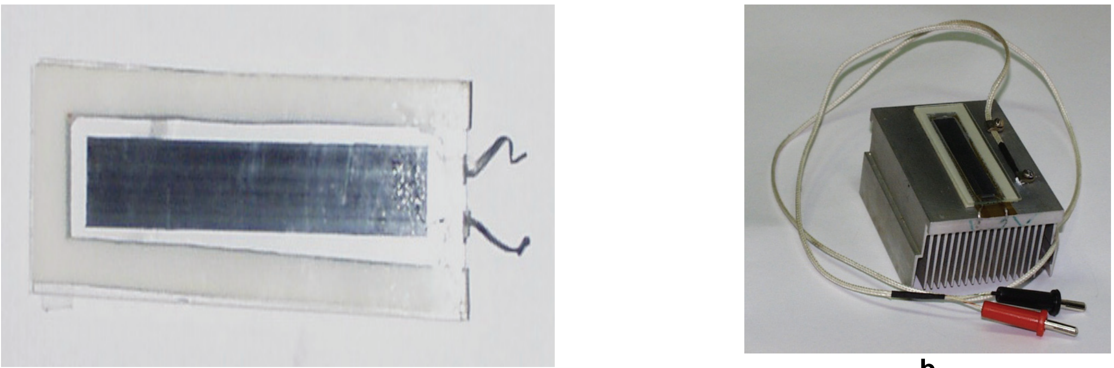
In efforts to improve the technology of HVSM fabrication we concentrated on reduction of the rate of surface recombination due to passivation of two HVSM operating surfaces. In the result photocurrent, electric capacity and efficiency are raised.

Figure 2-a demonstrates HVSM 10×60×0.4 mm section of HVSM in glass envelope, comprising 25 microcells, total width of contacts of all photovoltaic micro cells at the operating surface being 150 μm. At fig. 2-b the HVSM section is installed at a radiator.

Figure 3 demonstrates volt-ampere characteristics of 10×60×0.4 mm HVSM with an air cooling radiator at various illumination; fig. 4 – efficiency dependence on radiation intensity with the use a xenon pulse lamp for illumination [9-10].

At concentrated pulse radiation with 102.5 kW/m^2 flow density the efficiency of HVSM with 6 cm^2 area was 24%, operating voltage – 16.3 V, operating current – 0.9 A, photo emf – 19 V (curve 1′). HVSM short-circuit current is increasing linearly with increasing illumination, fill factor grows and voltage increases 1.3-1.4 times, thus raising efficiency up to 24% at 102.5 kW/m^2. 59.16 W electric capacity was obtained at 20% HVSM efficiency and at radiation intensity 493 kW/m^2 (fig. 3, curve 1″).

Thus, HVSM with 6 cm^2 area at 493 kW/m^2 radiation intensity has 60 W electric capacity, 15 V operating voltage and 4 A current equal to peak capacity, voltage and current of a conventional photovoltaic module on the basis of planar silicon SC at standard illumination of 1 kW/ м^2 and 25^o C temperature. It should be mentioned that conventional modules area is nearly 1 000 times larger than the area of the third generation HVSM, which practically means 1000-fold reduction of silicon consumption per one unit of capacity.



a b

Fig. 2. Section of the high-voltage solar module (a) and with an air cooling radiator (b)

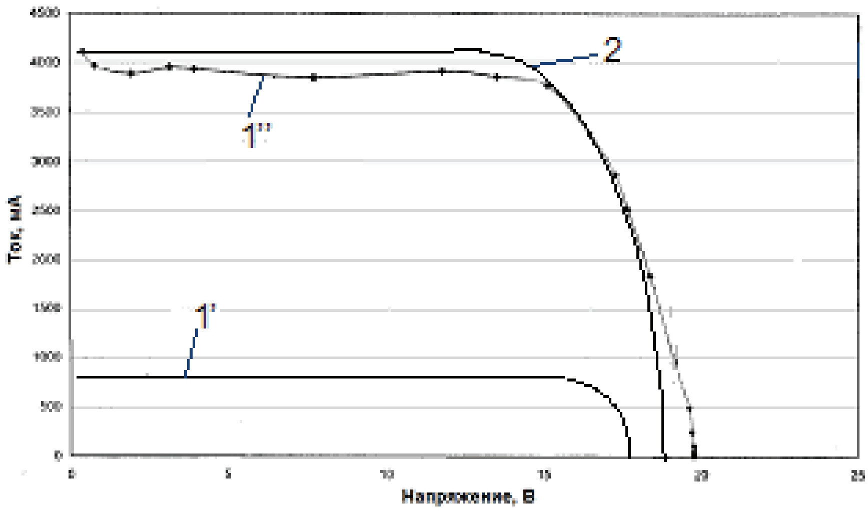


Fig. 3. Volt-ampere characteristics of 10 x 60 x 0.4 mm HCSM:
1' – illumination - 102 kW/m^2, efficiency - 24%;
1'' – 493 kW/m^2, efficiency - 20%; 2 – 1.2x0.54 m planar solar module at 1 kW/m^2 illumination, efficiency – 12 %

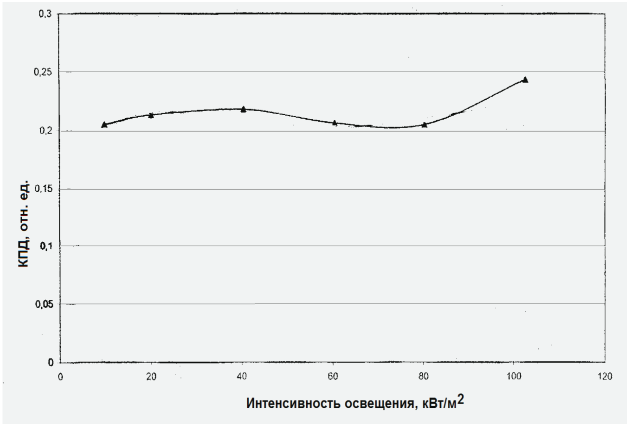
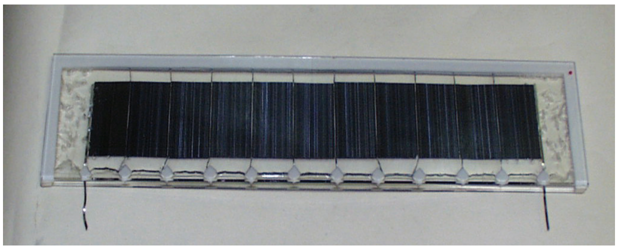


Fig. 4. Dependence of HVSM efficiency on radiation intensity. HVSM dimensions - 10×60×0.4 mm



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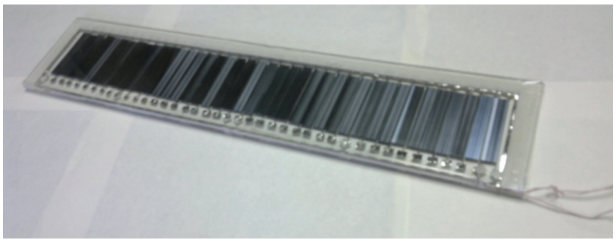

b

Fig. 5. High voltage solar modules with 400×60 ×0.4 mm dimensions in glass envelope comprising 11 60×35 mm sections (a) and 40 60×10 mm sections (b)

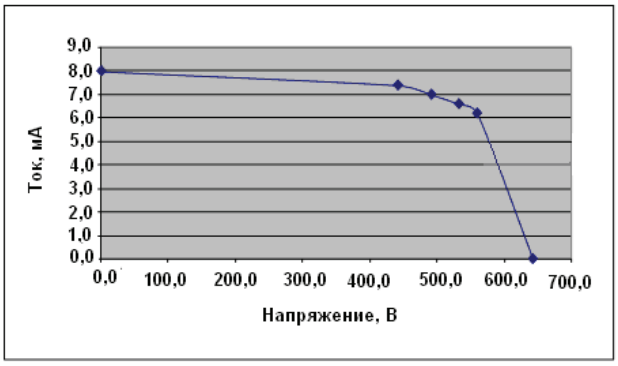

Fig. 6.Volt-ampere characteristic of HVSM comprising 40 sections at 1 kW/m^2 solar illumination

Dependence of HUSM efficiency on radiation intensity is presented in fig. 4.

Figure 5 demonstrates a general configuration of two types of high-voltage solar modules with 400×60×0.4 mm dimensions in glass envelope, and Fig. 6 shows HVSM (Fig. 5-b) volt-ampere characteristics at 1 kW/m^2 solar radiation.

The HVSM operating voltage was 500 V, operating current – 3.5 W, efficiency – 14.58%.

Figure 7 presents volt-ampere characteristic of one HVSM section (60×10 mm, 33 microcells) at 51.783 kW/m^2. HVSM comprises 33 60×10 mm microcells connected in series.

Summarizing volt-ampere characteristics of all sections one can calculate volt-ampere characteristics of 400×60 mm HVSM at 51.783 kW/m^2 illumination. Short-circuit current is 337.1 mA, photo emf – 959 V, operating voltage 840 V, fill factor – 0.784, operating current 0,3 A, optimal capacity – 252 W and efficiency – 20.42%. In-series commutation of 595 high-voltage modules in solar power plant will make it possible to obtain output voltage of 500 kV at 157 kW electric capacity. Further capacity enhancement can be obtained due to parallel HVSM connection.

For photoreceivers on the HVSM basis (fig. 8) original solar concentrators of cylindrical parabolic and paraboloid types have been developed, whose surface profile provides uniform illumination of the photoreceiver surface.

In operating solar plants with concentrators some positive aspects should be mentioned, such as reduced solar grade silicon consumption; alongside with electricity, heat energy is generated thus reducing total cost of installed capacity due to aggregation of these components; cosine effect influencing nontracking solar plants, is considered, that increases energy output by 25-30% in comparison with stationary nontracking models.

Comparison of Characteristics of Planar and High-Voltage Solar Modules

The comparison of characteristics of planar and high-voltage solar modules made of single-crystal silicon is given in Table 1.

The Photon International annual report of 2012 [11] demonstrates that average efficiency of planar solar modules (PSM) made of single-crystal silicon, increased from 14.6 to 15.1 %, and that of modules made of multi-crystal silicon – from 14.1 to 14.7%. The single-crystal PSM share in the overall production amounts to 49%, the multi-crystal PSM share is 48.4%, the thin-film SM share is 2.38%.

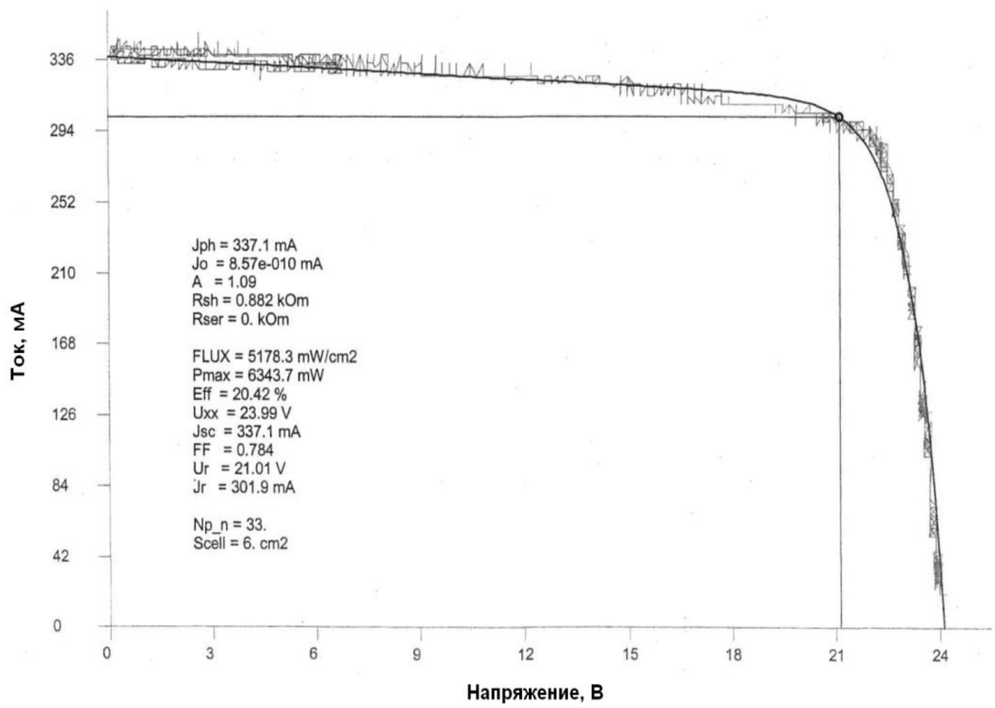

Fig. 7. Volt-ampere characteristic of one section of a high-voltage solar module at 51.783 kW/m^2. The section area is 6 cm^2, 33 microcells

a **b**

Fig. 8. Concentrator modules of cylindrical parabolic (a) and paraboloid types (b) with even illumination of a photoreceiver on the basis of HVSM

In 2009 the number of PSM manufacturing companies decreased by 30% - from 181 to 129 [11].

HVSM have bifacial working surface. Due to solar radiation reflection to back surface HVSM electric capacity and efficiency are increased by 20-23% [12] and that should be taken into account in comparison of planar and high-voltage SM.

The HVSM service life is twice as long (40-50 years) and their efficiency is 18-20% at 50-200 concentration, which is 10 times higher than that of PSM. The 18-20% HVSM efficiency persists even when temperature increases up to 60°C, which allows to simplify a cooling system.

Table 1. Comparison of Characteristics of Planar and High-Voltage SM

Characteristic	High-voltage solar module	Planar solar model
Voltage, V	750	12 – 24
Service life, years	40 – 50	20 – 25
Average efficiency at solar radiation 1 kW/m^2, Spectrum AM 1.5 and temperature 25 °C, %	12 – 14	15.1
Efficiency at concentrated solar radiation 100 kW/m^2, AM 1.5 and temperature 25°C, %	18 – 20	1

Table 2.Comparison of Economic Performance of Solar Modules of Various Types

№ №	Characteristics	Standard modules with EVA insulation	GNU VIESH modules with silicon gel insulation
1.	Service life, years	25	40
2.	Electric power output for the whole service life, kW·h/kW: a) in Russia b) in southern countries	 25 000 37 500	 40 000 60 000
3.	Revenue from electricity sales for the whole service life of modules with 1 kW capacity: a) in Russia at the price of 9 rubles/kW·h, rubles б) in southern countries at the price of 0.48 USD/ kW·h, USD	225 000 18 000	360 000 28 800
4.	Revenue from sales of electricity for the whole service life of modules with total capacity of 2 MW: a) in Russia б) in southern countries	450 000 000 36 000 000	720 000 000 57 600 000
5.	Revenue from electricity sales for 5 years of operation of the line producing modules with overall capacity of 2 MW/year will amount to: a) in Russia, rubles б) in southern countries, USD	2 250 000 000 180 000 000	3 600 000 000 288 000 000

The 0.4 m long HVSM have up to 840 V operating voltage, which makes it possible to use them in combination with transformless inverters and to connect them to high-voltage DC transmission lines with 110-500 kV voltage without converter substations. The cost of high voltage converter substations constitutes up to 30% of the solar plants cost. To obtain operating voltage of 840 V with the use of conventional planar solar modules it would be necessary to connect in series over 1 500 planar solar modules with 150×150 mm dimensions, the module full length exceeding 252 m.

Let us calculate the output and volume of sales of electric power for solar modules with increased service life.

In Russia 1 kW of solar modules produces 1 000 kW·h of energy per year. In southern countries electric power output amounts to 1500 kW·h/year.

Table 2 presents the comparison of economic performance of solar modules made with the use of the GNU VIESH technology with silicon gel inscapsulation, with standard solar modules with ethylenevinylacetate (EVA) film lamination.

The cost of electric power from solar power plant with 100 kW capacity in Russian amounts to 9 rubles/kW·h. In the Ukraine the cost of electric power from a solar plant with 100 MW capacity is 0.48 $/kW·h.

In overall SM production of 10 MW for 5 years, expected revenue from electricity selling for modules with prolonged service life will be higher by 1.35 billion rubles in Russia, and in southern countries - by 108 million USD in comparison with solar modules with EVA insulation.

The HVSM production cost is commesurable with the cost of planar silicon SM per one area unit and is 1000 times lower in comparison with the cost of cascade heterostructure solar modules on the basis of $A_{III}B_V$ compounds while their efficiency is similar. The development of the technology of the third generation HVSM on the basis of single-crystal silicon will make it possible to build solar power plants with concentrators with lower specific costs per 1 kW of installed capacity and higher efficiency of electricity generation in comparison with thermal power plants using coal.

Conclusions

1. In the result of technological research HVSM with vertical p-n junction and operating voltage of up to 840 V have been developed. Maximal efficiency of the third generation HVSM is 14.58% at total insolation of 1 kW/m^2 and 25^o C temperature, and 24% when measured under a pulse simulator with 102 kW/m^2 intensity. Maximal capacity of the module with 6 cm^2 area is 60 W and efficiency is 20% which makes it possible to reduce silicon consumption 1000 times in comparison with standard planar silicon photovoltaic modules on the basis of single-crystal silicon without concentrators. The above-mentioned characteristics are obtained at HVSM without reflecting coating.

2. The design and technology of the fabrication of the third generation silicon modules for solar power plants with concentrators have been developed. The third generation MSC technology is adapted to industrial production conditions and does not involve such labor-intensive operations as multi-stage diffusion, photolithography, screen-printing, vacuum metallization, etc. We have succeeded in excluding silver for making contacts, as silver consumption at global level of SC production of 30 GW exceeds 400 tons per year, which creates serious problems to the future development of solar industry.

3. For effective use of HVSM with solar radiation concentrators it is necessary to provide even illumination of HVSM in the focal region and cooling in the conditions of concentrated insolation. It can be most easily done through the use of linear concentrators on the basis of parabolic troughs, linear lenses and Fresnel mirrors.

4. Advanced processes of semiconductor electronics and nanotechnologies will make it possible to raise efficiency of conversion of concentrated solar radiation through the use of HVSM on the basis of matrix silicon solar cells up to 30% in industrial production and maximum electric capacity – up to 50 W/cm^{2} [1] in conversion of concentrated solar radiation.

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ELECTROTECHNOLOGIES AS CONTROLLING INFLUENCE ON BIOLOGICAL OBJECTS IN AGRICULTURAL PRODUCTION

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Basic difference of technological processes in agricultural production from processes in other branches is work with biological objects. In controlling equipment and technological processes one has to face serious problems. However work with biological objects has also certain advantages, such as: presence of own stored energy which can be used for needs of technological process; sensitivity to low-energy influence; possibility to operate technological quality of object at various stages of its production through electrotechnological effect. To use the energy of a biological object it is necessary to observe certain algorithm. To work out such algorithm, energy, thermodynamic and information approaches were used. On the basis of the information approach the principles of the use of electrotechnologies for intensification of technological processes and reduction of their power consumption have been formulated.

Keywords: *grain, grain bed, seed, biological object, reaction, biological process, drying, technological process, electrotechnology, influence, reaction, energy consumption, steady state, entropy, information, adaptable reaction, humidity, temperature, choronomic influence, stable state.*

Basic difference of technological processes of agricultural production from processes in other industries is the fact that it involves biological objects.

In control of equipment and technological processes the following problems are faced:

- lack of operational monitoring of state of biological objects state;
- considerable delay in time of reaction of an object and its technological characteristics to external influence;
- uncertainty as to monitored parameters related to technological qualities of agricultural products;
- impact of electromagnetic fields on the formation of technological characteristics;
- considerable effect of the history of the formation of a biological object and its state on its reaction in processing;
- impossibility to correct changes that have occurred in a biological object after errors in control (processes irreversibility).

The specified problems are difficult to solve, so in the development of equipment and technological processes restrictions are imposed on control actions with due consideration to technological characteristics of biological product being processed. For example, in grain drying maximum temperature of drying agent is specified depending on types of grain. For example, in drying of pea with up to 18% humidity, heat carrier temperature can amount to 60 ^{0}C, and at 30% humidity – no more than 45 ^{0}C. Initial technological characteristics of products and the possibilities of their correction during processing can be taken into account.

In addition to specified problems, work with biological objects have certain advantages, such as: availability of own stored energy which can be used for technological process needs; sensitivity to low-energy effect; the possibility of controlling technological quality of an object at various stages of its production due to electrotechnical effects. These positive factors have allowed to formulate the following scientific hypothesis: “Improvement of product quality control, reduction of energy consumption of its production and increasing of equipment capacity are possible through the use of energy stored by a biological object, through the use of controlled electrotechnological effect”. As the subject of the author’s research is grain, grain layer, technological processes of postharvest and preseeding treatment and storage of grain, all specific arguments and examples relate specifically to these processes.

In this work the following problems were solved:

- to develop a scientific approach allowing to describe reactions and behavior of caryopsis;
- on the basis of the developed approach to formulate the concept of the use of controlling elec-

trophysical influence for intensification, reduction of energy consumption and raising of efficiency of processes of postharvest treatment, storage and pre-seeding treatment of grain.

In the development of the scientific approach the following possibilities were considered: energy approach; theory of adaptive responses; thermodynamic approach; information approach.

The essence of the energy approach [1] is as follows: energy consumption for plants development and seeds formation can be presented with the use of the functional relationship $Э_{разв.} = f\,(Э_{пит.в.}, Э_t, Э_{св.}, Э_w)$ (fig. 1).

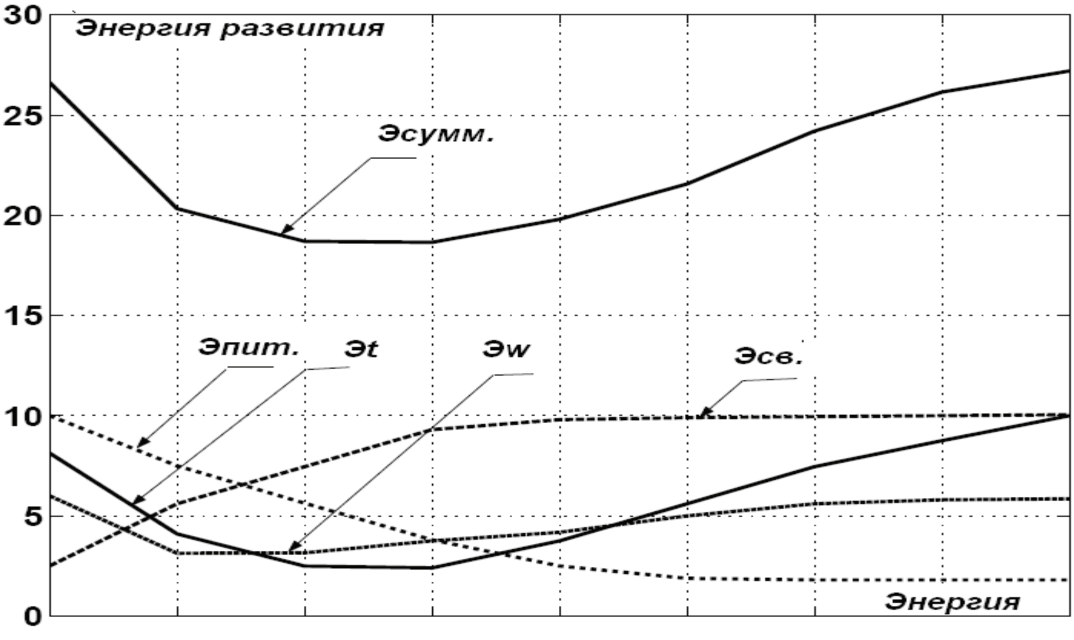

Fig. 1. Dependence of energy spent on the plant development, on energy components:
$Э_{разв.}$ – energy spent on the plant development and seeds formation; $Э_{пит.в}$ – energy spent by the plant in dependence on content of nutritive substances in soil; $Э_t$ – energy spent by the plant in dependence on air and soil temperature; $Э_{св.а}$ – energy spent by the plant in dependence on illumination intensity; $Э_w$ – energy spent by the plant in dependence on moisture content in soil and air

The presented diagrams have qualitative character and are designed to demonstrate changing plant (seeds) energy consumption for development. Having summarized all the diagrams, we shall obtain qualitative dependence $Э_{разв.} = f\,(Э_{сум})$ demonstrating changing of the plants (seeds) energy consumption for development on total energy they receive from environment.

This function minimum is clearly determined. That is, there exist certain external factors providing minimal energy consumption of seed (plant) for the development.

If we apply the diagrams of yield depending on total energy consumption $У_p = f\,(Э_{сум})$ and seeding characteristics depending on total energy consumption $П_к = f\,(Э_{сум})$, it will be found out that minimum of functions $Э_{разв.} = f\,(Э_{сум})$ is corresponded by maximum of functions $У_p = f\,(Э_{сум})$ и $П_к = f\,(Э_{сум})$.

This conclusion is quite evident and is confirmed by ample research by agronomists and plant breeders. Each bred variety of any crops has optimal values of natural-climatic and agricultural factors providing maximal yield.

Another conclusion reflecting dependence of internal transformations in a biological object (including caryopsis) was formulated by R. Rosen [2]. “All other conditions being equal, optimal structure will be such that provides minimal consumption of metabolic energy (at the same time sufficient for the organism needs)”.

In respect to seeding characteristics of seeds this provision may be formulated in the following way: in the presence of any agricultural and natural-climatic factors, a plant forms such seeding characteristics of seeds that would provide its development with lowest internal energy consumption.

Therefore, on the basis of "experience" of formation and development of a seed, it forms pattern of behavior in the process of germination and plant development. If next year a seed will get into conditions differing from those of the previous year, in its development it will rely on "former experience" which made its survival possible.

Considering all the above-said, the following conclusions can be made:

– the principle of energy conservation is not always a decisive factor in behavior and development of biological objects and cannot be accepted as the basic one;

– previous "experience" of formation and development of a seed can limit maximum use of its potential as a variety (conservative behavior). In practice it is manifested in limitation of period of seeds use before second reproduction;

– the system of self-regulation of biological processes have several stationary states determined by variety characteristics and "experience" of previous development and postharvest treatment.

Changing of types of adaptive responses under various types and intensity of external influence were used in description of behavior of biological objects with the use of the adaptation theory [3].

In the thermodynamic approach [4] to the description of seeds behavior, it is stated that all biological objects are classified as open thermodynamic systems exchanging energy and matter with environment. One of the most important characteristic of open systems is the establishment of stationary states therein. In the process of development and interaction with environment the system passes from one stationary state into another. In its responses to external actions caryopsis obeys certain principles. The Zingler principle states that an isolated system in its responses tends to approach a state characterized by maximal entropy and seeks to do that within the shortest possible time.

$$S(X) = \Sigma_i\, p(x_i) log(1/p(x_i)) \rightarrow max,$$

where $S(X)$ – the system entropy; $p(x_i)$ – probabilities of various states.

The Prigogine principle – in the process of response to external action caryopsis passes into one of stationary states characterized by lowest speed of entropy production.

$$d\beta/dX_1 \rightarrow \min.$$

The process of transition of caryopsis from one state to another in the process of preseeding treatment and afterwards can be illustrated in the following way (fig. 2) [5].

In its initial state (prior to preseeding treatment) caryopsis is in stable state described by differential equations whose solutions have negative real roots (λ_R<0). On the phase plane the "caryopsis" system state is presented as a stable node. The treatment process initiates exchange processes inside caryopsis. This in its turn, leads to changing the system dynamic parameters and its transition to a new stationary state (unstable focus, stable node, saddle). Dynamic parameters that will characterize a new state will depend on the type and dose of treatment.

In its turn, the type of stationary point influences the regularity (mechanisms) and rate of reverse changing of seeding characteristics. In particular, having got into the stationary point "unstable focus", changing of seeding characteristics assumes an oscillatory character.

The presented material allows to conclude that the use of the principle of maximal entropy makes it possible to describe behavior of a biological object, including caryopsis, searching for new states. However, scientific and production practice demonstrates that of all possible states (responses, actions) an organism prefers the one that provided successful functioning and useful effect to him in the past. Such state becomes a norm for the organism, observation of which is more important than energy conservation (saving) to him. In this case it means not the search for a new state but the system conservatism. Here the use of the principle of maximum entropy is evidently insufficient.

In the information approach [6] to the description of responses of a biological object under external influence, the key assumption is that to obtain best result by its response, the biological object must provide maximum mutual information between environment conditions and responses:

$$I(X,Y) \rightarrow max,$$

where X – external action on the biological object; Y – the organism response to external action (processes occurring in the object after external action), the organism (system) influence on external action.

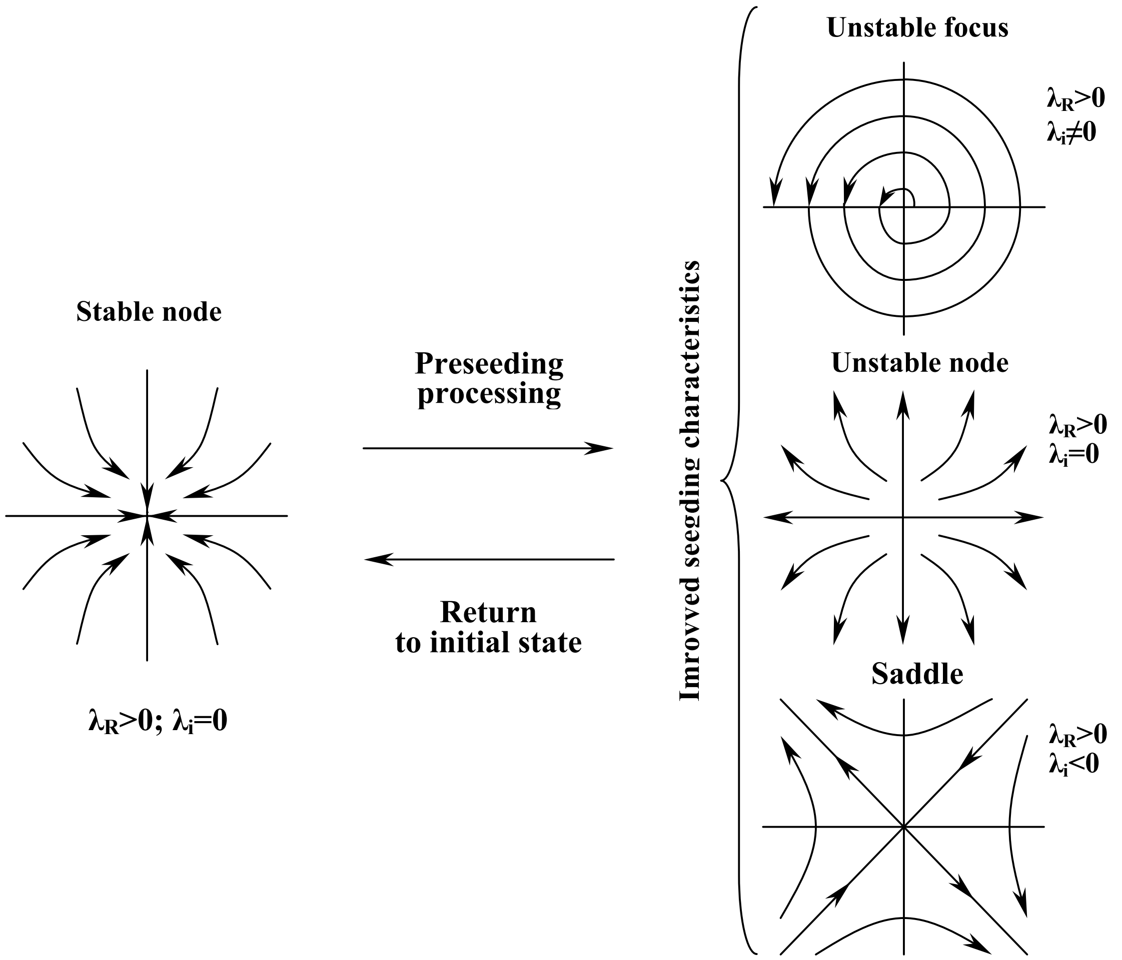

Fig. 2. Diagram of caryopsis transition from one stationary state to another in preseeding treatment

The principle of maximum information can be presented in two equivalent forms [6]:

$$I(X,Y) = H(X)- H(X/Y)= \\ =H(Y) - H\,(Y/X) \rightarrow max_{xy}. \quad (1)$$

In the first form the principle means the following: a biological object (system) seeks to adapt itself to a great variety of conditions of external environment $H(X)$, remaining constant in this process, that is, providing minimal variety of results $H(X/Y)$. The wording of the principle demonstrates the organism fitness to environment.

This principle to a large extent explains caryopsis behavior in ripening process when even at high values of relative humidity of the atmosphere air, caryopsis humidity is reduced.

The second formulation of the principle means that a biological object seeks to expand variety of responses $H(Y)$ (the more responses, the higher the probability to obtain maximal result), and at the same time to reduce conditional variety, that is, ambiguity of responses to specific external influence.

Resulting maximum information is conditional, as in real conditions there always exist limitations, including resource constraints:

$$U(X,Y) \leq const.$$

Using the Lagrange multiplier and resource constraints, the expression (1) can be presented in the following form [6]:

$$I(X,Y) = H(X) - H(X/Y) - \lambda U(X,Y) \rightarrow max. \quad (2)$$

The condition of maximum information considering recourse constraints can be replaced by the requirement of maximum utility $L= I(X,Y)$.

As it follows from the expression (2), utility L is changed generally if conditional entropy $H(X,Y)$ (conditional probability of event) fluctuates. The other members of the equation are subject to change to a lesser extent, so their changes can be ignored at the initial stage.

Negative utility will mean adverse reaction. For one conditional probability its dependence can be presented in the following way [6]:

$$-L = \{H(X/y_1) + [\lambda(U(x_1,y_1) - U(x_0,y_1))]p(x_1/y_1)\}p(y_1) + A, \quad (3)$$

or

$$-L = \{H(X/y_1) + Kp(x_1/y_1)\}p(y_1) + A, \quad (4)$$

where $H(X/y_1) = H(x_0/y_1) + H(x_1/y_1)$; A – summand comprising the equation members independent from $p(x_1/y_1)$; x_0 – stimulus affecting a biological object and reducing conditional entropy (x_1/y_1); x_1 – stimulus increasing conditional entropy while affecting the object.

The organism can control conditional probability, reducing or increasing flows x_0 and x_1. This is the manifestation of the biological object responses.

Let us consider behavior of a biological object – caryopsis to external action through the example of grain drying. In this case external action is drying agent. Changing in response utility can be represented by a diagram (fig. 3). Response dynamics will be given as coordinates "utility (L) – energy of effect ($U_{в.в.} = P_{в.в}\tau$).

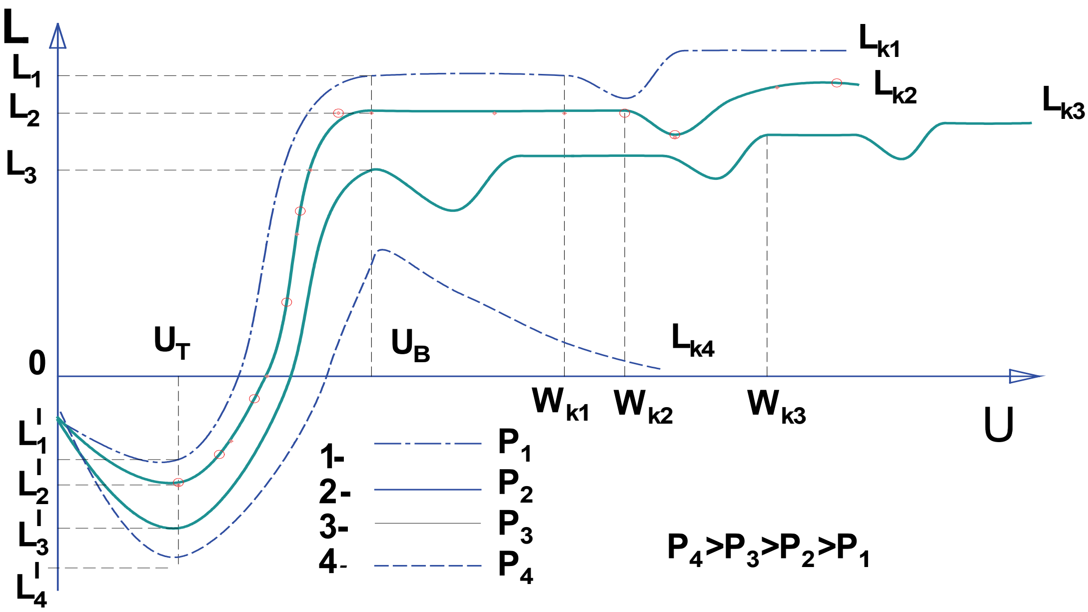

Fig. 3. Dynamics of caryopsis response to external influence in dependence on its power:
P – power of external action; W_k – final grain humidity; L_k – final utility of caryopsis response;
U_T – maximum energy of preventive inhibition; $U_в$ – maximum energy of excitation

Since the beginning of external action (the beginning of drying with heated air) caryopsis "resists" occurring changes: it activates its internal forces to preserve its initial state. As supply of heated air to grain layer leads to heating of caryopsis surface, its response is directed at lowering heating temperature. One of the elements of such response will be "equalization" of grain moisture from inner layers to its surface for cooling.

This is common for the first period of drying when caryopsis surface is heated. As the rate of temperature buildup is by far higher than the rate of bringing moisture to the surface by internal forces, at some time the regulation process is disrupted and the biological object – caryopsis passes to a new stable state.

At the diagram of dynamic reactions grain resistance is reflected in the sector 0, U_T. This is the so-called phase of primary (preventive) inhibition.

As the diagrams demonstrates, the utility of the caryopsis response in the sector of preventive inhibition decreases. The value of utility (harmfulness) depends on power of external action. The lower power, the higher utility is. As the energy threshold of response failure remains constant, the time period of the preventive inhibition stage also depends on power of external action. The higher the power, the shorter the time is.

Although at the stage of preventive inhibition the utility of caryopsis response is decreased, it contributes to achieving the aim of the technological process – to reduce grain humidity, that is, regulating influence of caryopsis is controlled variable of the technological process of drying. This means that the grain layer starts to perform functions of executing mechanism (energy source). This state duration is the longer, the greater energy reserve of the grain layer for resistance to external action is.

When internal energy reserve is exhausted or is nearing boundary value whose limits caryopsis cannot exceed, regulation is disrupted. Caryopsis stops recognizing external action as harmful. It stops resisting it and starts to adjust and adapt itself to it. This section at the energy scale U_T, $U_в$ is termed excitation zone. In drying process it is manifested through intensification of heat penetration to deep layers of grain. Utility of caryopsis biological response is increased. The utility value also depends on power of action. The higher the power, the lower the utility and the shorter the duration of excitation process is.

As the diagrams demonstrate (fig. 3), final utility of biological responses is varying with the use of different treatment technologies. Changing of utility in the process of grain treatment corresponds to changing of stable state of biological processes in caryopsis. That is why final value of utility corresponds to a stable stationary state of caryopsis upon completion of the process of postharvest treatment. Consequently, each technology of grain treatment results in a corresponding stationary state. Even at standard humidity of grain of one crop dried to required level with the use of various methods, stationary states of homeostasis will be at different levels. That means that grain will have different biological possibilities, which will affect its seeding and technological parameters. Moreover, even while using the same technology of postharvest treatment, especially of drying, external actions on caryopsis are usually non-uniform. That is why individuality of stationary states of each caryopsis laid down in the process of its development, is provided in the technological processes of treatment and storage.

It should be mentioned that in this example we consider the impact of only one factor (temperature) and of only one response of a biological object to it. That means that this is a binary case. The reality is that external actions generally have a complex character and involve a number of factors. There is a strong possibility that maximal utility of a biological object response to one action will turn out to be *min* response to another action. All these peculiarities should be taken into account in selecting external action on a biological object, notably, on caryopsis.

In the light of the principle of maximum mutual information, it appears that the drying process leads to increasing mutual information. However, to reduce energy intensity of a process, it is necessary to use such drying modes that would make caryopsis to be in preventive inhibition state as often and as longer as possible.

Theoretical research has demonstrated that, in the light of the principle of maximum mutual information, the process of treatment of a biological object by any external action leads to increase of mutual information. The highest utility of response will be observed in interchanging various actions or using cycles "action – rest".

Utility of response is the higher, the lower energy level of external action is. Under long low-energy influence and under short high-energy influence final utility of response of biological effect will be different.

In particular, the use of combination of two methods of increasing mutual information allows to develop brad new technologies and equipment for grain drying. The assessment of the use of electrotechnologies in grain drying in the light of the principle of maximum mutual information seems rather promising.

In the above-mentioned example, we considered only binary interaction, that is, one action – one response. The use of electrotechnologies (ozonation of drying agent, aeroionization, the use of electroosmosis) provides additional external actions on caryopsis. In this case its response cannot be considered in two-dimensional coordinate system. Let us restrict to the utility equation. For three actions, it will be as follows:

$$-L = Hx_0/y_1 + H(x_1/y_1) + H(x_2/y_1) + (U(x_1,y_1) - U(x_0,y_1) - U(x_2,y_1)) \cdot p(x_1/y_1) \cdot p(y_1) + A \quad (5)$$

or

$$-L = Hx/y_1 + (U(x_1,y_1) - U(x_0,y_1) - U(x_2,y_1)) \cdot p(x_1/y_1 \cdot p(y_1) + A, \quad (6)$$

where x_0 – action // of drying agent; effect of drying agent; x_1 – zero external influence (influence of natural conditions); x_2 – effect of electric technologies; y_1 – caryopsis response to external influence.

In the first instance, it is necessary to indicate that electrotechnical influence (x_2) must have the same directional effect as the basic influence (x_0).

The expression (5) implies that additional introduction of electrotechnical effect increases the number of summands in conditional entropy $H(X/y_1)$ (6) and the number of subtrahends in energy component of influence. It is of interest that relation “action effect – action energy” $U(x_2, y_1)/ U(x_2, y_1)$ of electrotechnologies may be higher than that of drying agent (x_0). This provides additional possibilities of more flexible control of drying process. Having rather low energy consumption, electrotechnologies can significantly affect the value of conditional entropy. That is, controlling the value of electrotechnological effect, it is possible to control caryopsis response to the main external influence – drying agent.

Even greater effect can be achieved through periodic eletrotechnological influence. It becomes possible to increase the number of periods of preventive inhibition in drying process, thus considerably reducing the energy intensity of the process.

The data of theoretical research has been substantiated by experiments with the use of electrotechnologies for intensification of grain drying [7, 8]. The use of electroactivated air saturated with air ions, as drying agent, increases drying speed and reduces energy consumption. The realization of similar but cyclic electrotechnological influence provides additional effect explained by biological responses.

Conclusions

The information approach to the description of responses to external influence made it possible to more effectively explain the processes occurring in biological objects in their treatment with the use of agricultural technological equipment. That is why it is this principle that was used as a basis for the formulation of the concept of application of electrotechnologies for intensification of processes involving biological objects, as well as for the reduction of their energy consumption and raising of their efficiency.

Considering the principle of maximum information, it is necessary to apply the following rules:

1) to use low-power electrotechnological influece;

2) to use cyclic, periodic external electrotechnical influence;

3) to change the type of electrotechnological external action in the process of biological objects treatment;

4) to use electrotechnical external influence directly determining the state of a biological object.

In this light, the use of electrotechnologies in technological processes involving biological objects assumes a more important role. Instead of being a secondary additional factor, electrotechnology becomes the most powerful low-energy controlling influence intensifying the process and allowing to considerably reduce its energy consumption and increase the process speed.

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MULTIFUNCTIONAL SYSTEMS OF TRAINING AND CERTIFICATION OF THE PERSONNEL FOR SAFETY OF PRODUCTION

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Multifunctional systems of training and certification of the personnel for safety of production represent the open user program covers which are based on expert methods and information and communication technologies, containing formalized knowledge in text and graphic representation and providing demanded professional level, stability of safe production skills of workers.
Keywords: *multifunctional program complexes training and certification of personnel, safety of the production, the open program cover, the formalized professional knowledge, not programming user, efficiency of a program complex.*

The most important condition of creation of safe production is the trained personnel. Necessary professional level, stability of safe production skills is provided with the organization of training and examinations of workers not formal effective remedies and methods. **Multifunctional program complexes of preparation and certification of the personnel for safety of the production (MPC PCSP)** which is based on expert methods and infocommunication technologies, the containing formalized knowledge in a text and graphic look represent the modern computer and telecommunication resource, allowing to equip production by tools for the effective solution of all operational tasks on training and control of knowledge of the personnel in the organizations and at the enterprises with application of actual knowledge of safety and labor protection.

The main purpose of MPC PCSP consists in the following:

the fullest formalization of existing normative documents and rules on labor protection and safety of production in the form of questions, answers and graphic descriptions;

comfortable and controlled training of the personnel;

objective and timely certification of knowledge of the personnel;

continuous control of execution of terms of certification;

the automated maintaining and the printing of working and reporting documentation on results of training and control of knowledge of the personnel;

openness of a program complex;

ease of use.

General characteristic. MPC PCSP is the open program cover allowing the expert, organizing training and control of knowledge to concentrate any professional data on the personnel which is trained, instructing and certification, is automated to carry out these procedures, and also to form the necessary, reporting documents established by existing requirements. Openness of program complexes is reached also by possibility of replenishment by not programming user of the formalized knowledge in the form of text and graphic descriptions (set of questions and the answers, the interconnected graphic images), formations of new sections (new target systems), formations various, meeting the requirements of concrete production, certification options [1, 2].

The hierarchical, deeply structured scheme of electronic documentation of MPC PCSP supports steady and faultless work of the expert responsible for preparation and certification, trained and certified, approaches interaction with a program complex to natural communication between people, any reaction of system is clear and doesn't cause in the user of difficulties and irritation.

MPC PCSP is delivered with unique multipurpose base of questions according to the main normative documents on safety of production and labor protection. At intersectional purpose of systems volumes of knowledge bases can be very considerable (for example, for 17 branches, types of the equipment and sections of safety it is only about 90 documents and more than 32000 professionally constructed questions, including for the communication organizations – 9000 questions).

Multifunctional program complexes can include the following target systems formed as knowledge concentrated in them: electrical safety; safety of thermal power installations; safety steam and boilers; safety of the vessels working under pressure; safety of load-lifting cars; safety of elevators; safety of the oil and gas industry; safety of gas economy; safety of compressor installations; safety of refrigeration units; safety of the motor transport; safety of railway transport; safety of work in construction; safety of metallurgical production; safety of work on means of communication; fire safety; the general rules on labor protection.

MPC PCSP are adjusted on any volume of requirements, more than 900 functions and actions responsible for preparation and certification of the personnel for safety of production are automated. The system allows to reach quality examination training procedures, to turn tiresome work with large volumes of rules, instructions and other specifications and technical documentation into informative creative process, in essence to exclude mistakes at registration of output documents, to accumulate long-term data on instructing and results of certification of the personnel.

Characteristic of the main functions. Preparation of the personnel is made in several modes – viewing of questions, certification without restriction of time, certification with time restriction (see rice).

Certification of the personnel is carried out as according to the rigid scheme of the correct and wrong answer, and in a "soft" mode taking into account degree of accuracy of answers. The technology of entering in tickets of not repeating questions, protection against unauthorized access certified to the correct answers on questions is provided. The examiner enters not less than 11 conditions of examination including the characteristic and quantity of questions used in the ticket, including depending on document type, definition of a procedure of payments of an assessment and control of time of the answer, other parameters of conducting certification. Search of questions is carried out with use of system signs: like the document; like the equipment, installation; characteristics of the equipment, installation; qualification group, and also keywords, key phrases, key phrases.

Additional functionality. In addition to basic functions automation of the important actions carried out at the organization of safe production and connected with control of knowledge and training of the personnel is provided:

- the automated instructing, control and reminder on terms of carrying out instructing, maintaining and the printing of the Magazine of registration of instructing on a workplace;
- maintaining base of data on harmful production factors;
- maintaining base of data on means of individual protection of workers and press of the Personal card of the accounting of delivery of means of individual protection;
- maintaining base of data on medical examinations and printing of reporting output documentation: Contingents of the persons which are subject to periodic medical examinations, List of names of the persons which are subject to periodic medical examinations, List of the workers who are subject to periodic medical examination;
- maintaining base of short data on accidents with employees of the organization.

Professional knowledge on safety of production makes a basis of all procedures of training, instructing and control of knowledge, formations of accompanying documentation, is applied in filling of all system actions and functions of program complexes. The knowledge formalized within expert technologies can be used in the form of the text and graphic descriptions including system of interconnected text descriptions in the form of questions, answers and explanations to them and system of graphic images supplementing them in the form of set of the dynamic pictures changing depending on executed actions [3 – 5].

The technology of accumulation and replenishment of sections of the network knowledge base allows the user nonprogrammer to develop and adapt easily a program complex for concrete production features, independently to reflect changes in operating system of rules and requirements, to accumulate knowledge, experience and skills of professionals. The technology of replenishment of professional knowledge in system includes simple easily acquired procedures of formalization of text information with use of multilevel structures of

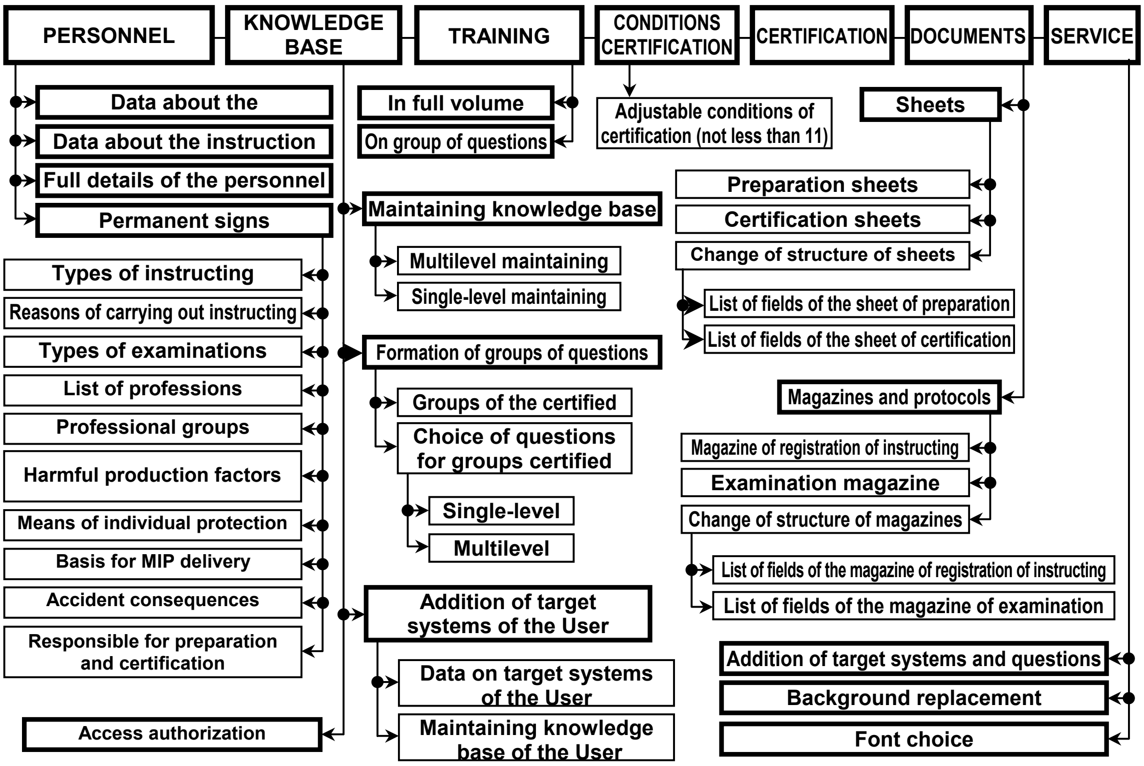

Fig. 1. Main modules and system functions training and certifications of the personnel for safety of production

obligatory data input and graphic descriptions with use of system of the interconnected primitives with control of an inaccuracy, consistency and repeatability of data and descriptions.

Text and graphic descriptions of standard emergency situations are a basis of the universal training procedures structured with use of descriptions of violations of operating modes of the equipment, accidents, traumas with a lethal outcome and temporary disability and formalized in the form of rules and graphic images as a part of the knowledge base.

Creation of the graphic descriptions imitating adverse working conditions, emergency situations, the accidents arising at operation of various types of the equipment, is made by search and configuration of primitives from an arsenal available, including the primitives saved up in network bases that provides public structuring experience and knowledge of highly qualified specialists of their prevention at the level necessary for acquisition by trainees of steady professional skills with the subsequent objective control of results of preparation. Created on a workplace of the user graphic descriptions are subject to periodic control in process of their construction on repetition, discrepancy and the increased complexity with use of resources of network base of graphic images.

Program complex provide rational current and vocational training of the personnel with expeditious finishing of the fullest and actual knowledge for formation of steady knowledge, skills and abilities in process of accumulation of knowledge, as allocated resource of a certain enterprise, the organization with attraction of available personnel resources of the organization and personnel network resources which each network user could use effectively.

The module of preparation is available to the trainee on a certain workplace without any control by the expert responsible for preparation, both before certification and after it, with possibility of renewal of training from any necessary question or a situation from previously appointed group, and necessary completeness of used information resources is provided with the chosen conditions.

Conditions of certification are regulated depending on arising production requirements and describe control programs of various professional levels and production scopes of application. Procedure of certification is carried out according to earlier created conditions (options), including with being in the network authorized access, and shows a series of questions and graphic descriptions by separate fragments of knowledge. Fixation of the general time spent by the worker at certification is provided.

Output documentation of MPC PCSP has flexible structure adjusted by the user and reflects the established existing requirements to reporting documentation and need of the user for fixation of data, knowledge and the data necessary for the organization effective preparation, instructing and personnel examinations in production.

Network versions MPC PCSP in the network hardware environment realize remote and network training and personnel examination according to the allocated sections of safety of production and realize expeditious control functions of the administrator of a program complex – the expert responsible for preparation and examination of employees of all production structure (the region, association), including territorially separated substructures and divisions.

Network opportunities. Multifunctional program complexes support:

- maintaining network base of professional data on the personnel which is trained, instructing and certification, and about the personnel which is organizing and carrying out them;

- personnel preparation at any convenient time on available network workplaces with control of preparation by the ranking officer;

- personnel certification in structural divisions with concentration of information on results of certification in one place – on the network server with authorization of access to it strictly assignees;

- confidentiality of personal data, results of preparation and certification, with application of multilevel passwords;

- independence of timely and high-quality realization of preparation and certification of territorial borders of the organization in the presence of efficient telecommunication networks;

- possibility of controlled data exchange and knowledge (additional questions, graphic descriptions, certification options) between responsible for certification of the personnel of divisions;

- the centralized and decentralized formation of options of certification;

- reassignment of personal data on workers when translating from one division in another.

- participation of certified workers in formation of groups of questions for options of control of knowledge.

About efficiency. It is necessary to carry to parameters of efficiency of program complexes:

- decrease in deficiency attracted for preparation and certification of the qualified teachers, administrative workers and technical instructors;

- elimination of need of systematic business trips of the qualified experts who are a part of examination committees;

- single input of basic knowledge and their repeated use at any level in hierarchy of management of safety of production;

- fast finishing to knowledge certified of necessary volume with use of usual communication channels for support of relevance of information and intellectual filling of system;

- ensuring highly skilled training, control and fixing of knowledge both the general requirements for safety of production, and the specific features inherent in individual information requirements, regardless of location of the certified;

- reduction of cost of one school hours;

- reduction of terms and increase of objectivity of training and certification;

- the individual automated form of preparation and control of knowledge within a certain qualification program according to specifically established purposes;

- transfer of elite knowledge and qualification of experts of high level;

- computer support of creative abilities and intellectualization of work of teachers and trainees;

- considerable decrease in the expenses connected with preparation of the personnel, mainly at the expense of decrease in number attracted at the organization of training and certification of experts;

- increase in life expectancy and especially its active able-bodied period at the expense of timely observance by the worker of safety requirements when performing production operations;
- depth and stability of acquired skills and the knowledge promoting adoption of rational safe decisions in real production;
- possibility of improvement of modules and components of a program complex not programming professional;
- reduction of wear or release of the equipment and the units applied for training.

Conclusions

1. Multipurpose systems of preparation and certification of the personnel for safety of production have to be created on the basis of expert and information and communication technologies, ways and the methods providing the operational and effective solution of problems of training and control of knowledge of the personnel on safety and labor protection in real production.

2. The considered multipurpose program complexes as open user covers, allow to reach necessary level of independence of developers, flexibility in control and operation in concrete production taking into account changes brought in the existing specifications and technical documentation.

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THE ANTHROPIC PRINCIPLE AS CONSEQUENCE OF PROGRESSIVE EVOLUTION AND LEVEL OF ITS PRECISION

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Initially the essence of the anthropic principle was not understood in ontology and scientific methodology. Philosophers' efforts to reveal a vital role of global evolution in cognition and the ontological substantiation of really ideal properties of progressive evolution allowed to determine objective reality of this entity as evolution consequence.

Keywords: *anthropology, anthropic principle, progressive evolution, law of survival, principle of energetic extremality, holon, Plato holon concept, immanent law of method inversion, really ideal materialism according to Plato.*

Generally speaking, the anthropic principle at macrolevel can be expressed in the following way: any general scientific theory is not true if it does not envisage the emergence of physical conditions for birth and existence of life and existence of man as observer. This statement reflects objective reality at the highest hierarchical level of self-organizing nature – life of thinking man-observer. His existence is real. The essence of the anthropic principle at microlevel: for the calculated determination of physical parameters of the Earth and the Solar system physical constants used in these calculations should be calculated to the accuracy to 9-12 decimal places. This is also objective reality related to the lowest level of self-organization of nature – physical constants.

All that exists in Nature – from values of physical constants to man-observer - is created by progressive evolution of self-organizing nature. As observed in [1, 2] progressive evolution has inseparable really ideal properties: natural systems spontaneous striving in their evolution for conservation of entities – energy, physical and informational. This conservation results in beauty and harmony of self-organized objects. As they become more sophisticated, the evolution process is accelerated. In accordance with Plato holon concept, it is reasonable to consider progressive evolution with its inseparable really ideal properties as holon of the highest level of self-organizing Nature.

Physical constants are Plato's holons – entities of lower level of self-organizing Nature. From these considerations, the anthropic principle would seem to be the most important consequence of progressive evolution, reflecting the level of exactness of its realization. It is evident that accuracy of observation of properties of progressive evolution is in correspondence with the accuracy of recording of physical constants in calculation of the Earth and the Solar system conditions (parameters) subject to the anthropic principle. This principle allows to solve the problems of global anthropology and reveal the nature of Man and his mission on principally new foundations. The anthropic principle and progressive evolution are natural-scientific source of all humanitarian knowledge.

Recognizing objective reality of the anthropic principle as a consequence of progressive evolution, it is possible to give a firm positive answer to an intricate question in [3]: "What psychological theories are describing – what reality…?" Reflection by the anthropic principle of really ideal properties of progressive evolution proves that psychological theory, in accordance with scientific principles, should proceed from an ideal object rather than from patterns which prevail in psychological theories of epistemological status. It stands to reason that, considering psychological theories of this status in [3], the author came to the following conclusion: "The only adequate notion of psyche could be possible if psychology was similar to natural science".

It is important to note the ethical aspect of the anthropic principle. It is directly related to the “eternal question” of ethics: “What is goodness in general?” According to the opinion expressed in [4], it is impossible to give a theoretically substantiated answer to this question. This problem is solved on the basis of intuition and experience, most often relying on egoistic considerations. The impossibility to give a theoretically substantiated answer to this question is evidently the result of lack of knowledge of the essence of life as cosmic phenomenon.

The substantiation of law of survival (LS), whose essence is opposite to the essence of the second law of thermodynamics (SLT), allowed to discover that LS and SLT form the general principle of natural science as mirror dynamic asymmetry – the principle of energy extremality of self-organization and progressive evolution (PEES and PE). Individually LS and SLT are not independent laws of nature [5]. In the process of evolution matter and energy periodically pass through two principally different states: self-organized (disequilibrium state) and equilibrium (non-self-organized, chaotic). Self-organizing objects come into existence and function in accordance with LS. Objects that have left self-organized state are utilized in accordance with SLT. The considered processes, LS, SLT, PEES and PE are applicable to space objects. It has been revealed that the phenomenon of birth of self-organizing objects, their existence (life) for some period of time and destruction (death) is natural-scientific axiom simulteneously reflecting LS, SLT, PEES and PE. In short: “life-death”.

The use of this concept has made it possible to solve scientific problem related to principles of classical thermodynamics that emerged in XIX century [5]. This methodology allowed to solve the basic problem of general biophysics – to logically and conceptually integrate the principles of physics and biology. On the basis of LS it became possible to offer natural-scientific explanation to a whole range of phenomena, which are reliably substantiated in empirical and mathematical terms but have not been explained by science. Among these phenomena are the following: golden proportion, ontogeny or bioenergetic law, solitons, fractal structures. They proved to be the mechanisms of manifestation of LS, or its consequences. Relying on LS, they have revealed the essence of phenomenal physicochemical principles used as initial provisions of physical theories – Fermat’s principles, the principle of least action offered by Maupertius and Le Chatelier, the Lenz law of electromagnetic inertia. General basic essence of these principles is reflected by LS (Diagram, fig. 1) [7].

The essence of the anthropic principle can be fully understood considering self-organization of evolving nature. The phenomenon of self-organization at microlevel was discovered by the Moscow State University Professor A.P. Rudenko in the process of researching the microevolution of elementary open catalytic systems [9]. At the level of macromolecules this phenomena was substantiated by Eigen [10] and Haken [11]. The principle of minimization of internal entropy generation was substantiated by I. Prigogine [12].

At macrolevel the self-organization phenomenon was revealed by the analysis of life-support subsystems of organisms [5] in accordance with bioenergetic directivity of structures and functions of living systems, or the law of survival. It should be noted that modern national philosophy attach extremely great importance to global evolution in cognition. It is evident that it is global due to its progressive character. It is not by chance that post-non-classical paradigm is termed evolutionary. In light of these paradigm, not only scientific advances but also achievements in religion and culture in general should be taken into account in cognition process. In this work, the authors relied on the evolutionary (post-non-classical) paradigm.

It is commonly supposed that progressive evolution of self-organizing systems can occur only in open systems [10]. Inflow and outflow of substances on the planet Earth is limited. It can be considered as thermodynamic closed system in terms of substance exchange. Progressive evolution therein occurs in the context of substances scarcity. This determines limited time of existence of individuals and various types of self-organizing systems, as well as the mechanisms (law) of utilization of systems that have left self-organizing state, to the state of substances that can be reused in self-organized systems. Without any doubt such law is the second law of thermodynamics. Without the utilization of systems that have left self-organizing state, progressive evolution on the planet earth would have been impossible. It is for this reason that the second law of thermodynamics plays such an important role in progressive evolution of self-organizing natural systems.

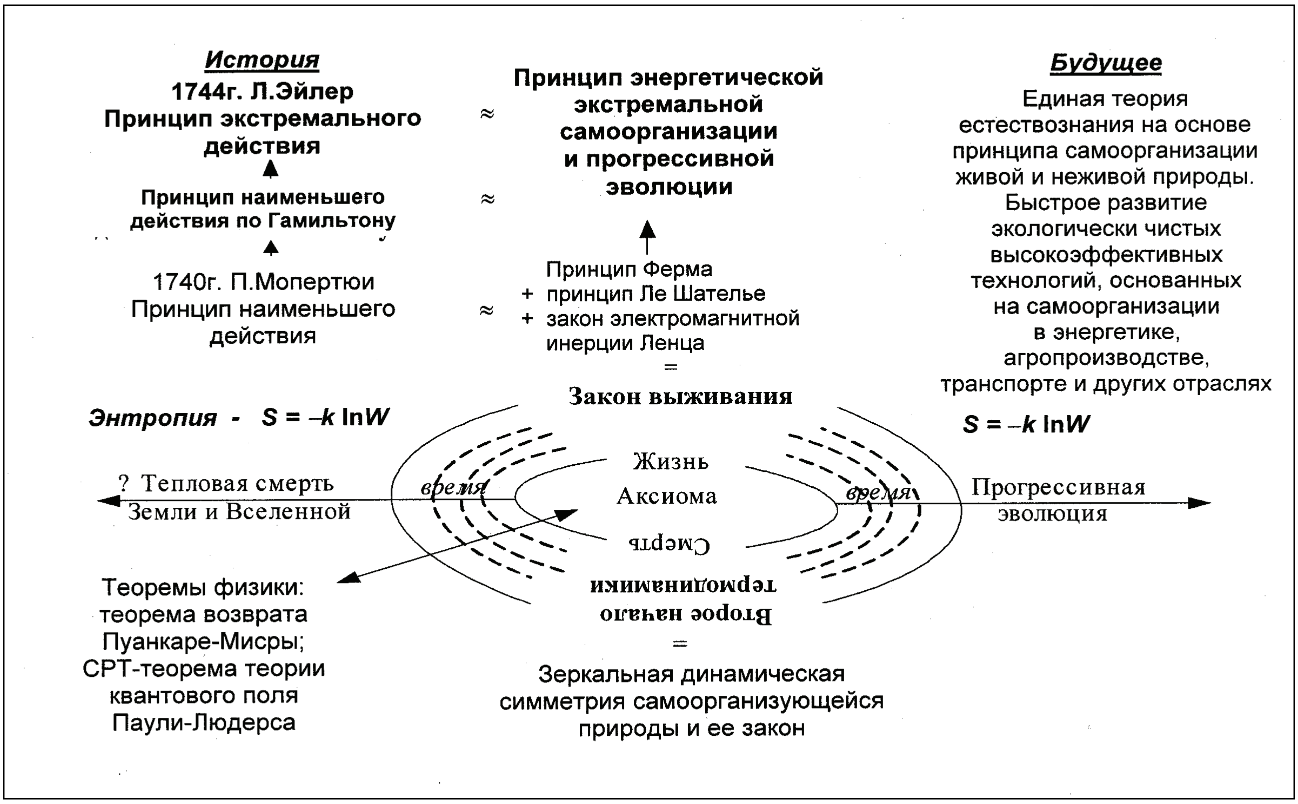

Fig. 1. Logical diagram. The principle of energy extremality of self-organization integrates the second law of thermodynamics and opposite in its essence law of survival as mirror dynamic symmetry, as well as phenomenal physical-chemical principles and theorems of physics

Modern theoretical physicists are searching for “final physical theories” resting their hopes in “superstring theory” [13] and experimental evidence of existence of elementary particles – Higgs bosons that can be produced with the use of rather expensive super colliders. Relying on principles of logic, it is impossible to determine principles (laws) of, for example, progressive evolution of nature – the highest level of self-organizing nature – on the basis of properties and laws of elementary particles interaction – the lowest hierarchical level of self-organization.

Since physical parameters of the Earth and the Solar system emerged in the process of progressive evolution [2], on the basis of the anthropic principle it is logical to conclude that properties of progressive evolution are observed with the same accuracy as physical constants involved in astronomical calculations. To avoid anthropogenic resistance to progressive evolution in natural resources management, man in his activities should observe the same accuracy as follows from the anthropic principle.

Understanding of the essence of progressive evolution on the Earth (in the thermodynamic system closed in terms of substance exchange) substantiated by the anthropic principle, justifies transition in cognition to evolutionary (post-non-classical) paradigm. In evolution process substances regularly pass through two principally different states: self-organized (nonequilibrium) and equilibrium (chaotic), which clearly determine the role of the second law of thermodynamics as the utilizer of objects that have left self-organized state. This circulation of elements in progressive evolution confirms the reality of existence of the law of survival whose essence is opposite to the essences of the second law of thermodynamics, as well as of the principle of energetic extremality of self-organization which is formed by these laws in the form of mirror dynamic symmetry.

Considering the properties of progressive evolution and the anthropic principle, it seems possible to accelerate revealing the nature of man and his role in phylogenesis as an integral part of self-organizing nature.

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OPERATIONAL CONTROL OF THE INSULATION STATE AND FORECASTING OF SERVICE LIFE OF ELECTRIC MOTOR WINDINGS

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The article presents generalized findings of research of operational reliability of electric motors in agricultural production and of changing in time of electric resistance of insulation in various operation conditions. Engineering techniques of evaluation, control and forecasting of technical state of electric motors insulation, their total and remaining service life with the use of built nomograms, have been suggested.

Keywords: *electric motor, operation, insulation resistance, service life, nomogram.*

When operated in the conditions of agricultural production, electric motors are affected by high humidity, temperature drops, chemically aggressive vapor and gas, irregular load and varying number of starts in the course of the day, as well as by seasonal operation variability and long service breaks. In the result, average service life of electric motors is only 3.5…4 year, and up to 80% of their failure is caused by winding burning. The most adverse conditions for operation affecting the equipment state, exist in livestock buildings and in the open air. That is why to obtain adequate results in the in-service evaluation of technical state of insulation of electric motors winding, it is important to apply the control method considering the variety of affecting factors, as well as to select the time for control diagnostic checking and measurements.

Years-long research with the use of automated systems of registration and accumulation of experimental data, carried out directly at farms, their findings being processed using advanced computer technologies and methods of mathematical statistics, has revealed laws and empirical dependences that are viewed as considered generalized operational characteristics allowing to promptly realize the suggested method of control of insulation state and service life of winding of asynchronous cage motors in agriculture [1, 2, 3].

The technology is designed to increase accuracy and reliability of control of the state of insulation and service life of electric motors winding, to record the degree of influence of characteristic operational factors, to specify the time and frequency of diagnostic checking with the use of elements of strategy of electric equipment maintenance to improve its state, increase service life, reduce operational costs and raise the level of electrical safety in production.

Figure 1 presents the general scheme of the realization of this method as applied to electric motors winding [4].

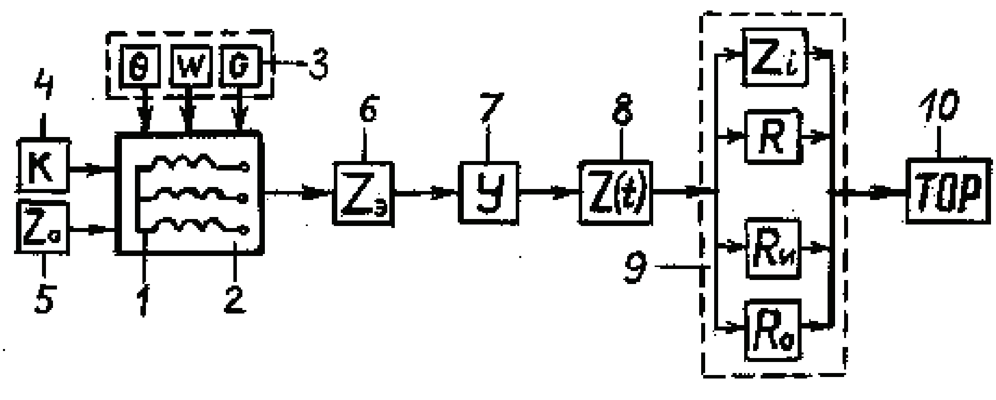

Fig. 1. The general scheme of control of insulation of electric motors winding

The winding 1 of the electric motor 2 is affected by changing factors of environment 3, major of them being temperature θ,°C, relative humidity W%, ammonia concentration G, mg/m^3, as well as the degree of charging and number of starts per day 4 – coefficient K. It is the values and combination of these factors that have the highest wearing out effect on the insulation of electric motors winding with the initial value of its electric resistance Z_0, Mohm – 5 and its service life expenditure R in time t.

In these conditions, a series of measurements 6 of environment parameters and insulation resistance Z_i (where i – current index), are regularly carried out, then using statistical processing and analysis the equation 7 is obtained determining its coefficients for various operational conditions, used to build the family of diagrams of dependence 8 of insulation resistance Z(t) on time t, used in practice for in-service forecasting 9 of current value of insulation resistance $Z(t_i)$, full R, used $R_и$ and remaining R_o resources; then decision 10 is taken as to the necessity, scale, terms and sequence of measures for maintenance and repair - TOP. For an electric motor being controlled they register the time of its commissioning, which is accepted as the beginning of counting its service life, the initial value of resistance of the winding insulation Z_0, the load degree and number of starts per day. The environment parameters are measured in the nearest adverse climatic period of its operation.

The Table 1 presents the most characteristic combinations of prevailing operational factors of agricultural production: θ1=10…20°C, θ2=21…25°C, θ3=26…30°C; W1<10%, W2=11…30%, W3=31…60%, W4=61…80%, W5>80%; K1=2, K2=2…3, K3=3…4, K4=4…5, K5>5; G1=0…0.1 мг/м^3, G2>0.1 мг/м^3 [3].

Table 1

Values of coefficients *a,b* for various combinations of operational factors

The curve number	Coefficients		Combination of operational factors
	a	*b*	
1	0.13	5.92	W1-θ2-K2-G2; W2-θ2-3K1-G1; W2-θ1-K1-G1,2; W3-θ3-K1-G2; W1-θ1-K2-G1
2	0.14	7.68	W4-θ2-K1-G1,2; W4-θ3-K1-G1; W5-θ1,2-K1-G1; W1-θ1-K3-G1; W3-θ3-K1-G2; W2-θ3-K2-G1, W2-θ1-K2-G2; W4-θ1,2,3-K1-G2
3	0.15	7.92	W3-θ1,2,3-K2-G1; W1-θ2,3-K3-G1; W2-θ2,3-K2-G2; W1-θ1-K3-G2; W3-θ1-K2-G2
4	0.17	9.14	W4-θ3-K2-G1,2; W5-θ1,2-K2-G1; W4-θ1,2-K2-G2; W3-θ1-K3-G1; W2-θ3-K3-G1; W2-θ1, 2-K3-G2
5	0.21	10.55	W1-θ1-K5-G1; W2-θ1,2-K4-G2; W2-θ3-K4-G1; W3-θ1-K4-G1; W5-θ2-K3-G1
6	0.26	12.55	W5-θ1, 2-K4-G1; W4-θ2,3-K4-G2; W2-θ3-K5-G1; W2-θ1-K5-G2
7	0.37	15.98	W5-θ3-K5-G1; W4-θ3-K5-G2; W5-θ2-K5-G1

The dependences of the value of electric resistance of insulation on time Z(t) have been determined – expression (1) which is square equation, and of its total service life R on the value of initial insulation resistance Z_0, measured directly prior to commissioning of a new or fully repaired electric motor – expression (2), being the root of this square equation:

$$Z(t) = Z_0 - at^2 - bt, \text{ Mohm}; \quad (1)$$

$$R = \frac{\sqrt{b^2 + 4aZ_o} - b}{2a} \text{ months}; \quad (2)$$

where t – current time, month; *a, b* – coefficients determined by a combination of operational factors (Table 1).

Figure 2 presents typical dependence for the determination of the value of insulation resistance and forecasting of windings service life in the process of motors operation for required combination of operational factors [4].

If the time of aging and wearing of insulation is equal to its total service life R or average service life, expected remaining life R_{oi} upon the completion of a certain time period t_i is equal to the difference between the total service life and used service life $R_{иi}$, where $R_{иi} = t_i$ (fig. 2). In the general case

$$R_0 = R - R_и, \quad \text{month} \qquad (3)$$

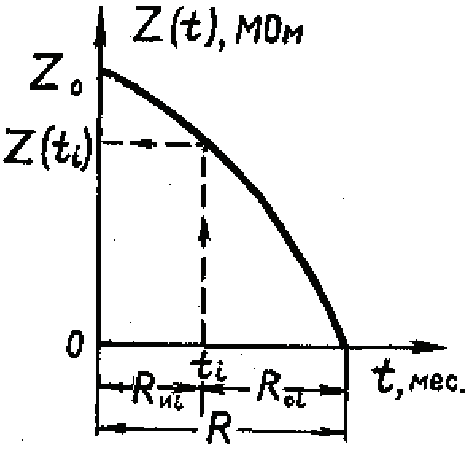

Fig. 2. Dependence of insulation resistance and resource of electric motors windings

In practical application in the conditions of agricultural production, it is suggested to use the family of dependences similar to the dependence (1), built for other combinations of major operational factors typical for various production facilities. The suggested method allows, with the use of simple calculations, to promptly evaluate the value of expected total and remaining life, to forecast current values of insulation electric resistance, which is extremely important for providing required operation of electric equipment and electrical safety of people and farm livestock, to considerably reduce the number of premature failures of electric equipment and economic damage from outage of electric technological equipment, as well as labor and material costs for operation and maintenance.

Table 1, dependences (1), (2), (3) and fig. 2 are designed for practical application in agricultural conditions. It is appropriate to use the dependence at fig. 2 as a universal basic one, at any real for similar operational conditions values $Z_{0ф}$ of any electric motor without additional calculations by formulas (1) and (2). In this case new current values of insulation resistance $Z(t_i)_ф$ will differ from the similar values $Z(t_i)_б$ of the basic curve by the value $(Z_{0б} – Z_{0ф})$, and a new curve is drawn parallel to the basic one, intercepting a segment of the X-axis equal to total service life at $Z_{0ф}$.

Example. A vacuum pump UVU-60/45 at a milk farm is equipped with an electric motor 4A 100SUZ with 3 kW capacity and rotation frequency 1500 min^{-1}. Typical parameters of environment measured at its installation area are as follows: θ=22°C, W=85%, G up to 0.1 mg/m^3, K=3. The value of initial resistance of its winding insulation is Z_0=2000 Mohm.

It is required to evaluate expected total service life of the electric motor winding and its remaining life after completion of its use period t= 3 year (36 months), as well as the current value of winding resistance after 3 years after commissioning.

Solution. On the basis of initial data, we obtain the combination of operational factors W5θ2K3G1, to which in Table 1 the curve 4 with coefficient *a* =0.17 and *b* =9.14 corresponds. Having substituted these values in the expression (1), we calculate expected current resistance of insulation Z(at t=3 years) = $2000 – 0.17 \times 36^2 – 9.14 \times 36$=1450.6 Mohm.

According to the formula (2) total service life of insulation will be as follows:

$R = [(9.14^2 + 4 \times 0.17 \times 2000)^{1/2} – 9.14]/2 \times \times 0.17$=84.9 month =7 years.

Insulation service life remaining after three years since commissioning, will be

$R(t=3 \text{ years})_o = 7 – 3 = 4$ years.

The same results are obtained if built dependence presented in fig. 2 is used.

Conclusions

Quantitative and qualitative values of various types of failures and their causes have been established with due consideration to peculiarities of the use of electric motors at various agricultural production facilities. Dependences of changing in time of resistance of insulation of electric motor windings at various combinations of characteristic operational factors of agricultural production have been determined. The use of built nomograms for operational evaluation and forecasting of total and remaining service life, as well as for evaluation of current values of insulation resistance, has been suggested.

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METHODS FOR EVALUATION OF COMBINED ENERGY-SAVING SYSTEMS FOR COOLING AND STORAGE OF AGRICULTURAL PRODUCTS WITH THE USE OF NATURAL COLD

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The article presents the methods for evaluation of combined energy-saving systems for cooling and storage of agricultural products with the use of natural cold potential, that provides energy consumption reduction 1.5…3 times.
Keywords: *energy saving, cold accumulation, the use of free or natural cold*

Preservation of quality of agricultural products is one of the most important problems of national economy. Products losses at enterprises in certain cases amount to 30 and more percent. Cold is one of the most effective and ecologically safe preserving agents and means of preservation of quality and reduction of losses of agricultural products. However, costs for electric energy for cold production are ever growing and power demands are increasing [1].

One of the ways of the solution of this problem is the use of free or natural cooling of external air and ground.

Atmospheric air is one of the basic sources of natural cold providing cooling and storage of agricultural products in cold season, as well as of charging accumulating devices with cold. Accumulating ability of these devices can provide year-round operation of cooling systems at enterprises producing agricultural products.

So far equipment for cooling and storage of agricultural products using natural cold of over 30 standard sizes has been developed at VIESH. It operates on the principle of air, vapor, water, ice and ground cooling. Energy-saving cooling systems operating on seasonal, year-round and combined basis, have been developed. Combined systems can include various refrigerating units: vapor compression, accumulation and vacuum evaporation; ejector, spray and reactive type; continuously and periodically operating condensers; ice accumulators with changing aggregating states of refrigerating agents and liquid or gas cooling media; accumulators of natural and artificial cold, devices for using natural cold of ground and ground water.

To determine optimal configurations of refrigerating equipment, the methods for evaluation of combined energy-saving technological systems for cooling and storage of agricultural products using natural cold, vacuum evaporation and other freonless techniques, have been elaborated.

Basic structural components of the combined energy-saving cooling system are presented at fig. 1.

A source of artificial cold is the most widespread vapor compressor refrigerating unit or a refrigerating unit for artificial cooling of another type, for example, vacuum evaporation unit, or a unit using the Peltier effect, etc.

Accumulators of natural or artificial cold are devices accumulating technological cold of any nature, including the ones operating on the principle of changing of aggregate state of refrigerating agent and cooling medium.

The source of secondary cold is evaporation equipment or equipment using ground cold, cooling refrigerating agent down to 8…15 ºC. Such devices are used for condensation of refrigerating agent or preliminary cooling of products, for example, milk.

The developed systems are able to operate in various agroclimatic regions of Russia. These regions are characterized by different potential of natural cold (PNC) of atmospheric air which is a basic cold source in energy-saving systems for cooling products. PNC reflects adequate amount of energy that can be used for cooling agricultural products in any region considering current level of the development of technical means, technologies and ecological standards.

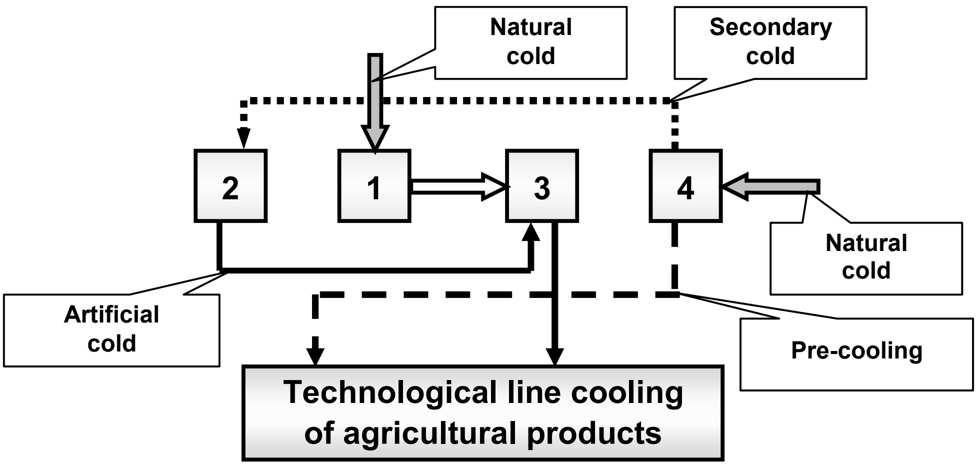

Fig 1. Basic structural components of the combined energy-saving system:
1 – source (receiver) of natural cold; 2 – source of artificial cold; 3 – accumulator of natural and artificial cold;
4 – sources of secondary cold

Monitoring was carried out in three regions of Russia:

In the first (nothern) zone measurement points were accepted in the following cities: Irkutsk, Barnaul, Novosibirsk, Saratov, Vyatka, Yekaterinburg and Kazan.

In the second (central) zone measurement points were accepted in the following cities: Moscow, Nizhniy Novgorod, Chelyabinsk, Yaroslavl, Ulyanovsk, St. Petersburg.

The third (southern) zone covers measurement points in Krasnodar, Rostov-on-Don, Volgograd.

In the development of the methods for evaluation of combined energy-saving technological schemes for cooling with the use of natural cold, vacuum evaporation and other freonless systems for cooling and storage of agricultural products for various agroclimatic zones of Russia, PNC of the central zone (2 zone) was taken as a unit of measure. In calculating generalized macro-indicators of energy-saving systems and their configuration, calculated temperature of external air in cold season and duration of cold season were taken as most significant for various agroclimatic regions.

Coefficient of natural cold ***Kexi*** characterizing natural cold potential of ***i*** – zone, can be calculated from the expression:

$$К_{exi} = П\left(К_i^m; К_i^д\right), \quad (1)$$

where: $К_i^т$ – coefficient characterizing influence of average temperature of external air in cold period PNc of ***i*** – zone; $К_i^д$ – coefficient characterizing influence of average duration of cold period on PNC of ***i*** – zone of average duration of cold period

$$K_i^m = \frac{1}{n}\sum_{j=1}^{n}\left(T_1;T_2;...T_j;...T_n\right), \quad (2)$$

where: T_j – temperature of cold period in ***j*** – point of ***i*** – region; ***n*** – number of points of measurements.

$$K_i^д = \frac{1}{n}\sum_{j=1}^{n}(Д_1;Д_2...Д_j...Д_n), \quad (3)$$

where: $Д_j$ – duration of cold period in ***j*** – point of ***i*** – region, day/year.

Research carried out demonstrated that coefficient of the use of natural cold $\boldsymbol{K_{ex}}$ for zone 1 is 7426, for zone 2 – 6142, for zone 3 – 3654.

Aligning quantitative values of coefficients of natural cold in relation to zone 2, we shall obtain:

$$К_{ex1} = 1{,}2 \qquad К_{ex2} = 1{,}0$$

$$К_{ex3} = 0{,}59$$

Thus, figures obtained characterize potential of natural cold of the northern, central and southern zones of Russia.

Each type of refrigerating equipment is characterized by efficiency criterion $\boldsymbol{\beta_i}$, which reflects increase of the system efficiency due to the use of ***i***-version of technical solution of subsystems, located in various climatic regions of Russia.

$$\beta_i = \frac{Э_i}{Э_б}, \quad (4)$$

where: ***Э****i* **,** ***Э****б* – economic effect of the system in ***i*** – and baseline scenarios.

The synthesis of the system was carried out with the use of criteria of compatibility of blocks composing the energy-saving refrigerating system, on the basis of generalized criterion of the system efficiency.

Efficiency of any version of the system configuration in a particular climatic region was evaluated on the basis of the curve extremum built in accordance with the expression

$$\beta_i = f(\lambda_i; K_{ex}), \quad (5)$$

where: λ_i – accumulation coefficient.

Coefficient λ_i can be calculated from the expression

$$\lambda_i = \frac{W_i}{W_б}, \quad (6)$$

where: W_i – real accumulating ability of the system, kW.hour; $W_б$ – daily demand of a regrigerating system for cooling required amount of agricultural products, kW.hour.

Objective function in this case will be written as follows

$$\beta_i = \mathop{\Pi}_{j=1}^{n} \left[\left(\beta_1 ...; \beta_j ;... \beta_n\right)\right] \rightarrow мах. \quad (7)$$

In dependence on real accumulative ability, required capacity, characteristic, capital and operational costs for all independent structure blocks of refrigerating systems are determined.

For this purpose obtained correlation dependences are used and the data is processed by computers with the use of dedicated software. The obtained curve extremum determines configuration and basic technical solutions of refrigerating systems with due account to their accumulating ability and physical potential of natural cold of a particular climatic region.

Total amount of natural cold in each region comprises two components: natural cold of external air and ground.

$$W_П = \sum [W_{HB}; W_Г]; \quad (8)$$

where: $W_П; W_{HB}; W_Г$ – total amount of natural cold, annual amount of natural cold of external air and ground.

Annual amount of energy of natural cold spent, for example, for cooling milk in the central zone, is calculated with the aid of the expression:

$$W_{HB} = \frac{1}{ч} n \cdot L K_Г X_2 C_M (t_1 - t_2); \quad (9)$$

where: ***ч*** – duration of annual cycle, days; ***n*** – cow population at a farm, heads; ***L*** – yearly milk production of one cow, kg/person; $\boldsymbol{K_Г}$ – coefficient of efficiency of the use of cold season, ($\boldsymbol{K_Г = 0,8}$; $\boldsymbol{X_2}$) – duration of cold season, days; $\boldsymbol{C_м}$ – milk heat capacity (0.940 kcal/kg.degree); $\boldsymbol{t_1}$ – warm milk temperature, ºC; $\boldsymbol{t_2}$ – cooled milk temperature, ºC.

For a farm with 400 heads and 5 000 kg milk production $\boldsymbol{W_{нв}=33,395}$ ***kW.hour***

The amount of energy of natural cold of ground spent for cooling milk with the use of the accumulator of ground cold of PAG type, is calculated with the aid of the expression:

$$W_Г = K_д n L C_в p \Delta t, \quad (10)$$

where: $\boldsymbol{K_д}$ – factor of merit of the cold accumulator, for practical calculation of accumulators of PAG-1 type is taken to be equal to 0.6; $\boldsymbol{C_в}$ – water heat capacity (0.998 kcal/kg.degree); ***p*** – number of heat exchangers (***p=3***); Δ_T – difference of temperature of ground water at the inlet and outlet of a heat exchanger, ºC.

$$\Delta t = t_{Г2} - t_{Г1}, \quad (11)$$

where: $\boldsymbol{t_{Г2}}$ – temperature of cooled milk, ºC; $\boldsymbol{t_{Г1}}$ – temperature of incoming ground water, ºC;

For a farm with 400 heads and 5 000 kg/head milk production: $W_г$*=26.233 kW.hour.*

Total amount of energy of artificial and natural cold fir cooling milk is calculated with the use of the expressions:

$$W_x = \sum (W_{HB}; W_Г; W_{ux}); \quad (12)$$

where $\boldsymbol{W_x}$ – total amount of energy of artificial and natural cold, kW.hour; $\boldsymbol{W_{их}}$ – energy of artificial cold, kW.hour.

$$\boldsymbol{W_x = n \cdot L \cdot C_м (t_1 - t_2)}. \quad (13)$$

The amount of cold that is to be compensated by the system of artificial cooling with use of natural cold of external air:

$$\boldsymbol{W_{ux1} = W_x - W_{HB}}. \quad (14)$$

The amount of cold that is to be compensated by the system of artificial cooling with the use of natural cold of ground:

$$W_{ux2}=W_x - W_Г. \quad (15)$$

The amount of cold compensated by the independent source of the combined refrigerating system with the use of natural cold of external air and ground:

$$W_{ux3}=W_x - W_n. \quad (16)$$

Using the suggested methods, diagrams for determination of basic characteristics of energy-saving refrigerating systems have been built: refrigerating capacity and heat load of sources of artificial and natural cold in regions with different potential of natural cold for farms with 400 heads and yearly milk production 5000 kg (fig. 2).

On the X-axis the value of potential of natural cold (PNC) of areas of location of milk farms is plotted, on the Y-axis – relative energy of cold spent for milk cooling.

Diagram **1-1** reflects the relative value of total energy for cooling milk with the use of natural cold. It does not depend on potential cold in the area of location of a farm and is presented as a horizontal line.

Diagram **2-2** reflects relative values of natural cold of external air used for cooling milk.

Diagram **3-3** reflects the used value of natural cold of ground. It practically does not depend on external air potential and is presented as a horizontal line.

Diagram **4-4** reflects the total (gross) relative energy of natural cold of external air and ground spent for cooling milk.

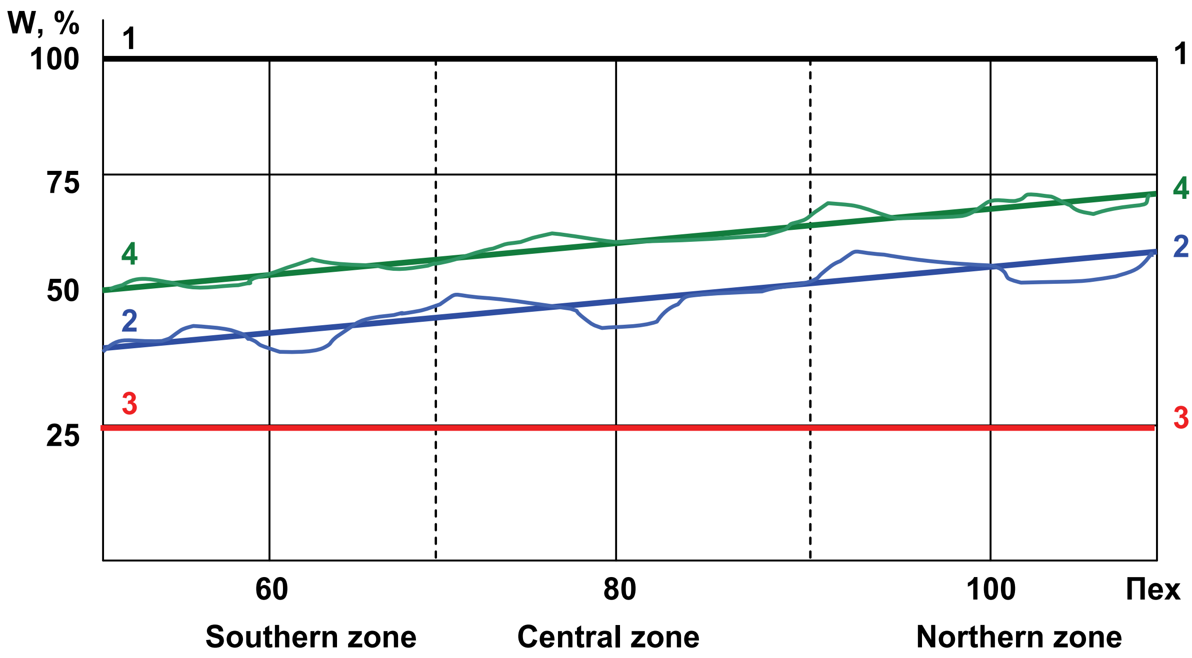

Fig. 2. Diagram of calculation of energy-saving refrigerating systems using natural cold of external air and ground

In accordance with the suggested methodology, at the first stage the potential of natural cold, calculated in the result of research of climatic characteristics of cities-type representatives located at these territories, is analyzed.

Analysis is carried out with the use of averaged values of temperature and duration of cold period.

At the second stage potential of natural cold of areas of location of agricultural farms considering both natural cold of external air and ground cold is analyzed. Potential of natural cold in these areas is determined considering calculated height of frozen-on ice pillars and is used for calculation of parameters of energy-saving refrigerating systems using natural cold.

Conclusion

The suggested methodology allows to research the influence of potential of natural cold of basic zones of Russia on the structure and efficiency of energy-saving refrigerating systems for cooling and storage of milk and other agricultural products with the use of natural sources of cold.

Research carried out demonstrated that in all agroclimatic regions of Russia, combined energy-saving refrigerating systems using natural cold, with various configurations and components, that provide 1.5…3 times energy consumption reduction, can be effectively used for cooling agricultural products.

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