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THE PROBLEMS OF INCREASING THE ENERGY CONVERSION EFFICIENCY

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Energy consumption per head of population in Russia is twice lower than in the USA and Canada, and electricity tariffs are higher. To reduce tariffs it is necessary to increase fuel utilization factor through energy generation using highly-efficient generation power plants and to develop distributed nonfuel and low carbon power production with the use of renewable energy sources.

In the southern areas of the Russian Federation situated at less than 500 north latitude it is advisable to allow designing, construction and operation of low-rise buildings, schools, hotels and health resorts equipped with cogeneration system for solar hot water supply on roofs and heating equipment on the basis of heat pumps with less than 5 years payback period.

The Russian scientists have developed the plasma technologies for solid domestic waste processing into electric energy and the technologies for liquid organic waste processing based on supercritical water oxidation (SCWO) of organic substances into liquids for mini thermal and power plants with 1 MW capacity.

To reduce costs for hydrocarbon fuel it is necessary to develop the production of biodiesel fuel and bioethanol from vegetable raw materials. In order not to provoke competition between the production of food products and biofuel, for biofuel production it is advisable to use non-food raw materials, for example, woody biomass for bioethanol and microalgae for biodiesel.

The use of multicomponent fuel makes it possible to reduce diesel fuel, gasoline and mazut consumption in transport by 20%.

In stove multicomponent fuel carbon fuel content is 50-60%,which allows to reduce heating costs twice.

A prospective line of motor fuel costs reduction is the replacement of internal combustion engines with electric drives, which allows to reduce costs down to 1 USD per 100 km. Because of high price of lithium-ion cells it is advisable to develop the technologies of wireless electric power transmission from an external energy source to mobile power generating units with the use of the N. Tesla techniques.

Nowadays fuel energy generating industry provides 87.1% of the world energy consumption. By our and foreign experts' estimates, by the end of this century over 80% of the global energy consumption will be provided by non-fuel energy technologies: hydro, bio, solar, wind and geothermal power plants, alongside with hydrogen energetics. The advanced Russian technologies for solar energy described in detail in [12], include chlorine-free technologies for solar-grade silicon production, the technologies for silicon solar modules with 20% efficiency at 60-fold concentration of solar radiation, the technologies of assembling solar modules with 40-50 years service life, the technologies of concentrator solar modules.

Keywords: *energy efficiency, energy resources, electricity tariffs, solid waste, plazma redactor, supercritical water oxidation, multicomponent fuel free flow gydroturbine, solar concentrator power plant.*

Introduction

Energy consumption per head of population in Russia is twice lower than in the USA and Canada, though Russia is the coldest country in the world. Maximum load on the energy system falls at winter season, and fuel consumption for heat and electricity supply to residential and industrial buildings accounts for nearly 65% of total fuel and energy consumption. Considering high energy cost for population, agricultural and industrial enterprises, we deem it necessary to draw attention to the main scientific and technological causes for growth of electricity and heating tariffs.

The Russian and World Electricity Tariffs

Electricity cost calculated at the exchange rate in 2012, was by 55% higher than in the USA. This comes from the fact that at thermal power plants using coal, energy carriers cost accounts for 50-70%, at gas power plants – for 60-80%, and the Russian energy carriers price calculated at the dollar rate in 2012 (1 $ = 31.07 rubles) exceeds their price in the USA by 35% for gas and by 6.7% for coal [1].

The comparison of prices for products and services at the US dollar or euro rate does not reflect the real situation. More adequate prices comparison is obtained through their consideration in terms of purchasing power parity (PPP). Calculation through purchasing power parity, comparing the basket of products and services measured by GDP, determines equilibrium value of currencies of a country expressed in terms of another country currency. The values of 1$ PPP and 1€ PPP in national currencies are officially published at Eurostat and Rosstat.

The production of all kinds of agricultural products in Russia is energy-intensive and RF GDP energy intensity exceeds GDP energy intensity of developed countries 2-4 times [3]. Energy intensity per unit of GDP in Russia in 2009 calculated in terms of the ruble purchasing power parity was 0.42 toe per 1000 USD, in the USA – 0.19 toe, in Great Britain – 0.11 toe, in France – 0.15 toe, in Germany – 0.14 toe and in Canada – 0.25 toe [4].

The ways of raising efficiency of the use of energy resources

According to the data available [5] fuel utilization factor in RF in 2011 was 57.3%, losses in power grids – 10.1%, in heat networks – 10.7%, service consumption of electric power plants– 6.3%, specific power consumption for heating greenhouses in winter season – 115 kt oe/m^2, specific fuel consumption for heat energy supply from boiler houses – 177 kg oe/ Gcal, specific fuel consumption for tractors operation – 21.1 kg oe./1 ha of farm field, fuel efficiency of motor cars using gasoline – 7.28 l/ 100 km, of cars using diesel fuel – 6.31 l/100 km, specific energy consumption in buildings of budget-funded organizations – 68 kg oe./m^2 per year, in residential buildings – 46.4 kg oe/m^2 per year.

To reduce energy tariffs in RF it is necessary to increase fuel utilization factor through energy generation at highly effective cogeneration plants, to decrease fuel cost and to develop non-fuel and low-carbon energy production with the use of renewable energy sources.

A prospective line of development of electric power generation is increasing the share of distributed power generation wherein energy production cost is reduced due to lower costs for energy carriers transportation from their deposits to power plants and for electric power transfer from power plants to customers.

The All-Russian Scientific-Research Institute for Electrification of Agriculture (VIESH of the Russian Academy of Agricultural Sciences) examined the state of power supply in housing and utility sector and the agro-industrial complex in the Russian Federation and revealed high production costs of energy services in housing and utility sector and agricultural goods production because of low efficiency of the fuel utilization. Unfortunately, because of the existing energy supply systems, specific energy consumption in Russia exceeds that in the European countries.

VIESH has developed and published the scientific and methodological recommendations “Energy Saving through Raising Efficiency of the Use of Fuel and Energy Resources in the Agro-Industrial Complex and Housing and Utility Sector”. The recommendations offer the evaluation of energy efficiency of the use of fuel and energy resources on the basis of advanced methods, and the calculation of parameters and selection of power-generating equipment for the improvement of energy supply at housing and public utilities and the agro-industrial complex [6].

Currently, approximately 45-50% of the total amount of fuel and energy resources are used in boiler houses and other heating systems generating only heat. The total number of boiler houses in Russia is over 200 000, of which 73 000 are municipal. In boiler houses servicing heating networks 47% of thermal energy is generated. In cities with 100 000-500 000 population a major part of consumers are provided with heat by boiler houses, and in Bryansk, Syktyvkar and some other cities – only by boilers. Even in Moscow 30% of thermal energy are generated by boiler houses. Energy carriers potential is not completely used in boilers. In order to improve the existing situation it is necessary to upgrade and reequip these boiler houses up to the level of mini heat power plants where both thermal and electric power will be generated (cogeneration).

We suggest to include designing and construction of new boilers based exclusively on cogeneration into the implementation of investment programs of energy companies, and to set the terms of upgrading existing boilers and other plants up to the level of mini TPP with cogeneration of electric and thermal energy at gas reciprocating units.

In the southern areas of the Russian Federation situated at less than 50o north latitude, it is advisable to allow designing, construction and operation of low-rise buildings, schools, hotels and health resorts equipped with cogeneration system for solar hot water supply on roofs and heating equipment on the basis of heat pumps with less than 5 years payback period.

It is also necessary to restore training of engineers in the field of electrical power engineering and electrotechnics at Russian higher educational institutions, and to include electrical power engineering and electrotechnics into the category of knowledge-intensive industries having a global impact on the development of RF economy and of the military-industrial complex [7].

The Use of Solid and Liquid Waste as Fuel for Cogeneration Power Plants

The Russian scientists offered ecologically-clean innovation technologies for processing solid and liquid organic waste of cities and agricultural enterprises into electric energy and heat at plants with 100 t/day capacity with cogeneration of 1 MW of electric and thermal power. Waste is processed at high capacity sealed reactors and not combusted as at plants of foreign origin [8]. The application of such technologies will make it possible to considerably improve ecological situation and reduce energy intensiveness of the processes. The total volume of waste dumped at landfills of RF cities amounts to 95 billion tons and is annually increased by 3.5 billion tons. The total area of solid waste landfills in the Russian Federation is 2 500 km^2

Landfills contain metal, stones, glass and solid organic waste (SOW). SOW content can be evaluated at 75 % of the total landfill mass. Thus, 2.625 billion tons of new solid organic waste and 2.375 billion tons of SOW from old landfills can be annually used as fuel. This will allow to completely stop the setting-up of new landfills and eliminate old landfills in the amount of 5 billion tons for

$$95 : \frac{2.375}{0.75} = 30 \text{ years.}$$

We offer to use gas reciprocating units with 1.3 MW electric and heat capacity as cogeneration power plants, and to use the plasma technologies of rapid pyrolysis with the capacity of 100 t of solid organic waste per day and internal electricity consumption of 300 kW for gas fuel production for cogeneration power plants operation. Therefore, considering internal energy consumption, cogeneration power plants will generate 1 MW of electric capacity into energy systems and process 36 000 tons of solid organic waste per year.

To process 5 billion tons of SOW per year it is necessary to install $\frac{5 \cdot 10^9}{36 \cdot 10^3} = 180000$ cogeneration power modules with total capacity of 180 GW which, if operated all year round, will be able to generate 648 billion KW·h of electric energy for at least 30 years. At installed capacity utilization factor κ = 0.85, electric energy and heat output will amount to 488 billion KW·h, which constitutes 50% of the total amount of electric power output in Russia. It should be mentioned that we are considering distributed cogeneration that does not require construction of main power transmission lines, as well as fuel extraction and transportation.

In estimating payback periods of the energy projects being considered, it is necessary to take into consideration the economic effect from landfills elimination, land recultivation and environmental improvement of cities and rural settlements.

Other solid organic waste resources are forestry and agricultural residues, and in woodless areas – energy plantations of fast-growing trees at lands not suitable for agricultural production, for example, in areas around the nuclear power stations in Chernobyl and Fukushima, deserts, marshy and saline lands.

Key sources of environmental pollution that can also be used as renewable fuel resources for cogeneration power plants are liquid sewage effluents of cities and settlements, liquid effluents of pig farms, liquid waste of sugar refineries and distilling plants, etc.

To process liquid organic waste (LOW) with 80-95% water content into electric energy, pyrolysis technologies are not suitable because of high energy costs of the process of preliminary drying liquid organic waste. The Russian scientists offered new technologies for liquid organic waste processing based on supercritical water oxidation (SCWO) of organic substances into liquids [8]. For a cogeneration power plant with 1 MW capacity, processing of 150 t of liquid organic waste per day is required because of lower organic content in liquid organic waste in comparison with solid organic waste. For cities this allows to reduce areas occupied by waste treatment facilities and to eliminate sewage runoff into the sea, as in Sochi, Gelendzhik, Malaga, Barcelona (Spain), in towns on the sea in Australia and other countries.

Large-scale pig farms keeping several sediment ponds for dung effluents, will be able to provide electricity and heat not only for their own needs, but for the population of villages and rural areas situated nearby.

We offer to request the Federal Energy Service Company (FESCO) of the RF Ministry of Energy in cooperation with the Russian Academy of Agricultural Sciences to develop the program for the processing of solid and liquid organic waste of cities and agricultural enterprises (landfills, liquid sewage and pig farm effluents, etc.) into electric energy and heat with the use of knowledge-intensive advanced Russian technologies.

The ways to reduce motor and stove fuel costs

The comparison of oil prices in RF and the USA through the comparison of internal prices in currency demonstrate that in 2012 internal oil process in Russia (411.9 $/t) were by 41% lower than in the USA (690.6 $/t

The comparison of prices recalculated considering purchasing power parity (1 $ =1 $ PPP = 19.25 rubles) reveals oil prices 664.8 $/t in Russia and 690.9 $/t in the USA, that is, oil price in RF is by 4% lower than in the United States.

In accordance with the Rosstat data, in 2012 the RF gross domestic product amounted to 436 000 rubles per head, and the price of 1 ton of oil – to 12 797 rubles, which is equivalent to 34 t of oil per one resident of Russia. In the USA gross domestic product was 49 900 dollars per head and oil price WTI – 93 dollars per 1 barrel, which means 53.7 t of oil per one resident of the USA. Therefore, for Russian economy oil is 53.7/34.0 = 1.6 times less available than in the USA [1].

One of the ways to reduce carbon fuel costs is biofuel production – biodiesel fuel and bioethanol from vegetable raw materials. In order not to provoke competition between the production of food products and biofuel, for biofuel production it is advisable to use non-food raw materials, for example, woody biomass for bioethanol and microalgae for biodiesel [9].

Another approach to the reduction of costs for motor and stove fuel is the production of composite multicomponent fuel. Hydrocarbon fuel content (diesel fuel or mazut) in multicomponent diesel fuel amounts to 80%. The working model of equipment for multicomponent fuel production with 2 t/hour capacity is installed at the biofuel laboratory of GNU VIESH (Fig.1) [10]. The comparison of the characteristics of diesel, mazut and multicomponent fuel is given in Tables 1 and 2.

The technology and equipment advantages: low energy consumption – 0.5 kW·h/m3; small dimensions and weight; ease of maintenance; long service life.

The use of multicomponent fuel in tractor, ship, automobile, locomotive and stationary diesel engines leads to reduction of harmful emissions into the atmosphere by 30-40%.

The price of the equipment set with 10 000 l per hour capacity is 20 mln rubles. Motor fuel saving amounts to 20%, or 2 000 l per hour. At motor fuel price of 1 USD/l, the profit for the production of multicomponent fuel is 0.2 USD/l, or 3 000 USD/hour. The equipment payback period is 1 month.

Diesel fuel consumption in Russia is 6 mln tons per year, therefore, 100 sets of equipment are needed for the production of multicomponent diesel fuel with the capacity of 10 m^3/hour. Diesel fuel price being 30 rubles/l, annual saving in purchasing diesel fuel will amount to 48 billion rubles (1,0 billion USD).

Fig. 1. The plant for multicomponent fuel production with 2 t/hour capacity at the bioenergy department of VIESH

Table 1. Comparison of the characteristics of diesel, mazut and multicomponent motor fuel

№	Fuel characteristics	Summer diesel fuel	Multicomponent motor fuel with 80% diesel content
1.	Lowest combustion value, kJ/kg	42776	44327
2.	Mass fraction of sulphur, %	0.13	0.038
3.	Kinematic coefficient of viscosity, cSt at 20 ^oC	4.8	3.9
4.	Flash temperature in a closed cup, ^oC	75	73
5.	Cetane number	50	61 (standard Euro-4)
6.	Industrial purity class	12	over 17
7.	Fuel storage time, years	-	1

Table 2. Comparison of characteristics of mazut and multicomponent motor fuel

№	Fuel characteristics	High-sulphur mazut	Multicomponent fuel with 80% mazut content
1.	Lowest combustion value, kJ/kg	41816	44101
2.	Mass fraction of sulphur, %	1.71	0.87
3.	Kinematic coefficient of viscosity, cSt at 20 ^oC	7.3	5.9
4.	Flash temperature in a closed cup, ^oC	93	97
5.	Fuel storage time, years	-	1

The motor fuel consumption of cargo motor, water and railway transport in Russia amounts to 50 mln t of oil equivalent per year, cargo motor transport share being over 60%. The use of multicomponent fuel makes it possible to reduce diesel fuel, gasoline and mazut consumption in transport by 20% - by 10 mln t of oil equivalent per year which means costs reduction by 300 billion rubles per year.

In stove multicomponent fuel carbon fuel content is 50-60% which allows to reduce heating costs twice.

A prospective line of motor fuel costs reduction is the replacement of internal combustion engines with electric drives, which allows to reduce costs down to 1 USD per 100 km. Because of high price of lithium-ion cells it is advisable to develop the technologies of wireless electric power transmission from an external energy source to mobile power generating units with the use the N. Tesla techniques [10].

Non-Fuel Energy Generation

Nowadays fuel energy generating industry provides 87.1% of the world energy consumption [11]. By our and foreign experts' estimates, by the end of this century over 80% of the global energy consumption will be provided by non-fuel energy technologies: hydro, bio, solar, wind and geothermal energy plants alongside with hydrogen energetic. The advanced Russian technologies for solar energy described in detail in [12], include chlorine-free technologies for solar-grade silicon production, the technologies for silicon solar modules with 20% efficiency at 60-fold concentration of solar radiation, the technologies of assembling solar modules with 40-50 years service life and the technologies for concentrator solar modules.

A solar power plant (SP) comprises solar photovoltaic modules, a mounting structure, a grid tie inverter and an electric substation.

For the development and manufacturing of SPP we offer to use the generating units of the following types:

1. SPP with stationary concentrators and double-face planar solar modules with 3.5 concentration (the GNU VIESH technology and patent). The picture of the concentrator module with 0.8 kW peak capacity installed at the GNU VIESH testing site is shown at Fig. 2. The photoreceiver area is reduced 3 times in comparison with SPP without concentrators [13].

Fig. 2. Experimental model of a non-tracking solar cylindrical concentrator module with 800 W peak capacity

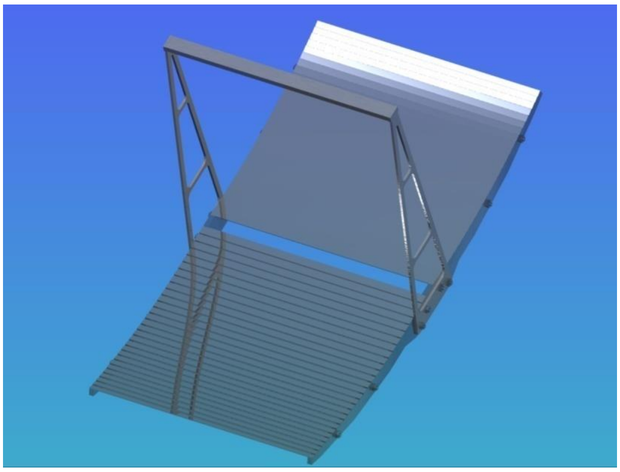

Fig. 3. Design of the concentrator module with 50-60 concentration

Fig. 4. Solar power plant with 1 150 W capacity

2. SPP with cylindrical concentrators and a photoreceiver on the basis of matrix solar cells (MSC) with 20% efficiency and 50-60 concentration (GNU VIESH technology and patent). The concentrator module design is demonstrated at Fig. 3 [14].

The area of photoreceivers with MSC without concentrators will be reduced 50-60 times.

Because of high level of solar energy concentration, a liquid cooling system and a solar tracking system should be developed.

3. SPP on the basis of solar modules without concentrators with 40-50 years service life (GNU VIESH technology and patent). Such SPP generating unit with 1 150 W peak capacity installed at the GNU VIESH testing site is demonstrated at Fig. 4 [15].

SPP described in p. 1 and 2, at customer's request can be developed for operation in cogeneration mode with electricity and heat production. .

VIESH can develop a technical design of all the three types of SPP, fabricate the equipment at the VIESH plant, place an order for component devices at manufacturing plants and supervise assembling and commissioning works.

In hydropower industry damless hydro power plants on the basis of free flow hydroturbines using not only rivers energy but the energy of ocean and sea undercurrents formed by the Coriolis forces brought force by the Earth rotation, as well as by the gravitational forces of the Moon and the Earth interaction, will be widely used [16].

Water speed in the Gulf Stream is 2.235 m/sec, in the La Perouse Strait – up to 4.5 m/sec. At water speed of 2.235 m/sec a hydroturbine with 500 W capacity will have blades with 17.73 m diameter, rotation velocity 2.463 rpm, shaft torque – 14 831 kg·m, 37% efficiency and generates electric power in the amount of 3725·103 kW·h per year [17].

In its installed capacity utilization factor (ICUF) the ocean hydroturbine (ICUF 0.75-0,95) 4-8 times exceeds SPP (ICUF 0.1-0.16) and WPP (ICUF 0.15-0.23) and is comparable to a coal-steam plant (ICUF 0.75-0.85). The hydroturbine price 2 500 $/kW is comparable to the price of a coal-steam plant. Electric power cost does not include fuel costs, operating costs are low (2%), and amortization expense amounts to 0.061$/ kW·h with amortization period of 20 years and 4% interest rate.

In comparison with a coal-steam plant the hydroturbine reduces CO_2 emission by 10 833 t/MW·year [18]. The hydroturbine is installed at 50-100 m depth at the bottom, so it does not impede ship movement and fishing and is not hazardous for marine organisms due to low rotation velocity of blades. VIESH in cooperation with industrial enterprises is developing river free flow hydroturbines with 10-100 kW capacity and sea hydroturbines with 100-1 000 kW capacity.

The implementation of the technologies considered above will allow to reduce energy-intensity of the RF gross domestic product to achieve indices envisaged in the Edict of the President of the Russian Federation № 889 of June 4, 2008, and will radically accelerate the implementation of the RF Federal Law № 261 "On Energy Saving and Increasing Energy Efficiency".

Conclusions

1. Energy consumption per head of population in Russia is twice lower than in the USA and Canada, and electricity tariffs are higher. To reduce tariffs it is necessary to increase fuel utilization factor through energy generation using highly-efficient generation power plants and to develop distributed nonfuel and low carbon power production with the use of renewable energy sources.

2. To raise the efficiency of the use of fuel and energy resources, we suggest to include designing and construction of new boilers based exclusively on cogeneration into the implementation of investment programs of energy companies, and to set the terms of upgrading existing boilers and other plants up to the level of mini TPP with cogeneration of electric and thermal energy at gas reciprocating units.

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TECHNOLOGICAL PROSPECTS OF RESOLVING THE CIVILIZATIONAL IMPASS IN THE FIELD OF FOOD PRODUCTION

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Prospective lines of technological development of food security of population of the Russian Federation are discussed against the background of radical civilizational changes in historical patterns of development of the state, changes in its administrative structure, financial and economic activities, problems arising in ecology, demography and health care, as well as miscalculations and errors in the development of modern agriculture and food industry.

On the basis of extensive information a well-grounded conclusion is made that the quickest and most efficient way of solving the problem of Russia's food security is possible on the basis of the techniques and technologies aimed at the setting-up of «Fractal Innovative Biotechnological Cluster Platforms», intended for the accomplishment of different-scale projects for the production of organo-functional food products. General description of technologies and hardware schemes of developed and partially implemented food complexes is provided. Comparative assessment of their advantages as compared to conventional methods, technologies and engineering methods is given.

The solution of the problems of food security is considered taking into account its historical community roots and social structure of society, as well as the latest achievements of Russian scientific economic school.

Keywords: *technology foresight, solidarity corporatization, technological reformatting of society, bifurcation point, the law of acceleration of frequency of technological cycles, innovative development, adaptative type of agriculture, binary nutrient solution, mycorrhiza effect, fractal innovative biotechnological cluster platforms, universal bionic modules, phytotron, adaptational type of farming, vertical farming, organo-functional food products.*

"A May beetle is flying violating all the laws of aerodynamics…
But it is flying because it doesn't know this".
The inscription at the entrance to the office of the Aérospatiale-Concorde company

Introduction

Modern civilization does not have any prospects of historical development in most spheres of its activities because of its total contradiction with the design of God. Most regrettably, we now see too much evidence of this fact. The world is rapidly nearing the bifurcation point beyond which either we face a moment of truth comes, or humanity meets civilizational collapse. The most tragic situation is observed in the branches ensuring life and activities of humans as biological species, such as: health care, urban development, agriculture and food industry. This is explained by the following reasons:

- ineffective organization of productive labor in agriculture and food industry inconsistent with the communal mode of production and acquisition of labor products that has been forming for centuries;
- unsettled problems of provision of organo-functional products to population in the conditions of growing cumulative ecological stress;
- unsolved problems of food safety in terms of both quantity of products and their quality;
- incompetent and ineffective state financing of morally obsolete enterprises, technologies, trends of scientific work, etc., that, figuratively speaking, can be compared with equipping an outdated car with a rocket motor;
- necessity of reduction of sale price of organo-functional products due to the implementation of the method of zeroed profit at the points of its processing;
- catastrophic state of agricultural ecosystems caused by their anthropogenic contamination and barbarous exploitation;
- extreme and uncontrolled growth of urban population accompanied by reduction and lumpenization of rural population;
- declining level of specialist training, primarily in engineering sphere;
- ineffective use of social, natural and technological resources, such as labor, water, heat and electric energy, etc.;

- impossibility to offer effective countermeasures to prevent possible damage to food products that can be harmful to population, in the context of military technical confrontation with foreign enemies and terrorist organizations.

The Stages of the Development of Agricultural Production

Evaluating prospects and patterns of food supply in Russia, it is necessary to consider historical background preceding the current situation, rooted into the genetic apparatus of the nation. In this respect, it is reasonable to single out a number of stages in the development of agriculture and food industry in this country.

1st Stage. This stage came to an end approximately 8 000 years B.C. It was characterized by primitive (communal) habit of food capturing through gathering of the so-called "bounty of nature" (plants, honey, mushrooms, berries) and hunting wild animals; transition from hunting wild animals to domestication of some breeds of livestock and nomad livestock breeding; lack of thermal processing of food resources; the absence of systematic procuring and storing of provisions.

2nd Stage. This stage came to an end approximately by the Xth century A.C. It was characterized by the complete formation of communal character of food production as civilizational phenomenon determined by the national mentality and natural conditions unfavorable for farming; the use of primitive tools and horse drive; the development of simple technologies of raw materials processing and food preparation (fermentation, drying, thermal processing, methods of long-term storage, etc.); the development of simple methods of soil fertility recovery through the use of many-field system of farming , organic fertilizer application and some simple elements of land improvement; the development of territorial exchange of surplus supplies.

3rd Stage. This stage lasted from the Xth century to the end of the XVth century. It was characterized by legislative consolidation of communal character of food production; considerable expansion of cultivated and pasture areas; the improvement of technologies of agricultural products production and industrial processing, further labor specialization and higher productivity; extension and localization of urban settlements and the beginning of steady growth of urban population; expansion of navigation and mass inclusion of sea food in the diet.

4th Stage. This stage lasted from the end of the XVth century to the middle of the XVIIIth century. It was characterized by absolute domination of communal character of food production consolidated in technologies, spatial distribution of production facilities, population specialization, formation of sales markets, etc.; the complete formation of extensive character of agricultural development; the beginning of drastic growth of urban population alongside with the formation of specific "dependency' mode of life in relation to food production; intensification of commodity exchanges between town and countryside, the emergence of developed food industry and introduction of industrialization into agriculture; the development of "oceanic civilizations" with long-distance sea routes, that resulted in globalization of many processes (commodities exchange, technology transfer, equipment exchange, etc.); the introduction of chemical substances and compounds into production of agricultural products.

5th Stage. This stage lasted from the mid-XVIIIth century to the end of the XXth century. It was characterized by pronounced communal character of food production in the USSR; the escalation of the world domination of the USA and its banking system against the background of global robbery of all the countries of the world through dollar intervention by the Federal Reserve System (FRS); deliberate blocking of outstanding scientific discoveries and achievements that are beyond the sphere of business interests of the international monopolies and corporations. One of vivid examples are the works by prominent scientist Nikola Tesla who at the beginning of the XXth century solved the problem of electric power supply in all the areas of human activities, that have been buried in oblivion; growing size of urban population that in some countries reached 45.0-50.0%; the emergence of transnational biochemical companies, such as Syngenta (Switzerland), Monsanto (US), that changed the natural paradigm of production of agricultural products replacing natural plant and animal farming by the so-called adaptation for constantly worsening environmental conditions; total distribution of transgenic technologies of agricultural production, as well as a wide range of harmful biochemical agents and compounds; the modernization of agricultural equipment for food-producing enterprises; the formation of food industry on the principles of "strictly structured logic" and large-scale production complexes; growing exhaustion and degradation of arable lands; aggravation of ecological situation; the beginning of the use of agriculture and food industry for political ends; the formation of international monopoly-clan companies with contractual (and not market) division of economy sectors and product markets, in whose activities innovative development of industries is by far not a priority.

6th Stage (forecasted). It lasts from the beginning of the XXIth century to the present day. This stage is characterized by absolute inadequacy of food production in the conditions of open natural environment and on the basis of currently dominating harmful methods and technologies (transgenization and chemization of plant and animal breeding, technologies of deep plowing, excessive exploitation of water resources, etc.); the necessity to change the civilization paradigm of production and consumption of food products based on rejection of production in the conditions of open natural environment and the formation of cluster-fractal network of industrial complexes formed on the principles of joint corporatization; the necessity to produce new type of organo-fucntional food products, essential for food supply to population in the conditions of cumulative ecological stress; systemic crisis and destruction of existing world banking system and the formation of zones of direct (currency-free) settlements; unblocking of outstanding scientific discoveries and achievements; growing size of urban population amounting to 85.0 % - 90.0 % in developed countries alongside with rural depopulation decrease and lumpenization; final formation and consolidation of international monopoly-clan companies with contractual (and not market) division of economy sectors and product markets in whose activities innovation development is purely market-oriented; total corruptness and criminalization of food industry in the field of quality control and food safety; the use of agriculture and food industry for political ends, such as population reduction, dominance at product market, economic pressure on governments and states, etc.

It is necessary to mention that the logic of the six stages of historical development of agriculture and food industry is completely in line with the six orders of economic development, notably, the first three stages are classified as the so-called traditional society, the forth and the third –as industrial society, and the fifth – as post-industrial society. Thus, currently, we are living in transitional period, that is the period of overcoming of the so-called post-industrial barrier and transition to the sixth economical order. This period will be accompanied by radical civilizational shifts entailing the necessity of systematic restructuring of all the branches of economy.

The Necessity of Restructuring the RF Agro-Industrial Complex

The necessity to determine the strategy and tactics of food self-sufficiency of Russia as soon as possible is explained, first and foremost, by the acceleration of social time frequency (refer to Fig. 1) and, as a consequence, the acceleration of technological cycles frequency. You buy the latest version of a mobile phone and in a week you are upset by the fact that a new improved version of the same gadget is resealed. The majority of technologies and hardware schemes applied in agriculture and food industry become obsolete in one-two years. Solutions that were selected by leisurely consideration of scenarios for thousands and hundreds of years are ineffective now because of rapid exhaustion of time limit. Replication of incorrect scenarios of the development of Russia will very soon undermine the viability of the state up to its dissolution alongside with the loss of territorial, economical and geopolitical independence. Unfortunately, modern trends of the development of agriculture and food industry are not duly considered in basic documents concerning these branches development [1 – 2].

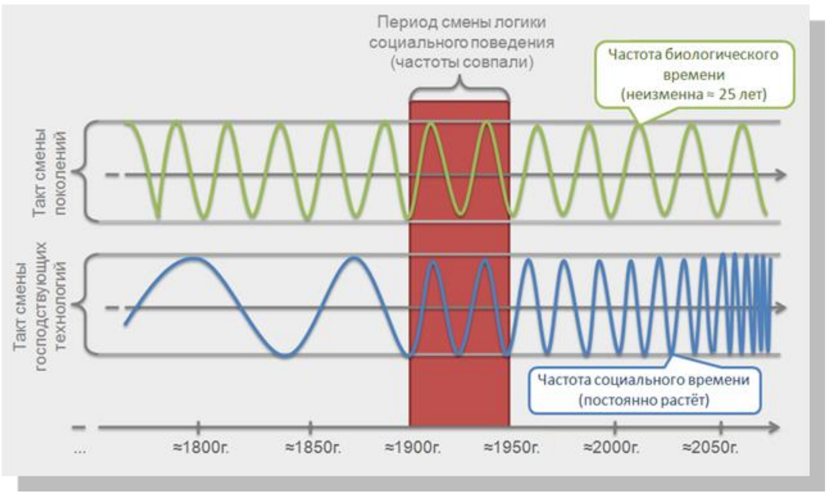


Fig. 1. Change in the logic of social behavior

Incorrectly selected vector of the development of agriculture and food industry whips up and deepens negative dynamics of the development of the both branches. In 1991 the Russian Federation possessed 455.0 mln ha of agricultural lands (of them, 117.0 mln ha of tilled areas). Currently about one third of agricultural lands require recultivation and this process requires extremely high costs for several coming decades. For more than twenty years, of the above-mentioned tilled lands 41.0 ha (over one third of the total area) have been abandoned, and 10.0 mln ha are now used for unauthorized purposes. Evidently, the class of capitalists that has been formed is not going to cultivate these lands as they consider that agricultural estate does not generate enough profit. In other words, systematic deterioration of agriculture of the Northern country is underway which is confirmed by excessive share of food import and total falsification of food products.

An attempt to solve any problem of the degrading system aggravates a number of related problems, whose solution entails a whole range of newly formed disproportions and this is a constant process. That is the way any outdated technology manifests itself. In this connection, the production of food products must be restored either in the whole – with the entire infrastructure and social sphere (which is already impossible) or we should restructure the branch on a systematic basis using alternative, clearly determined principles substantiated by science.

Russia is a northern country. Two thirds of the territory of the Russian Federation is iced over by permafrost. So far our agricultural science has ignored that at low latitudes that are closer to the Equator many countries obtain 2-3 harvests per year, and in Russia obtaining even one harvest a year is a great challenge and requires additional energy. Because of high energy consumption this country is unable to compete with other countries and is doomed to remain uncompetitive. The same situation is observed in animal breeding. Procurement of fodder and capital costs for the construction of winterized farms make meat more expensive than that from Argentina and New Zealand for the same key natural and climatic reasons.

From our viewpoint, prospective trend of the development of modern agriculture with low natural bioproductivity could be provided maximally reducing influence of external negative natural factors on production and excluding the application of transgenic technologies and biochemical agents harmful for human health.

For this purpose it is necessary to learn to determine the “requirements” of plans and animals to their environment, which can be compared to the way we create comfortable conditions for ourselves in modern flats. By the way, the term “cultivation” in its true sense presupposes the formation of environment parameters most suitable to the organisms of plants or animals at corresponding stages of their growth while excluding harmful factors. And this is by far more complicated than adaptation dominating in modern agriculture. This is the only prospect that can be seen for the future. Food products produced within walking distance from urban and rural citizens habitat must be immediately sold to them, thus completely excluding currently dominating mediation of warehouse complexes and vegetable warehouses with their criminalized environment and poor hygienic and sanitary conditions.

The new system of production of organofunctional food products in unfavorable natural conditions should be set up on totally new scientific principles based on effective technological consideration for any plant and animal. It should be scalable and suitable for implementation at the whole RF territory, including the Arctic region, desert and mountain areas, oil platforms, distant military troops, etc.

Russia has to make transition to the sixth order of the development of agriculture and food industry at heightened rates. Being the largest Northern country of the world, for the last quarter of a century Russia historically faces unfavorable conditions for conventional farming of adaptation type. Tou should merely look at the changes of the state boundaries from 1945 to 2013. The area of agricultural lands with mean annual temperature favorable for planting has been considerably reduced. This geopolitical fact should be considered in all seriousness and concern. Russia has lost beneficial soil-climatic resources with developed animal breeding and high density of working population, thus loosing the possibility of extensive growth of production of competitive agricultural and food products. From 20.0% to 50.0% of products amount is lost on the way from field or farm to urban consumers. In addition, share of costs for transporting food products to consumers reaches almost half of their retail price. For the past century, ideology and economic and social policy suffered radical changed three times. In the result, various population strata (age, ethnic, social, regional, religious) now represent a sort of Babeldom including contradictory value paradigms of different historical eras.

System analysis and simulation of current scenarios of development of agricultural and food industry carried out on the basis of the method of technological foresight [3, 4], demonstrates that systemic errors have been laid into the structure of perspective development of this branch. In the context of current cognitive stage of the development of the world economy and the necessity of overcoming the so-called "post-industrial barrier" this can lead directly into deadlock… For radical solution of the problem, we need a principally new technology package including the so-called "closing technologies" developed by Russian scientists. Only in this case we would be able to carry out effective innovation policy involving both state and private capital that would not be afraid of depreciation of capital assets or circulating capital…This very factor explains the curse of current antagonism between science and financial capital.

The Fractal Innovative Biotechnological Cluster Platforms

Meeting the challenges of current development of Russian food industry, VIESH elaborated a complex approach to systemic restructuring of agriculture and food industry. The new scientific approach is based on the complex use of basic laws of the sixth economical order, the brand-new principles of "vertical farming", original thinking paradigms and scientific results able to affect the current situation in the context of multiple deficits in Russia [5-10]. They include: finance and investment, raw materials, personnel, technological, equipment and other deficits.

A module principle will be used as a basic dominant trait in the construction of future production facilities. Later, as sectoral science advances, new dominating traits will emerge, for example, some advanced material for fabricating special equipment, new technological principles of module construction, effective schemes of automation of production processes, etc.

The above-mentioned trends should find application both in agriculture and food industry. In this connection, the construction of production complexes is based on a new element – Unified Bionic Module" – UBM whose implementation would make it possible to effectively solve the following tasks: to optimize the scale of production technological process; to provide effective compilation of existing and newly established production facilities; to reduce costs for the setting-up of production facilities and to lower down production cost of goods; to reduce the terms of construction and commissioning of enterprises; to guarantee sales of products; to optimize certification and production of products of highest quality and safety; to ensure reliable and trouble-free operation and easy maintenance; to provide conditions for fast transfer of enterprises to production of other competitive products; to considerably simplify the mode of control of technological process of production being set up.

New principles of modernization of industries are based on the technology of construction of the so-called "Fractal Innovation Biotechnological Cluster Platforms" – FIBCP whose mission is as follows.

- Production of food products with due regard to the provisions of the advanced economic theory of social corporization, taking into account a communal character of economy that has been formed in Russia in conditions of low bioproductivity and total environmental contamination, considerable negative shifts in demography and territorial distribution of population, as well as the necessity of radical change of dietary habits dominating in our society.
- Transfer of production of most types of organo-functional food products directly to places of residence of majority of population, that is, to cities and towns, settlements, villages, flats, which totally changes the logistics of products delivery to consumers and also excludes the necessity of its long-term storage.
- Restructuring of agriculture on the basis of new technological approaches to food products production, based on the principles of the so-called "vertical farming" and "universal bionic modules" (phytotrons), which makes it possible to saturate markets with inexpensive, high-quality and safe food products in very short terms.
- Setting-up of industrial resource and food complexes with zero cost-effectiveness at points of preparation of food products, which radically (by an order of magnitude) reduces production costs and considerably raises efficiency.
- Total exclusion of food products containing GMO and chemical agents and ingredients harmful for human organism, from production process. Rejection of the use of hydro- and aeroponics that does not provide quality, safety and nutrition and biological value of food products.
- Effective use of natural raw materials resources, primarily, of water, due to synergism and bionic principles of construction of production complexes.
- Ecologic cleanness of production processes with zero waste, as well as their complete in-

difference to force-majeure natural anomalies, such as draughts, natural disasters, pest and rodents invasion, etc.

- Low and independent energy consumption of production facilities due to non-conventional sources of electric energy and original methods of its transmission.
- High competitive ability of food products that would allow Russia to dominate at global market of food products and agricultural raw materials in a very short time.
- Release of vast areas of arable land and pastures which are unreasonably used for agricultural production of vegetable and animal food products thus providing the possibility of restoration of natural ecosystems.
- Deallocation of a large part of labor force ineffectively used in agriculture for industrial development which is extremely important for Russia with its demographic problems.
- The change of roles of such industries as agricultural engineering; production of crops protection chemicals; land reclamation and irrigation; production of chemical fertilizers; storage facilities, etc. In the future structural diversification of the above-mentioned industries should be carried out.
- Health improvement of Russian citizens due to effective overcoming of negative consequences of cumulative ecological stress and normalization of life-support system due to the introduction of new foods for special medical purposes in the form of organo-functional food products.
- Transfer of FIBCP technology to the economical development of the Arctic zone, Siberia, the Far East and the shelf zone of the RF territory.

The FIBCP Technological Subsystems

In structural terms FIBCP comprises two engineering and manufacturing subsystems:

1st Subsystem. «Raw-Material Production and Technological Complex” (RMPTC) is designed for industrial production of organo-functional vegetable and animal food products of the A-category (fish, grain and bean crops, fruits, vegetables, root crops, green vegetables, etc.).

2nd Subsystem. «Processing Production and Technological Complex” (PPTC) is designed for industrial production of organo-functional food products of B-category – nutritional supplements, and of D-category – beverage foods.

RMPTC. The RMPTC organization is considered through the example of industrial production of plant material products. In structural terms, the Complex comprises a basic multistoried building designed for “technological reloading” of UBM which after technological reloading are placed at the basic building stairs. Accelerated growth of plant raw material in UBM is obtained through the application of a new method – synergoponics, the technology of natural accelerated development of plants in the conditions of integrated effect on the root system and external part of plants. In RMPTC special seed material is used in the form of plant clones, as well as special binary nutrient solutions with mycorrhizal effect. All the above-mentioned factors and a number of others make it possible to raise profitability of production of plant raw materials in tens of times. RMPTC has been developed on the basis of the design of multistoried autoparkings, which allows to place a great number of modules inside the structures. Harvesting is carried out every day and raw material is processed in three ways:

1 – for further processing at PPTC;

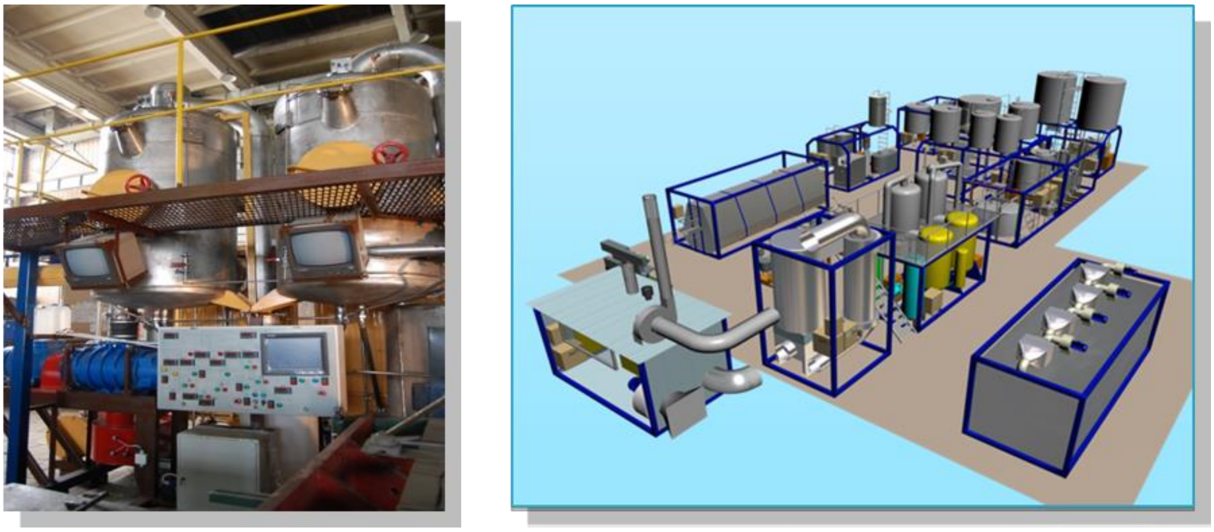
2 – for special biotechnological placement in storage of integrate products for temporary storing (two weeks);

3 – for placement in storage of instant products. Production waste is processed and ***utilized at RMPTC on a daily basis.***

PPTC. A basic structural element of PPTC is UBM (refer to Fig. 2). The module is a pre-integrated set of technological equipment designed for performing some biotechnological operation (or a group of operations), installed inside a metal frame prism. It is certified at the manufacturing stage and equipped with an automatic local control system (LCS) or an automated technological process control system (PCS), as well as with connectors for interfacing with engineering systems and other UBM composing PPTC.

The use of UBM makes it possible to solve the following problems: to provide optimal scale of PPTC; to optimize the logistic chain of production; to reduce production cost of products; to reduce the terms of PPTC construction; to provide reliable and accident-free operation of PPTC and its easy maintenance; to ensure fast transfer of PPTC production facilities to the production of other types of competitive products. Major business advantage of UBM in comparison with other types of technological equipment available at the marker, are as follows: complete delivery of ready-to-work large units, accelerated and simplified installation on site, as well as advance approval of a major part of permission and other documentation.

The delivery set comprises: technical specifications and engineering instructions for equipment



a **b**

Fig 2. General overview of UBM- PPTC - "drying block" (a), PPTC - milk processing department (b)

set with its basic technological blocks; standards and technical documentation for commercial products and production and management documentation conforming to standard operating procedure (SOP); main and auxiliary technological equipment; the system for providing enterprises with engineering and technical resources approved by any definition; the instrumentation and control system comprising local management systems; the system of automated information management of the whole enterprise.

The suggested technical approach to the modernization of food and agricultural industries offers the possibility of further reproduction of FIBCP in all the regions of Russia, as well as in the countries of SCO and EusAsEC. This approach is of paramount significance for the development of the Russian Far East, Siberia and the Arctic regions, as it saves time, resources and labor. It is equally important for various department of the Russian Ministry of Emergency situations, the Ministry of Internal Affairs, the Ministry of Defense, ROC and corrective labor institutions, the RF Ministry for Sport and Tourism, as it allows to provide the above-mentioned institutions with necessary range of special C-rations, sport and infant food, products for zones of natural disasters, functional foods for medical purposes, etc., in a very short time.

In this connection it should be mentioned that there is no alternative to the suggested scenario of food supply to the zone of the development of the Arctic, Far East and shelf territories of Russia. To rely on the so-called seasonal "Severny Zavoz" - supply of goods to Northern Russia means unreasonable expenditure of resources.

The Russian version of FIBCP is the first in the world project with fully canvassed technological and hardware schemes of the construction of industrial complexes for the production of organo-functional foods with specified functional properties. While developing the FIBCP design, all the stages of the technological process have been optimized and standard (industrial) technological lines and equipment have been included. This makes FIBCP construction considerably cheaper and reduces the terms of the project implementation.

Conclusions

1. The effective scenario of overcoming the civilizational deadlock in the field of the production of organo-functional food products on the basis of the stage-by-stage formation of the network of different scale automated production complexes in the form of "Fractal Innovative Biotechnological Cluster Platform" – FIBCP, has been suggested.

2. Historical, technological and economical advantages of the new approach to the solution of the problem of food safety in Russia, primarily, of the problems of food supply to the regions of Siberia, the Far East and the Arctic zone, as well as special food provision to a number of ministries and institutions, have been considered.

3. The general description of the basic Raw Material Production and Technological Complex (RMPTC) and of Processing Production and Technological Complex (PPTC) developed on the basis of multifunction devices in the form of Universal Bionic Modules – UBM has been given.

4. Advanced biotechnologies of accelerated growing of agricultural plants with the use of syn-

ergoponics, new technological equipment for industrial production of organo-functional food products, as well as ingenious methods of quality control and safety of produced goods on the basis of biotesting, have been developed and implemented.

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THERMAL STATES ANALYSIS OF A VACUUM TUBE SOLAR COLLECTOR

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Paper presents thermal states analysis of a four main components of a vacuum tube solar collector. The heat resistance analogue and governing equations for each component (glass cover, absorber, condenser and working fluid) are presented. The model was simulated with Matlab&Simulink Software. It is investigated on the real object which is constructed as a research object of NULES Ukraine. Thermal states are confirmed by thermographic camera.

Keywords: *solar collector, heat pipe, thermal states, Simulink model.*

Introduction

Solar water heaters – also called solar domestic hot water systems – can be a cost-effective way to generate hot water for our home. They can be used in any climate, and the fuel they use – sunshine – is free. Solar water heating systems include storage tanks and solar collectors. There are two types of solar water heating systems: active, which have circulating pumps and controls, and passive, which don't. There are two main types of solar collector used in the system: flat plate solar collector and vacuum tube solar collector. Example of active system with vacuum tube collector for water heating is constructed as a research object of Education and Research Institute of Energetics and Automatics (NULES of Ukraine).

Nomenclature

Symbols	ε – emissivity
C – heat capacity, J kg^{-1} K^{-1}	τα – transmission-absorptance coefficient
G – solar global radiation, W m^{2}	σ – Stefan Boltzmann constant, W K^{-4} m^{-2}
h – heat transfer coefficient, W K^{-1} m^{-2}	
L – latent heat of vaporization, J kg^{-1}	*Subscripts*
m – mass flow rate, kg s^{-1}	a – ambient
M – mass, kg	c – condenser
S – area, m^{2}	f – storage fluid
T – temperature, °C	g – glass
R – thermal resistance, W^{-1} K m^{2}	H – heat pipe
u – fluid velocity, m s^{-1}	p – plate absorber
z – coordinate in the fluid direction, m	sat – saturation

Materials and methods

Thermal states analysis is simulated for this system. In an evacuated heat pipe collector (Fig. 1), a sealed copper pipe containing a vaporizable fluid is bonded to a aluminum fin plate absorber located inside a glass tube. A small copper condenser is attached from one side to the top of the heat pipe and from the other side to the storage working fluid. The heat pipe is an evaporating-condensing device. As the sun shines on the absorber, the pipe is heated and some of the liquid inside evaporates. The vapour rises toward the condenser at the top of the heat pipe and condenses on being cooled by the storage water circulating in the manifold. The liquid then returns to the heat pipe. The vacuum tube ensures minimization of the heat losses of the collector [1].

A model for the heat pipe collector is proposed below, separately considering each component of the tube, i.e. the glass cover, the absorber, the condenser and the storage fluid (Fig. 2) [2].

The following assumptions are made regarding the model [1].

- The properties of the materials are independent of the temperature.
- The temperature gradient along the absorber and the condenser is negligible.
- Due to the sufficient quantity of fluid in the heat pipe (more than 90% of the heat pipe volume), the vapour is not superheated.
- The liquid returning from the condenser to the heat pipe is saturated.
- The glass cover is clean and completely transparent to solar radiation.
- The part of radiation reflected by the absorber leaves the tube.
- Due to the vacuum, convection does not occur inside the Tube.
- Conduction in the storage fluid direction (z) is considered to be negligible.

The glass cover exchanges heat by convection with the outside air and by radiation with the

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Fig. 1. Heat pipe vacuum tube collector

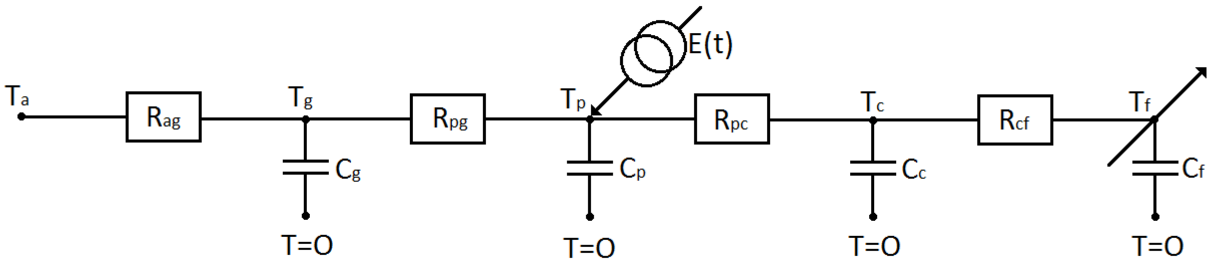

Fig. 2. The heat resistance analogue representing the vacuum tube solar collector

sky and the absorber. The absorber receives solar radiation and heats the fluid inside the tube. The vapour rising from the heat pipe enters the condenser and releases energy to the circulating storage fluid, then exits the condenser as a saturated liquid. The heat pipe liquid is heated to saturation before the evaporation process begins [3].

The governing equations (1-5) for each component [1] (characterized by heat capacity C and temperature T) are given:

a) for glass cover:

$$M_g C_g \frac{dT_g}{dt} = \varepsilon_g \sigma S_g \left(T_{sky}^4 - T_g^4\right) + \\ + \varepsilon_o \sigma S_p \left(T_p^4 - T_g^4\right) + S_g h_g \left(T_a - T_g\right) \quad 1)$$

b) for absorber:

$$M_p C_p \left(\frac{dT_p}{dt}\right) = \varepsilon_p \sigma S_p \left(T_g^4 - T_p^4\right) + \\ + G\tau\alpha S_p + S_H h_H \left(T_{sat} - T_p\right) \quad (2)$$

c) for vapour flow rate:

$$m_v L = S_H h_H \left(T_p - T_{sat}\right) \quad (3)$$

d) for condenser:

$$M_c C_c \frac{dT_c}{dt} = m_v L + S_c h_c \left(T_f - T_c\right) \quad (4)$$

e) for storage fluid:

$$m_1 C_f \left(\frac{\partial T_f}{\partial t} + u \frac{\partial T_f}{\partial z}\right) = S_c h_c \left(T_c - T_f\right) \quad (5)$$

Experimental part

On the base of the following equations it is illustrated the model of a vacuum tube collector using the Matlab&Simulink [4] software (Fig. 3). Values of the physical properties for each vacuum tube are presented in the table 1. Data, like C1,2,3 and R1,2,3 which is shown in the figure 3 does not correspond with heat capacity C and heat resistance R. This data is used only to simplify the calculation. C1 correspond with equation $\frac{1}{M_g C_g}$, C2 with $\frac{1}{M_p C_p}$ and C3 with $\frac{1}{M_c C_c}$. R1 correspond with the part of a 1st equation $\varepsilon_g \sigma S_g \left(T_{sky}^4 - T_g^4\right) + \varepsilon_o \sigma S_p \left(T_p^4 - T_g^4\right) + + S_g h_g \left(T_a - T_g\right)$, R2 with part of 2nd $\varepsilon_p \sigma S_p \left(T_g^4 - - T_p^4\right) + G\tau\alpha S_p + S_H h_H \left(T_{sat} - T_p\right)$ and part of 4th R3 with $S_H h_H \left(T_p - T_{sat}\right) + S_c h_c \left(T_f - T_c\right)$.

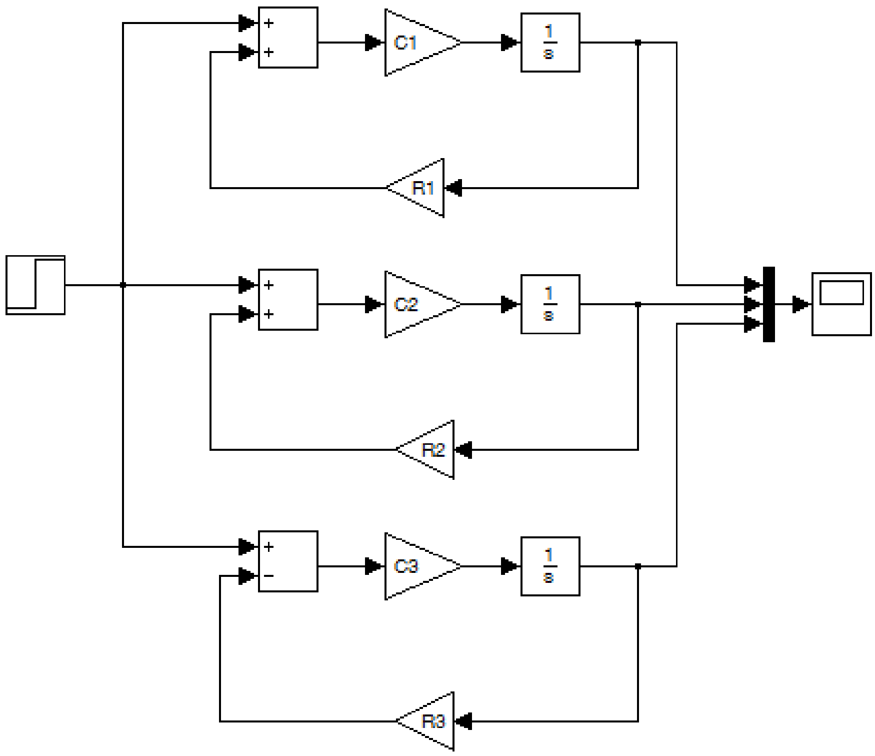

Fig. 3. Vacuum tube collector model

Table 1. Values of the physical properties for each vacuum tube

Symbol	Value
M_g, kg	1,36
C_g, J kg^{-1} K^{-1}	815
ε_g	0,93
ε_p	0,05
S_g, m^2	0,2
h_g, W K^{-1} m^{-2}	4
C_p, J kg^{-1} K^{-1}	390
M_p, kg	0,32
S_p, m^2	0,058
S_H, m^2	0,05
h_H, W K^{-1} m^{-2}	41,8
M_c, kg	0,15
C_c, J kg^{-1} K^{-1}	390
h_c, W K^{-1} m^{-2}	21,4
S_c, m^2	0,015
τα	0,88

Results and discussion

According to the above values it is simulated the temperature of the glass cover, absorber and condenser. Temperature of the fluid in storage is predicted to be close to the condenser temperature. It also depends on the velocity of the working fluid, so the dynamic properties will be solved by another method (Fig. 4; 5).

Conclusions

Vacuum tube collector model corresponds with four components: glass, plate absorber, condenser and fluid storage. The fourth one component was omitted in simulation. Simulation was investigated for sunny day with 10 °C of ambient temperature. Maximum temperature of glass reached almost 40°C, of absorber - 53°C and of condenser almost 60°C.

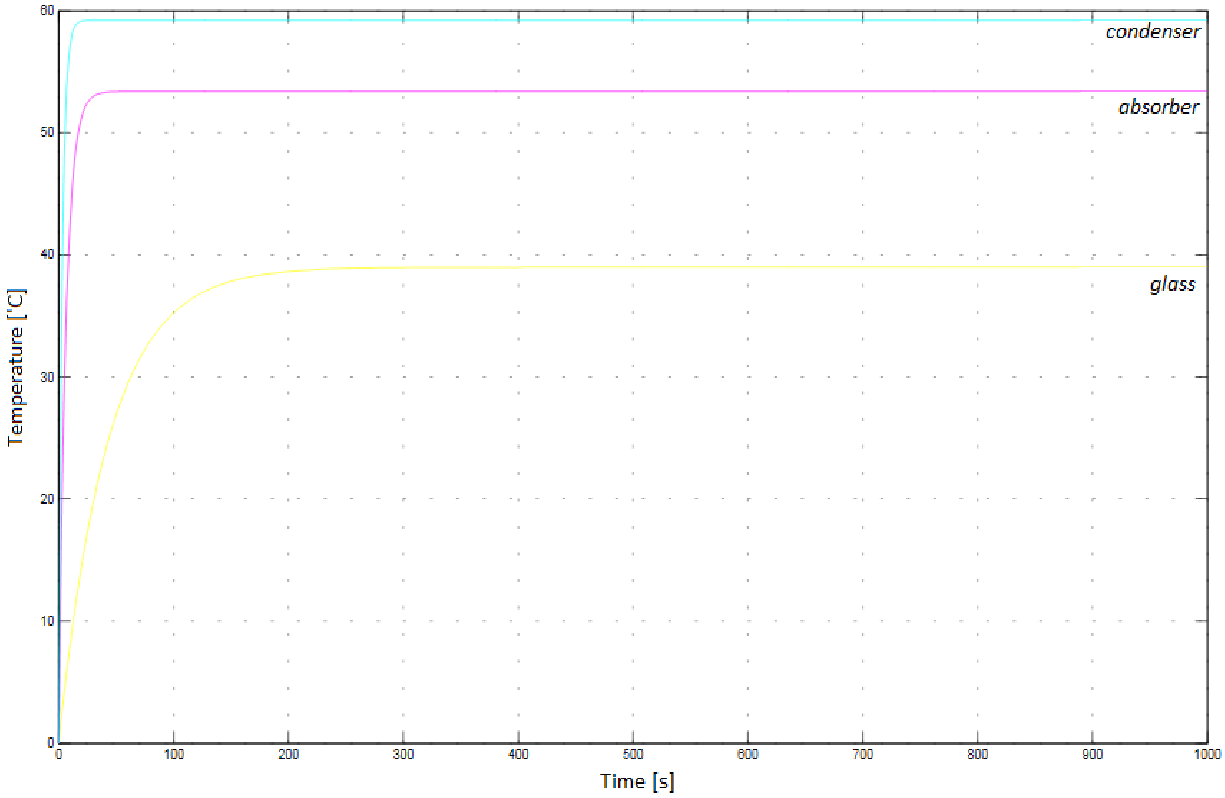

Fig. 4. Result of the simulation in Matlab&Simulink Software

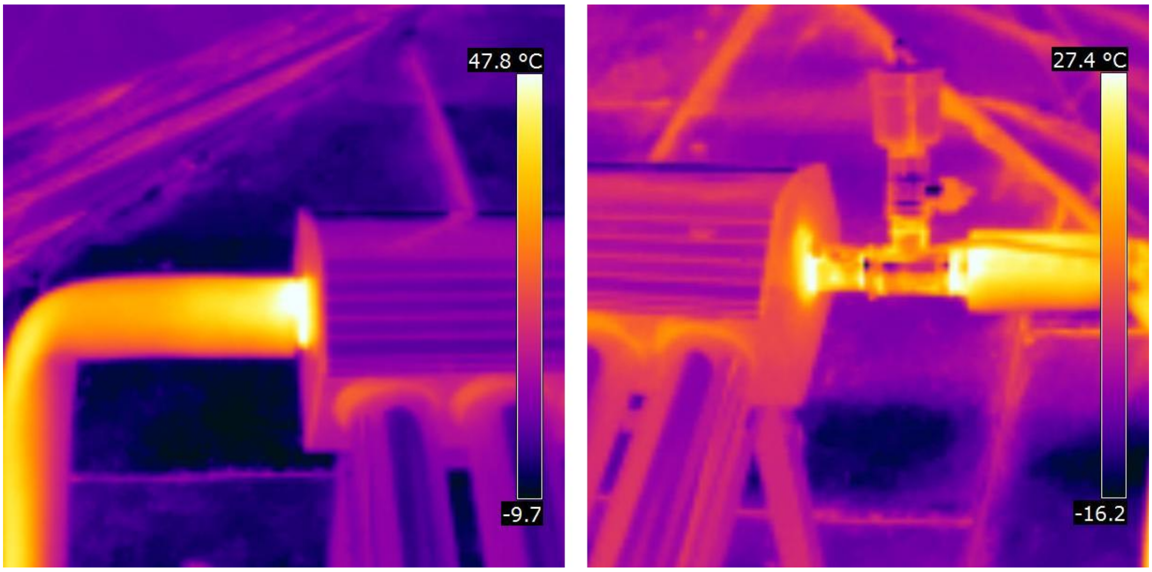

Fig. 5. Photos from a thermographic camera

A step response of each component has classic inert character. It is typical for thermal objects. As you see on the photo from thermographic camera, inlet temperature reached more than 27 °C, and outlet - 48°C. It can be approved that working fluid could reached that level of temperature by heat exchange with hot absorber and condenser.

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EQUATION FOR PLANCK CONSTANT AND ELECTRINO DISCOVERY

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An oscillator and his individual space represent an indivisible unity, this is a globula. Within the new theory, the behavior of gas is determined by only two parameters: volume of globula and energy of an oscillator, while pressure and temperature are their derivatives. Application of Planck constant for describing the thermodynamics of real gases is justified. The generalized description with a derivation of the equations for Planck constant understanding the essence of Planck constant is presented. The physical basis of Planck constant is the moment of momentum of oscillator which can take place only at scattering of an oscillator on an oscillator. Planck equation in improved form confirms that the ray of light consists of material particles (with final masses) as they possess the moment of momentum (kg·m2/sec). Propagation speed of ray of light is a function of wave length. The experimentally established propagation speed of ray of white light c_1 = 2.99792458·108 m/s concerns only to the violet beams. In experimental conditions, the violet beams form the front of a bunch of white beams and are the first to reach receiver. The fundamental constant characterizing a beam of natural light is not a speed of its propagation in vacuum but a sectorial speed of a photon-Milliken constant.

Keywords: *Planck constant, gas thermodynamics, molecular physics, globul energy of oscillator, photon, hyper-frequency mechanics, Milliken constant, wavelengths.*

1. State of gas thermodynamics

According to the dominating concept, a gas is a substance in which there is a chaotic motion of molecules without interactions. All known gases are considered in physics using the model of «ideal gas». Behavior of the real gases is not described by any of the known equations.

In 1834 French researcher Clapeyron derived the equation of state for the «ideal gas». This equation was presented in 1874 by D.I. Mendeleyev in the following general form:

$$P \cdot V = n \cdot R \cdot T, J, \qquad (1)$$

where P is apressure of the gas, Pa; V is a volume of the gas, m^3; n is a number of moles; T is a thermodynamic temperature of the gas; R is the gas constant.

However, the state of real gases is well described by equation (1) only near normal conditions, i.e. near:

$$P_0 = 101\ 325 \text{ Pa and } T_0 = 273.15 \text{ C}.$$

Known Dutch physicist V*an der Waals* was the only scientist who considered complicate interactions between molecules inside a gas. In 1873 he presented the equation of state of a gas based on a system of empirically obtained coefficients. This was a development of the Clapeyron-Mendeleyev equation, but the equation was also incapable to describe the physical nature of these phenomena.

Considering the early history of the problem, we see that the study of gases was begun by works of English scientist Robert Boyle which in 1652 established connection between variation of volume of gas and variation of pressure. However, the nature of gases remained to be a mysterious microcosm since there was no the equation describing a state of real gases as a function of variables P, V, T.

What is a reason for such situation in this area of science?

In our opinion, the reason of it is a fact, that work (1844) of J. Waterston who explained a pressure in gases by blows of molecules at the vessel walls, has been supported by J. Maxwell and also by A. Krönig, R. Clausius and L. Boltzmann.

This group of scientists with indisputable authority, developing idea Waterston, has come to a conclusion that the interaction of molecules in a gas is absolutely random collisions between them, which can be described, as random events. Thus, their academic conclusions for a long time became postulates of the theory of gases and consideration of a real physical nature of interaction between molecules has been replacedby a mathematical game describing random events. For this reason, we believe that *there was no theory* of real gases until the publication of our monograph [1] in 1994.

We did not accept the fact that at the beginning of XXI century the physicists and chemists still continue to use the Clapeyron-Mendeleyev equation (created in the middle of XIX century) for the description of ideal gas not existing in the nature. It was serious motive for the described research and the attempt to create the theory of real gases.

2. Oscillator and its energy

Our theory can be considered to be a new one since some fundamental distinctive features lies at the heart of our concept. These feature shave a theoretical justification and are tested experimentally ([2], [3], and [4]).

Firstly, we have established that gases are not a chaotic substance. There is an accurate order and a certain structure in them. Thus application of methods of probability theory and statistics became impossible. In particular, we have proved that there is no phenomenon of touches and collisions of molecules among themselves in the gases. For example, there are $2.678 \cdot 10^{25}$ molecules of air moving with speeds υ = 47 131 m/s in volume V = 1m^3 but they do not touch each other since their interactions are elastic with participation of electro-dynamic forces. That is not described absolutely in the existing physical theory.

Secondly, the existing molecular physics takes for granted the distribution of molecules according to their speeds in stationary system, which is in line without-of-date concepts of Maxwell, Poisson, and Gauss. The new theory has obtained the convincing proof that it is impossible in principle (this is shown below).

We have proved that all classes of matter: gases, liquids, and solid bodies are united by one universal property which is a hyper-frequency oscillation of their structural elements (atoms and molecules) occurring with frequency $f_0 = 5.689 \cdot 10^{12} c^{-1}$ under the normal conditions (T_0 = 273.15 C and P_0 = 101 325 Pa).

Establishment of this fact has led to the revival of the known term "oscillator" in gas dynamics and to absolutely new concept of "globula" introduced by us. This permits to describe the real processes in the gases rather simply.

Definitions: **«Oscillator»** is a structural element of substance possessing hyper frequency fluctuation in coordinates of its Globula.

«Globula» is an oscillator together with its individual space.

The calculations given below correspond to the normal conditions determined by the following parameters:

P_0 = 760 mm Hg = 101325 Pa = N/m^2 = J/m^3,

T_0 = 273.15 C = 0°C.

Research of real gases was carried out on the basis of the atmospheric air possessing, as we know, the following properties:

ρ_0 = 1.2929 kg/m^3 is the density of the air,

$m_0 = 4.810\ 6712 \cdot 10^{-26}$ kg is a mass of an average molecule,

Vunit = 1 m^3 is the unit volume of gas,

N_0 = 2.687 566 757 84·1025m^{-3}is the volume density of molecules, Loschmidt number,

$k_0 = 1.380\ 244\ 886\ 47 \cdot 10^{-23}$ J/C is the Boltzmann constant for the air.

According to Clapeyron-Mendeleyev's equation, the total energy of molecules of one cubic meter of gas is equal to E_0:

$$E_0 = P_0 \cdot V_{unit} = 101325 \text{ J}. \tag{2}$$

Using the known equation of molecular physics, we obtain that the energy of one oscillatoris ε'_0 [5, page 199]:

$$\varepsilon_0^{/} = \frac{m\upsilon^2}{2} = \frac{3}{2} \cdot \kappa_0 \cdot T_0 = 5,655208361 \cdot 10^{-21} J. \tag{3}$$

But, according to the equation of the new theory presented by us, energy of an oscillator is equal to ε_0:

$$\varepsilon_0 = k_0 \cdot T_0 = 3.770\ 138\ 907\ 38 \cdot 10^{-21} \text{J}, \tag{4}$$

$$\varepsilon_o = \frac{E_0}{N_0 \cdot V_{e\partial}} = \frac{101325 J}{2,68756675789 \cdot 10^{25}} = \\ = 3,770138907 \cdot 10^{-21} J, \tag{5}$$

$$\varepsilon_0 = P_0 \cdot V_{g0} = 3,77013890738 \cdot 10^{-21} J, \tag{6}$$

where

$$Vg_0 = 1/N_0 = 3.720\ 837\ 806\ 48 \cdot 10^{-26} \text{ m}^3$$

is the volume of the globula. (7)

From comparison (3) with (4), (5), and (6) we see the serious divergences of values in our results and in the data obtained with use of the official theory. This justifies a further research of air in this way.

Thus (6) and (7) testify that we have passed from consideration of a continuum of molecules in macro volume Vunit to consideration of microvolume Vg_0 in which the only oscillator is concentrated. This is the most essential distinction in the description of the gas nature from the models existing until the present time. This extremely important qualitative point in research of gases was not considered by anybody from our predecessors.

If we find P_0 using equation (6), we obtain:

$$P_0 = \frac{\varepsilon_0}{V_{g0}} = \frac{k_0 \cdot T_0}{V_{g0}} = 101325\frac{J}{m^3} = \frac{N}{m^2} \quad . \qquad (8)$$

This expression forces us to think of the real nature of gas pressure which is solved at the level of one globula in this case. The situation is impossible from a position of the theory of Waterston and his followers: **how to explain gas pressure in its elementary volume which is one globula. There is no a wall on which the oscillator must impact?**

Search of the answer to this question leads to a conclusion: the gas pressure is a volume concentration of energy of oscillators. At the level of one oscillator, the gas pressure is a ratio of energy of an oscillator to volume of its individual space, to its Globula.

For confirmation of such conclusion it was required to understand the physical mechanism of gas pressure.

Having analyzed a set of options, we have come to the unique solution explaining this phenomenon: retaining the individual space by each oscillatoris possible only in the case of its hyper-frequency motion with almost simultaneous stay in all its points. In addition, the main form of motion of an oscillatoris reciprocation, border of globula consists of globulas located in its immediate environment and the number of these globulas is always equal to 12. Therefore the coordination number k = 12 is inherent in a gas continuum and, so, the gas possesses globula structure and near order.

The additional reason for introducing the scientific concept of globula is the fact that the gas density and pressure has exact values at the level of one globula.

$$\rho_0 = \frac{m_0}{V_{go}} = \frac{4,8106712 \cdot 10^{-26} kg}{3,72083780648 \cdot 10^{-26} m^3} = 1,2929 kg / m^3 . \qquad (9)$$

Acceptance of globula as a structural unit of gas has demanded a full and notcontradictory acceptance of existence of hyper-frequency motion of the oscillator. Attempt to describe this phenomenon on the basis of the formula accepted in molecular physics

$$\varepsilon_0 = m_0 \upsilon_0^2 / 2 , \qquad (10)$$

has ended with a total failure that has forced us to look for a new original way for solving the problem.

Surprisingly, the search for an explanation of physics of process has brought us to the well-known Max Planck formula which is a basis of quantum mechanics:

$$\varepsilon = h\nu, \qquad (11)$$

where ν is a frequency of photons in a ray of light, $h = 6.626\ 2681 \cdot 10^{-34}$ kg·m²/s = const is Planck constant acting as quantum of beam energy [6].

But how to be with the fact that in the last 112 years after writing this formula nobody applied it to research of gas thermodynamics since it describes the second energy of an elementary beam of the natural light radiated by warm bodies? Whether its application to the description of energy of our oscillator is correct?

After the careful analysis of this situation, the simple decision to try to use Planck constant has been made, being based on the fact that energy of an oscillator and the most important properties of gases established empirically are rather correctly described. If the use of Planck constant in ours calculations wrongfully, it will inevitably lead to distortions and a divergence with the true parameters of air and weshall be forced to refuse this idea.

We denote the frequency of an oscillatorby f_0 and derive the following equations:

$$\left.\begin{aligned} \varepsilon_0 &= k_0 \cdot T_0 \\ \varepsilon_0 &= h \cdot f_0 \end{aligned}\right\} \qquad (12)$$

In this system of two equations, only the frequency of oscillator f_0 is unknown and can be calculated

$$hf_0 = k_0 \cdot T_0, \qquad (13)$$

$$f_0 = k_0 \cdot T_0 / h = 5.689\ 686\ 639 \cdot 10^{12} s^{-1}. \qquad (14)$$

This result is 1000 times greater than the accepted value of zero fluctuation of molecules of gas in normal conditions, but it is 100 times smaller than frequency of photons in beams of visible light. It is very probably that Planck constant has found one more application.

Now, taking into account (12), we have already three formulas for describing the oscillator energy:

$\varepsilon_0 = P_0 \cdot Vg_0$,

$\varepsilon_0 = k_0 \cdot T_0$,

$\varepsilon_0 = h \cdot f_0$,

but the oscillator is not presented in them. It will appear only if its mass m and speeds v_0 will take part in the description of energy.

Since a globula volume is already known, it is easy to determine its diameter d_g, which can be taken for the maximum value of amplitude of fluctuation of an oscillator in coordinates of globula, $A_0 \leq d_{g0}$:

$$d_{g0} = \sqrt[3]{6V_{g0} / \pi} = 4,14203761943 \cdot 10^{-9}\, m \approx A_0\,, \quad (15)$$

(in old terminology this is a length of free run).

In one period of fluctuation, an oscillator, making back and forth motion, passes through the center of globula twice. Thus we can express its linear speed by the equation:

$$\upsilon_0 = 2A_0 \cdot f_0 \approx 2d_{g0} \cdot f_0 = 47133,7922 m/c\,. \quad (16)$$

The obtained value is 6 times greater than the first space speed and looks improbably, though there is no mistake in ours calculations.

The obtained so great value of linear speed of an oscillator has shown that the old mechanical equation of an oscillatoris inapplicable to the description of gas thermodynamics.

Attempt to explain this situation has brought to the following conclusions. Firstly, the energy of an oscillator is evenly distributed on volume of globula, i.e. in three-dimensional real space. Therefore, this energy must be expressed quantitatively in terms of the cubic root. Secondly, it was established correctly long time ago that a diffusive transfer of substance with small speed takes place in gases and in liquids. So we have admitted that the oscillator possesses two speeds υ_0 and u_0 at the same time. This allows us to derive the following equation

$$\varepsilon_0 = \sqrt[3]{4\pi \cdot (m_0 \upsilon_0 u_0)^3 / 3} = m_0 \upsilon_0 u_0 \cdot \sqrt[3]{4\pi / 3}\,, \quad (17)$$

where

$a = \sqrt[3]{4\pi / 3} = 1,61199195402\,радиан = 92^\circ 21'$ is an average angle of dispersion of an oscillator on an oscillator during its interaction with the next 12 oscillators from its immediate environment.

The radicand in equation (17) is presented by the known formula for calculating a volume of a spherical body, where the radius of this body is equal to production ($m_0 v_0 u_0$) describing frequency energy in spherical space of globula.

Derivation of this equation has led to full assurance that carried out work goes on a right way, and the main equation of a new nyper-frequency mechanics can be published:

$$\varepsilon_i = P_i V_{gi} = k_i T_i = h \cdot f_i = m_i \upsilon_i u_i \cdot a, J\,, \quad (18)$$

where energy of an oscillator in any thermodynamic conditions is taken into account, and k_i is the Boltzmann constant for *i*-th gas.

The following important indicators follow from equation (18):

$$u_0 = \frac{k_0 T_0}{m_0 \cdot \upsilon_0 \cdot a} = 1,031469 m/c\,, \quad (19)$$

is a speed of «wandering» oscillator,

$$A_0 = d_{g0} - r_0, m\,, \quad (20)$$

is an amplitude of fluctuation of oscillator,

$$r_0 = \frac{h}{m_0 \upsilon_0 \cdot a}, m \quad (21)$$

is a distance of critical rapprochement of pair of oscillator, temperature constant of air:

$$T_0 = \frac{hf_0}{k_0} = \frac{h}{k_0} \cdot f_0 = \xi \cdot f_0, K, \quad (22)$$

where

$$\xi = h / k = 4,8007963122 \cdot 10^{-11} K \cdot c = const\,, \quad (23)$$

$$f_0 = \frac{k_0 T_0}{h} = \frac{k_0}{h} \cdot T_0 = \varphi \cdot T_0, s^{-1}\,, \quad (24)$$

where

$$\varphi = k_0 / h = 2,08298980005 \cdot 10^{10} K \cdot c = const\,, \quad (25)$$

is a frequency constant.

Equations (22) – (25) reveal at rue connection between the temperature of the gas environment and the frequency of fluctuation of its structural elements that is a new mathematical description of physical processes occurring in the real gases.

By the way, the molecular physics states that when we cool a gas (for example, helium) to T1 = 1C, we come nearer to absolute zero with a difference in one degree. But, the presented theory of hyper-frequency fluctuations shows that such statement is deeply erroneous.

It is known that achievement of absolute zero is understood as a full stop of motion of molecules. But at T_1 = 1C, we have:

$$f_1 = \varphi \cdot T_1 = 2,08298980005 \cdot 10^{10} s^{-1}, \quad (26)$$

$$\upsilon_1 = 2d_{g0} \cdot f_1 = 172,556 m/s. \quad (27)$$

It is easy to see that cooling the gas by the factor n_1 where

$$n_1 = T_0 / T_1 = 273,15$$

leads to decrease of frequency of the oscillator and speed of their motion also by the factor $n_1 = f_0/f_1$. Therefore, to come nearer to true absolute zero, it is necessary to make a frequency of their interaction equal to f_2 = 1 Hz. This is possible only at T_2 where:

$$T_2 = \xi \cdot f_2 = 4{,}800791 \cdot 10^{-11} K! \qquad (28)$$

This result can be very surprising for the physicists working in the field of low temperatures who by the present moment have reached only T = 2.5·10^{-4} C. To reach really the true absolute zero it is necessary to fall below for 107 steps on the temperature scale!

Summing up it is possible to state the following with assurance.

1. An oscillator and his individual space represent an indivisible unity, this is a globula. The mistake of scientists of the XIX century, trying to describe gas thermodynamics, is that they have not found this unity.

2. The opinion, that the behavior of gas is determined by the three parameters: pressure P, volume V, and temperature T, is not correct. Within the new theory of gas, only two parameters operate: volume of globula V_{gi} and energy of an oscillator $\varepsilon = m_i \cdot v_i u_i a$, while pressure and temperature are their derivatives.

3. Application of Planck constant for describing the thermodynamics of real gases is not only justified. This is our main discovery leading to construction of hyper-frequency mechanics as a new section of physics.

3. Physical nature of Planck constant

In the subsequent researches, we have described the physical theory of gas thermodynamics and derived 59 parametrical equations for practical application in calculations. We have derived the equation of state of real gas where there are 16 parameters in an explicit form and 9 more parameters in implicit form. In addition to this theory, we present 25 parameters for normal conditions for 16 real gases studied by us. Not less than 10 parameters of the mare established for the first time [1, Chapter III].

But, we have faced a surprising paradox. Planck constant is not included into these 25 parameters characterizing a gas, and, at the same time, no one real gas can be described without this constant! Words of the Nobel Prize winner Louis de Brogliewho called the Planck's constant by a «mysterious constant» are involuntarily remembered.

This circumstance has raised the question: what is a physical essence of this constant?

In 1934 M. Planck, addressing to the colleagueson a scientific conferences, spoke: «Misters, it is time to understand a physical essence of this constant. If we do it, new horizons and hitherto unknown depths will open before the science!».

However, neither during lifetime of M. Planck (1858-1947) nor after his death, not any his students and colleagues could solve this problem.

We were lucky more and have derived the equation for Planck constant. Further, we present the generalized description with a derivation of the equations for understanding the essence of Planck constant. This was obtained by us in 1982 and since then, repeatedly tested in practice and confirmed in experiments [2, pp. 63-65].

From (18) the following equation can be derived:

$$hf_0 = m_0 \upsilon_0 u_0 \cdot a, \qquad (29)$$

solving (29) with respect to h, we obtain:

$$h = \frac{m_0 \upsilon_0 u_0 \cdot a}{f_0} = \frac{m_0 \cdot 2d_{g0} \cdot f_0 \cdot u_0 \cdot a}{f_0} = 2m_0 \cdot d_{g0} \cdot u_0 \cdot a, \qquad (30)$$

Dividing equation (30) by the constant $a = \sqrt[3]{4\pi/3}$ we get:

$$\frac{h}{a} = 2m_0 d_{g0} u_0 = 4m_0 \cdot r_g \cdot u_0, \qquad (31)$$

where d_g is replaced by $2r_g$.

The left part of (31) represents a new fundamental constant $\hbar$ called us by «Hertz constant» in honor of Henry Hertz who has proved existence of the electromagnetic waves:

$$\hbar = h/a = 4{,}11060869204 \cdot 10^{-34} kg \cdot m^2 / s = const \qquad (32)$$

It is clear that the right part of equation (31) also must be equal to Hertz constant

$$\hbar = 4m_0 \cdot r_0 \cdot u_0 = 4m_0 \cdot \upsilon_{s0} =$$

$$= 4{,}110608692 \cdot 10^{-34} kg \cdot m^2 / s = const, \qquad (33)$$

where υ_{s0} is the sectorial speed of an oscillator which is defined as the production of the radius of globula and speed of "wandering"

$$\upsilon_{s0} = r_g \cdot u_0 = 2{,}363675167 \cdot 10^{-9} m^2 / s = const \qquad (34)$$

Since a sectorial speed of a body is a property of only curvilinear motion (for example, motion on an orbit round the force center), from (34) follows that u_0 of oscillator occurs on a curve of the 2nd order and along the external border of the globula possessing a spherical form.

It is natural to conclude that the physical basis of Planck constant is the moment of momentum of oscillator which can take place only at scattering of an oscillator on anoscillator.

In this regard, it was very instructive to compare the sectorial speed of an oscillator, for example, with the similar speed of the planet Earth.

According to the second Kepler law we have:

$$\upsilon_{s\oplus} = r_{\oplus} \cdot u_{\oplus} = 2,083495 \cdot 10^{15} m^2 / s = const , \quad (35)$$

where $r_{\oplus}$ is the radius of the orbit of Earth, $u_{\oplus}$ is its orbital speed,

$$L_{\oplus} = m_{\oplus} \cdot \upsilon_{S\oplus} = 1,246691 \cdot 10^{40} kg \cdot m^2 / s = const , \quad (36)$$

is the moment of momentum of the Earth in any point of its orbit.

From comparison of the equations (33–34) with (35) and (36) follows that between them there is a perfect analogy. But at the same time, the low speed u_0 equal only to 0.002188 % of υ_0 testifies that the Hertz constant cannot be a leading parameter in definition of the Planck constant. To be convinced of it, it was necessary to establish the nature of speed of "wandering" which has appeared very specific:

$$r_{c0} = \frac{\hbar}{m_0 \upsilon_0} = \frac{\hbar}{2,267352521 \cdot 10^{-21}} = = 1,812955265 \cdot 10^{-13} m , \quad (37)$$

This is distance of critical rapprochement of pair of oscillators, and it is also a curvature radius of an arch of scattering of an oscillator on an oscillator.

$$u_0 = f_0 \cdot r_{c0} = 1.031\ 514 \text{ m/s}. \quad (38)$$

It turns out that speed of wandering for the 16 investigated gases varies from 0.2 m/s for xenon (Xe) to 14.8 m/s for hydrogen (H) that confirms the point of view concerning the nature of Planck constant stated above.

Returning to Planck formula for a ray of light (11), we have a new question: why Planck constant is applicable to a ray of light and to determination of energy of an oscillator? Which features have they in common? At first sight, a ray of light and a gas oscillator strikingly differ among themselves. Besides it is unclear why, during temperature change of gas from T_0 to $T = (T_0 \pm t)$, all parameters of gas change but Planck constant keeps its value?

To find answers to these questions, it was necessary to assume that a certain third particle participates in interaction of pair of oscillators, which possesses an electric charge, is a part of oscillator, is radiated by them, and self-annihilates. In addition, oscillators do not lose high-speed rotation around the axes even at a full stop of translational motion ($\upsilon_0 = 0$). Otherwise so high speed of interaction between them cannot be achieved. (Pair of oscillatorsin $\Delta\tau = 1/f_0 = 1.75 \cdot 10^{-13} s$ manages to run each at other with the speed $\upsilon_0 = 4,7 \cdot 10^4$ m/sec, to stop after having reached a critical distance rc0, and then to run into the opposite directions with same speed υ_0 again. Further analysis has shown that the following condition must be satisfied:

$$\frac{\hbar}{r_{c0}} = 2 m_0 \upsilon_0 , \quad (39)$$

i.e. the moment of momentum of the first intermediary particle must be equal to the moments of momentum of both oscillators running at each other, and its vector must be opposite vector to both oscillators which have run at each other. After a short instant, the second intermediary particle whose impulse returns speed υ_0 to the oscillators must be radiated and they scatter.

If these arguments are true then the quantitative description of this phenomenon must have the following form:

$$m_{\varepsilon} \cdot \mu = 2\hbar , \quad (40)$$

where m_ε is a mass of an unknown particle, kg; μ is a sectorial speed of this particle in a force electric field of an oscillator.

$$\hbar = m_{\varepsilon} \cdot \mu / 2 \text{ is Hertz constant.} \quad (41)$$

In such form, equations (40) and (41) have no solution, since there have two unknowns in them.

To find final answer to these questions, we dare to modify the M. Planck doctrine, since we have proved that it is necessary to apply Hertz constant $\hbar$ to an elementary ray of light, as in a ray of light there is no scattering of a photon on a photon as it takes place at oscillator scattering on an oscillator by the angle $a = \sqrt[3]{4\pi / 3}$

$$\varepsilon_i = \hbar \cdot \nu_i \text{, J is the true energy of an elementary ray of light.} \quad (42)$$

It turns out that the given formula more exact than M. Planck formula which overestimated the value in a = 1.611 991 rad.

Planck equation in this improved form confirms absolutely that the ray of light consists of material particles (with final masses) as they possess the moment of momentum (kg·m^2/sec). They can be called Newton's corpuscles or Lewis's photons, or anyhow.

If we wish to gain a more penetrating insight into this situation, we must understand the structure of an elementary ray of light. Leaning on a course of geometrical optics [7] it was possible to investigate the structure of an elementary ray of light which has nothing to do with the concepts developed by J. Maxwell.

Firstly, the ray of light is not an electromagnetic wave.

Secondly, it consists of the electric axial field whose diameter is $d = 2.078\cdot10^{-16}$ m, and sign of a charge of this field (proceeding from the structural electron which is a part of an oscillator) is negative.

Thirdly, the photons move by half-circle steps along the axis of the beam, must possess a positive electric charge, and have simultaneously two speeds: an orbital speed ui and step-by-step c_i.

Fourthly, propagation speed of ray of light is a function of wave length. The experimentally established propagation speed of ray of white light c_1 = 2.99792458·108 m/s concerns only to the violet beams. In experimental conditions, the violet beams form the front of a bunch of white beams and are the first to reach receiver.

Fifthly, the fundamental constant characterizing a beam of natural light is not a speed of its propagation in vacuum but a sectorial speed of a photon μ

$$\mu = c_1\cdot \lambda_1 = c_2\cdot \lambda_2 = \dots c_i \cdot \lambda_i = const, \qquad (43)$$

where c_i is a speed of propagation of a beam with wavelength λ_i.

Having reached this result, it was necessary only to insert values for the violet beams forming the most short-wave part of visible solar range ($\lambda_1 = 4\cdot10^{-7}$ m) into (43):

$$\mu = c_1\cdot \lambda_1 = 119.916\ 984\ \text{m}^2/\text{s} = const. \qquad (44)$$

We called this constant by «Milliken constant» in honor of outstanding American physicist Robert Milliken who has experimentally established an electron charge.

Result (44) has allowed solving the equation (40) concerning mass of a photon m_ε

$$m_\varepsilon = \frac{2\hbar}{\mu} = \frac{2\cdot 4{,}110\,608\,692\,04\cdot10^{-34}\ kg\cdot m^2/s}{119{,}916\,984\ m^2/s} =$$
$$= 6{,}855\,757\,299\,63\cdot10^{-36}\ kg = const. \qquad (45)$$

It turns out that solution of equation (45) describes theoretically the new truly elementary particle called us by **«Electrino»** with application of a diminutive-hypocoristic suffix of Russian to the term Electron.

This particle is the material carrier of an electric current and a magnetic field, it is a neutrino when moving on a trajectory of the 1st order, and it is a part of atom. Electrino constitutes 50 % of the atom charge and 99.83 % of the atom mass [1, pp. 19-27].

For confirming such fundamental discovery it was necessary to find the proofs that such conclusions are objective and valid.

For this purpose, further researches of an elementary ray of light (taking into account its energy nature) have been undertaken to establish quantitative and qualitative relation between orbital and step-by-step speeds of photons.

We have used several, different methods for calculating the second energy of a ray of light. If our conclusions about existence of Electrino are erroneous, the results of the calculations would be inevitable different.

Results of calculations have coincided among themselves with accuracy **to the 12th decimal place**. Here are these results:

$$u_i = 2c_i$$
$$c_i = \sqrt{\mu\cdot\nu_i} = \mu/\lambda_i,\ м/с$$
$$c_i = \lambda_i\cdot\nu_i,\ м/с$$
$$\varepsilon_i = \frac{m_\varepsilon\cdot u_i\cdot c_i}{\gamma},\ Дж,$$

where γ = 4 radian is an angular step of a photon in its orbital motion along a beam axis. [1, pp 156-171]

$$\varepsilon_i = \frac{m_\varepsilon\cdot u_i\cdot c_i}{\gamma} = \frac{m_\varepsilon\cdot 2c_i\cdot c_i}{4} = \frac{m_\varepsilon\cdot c_i^2}{2},\ \text{J}$$
$$\varepsilon_i = \frac{m_\varepsilon\cdot u_i\cdot c_i}{\gamma} = \frac{m_\varepsilon\cdot u_{ii}\cdot u_i/2}{\gamma} = \frac{m_\varepsilon\cdot u_i^2}{8},\ \text{J}$$
$$\varepsilon_i = \hbar\cdot\nu_i,\ \text{J}$$

Example of calculation for the violet beam with wave length $\lambda_1 = 4\cdot10^{-7}$ m:

$c_1 = \mu/\lambda_1$ = 119.916 984m^{2}s^{-1}/4·10^{-7} m =
= 2.997 9246·10^8 m/s,

$u_1 = 2c_1$ = 5.995 8492·10^8 m/sis an orbital speed of a photon,

$\nu_1 = \mu/\lambda^2{}_1$ = 119.916 984/16·10^{-14} m^2 =
= 7.494 8115·1014s^{-1}

is a frequency of photons on the violet beam,

$\varepsilon_1 = \hbar\cdot\nu_1$ = 4.110 608 69204·10^{-34}·ν_1 =
= 3.080 823 729 71·10^{-19} J

is a frequency energy of an elementary beam,

$$\varepsilon_i = \frac{m_\varepsilon \cdot c_i^2}{2} =$$

$$= \frac{6,855\,757\,29963 \cdot 10^{-36}\ кг \cdot 8,98755190728 \cdot 10^{16} \cdot м^2/c^2}{2} =$$

$$= 3,080\,823\,72971 \cdot 10^{-19},\ J$$

is the mechanical energy of a beam on c_1,

$$\varepsilon_1 = \frac{m_\varepsilon \cdot u_1^2}{8} =$$

$$= \frac{m_\varepsilon \cdot 35,950\,207\,6291 \cdot 10^{16}\ м^2/c^2}{8} =$$

$$= 3,080\,823\,72971 \cdot 10^{-19}\ J,$$

$$\varepsilon_1 = \frac{m_\varepsilon \cdot u_1 \cdot c_1}{4} = 3,080\,823\,72971 \cdot 10^{-19}\ J$$

is an energy of a beam according to the natural equation with participation of both speeds of a photon.

These results have proved the theoretical conclusions that Electrino discovery has taken place. To disprove precise mathematical calculations is impossible. Therefore, for the physicists capable to be surprised by this discovery, it remains to test (only for themselves) the presented conclusions by independent calculations and experiments.

It is worth to note that in the existing theory of physics, there is no mathematical expression describing speed of light propagation. In addition, to justify the existence of energy of a ray of light is simply impossible on the basis of the existing theory, according to which a photon has neither a mass nor a charge. This contradicts sharply to Planck formula $\varepsilon = \hbar \cdot \nu$.

By means of the presented equation considering a mass and a charge of Electrino, it is possible to describe mathematically the various earlier non-solvable scientific problems.

The presented equations have obtained experimental confirmationin addition to purely theoretical justifications.

The following fundamental physical properties of Electrino are obtained:

m_ε = 6.855 757299 63·10^{-36} kg = *const* ,

ε = 1.987 664316 71·10^{-27} *Coulomb = const*

ε(m) = ε/m_ε = 2.899 262954 97·10^{8} C/kg = constis the specific charge, it is confirmed experimentally and described in the book «Charge and mass of photon»,

d_ε = 1.106 7247·10^{-16} m = constis a diameter of a spherical body of Electrino,

V_ε = $\pi d^3_\varepsilon/6$= 7.097 696469 45·10^{-49} m^3 = = *const.*

ρ_ε = $m_\varepsilon/V_\varepsilon$ = 8.659 130013 72·10^{12} kg/m^3 = = *const.*

Thus, it is proved that Electrino is the second truly elementary particle representing a true antipode to the first truly elementary particle, Electron. Electrino discovery has restored the real charge symmetry in the nature which exists both in the physical theory and in the atom structure.

The experiments on measurement of speed of propagation of monochromatic beams of light in the atmospheric air give the experimental proof of correctness of the theory.

Data of experiment are described in the following article. We offer to each scientific center in Europe and in the USA to make similar experiment for an independent expert appraisal of the declared results and the presented theory. The theory has arisen on the basis of finding the physical nature of Planck constant, Electrino discovery, and understanding the structure of atom.

In conclusion, we present the improved equation for determining the absolute value of Planck constant and the structure of elementary atom:

$$h = \frac{m_\varepsilon \cdot \mu \cdot \sqrt[3]{4\pi/3}}{2} = 6,6262681 \cdot 10^{-31}\ \frac{kg \cdot m^2}{s} = const$$

$$m_u = n_\varepsilon \cdot m_\varepsilon + n_e \cdot m_e = 1,66057 \cdot 10^{-27} kg = const$$

where n_e = 3 is the number of electrons in the elementary atom;

$n_\varepsilon = 2,41819886768 \cdot 10^{8}$ is the number of Electrino in the elementary atom;

$m_e = 9,038487 \cdot 10^{-31} kg$ is the improved value of the mass of the electron.

It should be noted that there is no any third particle in the elementary atom or in any atoms from periodic table. Therefore, investigations of atom structure with use of accelerators lose their significance since the structure of atom is established already [1, pp12-27]. It is worth stressing that description of atom structure is the main aim of theoretical physics.

Conclusions

1. An oscillator and his individual space represent an indivisible unity, this is a globula. Within the new theory, the behavior of gas is determined by only two parameters: volume of globula and energy of an oscillator, while pressure and temperature are their derivatives.

2. Application of Planck constant for describing the thermodynamics of real gases is justified. The generalized description with a derivation of the

equations for Planck constant understanding the essence of Planck constant is presented. The physical basis of Planck constant is the moment of momentum of oscillator which can take place only at scattering of an oscillator on an oscillator.

3. Planck equation in improved form confirms that the ray of light consists of material particles (with final masses) as they possess the moment of momentum (kg·m^2/sec).

4. Propagation speed of ray of light is a function of wave length. The experimentally established propagation speed of ray of white light $c_1 = 2.99792458 \cdot 10^8$ m/s concerns only to the violet beams. In experimental conditions, the violet beams form the front of a bunch of white beams and are the first to reach receiver. The fundamental constant characterizing a beam of natural light is not a speed of its propagation in vacuum but a sectorial speed of a photon-Milliken constant.

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THE MATHEMATICAL MODEL OF GRAIN DRYING WITH THE USE OF ELECTROACTIVATED AIR

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The development of equipment for energy-saving grain drying is not losing its relevance. For its effective implementation it is reasonable to apply the most promising solutions in electrotechnologies, such as the use of air ions. This work is an attempt to formulate the description of the use of electroactivated drying agent for dryeration bins. To obtain the sought-for model, the foundations of similarity theory, as well as the dimensional method were used. The electroactivation coefficient introduced to consider air ions influence in drying process, was described. In the result, the mathematical model has been obtained, that can be used both in the description of drying process and optimization of drying equipment parameters to intensify drying process.

Keywords: *air ions, similarity parameters, forced ventilation, grain drying, moisture transfer.*

Forced ventilation is a "soft" method of grain drying when atmosphere air is blown through grain layer. It may be heated up but only to reduce relative humidity down to equilibrium moisture content. As air heating by 1 °C reduces its relative humidity by 5%, atmosphere air supplied to grain layer is heated by 7…8 °C at most. Therefore, drying rate in forced ventilation units is not high, which reduces efficiency of postharvest treatment lines.

The research [1] on the use of electroactivated air for intensifying grain drying through forced ventilation has demonstrated this method efficiency. However, to calculate the process and simulate the operation modes of forced ventilation units using electroactivated air, it is necessary to have analytical description of drying process. To obtain it, let us turn to known methods.

V.I. Aniskin conducted thorough research of grain drying process in dryeration bins [2]. To describe grain drying process in thick layer with the use of forced ventilation, he developed and experimentally tested criteria equations for grain drying through forced ventilation in the conditions of both vertical and radial feed of drying agent.

$$Ho = A \cdot Ko^{\beta 1} \cdot Gu^{\beta 2} \cdot Re^{\beta 3} \left(\frac{d}{L}\right)^{\beta 4}. \qquad (1)$$

Each criterion describes the mechanism of internal or external heat-and-moisture exchange.

The homochronicity criterion, Ho, (2) describes duration of grain layer drying at a constant rate of drying agent velocity.

$$Ho = \frac{v \cdot \tau}{L}, \qquad (2)$$

where v – drying agent velocity, m/s; τ – drying duration, sec; L – grain layer thickness, m.

The homochronicity criterion, Ho, changes over time at a constant velocity of drying agent and fixed thickness of grain layer.

The Kossovich criterion, Ko, reflects the relationship between heat spent to evaporate moisture, and heat spent to warm up grain.

$$Ko = \frac{r' \cdot \Delta w}{c_з \cdot \Delta \Theta}, \qquad (3)$$

where w – grain humidity, o.e.; r' – specific heat of evaporation, kJ/kg; $c_з$ – grain heat capacity, kJ/kg· ℃; Θ – grain temperature, °C

Considering the use of electroactivated air, the Kossovich criterion, Ko, would be reduced, as specific heat of evaporation decreases due to lower viscosity of moisture contained inside caryopses.

The Guchman criterion, Gu, characterizes air potentials as a drying agent.

$$Gu = \frac{t_c - t_м}{273 + t_c}, \qquad (4)$$

where t_c – drying agent temperature, °C; $t_м$ – wet thermometer temperature, °C.

In the Guchman criterion, Gu, drying potential is contained in changing difference between drying agent temperature and wet thermometer temperature. Wet thermometer temperature is in direct relationship to air humidity.

The Reynolds criterion, Re, reflects a hydrodynamic mode of drying agent movement.

$$Re = \frac{\nu \cdot d}{\vartheta}, \quad (5)$$

where ν – drying agent velocity, m/s; d – specific diameter of caryopsis, m; ϑ – air kinematic viscosity, m^2/s.

In the result of experimental data processing V.I. Aniskin [2] obtained two criterion equations – for vertical and radial feed of drying agent, that reflect the process of grain drying through forced ventilation in thick layer:

$$Ho = 40{,}5 \cdot 10^{-5} Ko^{0{,}95} Gu^{-1{,}9} Re^{0{,}31} \left(\frac{d}{L}\right)^{-0{,}07} \quad (6)$$

$$Ho = 50 \cdot 10^{-5} Ko^{0{,}95} Gu^{-1{,}9} Re^{0{,}31} \left(\frac{d}{R - r_0}\right). \quad (7)$$

As has been noted before, one of the fundamental problems of the use of electrotechnologies in grain drying is the absence of mathematical description of processes occurring in grain layer. The thermodynamic criteria used by V.I. Aniskin for this process description, reflect them to the full extent, with the exeption of processes with the use of electroactivated air. To a certain degree the Kossovich criterion can reflect processes occurring in caryopsis when affected by electroactivated air. However, that can prove to be insufficient. Therefore, it is reasonable to apply an additional criterion that could reflect changing of processes in caryopsis. It is the Lykov criterion that can be accepted as such thermodynamic criterion.

A.I. Lykov criterion provides connection between the intensity of the development of moisture and temperature fields inside material in the process of moisture transfer [3]:

$$Lu = \frac{a_m}{a}, \quad (8)$$

where a – heat exchange rate, m^2/s; a_m– moisture diffusion coefficient, m^2/s.

In accordance with [4], temperature conductivity coefficient of grain layer at $0 - 60$ °C temperature and $\omega = 8 - 12\%$ may be described by the following equation:

$$lga = (-7157 + 3.8T + 0.25T\omega) \cdot 10^{-3}, \quad (9)$$

where T– grain temperature, °C; ω– grain moisture, %.

Within the moisture range $\omega = 12 - 21{,}5\%$ $lga = (-71.69 + 7.51T\omega) \cdot 10^{-3}$.

In accordance with [4], dependence of temperature conductivity of wheat fixed layer at 10 – 20% moisture content can be described by the following equation:

$$a = (0.70 + 0.014 \cdot W_c) \cdot 10^{-7},\ m^2/s. \quad (11)$$

Within the moisture content range of 20 – 30% this dependence is negative:

$$a = (1.80 - 0.042 \cdot W_c) \cdot 10^{-7},\ m^2/s, \quad (12)$$

where W_c – moisture content, %.

In accordance with [4], the relationship between moisture content and humidity of loose material can be presented in the following way:

$$W_c = \omega/(100 - \omega). \quad (13)$$

The formulas (11) and (12) come out right for grain with moisture range of 9.09–16.67% and 16.67–23.08% correspondingly.

At Fig. 1 nomogram chart of dependence of temperature conductivity on moisture content is presented. Temperature conductivity coefficient tends to increase at up to 20% moisture content or up to 16.67% grain layer humidity, and decreases as moisture content of grain layer humidity is increased.

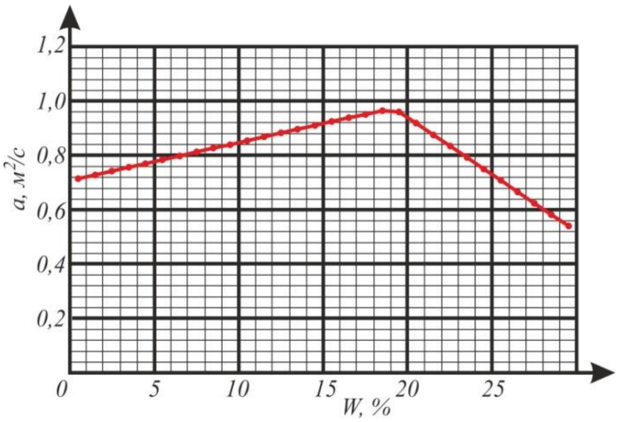

Fig. 1. Dependence of temperature conductivity on moisture content

The determination of moisture diffusion coefficient,a_m, in grain is quite a problem [4]. In various scientific sources data on this coefficient value sometimes varies considerably. It has been established [4] that the value of moisture diffusion in grain at 20 °C is about $10^{-11},\ m^2/s$. If grain moisture exceeds 10%, the value of moisture diffusion coefficient are reduced practically in accordance with linear dependence, but the order of value remains constant.

If temperature increases above 20 °C up to 50 °C , moisture diffusion coefficient grows rapidly in accordance with the following equation:

$$a_m = 10^{-49} T^{15{,}5}, \quad (14)$$

where T – grain temperature,°C.

It should be mentioned that in [4] the moisture of grain layer is not limited, and in [5] for the formula (14) grain moisture $\omega = 10 - 20\%$ is considered.

Let us take two assumptions while calculating the Lykov criterion, Lu:

- to calculate temperature conductivity coefficient, a, we shall use the formulas (11) - (13) at grain layer moisture $\omega = 10 - 24\%$;
- to calculate moisture diffusion coefficient we shall use the formula (14) with unlimited moisture of grain layer;
- in the result, we shall obtain the expression to calculate the Lykov criterion, Lu, (15) - (18):

$$Lu = \frac{10^{-49}T^{15,5}}{(0{,}70+0{,}014\cdot\omega/(1-\omega))\cdot 10^{-7}}, \qquad (15)$$

or

$$Lu = \frac{10^{-42}T^{15,5}}{(0{,}70+0{,}014\cdot\omega/(1-\omega))}, \qquad (16)$$

where T – grain temperature in the range from 20 ℃ to 50 ℃; ω – grain layer moisture in the range of 9–16.7%.

$$Lu = \frac{10^{-49}T^{15,5}}{(1{,}80+0{,}042\cdot\omega/(1-\omega))\cdot 10^{-7}}, \qquad (17)$$

or

$$Lu = \frac{10^{-42}T^{15,5}}{(1{,}80+0{,}042\cdot\omega/(1-\omega))}, \qquad (18)$$

where T – grain temperature I the range from 20 ℃ to 50 ℃; ω – grain layer moisture above 16.7%.

Now we have all the necessary data for calculation of criteria on whose basis we can obtain the equation for drying grain through forced ventilation. To consider the effect of electroactivated air on grain drying process let us add the so-called electroactivation criterion, $Q_э$, reflecting the process of drying agent saturation with air ions and the conditions of its interaction with grain.

At cyclic saturation of drying agent with air ions (Fig. 2) electroactivation criterion should reflect its mode peculiarities expressed in the ration of drying time under the effect of air ions and without them. In this case electroactivation criterion will be as follows:

$$Q_э = Q_1 \cdot Q_2, \qquad (19)$$

where Q_1 – air ions concentration when they enter grain layer, 1/m^3; Q_2 – air volume per one processing cycle, m^3.

Let us consider the first component of the equation (19). The process of transporting electroactivated air through the air duct determines the air ions concentration when they enter grain layer. In accordance with[1,6], air ions concentration when they come out of the air duct (that is, entering grain layer) depends on air ions concentration at the entry to the air duct, the coefficient of volume recombination of air ions, the velocity of air ionscontacting the air duct walls and the air duct dimensions.

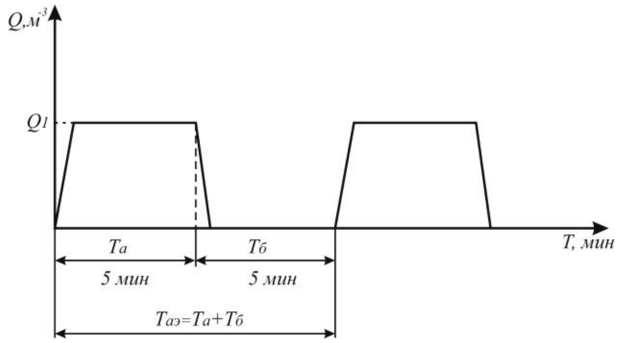

Fig. 2. Diagram of changing of air ions concentration in drying agent at cyclic mode of air ions supply

To obtain dependence of air ions concentration Q_1 in the air duct in the process of grain drying through forced ventilation by electroactivated air (from the air ions source to the entry into grain layer), let us use the following designations:
E – intensity of electric field generated by the electric activator, B/m; T_a– drying agent temperature, ℃; ν – drying agent velocity, m/s; L_T – distance from the electric activator to the entry to grain layer; α – volume recombination coefficient, m^3/s; V_0 – the velocity of air ions going to the air duct walls, s^{-1}.

To obtain the sought-for dependency let us apply the method of dimensional analysis [7]. The method of dimensional analysis is the most effective when the desired dependency is sought in not direct way, involves some mathematical problems, or requires the knowledge of such details of the process that are still unknown. The processes of air ions interaction with grain layer are graded as such.

The dimensional analysis is based on the requirement of independence of relation of physical quantities from the selection of units, which is equivalent to the requirement of compliance of dimensions in the both parts of the equation [7].

In order to apply the method of dimensional analysis, let us present the full physical equation describing the process being researched [7]:

$$Q_1 = f(E, T_a, \nu, L_T, \alpha, V_0). \qquad (20)$$

Let us compose the full matrix of dimensions $\|A\|$ for parameters being researched, and write all the parameters in the selected system of fundamental units (the SI system) $-[M], [L], [T], [I], [\Theta]$[7]:

$$Q_1 = [M]^0[L]^{-3}[T]^0[I]^0[\Theta]^0;$$
$$E = [M]^1[L]^1[T]^{-3}[I]^{-1}[\Theta]^0;$$
$$T_a = [M]^0[L]^0[T]^0[I]^0[\Theta]^1;$$
$$V_a = [M]^0[L]^1[T]^{-1}[I]^0[\Theta]^0;$$
$$L_T = [M]^0[L]^1[T]^0[I]^0[\Theta]^0;$$
$$\alpha = [M]^0[L]^3[T]^{-1}[I]^0[\Theta]^0;$$
$$V_0 = [M]^0[L]^0[T]^{-1}[I]^0[\Theta]^0.$$

Thus, we shall obtain the full matrix of dimensions $\|A\|$ wherein raw dimension is number of parameters $m = 7$, column dimension – number of units $q = 5$.

$$\|A\| = \left\| \begin{matrix} 0 & -3 & 0 & 0 & 0 \\ 1 & 1 & -3 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 3 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 \end{matrix} \right\|. \qquad (21)$$

The number of independent parameters is equal to the rank of matrix of dimensions $\|A\|$, and the number of similarity criteria $-(m-k)$.

Following matrix analysis, determinant having two linearly dependent rows (columns) is equal to zero. In this case the first and fifth rows are linearly dependent; the sixth and fourth rows are linear combination of the fifth and seventh rows; the first and fourth columns are linearly dependent. Therefore, let us exclude the linearly dependent rows and columns. We shall obtain the contracted trix $\|A'\|$:

$$\|A'\| = \left\| \begin{matrix} 1 & 1 & -3 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \end{matrix} \right\|. \qquad (22)$$

For this matrix there are determinants of the forth order that are not equal to zero ($k = 4$). Thus, of the seven parameters we can select the four independent ones. So, the process being studied is characterized by three similarity criteria. Let us choose E, T_a, L_T, V_0 as independent parameters (in accordance with nonzero determinant of the matrix), and Q_1, ν, α as similarity criteria.

To identify dependence of similarity criteria on independent parameters, let us write the equation (20) in the following way:

$$\frac{Q_1}{[E]^{\alpha_1}[T_a]^{\beta_1}[L_T]^{\gamma_1}[V_0]^{\tau_1}} =$$
$$= \left(\frac{\nu}{[E]^{\alpha_2}[T_a]^{\beta_2}[L_T]^{\gamma_2}[V_0]^{\tau_2}} ; \frac{\alpha}{[E]^{\alpha_3}[T_a]^{\beta_3}[L_T]^{\gamma_3}[V_0]^{\tau_3}} \right). \qquad (23)$$

Let us calculate the value of coefficients α_1, β_1, γ_1, τ_1, α_2, β_2, γ_2, τ_2, α_3, β_3, γ_3, τ_3, then express each similarity criterion (23) through the system of fundamental units:

$$\frac{Q_1}{[E]^{\alpha_1}[T_a]^{\beta_1}[L_T]^{\gamma_1}[V_0]^{\tau_1}} =$$
$$= \frac{[L]^{-3}}{([M]^1[L]^1[T]^{-3}[I]^{-1})^{\alpha_1} \cdot ([\Theta]^1)^{\beta_1} \cdot ([L]^1)^{\gamma_1} \cdot ([T]^{-1})^{\tau_1}}. \qquad (24)$$

Now let us calculate coefficients in the degree of each fundamental unit:

$[M]$: $\alpha_1 = 0$;
$[L]$: $\alpha_1 + \gamma_1 = -3 \Rightarrow \gamma_1 = -3$;
$[T]$: $-3\alpha_1 - \tau_1 = 0 \Rightarrow \tau_1 = 0$;
$[I]$: $-\alpha_1 = 0$;
$[\Theta]$: $\beta_1 = 0$.

We shall obtain the first similarity criterion: $\pi_1 = Q_1 \cdot L_T^3$.

Let us do the same in regard to the criteria V_a, α.

$$\frac{\nu}{[E]^{\alpha_2}[T_a]^{\beta_2}[L_T]^{\gamma_2}[V_0]^{\tau_2}} =$$
$$= \frac{[L]^1[T]^{-1}}{([M]^1[L]^1[T]^{-3}[I]^{-1})^{\alpha_2} \cdot ([\Theta]^1)^{\beta_2} \cdot ([L]^1)^{\gamma_2} \cdot ([T]^{-1})^{\tau_2}}. \qquad (25)$$

$[M]$: $\alpha_2 = 0$;
$[L]$: $\alpha_2 + \gamma_2 = 1 \Rightarrow \gamma_2 = 1$;
$[T]$: $-3\alpha_2 - \tau_2 = -1 \Rightarrow \tau_2 = 1$;
$[I]$: $-\alpha_2 = 0$;
$[\Theta]$: $\beta_2 = 0$.

The second similarity criterion: $\pi_2 = \frac{\nu}{L_T \cdot V_0}$.

$$\frac{\alpha}{[E]^{\alpha_3}[T_a]^{\beta_3}[L_T]^{\gamma_3}[V_0]^{\tau_3}} =$$
$$= \frac{[L]^3[T]^{-1}}{([M]^1[L]^1[T]^{-3}[I]^{-1})^{\alpha_3} \cdot ([\Theta]^1)^{\beta_3} \cdot ([L]^1)^{\gamma_3} \cdot ([T]^{-1})^{\tau_3}}. \qquad (26)$$

$[M]$: $\alpha_3 = 0$;
$[L]$: $\alpha_3 + \gamma_3 = 3 \Rightarrow \gamma_3 = 3$;
$[T]$: $-3\alpha_3 - \tau_3 = -1 \Rightarrow \tau_3 = 1$;
$[I]$: $-\alpha_3 = 0$;
$[\Theta]$: $\beta_3 = 0$.

The third similarity criterion: $\pi_3 = \frac{\alpha}{{L_T}^3 \cdot V_0}$.

We shall obtain: $\pi_1 = \Phi(\pi_2,\ \pi_3)$ or

$$L_T{}^3 \cdot Q_1 = \Phi\left(\frac{\nu}{L_T \cdot V_0}, \frac{\alpha}{L_T{}^3 \cdot V_0}\right). \quad (27)$$

Using the dimensional analysis of quantity dimension of the expression (27) we shall obtain:

$$Q_1 = C \cdot \frac{\alpha \cdot \nu}{L_T{}^7 \cdot V_0{}^2}. \quad (28)$$

where C – coefficient determined experimentally.

Therefore, the obtained criteria dependenceT of air ions concentration $Q_{1\text{в}}$ in the air duct demonstrates that in the process of drying grain with the use of electroactivated air, ions concentration Q_1in the air duct is directly dependent on the velocity of drying agent ν, the coefficient of volume recombination of air ions α, and inverse dependence on the distance from the electric activator to grain layer $L_T -$ on the velocity of air ions coming to the walls of the air duct V_0, (dependence on dielectric properties of the material of which the air duct is made). Proportionality coefficient is L_T^{-3}.

It was suggested to carry out processing by air ions cyclically in accordance with the Diagram (Fig. 2). In this case air volume for one processing cycle, Q_2, will be determined on the basis of the following expression:

$$Q_2 = vST_{\text{аэ}}\ . \quad (29)$$

Considering the obtained expression for air ions concentration at the entry to grain layer, the expression (19) will be as follows:

$$Q_э = C \cdot \frac{\alpha \cdot \nu}{L_T{}^7 \cdot V_0{}^2} \cdot (v \cdot S \cdot T_{\text{аэ}}). \quad (30)$$

where v – drying agent velocity, m/s; S – area of the cross section of the processing chamber for grain drying, m^2; $T_{\text{аэ}}$ – semi-oscillation of air ions concentration in drying agent, s.

$$T_{аэ} = T_a + T_б, \quad (31)$$

where $T_{\text{аэ}}$– semi-oscillation of air ions concentration in drying agent, s; T_{a} – period of operation of the air ions generator for one cycle, s; $T_б$ – period when the air ions generator is switched-off, s.

In the result, the criterion equation of grain drying through forced ventilation will be as follows:

$$Ho = A \cdot Lu^{\beta 0} \cdot Ko^{\beta 1} \cdot Gu^{\beta 2} \cdot Re^{\beta 3} \cdot \left(\frac{d}{L}\right)^{\beta 4} \cdot Q_э{}^{\beta 5}. \quad (32)$$

This equation may be applied for the description of laws of heat and moisture exchange in drying thick layer. In a particular case, when elementary layer in researched, parametric criterion d/L may be neglected, then criterion equation will describe processes occurring in elementary layer and may be used as the basis for the building of simulation models for grain drying.

In practice for calculations it is reasonable to use not criterion equation itself but expression for drying period $\tau = f(Lu, Ko, Gu, Re)$obtained on its basis. Current methods of processing experimental data allow to immediately obtain such dependencies. It is necessary to consider that in this case the coefficient A' will have dimension of time.

Therefore, the criterion equation for period of elementary layer drying will be as follows:

$$\tau = A' \cdot Lu^{\beta 0} \cdot Ko^{\beta 1} \cdot Gu^{\beta 2} \cdot Re^{\beta 3} \cdot Q_э{}^{\beta 4}. \quad (33)$$

The obtained criterion equation may be used in practice only after experiments for grain drying by electroactivated air and regression analysis to determine the values of coefficient A' and indices $\beta 0,\ \beta 1,\ \beta 2,\ \beta 3,\ \beta 4$.

The purpose of this work is to intensify drying, therefore, the equation (33) may be used as criterial:

$$A' \cdot Lu^{\beta 0} \cdot Ko^{\beta 1} \cdot Gu^{\beta 2} \cdot Re^{\beta 3} \cdot Q_э{}^{\beta 4} \rightarrow min. \quad (34)$$

With this objective in view, in the equation (34) we are most interested in the influence of multiplier $Q_э{}^{\beta 4}$ to provide minimal drying period.

Constraints related to the peculiarities of design of forced ventilation units can be considered as boundary limitations. For the equation (30) this is the variable S. Thus, for dryeration bins S is the surface area of the central air duct.

$$S = 2\pi Rh,$$

where R – is the radius of the central air duct, m;h– the height of the central air duct .

Constraint can be written in such a way that changing the design of dryeration bins will not be necessary. For example, $5m$. If the improvement of technology involves changing the design of bins, then constraints may be written in the following way, for example:

$$S = -2\pi Rh \leq D - 2\pi R_1 h\ , \quad (35)$$

or

$$2\pi h(R_1 - R) \leq D, \quad (36)$$

where R_1 – the radius of the external cylinder of a dryeration bin, m.

This constraint allows to expand the radius of the central air duct but under the condition that its surface area on D (m^2) is less than the area of the external wall of the bin.

Limitation of drying agent velocity can consider the capacity of the electric motor for the ventilator drive

$$\frac{v \cdot S_1 \cdot P}{1000\eta} \leq N, \qquad (37)$$

where v – air velocity, m/s; S_1– cross-section of the air duct, m^2; P – ventilator head, *Па*; η – ventilator efficiency; N – capacity of the electric motor of the ventilator, kW.

It should be noted that changing S would also entail changing S_1, and changing the value v would result in changing the criterion Re.

Shared writing (34) with boundary limitations would gave us the mathematical model of the process of grain drying with the use of electroactivated air: $A' \cdot Lu^{\beta 0} \cdot Ko^{\beta 1} \cdot Gu^{\beta 2} \cdot Re^{\beta 3} \cdot Q_э{}^{\beta 4} \to min$;

$$\begin{cases} 2\pi h(R_1 - R) \leq D, \\ S_1 = \pi R^2, \\ \frac{v \cdot S_1 \cdot P}{1000 \cdot \eta} \leq N, \\ R, R_1, S_1, v > 0. \end{cases} \qquad (38)$$

This model allows to optimize the parameters of the dryerationbins and ventilator performance, as well as the parameters of the criterion of electroactivation to minimize the period of grain drying through the use of electroactivated air.

Conclusions

1. The use of the method of dimensional analysis of similarity theory made it possible to obtain dimensionless criterion that can be used for the description of the process of changing concentration of air ions in their transportation from a radiating unit to grain layer.

2. The application of the method of putting the equations of physical process to dimensionless form made it possible to develop the criterion equation for the description of processes of heat and moisture exchange in grain layer during its drying through the use of electroactivated air, that can be used as the basis in building simulation models of drying of grain thick layer by electroactivated air.

3. The obtained mathematical model allows to optimize the parameters of dryeration bins and ventilator performance, as well as the parameters of the criterion of electroactivation to minimize the period of grain drying through the use of electroactivated air.

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LINEAR APPROXIMATIONS OF TEMPERATURE DEPENDENCES OF WATER PROPERTIES

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In the work extreme properties of liquid water were studied with the use of the method of linear approximation of temperature dependences of its characteristics. Their analysis allowed to divide molecular dynamics responsible for extremity of temperature dependences of water properties into two types – barrier and barrier-free. Therefore, extreme points, parameters of linear approximations and gradients of temperature dependences were determined for density, isobaric heat capacity, compressibility, surface tension and sound speed. For dynamic viscosity, self-diffusion, time of dielectric relaxation, specific conductivity and a share of free molecules activation energy was evaluated and breaks in logarithmic approximation were revealed. The thermodynamically water model was suggested wherein changes of water dynamics and structure are limited by hydrogen bonds and temperature. Within the framework of this model and the concept of fluctuating hydrogen bonds the molecular mechanisms of temperature dependences of water properties were explained.

Keywords: *water thermodynamics, extreme points, linear approximations.*

1. Introduction

Water in liquid state and under normal atmosphere pressure plays a key role in bioenergetics and metabolism of living systems. Therefore, it is important to study water properties in the temperature range from ~0° C (ice point) to 100° C (boiling point). Hydrogen bond (H-bond) and dissociation of water molecules into proton and hydroxyl determine anomalous character of dependences of water physicochemical properties on temperature. Anomalies are in general manifested through extreme values of physical water properties at certain temperature points termed extreme points. Experience suggests that in the 0-100° C range each parameter generally has one peculiar extreme point. These are primarily the following temperatures: ~4° C (maximum density and minimum molar volume), ~35° C (minimum isobar heat capacity), ~45° C (minimum compressibility), ~75° C (maximum sound speed).

So far the thermodynamic mechanism of temperature differentiation of extreme values for various water characteristics have not been discovered. The reason for this is a complex structural organization of liquid water and the absence of its kinetic theory [1]. Therefore, in water properties research the methods of mathematical (numerical) simulation and statistical physics are playing a significant part. With the application of these methods ideal interpolations for experimental dependences are found and various phenomenological models of molecular structure and dynamics of liquid water are calculated [2].

Dependence of water properties on temperature are usually approximated with the use of polynoms and exponents with nonintegral parameters. For example, to calculate the coefficient of water surface tension in the range from 0.01 to 370° C the following formula is used [3]:

$$\sigma = 235.5\,(T/T_0)^{1,256}[1 - 0.625(T/T_0)], \qquad (1)$$

where T_0 = 647.096K. Value error calculated according to the formula (1) amounts to 0.5% in the range 0 – 175° C, at 360° C is 5% and grows up to 22% at 370° C.

The formula for isobar heat capacity in the 0-100° C range is as follows [4]:

$$C_{p\,(t\,^oC)} / C_{p\,(15\,^oC)} = 0.99618 + 0.0002874 \times \times (1 + t/100)^{5,26} + 0.011160\;10^{-0,036\,t}. \qquad (2)$$

Approximations of (1), (2) type are useful for the solution of technical problems. However, mathematical complexity of trends, as a rule, completely disguises physical factors related to anomalous properties of water at extreme points.

In the work [5] the method of mathematical simulation of peculiarities of water thermodynamics using linear approximations of water dependencies on temperature is suggested. In the present work this method was used to reveal extreme points and determine kinetic regularities in water thermodynamics. For our research we used known data on dependences on temperature in the 0-100° C range of the following water characteristics: density, molar volume, dynamic viscosity, isobar heat capacity, sound speed, compressibility, coefficient of surface tension, specific conductivity, self-diffusion, the time of dielectric relaxation and a share of free molecules.

2. Mathematical models

Temperature dependences (TD) of water properties in the interval between critical points were approximated with the use of the following functions:

$$(\Delta A)^{1/n} = \alpha\,(1/T - 1/T_0) \qquad (3)$$

$$\ln A = \alpha/T, \qquad (4)$$

where T - absolute temperature, T_o – extreme point, $\Delta A = |A - A_o|$, A, A_o – tabular values of water characteristics at arbitrary and critical temperature, at which $\Delta A = 0$; α – tangent of inclination angle of a corresponding section of straight line, n = 2 or 3. At points T_o linear approximations were broken or crossed the axis 1/T.

The function (3) was applied for approximating TD of density (ρ), molar volume (V_m), sound speed (v), isobar heat capacity (C_p), compressibility (γ) and surface tension (σ). The expression (4) is transformed into the formula of dependence of water characteristics on temperature:

$$A = A_o \pm B\,(\Delta T/T)^n, \qquad (5)$$

where $\Delta T = |T - T_o|$, $B = (\alpha/T_o)^n$, sign and value B are determined by the sign and value α for a corresponding range of approximation. Values n, temperature ranges and values α and B are given in the Table.

With the use of the function (4) we approximated TD of dynamic viscosity (η), the coefficient of surface tension (σ), specific electric conductivity (λ), the share of free molecules (δ), the coefficient of self-diffusion (D) and the time of dielectric relaxation (τ_D) in the range specified in the Table 1.

To evaluate energy of dissociation of water molecules into H^+ and OH^- the Coulomb formula was applied:

$$E_q = q^2/(4\pi\varepsilon_o\varepsilon R), \qquad (6)$$

where q – single charge equal to $1.6\ 10^{-19}$ Coulomb; ε_o – dielectric constant of vacuum equal to 0.885 10^{-11} Am^{-1}, ε = 81 – dielectric constant of water (at t=25°C), R ≈ 0,1 nm – length of bond O-H. The evaluation revealed the value E_q = 17.3 kJ mol^{-1}.

Table 1. Critical points (t_0) and parameters of linear approximations (trends) ($y = \alpha\,T^{-1} + b$)

Characteristic	У	t_0 (°C)	Trend range Δt (°C)	r^2	α	E_a (kJ $mole^{-1}$)	b	B	Reference
Density (ρ, g sm^{-3})	$(\Delta\rho)^{1/2}$	4;75	0 – 4	1	217	-	-0.78	0.61	[6.7]
			4-30	1	-212	-	0.77	-0.59	[6]
			4 - 40	1	-211	-	0.76	-0.57	[7]
			4-73	0.9999	-214	-	0.78	-0.61	[8]
			80-100	0.9999	-237	-	0.84	-0.70	[8]
Isobar heat capacity (C_p, J $г^{-1}$ K^{-1})	$(\Delta C_p)^{1/3}$	4; 25; 35	0 – 4	0.9999	794	-	- 2.57	17	[4.9]
			4 – 25	0.9999	726	-	- 2.32	12.5	[4.9]
				1	692	-	-2.19	10.5	[8]
			25 – 35	0.9977	833	-	-2.68	19.2	[4.9]
				0.9989	827		-2.64	18.4	[8]
	$(\Delta C_p)^{1/2}$	75	35 – 74	0.9998	-311	-	1.00	-1.0	[4.9]
				0.9998	-325	-	1.05	-1.1	[8]
			78 – 100	0.9995	-384	-	1.22	-1.5	[9]
				0.9993	-387	-	1.23	-1.5	[4]
				0.9992	-375	-	1.19	-1.4	[8]
Compressibility (γ, bar^{-1})	$(\Delta\gamma)^{1/2}$	45	0 – 45	0.9978	4748	-	14.9	222	[12]
			45-100	0.9983	4557	-	14.4	207	
Molar volume (V, cm^3)	$(\Delta V)^{1/2}$	4	-4 - 4	0.9995	-927	-	3.35	11.2	[6.11]
			4 – 9	0.9997	901	-	-3.26	-10.6	
Sound speed (v, m s^{-1})	$(\Delta v)^{1/2}$	75	0-74	0.9998	15700	-	-45.2	2042	[11]
				0.9999	15716	-	-45.0	2025	[8]
			75-100	0.9997	-17300	-	49.7	-2420	[11]
				0.9995	-17016	-	49.0	-2401	[8]

Surface tension (σ, nm^{-1})	$(\Delta\sigma)^{1/2}$	25	25-100	0.9998	-26.6	-	0.1	-0.01	[3]
	ln σ	0; 25	0 – 25	0.9986	170.8	1.4	-3.2	-	
Dynamic viscosity (η, cPs)	ln η	4; 25; 35; 45; 75	0-4	0.9999	2535	21.1	-8.7	-	[10]
			4 – 25	0.9993	2203	18.3	- 7.5	-	
			25 – 35	0.9999	1951	16.2	- 6.7	-	
			35-45	0.9999	1839	15.3	-6.3	-	
			45 – 73	0.9997	1677	13.9	-5.8	-	
			78 – 100	0.9999	1513	12.6	-5.3	-	
			0 – 100	0.9927	1889	<15.7>	- 6.4	-	
Specific electric conductivity (λ, Om^{-1} m^{-1})	ln λ	-	0 – 50	0.9993	-4377	36.0	16.5	-	[13]
Coefficient of self-diffusion (D, cm^2 c^{-1})	lnD	25	-23-4	0.9974	-2696	22.4	7.6	-	[15]
			4-72	0.9995	-2178	18.7	6.0	-	
			-23-4	0.9955	-3093	25.7	13.7	-	[1]
			4-25	0.9984	-2508	20.8	11.5	-	
			27-72	0.9962	-2026	16.8	9.9	-	
Time of relaxation (τ_D, s)	$\ln\tau_D$	-	-3-57	0.9907	2447	20.3	-6.1	-	
Share of free molecules (δ, %)	ln δ	-	0-100	0.9993	-930	<7.7>	5.6	-	[14]

3. Materials and methods

The values of water characteristics at various temperatures were taken from the following sources: density (ρ) [6-8], isobar heat capacity (C_p) [4, 8, 9], dynamic viscosity (η) [10], sound speed (v) [8, 11], molar volume (V_m) [6, 11], compressibility (γ) [12], coefficient – f surface tension (σ) [3], electric conductivity (λ) [13], the share of free molecules (δ) [14], coefficient of self-diffusion (D) [1, 15] and time of relaxation (τ_D) [1].

In appropriate anamorphoses function (1) and (2) takes the form:

$$y = \alpha x + b. \qquad (7)$$

B (7) x = 1/T for function (3), $y = (\Delta A)^{1/n}$, and $b = -\alpha/T_0$ и $B = (b)^n$. For the function (4), y = lnA, $\alpha = E_a/R$, b = S/R (E_a – activation energy, S – entropy, R – gas constant, 8.31 J $K^{-1}mole^{-1}$). Consequently, $E_a = \alpha R$ and TD of the characteristic A I is in the form of the Arrenius equation:

$$A = \text{const}\ e^{(\pm Ea/RT)}, \qquad (8)$$

where const ~ e^b. For dynamic viscosity (8) coincides with the Fraenkel-Andrade approximation formula:

$$\eta = \text{const}\ \exp(E_a/RT),$$

where E_a – energy of activation of molecular jump.

Measure of reliability of the linear trend (7) was the degree of approximation of the value r^2 to 1. The value r^2 was reduced due to a small number of empiric points as in the case of compressibility, the share of free molecules, the coefficient of self-diffusion and the time of dielectric relaxation. Reliability also was reduced when several extreme points (dynamic viscosity) were included in the range of definition of the trend. To determine curves and breaks of linear approximations at extreme points the scale of diagrams of functions (3), (4) was increased four times. For approximations of TD of density, adiabatic heat capacity and sound speed various series of empirical and calculated data were used. Calculation error of α and B was determined by the accuracy of tabular values A and did not exceed 1%. Errors in evaluating E_q and E_a did not exceed 5%.

For digitization of known experimental curves, calculations, approximations and construction of diagrams the Adobe Photoshop and Microsoft Office Excel were used.

4. Results

Linear approximations of TD of water properties are presented at Fig. 1-4 and their parameters and extreme points are given in the Table 1. The analysis of linear approximations of TD demonstrated composite distribution of extreme points (4, 25, 35, 45, 75° C) in terms of water characteristics.

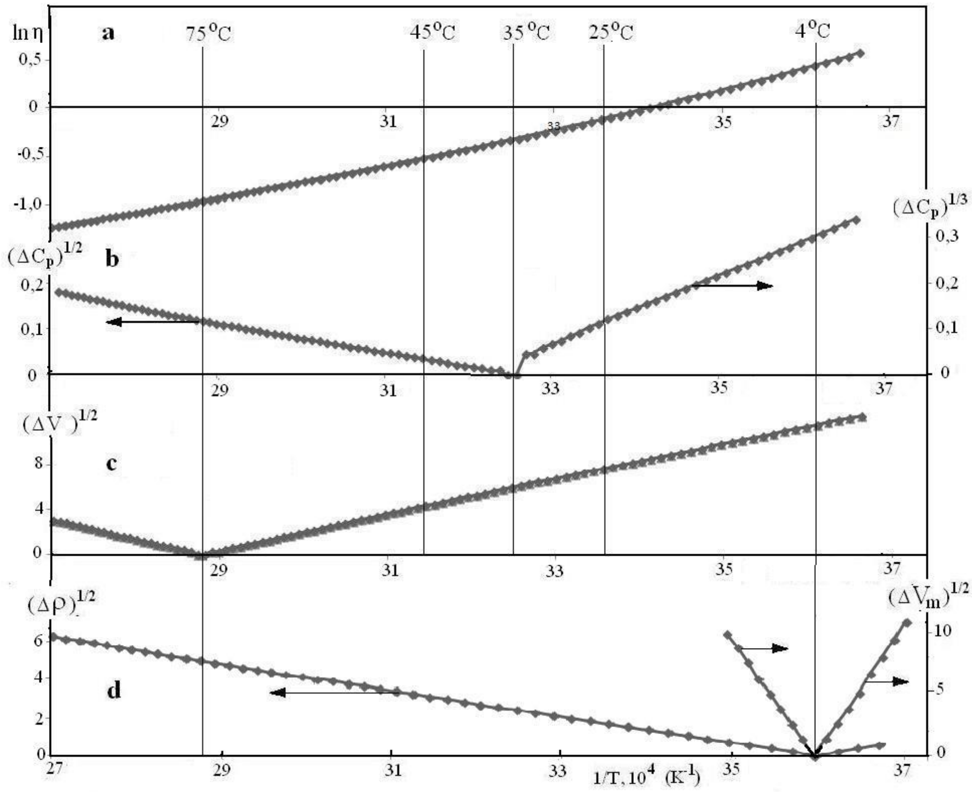


Fig. 1. Linear approximations of temperature dependences of dynamic viscosity (a), isobar heat capacity (b), sound speed (c), water density and molar volume (d)

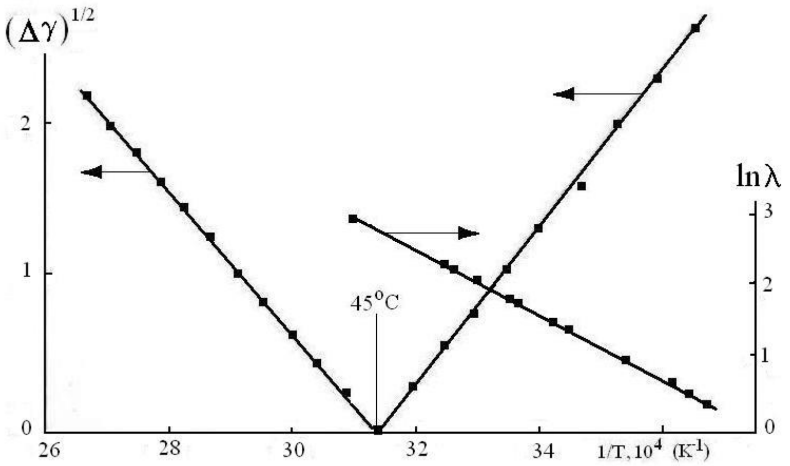


Fig. 2. Linear approximation of temperature dependences of water compressibility (γ) and electric conductivity (λ)

In addition to known extreme points of density, molar volume and heat capacity at constant pressure (35° C), at TD of these characteristics breaks at points 75° C (ρ) and 25, 45, 75° C (C_p) have been detected. The 25° C point was also manifested at TD of σ, D and τ_D.

The approximation of TD of dynamic viscosity by the function (4) in the range 0-100° C considerably deviated from the linear one in the coordinates lnη - 1/T at a comparably low value of r^2. Considering high reliability of linear approximations TD of ρ, V_m, C_p, γ, v and σ, the 0-100° C temperature range for TD was subdivided into 6 intervals by points: 4, 25, 35, 45, 75° C, presenting it as a jogged line with rather narrow interfacing sections of complementary intervals not exceeding 3-5 degrees.

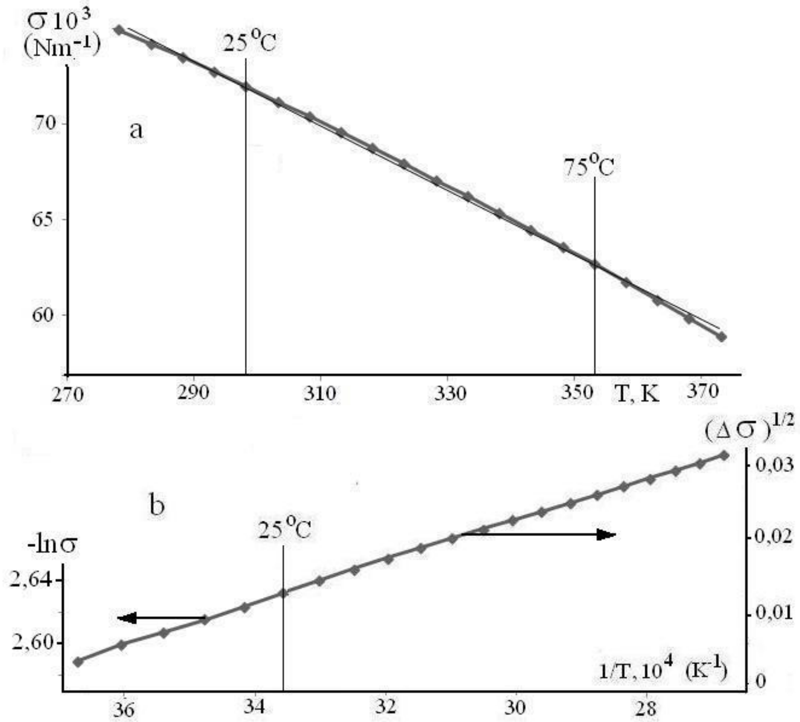


Fig. 3. Dependence of water surface tension on temperature (a) and its linear approximation (b)

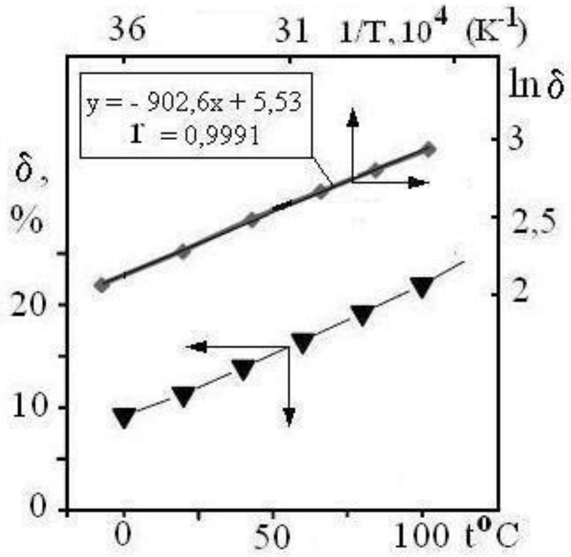


Fig. 4. Dependence of the share of water free molecules (δ) on temperature [14] and its linear approximation

Within these intervals linear approximations of TD of viscosity by the function (4) had high degree of reliability. For each interval the value E_a, included in the function (8) was assessed. The values E_a for viscosity were reduced while temperature increased, and were close to the values E_a for D and τ_D in corresponding temperature intervals.

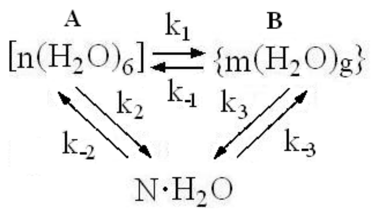
Due to approximation of TD of λ and δ by the function (4) the values E_a were obtained for corresponding functions (8). For specific electric conductivity the value E_a = 36.0 kJ/mole in the 0-45° C range is close to the sum of average E_a for η (17.7 kJ/mole) and energy of water dissociation into H^+ and OH^- (17.3 kJ/mole) calculated in accordance with the formula (6). For σ the value E_a = 1.4 kJ/mole in the 0-25° C interval in order of values can be attributed to energy of activation of translational movement of molecules in water surface layer. Average value E_a for the share of free molecules H_2O amounted to 7.7 kJ/mole. It is close to the sum of specific ice-melting heat (6.0 kJ/mole) and energy of activation of translational movement of water free molecules (~1.4-2.4 kJ/mole).

It appears from the linear approximations of extreme points of water characteristics in the 0-100^o C range that the values ρ, V_m, C_p, γ, v and σ (at t > 25^o C) can be calculated according to the formula (5), and the values η, λ, δ, D, τ_D and σ (at t < 25^o C) according to the formula (8). Linear approximations of TD of ρ, V_m, C_p, γ and v have extreme value (minimum or maximum) at one extreme point of the range 4, 25, 35, 45, 75^o C. In addition, in approximations of TD of η, ρ, C_p, σ and D breaks were revealed at some other points of the same temperature range.

5. Discussion

5.1. Kinetics of structural modifications

Determined variations of the values of activation energy and extreme points of various water characteristics are evidently a consequence of dependence of water structural organization and molecular dynamics on temperature. Considering the known data [1, 2, 16-18] let us present dynamics of structural modifications in liquid water in approximation of thermodynamic equilibrium with the use of the following kinetic Scheme:



(9)

At Scheme (9) **A** is a three-dimensional network with dominating tetrahedral metrics of ice-like associates including n hexametric clusters $(H_2O)_6$; **B** - various supramolecular structures associating m homogeneous elements formed by clusters with g = 2, 3, 4, 5. The number N is used to designate water molecules participating in processes of self-diffusion, dielectric relaxation and water fluidity. These molecules can be considered virtually free from H-bonds during the time of jump of water molecule or rearrangement of network. It is evident that this time period will correlate with the time of H-bond lifetime (τ_H). In principle the value δ is determined by the Boltzmann distribution and is equal to the relation N/(N+6n+Σgm) where summation is carried out in relation to all g. The values n, m и N are proportional to the Avogadro's number (N_o). Velocity constants characterize the dynamics of lattice transformation and the lifetime of free molecules and various "flickering" clusters [1, 16, 17].

Kinetics of processes described by the Scheme (9) is limited by the dynamics of H-bond, whose breaking energy ($E_н$) depends on temperature and changes within the range 0 – 23 kJ/mole range [19]. The value E_a of dynamic viscosity η approaches to the limiting value $E_н$ = 23 kJ/mole in the 0-4^o C range and self-diffusion D in the -23-4^o C range (supercooled water, refer to the Table). The calculation of $E_н$ within the framework of the fluctuation concept of hydrogen [20, 21] gives the value – 14,14 kJ/mole at 293K. In the work [16] for the description of kinetics of the process of spin-lattice relaxation of water (T_1) the Scheme similar to (9) was used and TD T_1 were approximated by the sum of two exponents.

At Diagrams lnA ÷ 1/T (A = η, T_1), given in [16] at approximately 25^{o}C a transition from linear dependence at t > 25^o C to the curved one at t < 25^o C is observed. Evaluations of E_a at the sections 0–25^o C and 25 – 100^o C with the use of the function (5) give 20.8; 13.8 kJ/mole for T_1 and 24; 13.2 kJ/mole for для η, correspondingly. Our evaluation of the values E_a for η, D and τ_D considering closeness of point of dependence for T_1, D and τ_D [16,17], are generally in agreement with the known calculated and experimental values E_a for corresponding temperature intervals (Table 1).

The variations $E_н$ are in congruence with a wide range of changes of rate constants of lifetime of structures that are part of **A** and **B**. Kinetics of their transformation and decay will in principle be determined by the τ_H which changes within the range from 0.08 to ~30 ps [1, 2]. It is suggested that H-bonds can emerge and be broken cooperatively for the lifetime of "flickering" clusters whose values change in the 10-100 ps range. Mathematical simulation of the dynamics of liquid water demonstrated that in every molecule donor-acceptor bonds alternate in tetrahedral metrics of hydrogen bonds in a period of an order of 0.1-0.2 ps [22]. The inverse value 10-20 tHz can be considered limiting frequency of flickering of an individual cell in net structure **A** and **B**. The period of thermal orientational oscillations of water molecules with ~20-30^o amplitude is about 50 fsec [1]. They are manifested in water infrared spectrum by structureless band in the 15-85 $см^{-1}$ range and have energy from 0.18 to 1.0 kJ/mole.

For each temperature in a thermally insulated system thermodynamic equilibrium will be established with its own value of concentrations [**A**], [**B**] and the number N. Experience suggests that when water temperature is approaching 100^o C n in [**A**] is nearing 0; m in **B** is nearing 1, g does not exceed 2 (dimers) and the share of N reaches ~20%. Considering this fact and the data on the lifetime of H-bonds we can accept $k_1 >> k_{-1}$; $k_2 >> k_{-2}$; $k_3 >> k_{-3}$ and $k_3 >> k_{-1}$. Under such assumptions the relations $k_1 = k_2$ и $Nk_{-3} = k_3$ [**B**] follow from the condition of thermodynamic equilibrium.

5.2. Frequency dominants of equilibrium thermodynamics

For the explanation of obtained results the fluctuation theory of H-bonds can be used [19-21]. In this theory the algorithm of calculation of influence of H-bonds on water vibration spectrum and its thermodynamics has been developed. The algorithm is based on the Boltzmann distribution of H-bonds in terms of energy which is proportional to $\exp[-E_н/(RT)]$, as well as on formalism of consideration of influence of fluctuating configuration of H-bonds on dynamics of water molecules.

Due to high sensibility of H-bond and its configurations to the effect of external factors (temperature, pressure, radiation, dissolved substances) it can be considered the functional that is in general responsible for the whole variety of water physicochemical properties. Considering a wide range of energy fluctuations and lifetime of H-bond, we can suggest that in thermodynamic equilibrium their frequency distribution is modulated by the frequency of thermal photons ($\nu_{мах}$), related to temperature by the Wien displacement law:

$$\nu_{мах} \approx 5{,}9\ 10^{10}\ T\ (s^{-1}). \qquad (10)$$

Due to the effect of frequency modulation in distribution of energy fluctuations of H-bond the configuration whose kinetics resonates with the frequency of electromagnetic quanta $\nu_{мах}$ will dominate. Evidently, the spectrum of frequency distribution of H-bonds has inherent extremes ($\nu_н$), corresponding to thermodynamic equilibrium state of water molecules and their clusters. At multiplicity $\nu_н$ and $\nu_{мах}$ resonant activation and synchronization of fluctuations in cooperative sets of H-bond can cause the emergence of extremes of any water characteristic.

According to (10), extreme points (4, 25, 35, 45, 75^o C) will be responsible for 5 frequencies of electromagnetic oscillations with $\nu_{мах}$ from ~12 to 15 tHz and the period from ~70 to 80 fsec. As it has been mentioned above, τ_H in various fluctuating (flickering) water configurations changes from 80 fsec to 30 psec. In the work [23] they determined the formula for frequency of electromagnetic coherent oscillations of protons forming a spiral cluster in B: $\nu = 22n^{-1}(n-1)^{1/2}$ (tHz) where n is a number of protons. For example, for n = 20 oscillation frequency was 4.8 tHz and energy ~2 kJ/mole. This evaluation demonstrates that resonance effect in principle can provide extreme character of TD of water properties within the kinetic Scheme (9) and the fluctuation theory of H-bond.

Division of linear approximations into two types (4) and (5) testifies to the absence of a barrier diffusion component at TD of the characteristics ρ, V_m, C_p, γ and v. The absence of energy barrier in changing the specified water properties can be associated with isoenergetic transitions in the Scheme (9). In addition to transition **A** → **B** they will include restructuring of clusters forming **B** with changing values m and g, as well as reversible intracellular dissociation of dimer $(H_2O)_2$ [17].

Isoenergetic restructuring of H-bonds configurations will correlate with isoenergetic fluctuations of electromagnetic field accompanying transitions between quantum states of molecules in the ensembles **A** и **B**. Evidently, energy of electromagnetic fluctuations is determined by the Planck formula for equilibrium thermal radiation on which the formula (10) is based. Isoenergetic fluctuations and transitions between states of quantum system are formalized within the framework of the theory of fractal-resonant transitions [24].

5.3. Molecular mechanisms of extreme thermodynamics

We can obtain information on the mechanisms of intracellular molecular dynamics though analyzing reduced gradients of TD (a_t) of water characteristics approximated by the function (3):

$$a_t = \frac{1}{A_0}\frac{\Delta A}{\Delta t}100\ .$$

Absence of activation energy in the process of water restructuring, determining TD of ρ (V_m), C_p, v and γ in the 0-100^o C range allows to suggest that this restructuring is limited by oscillating rotational movement of molecules within elements (cells) of network structures **A** and **B**. It is conceivable that maximum statistical distribution of energy of H-bonds forming a cell skeleton is determined by frequency (10). In this process each frequency and TD will account for its own dominant factor in molecules dynamics. Mathematical simulation of water thermodynamics with the use of the concept of fluctuation H-bond has made it possible to reveal the types of movement responsible for extremity of some TD.

For example, calculation of dependence of distribution of frequency of O-H oscillations on energy and the number of H-bonds demonstrated [19], that in the 4-5^o C range asymmetry of O-H oscillations of one molecule grows and randomized network of H-bonds becomes ordered. The average value of energy of H-bond is considerably lower than that of O-H oscillations (~3500 cm^{-1}, ~42 kJ/mole). This evidently explains smallness of temperature gradient a_t of points of dependence of water density. Consideration of influence of fluctuating H-bonds on equilibrium distribution of length of O-H bonds allowed to theoretically substantiate the influence of asymmetry of water molecules on cell dynamics and to establish that maximum difference in length of bonds is obtained at 32^o C. As this temperature is close to t_o of isobar heat capacity, this result confirms an essential role of dynamic asymmetry of a water molecule in bioenergetics [5, 24].

One can reasonably suggest that the factor of asymmetry is to a certain degree responsible also for breaks of TD of other water characteristics approximately at 25^o C. Asymmetry of water molecules in combination with tetrahedral metrics of its network configurations facilitates the formation of spiral clusters [23]. In [24] they suggested that water has dynamic chirality and its extreme point is t = 25^o C. At that temperature a break at TD of optical activity of glucose solution is observed [25]. Extreme point 25^{o}C is revealed also on the curves of points of dependence of functions of radial distribution of water molecules, obtained through X-ray analysis [18, 26]. It should also be mentioned that at ~33^o C temperature the character of dependence of water viscosity on external pressure is changed [27].

It is evident that lifetime and density of water chiral clusters would grow as temperature lowers to 3-4^o C. Therefore, their participation in bioenergetics of water systems containing optically active substances, will increase. Apparently, this explains the fact that stratification of seeds reaches maximum effect at temperatures close to 4^o C [5].

The presence of correlation between the frequencies of O-H oscillations and the length of the hydrogen bridge O-H…O has made it possible to establish that at temperatures exceeding 45^o C structures with 0.315 nm distance between oxygen atoms emerge. Their emergence was explained by a growing share of very weak H-bonds. In infrared spectrum when temperature is raised up to 50^{o}C a band of translational oscillations at ~300 cm^{-1} (~3,6 kJ/mole) disappears [26]. Therefore, the dynamics of hydrogen bridge and the molecule itself within a cell, demonstrating sensibility of the effect of fluctuating H-bonds, can be responsible for extreme character of points of dependence of water hardness.

Table 2. Reduced temperature gradients of water characteristics

A	t_0, ^{o}C	a_t (% ^{o}C^{-1})	
		$0 \rightarrow t_0$	$t_0 \rightarrow 100$
ρ	4 (max)	0.003	-0.045
σ	25*	-0.2	-0.31
C_p	35 (min)	-0.63	0.31
γ	45 (min)	-0.33	0.18
v	75 (max)	0.13	-0.032

* Transition point of approximation (3) into (4).

The fact that the value a_t of points of dependence C_p is twice as high as a_t of TD of γ (Table 2) demonstrates participation of large number of parameters of molecular dynamics in the process of absorption of quanta of thermal energy by water through mediation of fluctuating H-bonds. Closeness of positive values a_t of TD of v and γ and negative values for TD of v and ρ (Table 2) considering the formula $v = \gamma^{1/2} \rho^{-1/2}$, allows to extrapolate molecular mechanisms of extreme points of dependence of water density and hardness to the corresponding intervals of TD of sound speed.

Approximations of the type (4) are applicable to TD based on kinetic stages of the Scheme (9) leading to the formation of water molecules virtually free from H-bonds. Consequently, the lifetime of such molecules and their stationary density (N) are also determined by dynamics of fluctuating H-bonds. The possibility of absorption of heat energy sufficient for breaking of H-bonds and molecule withdrawal from a cell, on water molecules or clusters, depends on the number and energy of fluctuating N-bonds. In this process the molecule is destroyed which was described by J. Bernal: “liquid fluidity is a consequence of molecular irregularity and not vice versa" [28].

It is evident that in the case of TD of dynamic viscosity the mechanism of diffusion mobility of molecules will be supplemented by the effect of external pressure in the form of a dominant vector of translational movement of free molecules. It can be suggested that intracellular mechanisms of control of molecular dynamics by fluctuating H-bonds will be manifested at the level of disturbance and in the mechanism of water molecular mobility. It is testified by the breaks of linear approximations of TD of η and D at points t_o (refer to Table 1).

6. Conclusions

In this work the method of researching anomalous properties of liquid water based on the analysis of linear approximations of its properties demonstrated its efficiency. With the use of this method molecular dynamics responsible for extremality of temperature dependences of water properties was subdivided into two types: barrier and barrier-free. Therefore, the values of extreme points, the parameters of linear approximations and temperature gradients were determined for density, molecular volume, surface tension and sound speed. For dynamic viscosity, self-diffusion, specific electric conductivity and the share of free molecules, activation energy was determined and breaks of logarithmic anamorphoses of temperature dependencies at critical points were revealed. The thermodynamic model of water where changes of molecular dynamics and structure were limited by hydrogen bonds, allowed to explain the molecular mechanisms of extremity of temperature dependences. The present interpretation relied on the concept of fluctuating hydrogen bonds.

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