

## «The Ball Lightning»: Physics Base & Conceptual Views Complex

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### Abstract

The complex of conceptual views about ball lightning (BL) as containing surplus electrical charge quasi-stationary material foundation with distinctions between levels of translation temperature and exciting temperatures of chemical bonds and electron energy states has been offered and is substantiated in the paper. The being formed complex is grounded upon overstepping the limits of generally accepted physical base and is aimed at all-round substantiation of jointly observed in nature manifestations of BL.

Within the limits of the being formed complex the possibility of localization of ball lightning in airspace is confirmed. The nature of the one's radiate capacity is substantiated. The role of environment as source that feeds BL with energy is established. Power supply mechanisms, conditions and peculiarities of BL's characteristics reproduction through lifetime are specified. The formations channels of energy resources of BL are turned out. Levels of BL's energy potentialities, both permissibility proper and wide diapason of variation of the ones (multi-faces of ball lightning) are substantiated. Adequacy of being formulated conceptual views as a whole is confirmed.

### Nomenclatures

$e$  – elementary charge (C);  $g$  – statistical state weight;  $h$  – Planck's constant (J·s);  $k$  – Boltzman's constant (J/K);  $d$  – dipole moment (C·m);  $\Phi$  – thermodynamic potential (J/m<sup>3</sup>);  $\mu$  – chemical potential (J/kmole);  $q$  – electrical charge, (C);  $C$  – electrical capacity (C/V);  $c_p$  – specific heat capacity (J/(kg·K));  $Q$  – energy (J), power (J/s);  $R$  – radius (m), universal gas constant J/(mole·K));  $N$  – molar concentration (mole/m<sup>3</sup>);  $S$  – area (m<sup>2</sup>);  $n$  – species concentration (m<sup>-3</sup>);  $\alpha$  – ionization degree, heat transmission coefficient (W/(m<sup>2</sup>·K));  $\psi$  – relative keeping of surplus electron component;  $P, p$  – pressure (kg/(m·s<sup>2</sup>));  $T$  – temperature (K);  $\rho$  – density (kg/m<sup>3</sup>);  $\chi$  – relative keeping of dipole component;  $\epsilon_0$  – electrical constant (C/(V·m));  $C_0$  – radiate ability coefficient of absolute black surface (W/(m<sup>2</sup>·K<sup>4</sup>));  $\epsilon_g$  – relative blackness degree;  $\Omega$  – electrical potential (V);  $V$  – volume (m<sup>3</sup>); ionization potential (V);  $W$  – velocity (m/s).

### Symbols

0 – undisturbed parameter;  $a$  – neutral;  $e$  – el-

ectron;  $i$  – ion;  $c$  – capacitor;  $conv$  – convection;  $mt$  – mass transfer;  $sf$  – safe;  $st$  – safe tension;  $rad$  – radiation;  $hi$  – heat input;  $bl$  – ball lightning;  $env$  – environment;  $exc$  – excited parameter, “-“ – true to equilibrium

### Introduction

The numerous works (Barry J., Dmitriev M.T., Elliott lo., Singer S., Silberg P., Smirnov B.M., Stakhanov I.P., ...) directed onto both the generalization of ball lightning observations and making-up of a common ideas of the ones are known. However up to now the generally accepted conception of both nature and jointly fixed characteristics of BL on the base of universally recognized physical views is not turned out yet. What's more the true sensation of pessimism in estimations of principal possibilities to interpret the BL nature on this basis is felt.

It's undoubtedly, that the being settled situation shows first of all to exceptional complexity of BL as the investigation object. At the same time, it unquestionably notes too towards the principal insufficiency of resolving power of used investigation methods being formed in these cases in the framework of traditional physical restrictions (i.e. towards imperfection of the physical basis as itself).

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The attempts to work out the complex substantiation of both the nature and manifestation of BL on the basis of overstepping the limits of traditional physical restrictions, earlier unknown Internal Energy Equilibrium Conditions (IEEC – between energy states with different nature) of material media are known too [1-13].

Admittedly, the developed views of BL so far do not obtain of due expansion and of necessary public recognition (in that number owing to the being kept till now doubts about substantiations of proper IEEC) and demand so additional explanation and progress.

Having been formed situation and determined in essence expediency and purposefulness of this work. The paper is based upon materials of [1-13] and, at the same time, is aimed onto generalization and further logical progress of the ones.

## Strategy Forming

### *Initial views*

On being formed of initial views of BL we will take into account only common, beyond all doubt observed of ball lightning's characteristics.

It must be admitted so that BLs exist and are spring up under conditions of developed electro-static fields. They are moved somewhere else and are observed as localized in the airspace material formations having form similar to sphere. The prevailing transferences directions of ball lightning in airspace are not determined by the both gravitation and/ or forces of aerodynamic origin<sup>1</sup>. BL's lifetime may achieve at least to several tens seconds.

The BL occurrence, as a rule, is accompanied by energy radiation into environment (thermodynamically opened system) that is watched in the range of visible spectrum part in that number. As this takes place, characteristics of BL's radiation are changed insignificantly or even are kept practically an invariable. What is more, disintegration of ball lightning often is accompanied with extra energy escape into environment. The multi-faces, revealed by considerable incompatibility of specific energy resources under seemingly equal or at least comparable cir-

umstances, else is peculiar to BL (see, for example, [15, 16]).

The enumerated common properties with a great degree of trustworthiness are suited to the real manifestations of balls lightning. However, up till now the possibilities to realize the medium states with noted characteristics intake, in the context of generally accounted physics-chemistry views, are retained beyond verge of explainable ones.

### *Basic assumption*

In evaluating of prospects for refinements of BL's nature in the framework of [1-13] the attention was being given first of all to the established by observations fact that the BL-medium contains surplus (uncompensated) electric charge.

As an assumption, in connection with this, it was presupposed that *“the observed characteristics of BL could be substantiated, say, by the existence of traditionally not accounted (earlier unknown) peculiarities of internal energy equilibrium conditions (IEEC - between energy states with physical nature's different kinds) for material foundations with surplus electric charge (AQN- or aquasi-neutral foundations) as determining, in that case by the results of inevitably being exited relaxation of AQN-foundations on interacting with environment, the formation and subsequent conservation in time (reproduction) of medium in the AQN-formation's composition with differing from the environment's and inherent of BL's characteristics”*.

The possibilities to build on this base the physics-chemic BL's model will be estimate drawing away our attention from both the composition and the nature of BL's formation mechanisms as the subjects of specific interest as itself.

## The internal energy equilibrium conditions

### *Ionization equilibrium conditions*

Let's estimate for the first time the possibly arising, in connection with presence in medium's composition of surplus charge to fit the being expressed assumption, the peculiarities of the medium's inner ionization equilibrium.

### *Small disturbances method*

As applied to  $p, T = Const$  let us separate out now some volume of medium containing neutral (a),

<sup>1</sup> The marked indicates so that BL is subjected to force influences of electric nature, i.e. keeps an uncompensated (surplus) electric charge. The last is confirmed else by known theoretical investigations [14].

electron (e) and ion (i) components. Let us account that the separated so volume is bounded, for instance, by sphere of radius  $R_{bl}$  and is thermodynamically opened system itself with variable particles number and description of the one conforms to three – liquid model ideas [17].

We'll be take, as state parameters, the ionization degree

$$\alpha^* = \frac{p_i^*}{p_a(0)} = \frac{n_i^* kT}{n_a(0) kT} = \frac{n_i^*}{n_a(0)} \quad (1)$$

and relative content of uncompensated electron component

$$\psi = \frac{pe^* - pi^*}{pi^*} = \frac{(ne^* - ni^*)kT}{ni^* kT} = \frac{ne^* - ni^*}{ni^*}. \quad (2)$$

Give up advantage to thermodynamic method as not leaning upon any ideas of substance atomic-molecular structure and being essentially phenomenological. Assume that by external in relation to sphere actions an excess electric charge is inputted and at a later time is retained in the composition of separated so medium volume.

Accordingly generally adopted ideas inner equilibrium of separated system should be in conformity with the minimum of its thermodynamic isobaric-isothermal potential “ $\Phi$ ” and, for  $p, T = Const$ , will be determined in that case by equation

$$\begin{aligned} \delta\Phi &= \sum_1^J \left( \frac{\partial\Phi}{\partial N_j} \right)_{p,T} \left( \frac{\partial N_j}{\partial\psi} \right)_{\alpha^*} \delta\psi + \sum_1^J \left( \frac{\partial\Phi}{\partial N_j} \right)_{p,T} \left( \frac{\partial N_j}{\partial\alpha^*} \right)_{\psi} \delta\alpha^* = \\ &= \sum_1^J \mu_j \left( \frac{\partial N_j}{\partial\psi} \right)_{\alpha^*} \delta\psi + \sum_1^J \mu_j \left( \frac{\partial N_j}{\partial\alpha^*} \right)_{\psi} \delta\alpha^* = 0. \end{aligned} \quad (3)$$

Here:  $\mu_j$  chemical potential of j's media component ( $j = a, e, i$ ).

Draw attention to the fact that under conditions when the charge within the sphere is constant parameter ( $\Delta n_q = n_e^* - n_i^* = Const$ )

$$\psi = \frac{n_e^* - n_i^*}{n_i^*} = \frac{\Delta n_q}{\alpha n_a(0)} = f(\alpha^*) \quad (4)$$

and first term of right part in equation (3) is identically equal to zero. Equation (3) is transformed so to expression

<sup>2</sup> Here and below with «\*» the parameters of media that contains surplus charge are noted.

$$\sum_1^J \mu_j \left( \frac{\partial N_j}{\partial\alpha^*} \right)_{\psi} \delta\alpha^* = \sum_1^J \mu_j \delta N_j = 0 \quad (5)$$

and may be used for detecting of correlations between states parameters of media plasma foundations corresponding to inner energy equilibrium.

For the material system of examined composition the equation (5) is rewrite in kind of

$$\mu_i \delta N_i + \mu_e \delta N_e + \mu_a \delta N_a = 0 \quad (6)$$

and, with account of correlations between moles numbers variations  $\delta N_i \approx \delta n_i = n_a(0) \delta\alpha$ ;  $\delta N_e \approx \delta n_e = (1+\psi) n_a(0) \delta\alpha$ ;  $\delta N_a \approx \delta n_a = -n_a(0) \delta\alpha$  in accordance with (1), (2), is reduced to relationship

$$\mu_i + \mu_e (1+\psi) - \mu_a = 0 \quad (7)$$

For single-atom gas

$$\begin{aligned} \mu_j &= RT \left[ \ln p_j - \ln \frac{g_j (2\pi m_j)^{3/2} (kT)^{5/2}}{h^3} \right] + \varepsilon_j^0 + eZ_j N_A \Omega, \\ Z_j &= \begin{cases} 1, & \text{если } j=i, \\ 0, & \text{если } j=a, \\ -1, & \text{если } j=e. \end{cases} \end{aligned} \quad (8)$$

Expression (7) is converted into

$$\begin{aligned} \prod_j p_j^{c_j} &= \prod_j \left[ g_j \frac{(2\pi m_j)^{3/2} (kT)^{5/2}}{h^3} \right]^{c_j} \exp \left( -e \frac{V - \psi \Omega}{kT} \right), \\ c_j &= \begin{cases} 1, & \text{если } j=i, \\ (1+\psi), & \text{если } j=e, \\ -1, & \text{если } j=a. \end{cases} \end{aligned} \quad (9)$$

and, on the neglect of 2-order infinitesimal members, corresponds to any from equations:

$$\frac{p_i^* p_e^{*(1+\psi)}}{p_a} = \frac{g_i}{g_a} \left[ g_e \frac{(2\pi m_e)^{3/2} (kT)^{5/2}}{h^3} \right]^{(1+\psi)} \exp \left( -e \frac{V - \psi \Omega}{kT} \right), \quad (10)$$

$$\frac{n_i^* n_e^{*(1+\psi)}}{n_a} = \frac{g_i}{g_a} \left[ g_e \frac{(2\pi m_e kT)^{3/2}}{h^3} \right]^{(1+\psi)} \exp \left( -e \frac{V - \psi \Omega}{kT} \right) \quad (11)$$

or

$$\begin{aligned} \frac{\alpha^{*(2+\psi)} (1+\psi)^{(1+\psi)}}{(1-\alpha^*) [1+\alpha^*(1+\psi)]^{(1+\psi)}} &= \\ &= \frac{1}{P_\Sigma^{(1+\psi)}} \frac{g_i}{g_a} \left[ g_e \frac{(2\pi m_e)^{3/2} (kT)^{5/2}}{h^3} \right]^{(1+\psi)} \exp \left( -e \frac{V - \psi \Omega}{kT} \right) \end{aligned} \quad (12)$$

Here:  $V$  – media ionization potential determined in the ordinary way;  $\Omega$  – remote coulomb interaction potential (potentials difference stipulating electrical action onto charge). More detailed interpretation of its physical sense will be given lower.

### ***Ionization equilibrium as reaction onto disturbance***

Assume as previously that some quantity of the same charged particles are brought in (taken out from) the considered volume owing to the system is moved up (and at a later time exists) into the state with uncompensated electric charge. It is obvious that charge introduction into a system is equivalent to a work performance under the one and causes so violation of inner energy equilibrium of the system. With account of Le Chatelier Principle the last should being reestablished by inevitably arising in these conditions system reaction, suppose in the  $A \leftrightarrow A^+ + e$  kind.

If a work has been done under the system by external actions is  $\delta L_1 = \mu_e \delta N_{e_1}$  and a change of the system's thermodynamic potential was stipulated on the system with external actions is  $\delta \Phi = \mu_i \delta N_i + \mu_e \delta N_e + \mu_a \delta N_a$  then being anew settled equilibrium must corresponds to to condition

$$\mu_i \delta N_i + \mu_e \delta N_e + \mu_a \delta N_a = -\mu_e \delta N_{e_1}. \quad (13)$$

It is obvious that  $\delta N_i = \delta N_e = -\delta N_a$  and (13) is presented in the kind

$$\mu_i + \mu_e - \mu_a = -\mu_e \frac{\delta N_{e_1}}{\delta N_i}. \quad (14)$$

The ratio  $\delta N_{e_1} / \delta N_i = \delta N_{e_1} / \delta N_e$  determines the molar part of excess charge carriers per ion component mole and corresponds in being again settled gas medium composition to system's state parameter according (2). The equation (14) is truly kept to the relations (9)-(12), which proves the statement.

### ***Common character of inner equilibrium***

In deducing on (9)-(12) we assumed that inner equilibrium disturbance by carrying in system's composition of surplus charge is necessarily suppressed with reaction of  $A \leftrightarrow A^+ + e$  kind. However the noted is not having one.

Indeed, "from all possible steady states of thermodynamic system being allowed with border conditions of the law of mass transfer and conservation

along with 2<sup>nd</sup> law of thermodynamic the state with minimum production of entropy is realized" [18], to say, that which is priority one.

Let us assume that priority reaction formed in the subsystem as response onto disturbance in connection with carrying in medium composition of surplus charge is reaction of  $A+B \leftrightarrow AB$  shape. If the work was done in the case under system by external actions is  $\delta L_1 = \mu_e \delta N_{e_1}$  that being anew-formed equilibrium will correspond to the condition

$$\mu_{AB} \delta N_{AB} + \mu_A \delta N_A + \mu_B \delta N_B = -\mu_e \delta N_{e_1}. \quad (15)$$

Take into account that the relation molar contribution into a relaxation reaction of electron component  $\psi = \delta N_{e_1} / \delta N_{AB}$  (that in full measure correlates with physical interpretation of parameter according to expression (2)) and  $\delta N_{AB} = -\delta N_A = -\delta N_B$ . By this means in neglecting of 2-order infinitesimal quantities the expression (15) may be written in the form

$$\prod_j p_j^{c_j} = \prod_j K(T)_j^{c_j} \exp\left(-\frac{\varepsilon_{act} - e\psi\Omega}{kT}\right), \quad (16)$$

$$c_j = \begin{cases} 1, & \text{ecm } j = AB, \\ \psi, & \text{ecm } j = e, \\ -1, & \text{ecm } j = A, B. \end{cases}$$

Here:  $\varepsilon_{act}$  – association reaction's activation energy (or any other one's that in frame of specifically arising conditions in the system is priority one) being determined in essence by generally accepted method.

The expressions (9)-(12), (16) correspond to the mass action law and determine so inner energy equilibrium conditions of material media in that number in the composition of localized in the space AQN foundations.

Restricting by the problems of work's direction aim let us estimate first of all the presence of traditionally not accounted (earlier unknown) features of material system's inner energy equilibrium conditions according to (9)-(12), (16) and common conformity of the ones to the initial scientific supposition.

### ***Equilibrium inner peculiarities***

Traditionally not account (earlier unknown) peculiarities of inner energy equilibrium of material media in the state with uncompensated (surplus) electric charge are really displayed by expressions (9)-(12), (16). From analogues of generally accept-

ed form the lasts are distinguished essentially with only presence in exponent indexes of additional term  $e\psi\Omega$ . The proper sign and level of  $e\psi\Omega$  in relation to activation energy traditionally accounted by the index determine character along with meaningfulness of waited so differences between equilibrium populations distributions of chemical bonds and electron energy states fixed, all other things being the same, from expressions (9)-(12), (16) at one times and from equilibrium conditions of generally accepted form at another.

Concrete character of the equations indicates that, as applied to localized AQN-foundations temperature  $T$  as traditionally estimated parameter directly determines equilibrium populations of energy states only with "mechanical" nature (translation, oscillating, rotatory ones).

If in the framework of traditional description and with account of (9)-(12), (18)  $T_{exc}^*$  - the excitation temperatures of chemical bonds and electron energy states of medium with uncompensated electric charge to be entered into examination then their correlations with  $T$  - the excitation temperature of mechanical energy states (after referred to as translation one) to be determined by equation

$$T_{exc}^* = T \frac{\varepsilon_j}{\varepsilon_j - e\psi\Omega} \quad (17)$$

and corresponding to IEEC the distribution function of chemical bonds and electron energy states – by relation

$$N_{\varepsilon_j}^* \approx \exp\left(-\frac{\varepsilon_j - e\psi\Omega}{kT}\right) \quad (18)$$

which jointly point to reality of correlations  $T_{exc}^* \gg T$  or even  $T_{exc}^* < 0$  on  $e\psi\Omega > 0$  or, opposite  $T_{exc}^* < T$ , on  $e\psi\Omega < 0$ .

IEEC in the form of (9-12), (16) really point so to existence of traditionally not accounted (unknown) control channel over material media states (chargeous one), in what electrical charge plays a role of control factor.

By IEEC, the population distribution function of chemical bonds and electron energy states in medium of AQN-foundations (directly since formation moment of the ones) is necessarily transformed (or at least is put to the deformation) to the form (18), ensuring origin and, as one incline to think, even possible following existence of material foundations with distinctions between levels of translation te-

mperature and excitation temperatures of chemical bonds and electron energy states.

Common peculiarities of IEEC already at this stage testify to real perspectives to form on the ones' base of conceptual views model of BL.

The attempt to form so supposed model of BL let us forestall however with additional experimental confirmation of just IEEC themselves as base for the working out.

## IEEC as object for experimental investigation

### Common position

It was accounted, that both character and meaningfulness of waited changes of state parameters of medium in composition of AQN-formations being formed by one way or the other will be determined first with level and sign of complex  $e\psi\Omega$  that, obviously, are variable.

Really, if conservation of AQN-formation during time is substantiated with energy of the one's own medium, potential  $\Omega$  may be determined by the largest negative work being done by the medium for keeping of surplus charge in AQN-formation composition. If work done by the medium in this case is  $-L=q\Omega$ , then  $Sign(\Omega)=-Sign(q)=Sign(\psi)$  and  $Sign(\psi\Omega)>0$ . On (17), influence of surplus charge onto medium will be displayed first with exceeding of excitation temperatures of the one's chemical bonds and electron energy states over translation one.

Opposite, when conservation of AQN-formation during time is substantiated with one or other external in relation to the one forces, potential  $\Omega$  may be determined by the least positive work being done by these forces under medium for keeping of surplus charge in one's own composition. So if the work being done by the forces under medium now is  $L=q\Omega$ , then  $Sign(\Omega)=Sign(q)=-Sign(\psi)$  and  $Sign(\psi\Omega)<0$ . As this take place, the waited character of influences of surplus charge to medium becomes more complicated.

Indeed, at this case the populations of chemical bonds and electron energy states of medium of AQN-formation directly since origin moment of the one in relation to translation temperature of the medium become overexcited ones.

It should be waited so that, regardless of the composition, inevitably excited relaxation to IEEC at this case may be jointly accompanied by violations of chemical bonds of medium as well as flow out of electrons from upper electron states (steadiness

losses of electrons on orbits, ones' downfalls and even absorptions by nuclei with origin of neutrons - analogue of phenomena  $K$  - or  $e$  - capture), that is by very complicated manifestations jointly not precluding in that number from reactions excitation that produce energy of intra nucleus origin.

It is substantiation of the last (and, hence, of IEEC in a whole) that was estimated farther with account of experimental researches results of [9-13] in that number.

### Investigation method and installation

It was drawn attention to the fact, that according to

$$q_{sur} = \int_0^t dq = e \cdot f_a \int_0^t [\Phi_i^{a \rightarrow m} + \Phi_e^{m \rightarrow a}] dt - e \cdot f_c \int_0^t [\Phi_e^{c \rightarrow m} + \Phi_i^{m \rightarrow c}] dt \neq 0 \quad (19)$$

surplus charge in volume of some reactor could have been done, for example, by impulse of capacitor discharge owing to differences between quantity of electricity being brought in reactor during time "t" (through part of chain "positively charge cover of capacitor – electrode-anode in reactor") and, opposite, being brought out from reactor during the same time (through part of chain "electrode-cathode in reactor – negatively charged cover of capacitor).

In (19):  $\Phi_j = f(t)$ , ( $j=e,i$ ) – specific flow of carriers of charge (electrons, ions) on boundaries of media division parts of electrical chain  $a \leftrightarrow m$ ,  $c \leftrightarrow m$  (anode  $\leftrightarrow$  medium, cathode  $\leftrightarrow$  medium respectively).

As reactor a vessel done from quartz glass was used (see Fig.1). The reactor was equipped with electrodes: basic ones (anode and cathode) – for formation of controlling influences to medium – and, sometimes, with additional one – for information leading out from reactor. On examinations the reactor was placed in capsule from non-rusting stale (Fig. 2) with hollow walls of the one the reactor compartment was picked out.



Fig.1. Some reactor variants

For providing of controlling influences to medium with energy 2.0-2.5 mF capacitor was used. The potential differences on the capacitor covers in diapason of 0,8-2,5 kV was varied. Measuring of neutron flow on examinations was foreseen. As measure of flow power on examinations a number of events fixed per discharge impulse was accounted.



Fig. 2. Some sets of installation

### Common results

Figure 3 illustrates typical experimental oscillograms of tension and current between basic reactor electrodes on examinations. Current – below curve, 227 A/div, tension – upper curve, 500 V/div.

As material of electrodes Mo, W and/ or Kovar (Fe, Ni, Co)<sup>3</sup> were used.

As applied to concrete conditions of receiving of curves Fig. 3, both the electrical field laying onto

<sup>3</sup> Change of material at that case was determined in essence only with technological limitations, connecting with covering of side surfaces of electrodes by glass.

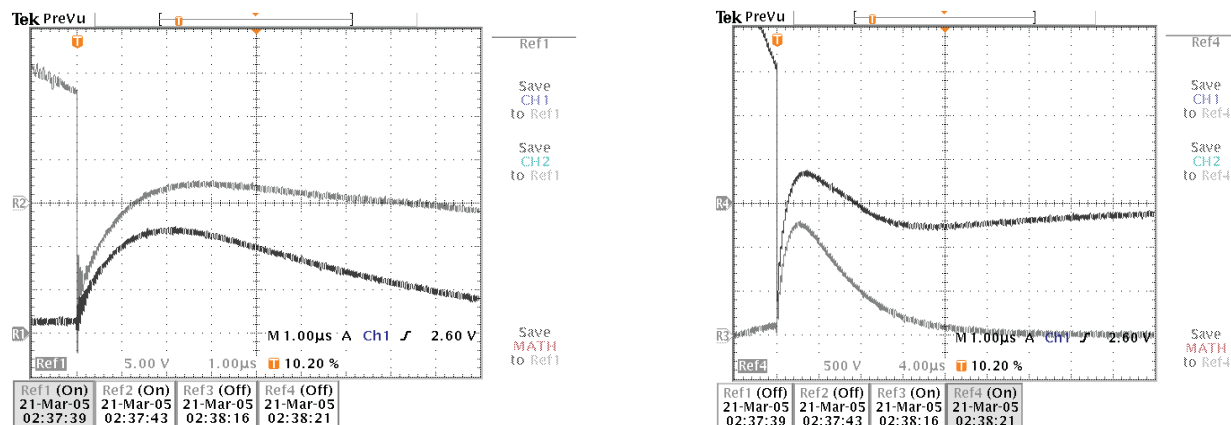


Fig. 3. Typical discharge on pressure: 0.5 - 1.5 Torr ( $H_2$ , He), 1.0-2.0 Torr ( $N_2$ , air,  $N_2 + H_2$ , molar ratio  $\sim 1/1$ ). Scanning: 1 ms/div - «a»; 4 ms/div - «b»

discharge interval of the reactor and switching on of oscillograph were carried at the same time with help of special electron key being brought in feeding chain of discharge zone of reactor. As it took place, the initial level of tensions between capacitor covers regardless of medium composition was kept the same one (was not varied).

Under conditions being typical ones for Fig. 3, from 100 to 200 events per discharge impulse were fixed at distance 0,5 meter from reactor (in general neutron radiation was able to be fixed up to 10 meter from reactor). The trustworthiness of conclusion that being registered radiation is really neutron one has been confirmed with additional investigations [9, 11-13]. Any dependence of results from electrodes material was not revealed.

The received so experimental results is typical to all investigations totality and, as it was assumed, in the frame of used media nomenclature do not display any once' dependence from medium composition. In other words, common rightfulness of IIEC themselves as well as of attempts to form, on the ones' base, model physics views about BL received so experimental confirmation too. Let us further in consecutive order consider key problems of BL.

## BL Model Views Forming

### Sphericity

The sphericity substantiation of BL (as a foundation with higher, in respect to the environment, temperature) is traditionally considered as extremely complicated one for solution (if not being defied explanation by ordinary means at all [19]).

In the framework of the developed point of view (i.e. when it is possible to assume that  $T_{bl}$  - translation temperature of BL and  $T_{env}$  - a temperature of environment are close to each other) the existence possibilities verification of material AQN-formations (after referred to as BL-formations or BLs) localized in the space is taking however some new tinge.

With the availability in medium of dipole molecules with moment  $d$  and at a concentration  $n_d = \chi n_\Sigma = \chi P_\Sigma / (kT_{bl})$  ( $\chi$  - the relative dipoles concentration) the surface tension forces energy will be determined by value

$$Q_{st} = U(r)rS_{sf}n_d = 4\pi R_{bl}^2 \frac{d^2}{\varepsilon_0} (\chi n_\Sigma)^{5/3} \quad (20)$$

If needed expenditures to retain the electric charge in BL composition to be estimated by means of energy accumulated by the BL sphere being under consideration as condenser ( $T_{bl} \approx T_{env}$ )

$$Q_c = \frac{q^2}{C} = \frac{q^2}{8\pi\varepsilon_0 R_{bl}} \quad (21)$$

then the greatest surplus charge being kept in the sphere of BL may be determined with level

$$q = 4\sqrt{2}Z_j\pi dR_{bl}^{3/2} (\chi n_\Sigma)^{5/6},$$

$$Z_j = \begin{cases} 1, & \text{if } j = i; \\ -1, & \text{if } j = e. \end{cases} \quad (22)$$

The excess electron concentration in BL medium complying with  $q$

$$\Delta n_q = -\frac{q}{eV_{bl}} = -\frac{3\sqrt{2}Z_j d(\chi n_\Sigma)^{5/6}}{eR_{bl}^{3/2}}. \quad (23)$$

Both physical meaning and level of potential  $\Omega$  would be determined in that case by the greatest negative work has been made by BL-medium itself when carrying in of the surplus charge into BL sphere. So if the work has been done with BL medium is  $L=-q^2/C=q\Omega$  then electrical potential will be determined as

$$\Omega = -q/C = -\frac{\sqrt{2}Z_j dR_{bl}^{1/2}(\chi n_\Sigma)^{5/6}}{2\varepsilon_0}. \quad (24)$$

For a case when the sphere radius of BL-formation  $R_{bl}=0.075m$  the absolute level of charge  $q$  held in BL-medium (a), electric potential  $\Omega$  (b) and energy accumulated by the BL sphere as a capacitor (c) versus relative dipoles keeping are shown at the Fig. 4.

It was suggested that  $d=1D$ ,  $P_\Sigma = 1.0325_{10^5}Pa$ ,  $T_{bl}=300K$ ,  $Z_j=-1$ . The analogous characteristics, but versus BL's sphere radius and for case when relative dipoles keeping  $\chi=0.01$ , are presented at the Fig.5.

Thus the possibilities for energy ensuring of BLs' sphericity even in a case when relative dipoles keeping in a medium corresponds to relatively low are confirmed by presented results.

### Energy Problem

#### Common remark

BL origin in form of material formations with uncompensated electric charge is made possible by only in connection with manifestations of external disturbances with one or another nature onto medium (the ones not considered by us within this work). Similarly, the existence proper of BL itself likewise is realized under BL - environment interactions.

In other words, the ball lightning presents by itself, first of all, thermodynamically opened system the properties of the one are typical for significantly upset medium formations and are necessary supported by especial processes aggregate (complex) of heat and mass transfer as between energy states of different physical nature of BL medium, so between BL as a whole and environment.

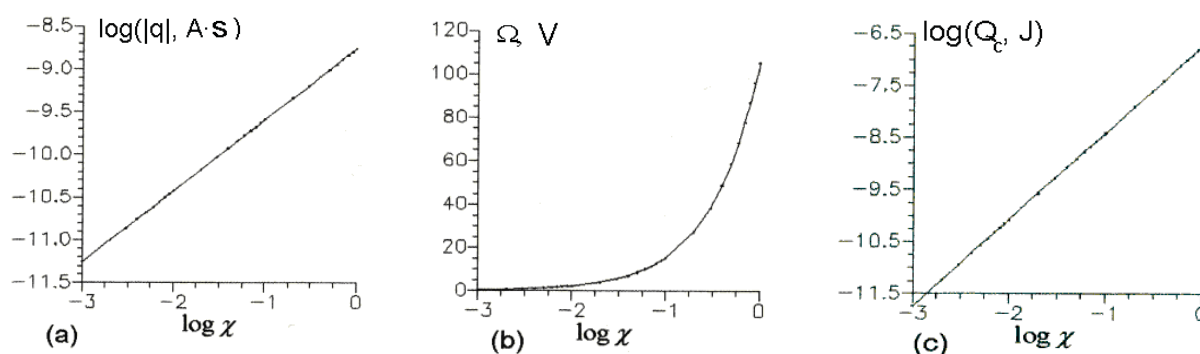


Fig. 4. The holdable charge's characteristics  $\log(|q|)$ ,  $\Omega$ ,  $\log(Q_c) = f(\chi)$

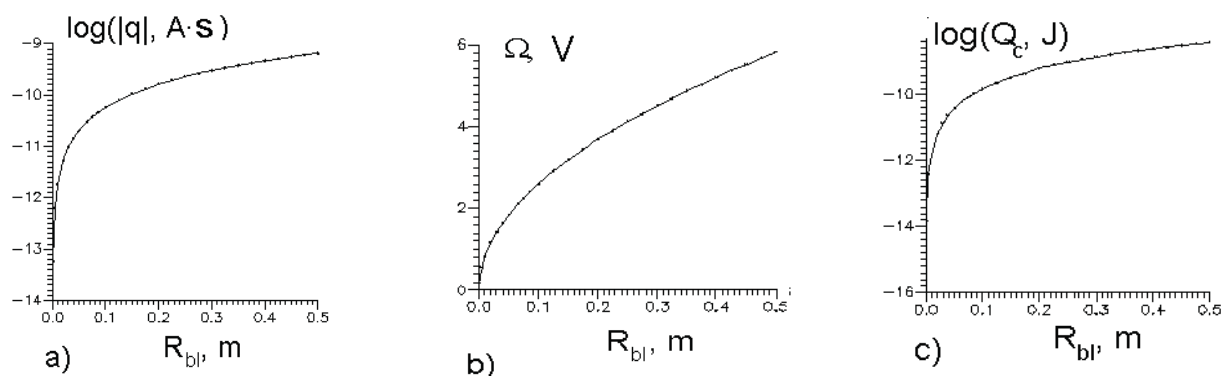


Fig.5. The holdable charge's characteristics  $\log(|q|)$ ,  $\Omega$ ,  $\log(Q_c) = f(R_{bl})$



Accounting significance of the noted let us underlines once again that, in framework of the work, the revealed conditions of inner energy equilibrium are wise to regard, before all, not as the postulate directly indicating the concrete characteristics of AQN formations but, to a greater extent, only as the physical appropriateness complex, justifying the excitation necessity of relaxation in AQN-medium composition towards new conditions of inner energy equilibrium (having been changed owing to carrying in medium composition of surplus charge) during of very that, with account of the concrete peculiarities of both relaxation proper and interactions between AQN-formations and environment, quasi-stationary characteristics of the AQN-formations themselves are being formed.

#### Radiate ability problem

Within the formed ideas of BL as of material formation with uncompensated electric charge the radiation capacity is substantiated first of all by typical for aquasineutral formations of excesses of chemical bonds and electron energy states excitation temperatures ( $T_{exc}^*$ ) over translation one ( $T_{bl}$ ) (in that number and especially on the distant approaches to the equilibrium conditions, see (5.2.1) and (17), (18))<sup>4</sup>.

In support of practical significance of the waited reflections a quantitative estimation of different composition media quasi-equilibrium parameters to fit the conditions are similar to Fig. 7, 8 has been performed.

<sup>4</sup> In so doing will bear in mind that, under generally accepted views, "any negative temperature  $T_{exc}^*$  is hotter relative any positive one".

The estimation was being conducted on the base of system including both ionization parameters bonds equations of plasma medium within of three liquid model [17] and expressions having been received in the work. Specifically the system was included following equilibriums:

$$n_a^{(0)} = P_\Sigma / \left\{ \left[ 1 + \alpha^* (1 + \psi) \right] k T_{bl} \right\}$$

$$n_\Sigma = P_\Sigma / k T_{bl}; \quad n_d = \chi n_\Sigma;$$

$$q = 4\sqrt{2} Z_j \pi d R_{bl}^{3/2} (\chi n_\Sigma)^{5/6}; \quad \Delta n_q = -\frac{3\sqrt{2} Z_j d (n_d)^{5/6}}{e R_{bl}^{3/2}};$$

$$n_i^* = \alpha^* n_a^{(0)}; \quad \psi = \Delta n_q / n_i^*;$$

$$\Omega = -\frac{\sqrt{2} Z_j d R_{bl}^{1/2} (n_d)^{5/6}}{2\epsilon_0}; \quad T_{exc}^* = T \frac{\epsilon_j}{\epsilon_j - e\psi\Omega}$$

$$\frac{\alpha^{*(2+\psi)} (1+\psi)^{(1+\psi)}}{(1-\alpha^*) \left[ 1 + \alpha^* (1+\psi) \right]^{(1+\psi)}} =$$

$$= \frac{1}{P_\Sigma^{(1+\psi)}} \frac{g_i}{g_a} \left[ \frac{g_e (2\pi m_e)^{3/2} (kT)^{5/2}}{h^3} \right]^{(1+\psi)} \times$$

$$\times \exp\left(-e \frac{V - \psi\Omega}{kT}\right);$$

Among unknowns in solution of the system ten following parameters are accounted:  $n_a^{(0)}$ ,  $n_\Sigma$ ,  $\alpha^*$ ,  $\psi$ ,  $n_d$ ,  $\Delta n_q$ ,  $n_i^*$ ,  $q$ ,  $\Omega$ ,  $T_{exc}^*$ . The system so is closed.

It was assumed that  $P_\Sigma = 1.01325 \cdot 10^5 \text{ Pa}$ ,  $T = 300 \text{ K}$ ,  $d = 1D$ . The parameters were being varied.

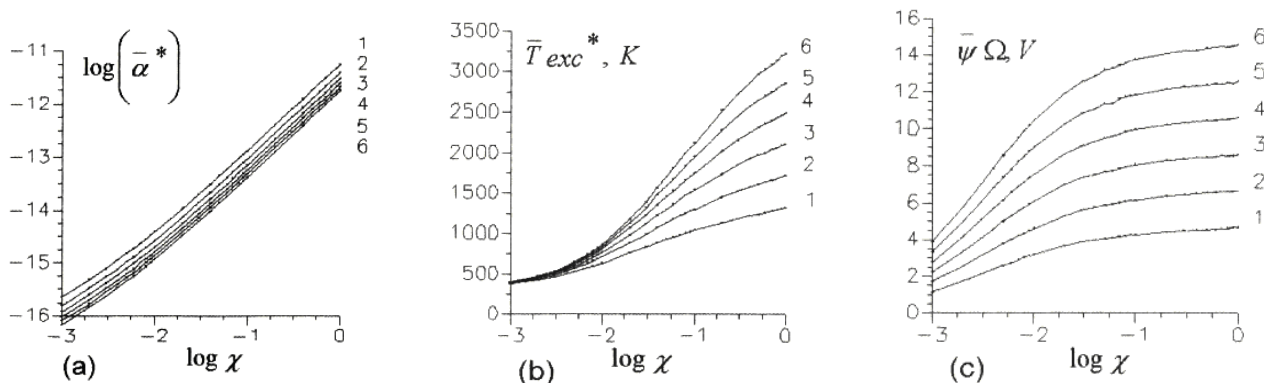


Fig. 6. The quasi-equilibrium characteristics  $\log(\bar{\alpha}^*)$ ,  $\bar{T}_{exc}$ ,  $\bar{\psi}\Omega = f(\log \chi)$

The revealed so ionization degrees  $\alpha^*$  of different composition media (a) in common with the both excite temperatures of electron energy states  $T_{exc}^*$  (b) and levels corrections of ionization potentials being stipulated by presence in media composition of surplus charge  $\psi\Omega$  (c) delivering the ionization degree versus relative dipole keeping in media composition of BL with radius  $R_{bl}=0.075m$  are presented at Fig. 6. The curves 1-6 conform to

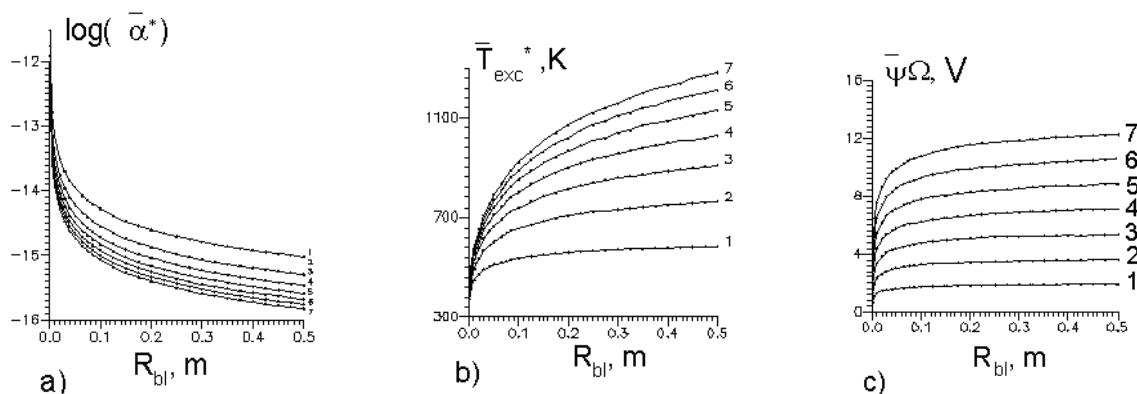


Fig. 7. The quasi-equilibrium characteristics  $\log(\bar{\alpha}^*)$ ,  $\bar{T}_{exc}$ ,  $\bar{\psi}\Omega = f(R_{bl})$

Let us noted that, as applied to no equilibrium aquasi-neutral foundations state, reflecting best of specific character of ones' relaxation under conditions of energy interchange with environment, the absolute values of present-day parameter  $|\psi| > |\bar{\psi}|$  and levels  $T_{exc}^* \gg \bar{T}^*$ .

In other words, the obtained upper results indicate convincingly as a whole that the natural air foundations with uncompensated charge keeping in ones' composition (BL) not only can exist themselves but also are really able to radiate energy in that number at that time, when translation temperature of the foundations is correlated with (or even less than) the environment temperature ( $T_{bl} \leq T_{env}$ ).

Let us bring into consideration an effective radiation temperature  $T_{rad}$  as parameter determining, on a basis of the generally accepted propositions, radiating power of BL into environment

$$Q_{rad} = S_{bl} q_{rad} = 4\pi R_{bl}^2 \varepsilon_g C_0 (T_{rad}/100)^4. \quad (25)$$

To concretize conditions for numerous estimations of  $Q_{rad}$  will be assumed that  $T_{rad}$  accordingly (25) at the same time correlates with excitation temperature of chemical bonds and electron energy states of some characteristic for BL (within of the ideas about common features along with a typical reactions relaxation composition and energy feeding

conventional media composition with  $V=6, 8, 10, 12, 14, 16 W/A$  (curves 1-6 accordingly).

Plots of Fig. 7 present the dependences of the same parameters but versus radius of BL foundation sphere. The plots conform to conventional media composition with  $V=6, 8, 10, 12, 14, 16 W/A$  (curves 1-7 accordingly). Being taken into account the relative dipole keeping in a composition of BL medium is 1% ( $\chi=0.01$ ).

mechanism) energy level  $\varepsilon_j^*$ <sup>5</sup>.

$$T_{rad} = T_{bl} \frac{\varepsilon_j^*}{\varepsilon_j^* - e\psi\Omega}. \quad (26)$$

In other words, the temperature  $T_{rad}$  will be considered as a parameter determining, in traditional mind, the radiating power of BL and, at the same time, as a factor being functionally stipulated by peculiarities of excitation temperature distribution of chemical bonds and electron energy states peculiar to BL media.

It is possible so within of taken into account with (26) bonds the degree of darkness  $\varepsilon_g$  to be estimated by the ionization degree of a media with  $eV = \varepsilon_j^*$  as determining, in that case, the settlement density of energy states with radiation transitions of electrons from one orbit to another in composition of BL media

$$\varepsilon_g = \frac{\Delta n_q}{\psi} \cdot \frac{kT_{bl}}{P_\Sigma}. \quad (27)$$

Here  $\Delta n_q$  - surplus concentration of particles - charge carriers.

<sup>5</sup> Admittedly, the accounted so character of bonds between  $T_{rad}$  and energy states excitation temperatures is substantiated essentially, within this work, by only the necessity to refinement conditions for following numerous estimations of  $Q_{rad}$  and in the future calls for a more precise definition.

### ***The energy feeding source***

The way of attack untwisted in this work opens else real prospects to solve the problem of nature substantiating of the energy source for feeding of BL.

Indeed, as it has been readily apparent from observations, the keeping up (continuous reproduction) of quasi-stationary states in process of BLs existence is realized in that number (unless not always) under conditions when the ones radiate energy into environment.

This seemingly that the radiation of energy into environment must be accompanied by reduction of settlement levels of energy states (relative to stationary settlement level of the ones) with radiation transitions of electrons from one orbit to another and so bring towards lowering of radiating capacity of BL. As applied to stationary state of BL the last however is practically kept constant one. In the framework of the formed method of attack the noted comes to be explicable.

Indeed, it is obviously that the settlements lowering of chemical bonds and electron energy states, in connection with radiation all other things being equal, to be necessary accompanied by (stipulates) an additional excitation (overheating) of “mechanical” energy states of BL medium ( $T_{bl}$ ) in relation to the being reduced so excitation levels of the “no mechanical” energy states ( $T_{exc}^*$ ).

The growth of misbalance in energy distribution over states in connection with radiation is suppressed so by the energy flow from mechanical energy states towards the ones but being no mechanical nature. Let us draw attention to the fact that the flow of energy from mechanical energy states leads to drop of BL's translation temperature ( $T_{bl}$ ) even to the levels below environment temperature ( $T_{env}$ ) and, in turn, stipulates origin of energy flow from environment to BL.

In other words the both existence and nature of source to feed BL with energy is really substantiated. This source feeding with energy of BL is so environment.

By this means in the framework of the formed model a quasi-stationary state of BL is necessary consistent with conditions when  $T_{bl} \leq T_{env}$ . Just that relation's range between the noted temperatures provides of BL with heat absorption from environment as clearly indemnifies for ball lightning's energy escape by radiation and essentially makes possible existing of BL in nature as itself. The common picture of exchange energy-mass processes in these

conditions in full measure corresponds to both Le Chatelier Principle and the common character of material systems reactions onto disturbances.

### ***Energy feeding mechanisms***

There can be no doubt that the feeding of BL with energy from environment on a stationary existence stage is realized by traditional mechanisms of energy-mass-exchange. Both convective heat input and input of energy inside BL in connection with mass-exchange between ball lightning and environment are naturally enough to account in components number of the energy supplying (energy feeding) mechanism.

### ***Energy resource components***

Channels as and sources to form energy-resources of BL along with needed conditions for supplying of the one's quasi-stationary characteristics are also substantiated within the formed ideas model of BL as about localized in the space containing uncompensated electric charge material foundation with differences between translational temperature and excitation temperatures of both chemical bonds and electron energy states.

In account with the revealed appropriateness in equilibriums and common conditions to localize material foundations in the space, the common level of BL's energy resources is advantageous to estimate in that case with discrete blocks. These are radiation flow energy  $Q_{rad}$ , energy saved up by sphere of BL as capacitor  $Q_c$ , energy  $Q_\varepsilon$  accumulated with BL media in account with deformation of settlements distribution function of chemical bonds and electron energy states under relaxation of BL-media towards equilibrium conditions accounting of availability of uncompensated electric charge in one's compositions.

### ***The multi-faces problem***

Making longer discussion in the framework of the being formed BL model let us attention draw to the fact that the energy absorbed by BL from environment at the same time can be used up at least in two directions. Firstly, it is the one for indemnity of energy losses in connection with radiation. For secondly, it is the one for putting down settlements levels diminution of excited chemical bonds and electron energy states (continuous reproduction of

radiation capacity) stipulated by mass-exchange processes between BL and environment.

It can be assumed that distribution character of feeding energy flow between the noted directions determines the total level of ball lightning's energy resources and, in its turn, is determined by common as well as being specifically established, as the existence conditions of BL require, peculiarities of energy feeding mechanism.

If this the case, the relative contribution of each from energy feeding mechanism's components (convective heat exchange or/ and mass transfer) must show essential influence over quasi-stationary characteristics of BL. The dependence of BL foundation's energy resources upon of concrete realized, at each single of occasion, energy feeding mechanism can be considered so as the most probable reason, from assumed ones, of being noted with observations so called multi-faces of ball lightning.

By way of the first step for following consideration let us more concrete formulate ideas upon waited, at each separate case in connection with the noted, common peculiarities of quasi-stationary states of balls lightning. For better visualization of these peculiarities, the needed consideration should be carry out with the supposition of limit contribution into the BL's energy feeding mechanism either of one or another its component from the accounted ones (only of convective heat exchange or, on contrary, only of energy input inside BL from environment in mutual mass-exchange connection with).

Even not accounting of cognitive advisability, allowance of the last is substantiated, among other factors, by possible variations of real environment characteristics and consequently of BL's existence conditions.

### ***Convective heat exchange***

Overpowering contribution of convective heat exchange into energy feeding mechanism of balls lightning with stationary characteristics corresponds to conditions, when BL-environment mass-exchange for the most part has been put down. The quasi-stationary states of BL being existed in the conditions must be characterized first of all by constancy with time of both the radiation characteristics and the settlements of chemical bonds and electron energy states. The energy being supplied to BL from environment must be expended in these conditions only to compensate energy loses of ball lightning with radiation (ideal case).

It should be emphasized that BL-media conforming to quasi-stationarity conditions (and being exceptional so with invariability of energy states and depression of mass-exchange) must be characterized in the case by essential deformation of distribution function of chemical bonds and electron energy states towards internal energy equilibrium with account of surplus electric charge in the media composition.

Let us note that specificity of the being established so distributions points to existence (and possibilities of effective displays) of nontraditional, in the framework of generally accepted physical views, energy resources formation channel of BL. Of the channel being substantiated with obvious capacity of media with surplus electric charge to absorb energy of one or other source to supply the deformation of media's energy states settlements and functioning, in principle, at any stage of ball lightning's vital cycle.

It is safe to assume also that the radiate characteristics of BL in quasi-stationary state under energy feeding by convective heat input (and hence when mass-exchange is depressed) likewise are must be stood out with some typical features.

By significant deformation of energy states settlements, the BL's radiation, in this case, must be mainly realized by transitions in the diapason energy states having been drawn (essentially!) to the internal equilibrium conditions accounting presence of surplus charge in media composition

### ***Mass-exchange energy feeding***

Contrary to the previous case the power supply of BL by mass-exchange mechanisms necessary assumes that the energy flow from environment to feed with energy of quasi-stationary states of ball lightning is being necessary expended at least towards two ways:

- Firstly, to supply radiation;
- To ensure with energy the continuous reproduction of energy states settlements that determine the radiate capacity of BL, secondly.

It is possible to assume also that radiate capacity of BL-medium is substantially (most probably) manifested in the field of distant approaches to equilibrium conditions and is realized, in that case, by radiate transitions between energy states with essentially higher levels of excitation temperatures (the ones at the relaxation stage undergo a rupture of  $(-\infty, +\infty)$  kind). But the BL,s energy resources component conditioned by settlements distribution

function deformation of chemical bonds and electron energy states with relaxation most likely in the case is kept only partly filled up.

### **Preliminary result**

The preliminary examination materials testify that account of revealed [1-13], earlier unknown peculiarities of inner energy equilibrium conditions of media with surplus (uncompensated) electric charge opens truly up new prospects for adequate ideas model substantiation of BL. The last however requires for addition confirmation rather by numerous estimations.

## **Quasi-stationary states of ball lightning**

### **Common positions**

Will be considered that the BL quasi-stationary state is manifested first of all with immutability in time of its radiate characteristics.

Common conceptions about BL in this conditions will be presided in connection with this by equations complex jointly substantiating just as both the existence reality and energy resources of the ball lightning in form of localized in space material foundation with uncompensated electric charge so others characteristic parameters of the BL versus media compositions and common specificity of feeding energy mechanisms of its quasi-stationary state.

With account of existence of differences channels for keeping/ radiation by BL from/ into environment the energy resource of BL in quasi-stationary state will be estimated with separate components. Will be taken into account specifically:

- radiation flow  $Q_{rad}$ ;
- energy  $Q_c$  having been accumulated by sphere of BL as electric capacitor;
- energy  $Q_\varepsilon$  having been accumulated under settlements distribution function deformation of chemical bonds and electron energy states of BL medium when relaxing the one towards new equilibrium conditions<sup>6</sup>.

<sup>6</sup> Existence of the energy resources' component  $Q_\varepsilon$  corresponds to inner energy equilibrium conditions with account of possible presence of excess charge in media composition and in the framework of generally accepted till now views is not substantiated.

### **Convective energy input**

When convective heat input to be considered as the mechanism feeding of quasi-stationary state of ball lightning with energy that equation determining the waited power input to BL from environment versus temperatures as titled above is

$$Q_{hi}^{conv} = S_{bl} q_{conv} = 4\pi R_{bl}^2 \alpha_{conv} (T_{env} - T_{bl}). \quad (28)$$

Here:  $\alpha_{conv}$  - heat transfer coefficient.

By the conditions of one-to-another equilibrium in value of introducing (to BL from environment) and radiated contrary (to environment from BL) energy flows will be determined in that case the demands to supply power mechanism feeding. In substantiated limitations so (mass-exchange between the ball lightning and environment is depressed) through correlation of (25) and (28) the conditions of BL's quasi-stationary states supplying with energy (of characteristics invariability) will be determined as

$$\Delta T_{conv}^* = T_{env} - T_{bl} = \frac{\varepsilon_g C_0}{\alpha_{conv}} \left( \frac{T_{rad}^{conv}}{100} \right)^4. \quad (29)$$

As applied to a case of convective heat input the numerous estimations of energy resources of balls lightning under quasi-stationary states as well as feasibility of the lasts by themselves were being conducted within equilibrium approximation (see 5.6.1).

As this take place, with account (26) the effective radiate temperatures were taken equal to quasi-equilibrium excitation temperatures  $\bar{T}_{exc}^*$  of electron energy states conforming to ionization energy

$$T_{rad}^{conv} = \bar{T}_{exc}^* = T_{bl} \frac{V}{V - \psi \Omega}. \quad (30)$$

As for relative blackness degrees  $\varepsilon_g$ , the ones, all other factors being the same, were set equal to quasi-equilibrium ionization degree  $\bar{\alpha}$  (estimations of  $\bar{\alpha}$  along with of  $\bar{T}_{exc}^*$  were presented above by Fig. 6, 7). The equation

$$Q_\varepsilon^{conv} = \frac{4}{3} \pi R_{bl}^3 \frac{P_\Sigma}{k T_{bl}} \varepsilon \psi \Omega \quad (31)$$

was being used to estimate the energy resources component  $Q_\varepsilon^{conv}$  of ball lightning in that case.

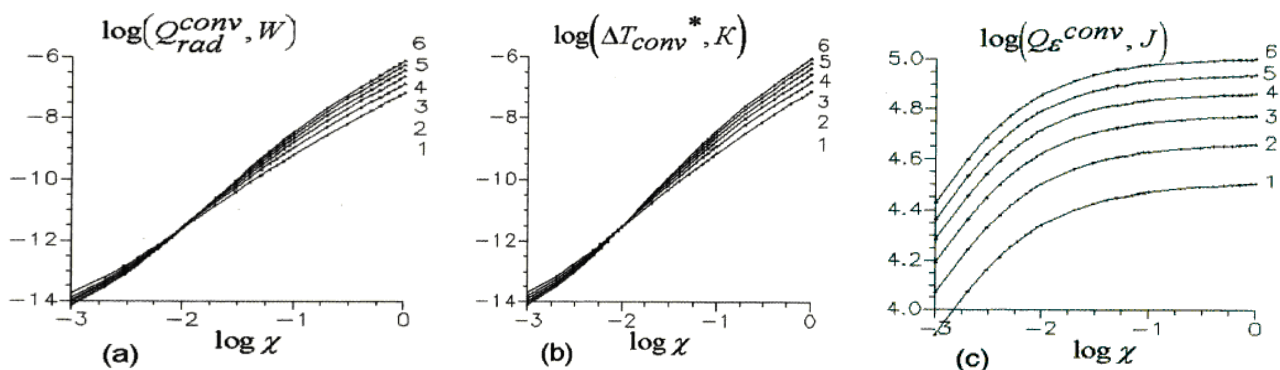


Fig. 8. The graphics  $Q_{rad}^{conv}, \Delta T_{conv}^*, Q_{\varepsilon}^{conv} = f(\chi)$  (Quasi-equilibrium approximation)

The evaluations of both the radiate power  $Q_{rad}^{conv}$  (“a”) according to (25) and the differences between the ball lightning’s translation temperatures and environment temperature (“b”) as well as of the BL’s energy resources component  $Q_{\varepsilon}^{conv}$  (“c”) versus the relative dipoles content in BL’s media composition are represent in Fig. 8. In during the estimations it was assumed that BL’s sphere radius  $R_{bl} = 0,075 m$ . The plots 1-6 correspond to conventional media composition with  $V=6, 8, 10, 12, 14, 16 W/A$  respectively. As for the rest taken into account in calculations characteristics, then ones correspond with analogues for results of Fig. 9.

Figure 9 gives the quasi-equilibrium levels of radiate power  $Q_{rad}^{conv}$  (“a”), the differences between  $\Delta T_{conv}^*$  the ball lightning’s translation temperatures and environment temperature (“b”) as well as of the BL’s energy resources component  $Q_{\varepsilon}^{conv}$  (“c”) but in the case, versus radius sphere of BL. The levels of others taken into account in calculations parameters correspond to conditions in

calculation of Fig. 7 ( $\chi=0.01, V=6, 8, 10, 12, 14, 16 W/A$  - plots 1-7 respectively).

The heat transfer coefficient from environment to BL taken into account during forming of equations was determined on the base of criterion equation

$$Nu = \frac{2\alpha_{conv} R_{bl}}{\lambda} = 2 + 0.03 Pr^{0.03} Re^{0.54} + 0.35 Pr^{0.356} Re^{0.58}, \quad (32)$$

being used for description of transfer heat between a sphere with radius  $R_{bl}$  and flow running over with velocity  $W$  [20]. With account of (32) and conformably to standard parameters of air the value of  $\alpha_{conv}$  was concrete estimated by equation

$$\alpha_{conv} = 2.581_{10^{-2}} \frac{1}{2R_{bl}} \times \left( 2 + 0.02 Re^{0.54} + 0.3080 Re^{0.58} \right). \quad (33)$$

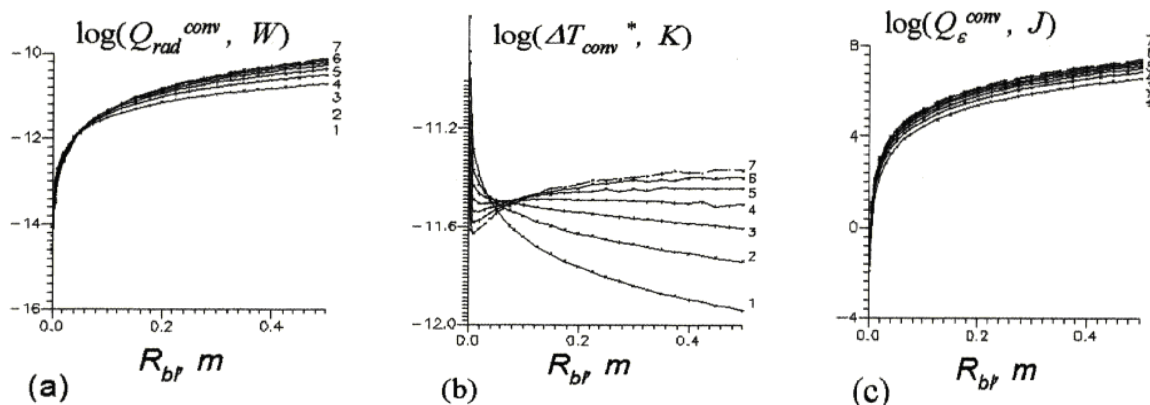


Fig. 9. Relations  $Q_{rad}^{conv}, \Delta T_{conv}^*, Q_{\varepsilon}^{conv} = f(R_{bl})$  (Quasi-equilibrium approximation)

Here:

$$\text{Re} = 0.680_{10^5} W \cdot (2R_{bl}) \quad (34)$$

### Heat-input with mass-exchange mechanism

For case of heat-input for energy feeding of BL in quasi-stationary state by mass-exchange mechanisms the energy input power was estimated by equation

$$Q_{hi}^{mt} = \pi R_{bl}^2 W \rho_{env} c_p (T_{env} - T_{bl}) \quad (35)$$

Here:  $c_p, \rho_{env}, T_{env}$  - density, heat capacity and temperature of environment accordingly;  $W$  - velocity of environment flow relative of ball lightning.

It was taken into account that energy being inputted to BL with environment flow, in that case in connection with blowing off BL sphere by the environment flow, is used up at least in two ways: to compensate a energy loses of BL in connection with radiation, firstly, and to suppress cutting of energy states settlements (reproduction of the ones) and practically to stabilize so, in conditions of continuous mass-exchange between the ball lightning and environment, the radiate capacity of BL as a whole (relation radiate capacity  $\varepsilon_g$ , effective radiate temperature  $T_{rad}$  and radiate power  $Q_{rad}$ ).

Taking into consideration the common dependences specificity of excitation temperatures (see (5.6.2)) it is assumed that the BL radiate capacity is realized in that case by radiate transitions "on the distant approaches to equilibrium of BL-medium" ( $T_{rad}^{mt} = T_{exc}^* > \bar{T}_{exc}^*$ ).

With estimations of radiation flow  $Q_{rad}^{mt}$  by (25) and expenditure power onto reproduction of energy states settlements with

$$\Delta Q_{hi}^{rep} = V_{bl} \frac{SW}{V_{bl}} \varepsilon_j^* n_j^* = \pi R_{bl}^2 W \varepsilon_j^* n_j^* \quad (36)$$

the quasi-stationary conditions of BL were determined as

$$\Delta T_{mt}^* = T_{env} - T_{bl} = \frac{W \varepsilon_j^* n_j^* + 4 \varepsilon_g C_0 (T_{rad}^{mt}/100)^4}{c_p \rho_{env} W} \quad (37)$$

Here:  $n_j^*$  - the settlement of level  $\varepsilon_j^*$  suitable to energy states excitation temperature;  $SW/V_{bl}$  - divisibility of BL-media mass-exchange.

In Fig. 10 are shown logarithmic relationships of the power  $Q_{rad}^{mt}$  ("a") radiated by ball lightning (with sphere radius  $R_{bl} = 0.075$  m), temperatures differences  $\Delta T_{mt}^*$  ("b") conforming to the power levels as well as the energy resources component  $Q_{\varepsilon}^{mt}$  ("c") accumulated of BL-media in that case with connection of continuously reproduced deformation of energy states settlements distribution function versus relational dipoles keeping in BL-media composition.

The plots are built on the supposition that radiation is realized by transitions on the distant approaches to equilibrium of BL-media.

It was suggested that radiation temperature  $T_{rad}^{mt} = 5000$  K and, in that case, corresponds to reproduced with connection of feeding the excitation temperature  $T_{exc}^*$  of BL-medium energy states with levels  $\varepsilon_j^* = 6, 8, 10, 12, 14, 16$  eV (curves 1-6 accordingly).

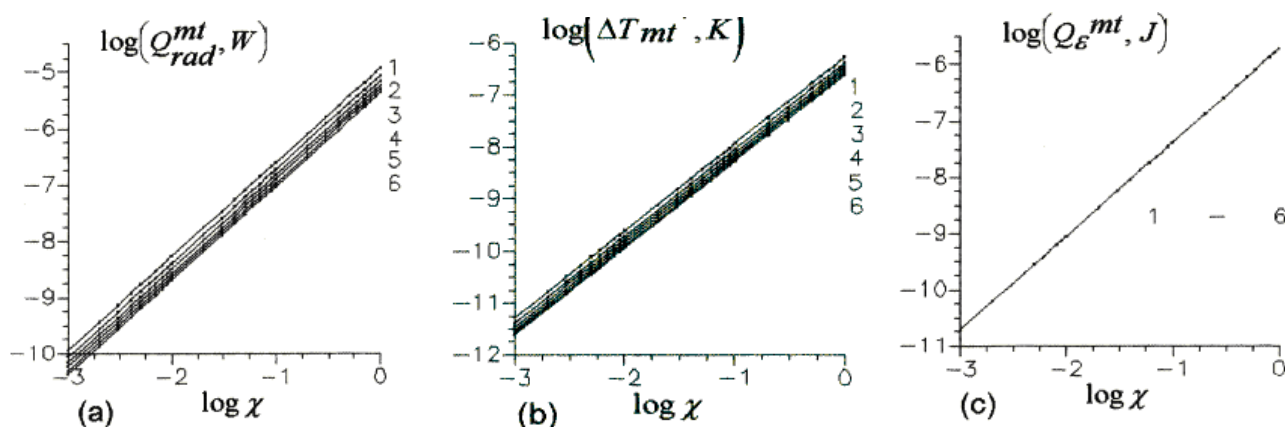


Fig. 10. Relationships  $Q_{rad}^{mt}, \Delta T_{mt}^*, Q_{\varepsilon}^{mt} = f(\chi)$

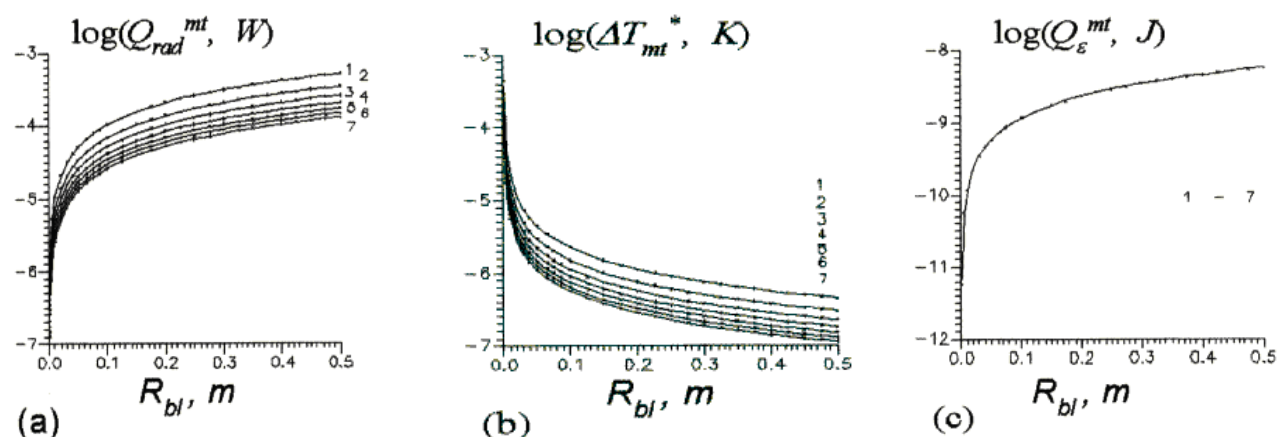


Fig. 11. Relationships  $Q_{rad}^{mt}, \Delta T_{mt}^*, Q_{\varepsilon}^{mt} = f(R_{bl})$  (Energy feeding by mass-transfer)

Taken into account quantity of environment temperature  $T_{bl}=300\text{ K}$  of pressure - atmospheric one, of velocity blowing -  $W=1\text{ m/s}$

To evaluate a quantity of  $\psi$  the dependence

$$\psi = \frac{\varepsilon_j^*}{e\Omega} \left( 1 - \frac{T_{bl}}{T_{rad}^{mt}} \right) \quad (38)$$

was used in that case.

It was taken into account that relational radiate degree  $\varepsilon_g$  is determined with equation (27). At last, the  $Q_{\varepsilon}^{mt}$  level was estimated by relationship

$$Q_{\varepsilon}^{mt} = \varepsilon_j^* n_j^* V_{bl} = \frac{4}{3} \pi R_{bl}^3 \varepsilon_j^* \frac{\Delta n q}{\psi} \quad (39)$$

On Fig. 11 the estimations relationships of the radiated power  $Q_{rad}^{mt}$  ("a") and the temperatures differences  $\Delta T_{mt}^*$  ("b") answering to being realized conditions along with energy  $Q_{\varepsilon}^{mt}$  ("c") accumu-

lated by BL-medium in connection with continuous reproduced deformation of energy states settlement distribution function versus sphere radius  $R_{bl}$  of BL are presented.

The curves are being estimated by analogous kind in assumption that energy radiation by BL into environment is realized with radiate transitions on distant approaches to equilibrium of BL-media.

It was assumed that the radiate temperature  $T_{rad}^{mt} = 5000\text{ K}$  and corresponds to excitation temperature  $T_{exc}^*$  of energy states with levels  $\varepsilon_j^* = 4, 6, 8, 10, 12, 14, 16\text{ eV}$  (plots 1-7 accordingly) under atmospheric pressure. Taken into account environment temperature level  $T_{bl}=300\text{ K}$ . The dipole molecules proportion  $\chi=0,01$  (dipole moment  $d=1D$ ). It was assumed also that the relative velocity of environment flow (BL blow-through)  $W=1\text{ m/s}$ .

On Fig. 12 the radiate power  $Q_{rad}^{mt}$  of BL with sphere radius  $R_{bl}=0,075\text{ m}$  and corresponding to le-

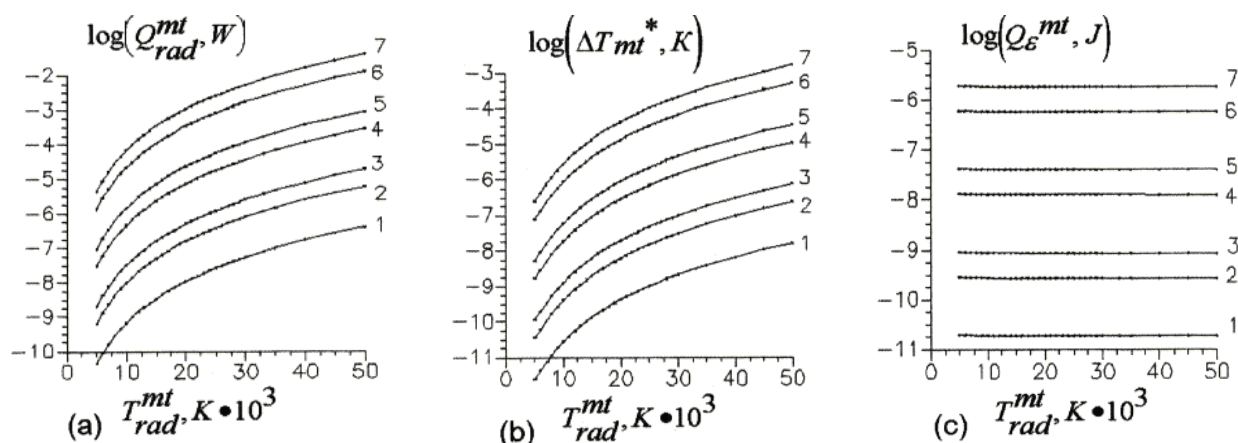


Fig. 12. Relationships  $Q_{rad}^{mt}, \Delta T_{mt}^*, Q_{\varepsilon}^{mt} = f(T_{rad}^{mt})$



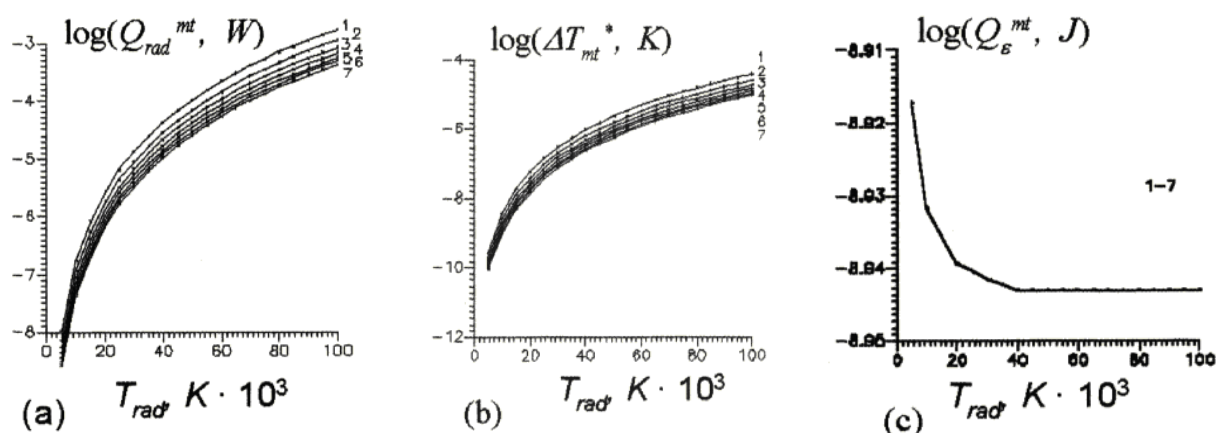


Fig. 13. Relationships  $Q_{rad}^{mt}, \Delta T_{mt}^*, Q_{\varepsilon}^{mt} = f(T_{rad}^{mt})$

vels of the one the temperatures differences  $\Delta T_{mt}^*$  as well as energy resources component  $Q_{\varepsilon}^{mt}$  versus radiate temperature  $T_{rad}^{mt}$  of the ball lightning are presented. The relationships are received by analogous with previous method and cover the diapason  $T_{rad}^{mt} \in (5000, 50000) K$ . Taken account of the conventional BL-media composition corresponds to both relative dipoles content  $\chi=0.001, 0.005, 0.001, 0.005, 0.1, 0.5, 1$  (the plots 1-7 correspondingly) and ionization potential  $V=16W/A$  ( $\varepsilon_j=16eV$ ).

As previous way it was assumed that  $T_{bl}=300 K$ , the pressure is atmospheric one, blow-through velocity  $W=1 m/s$ .

The analogous characteristics of BL with sphere radius  $R_{bl}=0.075m$  for different composition media ( $V=4, 6, 8, 10, 12, 14, 16 W/A$ , the curves 1-7 accordingly) with relative dipoles content  $\chi=0.01$  are represented on Fig.13.

As in the above, the taken into account  $T_{bl}=300 K$ , pressure is the atmospheric one, blow velocity through BL  $W=1 m/s$ . Taken into account the radiate temperature variation diapason in the case corresponds to  $T_{rad}^{mt} \in (5000, 100000) K$ .

Draw attention to the fact that levels of being estimated BL's energy characteristics (see fig. 6-13) are in gratifying agreement with characteristics of BL forecasted in the line of the notions about BL in the frame of the one's historically formed by observations portrait [15, 16, 19].

### Common results

By investigations results totality, upon overstepping the limits of generally accepted physical base, the conceptual views complex of ball lightning as about

of special shape localized in the airspace material foundation with differences between one's translation temperature and excitation temperatures of one's chemical bonds and electron energy states have been formulated and is substantiated.

Adequacy and common rightfulness of the complex is jointly established by inclusion to examination in totality of all most significant characteristics and necessary existence conditions of BL, by revealed true of BL's characteristics being estimated on the complex base and of the ones being prognosticated in the frame of historically composed portrait of ball lightning and else by experimental confirmation of trustworthiness of the IEEC as of the physical base complex.

The complex is aimed to substantiation of jointly observed manifestations of BL. In the context of views being determined complex composition the localization possibility in airspace of ball lightning as material foundation with noted temperature differences (sphericity of BL) is confirmed. The nature of BL's radiation ability is based. The role of environment as source providing of BL with energy was revealed. Energy feeding mechanisms along with keeping conditions of quasi-stationary characteristics of BL are determined.

Formation channels of BL's energy resources (in that number of untraditional character ones) is placed. By top numerical estimations the energy resources levels are confirmed, possibilities and variation diapason of the ones (multi-faces of BL) are substantiated too.

Being received characteristics estimations of BL on the formulated complex base is found in satisfactory consent with characteristics of BL being prognosticated in the frame of the one's historically composed portrait.

Being revealed conformity like results of the work as a whole testify to in all common rightfulness of being developed point of view, further progress expediency of the one, possibilities to extend on the one's base our knowledge of nature.

Let us note else to independent scientific importance of proper IEEC, obvious fundamental character of the ones.

## Conclusion

In the frame of an untraditional approach, upon overstepping the limits of generally accepted physical base the conceptual views complex about ball lightning as of quasi-stationary material foundation with differences between one's translation temperature and excitation temperatures of chemical bonds and electron energy states was formulated and are substantiated.

Every physical peculiarities of the base positions being used in the work present independent scientific interest. They note to existence of traditionally not accounted control channel of material media states in what electrical charge plays a role of control factor.

The being developed approach is based upon fundamental base and is presented as perspective one to use for wide circle solving of scientific and technical problems. The last, however, demands of confirmation with additional purposeful researches.

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