Electric pulse of nuclear explosion

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Abstract

Under the program «Starfish» on July, 9th 1962 USA have blown up in space over Pacific ocean a hydrogen bomb with a trotyl equivalent 1.4 Mt. This event has put many questions before scientific community. Before it in 1957 the future Nobel winner doctor Hans Albrecht Bethe, being based on the theory of dipolar radiation, has foretold that at similar explosion the electromagnetic impulse (EMI) will be observed, thus intensity of a field on an earth surface will make no more than 100 В/м. Therefore all measuring equipment which should register electromagnetic radiation, has been adjusted on registration such intensity fields. But at bomb explosion it has appeared that intensity of electric fields, since explosion epicenter, and further throughout more than 1000 km has reached several tens thousand volt on meter. Those about past more than seventy years, but, until now, in the scientific journals be absent publication on the explanation of this phenomenon. This article gives the explanation of this phenomenon on the basis of the concept of scalar- vector potential, developed by the author. This concept assumes the dependence of the scalar potential of charge on its relative speed.

1. Electric pulse of nuclear explosion and the rope tricks

According to the program "*Starfish*" of 9 июля 1962 the USA exploded in space above Pacific Ocean H-bomb. This event placed before the scientific community many questions. It is earlier into 1957 future Nobel laureate Hans A. Bethe, being based on the theory of dipole emission, predicted that with a similar explosion will be observed the electromagnetic pulse (EMI), the strength of field which on the earth's surface will comprise not more than 100 V/m. Therefore entire measuring equipment, which had to record electromagnetic radiation, was disposed for registering such tensions pour on. But with the explosion of bomb discomfiture

occurred, pour on the tension of electrical, beginning from the epicentre of explosion, and further for the elongation of more than 1000 km of it reached several ten thousand volt per meters. (Actual chart area and value of tensions pour on given in Fig. 1.

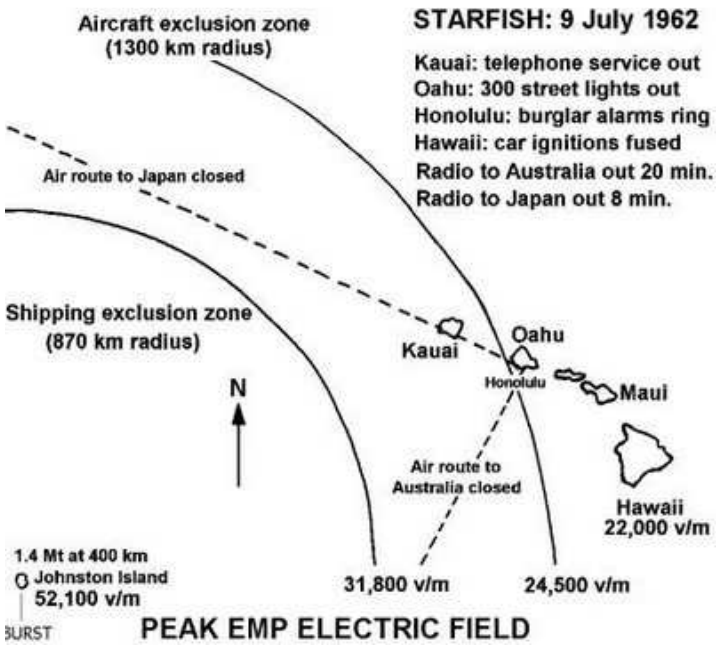

Fig. 1. Map of tests under the program «Starfish».

Unfortunately, in the materials of this reference is not contained information about the polarization of these pour on. Possibility to refine this question give the data, obtained in the USSR during the tests with the code name «*Программа К*» when not far from Dzhezkazgan at the height of 290 km was exploded H-bomb with the TNT equivalent 300 kt. Actual chart area with the indication of the values of tensions pour on, obtained with this explosion, it is shown in Fig. 2

Comparing data with respect to the tensions pour on, given on these two maps, it is possible to see that the values of tensions pour on in Fig. 1 diminish with an increase in the distance from the epicentre of explosion, while on the map, depicted

in Fig. 2, these values grow. From this it is possible to draw the conclusion that on the second map are cited the data on the measurement by the horizontal intensity of electrical pour on.

Is located the record of the shape of electrical pulse, made at a distance 1300 km from the point of impact (Fig. 3), obtained with the tests according to the program "*Starfish"*. It is evident from the given figure that EMI has not only very large amplitude, but also very short duration.

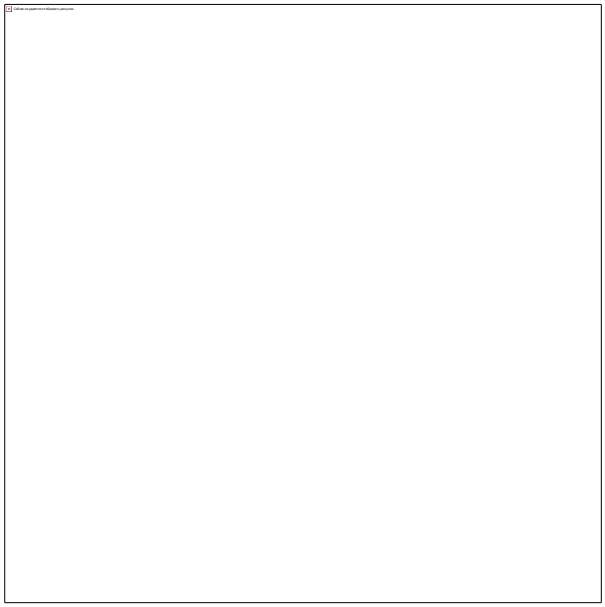

Fig. 2 Map of tests according to the program «*Программа К*».

Since the forecast Hans A. Bethe did not justify, then was subsequently advanced the two additional theories, intended to explain experimental data. The first of them was developed Conrad Longmire in 1963, which examined a question about the formation of the magnetic dipole, formed by the Compton electrons, which revolve around the lines of force of earth's magnetic field.

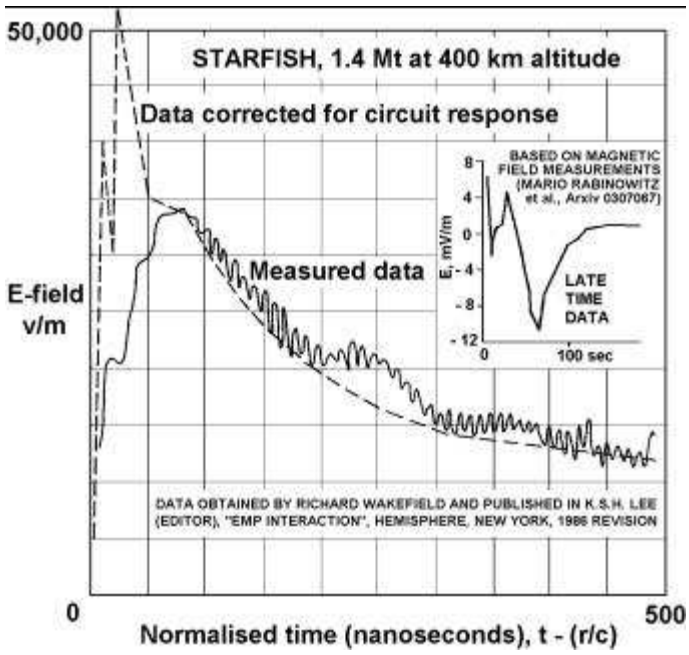

Fig. 3. Experimental dependence of amplitude EMI on the time, obtained with the tests according to the program "*Starfish*".

Subsequently in 1975 was developed the model Louis W. Seiler. *Jr*, in which is assumed that the formation EMI is obliged to the relativistic Compton electrons, which the rigid X-radiation knocks out from the molecules of air and which cophasal with gamma-radiation move with the relativistic speeds in the direction of propagation of electromagnetic wave. Neither one nor the other model is reliably accepted or disproved be it cannot, since further nuclear tests in space were ended, and there is no additional experimental data, which could confirm or refute the models examined.

It assumes this model that the process of the pulse shaping is not the property of explosion itself, but is the second effect, connected X-radiation it with the fact that knocks out from the molecules of air Compton electrons. From the last model, which received the greatest acknowledgement, it follows that EMI itself is extended of the ionosphere into the lower layers of the atmosphere, and therefore of its field higher than ionosphere, directly in space itself, they be absent. But, if we with the aid of the theories examined even somehow possible explain the

presence of electrical pour on in the visibility range of explosion, then the fact of strong ionospheric disturbances at large distances from the explosion, which it accompanied, to explain difficultly. Thus, after explosion in the course of several ten minutes there is no radio communication with Japan and Australia, and even at a distance into *3200 km* from the epicentre of explosion were fixed ionospheric disturbances, which several times exceeded those, which are caused by the most powerful solar flares. Explosion influenced also the automatic spacecraft. Three satellites were immediately disabled by electromagnetic pulse. The charged particles, which were appeared as a result explosion, were seized by the magnetosphere of the Earth, as a result of which their concentration in the artificial Earth radiation belt it increased by 2-3 orders. The action of radiation belts led to the very rapid degradation of solar batteries and electronics in seven more satellites, including in the first commercial telecommunication satellite tele-Star. On the whole explosion derived from system third of the automatic spacecraft, which were being found in low orbits at the moment of explosion.

With the explosion of nuclear charge according to «*Программа К*» which was realized into the USSR, the radio communication and the radar installations were also blocked at a distance to 1000 km of. As a result these tests it was established that the high-altitude nuclear explosions are accompanied by the emission of the powerful pulse, which considerably exceeds in the amplitude the value of the pulse, which occurs with the surface explosions of the same power. It was discovered, that the registration of the consequences of space nuclear explosion was possible at the large (to 10 thousand kilometers) distances from the point of impact.

From the point of view of the existing concepts of classical electrodynamics Compton models cause serious questions. For example, why all Compton electrons must move cophasal with the front of gamma-radiation with the relativistic speed. In Compton electrons the velocity vector has spatial distribution, in connection with this it is not possible to obtain such short of the pulse rise, as it takes place in actuality. In the electrodynamics such mechanisms, which give the possibility to

obtain the single-pole pulse of electric field without the three-dimensional separation of charges in this place theoretically be absent. But in the pulse rise time, which is calculated by tens of nanoseconds, to obtain the three-dimensional separation of charges, which will ensure the field strength obtained during the experiment, it is impossible. Compton ionization itself leaves entire system as a whole of electrically neutral.

Is known that the problem of this phenomenon attempted together with his students to solve and academician I. B. Zeldovich [1]. However, in the existing sources there is no information about the fact that this problem was solved by it. Consequently, the everything indicates that within the framework existing classical electrodynamics the results, obtained with the tests according to the program "*Starfish" of* and «*Программа К*».cannot be explained thus far.

In what does consist the danger of the forecasts, which does give the model of Compton electrons? Problem in the fact that this model excludes the possibility of the presence pour on pulse in space. It is known that during the tests according to the program "*Starfish"* three satellites, that are found at that time in space not far from the zone of explosion, malfunctioned. It is unknown, there are whether at present precise data apropos of the reasons for these failures. Let us assume that model advanced Louis W. Seiler, *Jr.* is incorrect, and, relying on it as in the past for the predictions Hans A. Bethe, will be produced the sequential explosion of nuclear charge in space, which will put out of action a large quantity of satellites. Moreover this explosion can be both the planned and realized for terrorist purposes. Then be justified already is late.

Let us undertake the attempt, using a concept of scalar- vector potential, to explain obtained experimental data, and let us also show that with the explosion of nuclear charge in space, there are not fields of electromagnetic pulse (EMI), but pulse electric fields (PEF), in which the magnetic field is absent. The fields PEF in space having much more significant magnitudes, than in the atmosphere and on the earth's surface.

Fccording to the estimations at the initial moment of thermonuclear explosion the temperature of plasmoid can reach several hundred million degrees. At such temperatures the electron gas is no longer degenerate and is subordinated to the distribution of Boltzmann. Let us assume that the temperature of the plasmoid at the initial moment formed with the explosion composes ~ 10^8 K, and the total weight of bomb and head part of the rocket, made from metal with the average electron density ~5×10^{22} 1/sm^3, composes 1000 kg. General a quantity of free electrons in the formed plasma, on the assumption that all atoms will be singly ionized with the specific weight of the metal ~ 8 g/cm^3, will comprise ~ 5×10^{27}. The most probable electron velocity at the temperature indicated let us determine from the relationship:

$$v = \sqrt{\frac{2k_Б T}{m}},$$

where $k_Б$ - Boltzmann constant, and m - mass of electron.

In works [2,3] was developed the concept of scalar-vector potential, which assumes the dependence of the scalar potential of charge on the speed, normal to the vector, which connects charge with the observation point

$$\varphi'(r, v_\perp) = \frac{e}{4\pi\varepsilon_0} ch \frac{v_\perp}{c},$$

for enumerating the increase in the scalar potential and taking into account only terms of the expansion ~ $\frac{v^2}{c^2}$, we obtain

$$\Delta\varphi \cong \frac{Nek_Б T}{4\pi\varepsilon_0 rmc^2} \tag{1}$$

where e - electron charge, and r - distance from the burst center to the observation point. We determine from the formula the tension of radial electric field, which corresponds to this increase in the potential:

$$E = \frac{Nek_Б T}{4\pi\varepsilon_0 r^2 mc^2} = \frac{\Delta q}{4\pi\varepsilon_0 r^2} \tag{2}$$

where

$$\Delta q = \frac{Nek_B T}{mc^2}, \qquad (3)$$

is an equivalent charge of explosion. By this value it is necessary to understand exceeding the charge of electron gas in comparison with its equilibrium value in the metal.

One should say that with the warming-up of plasma the ions also acquire additional speed, however, since their mass considerably more than the mass of electrons, increase in their charges can be disregarded.

In accordance with the formula (2) the tension of the radial electric field in the epicenter of the explosion under specified above options will be ~ 7×10^5 V/m at a distance of 870 km from this place it is ~ 1.5×10^5 V/m and at a distance of 1300 km it is ~ 6.5×10^4 V /m. It is evident that the computed values of electrical pour on on the earth's surface they exceed the values, obtained during the tests. The ratio of rasschetnykh values to those measured they comprise: in the epicentre of explosion - 13.5, at a distance 870 km from this place - 4.5, at a distance 1300 km - 2.4. Certainly, are unknown neither the precise initial of the temperature of plasmoid nor mass of bomb and launch vehicle, in which it undermine nor materials, from which are prepared these elements. Correcting these data, it is possible sufficiently simply to obtain values pour on those being approaching experimental values. Greater uneasiness causes that the fact that there is a large noncoincidence of three-dimensional dependences of experimental and calculation data. Let us attempt to explain the reason for such divergences.

Let us first examine the case, when the ionosphere is absent Fig. 4. For simplification in the task we will consider that the ideally conducting limitless plane represents by the earth's surface. The solution of allocation problem pour on for the charge, which is been located above this plane, well known [1].

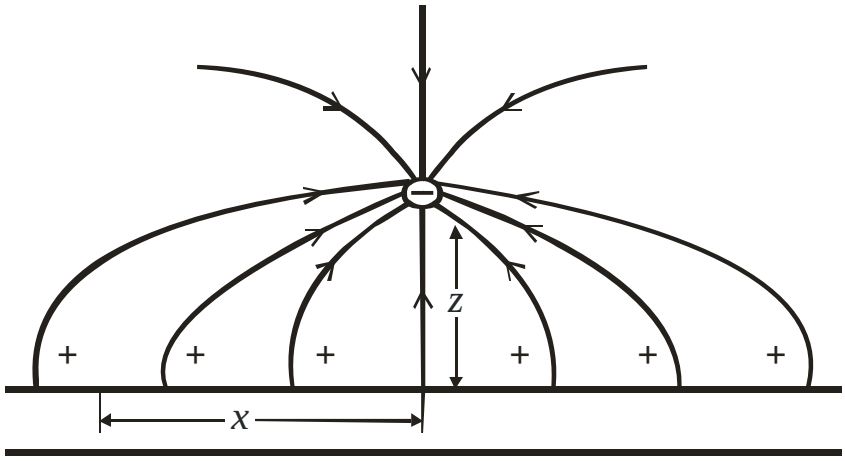

Fig. 4. Negative charge above the limitless conducting plane.

The horizontal component of electric field on the surface of this plane is equal to zero, and normal component is equal:

$$E_{\perp} = \frac{1}{2\pi\varepsilon_0} \frac{zq}{\left(z^2 + x^2\right)^{\frac{3}{2}}},$$

where q - magnitude of the charge, z - shortest distance from the charge to the plane, x - distance against the observation points to the point of intersection of vertical line, lowered from the point, where is located charge, to plane itself.

Lower than conducting plane electric fields be absent. This configuration pour on connected with the fact that charge, which is been located above the conducting plane, it induces in it such surface density of charges, which completely compensates horizontal and vertical component of the electric field of charge in the conducting plane and lower than it. The dependence of the area charge from the coordinate of x can be determined from the relationship

$$\sigma(x) = \varepsilon_0 E_{\perp} = \frac{1}{2\pi} \frac{zq}{\left(z^2 + x^2\right)^{\frac{3}{2}}}. \qquad (4)$$

If we integrate $\sigma(x)$ with respect to the coordinate x, then we will obtain magnitude of the charge, which is been located above the conducting plane. In such

a way as not to pass the electric fields of the charge q through the conducting plane, in it must be contained a quantity of free charges, which give summary charge not less than the charge q. If we periodically draw near and to move away charge from the plane, then in it will arise the periodic horizontal currents, which will create the compensating surface charges. The same effect will be observed, if charge at the particular point can be born and disappear. If at the assigned point above the plane charge suddenly in some time arises, then, so that the fields of charge would not penetrate through the conducting plane, in the same time on the conducting plane the compensating charges, which correspond to relationship must appear (4). This means that the strength of currents, which create the compensating charges, there will be the greater, the greater charge itself and the less the time of its appearance. If we calculate electric fields according to this formula, considering that with $x = 0$ the value of the tension of the vertical component of electric field on the surface equally to 5.2×10^4 V/m, then at a distance 870 km we will obtain field value of 4×10^3 V/m, and at a distance 1300 km - 1.3×10^3 V/m. It is evident that pour on the values of calculated and obtained experimentally again strongly they are differed from those calculated. This connected with the fact that between the earth's surface and the charge in question exists the ionosphere, which is also the conductor of current, although not very perfect. Let us examine this case Fig. 5.

If charge will appear at the indicated in the figure point, thus it will gather under itself the existing in the ionosphere free charges of opposite sign for compensating those pour on, which it creates in it. However, if a total quantity of free positive charge in the ionosphere will be less than the value of charge itself, then their quantity will not be sufficient for the complete compensation pour on the appearing charge and its fields will penetrate through the ionosphere. In this case the penetrated fields, in view of the screening effect of the ionosphere, can be less than the field above it. Entire this picture can be described only qualitatively, because are accurately known neither thickness of the ionosphere nor degree of its ionization on the height, moreover, such problems are solved only by numerical methods.

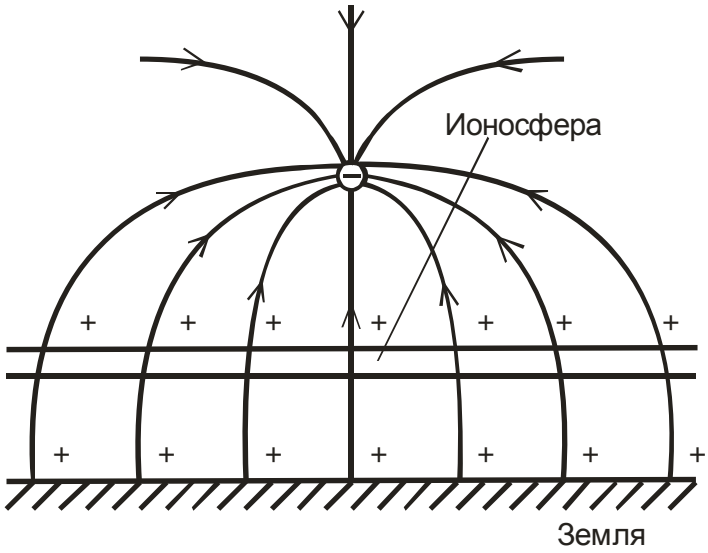

Fig. 5. Negative charge above the earth's surface with the presence of the ionosphere.

The sphericity of the ionosphere also superimposes its special features on the process of the appearance of the compensating surface charges. This process is depicted in Fig. 6 .

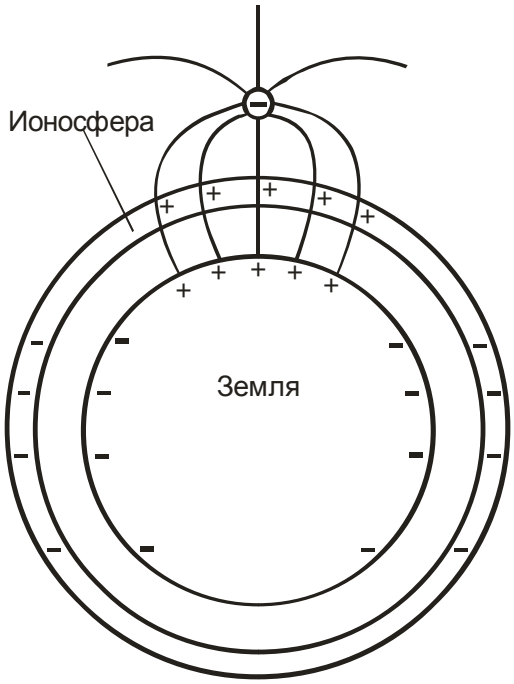

Fig. 6 . Negative charge above the earth's surface with the presence of the ionosphere.

The tendency of the emergent charge to gather under itself the compensating charges will lead to the longitudinal polarization of the substantial part of the ionosphere. The compensating positive chargex will be located in the ionosphere directly in the straight visibility under the charge and here them it will be in the surplus, while beyond the line-of-sight ranges in the surplus they will be negative charges. And entire system charge - the ionosphere - the earth will obtain additional dipole moment. The distribution of induced charge in the ionosphere will depend on the height, at which is located the charge, and also from the position of the sun with respect to the charge, since. the degree of ionization of the ionosphere depends on its position.

With the nuclear explosion is synchronous with the electrical radial fields, which are moved from the plasmoid with the speed of light, moves the front of X-radiation. This emission will ionize the atmosphere, increasing its conductivity, while this will, in turn, increase the shielding functions of the atmosphere from the penetration into it of the pulses of the subsequent explosions, if such arise. Furthermore, since the negative potential of plasmoid at the initial moment of the explosion of very large, from the cluster will be temporarily rejected some quantity of electrons, which also after a certain time will fall into the ionosphere. The partial neutralization of the electrons, which fell into the ionosphere, will occur, when the positive ions of plasmoid will also reach the ionosphere. But this will concern only those ions, the radial component of speed of which was directed to the side of the ionosphere. The same electrons and ions, whose radial component was directed to the side from it, will leave the limits of the earth's gravity and they will present the similarity of that solar wind, which is the consequence of the evaporation of the solar corona or flashes on the solar surface. Those complex processes, which accompany nuclear explosion, now are only schematically outlined, and is in prospect still extensive work, on the recreation of these processes for the actual conditions. It is obvious that to make this is possible only numerical methods.

The model examined speaks, that nuclear explosion will lead not only to the appearance PEF in the zone of straight visibility, but also to the global ionospheric disturbance. It is known that the explosions according to the program "*Starfish"* and according to the program "*Программа К"* led to the presence of large interferences with radio-technical and radar systems at large distances from the epicentre of explosion. Certainly, the electric fields in space, generated by this explosion, have very high values and present the major threat for the automatic spacecraft. The values of the maximum values of the tensions of electric field, depending on distance from ground zero for our specific case, are represented in the table № 2.

Table № 2

$r(км)$	500	1000	1500	2000	2500	3000
$E(В/м)$	$4\cdot10^5$	10^5	$4{,}5\cdot10^4$	$2{,}5\cdot10^4$	$1{,}6\cdot10^4$	$1{,}1\cdot10^4$

Now let us return to the horizontal component of electrical pour on on the earth's surface, generated with the explosion. It is understandable that these fields represent the tangential component of radial pour on, that go from the point of explosion. Specifically, these fields cause the compensating currents, which create the compensating surface charges. It is possible to calculate the order of the summed currents, which will have radial directivity with respect to the epicentre of explosion. For this let us calculate summary compensating grain surface on the earth's surface, which must be formed with the explosion of nuclear charge. This charge is equal to the charge of plasmoid with the opposite sign

$$q = 4\pi\varepsilon_0 r^2 E\,.$$

After conducting calculations according to this formula, on the basis of the actually measured vertical tensions of electrical pour on in the epicentre of explosion (5.2×10^4 V/m), with the distance to the explosion of 400 km of we obtain the charge ~ 10^6 Q. However, the value of charge they will compose ~ 1.2×10^7 Q. This

divergence, as it is already said, can be connected with the screening effect of the ionosphere. From the data on the topology PEF, given in Fig. 3, follow that the pulse rise time of electric field is ~ 50 ns. This means that the total current, directed to the epicenter of the explosion should be ~ 10^{12} A. Certainly, this number is somewhat overstated, because the compensating charges are attracted not to one point, which is been the epicentre of explosion, but to the sufficiently extensive region in its environment. But even if this value decreased several orders previous the strength of compensating currents will be very large. It is now understandable, why on Oahu island, that is been located at a distance of 1300 km of from the epicentre of explosion, burnt 300 street lamps, and near Dzheskazgana in the air telephone line with the extent 570 km of arose the currents ~ 2.5 kA, which burnt in it all safety fuses. Even to the power cable by extent is more than 1000 km of, which connects Almaata and Akmola, and the having armored screen from lead, braiding from the steel tape, and located on the depth 0.8 m, such focusings arose, that operated the automata, after opening from the cable power station. Certainly, the pulse of tangential currents, although the less significant than on the earth's surface, will be also in the ionosphere, which will lead to its disturbance on global scales.

entire process of formation PEF with the explosion of charge in space can be described as follows. At the moment of explosion in the time of the detonation of nuclear charge, which lasts several nanoseconds, is formed dense plasmoid with the temperature in several ten and even hundreds of millions of degrees. This cluster generates the powerful gamma emission, which is extended in different directions from the cluster with the speed of light. Simultaneously is generated the radial electric field, which also is extended in the radial direction from the cluster with the speed of light. Radial electric fields PEF and gamma-radiation reach the ionosphere simultaneously. During its further motion to the side of the earth's surface, if explosive force for this it is sufficient, X-radiation begins to ionize and the layers of the atmosphere, which are been located lower than the ionosphere. The process of the ionization of upper air and the penetrations in them of radial electric field will simultaneously occur. In the ionized layers due to the presence of radial electric

field will arise the radial currents, which will lead to the stratification of charges and to the vertical polarization of conducting layers. The processes of the polarization of the atmosphere will last as much time, as will exist radial field, and also conductivity of ionized air. Since the ionosphere will not be able to ensure the charge, necessary for the complete compensation for the radial field of plasmoid, these fields, although in the weakened form, they will continue to be extended in the direction of the earth's surface. Electric fields will create powerful radial currents. The process of propagation of X-radiation and radial pour on through the ionosphere it will lead to its additional ionization and polarization, and also to the appearance of a pulse of tangential currents. The pulse of tangential currents in the ionosphere will apply to distances considerably greater than the visibility range of explosion, which will lead to the global ionospheric disturbances.

Up to that moment, when the flow of rigid gamma emission and ionization of atmosphere cease, the part of the atmosphere, ionize lower than the existing boundary of the ionosphere, will cease to be conductor, and is, therefore, the three-dimensional divided charges will prove to be closed in it. The electrons closed in the atmosphere will as before create some static potential difference, which will slowly relax to the extent of the presence of the residual conductivity of the atmosphere. It should be noted that the polarity of this field will be opposite to the polarity of initial PEF, that also is observed in actuality. This means that the radial electric field, observed on the earth's surface, will be first directed from the earth toward the epicentre of explosion, but at some moment of time it will change its polarity. Specifically, this behavior of electric field is observed on the graph, depicted in the upper as right to angle Fig. 3.

Becomes clear and that, why after space nuclear explosion an even longer time is observed the residual glow of the atmosphere under the point of impact. This glow is obliged to those electrons, which during the first stage development PEF were displaced of the ionosphere into the denser layers of the atmosphere, and then, after the termination of the ionize effect of gamma emission, they remained closed in the little conducting atmosphere, continuing to ionize it.

Now let us be turned to Fig. 3. Since the value of radial field in accordance with relationship (2) is proportional to the work of a quantity of free electrons to the temperature of plasma, the like to this graph it is possible to judge the knocking processes of nuclear charge and the subsequent cooling of plasmoid. From the figure one can see that the most active process of formation PEF lasts in all ~ 100 ns. In this case even X-rays, which are extended with the speed of light, will have time to leave from the burst center in all on 30 m. In the figure there are two dependences. Solid line designated the curve, photographed from the oscilloscope face, dotted line presents the real shape of pulse, obtained by working by the photographed curve taking into account the parameters of the input circuits of oscillograph. In the initial stage of real dependence for the elongation strand 50 ns are visible two sequential peaks. The first peak presents nuclear blast, which ignites thermonuclear charge, the second peak presents the knocking process of thermonuclear fuel. The rapid decrease, which characterizes the process of cooling cluster, further goes. It is evident that it occurs very rapidly. Naturally to assume that this is that period, when basic energy losses are connected with the radiant losses caused by the rigid X-radiation. On the dependence, depicted on the graph, located in the upper by right to angle Fig. 3, are depicted processes in the time interval calculated by seconds after explosion. It is evident that the intensity of these processes is insignificant, however, characteristic property it is that that the field strength changes its sign.

The carried out analysis attests to the fact that the appearance EMI it is necessary to consider as the rapidly elapsing generation of new negative single-pole charge at the moment of the detonation of nuclear charge and its subsequent slower disappearance during cooling of plasma.

Thus, the appearance PEF with the nuclear explosion are the properties of explosion itself, but not second phenomena. Its properties and characteristics can be explained within the framework to the concept of scalar- vector potential. Studying topology PEF it is possible to study knocking processes with the nuclear explosion, moreover this method is remote. Studying topology PEF on the earth's surface, it is

possible to judge also the subsequent processes of polarization and depolarization of the ionosphere, atmosphere and earth's surface. With the explosion in the atmosphere very process of formation PEF and its development are connected with the presence of the atmosphere, and also by the presence of conductivity on the earth's surface and this will also superimpose its special features on shaping pour on PEF. With the explosions in immediate proximity from the earth's surface the equivalent charge of the cloud of explosion will see its mirror reflection under the earth's surface, forming the electric dipole. For this reason the region of propagation pour on PEF it will be strongly reduced, since the fields of dipole diminish according to the cubic law.

Now should be made one observation apropos of term itself the electromagnetic pulse EMI, utilized in the literary sources. From this name should be excluded the word magnetic, since. this process presents the propagation only of radial electrical pour on, and in this case magnetic fields be absent. It is another matter that electric fields can direct currents in the conducting environments, and these currents will generate magnetic fields, but this already second phenomenon.

Would seem, everything very well converges, however, there is one basic problem, which is not thus far examined, it concerns energy balance with the explosion. If we consider that one ton of the trotyl is equivalent 4.6×10^{9} J, then with the explosion of bomb with the TNT equivalent 1,4 Mt. are separated 6.44×10^{15} J. If we count, as it follows from Fig 3. If we consider that the time of detonation is equal to 50 ns, then explosive force composes $\sim1.3\times10^{23}$ W. Let us say for an example that the power of the radiation of the Sun of $\sim3.9\times10^{26}$ W. Let us examine a question, where how, in so short a time, can be the intake, isolated with this explosion.

In accordance with Stephan equation Boltzmann the power, radiated by the heated surface, is proportional to the fourth degree of its temperature:

$$P = \sigma s T^{4},$$

where $\sigma = 5.67 \cdot 10^{-8} \ \frac{W}{m^2 K^4}$ - Stefan-Boltsman constant, and s - area of radiating surface.

If we take the initial temperature of the plasmoid ~10^8 K, then with its initial diameter 1 m (in this case the surface area of cluster it is ~3 m^2 entire explosive energy will be radiated in the time ~ 0.4 ns. But if we take the initial temperature ~10^7, then this time will be already ~ 400 ns. Thus, one should assume that the initial temperature of plasmoid to be located somewhere between the undertaken values. Wavelength, on which will be radiated a maximum quantity of energy, is determined by the Wiens law

$$\lambda_{макс} = \frac{0,28975}{T} \ \frac{sm}{K}.$$

If we substitute here the value of the temperature 5×10^7 K, then we will obtain the wavelength on the order of 6 Å, which corresponds to rigid X-radiation. Its temperature will begin to fall in proportion to cooling cluster and $\lambda_{макс}$ will begin to be shifted into the visible part of the spectrum. In this case can be observed the interesting phenomenon, when the temperature of cluster will fall, and the visible brightness - grow.

But the mechanism of losses examined is not only. Since with the temperature of cluster are unambiguously connected its electric fields, immediately after detonation they will be maximum, and then with a temperature drop of cluster they will begin to decrease proportional to temperature. However, the energy, necessary for their creation, will fall not as rapidly as energy necessary for creating the X-radiation.

Besides these losses will be still loss to the thermionic emission of electrons from the plasmoid. The velocity of the electrons, which will leave cluster considerably less than pour on the speed of electrical since. it corresponds to the temperature of cluster; therefore the front of these electrons will substantially be late

relative to the fronts of X-radiation and radial electric field. And only after thermionic electrons will leave cluster, the basic reserve of energy of nuclear explosion will be exhausted. Will remain only ions with some quantity of compensating electrons, which will fly away in the radial direction from the point of impact. This remained relict of nuclear explosion will present ball lightning.

Appears one additional important question about which a quantity of electrons it will leave plasmoid. In order to answer it, let us examine the condition of the electroneutrality of plasma. At that moment when metal is converted into the plasma, occurs not only the passage of substance from one state of aggregation to another, but also changes the statistics of the description of electron gas. In the solid state statistician Fermi-Dirac's this, while in the state of plasma - statistician Boltzmann's this. When electron gas was located in the steadfast conductor, then in the state of electroneutrality to each ion it was fallen along one free electron. Let us determine from the point of view of the concept of scalar- vector potential, what relationship must be observed between the electrons and the ions in the plasma so that it would also remain electrically neutral. Before solid became plasma, the electron density and ions was identical and, therefore, the absolute values of their charges were equal, i.e.

$$eN_e = eN_{пр},$$

after the transformation of substance into the plasma general equivalent electron charge increased, to the value, determined by relationship (3), and in ions it remained practically before. Now already for observing the electroneutrality must be observed the relationship:

$$N_{e(пл)}\left(1+\frac{k_Б T}{m_e c^2}\right)=N_{пр},$$

where $N_{e(nn)}$ - equilibrium quantity of electrons in the plasma.

is evident that this equilibrium quantity is less than to the passage of substance into the state of plasma. Difference composes

$$\Delta N = N_{np}\left(1-\frac{1}{1+\frac{k_B T}{m_e c^2}}\right). \qquad (5)$$

For example, at a temperature ~10^8 the value, which stands in the brackets, will compose approximately 0.13. This means that at the temperature indicated, for retaining the electroneutrality of plasma, 13% of a total initial quantity of electrons had to it leave. We will call this effect the effect of temporarily excess electrons. Word “are temporarily " used by in the sense that temporary they they appear as long as plasma is hot. In this connection clear to become that, from where, for example, on the surface of the sun appear powerful magnetic fields, especially when at it appear spots. These fields are induced by those currents, which overflow between the regions of plasma, which have a different temperature.

We in sufficient detail examined the behavior of the static charge above the conducting plane. But in actuality there is not a static charge, but a charge, which lives only several hundred nanoseconds. Therefore the processes of short-term generation and disappearance of charge are differed from those, which are examined. The carried out analysis was directed toward that so that it is better to understand the kinematics of process itself.

If in the origin of coordinates is located the charge of , depending on time, then the electric fields, created by it in the surrounding space, can be found from the relationship:

$$\varphi(r,t)=\frac{Q(t)\left(t-\frac{r}{c}\right)}{4\pi\varepsilon r} \tag{6}$$

to which correspond the being late longitudinal electric fields:

$$E(r,t)=\frac{Q(t)\left(t-\frac{r}{c}\right)}{4\pi\varepsilon r^2}. \tag{7}$$

In accordance with relationships (6, 7) the short-lived charge generates so short-term a pulse of longitudinal electrical pour on, which in the space are extended with the speed of light and is formed the spherical layer, whose thickness is equal to the lifetime of charge, multiplied by the speed of light. If we consider that for our case the time of life of charge composes the half-width of pulse PEF (somewhere about 100 ns), then the thickness of this layer will be about 30 m. Spherical layer, first of the ionosphere, the earth will and then direct there the same radial currents, as if static charge appeared and, after existing 100 ns, it disappeared.

As was already said, analyzing the topology of pulse PEF, it is possible to judge about the temperature of plasma and the processes of proceeding in it. This method can be used also for diagnostics of other forms of plasma. For plasma itself there is no difference whatever in by what form of its energy they is important only quantity of free electrons, i.e., the degree of ionization, which depends on the final temperature of plasma. Laser warming-up is considered as the promising method of its warming-up for realizing of thermonuclear fusion. In this case the samples under investigation undergo the action of powerful laser pulse. Model in short time is converted into the high-temperature plasma, i.e., there is a certain similarity of the behavior of plasma with the nuclear explosion. For these purposes it suffices to surround sample under investigation by two conducting screens and to connect between them high-speed to oscillograph with the high input resistance. External

screen in this case should be grounded. At the moment of the warming-up of plasma by laser beam will arise IEP. Moreover a potential difference between the screens will arise much earlier than the material particles of plasma they will reach the walls of the first screen. Studying the topology of the recorded pulse, it is possible to judge the temporary energy processes of the warming-up of plasma. It is not difficult to calculate the expected potential difference between the screens depending on the temperature and quantities of free charge carriers in the plasma. After using relationships (5) and (7) for the case, when $k_Б T \ll mc^2$ we obtain:

$$U \simeq \frac{Nek_Б T}{4\pi\varepsilon_0 mc^2}\left(\frac{1}{r_1^2}-\frac{1}{r_2^2}\right),$$

where r_1 and r_2 - radii of external and internal screens respectively, and N - quantity of free electrons in the heated plasma.

The fact of the presence of excess electrons should be considered, also, with realizing of controlled thermonuclear fusion, since this phenomenon must influence also the stability of plasma with its warming-up.

It should be noted that despite the fact that nuclear explosions are studied already sufficiently long ago, however, until now, not all components of the development of this process obtained its explanation. Such processes include so those called rope trick, which was investigated John Malik.

In Fig. 7 and Fig. 8 are represented the photographs of cable it is special effect. These photographs removed American photographer Harold Edgerton by automatic camera, which is been located at a distance of 11.2 km of from the epicentre of explosion with the periodicity of survey 100 ms.

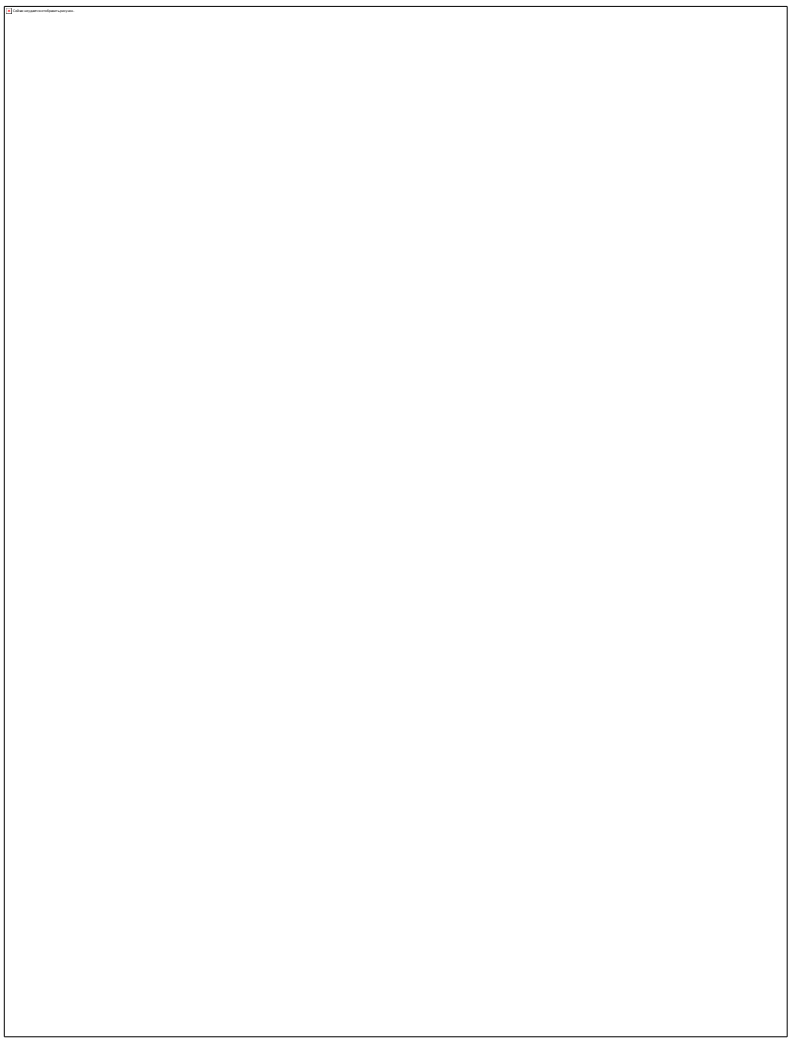

Fig. 7. Initial phase of the development of the cloud of explosion.

in Fig. to 7 is presented the initial phase of the development of the cloud of the explosion of charge, located on the metallic tower with the stretchings from the wire cables. Already it is evident on the initial phase of explosion that in the upper part of the cloud of explosion are three spinous formations.

the same shafts is especially well visible in the upper photograph (Fig. 8. Towers in this photograph already barely it remained, but it is evident that the shaft of large diameter, which exits to the earth, pierces it. Smaller two shafts are extended in the direction of the stretching ropes.

In the photographs is evident that the diameter of shaft grows with an increase in the volume of the cloud of explosion. Especially good this is evident in the lower

photograph Fig. 8, when the cloud of explosion already touched the earth. The shaft, located in the lower left side of the cloud of explosion, which exits to the earth, has already considerably larger diameter, than in the upper photograph.

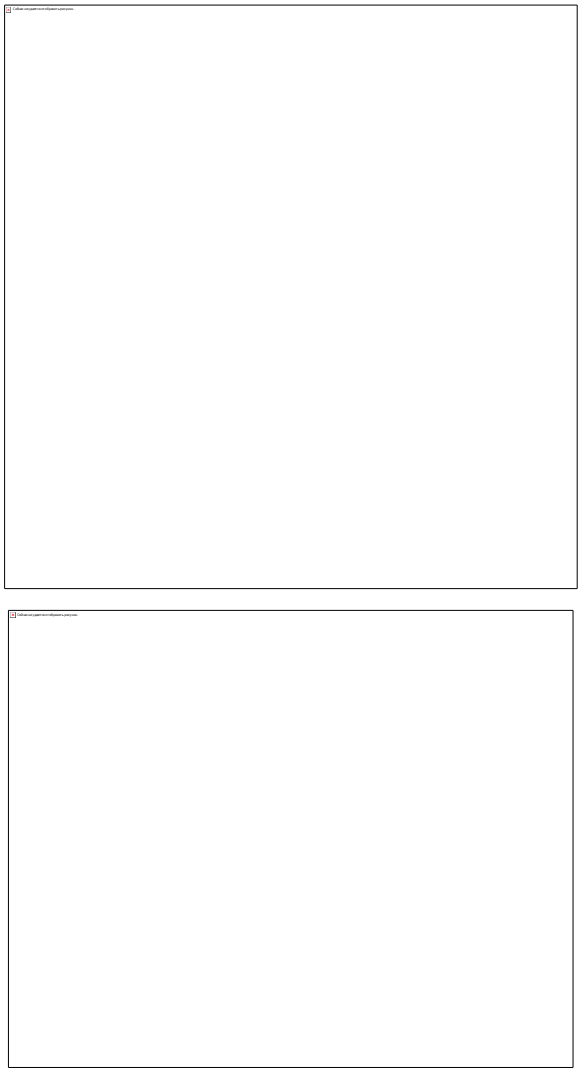

Fig. 8. Subsequent phases of the development of the cloud of explosion. Periodicity of semki 100 ms.

This phenomenon attempt to explain by the fact that powerful gamma-radiation of the cloud of explosion melts ropes, converting them into the plasma. It even attempted to bring the reflecting coatings to the ropes, which decreased, and in certain cases even liquidated this phenomenon. But this idea is not very productive,

since the ropes of stretchings go practically in parallel to light rays; therefore they cannot be heated strongly by emission.

Is certain that that the ropes and tower are guiding elements for the appearance of shafts, it is clearly evident in upper Fig. 8. Moreover, this photograph finally removes version about the fact that the ropes by the emission of the cloud of explosion. It is evident in the photograph that the luminosity of shafts is higher than in cloud itself, and means their temperature also higher. But, if they by the emission of cloud itself, then their temperature cannot be higher than its temperature. Consequently, must be some additional sources of the warming-up of ropes.

in the photograph is distinctly evident that the temperature of shafts is much higher than the temperature of the cloud of explosion. Their large quantity is connected, apparently with existence of the additional stretchings of the tower, where explosion was accomplished.

It is evident in the photographs that all visible shafts directly proceed from the cloud of explosion.

Even the more impressive photograph of the formation of the cloud of explosion and shafts is shown in Fig. 9.

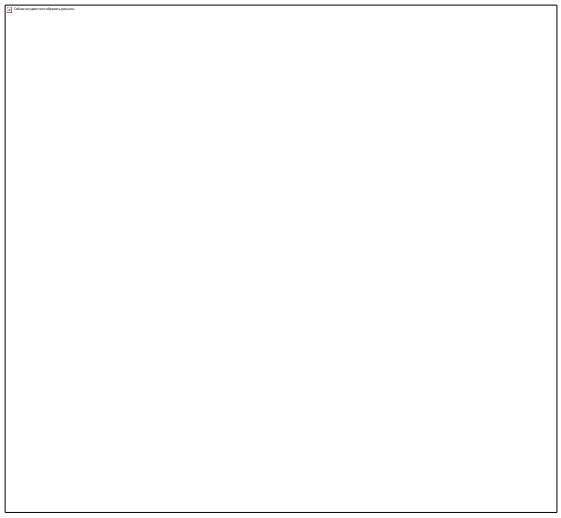

Fig. 9. Cloud species of explosion after 1 ms after the detonation of nuclear charge, time of exposure 1 s.

Therefore follows to assume that the warming-up of ropes it is connected with the advent of the equivalent charge of the explosion, which as along the lightning conductor departs through the ropes to the earth them. Since the part of the rope closest to the plasmoid is hottest, specific resistance in its this part is more than in the remaining parts of the rope. Therefore a basic voltage drop will precisely fall in this section, and, therefore, and to be melted it will begin from this place. Moreover, those sections of rope and tower itself, which are converted into the plasma, also add some quantity of excess electrons, which must be somewhere rejected. Therefore 3 \ the phenomenon is connected with the appearance of the equivalent charge of the explosion, which through the ropes and tower departs to the earth.

The appearance of the induced equivalent charge of explosion, and it, is as shown higher, it has very high value, it will melt not only the ropes of stretchings and tower. Very high currents will be induced on the earth's surface radial with respect to the epicentre of explosion, and also in the conducting elements of those located above the earth's surface and buried into the earth, which presents the specific danger with the ground-based or air nuclear explosion.

in the confirmation of the fact that the excess electrons are formed upon transfer from solid state to the state of plasma, let us lead one additional phenomenon, which is connected with the explosion of H-bombs, not received its thus far explanation. During the formation of the cloud of explosion from it to the side of the earth they beat lightning.

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