Electric pulse of nuclear and other explosions

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Abstract

Explosive processes are characterized by the fast separation of significant thermal energy, with which occurs the strong warming-up of decay products and is formed plasma. Depending on the type of explosion the plasma can have different degrees of ionization. With the nuclear explosions, when the temperature of plasma can reach several million degrees, the degree of ionization of plasma is high. With the realization of explosions by means of the conventional explosives cold plasma with the low degree of ionization is obtained. In either case the consequence of explosive processes is not only fast separation of significant thermal energy, but also emission in the wide frequency range. With the explosions of nuclear charges is formed also electric pulse with the high tension of the electric field, whose physical nature up to now completely is impossible to understand. To the examination of electrodynamic of processes, proceeding with the explosion is dedicated the proposed article.

1. Electric pulse of nuclear explosions

The explosion we will call the rapid warming-up of substance, which occurs with the detonation of the explosives, when cold or hot plasma is formed. With the explosions of nuclear charges is formed the hot strongly ionized plasma, whose temperature can reach several million degrees. With the explosion of usual charges of the type of trotyl the temperature of the products of explosion reaches several thousand degrees, in this case is formed the cold plasma, the degree of ionization by which is low.

According to the program *Starfish* USA exploded in space above Pacific Ocean H-bomb. The consequences of explosion were catastrophic. 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 of 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. 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 Telestar. On the whole explosion derived from system third of the automatic spacecraft, which were being found in low orbits at the moment of explosion.

This event placed before the scientific community many questions. It is earlier into 1957 future Nobel laureate doctor Hans Albrecht Bethe, being based on the theory of dipole emission, predicted that with a similar explosion will be observed the electromagnetic pulse (EMP), the strength of field of which on the earth's surface will comprise not more than 100 V/m. 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)

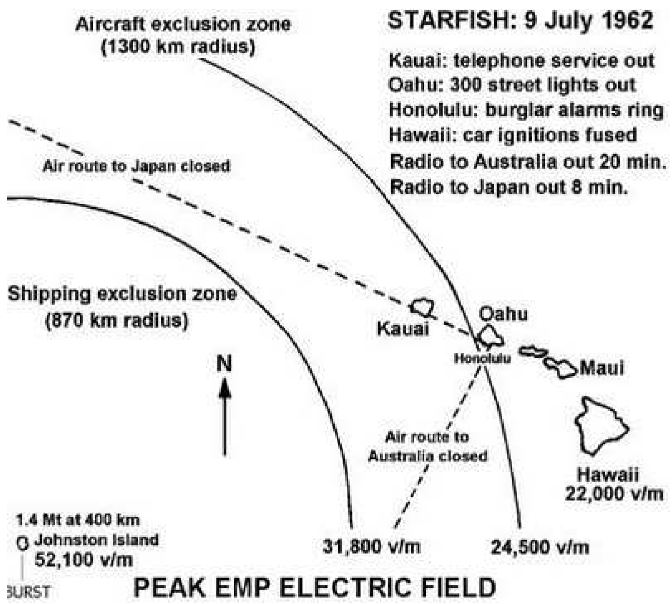

Fig. 1. Map of tests according to the program *Starfish*.

Possibility to refine this question give the data, obtained in the USSR during the tests with the code name *Program K*, 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

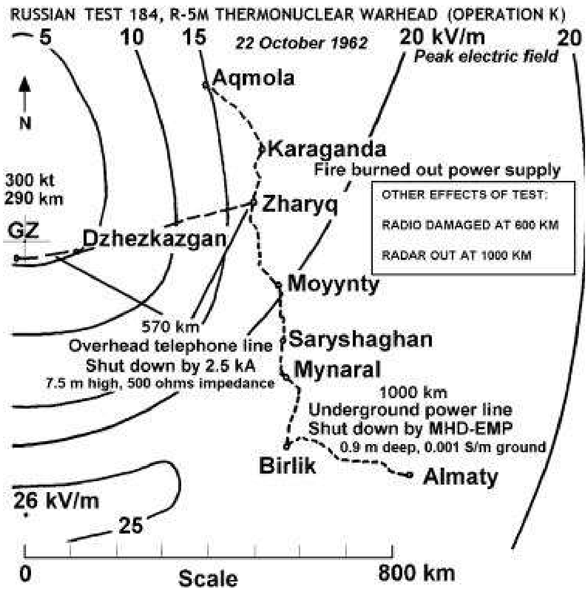

Fig. 2 Map of tests according to the program *Program K.*

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 EMP has not only very large amplitude, but also very short duration.

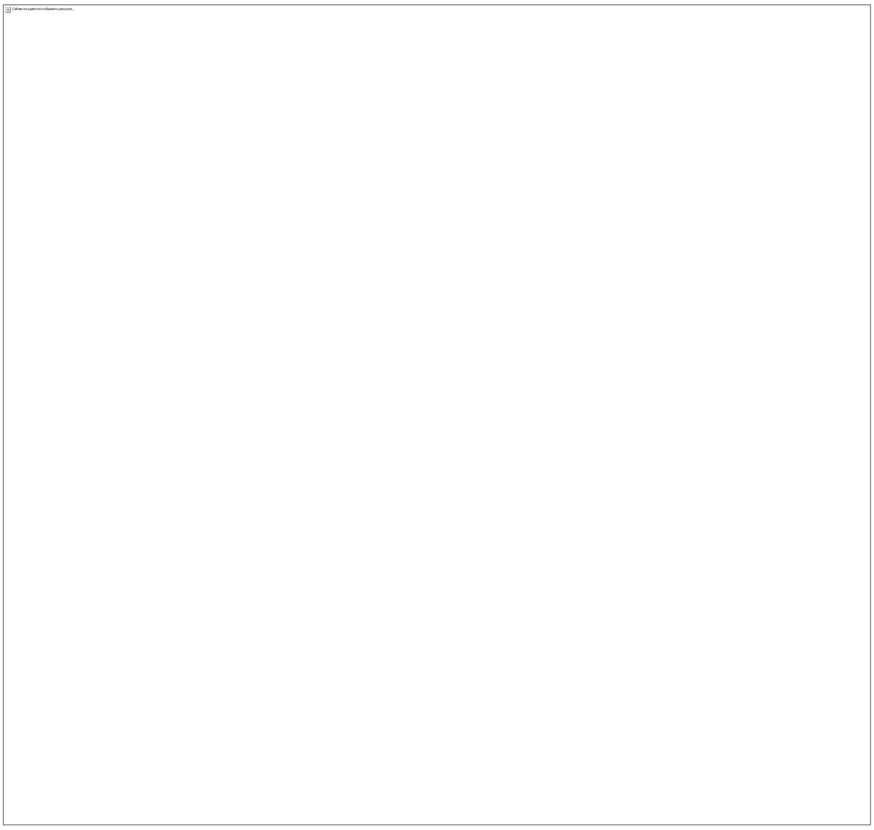

Fig. 3. Experimental dependence of amplitude EMP on the time, obtained with the tests according to the program *Starfish.*

Until most recently in the scientific journals was absent article with the explanation of this phenomenon. This indicates that the fact that there is no theory, which could give answer to the presented question. And only in 2013 in the periodical engineering physics appeared the first publication, in which was given an attempt at the explanation of the phenomenon [1]. In the work it is shown that as a result nuclear explosion appears not the electromagnetic, but electric pulse, the vector of electric field of which is directed toward the point of impact. For explaining physical nature of electric pulse are used the concept of scalar- vector potential, the assuming dependence of the scalar potential of charge on its relative speed. This concept is developed in works [2-7].

Is known that the problem of this phenomenon attempted together with his students to solve and academician I. B. Zeldovich [8]. However, in the existing sources there is no information about the fact that this problem was solved by it.

In the concept of scalar-vector potential, the scalar potential of charge it is determined from the relationship

$$\varphi(r) = \frac{g\ ch\frac{v_\perp}{c}}{4\pi\ \varepsilon_0 r}, \qquad (1)$$

where r - the distance between the charge and the observation point, $v_\perp$ - the component of the charge rate g, normal to the vector $\vec{r}$, ε_0 - dielectric constant of vacuum.

According 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 Boltzmann distribution. The most probable electron velocity in this case is determined by the relationship

$$v = \sqrt{\frac{2k_Б T}{m}}, \qquad (2)$$

where T - temperature of plasma, $k_Б$- Boltzmann constant, m- the mass of electron.

Using relationships (1) and (2), and taking into account with the expansion in the series of hyperbolic cosine the terms ~ $\frac{v^2}{c^2}$, we obtain the value of increase in the scalar potential at the observation point

$$\Delta\varphi \cong \frac{Nek_Б T}{4\pi\varepsilon_0 rmc^2}, \qquad (3)$$

where N - quantity of electrons in the cloud of explosion, e- electron charge. We determine from the formula the tension of radial electric field, which corresponds to this increase in the potential:

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

where

$$\Delta q = \frac{Nek_Б T}{mc^2} \tag{5}$$

is a nonequilibrium charge of explosion. By this value it is necessary to understand increase in the charge of the cloud of explosion.

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.

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} .

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 ~ 7.8×10^5 V/m at a distance 870 km from this place it is ~ 1.65×10^5 V/m and at a distance 1300 km it is ~ 7.3×10^4 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 - 15, at a distance 870 km from this place - 5, at a distance 1300 km - 3. 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].

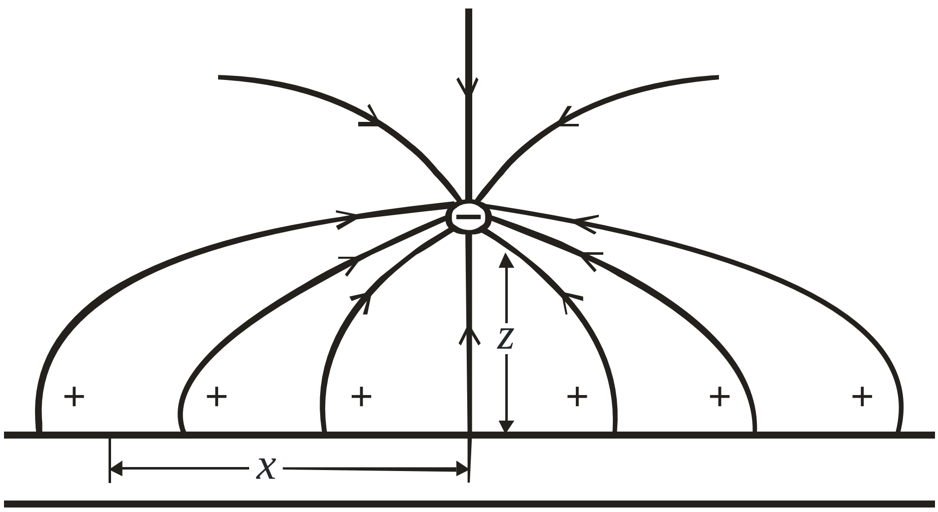

Fig. 4. Negative charge above the limitless conducting plane.

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

$$E_{\perp} = \frac{1}{2\pi\varepsilon_0} \frac{zq}{\left(z^2 + x^2\right)^{\frac{3}{2}}}, \tag{6}$$

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, but this configuration pour on equivalent to the presence under the conducting plane of the positive charge of the same value and at the same distance as initial charge. The pair of such charges presents the electric dipole with the appropriate distribution of electrical pour on. 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 can be determined from the relationship:

$$\sigma(x) = \varepsilon_0 E_{\perp} = \frac{1}{2\pi} \frac{zq}{\left(z^2 + x^2\right)^{\frac{3}{2}}}. \qquad (7)$$

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. In this case two cases can realize. With the low charge density, which occurs in the poor conductors, it will arrive to move up to the significant distances significant quantities of charges. With the high charge density, it is possible to only insignificantly move charges in the plane. This case realizes in the metallic conductors.

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 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 chargex in the ionosphere will be less than the value of charge itself, or their displacement is insufficient in order to fall into the necessary point at the assigned moment, 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.

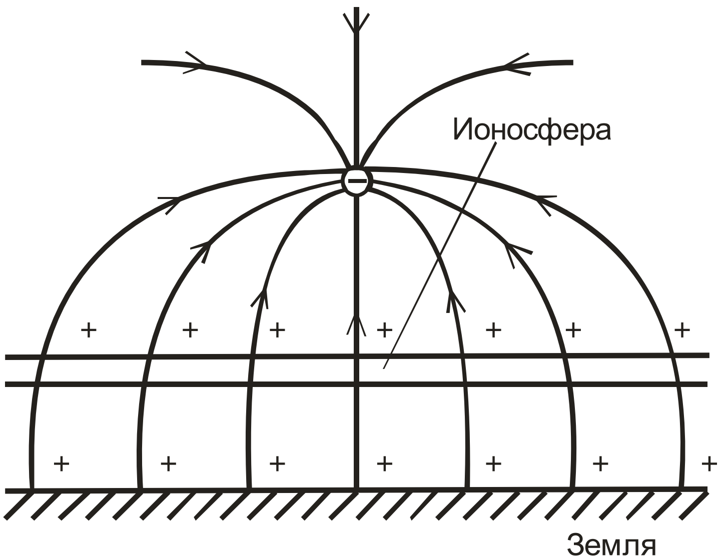

Fig. 5. Negative charge above the earth's surface with the presence of the ionosphere.

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 .

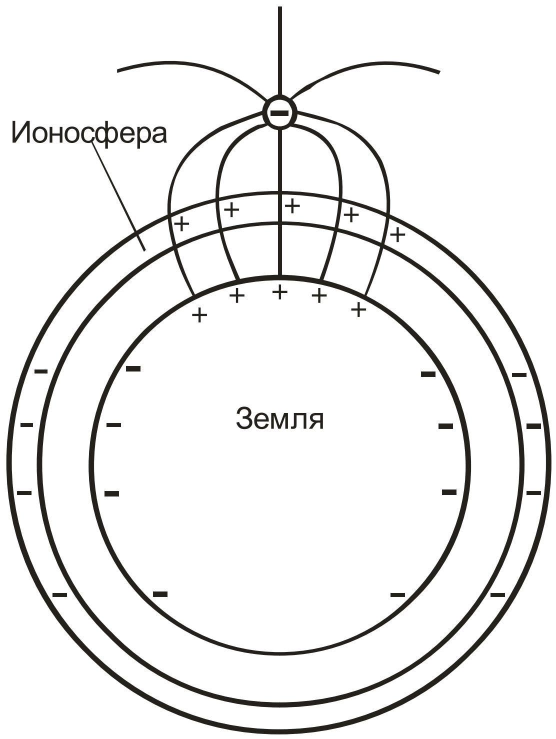

Fig. 6. Negative charge above the earth's surface with the presence of the ionosphere.

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 model examined speaks, that nuclear explosion will lead not only to the appearance IEP in the zone of straight visibility, but also to the global ionospheric disturbance. Certainly, electric fields in space in the environments of the explosion, where there is no screening effect of the ionosphere, have high values and present large danger to the automatic spacecraft.

Now let us be turned to Fig. 2 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 IEP lasts in all ~ 100 ns. 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.

The carried out analysis attests to the fact that the appearance EMP 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 presence of the pulse indicated they are the properties of explosion itself, but not second phenomenon.

Now should be made one observation apropos of term itself the electromagnetic pulse EMP, 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 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. If we consider that the time of detonation is equal to 50 ns, then explosive force composes ~1.3×10^{23} W. Let us say for an example that the power of the radiation of the Sun of ~3.9×10^{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 $\sigma = 5.67 \cdot 10^{-8}$ W/m^{2}K^4 - Stefan-Boltsman constant, and s- area of radiating surface.

If we take the initial temperature of the plasmoid of ~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 of ~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

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

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

Is known that the explosion of nuclear charge is accompanied by emission in the very wide frequency band, beginning from the rigid X-radiation and concluding by the long-wave range of radio frequencies. One should assume that for the emission in the X-ray and light range the processes, adjusted by Stefan-Boltzmann, are critical law. However, the presence of emission in the region of radio frequencies is obliged to the wide radiation spectrum of electric pulse. In this connection one cannot fail to note one important circumstance, which characterizes the propagation of the electric pulse of explosion. With the explosions, achieved in immediate proximity to the earth, the pulse amplitude very rapidly diminishes with the distance. But this completely corresponds to the case of the electric dipole, which is formed because of the screening effect of the conducting earth's surface, since the fields of this dipole are inversely proportional to the cube of distance.

The results, obtained in this paragraph, require the serious revision of a whole series of positions in existing physics.

2 Electric pulse of other explosions

If the principle of the formation of electric pulse examined is accurate, then the usual explosions, with which is formed cold plasma, they must be accompanied by the appearance of electric pulse, although less intensive than with the nuclear explosion.

The disintegration of the molecule of trotyl with its detonation occurs according to the following diagram:

$$C_7H_5O_6N_3 = 2H_2O + 3.5CO + 1.5N_2 .$$

If each of the molecules, that was released during explosion will be singly ionized, then upon decay the molecule of trotyl will be isolated 7 free electrons. Consequently, with the detonation of one mole of trotyl will be isolated $7N_A = 4.2\times10^{24}$ of the electrons, where N_A - Avagadro number. With the explosion of trotyl the temperature of the cloud of explosion reaches 3500K. If all molecules of disintegration obtain single ionization, then the maximum strength of field of electric pulse composed

$$E = 3.7\times10^9 \frac{1}{r^2} \text{ V/m}$$

at a distance 100 m from the point of impact this value there will be the wound 3.7×10^5 V/m, and if the degree of ionization composes only 0.01%, will be and even then obtained the strength of the field 37 V/m, which is completely sufficient for registering the pulse. The importance of this method consists in the fact that by studying the topology of pulse, it is possible to judge the knocking processes and subsequent relaxation of the cloud of explosion.

Thus, we come to the conclusion that in those places, where the plasma of any form is born, must appear electric pulse. Moreover the amplitude of this pulse strongly depends from the distance to the place of origin of plasma. It is known that the electro-welding creates the strong radio reception disturbances, but these interferences very rapidly diminish with the distance. Micro-bursts it is possible to consider sparking in the poor contacts in the electrical networks, or in the contact systems of electric transport means. But, since the amplitude of electric pulse rapidly diminishes with the distance, electric transport does not present special interferences for the radio reception.

Forked lightning heat plasma to the high temperature and are created the radio reception disturbances. There is an opinion that very channel of lightning serves as the antenna, which radiates the radio waves over a wide range of frequencies. But so whether this? With that length, which represents the track of lightning, this antenna must have excellent characteristics and reliably emit not only in the short-wave, but also in the long-wave radio-frequency band. But this would mean that with any lightning stroke in any place of the terrestial globe in our receivers the interferences would appear. But since they second-by-second in the world beat hundreds of lightning, entire ether would be oppressed by interferences. This it does not occur for that reason, that the plasma cylinder of lightning emits not radio waves, but electric pulses from all its sections. In this case the excess charges, which arose in different sections of the channel of lightning, see their mirror reflection under the earth's surface, forming the appropriate dipoles, whose fields diminish inversely proportional to the cube of distance.

All is that which is written in this paragraph, until it has experimental confirmation. But if these guesses are confirmed, then this will open way for the new procedures of a study of the knocking processes and development of the explosion of explosives.

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