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RESEARCH OF THE INFLUENCE OF NUCLEAR EXPLOSIONS ON THE CONTENTS OF OZONE IN THE ATMOSPHERE

ИССЛЕДОВАНИЕ ВЛИЯНИЯ ЯДЕРНЫХ ВЗРЫВОВ НА СОДЕРЖАНИИ ОЗОНА В АТМОСФЕРЕ

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Abstract: The influence of the atmospheric nuclear explosions over the local changes of the general contents of the atmospheric ozone is being investigated, with respect to the fomation of ozone in the atmosphere under the influence of ultraviolet and gamma radiation from a nuclear explosion and the photochemical reactions in the explosion cloud. An evaluation of the contents of the ozone in the atmosphere is being made.

Keywords: nuclear explosions, ozone in the stratosphere

I. Introduction

In the recent years, the consequences of a possible nuclear war are broadly discussed. The following issues are emphasized: radioactive pollution of the environment [7,14], the influence on the atmosphere and climate [2,5,12,13,16], the ecological consequences [3,6,8,9,12,15], etc.

One of the first consequences from using nuclear weapons is the sonsiderable change in the atmospheric contents and more specifically: changes in the ozonosphere, which is a result of photochemical effect of the nitrogen oxides which are produced by nuclear explosions, as well as the effect of the aerosole products from the explosion. With the purpose to realize the effect of photochemical reactions of the nitrogen oxides, some experiments have been carried out which model short local influence of single powerful nuclear explosions on the ozonosphere. At a possible nuclear explosion with power 10^4 Mt, the model values of different authors [5,11,16,17] prognosticate from 30 to 70% demolition of the total ozone content and its consequent recovery in a period of 2 – 4 years. An evaluation has been done of the influence of massive atmospheric megaton classes nuclear explosions over the short term changes of the natural concentration of the ozone [5,10,15,16] as well as evaluation of the change of the ozone content in the stratosphere after a series of nuclear explosions [5,17].

II. Materials and methods

Under the influence of ultraviolet and radioactive emissions form a nuclear explosion in the atmosphere, ozone is created. After an explosion of nuclear blast, a tremendous quantity of energy is dispensed in the form of light emissions, nuclear emissions and blast wave. About half of this energy is the light and nuclear emission [4] which leads to changes in the photochemistry of the atmospheric ozone. The photochemistry model of calculation of the quantity of the produced ozone includes 26 reactions in which the following 10 elements are basically taking part: O_3, O, $O(^1D)$, N, NO, NO_2, HNO_3, H, OH, HO_2. (Table 1).

They correspond to 10 differential equations which describe the change in the concentration of ten components in the air during a period of time. The ozone equation is:

$$\frac{[O_3]}{dt} = -(j_{3_a} + j_{3_b} + k_5[O] + k_{10}[NO] + k_{13}[OH] + k_{15}[H] + k_{17}[HO_2])[O_3] + \\ + G_2 + k_3[O][O_2][M]. \quad (1)$$

where: j_{3_a} - speed of photo dissociation of O_3 with formation of O in stationary state;

j_{3_b} - speed of dissociation of O_3 with formation of $O(^1D)$;

k_i - coefficient of the speed of the $i^{-\text{th}}$ chemical reaction;

G_2 and G_6 – parameters which describe the influence of the radioactive emission into formation of O_3 and N.

The equations for the other contents are similar. The change of the ozone concentration in time is defined by integration of a system of differential equations. The parameters, included in the system, are defined preliminarily. The coefficients for the speed of the reactions k_i are taken [1]. The speed of the photodissociation j_i describes the influence of the ultraviolet emission on the photodissociation of the ith component.

Table 1

N	reactions	Coefficient of the reaction speed
1	$O_2 + h\nu \rightarrow 2\,O$	j_2
2	$\begin{cases} O_2 + \gamma \rightarrow 2O \\ O_2 + \gamma + M \rightarrow O_3 + M \end{cases}$	g_2 = 4 mol/100 эв
3	$O_2 + \gamma + M \rightarrow O_3 + M$	$k_3 = 5{,}6.10^{-34}(300/T)^{2{,}36}$
4	$\begin{cases} O_3 + h\nu \rightarrow O + O_2 \\ \ldots\ldots\ldots \rightarrow O_2 + O(^1D) \end{cases}$	j_{3a}
		j_{3b}
5	$O_3 + O \rightarrow 2\,O_2$	$k_5 = 2.10^{-11}\exp(-2280/T)$
6	$N_2 + \gamma \rightarrow N + N$	g_6 = 3 mol/ 100 эв
7	$N + O_2 \rightarrow NO + O$	$k_7 = 4{,}4.\ 10^{-12}\exp(-3220/T)$
8	$N + NO \rightarrow N_2 + O$	$k_8 = 3{,}4.\ 10^{-11}$
9	$NO_2 + h\nu \rightarrow O + NO$	j_9
10	$O_3 + NO \rightarrow O_2 + NO_2$	$k_{10} = 2{,}3.10^{-12}\exp(-1465/T)$
11	$O + NO_2 \rightarrow NO + O_2$	$k_{11} = 9{,}3.10^{-12}$
12	$OH + NO_2 + M \rightarrow HNO_3 + M$	$k_{12} = 2{,}6.10^{-30}(300/T)^{2{,}7}$
13	$O_3 + OH \rightarrow HO_2 + O_2$	$k_{13} = 1{,}6.10^{-12}\exp(-940/T)$
14	$O + OH \rightarrow H + O_2$	$k_{14} = 3{,}8.10^{-11}$
15	$O_3 + H \rightarrow OH + O_2$	$k_{15} = 1{,}4.10^{-10}\exp(-480/T)$
16	$O + HO_2 \rightarrow OH + O_2$	$k_{16} = 3{,}1.10^{-11}$
17	$O_3 + HO_2 \rightarrow OH + 2O_2$	$k_{17} = 1{,}4.10^{-14}\exp(-600/T)$
18	$H + HO_2 \rightarrow 2\,OH$	$k_{18} = 3{,}2.10^{-11}$
19	$H_2O + O(^1D) \rightarrow 2\,OH$	$k_{19} = 1{,}4.10^{-10}$
20	$OH + OH \rightarrow H_2O + O$	$k_{20} = 1{,}0.10^{-11}\exp(-500/T)$
21	$HO_2 + NO + M \rightarrow HNO_3 + M$	$k_{21} = 3{,}3.10^{-33}$
22	$HNO_3 + h\nu \rightarrow OH + NO_2$	j_{22}
23	$OH + HO_2 \rightarrow H_2O + O_2$	$k_{23} = 3{,}5.10^{-11}$
24	$O(^1D) + O_2 \rightarrow O + O_2$	$k_{24} = 3{,}7.10^{-11}\exp(67/T)$

25	$O_2 + H + M \rightarrow HO_2 + M$	$k_{25} = 5{,}0.10\text{-}^{32}(300/T)$
26	$HO_2 + NO \rightarrow OH + NO_2$	$k_{26} = 4{,}3.10^{-12}\ \exp(-200/T)$

The parameters G_2 and G_6 are defined, using the fact that when the radioactive emission passes through the air, ozone and atom nitrogen are produced and the chemical result of the ozone (g_2) and the atom nitrogen (g_6) can be considered 4 and 3 molecules respectively for 100 eV absorbed energy.

For a blast with power 1 Mt at 5 km height, the duration of shining of the fire ball is approximately Δt = 10 s. For the duration of the shining 2% gamma emission is liberated from the blast energy. Alfa and beta emissions have little radius of effect on the air and because of this, they are not taken into consideration. The passing of the gamma emission through the air is described by an exponential law:

$$\text{where: } R_0\, E = E_0 \exp[-\alpha(R - R_0), \tag{2}$$

– radius of the fire ball;

α – coefficient which characterizes the decrease of the gamma emission in the air;

E – energy which carries the gamma emission, leaving the boundary of the blast sphere with radius R;

E_0 – the whole energy of gamma emission for the duration of the shining of the fire ball.

Quantity of energy which is absorbed for a unit of volume for different distances from the center of the blast:

$$E^{|} = \frac{\Delta E}{\Delta V} = \frac{E_0 \alpha \exp[-\alpha(R - R_0)}{4\pi R^2}. \tag{3}$$

When we know the consumed energy ($E^{|}$), we can estimate how much ozone and atomic nitrogen are produces for a unit of time.

$$G_2 = \frac{E^{|} g_2}{\Delta t} \qquad \text{and consequently} \qquad G_6 = \frac{E^{|} g_6}{\Delta t}. \tag{4}$$

The temperature of the fire ball for the time of illumination is decreased from 10000 K to 2000 K, or the average temperature is T = 6000 K, i.e. the illumination spectrum of the fire ball corresponds to the illumination spectrum of the absolute black substance at a certain temperature and it can be described by the formulae:

$$\varepsilon = \frac{2\pi c^2}{\lambda^5} \cdot \frac{h}{l^{hc/KT\lambda} - 1}, \tag{5}$$

where: c – speed of light;

λ – wave length of radiation;

h – Plank's constant;

K – Bolzman's constant;

T – temperature (T = 6000 K).

The spectral intensity of the blast can be defined at a distance R from the center of the fire ball:

$$I_R = \frac{A\varepsilon}{S\Delta t} \cdot \frac{\lambda}{hc}, \tag{6}$$

where: $S = 4\pi R^2$

A – constant, which is defined by the condition that the integral (from I_R) on the whole radiation spectrum is 1/3 from the energy of the nuclear blast (only the energy, produced from the illumination of the nuclear blast).

When the ultraviolet radiation decreases when it passes through the air, the speed of photodissociation can be described:

$$j_i(R) = \int_{\lambda_1}^{\lambda_2} \frac{A\varepsilon}{S\Delta t} \cdot \frac{\lambda}{hc} \exp[-K_\lambda (R - R_0)] \sigma_i(\lambda) d\lambda, \tag{7}$$

where: σ_i - section of the photodissociation of the $i^{\text{-th}}$ component.

The coefficient K_λ is defined:

$$K_\lambda = N_2 \sigma_2(\lambda) + N_3 \sigma_3(\lambda) + N_m \sigma_m(\lambda) \tag{8}$$

where: N_2, N_3, N_m – content of molecules O_2, O_3 and air in an unit of capacity;

σ_2, σ_3, σ_m – section of photodissociation of O_2, O_3 and section of molecular diffusion.

With receding from the center of the blast, the values of the above mentioned parameters are changed. When the distance from the center of the blast changes from 1 to 5 км the ozone concentration gradually decreases from $6{,}8.10^{14}$ mol/sm^3 to the natural concentration of the ozone at the height of the blast (H = 5 км). The total content O_3 in the spherical layer $1 \le R \le 5$ км is N_{O_3} = 5.10^{30} mol/1 Mt [11].

III. Conclusions:

It can be concluded that the influence of the ozone, which is produced by the ultraviolet and radioactive radiation, in the total balance of the ozone in the stratosphere is insignificant when modeling the influence of nuclear blasts.

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В статье исследуется влияние атмосферных ядерных взрывов на общие содержания атмосферного озона. Дана оценка содержания озона в атмосфере в результате влияния ультрафиолетовых излучений, радиационной гаммы от ядерного взрыва и фотохимических реакций в облаке взрыва. Ключевые слова: ядерный взрыв, озон в стратосфере.

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Мақалада атмосферадағы ядролық жарылыстың атмосфералық озонның мөлшеріне әсері зерттелген. Атмосфералық озон мөлшері ультракүлгін шағылыстың, ядролық жарылыстың радиациялық гамма және жарылыс бұлтындағы фотохимиялық реакция әсері арқылы бағаланған. Түйінді сөздер: ядролық жарылыс, стратосферадағы озон.

МЕХАНИЗАЦИЯ И ЭЛЕКТРИФИКАЦИЯ СЕЛЬСКОГО ХОЗЯЙСТВА

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РАСЧЕТ ТРЕХФАЗНЫХ СИСТЕМ С УГЛООБРАЗНЫМИ ЭЛЕКТРОДАМИ И ПЕРЕМЕННЫМ МЕЖЭЛЕКТРОДНЫМ РАССТОЯНИЕМ

CALCULATION OF THREE-PHASE SYSTEMS WITH ANGLED ELECTRODES AND VARIABLE INTERELECTRODE DISTANCE

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Предложена трехфазная система с углообразными электродами и переменным межэлектродным расстоянием для использования в водонагревателях сельскохозяйственного назначения. Выведена формула для определения оптимального значения угла установки взаимодействующих электродов относительно друг друга, при котором достигается равномерное распределение плотности тока, способствующее повышению надежности работы и срока службы водонагревателя. Разработана методика расчета параметров предложенной электродной системы.

Как известно, в электродных системах с постоянным межэлектродным расстоянием, используемых в проточных водонагревателях, имеет место неравномерное распределение плотности тока по их высоте [1]. Это обусловливает неравномерный износ электродов и появление зон с повышенной электрической напряженностью.

В связи с этим определенный научный и практический интерес представляют предлагаемые нами трехфазные электродные системы с переменным межэлектродным расстоянием.

Предлагаемая трехфазная система состоит из трех углообразных электродов, изогнутых под углом 120º (рисунок 1). Каждый электрод имеет два крыла с общим ребром. Причем, каждое крыло выполнено в форме прямоугольной трапеции с широким b_2 и узким b_1 основаниями. Электроды в корпусе располагаются широкими основаниями вниз, симметрично относительно соответствующих радиальных вертикальных плоскостей, смещенных относительно друг друга на 120º. При этом плоскости взаимодействующих между собой крыла электродов разных фаз располагаются под углом θ.

По мере увеличения межэлектродного расстояния l происходит плавное уменьшение ширины b крыла электрода от b_2 до b_1.

Закономерность изменения b можно выразить следующим образом:

$$b = b_2 - \left(\frac{l}{2} - \frac{l_2}{2}\right) tg30^0 = b_2 - \left(l - r_2\right) \sin\frac{\theta}{2} tg30^0 \qquad (1)$$

Поскольку при небольших углах θ $\sin\frac{\theta}{2} \approx \frac{\theta}{2}$, то