MODEL OF THERMAL BALL LIGHTNING

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Many ball lightning (BL) observations show that natural BLs have thin sheath and their destruction takes place with explosion. Our experiments on creation of artificial BL showed that some of such BL have a sheath of ~10 mcm filled with vapor. This allows to present the following model of BL. Impact of the linear lightning (or high power discharges) to different materials – organic and inorganic (soil metallic object) leads to creation of long-lived luminescent object with a sheath (thin solid or liquid layer) filled with a vapor of these materials. Such object possess non-compensated electric charge due to charging by linear lightning or streamer discharge. BL charge is realized in a form of atomic ions inside the sheath. This object can possess energy of evaporated gas, be: spherical like a bubble, unipolarly charged with capability to levitation, luminescent due to high temperature and plasma created at its surface at high values of transferred electric charge. This object we consider as BL.

The pressure balance $P_{at}+P_{pol}+P_{Lap}=P_C+P_{gas}$ (1). $P_{pol}=\dfrac{\sigma q a}{2\cdot\pi\cdot\varepsilon_0\cdot r^3}$ -pressure of the polarization forces when a dipole layer is created on a dielectric case (σ-is the surface density of charges on the dielectric surface) , $P_C=\dfrac{q^2}{2\cdot(4\pi)^2\cdot r^4\,\varepsilon\,\varepsilon_0}$ is the Coulomb charges rejection pressure acting the case, the pressure of the surface tension $P_{Lap}=2\cdot\alpha/r$, α - melted material surface tension coefficient, r - the radius of the sphere; $P_{gas}=N_a k T_a$, is the gas pressure inside the sphere. N_a is the concentration of the vapor atoms, T_a - their temperature, a is the thickness of the sheath, P_{at} is the atmospheric gas pressure, ε_0, k - the dielectric and Boltzmann constants. Main energy of this object due to evaporation of material can be estimated by the equation $E=m_a\cdot\dfrac{P_{gas}}{kT}\cdot\lambda$ (2), λ - is enthalpy of vaporization, m_a - mass of an atom, n_a - number of atoms, $m_{BL}=m_a\cdot n_a$ - BL mass. At interaction of linear lightning with the Earth, one can consider Si as the main material, $\lambda\approx 3.3\cdot10^7$ J/kg, T_a = 2600 K or atomized water with $\lambda\approx$ 2.73 $\cdot10^7$ J/kg.

Levitation of BL at height x and E_{lev} value of external electric field $m_{BL}g+\dfrac{1}{16\pi\varepsilon_0}\dfrac{q^2}{x^2}=E_{lev}q$ (3) (for estimates we considered thunderstorm electric field E_{lev}=5000 V/m). BL luminescence can be of two kinds –equilibrium and non-equilibrium due to plasma created at the surface. Equilibrium luminescence radiation can be determined $t_x=\dfrac{P_{gas}\cdot r}{8\cdot\sigma_{SB}\cdot T_1^4}$ .T_1 – temperature of cooled BL, σ_{SB} -Stefan Boltzmann constant. $t_x=356$ s for P_{gas} $=10^8$ Pa, T_1= 500 K, at r=0.1 m, and $t_x=3560$ s at r=1 m. Time of BL discharging ~144 s due ions drift to BL surface. At high level of electric charge (q~10^{-2} Q) time of Debye layer decrease in vicinity of BL 10^{-10}- 10^{-11}s, (BL RF electric field).

Table. Parameters of BL at solution of (1) and (2) and (3).

r, cm	a, cm	σ, Q/m^2	q, Q	P_{gas}, Pa	E, J/m^3	m_{BL}, kg	x, m
10	0,1	1,5	0,002	$3\cdot10^7$	$1.3\cdot10^9$Si, $1.0\cdot10^9$water	0,3	1.13