Electric Hypersonic Space Aircraft

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Abstract

Aviation, in general, and aerospace in particular needs new propulsion systems which allow a craft to reach high speeds by cheaper and more efficient methods. Author offers a new high efficiency propulsion system using electrons for acceleration of the craft. As this system does not heat the air, it does not have the heating limitations of conventional air ramjet hypersonic engines. Offered engine can produce a thrust from a zero flight speed up to the desired escape velocity for space launch. It can work in any planet atmosphere (gas, liquid) and at high altitude. The system can use apparatus surface for thrust and braking. For energy the system uses high voltage electricity which is not a problem if you have an appropriate electrostatic generator connected with any suitable engine. The new propulsion system applies to hypersonic long-range aviation, for launch of space craft and as a high efficiency rocket in solar space. This can be actualized using current technology.

Key words: Electron propulsion, hypersonic propulsion, space propulsion, ABEP.

1. INTRODUCTION

Let us consider the status of the problem succinctly.

Aviation and space launch. In the last half century, development of aviation and space launch proceeded very slowly. The last major advance in aviation was the introduction of the reactive engine. Space launch started using a chemical rocket and is still using it at the present time. For more than thirty years, employing the same old engines researchers unsurprisingly come up against the same barriers which do not allow significantly improving flight. Specifically, supersonic aircraft has high fuel consumption and chemical rocket engine is limited by the chemical energy of the rocket fuel.

Currently, turbojet engines are widely used in aviation. Although they are good for subsonic speed, they are worse for small ($M < 2 \div 3$) supersonic speed and has tremendous difficulties achieving hypersonic speed ($4 < M < 6$). The current designs of ramjet hypersonic engines using high temperature compressed air are limited because current materials cannot withstand any greater temperature. Another significant limitation is that hypersonic aircraft must use complex expensive hydrogen fuel [1]-[19].

A jet engine is a reaction engine that discharges a fast moving jet which generates thrust by *jet propulsion* in accordance with Newton's laws of motion. This broad definition of jet engines includes turbojets, turbofans, rockets, ramjets, and pulse jets. In general, most jet engines are internal combustion engines.

In common parlance, the term *jet engine* loosely refers to an internal combustion air breathing jet engine (a *duct engine*). These typically consist of an engine with a rotary (rotating) air compressor powered by a turbine ("Brayton cycle"), with the leftover power providing thrust via a propelling nozzle. These types of jet engines are primarily used by jet aircraft for long-distance travel. Early jet aircraft used turbojet engines which were relatively inefficient for subsonic flight. Modern subsonic jet aircraft usually use high-bypass turbofan engines which offer high speed with fuel efficiency comparable (over long distances) to piston and propeller aero-engines [24].

Hypersonic transport. While conventional turbo and ramjet engines are able to remain reasonably efficient up to Mach 5.5, some ideas for very high-speed flight above Mach 6 are also sometimes discussed, with the aim of reducing travel times down to one or two hours anywhere in the world.

These vehicle proposals very typically either use rocket or scramjet engines; pulse detonation engines have also been proposed. There are many difficulties with such flight, both technical and economic.

Rocket-engine vehicles, while technically practical (either as ballistic transports or as semiballistic transports using wings), use a very large amount of propellant and operate best at speeds between about Mach 8 and orbital speeds. Rockets compete best with air-breathing jet engines on cost at very long range; however, even for antipodal travel, costs would be only somewhat lower than orbital launch costs**.**

Scramjets currently are not practical for passenger-carrying vehicles due to technological limitations.

Ion wind, **ionic wind**, **coronal wind** or **electric wind** are expressions formerly used to describe the resulting localized neutral flow induced by electrostatic forces linked to Corona discharge arising at the tips of some sharp conductors (such as points or blades) submitted to high-voltages relative to ground. Modern implementations belong to the family of Electrohydrodynamic (EHD) devices. Ion wind production machines can be now considered as Electrohydrodynamic (EHD) pumps. Francis Hauksbee, curator of instruments for the Royal Society of London, made the earliest report of electric wind in 1709.

An **ionocraft** or **ion-propelled aircraft** (commonly known as a **lifter** or **hexalifter)** is a device that uses an electrical electrohydrodynamic (EHD) phenomenon to produce thrust in the air without requiring any combustion or moving parts. The term "Ionocraft" dates back to the 1960s, an era in which EHD experiments were at their peak. In its basic form, it simply consists of two parallel conductive electrodes; one in the form of a fine wire and another which may be formed of either a wire grid, tubes or foil skirts with a smooth round surface. When such an arrangement is powered up by high voltage in the range of a few kilovolts, it produces small thrust. The ionocraft forms part of the EHD thruster family, but is a special case in which the ionisation and accelerating stages are combined into a single stage. The device is a popular science fair project for students. It is also popular among anti-gravity or so-called "electrogravitics" proponents, especially on the Internet. The term "lifter" is an accurate description because it is not an anti-gravity device, but produces lift in the same sense as a rocket from the reaction force from driving the ionized air downward. Much like a rocket or a jet engine (it can actually be much more thrust efficient than a jet engine). The force that an ionocraft generates is oriented consistently along its own axis regardless of the surrounding gravitational field. Claims of the device working in a vacuum also have been disproved.

In its basic form, the ionocraft is able to produce forces great enough to lift about a gram of payload per watt, so its use is restricted to a tethered model. Ionocraft capable of payloads in the order of a few grams usually need to be powered by power sources and high voltage converters weighing a few kilograms, so although its simplistic design makes it an excellent way to experiment with this technology, it is unlikely that a fully autonomous ionocraft will be made with the present construction methods. This area has not been researched with good ideas, theory, design and experiment of ionocraft.

This article offers the new theory and principal design of the new engine, propulsion system for aviation, space launch and flight. These ideas include the new lightweight electrostatic high voltage electric generators. At present time **Electrostatic generators** operate by using manual (or other) power to transform mechanical work into electric energy. Electrostatic generators develop electrostatic charges of opposite signs rendered to two conductors, using only electric forces, and work by using moving plates, drums, or belts to carry electric charge to a high potential electrode. The charge is generated by one of two methods: either the triboelectric effect (friction) or electrostatic induction.

2. INNOVATIONS

One simple version of the offered electronic ramjet propulsion engine (ABEP) is shown in fig.1.

Engine contains the tube 2. The injectors of electrons 3 (or ions) are installed in the entrance of the tube. The second electrode-collector of electrons (ring, plats or net) 4 is installed in the end of tube. The electric circle having the battery (electrostatic generator) 8 and regulator of voltage connects the injectors 3 and back electrode (net, plats) 4. There is compensator 5 connected with forward 3 and back injectors 6 which discharges an excess charges in an exit flow. The charge compensator 5 is one of the most important innovations. All early proposed models of ion lifters cannot work without connection to Earth because they get self-charge and loss efficiency.

The engine works the following way. The injectors 3 eject the electrons (or ions) into tube (engine) 2. The strong electric field between injectors 3 and back electrode (ring, plats, net) 4 moves them to back electrode 4. Electrons (or ions) push (accelerate) the air to the tube exit. When the electrons (ions) reach the collector (electrode) 4, they (or part of them) enter the electrode and close the electric circuit. The excess part of charges is compensated by compensator 5. The accelerated air (air jet) with high speed flows out from engine and creates the thrust. In correctly designed engine this thrust may be enough for vertical start or moving the craft up to high hypersonic speed.

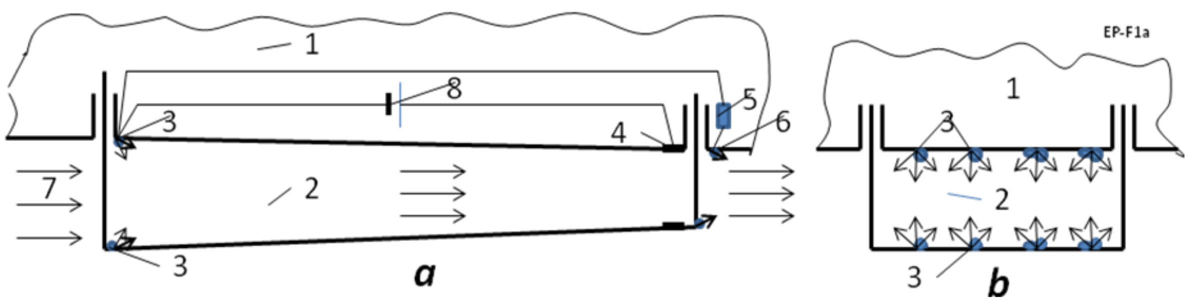

Fig.1. Electron ramjet engine (ABEP). ***a*** – side view, ***b*** – forward view. *Notations:* 1 – aircraft body, 2 – propulsion body, 3 – injector of charges (forward electrode), 4 – back electrode, 5 - separator (compensator) of charges; 6 – back injector of charges (opposed the forward injector 3), 7 – air flow. 8 – issue of high voltage (example, the electrostatic generator).

The proposed idea of a propulsion engine has many versions. One of them suitable for VTOL (aircraft with vertical start and lending) or helicopter is shown in fig. 2.

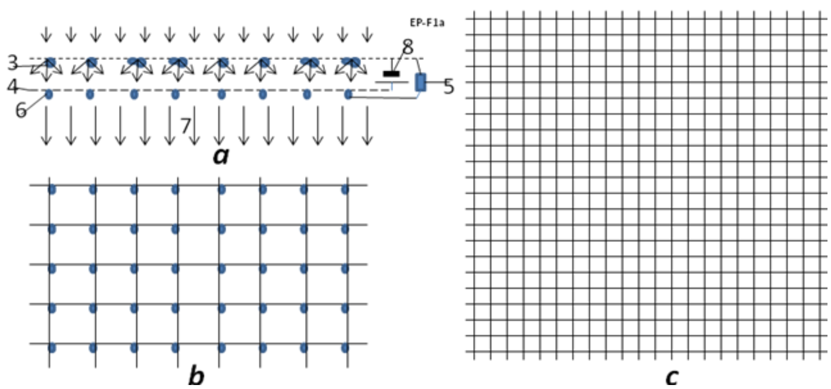

Fig.2. Electron ramjet engine (ABEP) for vertical start. ***a*** – side view, ***b*** –net of injector (top view), ***c*** – lover electrode (lower view). *Notations:* 3 – injector of charges (forward electrode), 4 – back electrode, 5 separator of charges; 6 – lower injector of charges (opposed the forward injector 3), 7 – air flow. 8 – source of high voltage (example, the electrostatic generator).

For economical vertical start and helicopter flight we need in the engine a large area for entrance and exit. This version has two nets: rare upper net with injectors (fig. 2b) and a denser mesh from a thin wire (fig.2c). These nets can be foldable and installed in the fuselage and under wings. The aircraft in disk form is a suitable form in this case (subsonic high speed aircraft – helicopter).

One possible electric schema of the proposed engine, shown in fig. 3, has an additional closed loop electric circles which allows more efficiency extracting the electrons from main electric circle and collecting electrons from air flow to back into main circle, to heat the electron injectors (cathodes) if it is necessary.

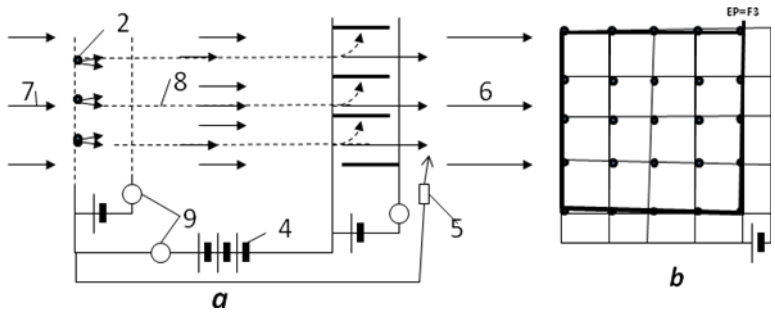

Fig.3. The electrical circuit of one version ABEP engine. Notations: ***a*** is side view, ***b*** is forward view; 2 – injector; 4 – electric issue, for example, the electrostatic generator, 5 – Compensator; 6 **-** exit flow, 7 – air flow, 8 – trajectory of the charges, 9 – regulator.

Principal differences the offered ABEP engines from known propulsion systems/engines.

From air-breathing engine:

1. Air-breathing propulsion engine as any heat engine compresses and HEATS the air. The electronic propulsion engine does not compress and does not heat the entered air.
2. Air-breathing propulsion engine expends liquid fuel. The electronic propulsion engine expends electric energy. But one may have the turbojet engine and electrostatic generator.

From rockets:

1. Rocket expends fuel.
   The electronic propulsion engine expends electric energy.

From the electric rocket engine.

1. The electric rocket engines and the electronic propulsion work in different mediums. The electronic propulsion uses the outer medium (atmosphere, gas, liquid, etc.) while most electric rockets may work only in vacuum. The ABEP has in tens-hundreds times more the ratio thrust/power. But ABEP can work in vacuum if one has the electric source.
2. The electric rocket engines can accelerate only positive ions.
   The electronic propulsion system accelerate electrons and positive ions.
3. The electric rocket engines expend the apparatus mass (special fuel).
   The electronic propulsion systems do NOT expend the apparatus mass or expends very few it.
   ABEP can accelerates (uses as passive fuel) ANY mass of space body (meteorites, asteroids, planets, planet satellites, dust, etc.)

From electrostatic lifter.

1. The ABEP has **correct** design. In particular the ABEP has body, **tube**, new injector and the charge **compensator**.
   As a result:
   1. The electrostatic lifter, using maximum voltage can produce only some grams of lift force and additional wind speed up 10 m/s. The ABEP can produce tons of thrust, accelerate air up hundreds m/s and works in flow having hypersonic speed. It may be used in both atmospheric as well as in space ships.

2. The electrostatic lifter has very low efficiency. This is why the lifter had no application in aerospace although his idea is known for some hundreds of years and tested numerous times. The ABEP has significantly higher efficiency (ratio thrust/power) than any current lifter because of our unique design.
3. ABEP works in hypersonic speed in atmosphere and can work in vacuum (outer space) using as passive propulsion any matter of the space bodies.

Advantages and disadvantages of the proposed electron propulsion system in comparison with the conventional air propulsion systems.

The suggested new propulsion principle has the following advantages and disadvantages in comparison with conventional air-breathing engine propulsion systems used at present time.

Advantages:

1. All current air-breathing propulsion engines as any heat engine compresses and HEATS the air. As a result the heat efficiency is about 30% or low. The electronic propulsion engine (ABEP) does not compress and does not heat the entered air. Its electric efficiency is about 100% which makes it 3 more times efficient.
2. All current the air-breathing engines has small efficiency in hypersonic speed ($3 < M < 5$), because the high compressed air has high temperature and current material cannot sustain them. Conventional hypersonic engine (for $M > 5$) is very complex, needs hydrogen fuel. There is no production of the hypersonic engine at present time although its research and design has been completed about 20 years. For $M > 6$ the heat hypersonic engine cannot work because the hot air (fuel) begins to dissociate and ionize. The electron engine does not heat the air and can work at any speed. That means it may be used as a cheap space launcher and engine of a super speed aircraft.
3. The electronic engine is very simple and cheap.
4. The outer air ship surface may be used as engine [1]. The aircraft may not have nacelles (moto-gondolas). That means higher aerodynamic efficiency of flight apparatus.
5. The outer surface electronic engine ([1] fig.2b) may be used for creating the laminar boundary layer. That means low (minimal) air friction and very high aerodynamic efficiency of flight apparatus.
6. The offered engine and outer surface electronic engine ([1] fig.2b) may be used for creating the high lift force. That means a lower landing speed, decreasing the take-off and landing distances, VTOL aircraft.
7. The electron engines can work at very high atmosphere and vacuum. If ABEP has an independent electric source (for example nuclear reactor), it operates with high efficiency (high exit speed) and can use as fuel (reaction mass) any matter of space bodies: space dust, meteorites, asteroids and planets, converted in the dust, liquid or gas.
8. The ABEP having source of electricity can works in any atmosphere and in other planets; space craft can use any matter of planets, asteroids and apparatus garbage in the ABEP engine.

Possible Disadvantages:

1. Main disadvantage of electron propulsion engine: the aircraft needs strong high voltage electric power. This problem may be solved by connecting the conventional engine with static electric generator. The static electric generator is lightweight and cheap. Electrostatic generator must be researched and developed in order for it to produce high voltage direct electricity. One, although not suitable for use by population and industry at present time, but the electrostatic generators are needed for electron propulsion engine needed in very high voltage (up 2 millions volts). High voltage electricity is more suitable for efficiency long distance transmission. The author has works which allow easy transfer the high voltage to low voltage of direct or variable electric currency (or

back).

3. THEORY OF ELECTRON PROPULSION (ABEP). COMPUTATION AND ESTIMATION.

1. Thrust of ABEP. The thrust of the jet electron engine is (we use the Law of Impulse):

$$T = m\ (V_f - V) = m\Delta V, \quad m = \rho SV, \quad T = \rho SV\Delta V,$$

$$T_s = \rho V\Delta V, \quad T \approx Id / b \approx P / bE, \quad T_s \approx P_s / bE, \qquad (1)$$

where T is thrust, N; m is air mass passed through engine in one second, kg/s; V_f is an exit speed of air (medium), m/s; V is an entry speed of air (medium), (flight speed of the apparatus), m/s; ΔV is increasing of air (medium) speed into engine, m/s; ρ is air (medium) density, kg/m^3; S is entrance area of engine, m^2; T_s is specific thrust of engine, N/m^2, I is electric currency, A; d is distance between cathode and anode, m; b is mobility of charges, m^2/sV (ions in air in atmospheric pressure has $b \approx 2\cdot10^{-4}$ m^2/sV, where V is voltage in V); P is power of electricity, W; $E = U/d$ is intensity of an electric field, V/m; U is voltage between cathode and anode, V.

The energy A_t [J] getting by flight apparatus from thrust is

$$A_t = TVt\ , \qquad (2)$$

where t is time, sec.

On other hand, the energy A_e [J] getting from of electric current is

$$A_e = UIt\ , \qquad (3)$$

where U is voltage between entrance and exit of engine, V; I is electric current, A.

The heat efficiency of the ABEP is close to 1, because no heating of air into engine (the increasing the speed of all air mass is in one direction by electric field).

That way

$$A_t \approx A_e\ . \qquad (4)$$

From (1) – (4) and $I_s = I/S$ we get ($V \neq 0$)

$$T_s = \frac{U}{V} I_s\ , \quad \Delta V = \frac{U I_s}{\rho V^2}\ , \qquad (5)$$

where I_s is density of electric currency about apparatus, A/m^2; ΔV is increasing air (medium) speed into engine, m/s.

Example 1. Let us take the $U = 10^6$ V, $I_s = 10$ A/m^2, flight speed $V = 200$ m/s, $\rho = 1$ kg/m^3. Then $T_s = 5\times10^4$ N/m^2 = 5 tons/m^2, $\Delta V = 250$ m/s.

Example 2. Let us take the $U = 4\times10^6$ V, $I_s = 100$ A/m^2, flight speed $V = 8000$ m/s, $\rho = 1$ kg/m^3. Then $T_s = 5\times10^4$ N/m^2 = 5 tons/m^2, $\Delta V = 6.25$ m/s.

The same way we can get the request power and getting thrust when the flight speed equals zero:

$$A_s = 0.5 m_s \Delta V^2,\ \ m_s = \rho\Delta V\ , \quad T_s = m_s\cdot\Delta V = \rho\Delta V^2\ , \ \ P_s = T_s\cdot 0.5\Delta V = 0.5\rho\Delta V^3\ , \qquad (6)$$

where P_s is electric power for 1 m^2, W/m^2; ΔV is increasing air speed into engine, m/s; m_s is air exemption mass passed throw engine in one second, kg/s·m^2; A_s is energy, J/m^2 .

Example 3. Let us take the $U = 10^6$ V, $I_s = 10$ A/m^2, $\rho = 1$ kg/m^3. Then the start thrust is $T_s \approx 7.35\cdot10^4$ N/m^2 = 7.35 tons/m^2 if the start power is $P_s \approx 10^7$ W/m^2, exit speed $\Delta V = 270$ m/s.

2. Efficiency of Electron ABEP engine. Efficiency η of any jet (air flight) propulsion is production of two values: propulsion efficiency η_p and engine (cycle) efficiency η_e :

$$\eta = \eta_p\eta_e\ , \quad \text{where} \quad \eta_p = V/(V + 0.5\,\Delta V)\ . \qquad (7)$$

The flight efficiency for heat and electronic propulsion are same. They depend only on ΔV . But thermodynamic (cycle) efficiency η_e of the heat engine is low about 25 ÷ 35%**.** The heat engine looses a great deal of energy from the hot exit jet. For high speed over $M > 3$ the conventional air rocket (jet) engine (TRP) looses efficiency very quickly, because air has dessaciation and ionization at high temperature. The aviation designers try to use the hydrogen fuel, but after M > 5 the hydrogen fuel is also useless. The offered electronic jet engine accelerates air by electricity. It has efficiency close to 100% as the only loss of energy is the extraction of the electrons from cathode, ionizations of air molecules and the compensator. This energy is about some electron-volts (eV). The energy spent for acceleration of the air molecules by electrons/ions is hundreds of thousands of eV. That means the total efficiency of ABEP is 3 times more than conventional air jet propulsion.

The second very important point: electric efficiency of ABEP does not depend upon speed of apparatus.

The other advantages: we can make a very large entrance area of engine, we can use the fuselage and wings, stabilizer and keel of plane as engine.

3. Ion and electron speed.

Ion mobility. The ion speed onto the gas (air) jet may be computed by equation:

$$j_s = qn_-b_-E + qD_-(dn_-/dx) , \qquad (8)$$

where j_s is density of electric currency about jet, A/m^2; $q = 1.6\times10^{-19}$ C is charge of single electron, C; n_- is density of injected negative charges in 1 m^3; b_- is charge mobility of negative charges, m^2/sV; E is electric intensity, V/m; D_- is diffusion coefficient of charges; dn_-/dx is gradient of charges. For our estimation we put $dn_-/dx = 0$. In this case

$$j_s = qn_-b_-E , \quad Q = qn , \quad v = bE , \quad j_s = Qv , \qquad (9)$$

where Q is density of the negative charge in 1 m^3; v is speed of the negative charges about jet, m/s.

The air negative charge mobility for normal pressure and temperature $T = 20^oC$ is:

In dry air $b_- = 1.9\times10^{-4}$ m^2/sV, in humid air $b_- = 2.1\times10^{-4}$ m^2/sV. (10)

In Table 1 there is given the ions mobility of different gases for pressure 700 mm Hg and for T = 18 ^{o}C.

Table 1. Ions mobility of different gases for pressure 700 mm Hg and for T = 18 ^{o}C.

Gas	Ion mobility 10^{-4} m^2/sV, b_+, b_-		Gas	Ion mobility 10^{-4} m^2/sV, b_+ , b_-		Gas	Ion mobility 10^{-4} m^2/sV, b_+, b_-	
Hydrogen	5.91	8.26	Nitrogen	1.27	1.82	Chloride	0.65	0.51
Oxygen	1.29	1.81	CO_2	1.10	1.14			

Source [22] p.357.

In diapason of pressure from 13 to 6×10^6 Pa the mobility follows the Law bp = const, where p is air pressure. When air density decreases, the charge mobility increases. The mobility strength depends upon the purity of gas. The ion gas mobility may be recalculated in other gas pressure p and temperature T by equation:

$$b = b_0 \frac{T p_0}{T_0 p},$$ (11)

where lower index "$_o$" mean the initial (known) point. At the Earth surface H = 0 km, T_0 = 288 K, p = 1atm; at altitude H = 10 km, T_0 = 223 K, p = 0.261 atm;

For normal air density the electric intensity must be less than 3 MV (E < 3 MV/m) and depends from pressure.

Electron mobility. The ratio $E/p \approx$ constant. Conductivity σ of gas depends upon density of charges particles n and their mobility b, for example:

$$\sigma = neb, \quad \lambda = 1/n\sigma,$$ (12)

where b is mobility of the electron, λ is a free path of electron.

Electron mobility depends from ratio E/n . This ratio is given in Table 2.

Table 2. Electron mobility b_e in gas vs E/n

Gas	***E/n*** $\times 10^{-17}$ 0.03 V·cm^2	***E/n*** $\times 10^{-17}$ 1 V·cm^2	***E/n*** $\times 10^{-17}$ 100 V·cm^2	Gas	***E/n*** $\times 10^{-17}$ 0.03 V·cm^2	***E/n*** $\times 10^{-17}$ 1 V·cm^2	***E/n*** $\times 10^{-17}$ 100 V·cm^2
N_2	13600	670	370	He	8700	930	1030
O_2	32000	1150	590	Ne	16000	1400	960
CO_2	670	780	480	Ar	14800	410	270
H_2	5700	700	470	Xe	1980	-	240

Source: Physic Encyclopedia http://www.femto.com.ua/articles/part_2/2926.html

The electrons may connect to the neutral molecules and produce the negative ions (for example, affinity of electron to O_2 equals 0.3 ÷ 0.87 eV [21] p.424). That way the computation the mobility of a gas contains the electrons and ions is complex problem. Usually the computations are made for all electrons converted to ions.

If $v > 0$, the charged particles accelerate the air into engine (E > 0 and engine spend energy). If $v < 0$, the charged particles beak the air into engine (E < 0 and engine can produce energy). If $v = 0$ (charged speed about apparatus equals 0), the electric resistance of jet into engine is zero.

The maximal electric intensity in air at the Earth surface is E_m = 3 MV/m. If atmospheric pressure changes the E_m also changes by law E_m/p = constant.

Example 4. If $E = 10^6$ V/m, than v = 200 m/s in the Earth surface conditions.

4. Electron injectors.

There are some methods for getting the electron emissions: hot cathode emission, cold field electron emission (edge cold emission, edge cathode). The photo emission, radiation emission, radioisotope emission and so on usually produce the positive and negative ions together. We consider only the hot emission and the cold field electron emission (edge cathodes).

Hot electron emission.

Currency i of diode from potential (voltage) U is

$$i = CU^{3/2}$$ (13)

where C is constant which depends from form and size cathode. For plate diode

$$C = \frac{4}{9}\varepsilon_0 \frac{S}{d^2}\sqrt{\frac{2e}{m_e}} \approx 2.33\cdot 10^{-6}\frac{S}{d^2}, \qquad (14)$$

where $\varepsilon_o = 8.85\cdot 10^{-12}$ F/m; S is area of cathode (equals area of anode), cm^2; d is distance between cathode and anode, cm; e/m_e is the ratio of the electron charge to electron mass, C/kg;

Result of computation equation (13) is in fig.4.

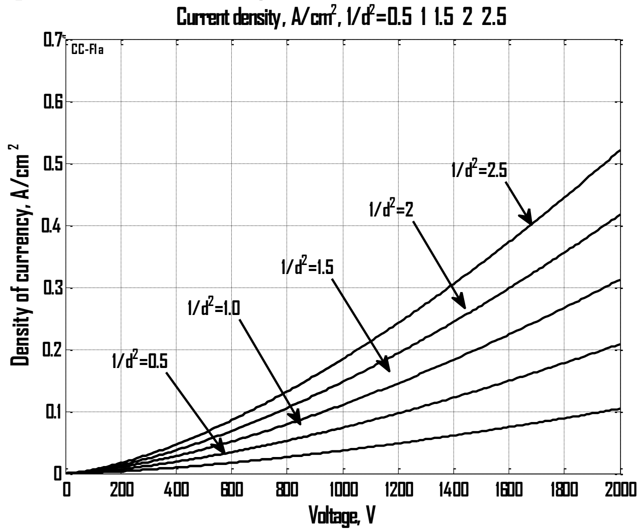

Fig.4. Electric currency via voltage the plain cathodes for different ratio of the distance.

The maximal **hot cathode** emission computed by equation:

$$j_s = BT^2 exp(-A/kT), \qquad (15)$$

where B is coefficient, A/cm^{2}K^2; T is catode temperature, K; $k = 1.38\times 10^{-23}$ [J/K] is Bolzmann constant; $A = e\varphi$ is thermoelectron exit work, J ; φ is the exit work (output energy of electron) in eV, $e = 1.6\cdot 10^{-19}$. Both values A, B depend from material of cathode and its cover. The "*A*" changes from 1.3 to 5 eV, the "*B*" changes from 0.5 to120 A/cm^{2}K^2. Boron thermo-cathode produces electric currency up 200 A/cm^2. For temperature 1400 ÷1500K the cathode can produce currency up 1000 A/cm^2. The life of cathode can reach some years [20]-[21].

Exit energy from metal are (eV):

W 4.5, Mo 4.3, Fe 4.3, Na 2.2 eV, (16)

From cathode covered by optimal layer(s) the exit work is in Table 3.

Table 3**.** Exit work (eV) from cathode is covered by the optimal layer(s):

Cr – Cs	Ti – Cs	Ni – Cs	Mo – Cs	W – Ba	Pt - Cs	W - O – K	Steel- Cs	Mo_2C-Cs	WSi_2-Cs
1.71	1.32	1.37	1.54	1.75	1.38	1.76	1.52	1.45	1.47

Source [20]: Kikoin, Table of physic values, 1976, p. 445 (in Russian).

Results of computation the maximal electric currency (in vacuum) via cathode temperature for the different exit work of electrons *f* are presented in fig.5.

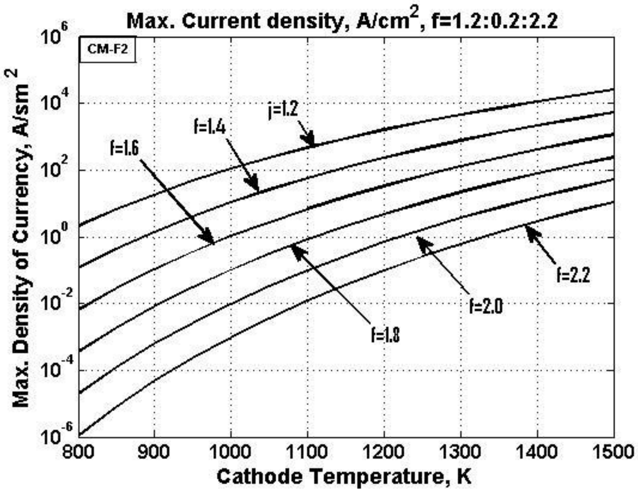

Fig.5. The maximal electric currency via cathode temperature for the different exit work of electrons *f*.

Method of producing electrons and positive ions is well developed in the ionic thrusters for space apparatus.

The field electron emission

The edge cold emission. The cold field electron emission uses the edge cathodes. It is known that the electric intensity E_e in the edge (needle) is

$$E_e = U/a \,. \qquad (17)$$

Here a is radios of the edge. If voltage between the edge and nears net (anode) is U = 1000 V, the radius of edge $a = 10^{-5}$ m, electric intensity at edge is the $E_a = 10^8$ V/m. That is enough for the electron emission. The density of electric current may reach up 10^4 A/cm^2 . For getting the required currency we make the need number of edges.

The density of electric currency approximately is computed by equation:

$$j \approx 1.4 \cdot 10^{-6} \frac{E^2}{\varphi} 10^{(4.39\varphi^{-1/2} - 2.82 \cdot 10^7 \varphi^{3/2}/E)} \,, \qquad (18)$$

where j is density of electric currency, A/cm^2; E is electric intensity near edge, V/cm; φ is exit work (output energy of electron, field electron emission), eV.

The density of currency is computed by equation (18) in Table 4 below.

Φ = 2,0 eV		φ = 4,5 eV		φ = 6,3 eV	
$E\times10^{-7}$	lg j	$E\times10^{-7}$	lg j	$E\times10^{-7}$	lg j
1,0	2,98	2,0	-3,33	2,0	-12,9
1,2	4,45	3,0	1,57	4,0	-0,88
1,4	5, 49	4,0	4,06	6,0	3,25
1,6	6,27	5,0	5,59	8,0	5,34
1,8	6,89	6,0	6,62	10,0	6,66
2,0	7,40	7,0	7,36	12,0	7,52
2,2	7,82	8,0	7,94	14,0	8,16
2,4	8,16	9,0	8,39	16,0	8,65
2,6	8,45	10.0	8,76	18,0	9,04
		12,0	9,32	20,0	9,36

Source: http://www.femto.com.ua/articles/part_1/0034.html

Example: Assume we have needle with edge $S_1 = 10^{-4}$ cm^2, $\varphi = 2$ eV and net $S_2 = 10\times10 = 10^2$ cm^2 located at distance $L = 10$ cm. The local voltage between the needle and net is $U = 10^2$ volts. Than electric intensity at edge of needle, current density and the electric currency is:

$$E = \frac{S_2 U}{S_1 L} = \frac{10^2 10^2}{10^{-4} 10^1} = 10^7 \text{ V/cm}, \quad j = 10^3 \text{ A/cm}^2, \quad i = jS_1 = 10^3 10^{-4} = 0.1 \text{ A}, \qquad (19)$$

Here j is taken from Table 4 or computed by equation (18). If we need in the electric currency 10 A, we must locate 100 needles in the entrance area 1×1 m of engine.

Computation of equation (18) is presented in fig. 6.

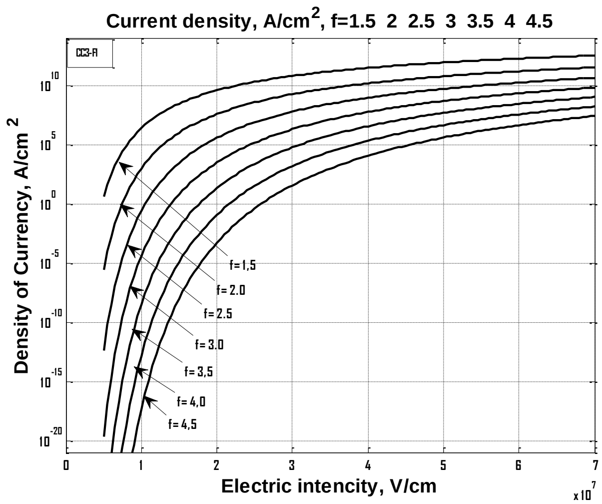

Fig.6. Density of electric currency the noodle injector via the electric intensity for different the field electron emissions *f*.

Internal and outer pressure on the engine surface.

The electric charges located in the ABEP engine produce electric intensity and internal and outer pressure. The electric intensity can create the electrical breakdown; the pressure can destroy the engine.

a) For the cylindrical engine the electric intensity and pressure may be estimated by equations:

$$E = k\frac{2\tau}{\varepsilon r}, \quad \tau = \frac{i}{V_a}, \quad V_a \approx V + 0.5\cdot\Delta V, \quad p = E\sigma, \qquad (20)$$

where E is electric intensify, V/m; $k = 9\cdot10^9$ is electric constant, Nm^2/C^2; τ is the linear charge, C/m; ε is dielectric constant for given material ($\varepsilon = 1 \div 1000$), r is radius of engine. m; i is electric currency A; V_a is average speed of flow inside of engine, m/s; p is pressure, N/m^2; σ is the density of charge, C/m^2 at an engine surface.

Example. Assume the engine has $r = 0.5$ m, $V = 270$ m/s, $\Delta V = 200$ m/s, $i = 5$ A. Let us take as isolator the Lexan having the dielectric strength $E_m = 640$ MV/m and $\varepsilon = 3$. Than from (14) we have $E = 81$ MV/m $< E_m = 640$ MV/m.

If $E > E_m$ we can locate the part of the compensate charge inside engine.

b) For plate engine having entrance h×w = 1× 3 m and compensation charges on two sides, the electric intensity and pressure may be estimated by equations:

$$E = 4\pi k \frac{\sigma}{\varepsilon}, \quad \sigma = \frac{i}{2V_a w}, \quad V_a \approx V + 0.5 \cdot \Delta V, \quad p = 2\varepsilon\varepsilon_0 E^2, \tag{21}$$

where w is width of entrance, m; ε is dielectric coefficient of the isolator.

5. Electrical Generator

Suggested engine needs a great deal of electricity which can be gotten either from a nuclear reactor or from connection of the conventional turbojet engine with an electric generator. Let us consider the last possibility.

When aircraft is in needs of electricity, most aviation engineers offer the conventional way: take the usual magnetic electric generator and connect it to the turbojet or take other (for example, piston) engine. Let us analyze the limiting possibilities of different versions.

Magnetic electric generator. Magnetic electric generator was first produced about century ago and has been very well studied. The ratio of power/mass of magmatic generator for 1 m^3 may be estimated by equation:

$$A = \frac{B^2}{2\mu_0}, \quad P = A\nu, \quad M = \gamma, \quad \frac{P}{M} = c\frac{B^2\nu}{2\mu_0\gamma}, \tag{22}$$

Here A is density of energy into 1 m^3 of magnetic material J/m^3; B is maximal magnetic intensity, T; $\mu_0 = 4\pi 10^{-7}$ is permeability (magnetic constant), N/A^2; P is power, W; υ is electric frequency, 1/s (*υ = 50 ÷ 400 1/s);* M is mass 1 m^3 of generator, kg/m^3; γ is specific mass of the generator bogy, kg/m^3 ($\gamma \approx 8000$ kg/m^3); $c \approx 1/8$ correction coefficient, because average $B = 0.5B_{max}$ and ferromagnetic iron uses only about ½ engine volume. The maximal frequency determinates the ratio L/r, where L is inductance, r is electric resistance. That equals about 500 – 1000 1/s.

Example. Let us take the typical data B = 1 T, υ = 400 1/s, γ = 8000 kg/m^3. We get maximal P/M = 2.5 kW/kg.

Typical aviation generator has:

Type: ГТ-120ПЧ8 (Russian)	Power 120 kW	Phases 3	Voltage 208V	Currency 334 A	Frequency 400 1/s	Number of rev. 8000 in min	Mass 90 kg

The ratio for the usual aircraft generator equals 1.33 kW/kg. That is two time less than maximal possible. For our purposes that will be two times less because we need high voltage. But the high voltage transformer will weigh not less than electric generator. If aircraft has turbo 10,000 kW the magnetic propulsion system will weigh about 14 tons, 5 times more than turbojet. That is not acceptable in aviation. In addition, we need a constant (direct) current. The generator of DC weighs significantly more. No suitable transformer for transformation the DC into in very high voltage.

Electrostatic generator (EG). Electrostatic electric generator is known for about two centuries but it is not used because it produces very high voltage which is very dangerous for people and not suitable for practice and home devises. As a result, EG is studied very little and no power EG is produced by industry.

The ratio power/mass of electrostatic generator for area S = 1 m^2 may be estimated by equation:

$$A = \frac{CU^2}{2}, \quad C = \frac{\varepsilon\varepsilon_0 S}{d}, \quad U = Ed, \quad P = \frac{A}{t}, \quad M = \gamma\delta S, \quad \frac{P}{M} = \frac{\varepsilon\varepsilon_0 E^2\delta}{2\gamma d^2}V_a, \tag{23}$$

where A is density of energy on 1 m^2 of the electrostatic (isolator plate) material J/m^2; C is capacitance of plate (one plate of condenser), F/m^2; U is voltage, V; ε (1 ÷ 3000) dielectric constant of plate matter; $\varepsilon_0 = 8.85 \cdot 10^{-12}$ is permittivity, F/m; S is area of one plate, m^2; d is distance between plates (include thickness of one plate, m); P is power, W; t is time, s; M is mass 1 m^2 of generator plate, kg/m^3; γ is specific mass of the generator plate, kg/m^3 ($\gamma \approx 1800$ kg/m^3), δ is clearance between plates, m; V_a is the average relative speed of two plates, m/s ($V_a \approx 0.5V$, where V is the peripheral disk (plate) speed).

Properties of some insulators in Table 5.

Table 5. Properties of various good insulators (recalculated in metric system)

Insulator	Resistivity Ohm-m.	Dielectric strength MV/m.. E_i	Dielectric constant, ε	Tensile strength kg/mm^2, $\sigma \times 10^7$N/m^2
Lexan	10^{17}–10^{19}	320–640	3	5.5
Kapton H	10^{19}–10^{20}	120–320	3	15.2
Kel-F	10^{17}–10^{19}	80–240	2–3	3.45
Mylar	10^{15}–10^{16}	160–640	3	13.8
Parylene	10^{17}–10^{20}	240–400	2–3	6.9
Polyethylene	10^{18}–5×10^{18}	40–680*	2	2.8–4.1
Poly (tetra-fluoraethylene)	10^{15}–5×10^{19}	40–280**	2	2.8–3.5
Air (1 atm, 1 mm gap)	-	4	1	0
Vacuum (1.3×10^{-3} Pa, 1 mm gap)	-	80–120	1	0

*For room temperature 500–700 MV/m.
** 400–500 MV/m.

Source: Encyclopedia of Science & Technology[9] (Vol. 6, p. 104, p. 229, p. 231).(See also [10], p.283.

Note: Dielectric constant ε can reach 4.5 – 7.5 for mica (E is up 200 MV/m); 6 – 10 for glasses (E = 40 MV/m) and 900 – 3000 for special ceramics (marks are CM-1, T-900) [21] p.32 (E = 13 – 28 MV/m). Dielectric strength appreciable depends from surface roughness, thickness, purity, temperature and other conditions of material. It is necessary to find good insulate materials and reach conditions which increase the dielectric strength.

The safety peripheral disk speed may be estimated by equation $V = (\sigma/\gamma)^{0.5}$ where σ is safety tensile stress (N/m^2), γ is specific weight, kg/m^3. The disk may be reinforced by fiber having high tensile stress.

Let us consider the following experimental and industrial fibers, whiskers, and nanotubes:

1. Experimental nanotubes CNT (carbon nanotubes) have a tensile strength of 200 Giga-Pascals (20,000 kg/mm^2), Young's modulus is over 1 Tera Pascal, specific density γ=1800 kg/m^3 (1.8 g/cc) (year 2000). For safety factor n = 2.4, σ = 8300 kg/mm^2 = 8.3×10^{10} N/m^2, γ=1800 kg/m^3, $(\sigma/\gamma)=46\times10^6$, K = 4.6. The SWNTs nanotubes have a density of 0.8 g/cc, and MWNTs have a density of 1.8 g/cc. Unfortunately, the nanotubes are very expensive at the present time (1994).
2. For whiskers C_D σ = 8000 kg/mm^2, γ = 3500 kg/m^3 (1989) [10].
3. For industrial fibers σ = 500 – 600 kg/mm^2, γ = 1800 kg/m^3, $\sigma\gamma$ = 2,78×10^6, K = 0.278 – 0.333,

Figures for some other experimental whiskers and industrial fibers are given in Table 6.

Table 6. Properties of fiber and whiskers

Material Whiskers	Tensile strength kgf/mm^2	Density g/cc	Material Fibers	Tensile strength MPa	Density g/cc
AlB_{12}	2650	2.6	QC-8805	6200	1.95

B	2500	2.3	TM9	6000	1.79
B_4C	2800	2.5	Thorael	5650	1.81
TiB_2	3370	4.5	Allien 1	5800	1.56
SiC	1380–4140	3.22	Allien 2	3000	0.97

See Reference [10] p. 33.

Example: Let us estimate ratio *P/M* of the electrostatic generator by equation (23). Take the electric intensity $E = 10^7$ V/m, area of the disk 1 m^2, thickness of the disk 0.003m, clearance between disks δ = 0,002 m, (d = 0.005 m), V = 500 m/s, γ = 1800 kg/m^3, ε = 3. Substitute these data in equation (23) we get *P/M* = 53 kW/kg. That means the electrostatic generator (motor) of equal power will be in 20 times less than magnetic generator (motor). The 10,000 kW electrostatic generator (motor) will be weight only 400 kg (200 disks). And additional the electrostatic generator produces high voltage direct (constant) electric currency. The powerful turbo-propeller jet HK-12 (Russia) has a start power 8700 kW and mass 2800 kg. The propeller (5.6 m) weights 1156 kg in it. We can delete propeller, installs the electrostatic generator (volume 1 m^3), the light offered ABEP engine and flights with hypersonic speed. The electricity easy transverses to other (for example to VTOL) engine.

Air friction in electrostatic generator and its efficiency.

Let us estimate ratio of the air friction/produced power 1 m^2 of disk the electrostatic generator. Compute the friction, produced power and efficiency:

$$P_f = 2FV_a\,, \quad F = \varsigma\frac{V_a}{\delta}\,, \quad P_f = 2\frac{\varsigma V_a^2}{\delta}\,, \quad P = \frac{\varepsilon\varepsilon_0 E^2}{2}V_a\,, \quad \eta = 1-\frac{P_f}{P} = 1-\frac{4\varsigma V_a}{\varepsilon\,\varepsilon_0 \delta E^2}\,, \qquad (24)$$

where P_f is power of friction 1 m^2 of disk, W/m^2; F is friction force 1 m^2 of disk, N/m^2; V_a is average disk speed, m/s; ς is viscosity of the gas (for air $\varsigma = 1.72\cdot10^{-5}$ Pa·s, for hydrogen $\varsigma = 0.84\cdot10^{-5}$ at atmospheric pressure and $T = 0^oC$); P is power produced 1 m^2 of disk, W/m^2; ε is dielectric constant of plate matter; $\varepsilon_0 = 8{,}85\cdot10^{-12}$ is permeability, F/m; δ is clearance between disk, m; E is electric intensity, V/m ; η is efficiency of generator related to air friction.

Example: If V_a = 250 m/s; $E = 2\cdot10^6$ V/m; δ = 0.002 m, then η = 0.92.

The coefficient of gas friction weak depends from the pressure and temperature. If we change the air into the electrostatic generator by hydrogen, the loss of friction decreases in two times. If we create the vacuum into the electrostatic generator, the gas friction will be zero and the safety electric intensity is increased in many times.

Loss of energy and matter for ionization.

Let us estimate the energy and matter is requested for ionization and discharge the offered ABEP propulsion. Assume we have ABEP engine having the power P = 10,000 kW and a work voltage V = 1 MV. In this case the electric currency is $i = P/V$ = 10 A = 10 C/s.

Assume we use the nitrogen N_2 for ionization (very bad gas for it). It has exit work about 5 eV and relative molecular weight 14. One molecule (ion) of N_2 weights $m_N = 14\cdot1.67\cdot10^{-27} = 2.34\cdot10^{-26}$ kg. The 1 ampere has $n_A = 1/e = 1/1.6\cdot10^{-19} = 6.25\cdot10^{18}$ ions/s. Consumption of the ion mass is:
$M = m_N i\, n_A = 2.34\cdot10^{-26}\cdot10\cdot\ 6.25\cdot10^{18} = 1.46\cdot10^{-6}$ kg/s $= 1.46\cdot10^{-6}\cdot3.6\cdot10^{-3} = 5.26\cdot10^{-3}$ kg/hour $\approx$ 5 gram/hour.

If electron exit work equals φ = 4.5 eV the power spent extraction of one electron is: $E_1 = \varphi e = 4.5\cdot1.6\cdot10^{-19} = 7.2\cdot10^{-19}$ J.

The total power for the electron extraction is $E = i \cdot n_A \cdot E_1 = 10 \cdot 6.25 \cdot 10^{18} \cdot 7.2 \cdot 10^{-19} = 45$ W.
The received values mass M and power E are very small in comparison with conventional consumption of fuel (tons in hour) and engine power (thousands of kW).

Important note (Compensation of flow charge). Any contact collector cannot collect ALL charges. Part of them will fly away. That means the engine (apparatus) will be charged positive (if fly away electrons or negative ions) or negative (if fly away the positive ions). It is easy delete the negative charges by edge. The large positive charge we may delete by small ion accelerator. The ion engines (trasters) for vacuum are R&D well. They may be used as injectors and dischargers in the first design of ABEP.

Fuel efficiency of ABEP engine.

For passenger and transport aircraft about half of the cost of transportation is cost of fuel. Let us estimate the consumption of fuel for ABEP engine in hypersonic flight. The hypersonic flight has three stages [1]: acceleration, ballistic, braking. But in contrast to subsonic plane the hypersonic plane expends fuel only in the first stage: acceleration. The second stage "ballistic" for "flight with constant hypersonic speed in atmosphere", usually requires more fuel than subsonic flight (because the coefficient of aerodynamic efficiency of subsonic flight in 2 – 3 times more than hypersonic flight).
a) Data of the Stage of acceleration the mass 1 kg up the given high hypersonic speed V is

$$L_a = \frac{V^2}{2a}, \quad E_a = \frac{V^2}{2}, \quad E_d = F \cdot L_a = \frac{g}{K_2} \cdot \frac{V^2}{2a}, \quad E = E_a + E_d = \frac{V^2}{2}\left(1 + \frac{g}{aK_2}\right), \tag{25}$$

where L_a is distance of acceleration, m; V is final speed of acceleration, m/s; $a > 0$ is acceleration, m/s^2; E_a is energy of acceleration 1 kg, J; E_d is energy of drag (1kg) in acceleration distance, J; E is full energy (for mass 1 kg) spent in the acceleration distance, J; $g = 9.81$ m/s^2 is gravitation; K_2 is ratio Lift/Drag (coefficient of aerodynamic efficiency, for $M > 1.5$, $K_2 \approx 4(1 + 1/M)$, where M is Max number).

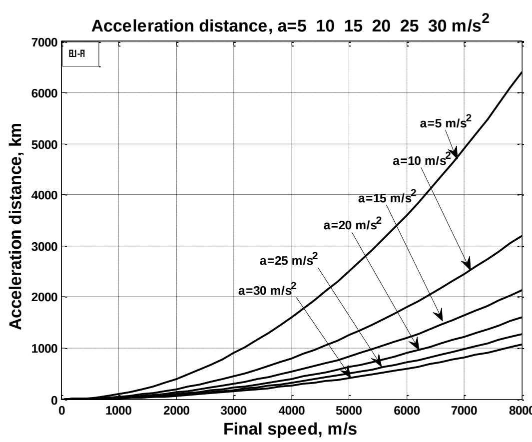

Fig. 7. Acceleration distance of hypersonic aircraft via final speed of ABEP for different acceleration m/s^2.

b) Flight in ballistic trajectory at high altitude in a rare atmosphere with neglect the air drag, 3 < M < 6 is described:

$$L_b = \frac{V^2 \sin 2\alpha}{g}, \quad H_b = \frac{V^2 \sin^2 \alpha}{2g}, \tag{26}$$

where L_b is distance of ballistic trajectory, m; H_b is maximal altitude, m; α is angle of incidence into rare atmosphere (optimal $\alpha \approx 45^o$) .
c) Flight in high ballistic trajectory in high altitude at vacuum with neglect the air drag, M > 10, (the angle of incidence is optimal ($\alpha \approx 30^o - 40^o$)) is described.

$$\nu = \left(\frac{V}{V_0}\right)^2, \quad \nu < 1, \quad tg\beta = \frac{\nu}{2\sqrt{1-\nu}}, \quad L_w = 2R\beta \ , \qquad (27)$$

where υ is relative speed; V_o = 7.93 km/s is circle space speed of Earth satellite, m/s; β is angle from entrance in space to maximal altitude measured from Earth center, rad; R = 6378 km – radius of Earth, km; L_w is distance ballistic flight into space, km.

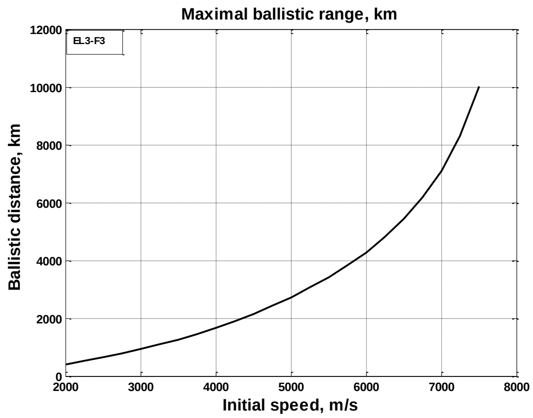

Fig.8.maximal ballistic range via initial speed of space sraft.

d) Brake (inertial, kinetic) flight into atmosphere [3].

$$L_i \approx \frac{K_2 V^2}{2g} \ , \qquad (28)$$

where K_2 is coefficient of aerodynamic efficiency (ratio Lift/Drag).

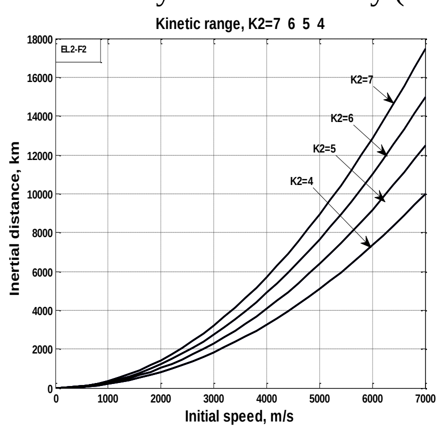

Fig.9. Kinetic (inertial) range of hypersonic aircraft via initial speed.

e) Total range of hypersonic aircraft is (with exit to space, $M > 10$)

$$L = L_a + L_w + L_i \ . \qquad (29)$$

If $M < 10$ and there is exit to ballistic trajectory, the full range is

$$L = L_a + L_b + L_i \ . \qquad (30)$$

If $M < 10$ and **no** exit to ballistic trajectory, the range is

$$L = L_a + L_h + L_i \text{ , where } L_h = E_h K_2/g \text{ ,} \qquad (31)$$

where L_h is distance with constant hypersonic flight, m or km; E_h is energy spent in this distance.

The total range compare with range of the conventional subsonic aircraft:

$$L_s \approx \frac{EK_1}{g}, \quad \text{where} \quad E = E_a \quad \text{or} \quad E = E_a + E_h \text{ ,} \qquad (32)$$

Here is L_s is range of the subsonic aircraft, m or km; K_1 is ratio Lift/Drag (coefficient of aerodynamic efficiency of subsonic aircraft), $K_1 \approx 10 \div 18$.

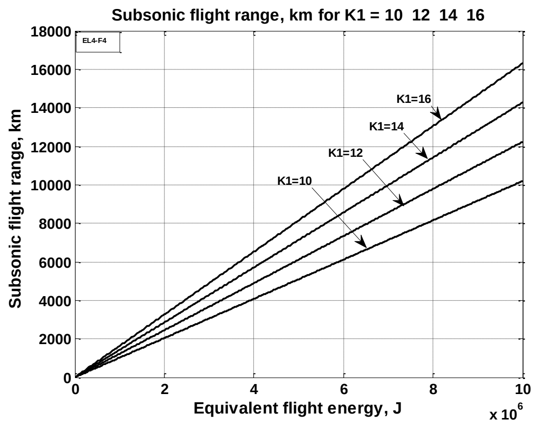

Fig.10. Flight range of subsonic aircraft via the equivalent flight energy for different ratio Lift/Drag.

If range L_s of the subsonic aircraft is less than range of hypersonic aircraft, the hypersonic aircraft is more profitable (spend less fuel in 1 kg·km) than subsonic plane, and conversely (without accounting of other advantages the hypersonic speed!).

The estimations show: in speed diapason $M \approx 1{,}5 \div 5$ the supersonic aircraft spend fuel in 1.5 – 2.5 more than subsonic airplane, but after $M > (12 \div 20)$ hypersonic aircraft with ABEP engine spent less the fuel. If $M > 25$ the range may be any for constant fuel consumption. The men or load can be delivered in any point of the Earth in during 45 – 50 min. That means the cost of travel through space may be faster and cheaper than long distance travel by subsonic airplane. For example, the time of flight are: New-York – Paris 12 min (5837 km), San-Francisco - Tokyo 16 min (8277 km), NY – Moscow 17 min (7519 km).

The offered engine as rocket motor.

Offered engine has the principal differences from rocket engine, in particular: one need in environment (which it accelerates) and electric energy. Unlike rockets and most space propulsions methods, ABEP engine does not use a thermal principle but rather accelerates an environment matter by electrons. But if ABEP has as source of electric energy such as a nuclear reactor, the offered engine may be used as very high efficiency rocket engine.

Conventional nuclear rocket engine has limited impulse (limited exhaust speed of gas) because engine material has limited temperature and gas became dissociate. Rockets need **special fuel**. The ABEP engine is limited only by electric power (energy). It can have a higher impulse and (main advantage) can use ANY matter as propulsion material. ABEP having nuclear electric reactor can use (as refuel) any space body (meteorites, asteroids, planets) to refill its fuel supply. If astronauts (being on outer body) have a choice between using a fuel for conventional rocket and by ABEP may be situation when a using ABEP is more useful.

Let us make the estimation of the next case. Space ship having total mass M_o = 1000 kg has M_F = 100 kg fuel (oxygen – hydrogen) and must start from the asteroid with maximal speed. Ship can use conventional rocket engine or take 9000 kg of asteroid matter (in dust form), convert fuel in electricity and use offered engine. Equations requested for estimation are below:

$$V_1 = -w_1 \ln \frac{M_f}{M_0}, \quad E = \eta M_F E_1, \quad w_2 = \left(\frac{2E}{M_{0,a}} \right)^{0.5}, \quad V_2 = -w_2 \ln \frac{M_{f,a}}{M_{0,a}}, \qquad (33)$$

where w_1 = 4000 m/s is speed of rocket exhaust gas (rocket impulse in m/s); M_f = 900 kg is final ship mass; E is fuel energy, J; $\eta \approx 0.5$ is total coefficient convert efficiency; $E_1 \approx 13.45 \cdot 10^6$ J is energy ability of fuel (oxygen – hydrogen) ; $w_2 \approx 348$ m/s is computed impulse ABEP in given case; $V_2 \approx 800$ m/s is new speed of space ship with offered propulsion.

Using rocket theory (33) we find: ship can reach the speed of about 400 m/s by a conventional rocket engine and 800 m/s by the offered propulsion system. Than means two times more than conventional methods.

SUMMARY AND DISCUSSION.

The author proposed a fundamentally new propulsion system (engine) using the environment medium (air, space material) and electric energy. It is not comparable to conventional heat propulsion because the usual heat jet engine gets the thrust by compressing the air, burning the fuel into air, heating of air, accelerating the hot air and expiring the hot gas in atmosphere.

The offered ABEP engine is accelerating the air (medium) by a principally new method – by electrons and electric field which does not need atmospheric oxygen and thus can work in any atmosphere of other planets. This engine does not require compressing and heating of medium and, as such, does not have limitations of high temperature, high flight speed and composition of the atmosphere.

This engine is also dissimilar to the known space electric engines. The conventional space electric engine takes an extracted mass from itself, ionizes it, and accelerates springing forward in a vacuum. It has very small thrust, works poorly into any atmosphere and works worse if the atmosphere has a high density. The ABEP does not take the extracted mass, can work only in atmosphere and works better if the atmosphere has a high density.

The main disadvantage of the offered engine is the requirement of high voltage electricity. For getting the electricity it may use the conventional internal turbo engine connected to electrostatic generator. Electrostatic power generator is lightweight and produces high voltage electricity. The weight system turbojet engine + electrostatic generator + is same (or less) than mass system turbojet engine + propeller system.

Researches related to this topic are presented in [1]-[19]. See also [20]-[24].

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